The Striped Bass Fishery of the Gulf of Mexico, United States: A Regional Management Plan

2006 Revision

Gulf States Marine Fisheries Commission

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THE STRIPED BASS FISHERY OF THE GULF OF MEXICO, UNITED STATES:

A REGIONAL MANAGEMENT PLAN

by the

Striped Bass Technical Task Force

edited by

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Mr. Pete Cooper, Jr., near his former home in Buras, Louisiana, with a 7 lb 6 oz striped bass.

Preface

The Gulf States Marine Fisheries Commission (GSMFC) was established by the Gulf States Marine Fisheries Compact under Public Law 81-66 approved May 19, 1949. Its charge is to promote better management and utilization of marine resources in the Gulf of Mexico.

The Commission is composed of three members from each of the five Gulf States. The head of the marine resource agency of each state is an *ex officio* member. The second is a member of the legislature. The third is a governor-appointed citizen with knowledge of or interest in marine fisheries. The offices of the chairman and vice chairmen are rotated annually from state to state.

The Commission is empowered to recommend to the governor and legislature of the respective states action on programs helpful to the management of marine fisheries. The states, however, do not relinquish any of their rights or responsibilities to regulate their own fisheries as a result of being members of the Commission.

One of the most important functions of the GSMFC is to serve as a forum for the discussion of various problems and needs of marine management authorities, the commercial and recreational industries, researchers, and others. The GSMFC also plays a key role in the implementation of the Interjurisdictional Fisheries (IJF) Act. Paramount to this role are the Commission's activities to develop and maintain regional fishery management plans for important Gulf species.

The striped bass fishery management plan is a cooperative planning effort of the five Gulf States under the IJF Act. Members of the task force contributed by drafting individually-assigned sections. In addition, each member contributed their expertise to discussions that resulted in revisions and led to the final draft of the plan.

The GSMFC made all necessary arrangements for task force workshops. Under contract with the National Marine Fisheries Service (NMFS), the GSMFC funded travel for state agency representatives and consultants other than federal employees.

Throughout this document, metric equivalents are used wherever possible with the exceptions of reported landings data and size limits which, by convention, are reported in English units. A glossary of fisheries terms pertinent to this FMP is provided in the appendix (Section 12.1).

Recreational landings in this document are Type A and B1 and actually represent total harvest as designated by the NMFS. Type A catch is fish that are brought back to the dock in a form that can be identified by trained interviewers and type B1 catch is fish that are used for bait, released dead, or filleted (i.e., they are killed but identification is by individual anglers). Type B2 catch is fish that are released alive, identified by individual anglers, and is excluded from the values in this FMP.

Abbreviations and Symbols

ACF	Apalachicola-Chattahoochee-Flint rivers system
ADCNR/WFF	Alabama Department of Conservation Natural Resources/Wildlife and Freshwater Fisheries
ADCNR/MRD	Alabama Department of Conservation Natural Resources/Marine Resources Division
BRD	bycatch reduction device
°C	degrees Celsius
DO	dissolved oxygen
DMS	Data Management Subcommittee
DNA	deoxyribonucleic acid
EEZ	exclusive economic zone
EFH	essential fish habitat
ESU	evolutionary significant units
FWC/FWRI	Florida Fish and Wildlife Conservation Commission/Fish and Wildlife Research Institute
FMP	fishery management plan
ft	feet
g	gram
GDNR	Georgia Department of Natural Resources
GSI	gonadal somatic index
GMFMC	Gulf of Mexico Fishery Management Council
GSMFC	Gulf States Marine Fisheries Commission
hr(s)	hour(s)
ha	hectare
IJF	interjurisdictional fisheries
kg	kilogram
km	kilometer
lbs	pounds
L&D	lock and dam
LDWF	Louisiana Department of Wildlife and Fisheries
LLSC	lateral line scale count
LMR	Lower Mississippi River
MAT	Mobile-Alabama-Tombigbee
MFCMA	Magnuson Fishery Conservation and Management Act
m	meter
mm	millimeters
min(s)	minute(s)
MDMR	Mississippi Department of Marine Resources
MRFSS	Marine Recreational Fisheries Statistical Survey
μg	microgram
mt	metric ton
mtDNA	mitochondrial deoxyribonucleic acid
n	number
nDNA	nuclear deoxyribonucleic acid
NFH	National Fish Hatchery
NL	notocord length
NM	nautical mile
NMFS	National Marine Fisheries Service
ppm	parts per million
ppt	parts per thousand
PPI	producer price index
PCR	polymerase chain reaction
RFLP	restriction fragment length polymorphism
RK	river kilometer
RM	river mile
SAT	Stock Assessment Team
SD	standard deviation
SE	standard error
sec(s)	Second(s)
SL	standard length
S-FFMC	State-Federal Fisheries Management Committee
SPR	spawning potential ratio
TCC	Technical Coordinating Committee
TED	turtle exclusion device
TL	total length
TPWD	Texas Parks and Wildlife Department
TTF	technical task force
USACOE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USDOC	U.S. Department of Commerce
USDOI	U.S. Department of the Interior
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
YOY	young-of-the-year
yr(s)	year(s)

Table of Contents

Page

List of Tables

List of Figures

1.0 SUMMARY

The range of native striped bass in Gulf of Mexico (Gulf) rivers was disjunct from that of other populations of the species found in Atlantic Ocean rivers of eastern North America. Prior to artificial propagation, striped bass in the Gulf of Mexico were found from the Suwannee River of Florida westward to rivers of southeastern Louisiana that drain to Lake Pontchartrain. The rivers of the Gulf of Mexico represented the southern extreme of the species' native range in North America during recent times.

The largest native populations of striped bass in Gulf of Mexico rivers probably occurred in the Apalachicola-Chattahoochee-Flint (ACF) and Mobile-Alabama-Tombigbee (MAT) rivers systems of Alabama, Georgia, and Florida. By the mid-1960s native striped bass had been extirpated from all Gulf rivers except for small remnant populations in those two systems. The ACF population is now considered a distinct "race" from those in Atlantic rivers. Many Gulf of Mexico rivers contain mixtures of striped bass introduced from the ACF and from one or more Atlantic rivers.

Striped bass in Gulf rivers were first differentiated from those in Atlantic rivers based primarily on the lateral line scale counts, but other differentiating meristic features included mean numbers of dorsal, anal, and pectoral fin rays. Striped bass in the ACF system exhibited lateral line scale counts (LLSC) significantly higher than those found in any Atlantic Coast population, and minimal overlap was observed between fish from the two coasts suggesting that striped bass in Gulf rivers should be considered a separate stock (or race) from those in Atlantic rivers and provided strong support for efforts to conserve and restore Gulf populations. To investigate genetic differences between native ACF and introduced Atlantic fish, mtDNA was initially used to determine the frequencies of original haplotypes in the ACF using preserved specimens of native ACF striped bass collected prior to introductions of Atlantic fish. Based on this evaluation, it was concluded that significant maternally-mediated introgression of Atlantic mtDNA alleles into the native ACF gene pool had not occurred. Although a subsequent similar comparison using nDNA microsatellites revealed that significant introgression of Atlantic alleles into the ACF population had occurred, a high frequency of nDNA alleles unique to the Gulf were still present. Some taxonomists believe the Gulf race may warrant description as a subspecies.

Although striped bass are generally considered to be an anadromous species, populations at the northern and southern extremes of the range tend to be more potadromous, with individuals rarely venturing into coastal waters. Spawning occurs during spring in fresh or nearly fresh water. An upstream spawning migration takes place several weeks in advance of the time of spawning with males generally arriving on the spawning grounds before females. In addition to the "typical" anadromous pattern of upstream migrations from estuaries and the ocean, striped bass are capable of completing their life cycles entirely in fresh water.

Striped bass are broadcast spawners, expelling their eggs into the water column rather than utilizing nests or structure. They spawn at or in close proximity to the surface of the water, and the eggs drift downstream. The species requires suitable habitats a sufficient distance upstream from a river mouth to assure that eggs and larvae have time to hatch, develop, and locate nursery area concurrent with the onset of feeding. Water velocity and discharge rates are important for suspension of eggs and larvae upstream and for transport to the vicinity of suitable nursery habitats downstream – generally shoal, gravel, and sand bar areas in the lower reaches of river systems.

It has been hypothesized that poor reproduction by Gulf race striped bass in some Gulf rivers may be due, in part, to evolutionary adaptations, which may no longer be advantageous to the species' survival in rivers segmented by blockages caused by dams and other structures. In general, unaltered Gulf rivers are longer and have higher current velocities than most of those on the Atlantic coast. These physical features may have resulted in adaptive selection for striped bass in these rivers to spawn farther upstream and not require eggs to be as buoyant as those in some Atlantic populations. Construction of dams in Gulf rivers have effectively moved primary spawning sites farther downstream (i.e., below the dams) and created a series of shorter river segments with slack-water reservoirs on their lower ends. In both cases, eggs and larvae may be transported to estuaries, the ocean, or to open-water reservoir habitats, either before they hatch or are old enough to keep themselves suspended in the water column or actively feed. One ironic supposition is that because of these physical changes in the river systems, Atlantic striped bass may now be better suited to reproduce in these rivers than the Gulf race. Some Atlantic populations have more buoyant eggs that may offer a survival advantage in the lower portions of rivers, reservoirs, or in controlled river segments where water velocity may be lower than under free-flowing conditions. However, these hypotheses are unproven.

Striped bass movements are typically associated with foraging, physiological demands, and reproduction. Physiological demands may include the need for striped bass to find thermally optimal conditions. Directly and indirectly, environmental factors dictate to a great extent all aspects of these movements. Tagging returns indicate relatively limited movement by striped bass in Gulf rivers between release sites and recapture locations, and rarely do tagged fish move outside the system in which released. One of the factors negatively affecting striped bass reproductive success is dams and water control structures that block upstream movement and spawning migrations. Dams may also block access to springs and cool water creeks that may provide critical thermal habitat.

Cool water refuges are one of the most critical habitats for striped bass survival in Gulf rivers and are probably the most important factor limiting their abundance in Gulf rivers. Striped bass actively seek out springs and river sections with dense overstory riparian habitat to reduce thermal stress during the summer months. It has been determined that these refuges are a limiting factor for striped bass survival when they attain a larger size, and they may not reach maturity if sufficient oxygenated, cool water habitat is not accessible.

Striped bass are long-lived, produce extremely large numbers of eggs, and individual fish usually reproduce over multiple years. Recruitment is highly variable annually, and one or a few large year classes usually dominate populations at any one time. Recruitment is strongly density-independent, with environmental conditions usually dictating year class success. Longevity of the species provides an opportunity for dominant year classes to spawn over a number of years, thus dampening the effects of poor year classes. Striped bass populations are quite sensitive to fishing mortality, however, which tends to decrease the average age of the population and the likelihood of forming strong year classes. Limited summer thermal refuge habitat is probably the major factor responsible for high adult striped bass mortality in Gulf rivers.

Stock enhancement using striped bass began in the late 19th Century with progeny from propagation programs being used to stock some east coast rivers and establish wild populations on the west coast. Striped bass stocking into inland reservoirs began in the 1930s, and by the 1950s some landlocked reproducing populations of striped bass supported significant fisheries. Striped bass have been introduced into many rivers across the United States where they were not native, including some Gulf river systems. Stock enhancement activities in Gulf coastal rivers began during the late 1960s when state fisheries agencies recognized that the native striped bass populations had either been extirpated or experienced severe declines. At that time Alabama, Florida, Louisiana, and Mississippi embarked on coastal striped bass stock enhancement programs, as did Texas in 1975. Early stock enhancement efforts in Gulf reservoirs and coastal rivers utilized Atlantic race fry or fingerlings because of their ready availability, and most Gulf rivers have been stocked at times with Atlantic origin fish. Efforts began in the early 1980s to shift Gulf coastal stock enhancement programs in rivers east of the Mississippi to use of Gulf race fish, particularly in the ACF and MAT systems. The USFWS artificially spawned Gulf race striped bass for the first time in 1980. Although the ACF system has been stocked predominantly with Gulf race fish since that time, stocking of Atlantic race fish or mixtures of Gulf and Atlantic origin fish continues in some rivers through the present time.

No substantial data exist on the status and sizes of native striped bass populations in Gulf rivers prior to the 1960s. Limited anecdotal accounts indicate that striped bass in the Gulf were probably never very abundant and certainly not as numerous as in the mid-Atlantic rivers where striped bass have supported significant recreational and commercial fisheries. Despite the lack of quantitative data, anecdotal evidence indicates that severe depletions of Gulf striped bass populations occurred during the 1950s. Reasons for these declines have never been determined conclusively; however, contaminants (primarily pesticides) were thought to have been a major factor, along with other habitat disruptions. Although dam construction on rivers may have destroyed or prevented access to key habitat areas, most Gulf rivers did not have dams on them by the time their striped bass populations were either extinct or seriously depleted.

While striped bass have probably never been a major species supporting nearshore saltwater sportfishing in the Gulf of Mexico, recreational fisheries have developed in some areas of the Gulf because of coastal stock enhancement and contributions to downstream striped bass populations through escapement from reservoirs. The largest recreational striped bass fishery occurs on the ACF rivers system where a substantial number of fish are easily accessible to anglers. Smaller fisheries exist in other systems associated with reservoirs, dams, and their tailraces. While a few anglers target striped bass in these locations, the majority of fish are caught incidentally by anglers targeting other fish such as catfish, bass, and seatrout. Striped bass are rarely encountered in creel and other recreational fishing surveys for Gulf rivers.

Although numerous references to striped bass appear in early American literature for the Atlantic coast, there is little historical information on a targeted commercial fishery in the Gulf of Mexico. While there is some historical data on commercial landings for some Gulf states, relatively low numbers of fish were landed compared to fisheries on the Atlantic coast. The last commercial landings of striped bass in the Gulf occurred during the 1960s, and today, there is no commercial fishing for striped bass anywhere in the Gulf.

Anadromous striped bass management in Gulf rivers has predominantly focused on stock enhancement, management studies and research, and enforcement of laws and regulations. The US Fish and Wildlife Service internally considered a potential action in the late 1970s of listing the Gulf race of striped bass under the Endangered Species Act, although the Gulf race was never formally a candidate for listing, nor was there a petition to list. Subsequent concerns and consultation with state fish and wildlife agencies resulted in establishment of a cooperative program for restoration of Gulf race striped bass in the ACF rivers system as an alternative to pursuit of an ESA listing. The Gulf States Marine Fisheries Commission prepared an interjurisdictional fishery management plan (FMP) for striped bass in 1986. This document is its first major revision.

The primary goal of this interstate FMP is to restore and maintain self-sustaining Gulf race striped bass populations in suitable rivers within their native range. A secondary goal is to maintain optimum sustainable yield (OSY) from riverine, recreational striped bass fisheries within that range. The goals generally apply to the free-flowing portions of rivers within the native range of striped bass below the fall line or farthest downstream obstruction. Each river system also has a river-specific goal that supports the FMP primary goals

Management recommendations in the FMP are grouped into three major categories. General recommendations are those that generally apply to the entire management area or to two or more specific river systems. These address harvest regulations, stock enhancement, population data, habitat management, population and habitat modeling, and enforcement. Each general management recommendation may not apply to all rivers. Global recommendations are made that relate to the striped bass management program in the Gulf of Mexico region as a whole and do not specifically apply to any particular watershed or river basin. Such recommendations include those that address program coordination, funding, information and education, contaminants, taxonomic status, investigation of historic population levels, and conservation status. River specific recommendations specify and elaborate on the general recommendations as they apply to each river in support of the river-specific goals. These may also contain additional recommendations unique to specific river systems.

Goals for the specific river systems fall into five general categories. Rivers in which the goal is to establish and maintain a self-sustaining Gulf race population and fishery include the Pearl River (Louisiana and Mississippi), Pascagoula River (Mississippi), Escambia/Conecuh River (Alabama and Florida), Choctawhatchee River (Alabama and Florida), and ACF rivers system (Alabama, Florida, and Georgia). The goal in the MAT rivers system is to maintain mixed-race fisheries. The goal in the lower Mississippi River is to maintain a striped bass recreational fishery. Rivers in which the goal is to maintain Gulf race put-grow-take fisheries include the Tangipahoa and Tchefuncte rivers (Louisiana), the Perdido River (Alabama and Florida), Blackwater and Yellow Rivers (Florida), and the Ochlockonee River (Florida and Georgia). Rivers in which the goal is to maintain striped bass put-grow-take fisheries are the Wolf, Jourdan, Biloxi, and Tchoutacabouffa rivers and Old Fort Bayou (Mississippi).

2.0 INTRODUCTION

In March 1998, the State-Federal Fisheries Management Committee (S-FFMC) granted a request by the Technical Coordinating Committee's Anadromous Fish Subcommittee that a revision to the Striped Bass Fishery Management Plan (FMP) begin. The S-FFMC considers fisheries for FMP development based on a prioritized list of species. The original Striped Bass FMP was completed prior to the establishment of the Interjurisdictional Fisheries (IJF) Program and thus was not considered in this prioritized list. However, in an effort to include the species, a revision was determined necessary to both update the plan as well as reformat it as an IJF plan. A review began in 1999 to determine the extent of revision needed, and recommendations were made to the S-FFMC by the Anadromous Fish Subcommittee. On October 18, 2000, the S-FFMC agreed to establish the Striped Bass Technical Task Force (TTF) to begin the revision to the Striped Bass FMP. The Anadromous Fish Subcommittee would serve as the core for the TTF and would add additional expertise as necessary. An organizational meeting of the Striped Bass TTF was held January 30-31, 2001.

2.1 IJF Program and Management Process

The Interjurisdictional Fisheries Act of 1986 (Title III, Public Law 99-659) was approved by Congress to: (1) promote and encourage state activities in support of the management of interjurisdictional fishery resources and (2) promote and encourage management of interjurisdictional fishery resources throughout their range. Congress also authorized federal funding to support state research and management projects that were consistent with these purposes. Additional funds were authorized to support the development of interstate FMPs by the GSMFC and other marine fishery commissions. The GSMFC decided to pattern its plans after those of the Gulf of Mexico Fishery Management Council (GMFMC) under the Magnuson Fishery Conservation and Management Act of 1976. This decision ensured compatibility in format and approach to management among states, federal agencies, and the GMFMC.

After passage of the act, the GSMFC initiated the development of a planning and approval process for fishery profiles and FMPs. The process has evolved to its current form outlined below:

DMS
↕
TTF → **TCC** → **SFFMC** → **GSMFC**
↕ (TTF) ↕ (SFFMC)
SAT **Outside Review**

DMS = Data Management Subcommittee
SAT = Stock Assessment Team
TTF = Technical Task Force
TCC = Technical Coordinating Committee

SFFMC = State-Federal Fisheries Management Committee
GSMFC = Gulf States Marine Fisheries Commission
Outside Review = standing committees, trade associations, general public

The TTF is composed of a core group of scientists from each Gulf state and is appointed by the respective state directors that serve on the S-FFMC. Also, a TTF member from each of the GSMFC standing committees (Law Enforcement, Habitat Advisory, Commercial Fisheries Advisory, and Recreational Fisheries Advisory) is appointed by the respective committee. In addition, the TTF may include other experts in economics, socio-anthropology, population dynamics, and other specialty areas when needed. The TTF is responsible for development of the FMP and receives input in the form of data and other information from the DMS and the SAT.

Once the TTF completes the plan, it may be approved or modified by the Technical Coordinating Committee (TCC) before being sent to the S-FFMC for review. The S-FFMC may also approve or modify the plan before releasing it for public review and comment. After public review and final approval by the S-FFMC, the plan is submitted to the GSMFC where it may be accepted or rejected. If rejected, the plan is returned to the S-FFMC for further review.

Once approved by the GSMFC, plans are submitted to the Gulf States for their consideration for adoption and implementation of management recommendations.

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Section	9.0	All
Section	10.0	Staff
Section	11.0	All
Section	12.0	All
Section	12.1	All
Section	12.2	Long

2.5 FMP Management Objectives

The objectives of the Striped Bass FMP are:

1. To summarize, reference, and discuss relevant scientific information and studies regarding the management of striped bass in order to provide an understanding of past, present, and future efforts.
2. To describe the biological, social, and economic aspects of the striped bass fishery.
3. To review state and federal management authorities and their jurisdictions, laws, regulations, and policies affecting striped bass.
4. To ascertain optimum benefits of the striped bass fishery of the United States Gulf of Mexico to the region while perpetuating these benefits for future generations.
5. To set clear and attainable management goals for the striped bass fishery and to suggest management strategies and options needed to solve problems, meet the needs of the stock, and achieve these goals.

3.0 DESCRIPTION OF THE STOCK COMPRISING THE MANAGEMENT UNIT

3.1 Geographic Distribution

The striped bass' native range in North America was disjunct; the species was found in rivers of eastern North America from the St. Lawrence River, Canada, to the St. Johns River, Florida. In addition, it was found in rivers of the Gulf of Mexico from the Suwannee River, Florida, to those of the Lake Pontchartrain Basin, Louisiana (Pearson 1938, Raney et al. 1952, Lee et al. 1980 et seq., Swift et al. 1986) (Figure 3.1). Raney et al. (1952) considered the likelihood of exchange between striped bass populations of the Gulf and Atlantic to be "exceedingly remote," and McLane (1958) speculated that temperature tolerance probably limited striped bass to their present distribution in Florida.

Barkuloo (1970) concluded that the native striped bass population in the ACF rivers system of Alabama, Georgia, and Florida was a distinct "race" from those in Atlantic rivers (see more detailed discussion of this in Section 3.2.1.1.1). Although some may prefer to use another term such as "population" for unique forms within a species, three of four fish taxonomists consulted on this question considered the term "race" to be appropriate in referring to the ACF population (S. Mettee, S. Ross, R. Suttkus, and J. Williams personal communications) consistent with the view of Hubbs (1943) that the term has historically been used among ichthyologists as a valid taxonomic category. At least three recent papers on fish taxonomy use the term "race" interchangeably with the terms "population," "stock," and "strain" in referring to distinct forms within a species (Billington and Maceina 1997, Galbreath et al. 2001, Kinziger 2003). While the use of one of these other terms may also be appropriate, we have chosen to retain use of "race" in referring to the unique form of striped bass in the ACF for several reasons. Many Gulf rivers now contain mixtures of striped bass from the ACF and one or more Atlantic rivers, so it would be confusing to refer to the striped bass in such a river as being either a Gulf or Atlantic "population" or "stock". The term "strain," even though by definition technically means the same thing as a "race," "stock," or "population," may connote an artificially propagated form to some people. Also, as applied in some fish hatchery records the term "strain" may refer to fish propagated from a specific river system irrespective of whether they constitute a morphologically or genetically unique form. For instance, the National Fish Hatchery System has a designation for a Sabine River "strain" of striped bass, even though these are actually fish of Atlantic origin. For these reasons, and because they have become commonly used among biologists working with striped bass in Gulf rivers, the terms "Gulf race" and "Atlantic race" are used in this document to refer to fish descended from native stocks of either the ACF or one or more Atlantic rivers, respectively. Note that the term "Atlantic race," as used in this document, may refer to one or more unique forms of striped bass found in rivers of the Atlantic coast as determined by Raney (1957) and subsequent investigators.

Striped bass of Atlantic origin were introduced into San Francisco Bay on the Pacific Coast in 1879 and 1882 (Pearson 1938). Since then, striped bass have been introduced into other rivers and reservoirs throughout a large portion of the United States including some drainages of the northern Gulf of Mexico (Lee et al. 1980 et seq.). Raney et al. (1952) reported the Pacific Coast range as southern California (Orange and San Diego counties) to at least the Columbia River, Oregon, and Grays Harbor, Washington, with unconfirmed reports from Alaska. Lee et

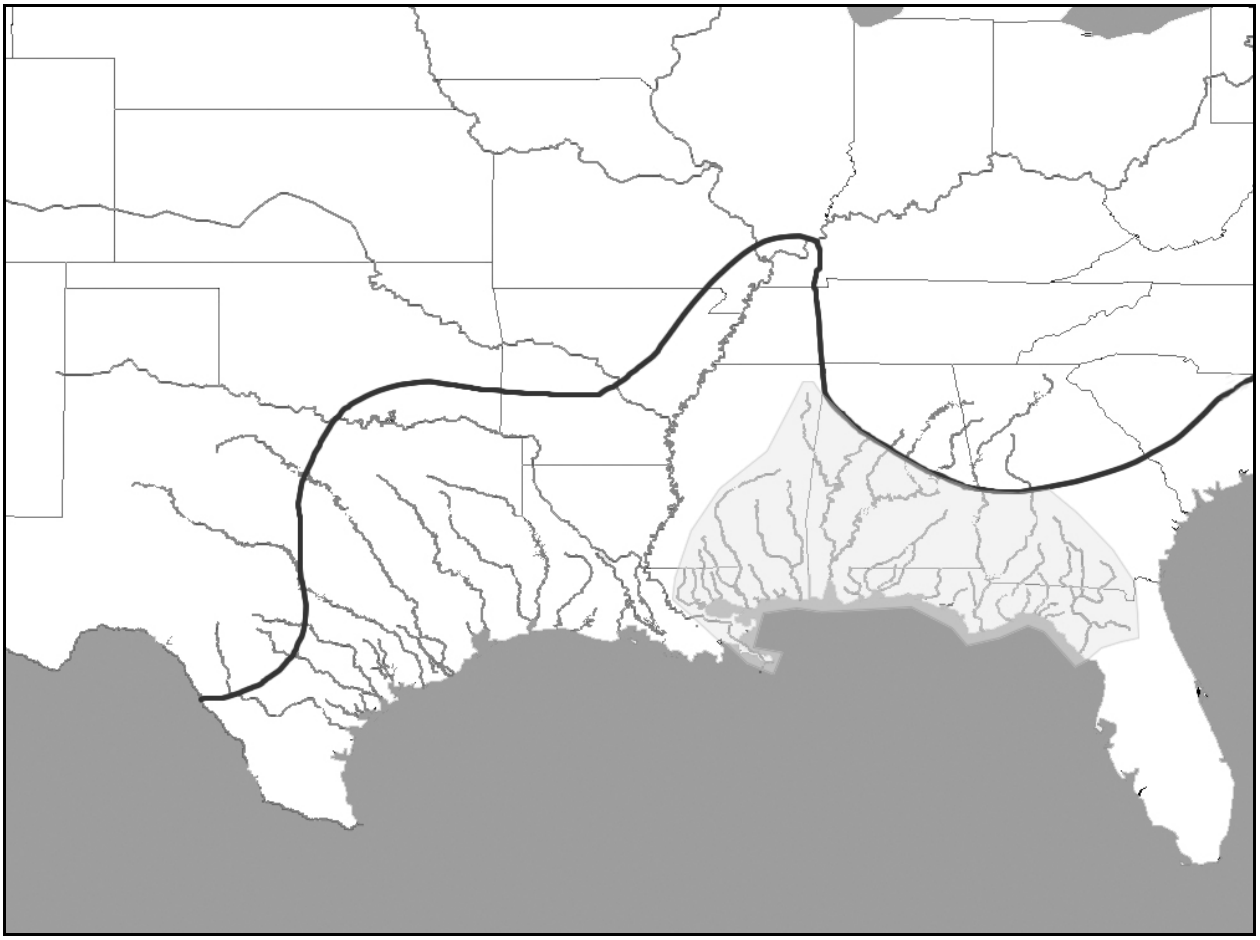


Figure 3.1 Rivers in the Gulf of Mexico region where Gulf and Atlantic race striped bass currently exist. The gray shaded area indicates the probable native range of Gulf race striped bass, and the heavy black line represents the fall line through the southern region of the United States.

al. (1980 et seq.) described the Pacific Coast range as being from northern Baja, California, to Vancouver, British Columbia.

Two of the earliest known references to striped bass in the Gulf of Mexico region include an account given by Mr. Silas Stearns, as reported by Goode (1887), who reported Captain John Washington of Mystic, Connecticut, captured a large school of striped bass in Pensacola Bay in 1850. The catch was composed of individuals weighing 15-40 lbs. The other reference was the listing by Wailes (1854) of striped bass as native to Mississippi. Bean (1883) reported the range of striped bass included the Gulf of Mexico and its rivers. Pearson (1938) reported that striped bass were found in fresh or brackish waters of Gulf rivers but not in salt water (see Jordan 1929 and Gowanloch 1933). Although striped bass have since been collected in Gulf waters (see Section 3.2.4.1), they appear to be more restricted to riverine habitats as compared with striped bass on the mid-Atlantic Coast (Barkuloo 1967). Pearson (1938) considered striped bass to probably have the most extensive geographical range of any American food and game fish. He found its ability to survive in fresh, brackish, or saltwater throughout the year from the cold rivers of eastern Canada to the subtropical bayous of Louisiana provided a unique record of successful adaptation.

Horst (1976) reported considerable disagreement among early authors regarding the westernmost limit of striped bass distribution in the Gulf. According to Jordan and Eigenmann (1890), it was the "Pensacola River." Jordan and Evermann (1902) and Jordan et al (1930) basically agreed, indicating the Escambia River as the western limit. Hildebrand and Schroeder (1928, as cited by Horst 1976) indicated Alabama as the western limit. Jordan (1929) and Pearson (1938) noted the species' presence in Louisiana. Goode (1887) and Bean (1903, as cited by Horst 1976) considered the Mississippi River as the western limit.

Although it has been reported that striped bass were found in the Mississippi River as far north as St. Louis, Missouri, and as far west as Corpus Christi Bay, Texas (Crateau ND, Nicholson et al. 1986), no primary documentation has been found to scientifically substantiate this information. See Sections 3.1.1 and 3.1.2 on distribution in Louisiana and Texas rivers for further discussion.

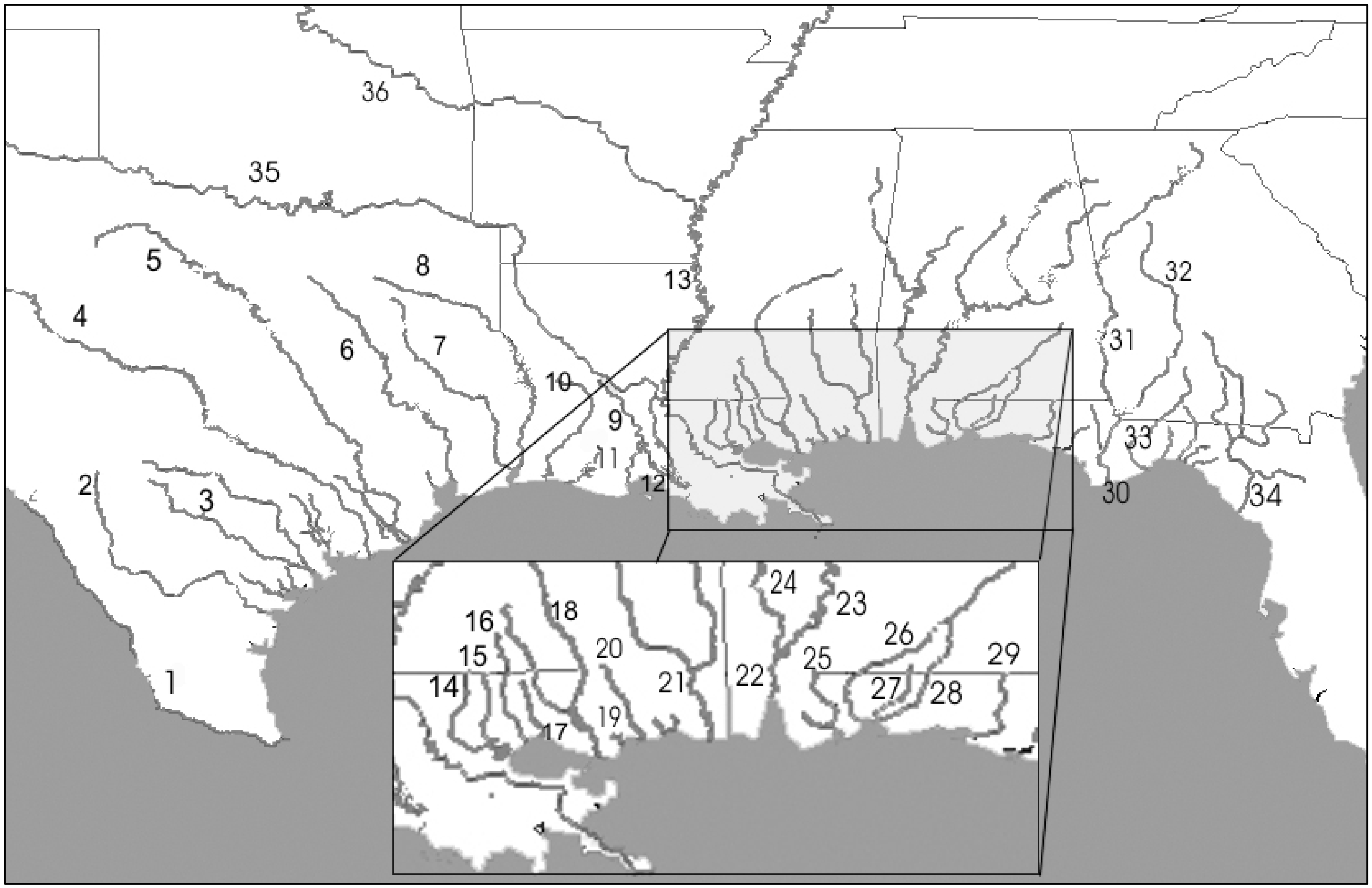
Recent references on the fish fauna of the Gulf of Mexico agree with the distribution described in the first paragraph of this section. Walls (1975) stated striped bass ranged west to the Mississippi River delta, and Hoese and Moore (1977) gave the striped bass' native range as the streams entering Lake Pontchartrain east to the Florida Panhandle. Shipp (1986) stated the range as being from the "central Gulf Coast of Florida to the Mississippi River delta," but represented only by "stragglers at each end of that range." With respect to the distribution of striped bass above the fall line, the rapids associated with the fall line probably limited upstream movement of striped bass in the Apalachicola and Mobile river systems. However, some movement of striped bass above the fall line likely occurred prior to the construction of dams in those rivers (Lupold and Schnell 1991), and historic records for striped bass exist above the fall line in some Atlantic coast rivers (USFWS, NMFS, and SCDNR 2001).

As of the early to mid-1960s, native striped bass were extirpated from Gulf rivers with the exception of small reproducing populations in the ACF river system and in the MAT river system (Barkuloo 1970, Brown 1965, Crateau ND, Crateau et al. 1981).

Information on the stocking of striped bass in Gulf rivers is provided in the following sections in order to provide background and context on geographic distribution. See Section 3.8 for a more complete and quantitative discussion of striped bass stocking. Figure 3.2 indicates the Gulf of Mexico rivers in which striped bass have been documented.

3.1.1 Texas

Although some reports and other documents concerning striped bass in the Gulf of Mexico indicate that striped bass occurred as a native species in Texas (Butler and Stelly 1993, McCabe 1989, Nicholson et al. 1986), the ichthyologic literature does not support this, and no sources to scientifically document striped bass as a native species in Texas have been found.



1 Rio Grande
2 Nueces River
3 Guadalupe River
4 Colorado River
5 Brazos River
6 Trinity River
7 Sabine River
8 Neches River
9 Vermilion River
10 Calcasieu River
11 Mermentau River
12 Bayou Teche
13 Mississippi River
14 Amite River
15 Tickfaw River
16 Tangipahoa River
17 Tchefuncte River
18 Pearl River
19 Jourdan River
20 Wolf River
21 Pascagoula River
22 Mobile River
23 Alabama River
24 Tombigbee River
25 Perdido River
26 Escambia/Conecuh River
27 Blackwater River
28 Yellow River
29 Choctawhatchee River
30 Apalachicola River
31 Chattahoochee River
32 Flint River
33 Ochlockonee River
34 Suwanee River
35 Red River
36 Arkansas River

Figure 3.2 Distribution of rivers along the Gulf coast within the current range of striped bass.

Collins and Smith (1893) reported commercial catches of striped bass in 1889 and 1890 from Chambers, Galveston, Brazoria, Refugio, Aransas, and Nueces counties in the shore seine and vessel fisheries, but they indicated data were collected over a three-month period in early 1891 by interviewing fishermen regarding fishing conducted during the past two-year period. They acknowledged the limitations of their information as lacking "actual specimens at hand for examination" and indicated their data for striped bass were tallied for catches reported using the common name "rockfish." Collins and Smith (1893) reported no commercial catches of striped bass in Alabama, Mississippi, or Florida for the same period. Similarly, Stevenson (1893) reported "rockfish or striped bass" taken in the seine fisheries from Galveston, Aransas, and Corpus Christi bays in 1890 but mentioned that the quantitative data used in his report were based on fish transport company records because the information from fishermen and markets was unreliable. Based on comparison, the data reported by Stevenson (1893) are likely the same used by Collins and Smith (1893) for Texas. However, Stevenson (1893) included a plate illustration of a striped bass in his report, which was cited by Waldman (1986) as evidence that the fish reported by Stevenson (1893) were actually striped bass. However, this cannot be relied upon as positive identification of the fish reported as striped bass, due to the aforementioned limitations of the data that were used.

Townsend (1900) reported fisheries data for the Gulf States for the year 1897 (data were actually collected in 1898) that indicated "striped bass" were present in Texas seine fisheries, but the same data limitations as in Stevenson (1893) are assumed. Similarly to Collins and Smith (1893), Townsend (1900) reported no striped bass harvest in Alabama, Mississippi, and Florida waters. Fiedler et al. (1934) reported 495 lbs of striped bass were harvested from Texas in 1933 but none from any other states south of North Carolina.

According to Butler and Stelly (1993), the last reports of commercial harvest of striped bass in Texas were in the 1945 and 1946 annual reports of the Texas Game, Fish, and Oyster Commission. Benefield et al. (1977) reported two striped bass captured in Texas coastal waters in the "late 1960s" and 1975 as being the first and second authenticated occurrences of striped bass in Texas waters. Since stocking of striped bass into Texas coastal rivers began in 1967 (McCabe 1981), it is possible that those reports were fish that migrated downriver from inland stocking areas to coastal waters.

Jordan and Gilbert (1887) reported on results of collecting fish during the summer of 1884 in the Sabine, Trinity, Lampasas, Colorado, San Marcos, and Comal rivers. Neither striped bass nor any other moronids were found.

Evermann and Kendall (1894) listed 230 species of fishes from Texas waters based on their own collecting as well as previous accounts. Striped bass were not included in their list of species. They did report white bass *(M. chrysops)* from the Red River and that yellow bass (*M. mississippiensis*) were common in the lower portions of the San Jacinto and Trinity rivers and were "brought in considerable numbers to the Houston market" (Evermann and Kendall 1894). Baughman (1950) indicated a striped bass reported for Texas by Taylor (1878) was probably a yellow bass. Hubbs (1972) did not include striped bass among a comprehensive list of Texas fishes even though the list was compiled a few years after striped bass stocking began in Texas lakes, rivers, and coastal waters in 1967 (McCabe 1989).

In light of the above information and considering that the native range of yellow bass extends westward to Galveston Bay and that of white bass to the Rio Grande River (Lee et al. 1980 et seq.), striped bass landings reported for Texas in the late 19th and early 20th centuries may not have actually been striped bass. It is more likely that they were either yellow or white bass or perhaps even some members of the family Serranidae that Stevenson (1893) reported were commonly called "rockfish" by fishermen.

3.1.1.1 Rio Grande

Atlantic race striped bass have been stocked into the Falcon and Amistad reservoirs on the main stem of the river (TPWD 2002). Smith and Miller (1986) did not indicate that striped bass were native to the Rio Grande.

3.1.1.2 Nueces River and Corpus Christi Bay

Atlantic race striped bass have been stocked into the Nueces River (Nicholson et al. 1986). Uvalde National Fish Hatchery (NFH) on the Leona River, a Nueces tributary, reared Gulf and/or Atlantic race striped bass fingerlings, and it is possible some escaped. Atlantic race striped bass have also been stocked into Corpus Christi Bay (Dailey 1989).

3.1.1.3 Guadalupe River and San Antonio Bay

Canyon Lake on the Guadalupe River has been stocked with Atlantic race striped bass (TPWD 2002), as has San Antonio Bay (Dailey 1989).

3.1.1.4 Matagorda Bay

Matagorda Bay has been stocked with Atlantic race striped bass (Dailey 1989).

3.1.1.5 Colorado River

Atlantic race striped bass have been stocked into Lakes Travis, Buchanan, and E.V. Spence on the main stem and into Twin Buttes Reservoir on a tributary (TPWD 2002) of the Colorado River. The Inks Dam NFH, located on the Colorado River, has reared both Atlantic and Gulf race striped bass, and some may have escaped.

3.1.1.6 Brazos River

Atlantic race striped bass have been stocked into Lakes Whitney, Granbury, Possum Kingdom (TPWD 2002) and Buffalo Springs (R. Weller, GDNR, personal communication). Conner and Suttkus (1986) listed striped bass as an introduced species in the Brazos River.

3.1.1.7 Trinity River and Galveston Bay

Atlantic race striped bass have been stocked into Lakes Livingston, Lewisville, and Lavon (TPWD 2002) in the Trinity River basin. Atlantic race striped bass were also stocked into

Trinity Bay and Galveston Bay (Dailey 1989). Conner and Suttkus (1986) listed striped bass as an introduced species in Galveston Bay.

3.1.1.8 Sabine River-Neches River System

Atlantic race striped bass have been stocked into Lake Palestine on the Neches River and into Lakes Toledo Bend and Tawakoni on the Sabine (TPWD 2002). Atlantic race striped bass have also been stocked into Sabine Lake (Dailey 1989). A relatively small number of Gulf race striped bass have been stocked into Toledo Bend Reservoir by the LDWF (USFWS unpublished data). Conner and Suttkus (1986) listed striped bass as an introduced species in Sabine Lake.

3.1.2 Louisiana

Collins and Smith (1893) reported commercial catches of striped bass in 1889 and 1890 from St. Tammany, Tangipahoa, St. John the Baptist, St. Charles, Jefferson, Orleans, and St. Bernard parishes in the shore seine and line fisheries. Townsend (1900) reported striped bass harvest from the same parishes except Tangipahoa in 1897. Limitations inherent in these data are discussed under Section 3.1.1 for Texas. Given those limitations, it seems possible that the reported striped bass harvest may have actually consisted of aggregates of striped bass, white bass, and perhaps yellow bass in Louisiana.

Gowanloch (1933) reported striped bass in Louisiana, and Davis et al. (1970) stated the area of southeastern Louisiana east of the Mississippi River had a native striped bass fishery. Swift et al. (1986) indicated striped bass as a native species in Lake Pontchartrain. Douglas (1974) stated that personnel of the LDWF reported striped bass from the Lake Pontchartrain, Pearl, and Atchafalaya River drainages, but it is unclear whether this was intended to portray the native or current range in the state.

In addition to the data below, Atlantic race striped bass have been stocked into Terrebonne Bay, Barataria Bay, and the Intracoastal Waterway (Nicholson et al. 1986).

3.1.2.1 Vermilion River

Atlantic race striped bass have been stocked into the Vermilion River (LDWF unpublished data).

3.1.2.2 Calcasieu River

Atlantic race striped bass have been stocked into the Calcasieu River (Horst 1976, Nicholson et al. 1986). Conner and Suttkus (1986) listed striped bass as an introduced species in this river.

3.1.2.3 Mermentau River

Atlantic race striped bass have been stocked into the Mermentau River (Horst 1976, Nicholson et al. 1986).

3.1.2.4 Bayou Teche

Atlantic and Gulf race striped bass have been stocked into Indian Creek Lake, which is located in the Teche drainage basin (Horst 1976, Nicholson et al. 1986, USFWS unpublished data).

3.1.2.5 Mississippi River

Striped bass have been reported to be native to the Mississippi River as far north as St. Louis, Missouri (Crateau ND, Nicholson et al. 1986). Bean (1883) indicated the range included the lower Mississippi Valley, but he followed the data in the text with a question mark in parentheses, presumably indicating that he had some doubt regarding the accuracy of the information. According to Goode (1903), the original source of Bean's information appeared to be an article in Hallock's *Sportsman's Gazetteer*. Goode (1903) stated that the fish identified as striped bass by Mr. Hallock and probably other fish reported from the mouth of the Mississippi River by Mr. Silas Stearns were actually "Brassy Bass, *Roccus interruptus*," now known as yellow bass. Fremling et al. (1989) described striped bass as an "introduced exotic" in the Mississippi River. Pflieger (1975) cited striped bass as a recent introduction to the Missouri fish fauna, first stocked in 1966. He reported striped bass being caught in the Mississippi and St. Francis Rivers in the years following stocking, but the source of those fish was unknown. Since the mid-1960s, Atlantic race striped bass have been stocked into many other areas throughout the Mississippi River system (Burr and Page 1986, Clay 1975, Cross et al. 1986, Etnier and Starnes 1993).

Rafinesque (1820) did not report striped bass being present in the Ohio River, although he described a species ("*Perca chrysops*") that he called "golden-eyes perch," now known as white bass. He distinguished it from the "Rock fish or Striped bass of the Atlantic Ocean," and indicated it was commonly mistaken for that species. Jordan and Gilbert (1887) reported on results of collecting fish during summer 1884 in the Mississippi River basin in the present states of Arkansas, Oklahoma, and Texas. They did not find striped bass, but they found white bass in the "Washita" (sic) River at Arkadelphia, Arkansas; in the Saline River at Benton, Arkansas; and in the Red River at Fulton, Arkansas. Meek (1895) reported on fish collection efforts in Arkansas during 1891-1893. He reported "*Roccus chrysops*" being common in the Arkansas and White rivers but used the common name "striped bass" for them; *R. saxatilis* was not listed among the species collected.

Goode (1887) and Bean (1903, as cited by Horst 1976) indicated the mouth of the Mississippi River as the westernmost limit of striped bass distribution in the Gulf. Horst (1976) interviewed 12 commercial fishermen in both the Mississippi and Atchafalaya Rivers regarding their catch of striped bass. Nine of the fishermen fished commercially for 30 years. None recalled catching striped bass before 1965-1966, which coincided approximately with the beginning of striped bass stocking in the southeastern United States (Southeast). Bailey (1951) did not list striped bass among the fish fauna of Iowa. Lambou (1959, 1961b) and Lambou and Geagan (1961) did not find any striped bass in sampling oxbow and backwater lakes along the Mississippi and Atchafalaya Rivers in Louisiana in 1954-1955. Although Lambou (1961a) reported striped bass in creel surveys of Clear Lake, located within the Mississippi River drainage in northeastern Louisiana and before known striped bass stocking in Louisiana, these were more than likely white bass. The creel form used in the survey listed white bass and yellow bass under the category "stripped bass," and these were probably reported as "striped bass" in the reports.

Cross et al. (1986) listed striped bass as an introduced species in the following rivers of the western Mississippi River basin: Arkansas (lower, middle, and upper); Canadian; Kansas; Missouri (lower); Ouachita; Mississippi (main stem); Platte-Niobrara; Red (lower and upper); St. Francis-Little; and White. Burr and Page (1986) described striped bass as an introduced species in the lower Ohio and upper Mississippi rivers and the following tributaries: Big Muddy, Des Moines, Green, Kentucky, Sangamon, Scioto, and Skunk rivers. Smith (1979) and Laird and Page (1996) noted striped bass first appeared in Illinois in 1974, probably as emigres from impoundments in western Kentucky. Smith noted that they spread from the Ohio River as far north as the lower Kaskaskia River. Starnes and Etnier (1986) listed 240 fishes native to the Tennessee and Cumberland river systems but did not include striped bass. Curiously, even though Jenkins et al. (1972) listed striped bass as an anadromous species among the ichthyofauna of the lower Cumberland and Tennessee rivers, they did not indicate whether it was introduced or if its range included the lower or central Mississippi basin. Clay (1975) described striped bass as an introduced species in Kentucky waters, as did Etnier and Starnes (1993) for Tennessee.

In the Red River drainage, Atlantic race striped bass have been stocked into Lakes Kemp and Diversion in Texas, as well as Lake Texoma, a Red River main stem impoundment between Texas and Oklahoma (TPWD 2002) and into Lakes Bistineau, Claiborne, and D'Arbonne in Louisiana (Horst 1976). In the Arkansas River basin, Atlantic race striped bass have been stocked in Keystone Reservoir near Tulsa (Mensinger 1970), and they have also been stocked in other areas within Arkansas (Gray 1958, Hardy 1978). Atlantic race striped bass have been stocked into Lake Bruin (Horst 1976), and Gulf race striped bass fingerlings have also been stocked into False River (USFWS unpublished data). Both of these are Mississippi River oxbow lakes. Atlantic race striped bass have been stocked into the Biloxi Marsh area of southeastern Louisiana east of New Orleans (Horst 1976, Nicholson et al. 1986, LDWF unpublished data).

Connor and Guillory (1974) documented that striped bass were present in the lower Mississippi River (LMR) and in the Atchafalaya River between Simmesport and Morgan City. They described striped bass as being "partly introduced" in the system, but they provided no dates for the occurrence records. Horst (1976) conducted a study of striped bass in the Atchafalaya River basin and found all appeared to be of Atlantic origin, based on LLSC. Citing unpublished data, Guillory (1982) documented the presence of striped bass in the LMR near St. Francisville, Louisiana. All these reports occurred after striped bass introductions began in the Mississippi River basin.

In conclusion, evidence does not support striped bass being native to the Mississippi River system as an anadromous population, but it is quite reasonable to assume they may have entered the extreme lower portions of the river at times due to the proximity of the river to their known western limit of distribution in the Gulf. Since the mid-1960s, they have been stocked extensively throughout the drainage basin.

3.1.2.6 Amite River

Davis et al. (1970) reported striped bass were present in the Amite River (a tributary of Lake Maurepas, west of and connected to Lake Pontchartrain) before their extirpation in Louisiana during the late 1950s.

3.1.2.7 Tickfaw River

Raney et al. (1952) reported a striped bass taken in 1951near Horse Bluff on the Tickfaw River, also a Lake Maurepas tributary. Davis et al. (1970) reported striped bass were present in the Tickfaw River and in the tributary Natalbany River before their extirpation in Louisiana during the late 1950s.

3.1.2.8 Tangipahoa River

Bean (1885) reported on a striped bass specimen taken from the Tangipahoa River near Osyka, Mississippi and deposited in the U.S. National Museum in 1884. He also noted that numerous others were observed in the river in the same vicinity. Based on verbal reports, McIlwain (1967) reported striped bass in the Tangipahoa River. Both Atlantic and Gulf race striped bass have been stocked into the Tangipahoa River (LDWF unpublished data, USFWS unpublished data).

3.1.2.9 Tchefuncte River

Gowanloch (1933) and Pearson (1938) reported striped bass taken from the Tchefuncte River. Davis et al. (1970) and Crateau (ND, citing Chipman 1956) reported striped bass were present in the Tchefuncte and Bogue Falaya rivers before their extirpation in Louisiana during the late 1950s. Atlantic and Gulf race striped bass have been stocked in the Tchefuncte River (Horst 1976, LDWF unpublished data, USFWS unpublished data).

3.1.3 Mississippi

Wailes (1854) included "Labrax" sp. and "*Labrax lineatus* (Cuv.)," using the common names striped bass and rockfish, respectively, in a catalog of the fishes of Mississippi. The catalog was based upon specimens examined by Louis Agassiz, but the publication did not contain any exact information regarding when or where the specimens were collected. Raney and Woolcott (1955) mentioned several specimens from Mississippi. Cook (1959) reported striped bass from the nearshore Gulf and coastal rivers of Mississippi. McIlwain (1967) indicated native striped bass were collected from "all major river systems of the Mississippi Gulf Coast from the Pascagoula River west to the Tangipahoa River." Ross (2001) indicated the native range in Mississippi included all the coastal rivers, but that striped bass also occurred as an introduced species in the Yazoo and Mississippi rivers.

3.1.3.1 Pearl River

McIlwain (1967) stated striped bass were present in the Pearl River based on verbal reports. Davis et al. (1970) and Crateau (ND, citing Chipman 1956) reported striped bass were present in the Louisiana portions of the Bogue Chitto and Pearl rivers before their extirpation in the late 1950s. Swift et al. (1986) identified striped bass as a species native to the Pearl River. Atlantic and Gulf race striped bass have been stocked into the Pearl River and Ross Barnett Reservoir, located on the river near Jackson (Bailey 1974, Horst 1976, Nicholson et al. 1986, Nicholson 1994, GCRL unpublished data, MDWFP unpublished data, USFWS unpublished data).

3.1.3.2 Jourdan and Wolf Rivers

Pearson (1938) reported striped bass being found in the "Jordan" (sic) and Wolf rivers. McIlwain (1967) stated striped bass were present in the Jourdan and Wolf rivers based on verbal reports. Swift et al. (1986) listed striped bass as native to the St. Louis Bay drainages but unsubstantiated by museum specimens or other evidence. Atlantic race striped bass have been stocked into the Jourdan and Wolf rivers (McIlwain 1976, Nicholson et al. 1986, GCRL unpublished data, MDWFP unpublished data, USFWS unpublished data).

3.1.3.3 Biloxi Bay

McIlwain (1967) reported striped bass being present in the Biloxi River based on verbal and written reports as well as personal interviews and in the Tchoutacabouffa River based on verbal reports. Atlantic and Gulf race striped bass have been stocked into the Biloxi and Tchoutacabouffa rivers and Fort Bayou, all tributaries of Biloxi Bay (McIlwain 1971, Nicholson et al. 1986, GCRL unpublished data, MDWFP unpublished data).

3.1.3.4 Pascagoula River

Cook (1959) reported a female striped bass with well-developed roe taken February 6, 1934, from the lower Pascagoula River. The specimen was preserved as a taxidermy mount in the Mississippi Game and Fish Commission collection. McIlwain (1967) reported striped bass being present in the Pascagoula River based on a variety of sources including verbal reports, photographs, personal interviews, newspaper reports, and mounted specimens. Swift et al. (1986) indicated striped bass were a native species of the Pascagoula River. Atlantic and Gulf race striped bass have been stocked into the Pascagoula (Bailey 1974, McIlwain 1971, Nicholson et al. 1986, Nicholson 1994, ADCNR unpublished data, GCRL unpublished data, MDWFP unpublished data, USFWS unpublished data).

3.1.4 Alabama

3.1.4.1 Mobile-Alabama-Tombigbee River System

A single museum specimen collected in the mid-1800s near Mobile is the earliest documented record of striped bass in Alabama (Howard University, Specimen MCZ 21763).

Another early account of striped bass in Alabama is Pearson's (1938) report of a female with eggs taken on April 7, 1883, in the Alabama River near Montgomery. Raney et al. (1952) reported their presence "in recent years" in the Coosa River at Wetumpka and in the "Tallassee River at Tallapoosa, Alabama" (sic). Specimens in museum collections further substantiate such reports. Two specimens collected in the Tombigbee River in 1954 are in the collection at Auburn University (Catalog Number AU 9402), and two others collected from Mobile Bay in 1956 and 1961 are in the collection at the University of Alabama (Catalog Numbers VAIC 2441.02 and VAIC 0506.12, respectively). Brown (1965) also reported the collection of 18 native striped bass from the Tallapoosa River near Tallassee in 1960-1961. Swift et al. (1986) listed striped bass as a native of the MAT River system. Within the drainage, they indicated striped bass were documented from Mobile Bay; the Tallapoosa, Coosa, and Tombigbee rivers; and present in the Cahaba, Alabama, and Black Warrior rivers but unsubstantiated by museum records or other evidence. However, see the above Pearson (1938) report for a specimen from the Alabama River.

While native striped bass were almost extirpated in the MAT by the late 1960s (Shell and Kelley 1968), there were some native fish remaining as late as 1979 (Crateau ND). As reported by Mettee et al. (1996), a mixture of Gulf and introduced Atlantic race striped bass currently exist in the system. Both Gulf and Atlantic race fish have been stocked into the system (Shell and Kelley 1968; Swingle 1968, 1970; Swingle and Kelley 1969; Bailey 1974; Nicholson et al. 1986; Beisser 1987; Powell 1989, 1990; Duffy 1993; Tatum et al. 1994; Davin et al. 1998; ADCNR/WFF unpublished data; MDWFP unpublished data; USFWS unpublished data).

3.1.5 Florida

Goode (1887) reported an account of the capture of a large school of striped bass in Pensacola Bay in 1850, and Evermann and Kendall (1899) listed striped bass being present in the Pensacola area. Pearson (1938) reported striped bass were found in "various coastal streams" of western Florida between St. Marks and Pensacola.

3.1.5.1 Perdido River

McLane (1958), based on a single specimen, reported striped bass occurring in the Perdido River during 1953-1955. Swift et al. (1986) listed striped bass as native to the Perdido River. Both Gulf and Atlantic race striped bass have been stocked into the Perdido River (Powell 1989, ADCNR/WFF unpublished data, USFWS unpublished data).

3.1.5.2 Escambia/Conecuh River

Goode and Bean (1880) reported a single striped bass specimen taken from the vicinity of Pensacola, Florida, some time during 1877-1879, most likely from the Escambia River. Pearson (1938) reported striped bass were found in the Escambia River at Pensacola, Florida, before 1884 (possibly based on the same specimen reported by Goode and Bean 1880). Bollman (1887) reported a single, 457 mm specimen collected from the Escambia River, and this provided the basis for Evermann and Kendall (1899) to list striped bass as present there. McLane (1958) reported striped bass in the Escambia River during 1953-1955 based on a verbal report.

Barkuloo (1961a, 1967, personal communication) reported striped bass in the river based on verbal reports during 1959-1961. He collected young striped bass as early as 1957 from the Escambia River before stocking programs began. Swift et al. (1986) listed striped bass as native to the Escambia River. Atlantic and Gulf race striped bass have been stocked into the Escambia River (Nicholson et al. 1986, Yeager 1988b).

3.1.5.3 Blackwater River

McLane (1958) reported striped bass in the Blackwater River near Milton during 1953-1955 based on a verbal report. Barkuloo (1961a, 1967) reported striped bass in the river based on verbal reports during 1959-1961. Swift et al. (1986) listed striped bass as a native to the Blackwater River, but that this was unsubstantiated by museum records. Atlantic and Gulf race striped bass have been stocked into the Blackwater River (Slack and Yeager 1993, Slack and Yeager 1996, FWC unpublished data, USFWS unpublished data).

3.1.5.4 Yellow River

McLane (1958) reported striped bass in Boiling and Wolf creeks in the Yellow River drainage during 1953-1955. These occurrences were based on verbal reports. Barkuloo (1961a, 1967) reported striped bass in the Yellow River based on fishermen interviews during 1959-1961. Swift et al. (1986) listed striped bass as a native of the Yellow River. Atlantic and Gulf race striped bass have been stocked into the Yellow River (FWC unpublished data).

3.1.5.5 Choctawhatchee River

Barkuloo (1961a, 1967) reported striped bass in the Choctawhatchee River based on commercial fishermen interviews and wildlife enforcement officer reports of illegal take during 1959-1961. Swift et al. (1986) listed striped bass as a native of the Choctawhatchee River. Both Gulf and Atlantic race striped bass have been stocked into the Choctawhatchee River (Smith et al. 1975, Wigfall and Barkuloo 1975, Nicholson et al. 1986, FWC unpublished data, USFWS unpublished data).

3.1.5.6 Panama City Area, Bay County

McLane (1958) reported striped bass in the Econfina/Bear Creek/North Bay watershed during 1953-1955 based on verbal reports and photographs. Barkuloo (1961a, 1967) reported striped bass in the Intracoastal Waterway near Panama City and the presence of striped bass in Bear Creek based on fishermen interviews during 1959-1961.

3.1.5.7 Apalachicola-Chattahoochee-Flint Rivers

McLane (1958) reported striped bass in the Chipola River and Dead Lake based on verbal reports and newspaper photographs, from the Intracoastal Waterway at White City based on verbal reports, and from the Apalachicola River above and below Jim Woodruff Lock and Dam (JWLD) based on many verbal reports during 1953-1955. Nineteen striped bass specimens were collected from the Apalachicola River during 1958-1960 and deposited in the museum collection at the University of Florida (Catalog Numbers 013970, 053151, 055237, 055278, 056422, 056422). Other specimens from the Apalachicola below JWLD were collected in 1957 and are housed in the Cornell University Ichthyology Museum (18 specimens, Catalog Number 48267) and 1958 (19 specimens, Catalog Number 48267). Barkuloo (1961a, 1967) described a seasonal recreational fishery for striped bass below JWLD during 1959-1961. Swift et al. (1986) listed striped bass as native to the Apalachicola, Chattahoochee, and Flint rivers. Chason (1987) reported first and second-hand anecdotal accounts of striped bass observed in the Chipola River in the 1880s and 1920s. Barkuloo (personal communication) noted that prior to the construction of the Dead Lake Dam, he observed about 15 large striped bass in a spring on the Chipola River above Highway 90. Both Gulf and Atlantic race striped bass have been stocked into the ACF (Wyatt et al. 1966, Holder 1969, Gennings 1970, McIlwain 1971, Pasch 1973, Keefer 1981, Nicholson et al. 1986, Barkuloo 1990, Mesing et al. 1993, Long and Rousseau 1996, Long 2001, GDNR unpublished data, USFWS unpublished data).

3.1.5.8 Ochlockonee River

McLane (1958) reported striped bass in the Ochlockonee River during 1953-1955 based on a specimen from below Jackson Bluff Dam and a verbal report from a site near McIntyre, Florida. Barkuloo (1961a, 1967) cited verbal reports and photographs of striped bass caught below the dam during 1959-1961. Swift et al. (1986) listed striped bass as being native to the Ochlockonee River. Both Gulf and Atlantic race striped bass have been stocked into the Ochlockonee River (Nicholson et al. 1986; Mesing 1993, 1994, 1995; J. Barkuloo unpublished data; FWC unpublished data; USFWS unpublished data).

3.1.5.9 Small Florida Gulf Coast Rivers

Barkuloo (1961a, 1967) cited a newspaper report of a striped bass from the St. Marks River during 1959-1961. Swift et al. (1986) also cited October 1958 and November 1963 newspaper reports of 1.4-10.9 kg striped bass caught in the St. Marks River. Swift et al. (1986) listed striped bass as native to the Steinhatchee and St. Marks Rivers. Gulf race striped bass have been stocked into the St. Marks River (Nicholson et al. 1986).

3.1.5.9.1 Suwannee River

Barkuloo (1961a, 1967) reported three striped bass specimens from the Suwannee River during 1959-1961. Swift et al. (1986) listed striped bass as native to the Suwannee River.

3.2 Biological Description

3.2.1 Classification and Morphology

3.2.1.1 Classification

The following complete classification of striped bass is from the Integrated Taxonomic Information System (ITIS 2003) and Nelson et al. (2004):

Kingdom: Animalia
Phylum: Chordata
Superclass: Osteichthyes
Class: Actinopterygii
Subclass: Neopterygii
Infraclass: Teleosti
Superorder: Acanthopterygii
Order: Perciformes
Suborder: Percoidei
Family: Moronidae
Genus: *Morone*
Species: *saxatilis* (Walbaum 1792)

The valid scientific name for striped bass is *Morone saxatilis* (Walbaum 1792, Robins et al. 1991). Type locality for the species is "New York" (Lee et al. 1980 et seq.). The preferred common name is striped bass (Robins et al. 1991) with another acceptable common name being "rockfish" (ITIS 2003), but other names have included striper, greenhead, linesider, rock, roller, and squid hound (Ross 2001). Synonyms in the scientific literature include *Perca saxatilis, Labrax lineatus, Roccus saxatilis* (Ross 2001), and *Morone lineatus* (Cook 1959). The etymology for *Morone* is not known; *saxatilis* means "dwelling among rocks" (Etnier and Starnes 1993).

Striped bass belongs to the family Moronidae, commonly referred to as the "temperate basses," and contains anadromous, euryhaline, and freshwater species (Etnier and Starnes 1993, Waldman 1986). The family consists of the single genus *Morone*, formerly placed in the families Serranidae and Percichthyidae (Waldman 1986). The other five species in the family include two found in eastern Atlantic drainages in Europe and northwest Africa (*M. labrax*, European bass and *M. punctata*, spotted bass); another found in Atlantic rivers of eastern North America (*M. americana*, white perch); and two found in drainages of central North America (*M. chrysops*, white bass and *M. mississippiensis*, yellow bass) (Waldman 1986). The striped bass is generally considered an anadromous "cool water" species tending to avoid water warmer than 21.0ºC (Hardy 1978). The striped bass' closest relative is the white bass, a freshwater species found in the Mississippi River and Great Lakes drainages (Raney 1957, Waldman 1986).

3.2.1.1.1 Gulf Race

Numerous studies have shown population or racial structure based on meristic and morphometric differences among populations of striped bass in Atlantic rivers (Lewis 1957, Raney and de Sylva 1953, Raney et al. 1954, Raney 1957), and these differences were manifested between upstream-downstream populations within certain rivers as well as between rivers. The term "race" as used here follows Raney and Woolcott (1955) in implying "a lower level of differentiation than that of a subspecies." Dorsal spine counts; LLSC; dorsal, anal, and pectoral soft fin ray counts; and character indices (combinations of dorsal spine, dorsal, anal, and pectoral ray counts); and number of gill rakers formed the major bases for defining these population/racial differences. Lund (1957) also differentiated Atlantic striped bass races using morphometric proportions.

Raney and Woolcott (1955) acknowledged that environmental factors, specifically temperature, might influence LLSC and fin ray counts that are otherwise genetically controlled. These meristic characters are usually inversely related to temperature. However, they could find no consistent north-south clinal relationships in these characteristics among Atlantic Coast striped bass populations and attributed this to the likelihood that striped bass along the Atlantic Coast undergo development at about the same water temperatures. Barkuloo (1967) reported that first generation offspring striped bass in hatcheries tend to retain the same average LLSC as found in the parents. Lewis (1957) similarly considered number of gill rakers to be genetically determined.

In their study of striped bass races in Atlantic rivers, Raney and Woolcott (1955) included four specimens of fish from Florida and Mississippi Gulf of Mexico rivers. They found that these four fish had the lowest average number of anal and pectoral fin rays among the populations they studied and represented the only population in which no specimens had more than ten anal rays or more than 32 pectoral rays. Using the character index, they found that specimens from the St. Johns River, Florida, had the highest; and four specimens from Gulf rivers had the lowest mean index values, representing extremes among the populations. They concluded that the St. Johns River population represented a distinct race. Although they had too few specimens from the Gulf rivers to draw such a conclusion, they acknowledged that the counts from their four specimens suggested significant differences from Atlantic specimens. While Lewis (1957) found no clear clinal trend, he found that striped bass from the Santee-Cooper River system had the lowest and those from the Hudson River had the highest gill raker counts among populations on the Atlantic Coast. The average total gill raker count for specimens from the Gulf of Mexico that he examined was similar to that for the Santee-Cooper population.

Brown (1965), using LLSC data from 30 Gulf river striped bass, including 19 from the Alabama River, found that striped bass in Gulf rivers were differentiated from those in Atlantic rivers based on this meristic character. Barkuloo (1970) also found several meristic differences between striped bass in the Apalachicola River, Florida, and those from a number of Atlantic rivers, including the St. Johns River, Florida. Significant differences in LLSCs were found between fish from the Apalachicola River and those from all eight Atlantic Coast rivers with which comparisons were made. Barkuloo's (1970) analyses, which included Brown's (1965) specimens, found no significant LLSC difference between fish from the Alabama and the Apalachicola rivers. Significant differences were also found in mean numbers of dorsal, anal, and pectoral fin rays between fish from the Apalachicola River and some (but not all) of the eight Atlantic rivers. Pectoral fin ray counts of fish from the Alabama and Apalachicola rivers were not significantly different ($p \leq 0.01$), but dorsal and anal ray counts were considerably different.

Based on his analyses, Barkuloo (1970) concluded that striped bass in the Apalachicola River should be considered a separate race from those in Atlantic rivers. Because of the similarities in LLSCs among native striped bass from the Apalachicola and Alabama rivers, and the coastal rivers of Mississippi (Raney and Woolcott 1955), the term "Gulf race" was generally applied to any native striped bass from Gulf rivers. It is interesting to note that the two specimens reported by Bean (1885) from the Alabama and Tangipahoa rivers had LLSCs that would characterize them as Gulf race. In addition, a single specimen reported from Pensacola (Goode and Bean 1880) had a LLSC near the mean for Gulf race fish, as did a specimen from the Perdido River collected in 1954 (McLane 1958). It should be emphasized, though, that most of the specimens on which this designation is based are from the ACF.

It has been speculated that there may have been distinct populations in numerous Gulf rivers, all of which became extirpated except for the remnant population in the ACF. Hollowell (1980) interviewed a number of individuals with expert knowledge of striped bass in Gulf rivers and found the majority in agreement with the racial designation, although there was some dispute on the matter. There was also speculation expressed in an interview conducted by Hollowell (1980) that there may have been a "riverine" and an "estuarine strain" of native striped bass in the Mobile River system.

In addition to documented meristic differences between races, a number of other differences have been anecdotally reported. Gulf race striped bass eggs appeared to be less buoyant than Atlantic striped bass eggs of Santee-Cooper system, South Carolina, and St. Johns River, Florida, origin (Crateau ND, Barkuloo and Yeager personal communications). Crateau (ND) also reported that Gulf race larvae are slightly larger at hatching, yolk sac absorption occurs earlier, and feeding begins sooner than is reported for Atlantic race larvae. The Gulf race was also reported to have darker stripes than the Atlantic race (Hollowell 1980), and the interrupted stripes occur less frequently than in the Atlantic race (Hollowell 1980). Specific differences in morphological characteristics between Gulf race and those of Atlantic descent are described in Section 3.2.1.2.

Results of molecular genetic investigations support the conclusion that Atlantic and Gulf origin striped bass are different (see Section 3.2.3). Using a variety of genetic techniques, including mitochondrial and nuclear deoxyribonuleic acid (mtDNA and nDNA, respectively) analyses, it was demonstrated that the native population of striped bass in the ACF is unique compared to striped bass populations on the Atlantic Coast (Wirgin et al. 1991, Wirgin and Maceda 1991, Diaz et al. 1997, Wirgin et al. 1997a). Specific approaches included use of restriction length fragment polymorphism (RLFP) analysis of mtDNA, DNA fingerprinting, single copy nDNA, and microsatellite analyses.

Wooley and Crateau (1983), Crateau (ND), Crateau et al. (1981), and Wooley (1982) hypothesized that Gulf race striped bass were more tolerant of warmer temperatures than those of Atlantic descent as manifested by greater longevity, faster growth, and higher summer condition factors for Gulf race as compared to Atlantic striped bass above 300 mm SL in the Apalachicola River. The authors speculated that the lower condition factors for Atlantic fish were due to greater thermal stress on these fish, and the Gulf race may be better physiologically adapted than Atlantic race fish to the generally found in Gulf rivers (Wooley and Crateau 1983).

The Florida Game and Fresh Water Fish Commission (now FWC) conducted a study to test the above hypothesis by co-stocking Gulf and Atlantic race (Santee-Cooper system) striped bass during 1988-1993 and 1995 in Lake Talquin, a reservoir on the Ochlockonee River in Florida (Mesing 1993, 1994, 1995, 1996). Some 1988-year class Gulf race genotypes exhibited faster growth, greater weight, and better condition through age-4 than Atlantic race fish (Mesing 1993). These observed differences disappeared beyond age-4, however no significant differences in survival, growth, or relative condition between the races were evident through age-6 for the 1988-1991 year classes (Mesing 1995), although Atlantic race fish had significantly higher survival than Gulf race among the 1992-year class at age-3 (Mesing 1996). It was acknowledged that results of the study may have been confounded by disparity in stocking sizes, YOY mortalities, and "genetic contamination" of the ACF genotypes by stocking Atlantic race fish into the system (Mesing 1993). Another issue, which may have further confounded Mesing's results, was a lack of genetic diversity in the parental stocks (C. Mesing personal communication).

Another Gulf-Atlantic race performance evaluation involved rearing Gulf and Atlantic race fingerlings in identical raceway systems and comparing growth and survival in a controlled environment (Nicholson 2001a). Following grow out to Phase II, fingerlings were tagged and released into Mississippi coastal rivers during 1997-2000, and tag return rates were compared to determine if there were differences in susceptibility to angler exploitation. Comparisons of growth and survival in the raceway systems were inconclusive because density-dependent interactions involving growth and survival in the individual rearing units obscured any differences between the two races. Tag return data indicated a higher apparent survival rate for the Atlantic race, but these data were not statistically analyzed.

In a radiotelemetry study in 1984-1985 in the Flint River, Van Den Avyle and Evans (1990) found temperature preferences for striped bass in this river did not differ significantly from those shown by striped bass in Atlantic rivers or those of Atlantic origin stocked into reservoirs. Based on LLSC, Van Den Avyle and Evans (1990) likewise found no differences between Gulf and Atlantic race fish with respect to seasonal distribution, temperatures at which fish moved into or out of thermal refuges, or temperatures selected within refuges. However, the determination of race for individual fish in this study based on LLSC may not have been valid due to changes in LLSC within the population that may have occurred as a result of stocking Atlantic race striped bass into the system in earlier years as further described below.

Although relatively limited in number, Atlantic race striped bass, fingerlings and fry, were stocked into the ACF from the mid to late 1960s into the mid 1970s (USFWS unpublished data, GDNR unpublished data). These introductions resulted in questions concerning the genetic integrity of the ACF population since apparent changes in LLSC were observed in fish from the ACF system (Wirgin et al. 1989). While mean LLSC in ACF fish was still significantly higher than in Atlantic populations, some ACF fish exhibited LLSC consistent with those seen in fish from Atlantic rivers. There are several explanations for erosion in LLSC, including environmental conditions such as developmental temperature, year class aberrations, spatially or temporally limited sampling, and introgression of Atlantic genes into the native Gulf population gene pool.

To genetically investigate the extent of introgression of Atlantic genotypes into the ACF population, preserved specimens of native ACF striped bass collected prior to introductions of Atlantic fish were obtained and analyzed using mtDNA (Wirgin et al. 1997a) and nDNA techniques (Wirgin et al. 2005b). Based on the mtDNA evaluation, it was concluded that significant maternally mediated introgression of Atlantic race mtDNA genomes into the native ACF gene pool had not occurred. Although the nDNA analysis indicated that significant introgression of Atlantic nDNA alleles into the population had occurred, a high frequency of unique Gulf mtDNA haplotypes and nDNA alleles remain in the population. For a more detailed explanation of these analyses, see Section 3.2.3.

The observed differences between Gulf and Atlantic races of striped bass may represent the beginning of speciation brought about by genetic separation due to the periodic exposure of the Florida Peninsula above sea level combined with the temperate nature of the species. Hoese and Moore (1977) cited the middle Florida Peninsula (roughly the latitude of Tampa, Florida) as the current approximate transition zone between the tropical fauna to the south and the temperate species to the north. During several glacial periods from the beginning of the Pleistocene Epoch (approximately two million years ago) until approximately 10,000 years ago, sea levels alternately dropped about 100 meters exposing most of the continental shelf and rose again during intervening warmer periods, sometimes covering much of the Florida Peninsula (Hoese and Moore 1977). Although during the periods of lower sea level, the Atlantic and Gulf coasts were more completely separated, cooler waters probably extended around the peninsula and may have actually facilitated movement of temperate species farther south during those times. Even though a more continuous connection between the Gulf and Atlantic may have existed during the interglacial episodes, the generally warmer sea conditions may have effectively blocked movement of temperate species across the peninsula during those times, especially during periods when the peninsula was more completely exposed, as exists today (Hoese and Moore 1977, Raney 1957). Although Hoese and Moore (1977) thought the periods of faunal separation across the Florida Peninsula may not have been long enough to allow speciation to occur, the existence of a number of allopatric “species pairs” in the Atlantic and Gulf points to the existence of some type of speciation mechanism acting between the two bodies of water (e.g., *Cyoscion regalis* and *C. arenarius* (Hoese and Moore 1977); *Acipenser oxyrinchus oxyrinchus* and *A. o. desotoi*; *Alosa mediocris* and *A. chrysochloris*; *A. sapidissima* and *A. alabamae*; *Hybognathus regius* and *H. nuchalis; Erimyzon oblongus oblongus* and *E.o. claviformis; Aphredoderus sayanus sayanus* and *A.s. gibbosus; Esox americanus americanus* and *E.a. vermiculatus*) (Lee et al. 1980 et seq.). Wooley (1985) speculated that the Florida Peninsula probably played a role in subspeciation of the Atlantic and Gulf of Mexico sturgeons (*Acipenser oxyrinchus oxyrinchus* and *A. o. desotoi*).

The concept of evolutionarily significant units (ESU) has been proposed as a criterion for defining a “distinct population segment” qualifying for protection under the federal Endangered Species Act (Waples 1991). According to this concept, a population can be considered an ESU if it: 1) is substantially reproductively isolated from other conspecific population units and 2) represents an important component in the evolutionary legacy of a species. According to Waples (1991), the use of molecular genetic differences were proposed for defining ESUs based on mtDNA divergence between populations, monophylla within them, and significant nuclear divergence in allelic frequencies. However, Waples (1991) advocated the use of additional criteria such as morphological and ecological factors in making such definitions. Although a formal determination of the Gulf race striped bass as an ESU has not been made, informal consideration of available evidence suggests such a designation should be made (Wirgin et al. 2005b).

Another question concerns whether the Gulf race should be considered a separate taxon (subspecies or species). Waples (1991) indicated that some authors suggest that ESU definitions based on genetic differences may warrant taxonomic recognition at the species level. While morphological and genetic differences between Gulf race and Atlantic populations of striped bass have been demonstrated, there has been no formal analysis of the extent of divergence between Atlantic and Gulf striped bass in a taxonomic or systematic context. Evaluation of differences between other Atlantic/Gulf anadromous “sibling” forms (American and Alabama shad and Atlantic and Gulf sturgeon), may provide insight into the importance of Gulf and Atlantic striped bass divergence and whether taxonomic recognition is warranted for the Gulf race. Hubbs (1943) stated he would designate as subspecies those forms showing reasonable geographical or ecological consistency and which usually can be distinguished on totality of characters among “much more than half” the population.

3.2.1.2 Morphology

In addition to general morphology of the species, this section also provides information available on morphological differences between Gulf and Atlantic races of striped bass.

3.2.1.2.1 Eggs

Hardy (1978) provided detailed descriptions of striped bass eggs and development, and the following summary was taken from that reference. Striped bass eggs in the ovary vary in size (0.01-0.23 mm diameter) and are opaque and yolkless. Yolk begins to form at 0.16-0.30 mm, and ripe eggs are generally 1.0-1.50 mm. Color changes from cream to yellow and then to green as eggs ripen. Ripe eggs have no perivitelline space, and a green yolk with an amber oil globule (or sometimes multiple oil globules) on top of the yolk is about half the diameter of the egg. Both the yolk and oil globule provide energy to the developing larva, but the oil globule has the higher energy content (Eldridge et al. 1977). Eggs become less buoyant immediately following fertilization but gain buoyancy during a process called “water hardening” over a two to three hour period (Fish and McCoy 1959). Fertilized, water-hardened eggs are spherical, non-adhesive, and tend to become more transparent as development proceeds, ranging in size from 1.30 to 4.6 mm. Fertilized eggs have a very wide (65%-85% egg diameter) perivitelline space. Specific gravity of water-hardened eggs varies from 1.0003 to 1.00065, averaging 1.0005. The oil globule has little effect on specific gravity (Eldridge et al. 1977). Unfertilized eggs turn opaque and are more buoyant than fertilized eggs after 12 hrs.

As early as 15 minutes after fertilization at about 17°C, the blastodisc may appear on the side of the yolk 90° from the oil globule. At 12 hrs, the blastoderm may cover about half the yolk. The embryo is halfway around the yolk by about 24 hrs with some pigment beginning to appear. At 36 hrs the eyes form but are not pigmented. At 40 hrs the embryo may start to move, and advanced embryos float freely within the egg. Hatching typically occurs in two to three days at temperatures of 15°-19°C.

It should be noted that egg characteristics such as density, diameter, oil globule size, surface:volume (S:V) ratio, and lipid content may vary among populations and even among watersheds (Bergey et al. 2003). Striped bass eggs from low energy streams tend to have higher

S:V ratios, larger oil globules, and are lighter (less dense). Eggs from striped bass broodfish collected from the Apalachicola River are often smaller in diameter and less buoyant (denser) than eggs from fish of Atlantic Coast origin (D. Yeager personal communication, A. Brown personal communication).

3.2.1.2.2 Larvae

Hardy (1978) summarized in detail the development and growth of striped bass larvae based on specimens from Atlantic rivers, and the following summary was taken from that reference, as were the following terms used to describe developmental stages:

- yolk-sac larva – the stage between hatching and yolk-absorption;
- larva – stage between absorption of yolk and acquisition of minimum adult fin ray complement;
- juvenile – stage between acquisition of minimum adult fin ray complement and sexual maturity;
- adult – sexually mature.

Length at hatching is 2.0-3.7 mm TL, averaging 3.1 mm. Crateau (ND) reported hatching length for Gulf race striped bass as slightly longer (2.5-4.0 mm). Depending on temperature, yolk-sac larvae are 4.5-5.2 mm at two days and 5.8-6.5 mm TL at eight days old. Yolk and oil absorption are also highly variable depending on temperature, normally varying from seven to 14 days. Crateau (ND) reported yolk sac absorption for Gulf race larvae at seven days. Yolk-sac larvae are slender and tadpole-like at hatching; the yolk sac is oval and generally projects anterior to the front of the head or eye. The mouth is formed or forming, pectoral fins apparent and brain divisions evident at 4.5-5.2 mm TL. At 5.8-6.5 mm, the eye is mobile, the gill almost completely covered, caudal and pectoral rays becoming evident, and intestines and internal organs becoming differentiated. A fin fold is present throughout the yolk-sac stage. Yolk-sac larvae are generally transparent, though melanophores and chromatophores may be apparent from the time of hatching. As development proceeds, three characteristic pigmented areas appear: a series of stellate chromatophores along the posterior two-thirds of the trunk and tail; heavy pigmentation along the dorsal peritoneal wall, on the dorsolateral and ventrolateral wall of a yolk and along the gut; and a heavy concentration around oil globule. Number of myomeres increases from 17 at hatching to 24-25 by the end of the yolk-sac stage, and feeding generally begins at about four to ten days. Crateau (ND) reported feeding initiation for Gulf race larvae at four days.

The larval stage may begin as early as 5 mm, but more generally at about 6-7 mm. The following description generalizes major changes during the larval stage; lengths are TL (Hardy 1978):

6-8 mm: branchostegal rays form; teeth become evident; dorsal fin fold no longer extends forward to head; urostyle becoming flexed; caudal fin rounded; pectoral fins fan shaped; pigmentation still generally as described above for yolk-sac larvae;

8-12 mm: teeth become biserial and differentiated on both jaws; opercular spines evident; fin fold greatly reduced and divided into three regions; anal spines and rays forming; caudal fin becoming forked; pelvic fin buds evident; pigmentation similar to earlier stages but becoming more intense;

12-15 mm: dorsal spines becoming visible, though rudimentary, and about one-third of dorsal rays present; two anal spines visible; caudal rays differentiated; pigmentation variable;

15-20 mm: opercle well serrated; anal rays complete; lateral line scales visible, but not yet complete; pigmentation variable, but may be present on head, snout, above and below eyes, on upper part of opercular flap, along posterior of body laterally dividing myomere upper and lower halves, along posteroventral keel, at base of anal fin, and on abdomen and fins;

20-30 mm: dorsal spines and rays complete; third anal spine present; pelvic fin rays developed; pigment generally uniform over body, but concentrations along backbone, on head and fin bases;

30-36 mm: all fin rays complete; lateral line scales complete; adult proportions attained. Crateau (ND) indicated the juvenile stage for the Gulf race begins (which implies the larval stage ends) at 25 mm.

3.2.1.2.3 Juveniles

Juveniles are defined as any fish that have completed larval metamorphosis but not reached sexual maturity. In general, first annulus formation occurs on average at about 85.7 mm, and gonads start to differentiate during the first year at about 130-150 mm FL (Hardy 1978). However, it should be kept in mind that there may be geographical differences in these characteristics. Crateau et al. (1981) found average back-calculated length at first annulus formation was 156 mm for striped bass in the Apalachicola River (see Section 3.2.3 for more discussion of age-and-growth). Hardy (1978) described color as “silvery” at about 46 mm. At 50-80 mm, there are six to ten poorly defined vertical bands on sides of body and five to six well-developed longitudinal stripes above and below the lateral line. At 130 mm the adult pattern of stripes is well developed, though faint traces of the vertical bars may persist, and the dorsal and caudal fins are heavily stippled with fine dots.

According to Setzler et al. (1980), sexual maturity of striped bass was positively related to temperature; maturity was reached earlier with warmer temperatures. As with many fish species, males reach maturity earlier than females. According to Setzler et al. (1980), minimum lengths at maturity were approximately 432 mm TL for females and 174 mm TL for males, although there are considerable variations in length at maturity among individuals and populations of striped bass.

As indicated above, Crateau (ND) considered the juvenile phase to begin at about 25 mm (FL or TL not specified) for striped bass in the Apalachicola River. For striped bass in general, Hardy (1978) indicated the juvenile phase might not begin until about 35 mm (FL or TL not specified). Although some males began to mature in their first year, all were generally mature by age-2, and some females began to mature at age-3 with all mature by age-5 (Setzler et al. 1980). Based on this, age at maturity information in Crateau (ND) and length at age information in Crateau et al. (1980) it can generally be stated that for male striped bass in Gulf rivers, the juvenile phase may end at approximately 180 mm FL for some individuals, with all mature at about 340 mm FL. For females, the juvenile phase may end as early as about 480 mm FL for some individuals, with all mature at about 700 mm FL. See other sections of this document for related discussions of ageing, age and growth (3.2.2), and maturity (3.2.4.1).

3.2.1.2.4 Adults

Adult striped bass have an elongate body that is moderately compressed and back slightly arched. Dorsally, their color ranges from light green to olive, or steel blue, to brown or black. Laterally, the fish are silver with six to nine dark, usually continuous stripes running longitudinally, though some stripes may be interrupted. One stripe always follows the lateral line. Three stripes are always below the lateral line. The uppermost stripe is darkest with those below the lateral line becoming successively weaker. It was anecdotally reported that Gulf race striped bass might have darker stripes than the Atlantic races (Hollowell 1980), and interrupted stripes may be less frequent than in some Atlantic populations (Hollowell 1980); however, neither of these differences have been systematically investigated. The ventral color varies from white to silver and has a brassy iridescence. One spiny and one soft dorsal fin are present. They are approximately equal in length and separated at the base. Median fins are dark to dusky, and the paired fins white to clear. The operculum is armed with two sharp spines on the posterior edge, and the preopercle is weakly serrate. Two distinct, parallel patches of teeth are present at the base of the tongue, as opposed to one single rounded patch in the white bass, a closely related species. The lower jaw projects, the maxillary extends approximately to the middle of the eye orbit, and the caudal fin is forked. Descriptions are based on Clay (1975), Fay et al. (1983), and Ross (2001).

The first dorsal fin has 8-11 spines, and normally the second dorsal fin has one spine and 8-14 rays, but commonly 12. Barkuloo (1970) reported the ACF Gulf race population as having 10-13 dorsal rays (means: ACF 11.5; MAT 11.8) with the ACF population significantly different from six of eight Atlantic populations in this meristic character. The anal fin has three spines, though young may have only two, and 7-14 rays but most often 11. Barkuloo (1970) reported Gulf race striped bass as having 8-12 anal rays (means: ACF 10.5; MAT 10.8) with the ACF population significantly different from all Atlantic populations except the Upper Hudson River population for this character. The anal spines increase in length anterior to posterior. Pectoral fin rays number 13-19. Barkuloo (1970) reported Gulf race populations as having 16-18 (means: ACF 16.8; MAT 16.9), the ACF population being significantly different from six of eight Atlantic populations in this characteristic. Scales are ctenoid with 50-72 present along the lateral line. Barkuloo (1970) reported the range of LLSC for Atlantic populations as 51-67 (means 54.4-62.2) and for Gulf race as 63-72 (means: MAT 66.3; ACF 66.7) indicating significant differences for both the MAT and ACF populations compared with all Atlantic populations. Vertebrae number 24-25 but usually 25. There are 19-29 gill rakers present on the first arch, 17 principal caudal rays, and seven branchiostegal rays. As in all percoid fishes, the pelvic fins have one spine and five rays. Meristic data are based on Fay et al. (1983), Hardy (1978), Ross (2001), and Etnier and Starnes (1993).

Body proportions as number of times into standard length are: greatest depth, 3.5-4.2; average depth at caudal peduncle, 9.6; and head length, 2.9-3.3. The eye diameter is contained in head length 3.0-4.9 times (Hardy 1978).

Maximum size reported for striped bass is 1,829 mm TL and weight up to 56.7 kg (Hardy 1978). Female striped bass normally grow larger than males, and on the Atlantic Coast most fish over 13.6 kg are females (Bigelow and Schroeder 1953). Maximum size reported above is for a female; maximum reported length for males is 1,156 mm FL (Hardy 1978). The largest reported Gulf race striped bass was from Georgia (29 kg or 65 lbs) but others have been caught which are believed to have been in excess of 32 kg (70 lbs) from the Flint River. The maximum size reported in the literature for Gulf striped bass is 30 kg and 1,130 mm TL (Van Den Avyle and Evans 1990). The sex of this fish was not determined. However, unlike Atlantic coast fish, males over 13.6 kg are not uncommon (R. Weller personal communication).

3.2.1.2.5 Length-Weight Relationships and Coefficient of Condition

After maturity, female striped bass of a given length normally weigh more than males (Setzler et al. 1980). Setzler et al. (1980) provided length-weight relationship formulae for striped bass from a number of different areas, and some of these segregate males from females. Crateau et al. (1981) determined the length-weight relationship for 321 Gulf race striped bass (sexes combined) collected from the Apalachicola River during 1957-1962 as:

$$\log_{10}W = 5.27 + 3.15\ (\log_{10}L),$$

where W is weight in grams and L is fork length in millimeters; r = 0.99. These authors also compared length-weight relationships of 161 Gulf race and 137 Atlantic race striped bass collected from the Apalachicola River during 1978-1981 and found no significant differences between them. Fries et al. (1991) developed four length-weight (using TL) tables using least squares regression for different size classes based on data collected from hatchery-reared striped bass, but their report did not present the length-weight formulae. Size definitions basically followed Brewer and Rees (1990):

Phase I – fry to fingerling stage, lengths to 25-60 mm;
Phase II – fish beyond Phase I but under age-1, lengths to 80-250 mm;
Phase III – yearling to adult.

Three of the tables were for pond-reared fish in the following length ranges (Phase I = 15-60 mm; Phase II = 40-250 mm; Phase III = >250 mm), and an additional table was provided for tank-reared Phase II fish.

For adult striped bass a factor of 0.93 may be used to approximately convert total length to fork length and 1.07 to convert fork length to total length (Setzler et al. 1980). Similarly, 1.08

may be used to convert standard length to total length and 0.92 to convert total length to standard length.

Brown and Murphy (1991) developed standard weight (W_s) relationships for striped bass throughout their range from which relative weights (W_r) can be developed. Relative weight is a comparison of the actual weight of a fish against a length-specific standard (expected) weight and can, therefore, be used as an expression of condition. They determined the 75th percentile W_s relationship for landlocked striped bass populations as $\log_{10}W_s = 4.924 + 3.007 \log_{10}TL$ (W_s in g and TL in mm). Length range considered was 150-1,194 mm.

Crateau (ND) reported that yearly coefficient of condition (K, where $K_{SL} = (W/L^3) \times 100{,}000$; W = weight and L = length) were similar for Gulf (2.3-2.9) and Atlantic (2.1-2.9) race striped bass in the ACF. Both races exhibited lower K values during summer (ambient water temperatures above 26.0°C) than winter. There were no differences in condition between the races at these temperatures for fish 150-300 mm TL, but for larger individuals, the Gulf race were found to be in better condition than Atlantic race (K = 2.2-2.7 and 2.1-2.2, respectively). A later study in Lake Talquin, Florida, found some Gulf race fish in higher condition (K) through age-4 (Mesing 1993), but these differences disappeared beyond that age, and no significant differences in condition between the races were evident through age-6 (Mesing 1995).

Crateau et al. (1981) found substantial weight loss in larger striped bass in the Apalachicola River during the summer. This weight loss in striped bass did not occur until the fish were >4.5-6.7 kg. They attributed the weight loss to stress caused by high water temperatures in the river and lack of food available in thermal refuges. They did not observe weight loss in striped bass <4.5 kg.

3.2.1.2.6 Hybrid Striped Bass

Hybrids of striped bass and other *Morone* species have been developed and are commonly used for stocking in rivers and reservoirs in the United States (Kerby and Harrell 1990). The first hybrids were produced in South Carolina in 1965 using female striped bass and male white bass producing a fish that was given the common name "palmetto bass" by the American Fisheries Society. The original objective of producing hybrids was to combine desirable characteristics of the two parent species, but it was later found that hybrids had better survival, faster early growth rates, higher disease resistance, and better general hardiness than the parent species. In addition to the original hybrid, other crosses include: female white bass x male striped bass (sunshine bass); female striped bass x male white perch (Virginia bass); female white perch x male striped bass (Maryland bass); and female striped bass x male yellow bass (paradise bass). The original cross (palmetto bass) has continued to be the most popular and commonly stocked hybrid. However, the use of sunshine bass is common in stocking the Gulf region (Mesing et al. 1997). The first generation offspring of all *Morone* hybrid crosses are fertile (Kerby and Harrell 1990), but they generally do not reproduce naturally (McCabe 1989, Karas 1993). However, evidence of hybrids interbreeding with wild *Morone* has been found sporadically in many places where they co-occur (Harrell et al. 1993).

Adult striped bass are distinguished from palmetto and sunshine bass by having a shallower body depth relative to FL (0.19-0.25 FL versus 0.25-0.33 FL for the hybrids) (Ross 2001). Also, the hybrids have a smaller head, a shorter and broader caudal region, a more steeply sloped forehead (Kerby and Harrell 1990), and the lateral stripes are mostly interrupted (Etnier and Starnes 1993). Various combinations of meristic characteristics, as well as molecular genetics, can also be used to distinguish striped bass and the various types of *Morone* hybrids (Kerby and Harrell 1990).

Feeding habits of hybrids are reported to be similar to those of striped bass, although hybrids are more aggressive feeders and consequently somewhat easier to catch than striped bass (Karas 1993). Because of similar food habits, hybrids and striped bass presumably tend to occupy the same or similar habitats. Patrick and Moser (2001) found hybrids and striped bass occupying the same estuarine habitats in the Cape Fear River; hybrids also participated in upstream spawning migrations with striped bass in that system so they were probably sharing spawning habitats with striped bass as well. However, Yeager (1982) found hybrids most often occupying the lower tidal portions of the Escambia River in Florida with no indication of significant upstream movement. Muncy et al. (1990) found that hybrids in Ross Barnett Reservoir, Mississippi, migrated upstream during late February-March and returned downstream into the upper reservoir during late April-May. During late May, they moved into the middle and lower reservoir and remained there for the summer, showing preference for water temperatures of 21º-27ºC (the coolest temperatures available) and dissolved oxygen (DO) $\geq$4 mg/l. Condition factors declined during summer indicating that temperature and DO conditions restricted feeding, though not completely. Hybrids were associated with logjams, stumps, cuts, and deep bends in the Pearl River, submerged sloughs with standing timber and areas adjacent to the submerged river channel in the reservoir. Similar patterns were reported for hybrids in reservoirs in South Carolina and Illinois (Muncy et al. 1990).

Mesing et al. (1997) reported that survival and growth of palmetto and sunshine bass were similar in the ACF, with some hybrids surviving to age-7. Yeager (1994) found no difference in tag return rates for palmetto and sunshine bass co-stocked into the Escambia River, Florida. Mesing et al. (1997) found differences in movement between the two crosses that indicated palmetto bass were more likely to migrate downstream from reservoirs where they were stocked and that downstream migrations could be substantial - through two reservoirs in the ACF, in excess of 125 km. Mesing et al. (1990) demonstrated downstream movement of age-0 palmetto bass through two reservoirs and to the mouth of the Apalachicola River, more than 296 km. Although moronid hybrids are generally smaller than 4.5 kg (Karas 1993), some may attain weights exceeding 9.0 kg (Mesing et al. 1997). The world record striped bass hybrid was a 9.2 kg specimen taken from the Savannah River in 1982 (Germann and Bunch 1983). See Section 4.4.9.6.1 for additional discussion of hybrids and their potential effects on native striped bass populations.

3.2.1.3 Abnormalities and Anomalies

Accounts of physical abnormalities such as dwarfism, spinal deformities, and pug-headedness in striped bass can be found in the literature dating back more than 400 years. Initially, abnormal fish were reported as monsters, which were taxonomically misrepresented and often grossly illustrated. These early reports were more concerned with sensationalism than science and were confined to single specimens rather than a major segment of a population (Hickey 1972). However, there were reports of relatively large numbers of anomalous fish being found. For instance, Sindermann et al. (1978) reported finding more than 10% of the striped bass collected from two trawl stations in the lower Hudson River estuary to be pug-headed.

Anomalies in fish can be considered part of the natural selection process, and even though many were reported for hundreds of years, little progress was made in understanding their complex derivation. As Hickey (1972) succinctly states:

> "the causes and effects of abnormalities in fishes, nevertheless, will largely remain matters of conjecture until more carefully selected data are obtained through controlled research."

Hickey (1972) divided abnormalities into three groups. The first is genetic in origin, caused by mutation or recombination of genes and is often heritable. The second group is epigenetic, with the abnormalities beginning during embryonic development. The third group of abnormalities appears during larval development and/or metamorphosis. These abnormalities can be caused by environmental perturbations during the most vulnerable stages of development.

Spinal abnormalities are a type of developmental abnormality seen in striped bass in the natural environment and more frequently in an aquaculture environment. Davis (1997) found endocrine disrupting chemicals (EDCs) play a major role in the development of skeletal abnormalities. Growth hormones, such as calcitonin and Vitamin D3, and the corpuscles of Stannius can all influence calcium homeostasis and consequently represent various ways that EDCs may affect calcium dynamics and subsequent skeletal development (Davis 1997). Kepone and chemically similar Mirex are examples of EDCs. The herbicide Trifluralin is another EDC that causes vertebral dysplasia in the form of hyperostosis (Couch et al. 1979). Dibutylphthalate was also reported by Davis (1988) to produce teratogenic effects in fish.

Lordosis (dorso-ventral flexure) is a spinal anomaly to which Rosenthal and Rosenthal (1950) applied the graphic term "humpbacked." Scoliosis (lateral curvature) is another common spinal abnormality found in various species of wild and cultured fish including striped bass (Kroger and Guthrie 1971, McGregor and Newcombe 1968).

Some anomalies of the vertebral column may not be readily apparent externally. For example, fusion or coalescence of vertebrae results from anchylosis of vertebral centra (Aida 1930) and can cause dwarfing, short tail syndrome (Sindermann 1970), and the misalignment of vertebrae (Ford 1930). Combinations of these maladies are also possible.

The effects of spinal or vertebral impairments are extremely detrimental to the survival of the afflicted fish. Their swimming ability is impaired which decreases their ability to escape predation, or conversely, to find prey in the case of piscivorus fish like striped bass (Kroger and Guthrie 1971). Their ability to compete for a mate and survive physiological stress is also greatly diminished.

An abnormality that has interested ichthyologists and fishermen all over the world is pug-headedness. Reports of this anomaly have come from North America, Europe, and the British Isles (Gudger 1930) as well as Africa (Junor 1967) and Asia. This malady, also known as pug nose (Sutton 1913), bulldog head, lion head, tête du chien, lowenkopf, mopskoph (Schwartz 1965), and mopsgesicht (Gudger 1929) is one of the earliest reported abnormalities in fishes. It was first described in 1555 by Rondelet and predates most anthropogenic pollution (Gudger 1930). The earliest report in the literature of a pug-headed striped bass dates from 1849 (Ayres 1849). Pug-headedness occurs to varying degrees of severity ranging from:

1. an acutely steep, bulging forehead and eyes (Schwartz 1965);
2. no upper jaw or associated structures (Mansueti 1958);
3. protrusion of the lower jaw way beyond the upper jaw (Schwartz 1965, Mansueti 1958);
4. incomplete closure of the mouth (Mansueti 1960); and
5. partial exposure of the tongue and gill arches (Schwartz 1965).

The effects of pug-headedness depend upon its severity and the existing environmental conditions. The fish may have difficulty passing water over the gills as well as catching, holding, and subsequently swallowing prey (Rose and Harris 1968, Gudger 1929). However, Mansueti (1958) described the feeding behavior of young pug-headed striped bass and found that they fed almost as efficiently as normal fish. The literature contains numerous examples of relatively large (up to 7.4 kg) pug-headed striped bass (Mansueti 1960, Covell 1957, Gudger 1930, Smith 1957, and Lyman 1961).

Fin abnormalities are another rather common occurrence in striped bass and other species. The fins may be:

1. reduced or missing (Dahlberg 1970, Patten 1968);
2. with additional or reduced number of fin rays (Patten 1968, Weisel 1955);
3. missing rays (Dawson 1967); and
4. with shortened or stubby rays (Dahlberg 1970).

The effects of this anomaly on fish are not normally as severe as the previously mentioned aberrations.

An uninflated swimbladder is a common malady of cultured striped bass. Striped bass are physoclistic as adults as opposed to physotomous. These terms relate to the way swimbladders are inflated. Generally, the more primitive species of fish are physostomous, while more modern species are physoclistic (Lagler et al. 1962). Physotomous fish possess a pneumatic duct that connects the gut and swimbladder throughout their entire life, whereas physoclistic fish do not. Physotomes inflate their swimbladder by gulping surface air and forcing it through their pneumatic duct. Striped bass possess the duct as larvae, but the duct quickly becomes nonfunctional. Striped bass normally inflate their swimbladder between days four and seven posthatch (Doroshev and Cornacchia 1979, Bulak and Heidinger 1980). Fish that do not inflate their swimbladder during this time are subsequently non-buoyant and generally short-lived. Tait (1960) found striped bass with uninflated swimbladders had slower growth rates, higher percentages of morphological abnormalities, and increased susceptibility to stress

(Lewis et al. 1977). Striped bass culture at the Gulf Coast Research Laboratory (GCRL) from 1978 to 2001 confirmed the observations of Tait (1960) and Lewis et al. (1977) (L. Nicholson personal communication). The fish with uninflated swimbladders must swim continuously or sink to the bottom of the culture tank. They cannot move fast enough to effectively compete for food, and the food consumed is converted to energy to remain in the water column rather than being used for growth. They are not as tolerant to stress as normal fish, and they are the first to die as a result of aberrant environmental conditions (L. Nicholson personal communication). These fish exhibit a broken back syndrome (Figure 3.3), appearing dorso-ventrally v-shaped. The vertebral column is not supported by the swimbladder and consequently deforms ventrally, reminiscent of a "sway back" horse.

3.2.2 Parasites and Diseases

Fish diseases can be divided into two major categories – infectious and non-infectious. Infectious diseases are contagious and caused by pathogenic organisms present in the environment or carried by other fish. Conversely, non-infectious diseases are attributable to environmental problems, nutritional deficiencies, or genetic anomalies. These diseases are not contagious (Francis-Floyd 1990).

Infectious diseases can be divided into four groups: 1) parasitic, 2) bacterial, 3) viral, and 4) fungal. Parasitic diseases can be internal, external, or both and can be caused by a plethora of organisms ranging from protozoa to lampreys. Bacterial diseases can also be internal, external, or both. Striped bass infected with a bacterial disease will typically have hemorrhagic spots or ulcers along the peritoneal cavity and around the eyes and mouth (Francis-Floyd 1991, Reed and Francis-Floyd 1993). They may also have an enlarged, fluid-filled abdomen and protruding

Figure 3.3 Radiograph of a young striped bass exhibiting "broken-back syndrome."

eyes. Bacterial diseases such as columnaris, septicemia, vibriosis, pasteurellosis, and mycobacteriosis are examples of parasitic bacterial infections.

Viral diseases are nearly impossible to distinguish from bacterial diseases without specialized testing. Lymphocystis and infectious pancreatic necrosis virus (IPNV) are examples of viral diseases of striped bass (Hughes et al. 1990).

Fungi such as *Saprolegnia* spp. and *Achlya* spp. can cause infections. These infections are primarily relegated to fresh water and are normally secondary invaders to mechanically damaged areas (Hughes et al. 1990). Fungal spores are prevalent in the aquatic environment but are not usually a problem for healthy, non-stressed fish (Francis-Floyd 1990).

Merriman (1941) and Raney et al. (1952) provided a comprehensive list of parasites and diseases of striped bass. Merriman summarized numerous individual reports of parasites that included helminths (Linton 1901); parasitic copepods (Wilson 1911, 1915); and Monogenea (Mueller 1936). Paperna and Zwerner (1976) updated the earlier works by looking at 514 striped bass from the lower Chesapeake Bay. They also looked at other species of fish to determine the specificity of striped bass parasites and to ascertain whether or not they were hosts for striped bass pathogens. They found 45 species of parasitic organisms in striped bass ranging from viruses to Metazoa. Unlike Merriman (1941), they found heavy infections definitely associated with pathological conditions and parasites to contribute to natural mortality of striped bass. Attrition becomes even more acute and economically important in confined populations (i.e., extensive and intensive aquaculture).

Disease is usually not a simple association between a pathogen and a host fish. Normally other circumstances must be present for active disease to develop in a population. Generally, these circumstances are grouped under the term "stress" (Francis-Floyd 1990; Sakanari et al. 1983; Coutant 1985a, 1985b). Stress is an umbrella term encompassing a wide variety of negative influences. Any and all factors, from water quality to overcrowding to inadequate forage, can contribute synergistically to the susceptibility to disease. Likewise, parasitized fish are prone to succumb to deteriorating water quality (oxygen depletion, algal blooms, or pollution). Paperna and Zwerner (1976) noted these facts in their studies of parasitic associations unique to the Chesapeake Bay area as opposed to other regions. The sporadic mortalities caused by *Pasteuraella sp.* were used as an example, and helminthoses were considered an important contributing factor in causing mortalities in YOY striped bass (Paperna and Zwerner 1976).

Mycobacteriosis was found in wild striped bass and 166 other species of fish on the Atlantic and Pacific Coasts (Rhodes et al. 2001). It is a subacute to chronic wasting disease that varies between species but typically includes granulomas in the spleen, kidney, and liver. Rhodes et al. (2001) found *Mycobacterium marinum* and six closely-related species to cause an epizootic outbreak in the Chesapeake Bay.

The nematode *Goezia* sp. caused striped bass mortalities in Florida freshwater lakes (Gaines and Rogers 1972). Lymphocystis and *Amyloodinium ocellatum* are common pathogens of striped bass as well as other species of fish in the warm waters of the states bordering the northern Gulf of Mexico (Sinderman and Lightner 1988, Lawler 1980). Hawke (1976) examined cultured striped bass in freshwater and brackish ponds in south Alabama and found no bacterial diseases during his 1974 and 1975 study. However, four bacteria were identified (*Aeromonas hydrophila, Vibrio anguillarum, Enterbacter cloacae, Flexibacter columnaris)* along with one fungus (*Saprolegnia* sp.).

In later studies of hatchery-reared striped bass in Alabama, several maladies were observed (Hawke and Minton 1985). Pasteurellosis caused by *Pasteurella piscicida* was the only bacteria/disease reported. *Ambiphrya* sp. was the most frequently occurring parasite. *Paratrichodina* sp. was present on the gills of striped bass at light to moderate levels. Other parasites encountered less frequently were *Bodomonas* sp.*, Chilodinella* sp.*,* and *Ergasilus* sp. Hawke (1976) also found five species of protozoan parasites considered a threat to striped bass, which included *Trichodina* sp., *Trichodinella* sp.*, Tripartiella* sp.*, Costia* sp.*,* and *Chilodonella* sp. Two of these five species (*Trichodina* sp. and *Chilodonella* sp.) caused mortality among striped bass fingerlings. Intense infections with the digenetic trematode *Clinostomum complanatum* (yellow grubs) have been a problem in striped bass in Florida freshwater hatchery ponds (A. Brown personal communication).

3.2.2.1 Pfiesteria

Although *Pfiesteria* and *Pfiesteria*-like organisms are algae and may cause blooms, in certain forms they can behave as predacious parasites. *Pfiesteria piscicida*, nicknamed the 'cell from hell,' causes lesions and disorientation in fish and ultimately causes death in its parasitic form, allowing the less noxious forms of the algae to 'consume' the decaying carcasses. The propensity of these organisms to affect fish along the Atlantic Coast has increased public concern along the Gulf of Mexico as well. *Pfiesteria*-like organisms have probably always occurred throughout coastal waters along the Atlantic and Gulf; however, the frequency, duration, and extent of the blooms depend greatly on the prevailing conditions (C. Moncreiff personal communication). These organisms occur in very low numbers and are only detectable after extreme manipulations under laboratory conditions. Under normal environmental conditions, these *Pfiesteria*-like organisms remain undetectable and relatively benign. Although several *Pfiesteria*-like species have been isolated along the Atlantic Coast of Florida and in the Gulf of Mexico around Pensacola and Mobile Bays (Burkholder et al. 1995), *Pfiesteria piscicida* has never been found in the Gulf of Mexico and has not affected striped bass in the region.

3.2.3 Age and Growth

Among Atlantic race striped bass, growth rates during the first growing season are inversely related to the length of the growing season (Brown et al. 1998). That is, striped bass in the higher latitudes exhibit greater growth within the first growing season than striped bass in the lower latitudes. The same study also compared larval striped bass between the Apalachicola River, Florida, and Santee-Cooper River system, South Carolina, and found faster (though not significant statistically) growth rates for striped bass in the Apalachicola River. Genetics may have some bearing on this slight difference in growth rates. Wirgin et al. (1991) found the remnant Gulf race population in the Apalachicola system contained unique mtDNA genotypes.

Historical length-at-age information determined for Louisiana (Horst 1976), Alabama (Bryce 1982), and Florida (Crateau et al. 1981) striped bass was determined using scales (Table 3.1). Accurate age assignment using scales has been called into question because scales can be reabsorbed in cases of severe stress, resulting in missing annuli (Simkiss 1974), or numerous false annuli may be produced as a result of environmental stress, poor water quality, or fluctuating forage availability (Humphreys and Kornegay 1985). Taubert and Tranquilli (1982) and authors cited therein (Witt et al. 1970, Siler and Clugston 1975) found that largemouth bass from thermally disturbed environments, such as cooling ponds which receive heated discharge, were difficult to age using scales because of the many false-annuli that are formed. It is likely that striped bass scales also form false-annuli during summer months when fish occupy thermal refuges and again in the fall when thermal refuges are vacated.

Heidinger and Clodfelter (1987) validated otoliths for aging striped bass to age-4 using known-age fish housed in a northern Illinois cooling pond. They reported that annuli became distinguishable from the margin of the otolith between April and May. Dobbins and Rousseau (1982) found annuli deposition occurred during April and May in Lake Talquin, Florida, and was complete by June. Mesing et al. (1996) also documented the use of otoliths to successfully age Lake Talquin striped bass through age-6, which were identified as known-age fish using mtDNA markers. For these reasons, otoliths are now the standard for aging striped bass in the Gulf region.

Rapid growth for striped bass in Gulf Coast drainages occurs October to April and slower summer growth coincides with habitation of thermal refuges (Crateau et al. 1981, Wooley and Crateau 1983) and separation from prey (Bryce and Shelton 1982). Annuli formation on scales from striped bass on the Gulf Coast occurs during the summer habitation of the thermal refuges (Crateau et al. 1981). This pattern is similar to striped bass in the southern half (South Carolina

Table 3.1. Growth of striped bass populations in Gulf of Mexico drainages.

Location	Length at age (mm TL)							Source (aging source)
	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	
Tallapoosa River AL	281	419	549	656	756	841		Bryce 1982 (scales)
Apalachicola River FL	174	329	466	586	683	755	819	Wooley & Crateau 1983 (scales)
Lake Talquin FL								Mesing et al. 1996 (otoliths)
Gulf	460	594	684	784				
Atlantic		620	683	730		791		
Pearl & Tchefuncte Rivers LA	214	400	533	658	735		781	Monzyk et al. 2001 (otoliths)

and south) and opposite to the northern half (North Carolina and north) of the Atlantic Coast. See section 4.2.4.1 for additional discussion of "cool water thermal refuge."

Using LLSC to determine race, Wooley and Crateau (1983) reported Gulf race striped bass coefficients of condition, average weights, and average lengths were substantially higher than for introduced Atlantic race striped bass in the Apalachicola River, Florida. Using mtDNA tags and otoliths, Mesing (1996) compared growth between Atlantic and Gulf race striped bass in Lake Talquin, Florida (Table 3.2). They found no significant differences (P>0.05) in coefficient of condition, mean TL, and mean weights at ages-0, -2, -3, and -4 between the races. Growth rates of Atlantic and Gulf race striped bass in Gulf of Mexico drainages appear to be similar (Monzyk et al. 2001). Slight variations in size, weight, and condition may be due to forage availability and environmental influences, as well as genetics.

3.2.4 Genetics

3.2.4.1 Differences in Lateral Line Scale Count between Gulf and Atlantic Coast Striped Bass

Meristic and morphometric studies have frequently been used to distinguish striped bass populations (See Section 3.2.1.1.1). Studies conducted on striped bass collected in the early 1960s evaluated the extent of morphological divergence between fish from Gulf and Atlantic populations. Striped bass from the two Gulf systems studied, the ACF and Alabama rivers, exhibited LLSC significantly higher than those found in any Atlantic Coast population, and minimal overlap was observed between fish from the two coasts (Brown 1965, Barkuloo 1970). These results indicated that Gulf and Atlantic striped bass were separate stocks (or races) and provided strong support for efforts to conserve and restore Gulf populations.

Despite the observed differences between striped bass in Gulf and Atlantic rivers, hatchery-reared striped bass of Atlantic origin have been transplanted into many Gulf systems, including the ACF, beginning in the mid-1960s. Approximately 1.8 million fry (<15 mm) and 125,000 fingerlings (25-50 mm) of Atlantic ancestry were released into the ACF over the twelve-year period from 1965 to 1976 (Pasch 1973, Nicholson et al. 1986). These fish were progeny of broodstock collected from the Santee-Cooper system, South Carolina. Anadromous Atlantic striped bass from the Santee-Cooper system were trapped there when dams were completed in the early 1940s; however, striped bass populations in the Santee-Cooper system are now landlocked and complete their entire lifecycle in freshwater (Scruggs 1957).

Subsequent to Atlantic striped bass introductions into the ACF, studies of LLSC in fish from the system failed to yield the uniformly high counts reported earlier (Wirgin et al. 1989). Although mean LLSC in ACF fish was significantly higher than in Atlantic populations, some ACF fish exhibited LLSC that were consistent with those seen in fish from the Atlantic. Because LLSC probably have both genetic and environmental components to their expression (Blaxter 1984), it was not certain whether the reduction in LLSC in the ACF population was due to the introduction of Atlantic fish, temporal instability in environmental factors, or a combination of the two. Nevertheless, this finding raised questions concerning the genetic integrity of the ACF population.

Table 3.2. Summary of age, mean lengths, weights, and condition factors of Gulf and Atlantic striped bass collected from Lake Talquin, Florida, November-December 1995 (Mesing 1996).

Race	Age (Yr)	mtDNA Type	Sample (N)(%)	Mean TL (mm)	SE (±2)	Mean Wt (kg)	SE (±2)	Mean K_{sl}	S.E. (±2)
Gulf	7	D-1, C-2	0						
Atlantic	7	C-1	0						
Total			**0**						
1989 Year Class									
Gulf	6	C-2	0						
Atlantic	6	C-1	2 (100)	791	(20)	6.14	(0.54)	2.23	(0.00)
Total			**2**						
1990 Year Class									
Gulf	5	X-2	0						
Atlantic	5		0						
Total			**0**						
1991 Year Class									
Gulf	4	C-2, B-2, B-2	6 (60)	784	(30)	5.85	(0.70)	2.14	(0.08)
Atlantic	4	C-1	4 (40)	730	(28)	4.90	(0.44)	2.19	(0.10)
Total			**10**						
1992 Year Class									
Gulf	3	C-2, B-2, A-2, AB-2	14 (28)	684	(14)	4.21	(0.11)	2.42	(0.04)
Atlantic	3	C-1, D-1, BC-1	36 (72)	683	(10)	4.16	(0.16)	2.31	(0.04)
Total			**50**						
1993 Year Class									
Gulf	2	C-2, A-2	6 (35)	594	(44)	2.58	(0.76)	2.18	(0.30)
Atlantic	2	C-1, BC-1	11 (65)	620	(16)	3.13	(0.20)	2.32	(0.12)
Total			**17**						
1994 Year Class									
Gulf	1	C-2	12 (38)	460	(18)	1.23	(0.14)	2.33	(0.08)
Gulf	1	B-2	0						
Gulf	1	C-1	0						
Gulf	1	D-1	19 (59)	476	(12)	1.35	(0.10)	2.27	(0.08)
Gulf	1	XbaI-1	1 (3)	452	(0)	1.11	(0.00)	2.09	(0.08)
Total			**32**						
1995 Year Class									
Gulf	0	C-2	20 (67)	240	(24)	0.19	(0.04)	2.23	(0.10)
Atlantic	0	C-1, D-1	10 (33)	217	(34)	0.14	(0.06)	2.17	(0.18)
Total			30						
Grand Total			**141**						

3.2.4.2 Use of Genetics to Distinguish Atlantic Coast Populations

Genetic approaches have been used for the past four decades to distinguish selected striped bass populations along the Atlantic Coast (reviewed in Waldman et al. 1988 and Wirgin and Waldman 1994; Robinson et al. 2004). In general, striped bass populations along the Atlantic Coast exhibited unusually low levels of genetic diversity using a variety of techniques. Most allozyme studies which attempted to distinguish the major contributors to the coastal migratory stock (the Roanoke River, Chesapeake Bay, and Hudson River populations) failed to reveal sufficient levels of variation to distinguish stocks (Morgan et al. 1973, Otto 1975, Grove et al. 1976, Sidell et al. 1980). This was probably due to functional constraints on the primary amino acid sequences of the enzymes investigated.

Restriction fragment length polymorphism (RFLP) analysis of the entire mtDNA genome revealed unusually low levels of nucleotide diversity within and between Hudson River and Chesapeake Bay populations (Chapman 1990, Wirgin et al. 1990). Variation in the overall length of the mtDNA molecule and a very limited number of single nucleotide substitutions permitted discrimination of some stocks (Wirgin et al. 1993a, Wirgin et al. 1993b) but not with the resolution that was often desired. Other studies demonstrated that the use of additional multi-cutting restriction enzymes may reveal further polymorphisms (Stellwag et al. 1994), but similar results were previously seen in a southern population where higher levels of mtDNA variation were observed (Wirgin 1987). However, mtDNA polymorphisms were successfully used to estimate the relative contributions of individual populations to mixed stocks (Wirgin et al. 1993a) along the Atlantic Coast of Long Island, New York, and two rivers in Canada (Wirgin et al. 1995).

New generations of nDNA markers have revealed higher levels of genetic variation and provided additional potential resolution in distinguishing Atlantic Coast striped bass stocks. Polymorphisms at single copy, anonymous nDNA loci were used to distinguish between striped bass stocks in rivers of South Carolina and Maryland (Leclerc et al. 1996), the Hudson River and Chesapeake Bay (Wirgin and Maceda 1991), and among rivers in South Carolina (Leclerc et al. 1996). A subset of these anonymous nDNA markers and mtDNA variants were used to estimate the relative contributions of the Chesapeake Bay and Hudson River populations to the mixed-stock fishery at eastern Long Island, New York (Wirgin et al. 1997b). Multilocus nDNA fingerprints revealed little stock structuring, but high levels of genetic variation were revealed among three striped bass stocks in the lower Chesapeake Bay (Laughlin and Turner 1996) and other Atlantic Coast populations (Wirgin et al. 1991). Hypervariable microsatellite nDNA loci were isolated from striped bass (Roy et al. 2000) and were used to sensitively distinguish striped bass from Canadian rivers in the Bay of Fundy and the Gulf of St. Lawrence (Robinson et al. 2004). These markers were also used to distinguish between striped bass from these Canadian rivers and those from the Hudson River.

3.2.4.2.1 Mitochondrial DNA Divergence Between Gulf and Atlantic Coast Striped Bass

Although relatively low levels of mtDNA nucleotide sequence heterogeneity were observed in striped bass from the ACF, a base substitution revealed by the restriction endonuclease enzyme, *Xba* I, was detected in a high percentage of striped bass from the ACF.

This variant, *Xba* I-2, was originally reported in approximately 60% of fish from the ACF and was absent in striped bass from Atlantic Coast systems (Hudson, Chesapeake, Roanoke) as far south as the Santee-Cooper system, South Carolina (Wirgin et al. 1989) and was found in one fish (1/37) from the Ogeechee River, Georgia (Dunham et al. 1988). Subsequent population screenings failed to detect the Gulf-specific variant in any striped bass from the Ogeechee River (n = 37) (Wirgin unpublished data). In very recent studies (Wirgin et al. 2005b) of a robust (n = 80) sample of striped bass from the St. Mary's River on the Georgia/Florida border, the absence of the *Xba* I-2 haplotype in an additional southeastern population was confirmed. In summary, from 1983 to 1997, 54% of striped bass broodstock or subadults (n = 680) collected from the ACF exhibited the diagnostic Gulf *Xba* I-2 haplotype (Wirgin et al. 1997a). Furthermore, the diagnostic *Xba* I-2 haplotype was absent in striped bass from rivers and reservoirs in Mississippi, Louisiana, and Texas that had been stocked with Atlantic race fish before the introduction of the ACF-origin fish with this haplotype (Wirgin et al. 1997a). These results are most consistent with the hypothesis that the striped bass population in the ACF was the last remnant of a genetically distinct Gulf race which was extirpated from all but the ACF and perhaps the MAT river systems, and striped bass in the other Gulf rivers were descendants of transplants of Atlantic race ancestry. However, it is also possible that the *Xba* I-2 haplotype may not have been present in the native populations of those rivers farther west.

The *Xba* I polymorphism can, therefore, be used to uniquely identify striped bass of ACF (and perhaps Gulf race) maternal ancestry. It should be emphasized, however, that not all fish from the ACF exhibit the variant *Xba* I-2 haplotype due to either 1) a historical mtDNA polymorphism within the ACF population or 2) introgression of Atlantic mtDNA. The restriction endonuclease enzyme *Rsa* I also revealed a unique polymorphism, but this variant haplotype was present in a smaller percentage of ACF fish (20%). Dunham et al. (1988) also reported the presence of a unique *Bgl* I restriction site in 7 of 17 striped bass from the ACF, but this mtDNA haplotype was not observed in >200 ACF fish characterized by Wirgin and colleagues (Wirgin et al. 1989, Wirgin unpublished data).

3.2.4.3 Nuclear DNA Divergence between ACF and Atlantic Coast Fish

While the prevalence of the mtDNA polymorphisms confirmed the presence of a remnant maternally inherited mtDNA lineage within the ACF population, the possibility of significant introgression of biparentally transmitted Atlantic nDNA had not been evaluated. Initial studies using a DNA fingerprinting (multilocus minisatellite DNA) approach showed that the vast majority (90%) of striped bass from the ACF shared nDNA fragments which were absent from all striped bass populations along the mid and south Atlantic Coast (Wirgin et al. 1991). Similarly, a pilot study using single copy, non-coding nDNA probes which were developed from a striped bass genomic DNA library (Wirgin and Maceda 1991), revealed significant allelic frequency differences between ACF and Atlantic Coast fish. Using anonymous nDNA markers, Diaz et al. (1997) reported frequent, although not fixed, differences between Gulf and Atlantic Coast striped bass at one of three loci investigated. The fact that their Gulf Coast sample was collected from Lake Talquin, Florida, where co-stocking of Atlantic and Gulf Coast fish occurred (C. Mesing personal communication) may account for the absence of more pronounced differences between fish from the two coasts at these loci. In summary, these studies confirmed that the ACF harbored a genetically distinct stock and demonstrated that a high percentage of striped bass from the ACF exhibited both mtDNA and nDNA genotypes that were not seen elsewhere. However, these studies did not provide a quantitative evaluation of the extent of potential introgression of Atlantic genomes into the ACF gene pool. This question could only be addressed by comparing genetic profiles in the extant ACF population to what existed prior to the introduction of any Atlantic fish.

3.2.4.4 Frequency of the Diagnostic *Xba* I mtDNA Polymorphism in Archived Gulf Striped Bass

To investigate possible introgression of Atlantic genotypes into the ACF population, samples of native striped bass collected prior to the introductions of Atlantic fish were obtained from Tulane and Cornell Universities. A polymerase chain reaction (PCR) based system was developed to screen for the informative *Xba* I polymorphism in the livers of formalin-preserved archived ACF samples (Wirgin et al. 1997a). A mtDNA fragment containing the informative *Xba* I restriction site was cloned into a plasmid vector, smaller fragments were subcloned, and PCR primers were developed that allowed for amplification of a small 191 base pair mtDNA fragment that contained the diagnostic *Xba* I restriction site.

Using RFLP and direct sequence analysis of the PCR products, no significant differences in mtDNA haplotype frequencies were found between the archived and extant ACF samples collected over a fifteen year period. This suggested that significant maternally-mediated introgression of Atlantic Coast mtDNA genomes into the ACF gene pool had not occurred. These results further highlighted the importance of the ACF as a repository of striped bass to restore extirpated Gulf populations.

3.2.4.5 Nuclear DNA Analysis of Archived ACF Specimens

Because mtDNA is almost always maternally inherited, it is possible that significant introgression into the ACF of Atlantic nDNA genes by paternal contributions may have occurred and yet gone undetected by using an exclusively mtDNA approach. Therefore, a study was initiated to evaluate the extent of introgression of Atlantic nDNA into the extant ACF population. This required the development of diagnostic nDNA markers that could be used to distinguish extant ACF and Atlantic populations and be applied to the partially degraded DNAs that had been isolated from the archived striped bass samples.

To achieve this objective, a battery of ten microsatellite nDNA loci were isolated from a striped bass genomic DNA library (Roy et al. 2000), and five loci were identified (SB20, SB111, SB1021, SB113, SB117) that were highly diagnostic in discriminating between Atlantic Coast and extant ACF fish (Wirgin et al. 2005b). Allelic frequencies were determined at these five microsatellite loci in robust samples from the extant ACF and various Atlantic Coast populations. Significant frequency differences between ACF and Atlantic Coast samples were detected at all five loci. At three highly diagnostic loci (SB20, SB111, and SB1021), at least 65% of fish from one coast exhibited single alleles and multiple genotypes that were absent or in extremely low frequencies (3%-5%) in samples from the second coast. This demonstrated that microsatellite alleles could be used to distinguish fish of Atlantic and Gulf Coast lineage.

This PCR-based system was then used to genotype the three most informative microsatellite loci in DNA isolated from the archived ACF liver samples as described above (Wirgin et al. 2005b). Only a small subset of these samples could be successfully genotyped at these loci. However, archived scales were obtained from striped bass collected in the early 1960s from multiple sites in the ACF and the St. Johns River, Florida (Atlantic Coast river) and successfully analyzed using the microsatellite approach. Archived samples from the ACF and the St Johns River exhibited fixed or near-fixed allelic differences at these three loci.

Based on nDNA genotypes observed in these archived scale samples, significant allelic frequency differences at all three loci were observed between the extant and "pure" ACF populations suggesting that significant introgression of Atlantic nDNA alleles had occurred (Wirgin et al. 2005b). These results suggested that slightly less than 50% of the alleles observed in the extant ACF population were of Gulf origin. Despite the introgression of Atlantic alleles, however, genetic investigations support management efforts to conserve and restore the ACF population because of continued successful natural reproduction in the ACF and the high frequency of unique Gulf mtDNA haplotypes and nDNA alleles in this population.

3.2.5 Reproduction

Reproduction is obviously important in maintaining striped bass populations, and egg viability and larval survival have been identified as two important factors in determining year-class success (Rulifson et al. 1982). Temperature and stream discharge rates influence these factors, and the effects of contaminants also are suspected to be important.

Although hermaphroditism has occasionally been reported, Schlutz (1931), Morgan and Gerlach (1950), and Westin and Rogers (1978) found that striped bass on the Atlantic Coast were heterosexual and polygamous (Setzler-Hamilton et al. 1981). No references to hermaphroditism were found for the Gulf race or Atlantic race fish stocked into rivers of the northern Gulf. No indication of protogyny has been reported for striped bass.

3.2.5.1 Gonadal Development

Considered range-wide, most striped bass females are sexually mature by their fourth or fifth year, while most males are sexually mature by their second or third year (Pearson 1938; Bason 1971; Texas Instruments, Inc. 1975; Wilson et al. 1976). According to Hardy (1978), average rates of maturity for females are 18.2% by age-3; 25%-94% by age-4; 75%-100% by age-5; and 100% after age-6. Males are mature at age-2. Minimum lengths at maturity have been reported as 174 mm for males and 432 mm TL for females (Setzler et al. 1980).

Setzler et al. (1980) indicated that rate of sexual maturity for striped bass might be higher at warmer temperatures. Evidence indicated that striped bass in Gulf rivers (irrespective of race) might mature at an earlier age than in Atlantic rivers. The youngest Atlantic race female found by Horst (1976) in the Atchafalaya River basin, Louisiana, carrying mature ova was three years old. Crateau et al. (1980) found the smallest Gulf race male with flowing milt and gravid female in the ACF rivers system were 2.3 and 4.8 kg, respectively. Monzyk et al. (2001) found two female striped bass of uncertain race from the Tchefuncte River, Louisiana, with mature eggs were both age-4 but were similar in size to age-7 striped bass from the Roanoke River-Albemarle Sound on the Atlantic Coast. They reported average egg diameter for these two fish as 0.86 mm, above the minimum for mature eggs, but smaller than the size specified for ripe eggs. Jackson et al. (2001) collected gravid age-2 female striped bass (probably Atlantic race) from the Pascagoula River, Mississippi, that averaged 476 mm TL. Working with Atlantic race striped bass, Ware (1970, 1971) found males in Florida showing "slight milt discharge" at 11 months but were not in spawning condition until 23 months. Females, which were the oldest fish examined in this project, had no gonadal development during their first two years. Crateau (ND) reported maturity rates for Gulf race striped bass as similar to that reported above for striped bass generally.

The gonads in both sexes become much larger as spawning season approaches (Raney et al. 1952). In males, the ratio of testes weight to body weight increases from approximately 1:80 in non-spawning individuals to 1:16 at spawning time and in females from 1:143 in immature individuals to 1:12 at spawning. Following spawning, the ovary becomes flabby and misshapen with thick walls for about a month. Large eggs that are not spawned are reabsorbed (Raney et al. 1952).

3.2.5.2 Spawning and Season

Striped bass are anadromous, spawning during spring in fresh or nearly fresh water. An upstream spawning migration takes place several weeks in advance of the time of spawning with males generally arriving on the spawning grounds before females (Raney et al. 1952). Secor (2000) pointed out that larger female striped bass spawned early in the season and hypothesized that female striped bass of different ages may tend to spawn at different times. Most evidence indicates that striped bass females generally do not feed during spawning periods, but fish of both sexes feed quite soon afterward (Raney et al. 1952). In addition to the typical anadromous pattern of upstream migrations from estuaries and the ocean, striped bass are also capable of completing their life cycles entirely in fresh water, as was discovered initially in the Santee-Cooper River system in South Carolina where a "land-locked" reservoir population was reproducing (Scruggs 1957). Similar examples have since been discovered in the southeastern and southwestern United States (Smith and Catchings 1998).

Striped bass broadcast spawn, expelling their eggs into the water column rather than utilizing nests or structure. They undergo a short courtship ritual – several males "butt " at the sides of the ripe female and "on occasion…bite at the pectoral fins" (Bishop 1974). Males and females disperse their gametes into the water column simultaneously, and the eggs are fertilized within the cloud of milt. Striped bass spawn at or in close proximity to the surface of the water and exhibit a thrashing, rolling, and sounding behavior (Woodhull 1947, Raney et al. 1952, Surber 1958); spawning by large groups of fish can extend for many hours. One female is normally accompanied by a host of males. Worth (1903) and Merriman (1941) found as many as 50 males escorting a single female. Males tend to greatly outnumber females on the spawning grounds (Raney et al. 1952). Fish and McCoy (1959) found striped bass spawning primarily at night, although others have found spawning evenly divided between daylight and night hours as reported by Rulifson et al. (1982). Raney et al. (1952) indicated that females might not spawn every year.

Salek et al. (2001) detailed the spawning behavior of captive striped bass. Little interaction between males and females occurred outside the spawning season; females were usually solitary, and males tended to school together. As early as 15 hrs before spawning, females led, followed, or were surrounded by schools of males. Within about five hours of spawning, males began "attending" behavior – a male closely following a female with the male's snout frequently contacting the female's abdomen near the urogenital pore. Within one hour of spawning, some males chased females or approached, made contact with females from the front or alongside, and began to shimmy. The females did not attempt to escape. Spawning events began with the female hovering motionless, often going into a headstand posture, and shimmying rather violently with the tail sometimes out of the water creating a disturbance at the surface. The female released a cloud of eggs, usually for less than ten seconds. Males contacted the female side-to-side or face-to-face, shimmied, and released their milt, often with dorsal fins erect; they sometimes flashed as this occurred (rapidly rolling over on one side). Many males were involved in spawning with a single female, and the males pushed against the female turning her in a circle. Females spawned two or three additional times following their first spawning event at 10-20 minute intervals; although the first spawn always involved the largest release of eggs. Males continued making physical contact with spawning females for about two hours after spawning and engaged in following behaviors for as long as five hours after spawning. Drewry and Mihursky (1982) reported spawning striped bass produced rhythmic sequences of low frequency sounds, and pre-spawning individuals produced similar isolated sounds several hours before spawning. These sounds may be important in coordinating spawning activities, which in striped bass may occur in highly turbid water and at night.

3.2.5.2.1 Spawning Habitat

Location of spawning habitat is related mostly to river length and water velocity. Gulf race striped bass require suitable habitats a sufficient distance upstream from a river mouth to assure that eggs and larvae have time to hatch, develop, and reach nursery areas concurrent with the onset of feeding (Lukens 1988). For a description of spawning habitat, see Section 4.2.1.

3.2.5.2.2 Spawning Season

Fluctuating water temperatures between 10° and 22°C trigger spawning (Shannon 1970, Secor and Houde 1995) with an upper limit of 25°C according to Merriman (1941). Consequently, spawning varies with latitude beginning as early as February in Florida and continuing through June or July in the St. Lawrence River, Canada (Rulifson et al. 1982). Peak spawning tends to occur at temperatures between 15º and 19ºC following a temperature rise of 3º-4ºC (Hardy 1978). Spawning activity may cease following sudden drops in temperature and passage of storm fronts (Rulifson et al. 1982, citing Calhoun et al. 1950) but may resume when weather clears and temperatures rise (Raney et al. 1952).

Duration of spawning season is variable, ranging from eight to 44 days according to Rulifson et al. (1982). While the spawning season may be extended, peak spawning generally occurs during a short time interval at temperatures of 13°-22°C (Albrecht 1964, Shannon 1970, Kernehan et al. 1981). For example, during 1998-1990, spawning in the Santee-Cooper system, South Carolina, occurred over a six to eight week period, but most of the hatched eggs came from one spawning week during each reproductive season (Bulak et al. 1997). Mihursky et al.

(1976) and Johnson and Koo (1975) also reported similar spawning peaks of relatively brief duration. During one five-day period in 1971, Johnson and Koo collected 76.6% of the eggs for the entire spawning season. Hardy (1978) indicated there might be multiple spawning peaks probably corresponding to major increases in water temperature.

The striped bass spawning period in Gulf coastal drainages ranges from February to May (Barkuloo 1970) with peak spawning occurring during early April to mid-May (Crateau et al. 1980). In the ACF river system, Crateau et al. (1980) found the first Gulf race male with flowing milt at 9.6°C and the first gravid Gulf race female at 14.8°C, though staged eggs were not observed until water temperatures reached 20°C. The first spent Gulf race female was captured at 20.8°C, and flowing Gulf race males were captured as late as mid-May at 22.3°C. The first staged Atlantic race female was collected in the system at 20°C, and gravid Atlantic race females were collected as late as May 7 at 22.3°C. Crateau (ND) reported nearly all Gulf race females in the ACF river system are "spawned out" when the temperatures reach 24°C. Horst (1976) found striped bass in the Atchafalaya River, Louisiana, in spawning condition in April and May based on gonadosomatic indices, as did Monzyk et al. (2001) in the Pearl River.

In addition to temperature, water discharge and velocity appear to be important factors in triggering and providing for successful striped bass spawning. Fish and McCoy (1959) indicated that spawning in the Roanoke River became more prevalent as stream discharge increased above 5,500 cubic feet per second (CFS); and at 3,500 CFS, spawning did not occur. In summarizing flow requirements, Lukens (1988) stated that successful spawning in the Apalachicola River, Florida, could occur at discharges of 9,000-290,000 CFS.

3.2.5.2.3 Texas Rivers

According to Kurzowski and Maddux (1991), plankton sampling in the Trinity River determined that striped bass spawned in that river based on collection of larvae. Striped bass also spawned in the Brazos River above Lakes Granbury and Whitney (Guest 1985).

3.2.5.2.4 Mississippi-Atchafalaya River System

Collections of juvenile striped bass by Horst (1976) and collections of eggs, larvae, and juveniles by LDWF personnel (Tilyou 1989) in the Mississippi River suggest that natural reproduction occurs in the lower Mississippi River system. Horst (1976) sampled for eggs and larvae in the Atchafalaya River but did not find any. He did, however, report two juvenile striped bass (91 and 111 mm FL) collected from seine samples in the Atchafalaya River and concluded they were too far from areas of stocking to have been other than naturally produced. He did not find any fish that appeared to have recently spawned but indicated the Atchafalaya River offered habitat suitable for striped bass spawning.

Nineteen "fingerling" striped bass were collected in the Mississippi River near Vidalia, Louisiana, in 1988 (M. Wood personal communication). Plankton and seine sampling in the Mississippi and Atchafalaya rivers during 1991-1993 yielded both larvae and juvenile striped bass during 1992 (Rogillio et al. 1994). Two striped bass larvae (5.5-6.0 mm TL) were positively identified from sampling, and another 6.3 mm TL larva was probably a striped bass. Eight striped bass juveniles (103-158 mm TL) were collected in both the Atchafalaya and

Mississippi rivers. In addition to the egg, larval, and juvenile sampling, Rogillio et al. (1994) reported capture of 60 adult striped bass (age-2 through age-5) in gill nets in the outflow channel of the Old River Control Auxiliary Structure at the upper end of the Atchafalaya River. Of these fish, 39 were females – of which 23 had recently spawned. The spent females ranged from 463 to 685 mm TL.

A highly successful striped bass fishery has been established and maintained through natural reproduction in Lake Texoma (just above the fall line on the Red River, between Oklahoma and Texas). Atlantic race striped bass were stocked into the reservoir from 1965 through 1974, and natural reproduction now supports a fishery that has received more than 60% of the lake's angling pressure (Schorr et al. 1995).

Striped bass reproduction has also occurred in Keystone Reservoir, Oklahoma (Mensinger 1970, Combs 1979) and Lake Dardanelle, Arkansas (Bailey 1974, Hogue et al. 1977), both on the Arkansas River. Striped bass of Atlantic origin were stocked in the reservoir during 1965-1969. Striped bass eggs and YOY were collected in 1970, which indicates reproduction took place in both the Arkansas and Cimarron rivers, the two major reservoir tributaries, and most of the reproduction apparently occurred in the Arkansas River.

In the Cumberland and Tennessee rivers, Tennessee, striped bass have spawned below Cheatham and Pickwick Dams (Hogue et al. 1977) and in the Ohio River near the Tanners Creek and W.C. Beckford power plants (ESE 1989). Henley (1987, 1988) reported indirect evidence of a major striped bass spawning event along the Ohio River in 1988; flow rates were substantially lower than normal that year. Laird and Page (1996) also noted that striped bass spawning occurred in the Ohio. Spawning occurred in tributaries of J. Percy Priest Reservoir on the Stones River, a Cumberland tributary, but successful hatching was not documented, presumably due to the short reach of stream available for incubation before reaching the upper reservoir (Stooksbury 1979).

3.2.5.2.5 Mississippi and Louisiana River Systems

Even though studies were undertaken (McIlwain 1976, 1979, 1981; Nicholson 1983, 1984, 1985), no striped bass eggs or larvae have been found in Mississippi. McIlwain (1976) reported anglers in Mississippi Sound and the Pearl River took female striped bass with ripe eggs in 1975 and 1976. Jackson et al. (2001) found that striped bass in the Pascagoula River, Mississippi, began upstream migration as early as mid-February at water temperatures of 13.5° and 14.8°C during 1998 and 1999, respectively. During a two-year study, 19 striped bass (most female) were collected, which may be problematic for a spawning population since males should be dominant. Some of the female striped bass were gravid, and one may have recently spawned. Although no spawning areas were documented, several of the gravid female fish as well as the apparently spent female were collected in the vicinity of where the Pascagoula River divides into east and west forks.

Monzyk et al. (2001) investigated reproductive aspects of striped bass in the lower Pearl and Tchefuncte rivers and found that fish reached peak reproductive condition during April and May. They found fish with mature but not ripe eggs. They concluded that flow conditions in the

Tchefuncte River were probably insufficient for successful striped bass spawning. Although appropriate flow conditions occurred in the Pearl River, there was no indication of striped bass spawning in that river.

3.2.5.2.6 Mobile-Alabama-Tombigbee River System

Pearson (1938) reported a female striped bass with ripe eggs was taken on April 7, 1883, in the Alabama River (in the MAT system), just below the fall line near Montgomery. Above the fall line in both 1997 and 1998, striped bass eggs were collected in the Coosa (an Alabama River tributary) and Oostanaula (a Coosa River tributary) rivers in Georgia; a site at Rome, Georgia, yielded the highest number of eggs (Davin and Smith 2001). A greater number of eggs were collected in 1998. Peak egg densities occurred on May 12 of both years. Eggs were present during only 12 days in 1997 but were present during a 30-day span in 1998. Estimates of the total number of eggs produced during the 1998 spawning season ranged from 134 million to two billion. Tissue from eggs spawned in this river has not been genetically analyzed.

Smith and Catchings (1998) collected what were assumed to be adult Atlantic race striped bass from Lake Weiss, the farthest upstream Alabama reservoir on the Coosa River, and from three successive reservoirs downstream (Neely Henry, Logan Martin, and Lay) representing striped bass year classes that had not been stocked into the system. They also found that these putative Atlantic race fish greatly outnumbered Gulf race striped bass, which were concurrently stocked into Georgia waters and the lower three lakes. They concluded the putative Atlantic race striped bass had been successfully reproducing in the Coosa River, possibly as early as 1988, with the 1993 year class being particularly strong, and that these fish had higher survival and recruitment in the system than the stocked Gulf race. No significant relationship was found between year class strength and river discharge, although there appeared to be an association between year class strength and lower discharge during July.

Through plankton sampling, Davin et al. (1999) confirmed the conclusions of Smith and Catchings (1998) by verifying that striped bass spawned in 1997 and 1998 in the Oostanaula and Conasauga rivers, two Coosa River tributaries located upstream of Lake Weiss. Davin and Smith (2001) indicated the spawning appeared to be primarily Atlantic race fish, although this has not been verified through genetic identification of the spawning adults or larvae.

Minton (1980, 1983, 1989) reported collecting spent females (probably Atlantic race) from below dams on the Alabama River. Efforts to collect eggs and larvae in the lower MAT system did not yield positive results (Minton 1981, 1983, 1985) until 1989 when eggs and larvae were collected in the Alabama River between Miller's Ferry L&D and Claiborne L&D and also below Claiborne L&D (Powell 1990). Eggs were also collected during 1990, but no larvae (Powell 1991). Striped bass eggs were collected in 1991 and 1992, and larvae were again collected in 1992 below Claiborne L&D (Duffy 1993).

3.2.5.2.7 Apalachicola-Chattahoochee-Flint River System

The primary historical spawning grounds for striped bass in the ACF were probably in the Flint and Chattahoochee rivers prior to completion of the JWLD in 1957 creating Lake

Seminole. Reproduction still occurs upstream of the JWLD, though some spawning may also occur in the Apalachicola River below the JWLD. Large numbers of young striped bass were captured by fishermen below JWLD in 1957, and YOY were collected below the JWLD and from the Chipola Cutoff of the Apalachicola River in 1959 (Barkuloo 1970). A major flood in the ACF may have facilitated many adult striped bass in the Apalachicola River traversing the JWLD upstream to spawn in the Flint and Chattahoochee rivers (Barkuloo 1960). Several YOY striped bass were collected in the Flint River arm of Lake Seminole that year, and there were unconfirmed reports of YOY from the Chattahoochee River near Columbus, Georgia (Barkuloo 1960). Few YOY striped bass were collected below the JWLD in 1960 (Barkuloo 1960), but 33 were collected in 1961 (Barkuloo 1961b).

Beach seine sampling in the Apalachicola River during October 1976 through October 1977 resulted in collecting nine juvenile striped bass (Miller 1977). Since stock enhancement had not occurred in the system during either year (Crateau et al. 1981), it was concluded these juvenile fish were the result of natural reproduction. Sampling during subsequent years resulted in collecting a few more juvenile striped bass (Crateau ND).

To evaluate natural reproduction in 1985, no striped bass were stocked into the ACF. Successful striped bass reproduction occurred as evidenced by collection of YOY in and above Lake Seminole and immediately below JWLD (Mesing 1990). The evaluation was repeated in 1997 when only Phase I striped bass with specific mtDNA haplotypes were stocked into Lakes Bartlett's Ferry (Chattahoochee River) and Blackshear (Flint River) (Long 2001). Electrofishing sampling for YOY and mtDNA analyses indicated that reproduction also occurred in 1997, and the catch rate for naturally produced YOY in 1997 was almost three times that found in 1985. Sampling in both years indicated most of the reproduction was probably occurring upstream of Lake Seminole.

Gulf race striped bass in spawning condition have been found at water temperatures of 20°C (April-May), and spent fish have been documented at 19.5°C below Columbia L&D on the Chattahoochee River (C. Mesing personal communication). Hess and Jennings (2001) sampled for striped bass eggs and larvae in the Chattahoochee River between West Point Lake and Morgan Falls Dam near Atlanta, Georgia, to determine whether natural reproduction occurred in that reach of the river above the fall line. No striped bass eggs or larvae were collected, but the collection of three age-3 striped bass in that portion of the river indicated some striped bass reproduction and recruitment occurred in the system as late as 1996. Striped bass had been stocked above West Point Dam only in 1990 and 1992.

The 1984 collection of ripe and spent female striped bass in the Flint River indicated spawning might be occurring (Keefer 1986). The Georgia Department of Natural Resources (GDNR) sampled the Flint River in 1970 and collected three suspected striped bass eggs that were never positively identified (Gennings 1970). In a subsequent study in 1985, the GDNR collected 91 striped bass eggs in the Flint River between Albany, Georgia, and Lake Seminole during a 22-day period (March 11-April 29) (Keefer 1986). Based on water velocity and egg developmental stage, spawning appeared to occur throughout most of the Flint River between Lake Seminole and Albany, Georgia. However, major spawning locations were determined to be between river km (RK) 88 and 90 and between RK 112 and 115. Numbers of eggs per unit volume of water were much lower than generally found in Atlantic Coast striped bass rivers. Because of required hatching time and length of available river, only 4% of the eggs sampled were judged to have had a good chance and only 44% a fair chance of successfully hatching. Eggs spawned downstream of RK 110.8 would probably have had poor survival under river conditions that year. Examination of Lake Seminole gill net data for 1974-1985 indicated exceptionally good recruitment for 1977 when fingerlings had not been stocked into the system (Keefer 1986). A unique combination of flow conditions that year (high steady flows in March and lower steady flows in April) may have been particularly conducive to spawning and egg survival. Lateral line scale counts for YOY collected during 1985 indicated successful spawning by both Atlantic and Gulf race fish.

There have been at least four separate projects to document striped bass spawning in the Apalachicola River through plankton sampling for eggs and larvae (Barkuloo 1989). A study in 1961 found no eggs or larvae (Barkuloo 1961b). Although positive identification as Gulf race was not possible, four striped bass eggs were collected approximately 42 km below JWLD in 1976 (Smith ND, Barkuloo 1989). Given the embryonic stage at collection, incubation time relative to temperature and existing water velocities, spawning had probably occurred just below the JWLD. However, a follow-up study in 1977 found no eggs or larvae (Barkuloo 1989). Sampling for striped bass eggs and larvae was conducted again in 1987; a single striped bass egg was collected in that study and was estimated to have been spawned at RK 55.4 within the lower third of the river (Foster et al. 1988).

3.2.5.2.8 Other Florida River Systems

Reproduction by Atlantic race striped bass in the Ochlockonee River below the Lake Talquin Dam was documented in 1987 through collection of YOY when hatchery-reared striped bass were not stocked into the system (Mesing 1989). Barkuloo (personal communication) collected young striped bass as early as 1957 from the Escambia River before any stocking had taken place. One striped bass egg was collected in the Choctawhatchee River in 1975 (Smith et al. 1975). The egg was estimated to have been spawned about 32-48 km upstream from the river's mouth.

3.2.5.3 Fecundity

Considerable differences have been found in fecundity for striped bass, which may be due in part to using eggs in various stages of maturity for these estimates; eggs from three consecutive seasons may be contained in the ovary simultaneously (Rulifson et al. 1982). While an average fecundity of 700,000 eggs per female has been cited (Hardy 1978), the number of eggs produced by striped bass females is highly correlated with weight, length, and age of the fish (Westin and Rogers 1978). Mansueti and Hollis (1963) found total fecundity for Atlantic Coast striped bass to be only 15,000 eggs in a 460 mm female; however, Raney et al. (1952) reported more than 40.5 million eggs in a 14.5 kg fish. Striped bass from Albemarle Sound produced approximately 180,000 eggs per kg of body weight each spawning season; females >27.2 kg from Roanoke River produced 105,600 to 215,000 eggs per kg of body weight (Rulifson et al. 1982). Horst (1976) found that female Atlantic race striped bass in the Atchafalaya River basin, Louisiana, weighing 1 to 2 kg produced from 137,000 to 220,000 eggs/kg of body weight. Relationships of fecundity to FL, weight, and age have been developed for striped bass age-7 through age-13 in offshore North Carolina waters (Rulifson et al. 1982). Eggs of fish weighing <4.53 kg have been found to be less viable than eggs from older fish (Rago et al. 1990).

For Gulf race striped bass, Crateau (ND) found that females produced an average of approximately 45,000 eggs/kg of body weight and at least 90% of the ova matured in a single spawning season. Monzyk et al. (2001) found two striped bass from the Tchefuncte River, Louisiana, contained approximately 180,000 and 227,000 eggs/kg of body weight. These fish were both age-4 but had total fecundities comparable to age-7 striped bass from Roanoke River-Albemarle Sound on the Atlantic Coast. Genetic identification of these two fish was not determined.

3.2.5.4 Incubation and Larval Transport

See Sections 3.2.1 and 3.3.1 for detailed discussions of morphology of various life stages and physiological requirements for eggs and larvae. Striped bass eggs water harden within 12 hours more or less following release (Bain and Bain 1982), although Crateau (ND) reported water hardening within two to three hours for Gulf race eggs. Eggs are distributed throughout the water column (Raney et al. 1952), but at lower current velocities they may be concentrated at greater depth. The incubation period is positively related to water temperature, with hatch occurring in as little as 29 hrs at 23.9°C and as much as 80 hrs at 12.2°C (Hardy 1978). The relationship between hatching time and ambient water temperature can be expressed by the formula:

$$I = (-4.60T) + 131.6,$$

where I is the time to hatching in hrs and T is temperature in °C (Rulifson et al. 1982). Crateau (ND) indicated Gulf race striped bass eggs hatch in 40-60 hrs at 18°-20°C.

Although suspension in the water column is not strictly required for hatching if eggs remain adequately oxygenated on the bottom (Enamait et al. 1991), success improved with increased suspension during the first 15 hrs of incubation (Rulifson et al. 1982). Substrate composition also apparently increases hatching success, with coarser substrates typically yielding higher hatching rates (Rulifson et al. 1982). Sunlight enhances egg survival (Rulifson et al. 1982), and high turbidity and suspended solids do not have detrimental effects on hatching success (Bain and Bain 1982, Talbot 1966).

Rulifson et al. (1982) reported striped bass larvae generally are 2.0-3.7 mm TL at hatching, and Crateau (ND) gave Gulf race striped bass hatching lengths as 2.5-4.0 mm. Within temperature limits of 12°-26°C, mean length (L) of larvae one day after hatching is related to temperature (T) as follows (Rulifson et al. 1982):

$$L = (-0.013T^2) + (0.62T) - 2.22,\ r^2 = 0.70$$

Depending upon temperature, the yolk sac stage generally lasts seven to 14 days (1978) (three to seven days for Gulf race according to Crateau ND). Yolk absorption lasts approximately three days at 23.9°C, and oil traces may remain for up to 22 days (Rulifson et al. 1982). According to Setzler-Hamilton et al. (1981), yolk-sac larvae are not able to swim effectively and require turbulence to keep them from settling to the bottom. At this stage larvae may be found throughout the water column (Raney et al. 1952), again probably dependent on current velocity. After four to five days larvae are able to swim horizontally and move to the surface for feeding, which usually begins in four to ten days (Hardy 1978). Crateau (ND) indicated Gulf race larvae might mature faster than Atlantic race and began to feed at about four-days old.

The striped bass postlarval stage (9 mm TL) is reached in approximately 20 days, and postlarvae generally become juveniles in three to four weeks at about 36 mm TL (Pearson 1938), although Crateau (ND) indicated the juvenile stage for Gulf race fish begins at 25 mm. See Sections 4.2.1 and 4.2.2 for more comprehensive discussion of egg, larval, and juvenile habitats.

Water velocity and discharge rates are critically important for suspension of eggs and larvae and for transport to the vicinity of suitable nursery habitats – generally shoal, gravel, and sand bar areas in the lower reaches of river systems. However, for "land-locked" reproducing populations in reservoirs, the upper portions of reservoirs may provide the most suitable nursery habitat (Bulak et al. 1997). Suitable water velocity for a specific river system varies depending on factors such as egg buoyancy, water temperature, and distance from spawning sites to suitable nursery habitat. It is important that larvae arrive at critical habitats when they begin active feeding (Lukens 1988). A stream velocity of about 0.30 m/sec (1 ft/sec) is required to keep eggs and larvae suspended in the water column and transported appropriate distances downstream (Lukens 1988). Flume tests reported by Bulak et al. (1993) found mean channel velocity of 0.06 m/sec sufficient to keep most eggs off the bottom in the Congaree and Wateree Rivers, South Carolina. Bulak et al. (1993) found striped bass eggs appeared to be transported at the same rate as dye placed in the water. In another study, (Cobb 1989) found eggs were transported at only 87% of the observed stream flow and concluded further investigation was needed.

Assuming a hatching time of 48 hrs and a current velocity of 0.3 m/sec, Crance (1984) calculated spawning areas should be a minimum of 52.6 km upstream from a river's mouth. Otherwise, eggs and larvae may be transported to the lower parts of estuaries or into the ocean before they hatch or are ready to feed and where they may die. The reach of stream required for successful hatch may vary significantly due to egg buoyancy and water physicochemical characteristics. In some rivers on the Atlantic Coast, successful egg and larval transport occurred with flows less than 0.3 m/sec where salinity/specific gravity and tidal current in the lower reaches may be sufficient to keep eggs suspended (Lukens 1988, Barkuloo personal communication). This may be due to the greater buoyancy of eggs produced by striped bass in those rivers or to stronger tidal currents occurring in East Coast estuaries. Striped bass have been known to spawn successfully in the lower 22.5 km of the Pokomoke and Blackwater Rivers, Maryland (Lukens 1988). Using these criteria, Lukens (1988) concluded that conditions of flow velocity and river length suitable for the survival of striped bass eggs and larvae existed in the following river systems within the historical range of striped bass in the Gulf: Apalachicola, Biloxi, Blackwater, Choctawhatchee, Escambia, Mobile, Pascagoula, Pearl, Suwannee, Wolf, and Yellow.

In the Roanoke River, years with low to moderate discharge rates appeared to have stronger striped bass year classes than did higher discharge years. Higher flows tended to carry eggs and larvae into flood plain swamps or into higher salinity waters beyond favorable riverine nursery areas, thus lowering survival (Rulifson et al. 1982). Van Den Avyle and Maynard (1994) noted similar patterns in the Savannah River. Flow rate was also identified as a major factor in regulating striped bass population size in the Sacramento-San Joaquin estuary in California by transporting young fish to nursery areas (Stevens 1977).

It has been hypothesized that poor reproduction by Gulf race striped bass in some Gulf rivers may be due, in part, to evolutionary adaptations which may no longer be advantageous to the species' survival in rivers segmented by blockages caused by dams and other structures (C. Mesing personal communication). In general, unaltered Gulf rivers are longer and have higher current velocities than most East Coast rivers. These physical features may have resulted in adaptive selection for striped bass in these rivers to spawn farther upstream and to not require eggs as buoyant as their East Coast counterparts. Construction of dams has effectively moved primary spawning sites farther downstream (i.e., below the dams) and created a series of shorter river segments with slack-water reservoirs on their lower ends. In both cases, eggs and larvae may be transported to estuaries, the ocean, or to open-water reservoir habitats, either before they hatch or are old enough to keep themselves suspended in the water column or actively feed. One ironic supposition is that because of these physical changes in the river systems, Atlantic race striped bass may now be better suited to reproduce in these rivers than the Gulf race. Some Atlantic populations have more buoyant eggs that may offer a survival advantage in the lower portions of rivers, reservoirs, or in controlled river segments where water velocity may be lower than under free-flowing conditions. Enamait et al. (1991) found successful reproduction of striped bass in two small Maryland impoundments that apparently lack tributaries with flow generally considered sufficient for striped bass spawning and egg incubation. The higher egg buoyancy of the Chesapeake strain striped bass stocked into those lakes allowed lower currents and wave action in the reservoirs to keep enough eggs suspended to allow hatching, larval survival, and recruitment to the population.

3.3 Physicochemical Requirements

Physical and chemical life history requirements for fish are closely related to a species' habitat selection. While DO, temperature, pH, turbidity, and water hardness are descriptive of those habitats, they also reflect the biological requirements of the fish. For this reason, these factors as they relate to striped bass physiology are separated from the habitat descriptions, recognizing overlap occurs between these sections and the preferred habitat information found in Section 4. While most of the information here is applicable to Gulf race striped bass, most studies were conducted using Atlantic race fish from both the Atlantic and Pacific coasts.

3.3.1 Eggs and Larvae

3.3.1.1 Salinity

Secor and Houde (1995) reported 98% of eggs and 99% of larvae were found above the freshwater-saltwater interface in the Patuxent River. They concluded that the salt front acted as a physical barrier that limited downstream displacement of eggs and larvae.

Albrecht (1964) found striped bass eggs can withstand a moderate increase in salinity, but high salinity (chlorides 14.1 ppt) resulted in near complete mortality or deformities of larvae within 48 hrs after hatching. Survival of larvae was better in water of low salinity (chlorides 0.92-0.95 ppt) than in freshwater or water of moderate salinity (chlorides 4.6-4.7 ppt).

Bayless (1972) found the chorion diameter of water-hardened eggs was inversely proportional to salinity. This was likely the effect of osmotic pressure inhibiting the expansion during water hardening. In other experiments, hardened eggs were transferred to saline water (28 ppt), which resulted in depressions in the chorion without an actual decrease in size.

Total mortality of two-day old larvae occurred within 36 hrs when held at 28 ppt salinity, while survival and growth were significant for larvae held at 21 ppt salinity for 17 days (Bayless 1972). Larvae held in salinities ranging from 3.5 ppt to 14.0 ppt exhibited better growth and survival than larvae held in freshwater controls. The best growth occurred at 14.0 ppt salinity; the best survival occurred at 10.5 ppt salinity.

Winger and Lasier (1994) found that 100% of striped bass eggs died within 24 hrs when exposed to salinity greater than 24 ppt, and nearly all eggs ruptured at salinities above 18 ppt. Survival and total length of larvae exposed to salinities above 15 ppt were reduced. Similar to Bayless's findings, egg diameter was reduced when exposed to salinity as low as 3 ppt, and egg size varied inversely with salinity. However, larval length 24-hr post hatch was greatest for eggs exposed to 3-9 ppt. Compared with eggs hardened in saline water, neither survival nor total length increased when eggs were hardened in fresh water before exposure. Winger and Lasier (1994) demonstrated that five-day old larvae were less sensitive to salinity than 48-hr post hatch larvae, and survival of 48-hr post hatch fish was negatively correlated with both salinity and exposure time. Ten day LC_{50} for 48-hr post hatch larvae was 10 ppt, and critical salinities for striped bass eggs and larvae were those greater than 9 ppt. In their experiments, all 48-hr post hatch fish died when exposed to 21 ppt salinity.

3.3.1.2 pH, Alkalinity, and Hardness

Mullis and Smith (1990) listed recommended water quality criteria for striped bass egg and fry culture including pH, alkalinity, and water hardness. The acceptable range for pH is 6.5-9.0; the optimum range is 7.5-8.5. Extremes in pH are stressful or toxic to striped bass eggs and larvae. A pH <6.8 or >10.0 may result in fry mortality (Bonn et al. 1976).

Striped bass larvae are sensitive to sharp changes in pH even within the optimum range (Hall et al. 1985). Rainfall events lowered hardness and pH in the Nanticoke River, Maryland, and were partly responsible for larval mortality during 1984 (Hall et al. 1985). Low or high pH may increase the effects of toxic contaminants by increasing the mobilization of the contaminant, increasing the toxicity, or increasing the susceptibility of striped bass to exposure (Palawski et al. 1985, Hall 1991). Hall et al. (1985) associated mortality of larval striped bass in the Nanticoke River with increased amounts of aluminum that caused a rapid drop in pH following rain events.

Water high in alkalinity is beneficial to striped bass and likely reduces osmoregulatory stress (Kerby 1993). Bayless (1972) described alkalinity at the Moncks Corner State Fish Hatchery, South Carolina, as ranging from 140 ppm to 200 ppm with a mean of 177 ppm and total hardness ranging from 110 ppm to 150 ppm with a mean of 137 ppm. He considered high total hardness, as well as other parameters that increase osmotic pressure to be detrimental to egg development due to arresting expansion of the chorion during water hardening similar to the effects of high salinity. In his synthesis of water quality data on early life stages, Hall (1991) reported 80% mortality of larvae after a four-day exposure to 34.6 ppm $CaCO_3$ and 90% mortality of larvae after a five-day exposure to <60 ppm $CaCO_3$.

Kane et al. (1990) observed lower mortality of 4-14 day old larvae exposed to 3 ppt salinity (NaCl) at hardness of 160 ppm ($CaCO_3$) than for larvae exposed to the same salinity at hardness levels of 40 and 100 ppm. He concluded that elevated hardness might have a protective effect at higher than optimal salinities. Bonn et al. (1976) and Mullis and Smith (1990) recommended optimal total hardness as 200-250 ppm.

3.3.1.3 Temperature

Hatching time varies with temperature but usually occurs at 48 hrs (more or less) post spawning within the optimum temperature range. Bayless (1972) summarized observations by several authors along with experimental results from Moncks Corner, South Carolina, which demonstrated that hatching time varies from 80 hrs at 12°C to 30 hrs at 23°C. He noted that complete hatch for a group of eggs may require 6-12 hrs and occasionally up to 24 hrs.

In laboratory experiments, Albrecht (1964) observed successful hatching (85%) among eggs subjected to 3.3°C fluctuations at temperatures of 14.4°-22.8°C. In other tests, hatching success at constant temperatures of 11°C, 12.8°C, 16.7°-17.7°C, and 19.4°-20.5°C was 4%, 88%, 85%, and 97%, respectively. Bayless (1972) observed that percent hatch decreased above 18.8°C and concluded that the optimum temperature range was 16.6°-18.3°C. Shannon (1970) found the longer eggs take to develop at 18°C, the more tolerant they become to thermal shock at higher temperatures.

Albrecht (1964) observed that 72-hour larval survival was 67% at 23.9°C but only 7% at 26.7°C. Further, he noted that 72-hour yolk-sac absorption among larvae reared at 23.9°C was similar to yolk-sac absorption for larvae reared at 16.7°-17.7°C after 144 hrs. Survival at these two temperatures might be similar if given an adequate food supply. Brewer and Rees (1990) reported that under controlled conditions, five-day-old (prolarvae) striped bass survived temperatures ranging from 13° to 24°C with optimal temperature ranging from 18° to 20°C. Temperatures below 13°C and above 24°C were considered detrimental to survival; however, extreme temperature tolerance may depend on age of fry and water quality characteristics.

In the Patuxent River, larval cohorts that experienced average temperatures less than 15°C or greater than 20°C during the first 25 days after hatching had significantly higher mortality rates than cohorts which experienced intermediate temperatures of 16°-19°C (Secor and Houde 1995). They also found that potential recruitment for cohorts spawned during early season, mid-season, and late-season were good, very good, and very low (respectively) indicating higher temperature late in the season may be more detrimental than low temperature early in the season. Shannon (1970) also observed that the percentage of normal fry produced at the hatchery in Weldon, North Carolina, decreased from 68% to 0% as test temperatures increased from 21° to 27°C.

Bulak et al. (1997) reported that in the Santee-Cooper system, during years of high recruitment in 1988 and 1990, highest relative survival occurred among eggs spawned during week four of the season. However, the peak spawn occurred during week five in both 1988 and 1990. In 1989, a year of relatively low juvenile recruitment, eggs spawned during week ten of the season exhibited the highest relative survival. They concluded that a substantial portion of recruitment resulted from a relatively few eggs transported to high-quality nursery habitat at the proper time (Bulak et al. 1997).

Mortality is inversely related to growth (Length). Fish length is influenced by environmental factors, particularly temperature (Logan 1985). Utilizing data from the Hudson River, Logan modeled the following variables: length at hatch, initial cohort standing crop (yolk-sac and post yolk-sac larvae), and growth rate. Reduction in growth rate caused the largest reduction in population size, followed by reduced length at hatch, and number at hatch, respectively. The largest portion of a year class should originate from a cohort for which length at hatch and larval growth rate are the greatest, both of which are influenced by incubation temperature, larval rearing temperature, and nutrition (Otwell and Merriner 1975, Cox and Coutant 1981, Morgan et al. 1981). Growth rates for young striped bass increase approximately 13.5% per degree Celsius at 12°-18°C (Otwell and Merriner 1975).

3.3.1.4 Dissolved Oxygen

Acceptable dissolved oxygen (DO) for striped bass eggs and larvae ranges from 4.0 ppm to 10.0 ppm and should optimally be at or near saturation (Mullis and Smith 1990). Low DO results in increased incubation time for eggs, and subsequent larval survival is inversely proportional to the length of time eggs are exposed to low DO (Kerby 1993). DO concentrations below 5.0 ppm during embryonic development may cause abnormalities in larval fish (Bonn et al. 1976, Hall 1991). Harrell and Bayless (1981) determined that normal development of embryos required a minimum DO concentration of 3.0 ppm. Their experiments revealed significant differences in the occurrence of truncation and scoliosis when DO decreased below 3.0 ppm. Low DO may also reduce feeding, negatively affect growth rates of larvae, and contribute to increased susceptibility to parasites, diseases, and shock (Bonn et al. 1976).

3.3.2 Juveniles

Environmental effects such as temperature, rainfall, river discharge, and salinity influence year class strength in natural striped bass populations, generally acting on eggs, prolarval (yolk-bearing larvae), and postlarval (larvae that have absorbed their yolks) fishes (Cooper and Polgar 1981, Kernehan et al. 1981, Rulifson and Manooch 1990, Uphoff 1989, Tsai

1991, Bulak et al. 1997) suggesting a non-critical role for the juvenile phase (Boynton et al. 1981). By the time striped bass reach the juvenile (post-metamorphic) stage, physical and chemical parameters do not normally affect survival, and mortality becomes a decreasing function of size (Uphoff 1989). Juvenile striped bass are able to survive a wide range of environmental conditions, and preferred habitats and physicochemical conditions may change as juveniles increase in size and age.

3.3.2.1 Salinity

Since striped bass are able to complete their life cycle in fresh water, it is evident that juvenile striped bass can survive a wide range of salinities from freshwater to saltwater. Brewer and Rees (1990) describe brackish water (0.5 ppt-10 ppt) as excellent for rearing juvenile striped bass in hatcheries. Likewise, Geiger and Parker (1985) implicated salinity as the most important factor influencing hatchery production. Salinity stabilizes pH, which buffers many contaminants and provides osmotic balance. Acute toxicity to many organic insecticides and inorganic chemicals may also be reduced in saline waters compared with fresh and soft water (Palawski et al. 1985).

In coastal rivers, juveniles (18-51 mm TL) tend to follow the tidal currents along the freshwater-saltwater interface. Their abundance typically peaks in this mixing zone, indicating better conditions for survival (Turner and Chadwick 1972).

Turner and Chadwick (1972) found that juvenile striped bass movement was related to river discharge and demonstrated that young fish inhabited areas further upstream in the Sacramento-San Joaquin Estuary during years of low outflow and high salinity than during years of high outflow and low salinity. Juvenile striped bass survival increased rapidly as mean June-July outflows increased from low to moderate levels. Rulifson and Manooch (1990) reported similar findings from the Roanoke River in North Carolina and suggested that larval transport and feeding, location of primary nursery grounds in Albemarle Sound, and concentration and distribution of plankton were factors affected by river discharge. Stevens (1977) and Stevens et al. (1985) reached similar conclusions concerning the effects of river discharge on the decline of striped bass in the Sacramento-San Joaquin Estuary.

3.3.2.2 pH, Alkalinity, and Hardness

Optimal pH for fingerling striped bass culture is 7.3 and should fall within a neutral to slightly alkaline range of 7.0-8.5 (Brewer and Rees 1990). Acidic conditions (pH <6.0) as well as alkaline conditions (pH >10.0) may be lethal to juvenile fish (Hall 1991). Juvenile striped bass are also susceptible to sudden changes in pH, and caution should be exercised when moving striped bass fingerlings from a hatchery to a stocking location. Waters high in alkalinity are well buffered (150-300 ppm $CaCO_3$) against sudden changes in pH. Under normal conditions, low or high pH may increase toxic effects of contaminants such as aluminum by increasing the mobilization of the contaminant or by physiologically increasing the susceptibility of striped bass to exposure (Palawski et al. 1985, Hall 1991).

Total water hardness greater than 150 ppm is considered good for fingerling culture, although successful rearing was reported under conditions ranging from 60 to 600 ppm (Brewer and Rees 1990). Hall (1991) reported improved survival of juveniles in Chesapeake Bay at water hardness >150 ppm $CaCO_3$. When water hardness is low or changes suddenly, striped bass tend to become more susceptible to stress, particularly handling.

3.3.2.3 Temperature

Temperature is more limiting to growth and survival of juvenile striped bass than salinity (Otwell and Merriner 1975). Tolerances for higher temperature increase with age in juveniles, and temperatures from 18°C to 30°C are considered acceptable for culture of Phase I (25-64 mm TL) fingerlings (Brewer and Rees 1990). The mid-range is preferred for growth and survival.

In laboratory experiments, maximal growth rate for older juvenile striped bass held at constant temperature occurred at 25°C, and growth rate declined to zero below 10.5°C and above 33.5°C (Cox and Coutant 1981). There was 50% mortality of striped bass at 34.5°C, and surviving fish lost weight and length. When temperatures were varied, daily temperature fluctuations at lower than optimum temperatures (which mimic natural conditions) resulted in enhanced growth and bioenergetic efficiency (food conversion). Thus, in the wild, diel temperature fluctuations below the empirical optimum result in faster growth than would be expected for fish exposed to a constant optimum temperature.

Researchers have proposed that juvenile, subadult, and adult striped bass have thermal niches that shift with age, thus resulting in the partitioning the use of habitat (Coutant 1980, Coutant et al. 1984). Coutant et al. (1984) described this niche for juveniles as ranging from 24°C to 27°C and found evidence of preference for lower temperatures as juvenile fish (age-1) grew from 202.2 mm mean TL (May) to 245.0 mm mean TL (July). Typically, YOY striped bass occupy areas of warmest temperature such as that occurring in estuary backwaters and bays. These habitats are most beneficial for rapid growth during their first summer (Coutant 1985b) except in the southern limits of their range. Summer temperatures in Florida and along the Gulf Coast may be above the optimum for maximum growth (Coutant 1985b), and fastest growth occurs during cooler months (Ware 1970). In temperature gradient experiments, Dorfman (1974) found that in high gradient tests juvenile striped bass failed to avoid lethal water temperatures and moved in and out of heated water areas frequently at lower gradients.

As striped bass approach the adult phase, their tolerance of warm temperatures decreases. During summer months, subadult and adult striped bass become more dependent on thermal refuges than younger fish and become thermally stressed as ambient water temperatures increase. Zale et al. (1990) suggested that the critical threshold influencing adult striped bass mortality in Keystone Reservoir, Oklahoma, was the temperature (27°C) at which feeding stops, and mortality becomes a function of the margin and duration that ambient temperatures exceed the threshold. McDaniel et al. (1991) found that smaller (<331 mm TL) striped bass in the St. Johns River, Florida, were more robust than larger fish in summer when ambient water temperature exceeded 29°C as compared to winter (ambient temperature 10.5°-25.0°C). They were unable to detect significant negative seasonal impacts of thermal stress for juvenile fish. However, they observed a 16.3% loss in body weight from winter to summer in larger juvenile and subadult

(331-500 mm TL) fish. Wooley and Crateau (1983) reported similar findings between smaller (<4.5 kg) Gulf and Atlantic race striped bass tagged and released in the Apalachicola River, Florida. In Lake Texoma, Oklahoma-Texas, juvenile striped bass (<1.36 kg but excluding age-0 individuals) remained abundant in gill net samples in the upper reservoir at temperatures as high as 29°C, although catch dropped nearly 85% as temperature increased from 28°C to 30°C (Mathews et al. 1989). Abundance of medium-size fish (1.39-2.27 kg) was significantly less in the up-lake area when water temperature exceeded 22°C than at cooler temperatures, indicating that larger juveniles may experience thermal stress and relocate. Long (2001) reported striped bass smaller than 1.4 kg occupying thermal refuges (20°C) in the Chipola River, Florida, during summer months when ambient temperature was 24°-27°C. These findings indicate that the threshold temperature for subadult fish is higher than for adults and may be nonexistent for juveniles. This supports the hypothesis that striped bass are stratified by size or age when occupying thermal refuges.

Moore and Burton (1975) found seasonal recapture locations of tagged juvenile striped bass (28-32 cm TL) in Chesapeake Bay indicated that deep water of the bay served as important over-winter habitat. Deeper water likely provided more constant temperatures than shallow bays and flats and served as a buffer against rapid decreases in temperature following cold fronts. Coutant and Carroll (1980) observed that subadult striped bass in quarry lakes selected the warmest water available at depths below 1.5 m when the surface temperatures dropped below 21°C. Coutant (1985b) indicated that adult striped bass in Cherokee Reservoir, Tennessee, avoided temperatures below 18°C when warmer water was available. Juvenile fish likely exhibit similar preferences.

3.3.2.4 Dissolved Oxygen

Brewer and Rees (1990) recommend maintaining oxygen levels above 6 ppm for hatchery production of Phase I striped bass. They advised that DO concentrations below 3 ppm generally require supplemental aeration. Coutant (1985b) noted that striped bass become physiologically distressed at DO concentrations of 3 ppm, and oxygen levels of 2 ppm are uninhabitable. Price et al. (1985) found that DO concentrations of 0.5 ppm caused death. Dissolved oxygen requirements are related to water temperature, and lower oxygen concentrations are generally more tolerable at cooler temperatures. For instance, Lewis (1983) reported gill netting striped bass (>400 mm TL) from the metalimnion of Lake Norman, North Carolina, during August 1978 at oxygen concentrations as low as 0.2 ppm. While many of the fish sampled may not have been juveniles, the findings demonstrated that striped bass could survive in extreme conditions.

3.3.3 Adults

3.3.3.1 Salinity

In general, striped bass are euryhaline and anadromous; some adults spend considerable time in the ocean and return to freshwater streams to spawn. In some areas, striped bass may spend their entire lives in fresh water (Pearson 1938, Raney et al. 1952, Scruggs 1957). Tupper and Able (2000) found salinity did not affect abundance, distribution, or the food habits of striped bass in tidal creeks and salt marshes in Delaware Bay, New Jersey.

Along the mid-Atlantic and New England states, and Canadian maritime sites, adult fish, particularly females, are involved in extensive coastal migrations (Waldman et al. 1988). Striped bass in these areas generally enter coastal waters and participate in migrations beginning at age-2 (Merriman 1941). However, among populations on the northern and southern extremes of the range, striped bass do not make coastal migrations, and the species is considered riverine (Barkuloo 1967, Dudley et al. 1977, McIlwain 1967, McIlwain 1980b, Wooley and Crateau 1983). This behavior appeared to be temperature related and not salinity related (Bettross 1991).

3.3.3.2 Temperature

In laboratory studies, Meldrim et al. (1974) found temperature avoidance response of striped bass varied with acclimation temperature. For striped bass acclimated at 27°C, avoidance temperature was 34°C. For acclimation at 5°C, avoidance temperature was 13°-18°C. Avoidance temperature appeared inversely affected by both light level and salinity. In addition, reducing DO in conjunction with increasing temperature generally reduced the avoidance temperature. Hall et al. (1984) found that striped bass avoided temperatures 34ºC or greater when acclimated to temperatures of 27º-30ºC. Meldrim et al. (1971) investigated thermal stress in striped bass, and at the acclimation temperatures studied (15°-26°C), thermal stress was evident upon sudden exposure to temperatures 8°C above the acclimation temperature.

In field studies, several researchers (Waddle 1979, Schaich 1979, Cheek 1983, Merriman 1941, Dudley et al. 1977) indicated adult striped bass avoid water temperatures in excess of 25°-26°C (77°-78.8°F). Zale et al. (1990) suggested that the critical threshold influencing adult striped bass mortality in Keystone Reservoir, Oklahoma, was the temperature (27°C) at which feeding stops, and mortality becomes a function of the margin and duration that ambient temperatures exceed the threshold. They found that striped bass could survive exposure to water temperatures of 27°-28°C for about a month. At higher temperatures, mortality occurred sooner. They concluded that mortality was a result of starvation, and temperature indirectly contributed to mortality. Van Den Avyle and Evans (1990) worked in the Flint River and Lake Seminole in Georgia and found that when ambient river temperature exceeded 23°C adult striped bass actively sought out cooler water temperatures. From mid-June through August when water temperatures ranged from 27.5° to 31°C, the majority of striped bass were in 20° to 23°C water. Coutant (1985b) reported similar temperature preferences for striped bass in Cherokee Reservoir, Tennessee. He also observed that while Atlantic coastal northern migrations in summer are commonly thought to occur because of feeding behavior, these movements tend to keep the fish in their preferred temperature range, as observed in reservoirs. He also suggested that striped bass may avoid Gulf waters during the summer because water temperatures generally exceed 25°C.

Van Den Avyle and Evans (1990) observed possible avoidance of cold water by striped bass in the Flint River, and Coutant and Carroll (1980) found that subadult bass sought out the warmest water available in a lake when surface temperatures were less than 21ºC. However, they also cited Cheek et al. (1985) who found striped bass to be widely distributed in a reservoir when ambient water temperature was 4º-10ºC despite the presence of warmer spring-fed sites.

3.3.3.3 Dissolved Oxygen

Crance (1984) stated that if DO concentrations were adequate for egg, larval, and juvenile survival, adults would also survive. Meldrim et al. (1974) stated adult striped bass avoid water of 44% or less in oxygen saturation. Dissolved oxygen concentrations can be critical for survival in thermal refuges during summer months. Coutant (1985b) described this as a “squeeze” phenomenon (Section 4.2.3.1). Dissolved oxygen can also limit habitability of refuges where springs are the source of cool water since individual aquifers have different DO characteristics. Hill et al. (1981) studied the locomotor responses of striped bass to DO and found that gradients of DO can markedly influence habitat selection by striped bass.

3.3.3.4 pH

The USEPA (1986) recommended a pH range of 6.5-9.0 for survival of freshwater aquatic life. The toxicity of some compounds may vary with varying levels of pH. Although specific pH levels for adult striped bass were not presented, Lukens (1988) conjectured that the pH conditions suitable for larvae and juveniles (i.e., 6-10) can probably also be applied to adults.

3.3.3.5 Total Hardness

Adult striped bass response to variations in total hardness has not been well documented; however, low hardness streams common along the northern Gulf of Mexico typically do not have records of striped bass usage (e.g. the Aucilla River, Florida). Also, low hardness streams usually have low primary productivity (Smock and Gilinsky 1992) and may not produce an adequate food supply for adult striped bass. Conversely, rivers with healthy striped bass populations typically have moderate to high water hardness.

3.3.3.6 Dissolved Solids

Crance (1984) reported on observations that total dissolved solids (TDS) levels of 180 mg/l may have curtailed spawning by striped bass in California but noted that spawning occurred in the Delaware River where TDS levels were 180 mg/l or less. This TDS level may have prevented upstream migration by adults in the San Joaquin River, California, though another study was cited indicating 350 mg/l TDS as the critical level for blocking spawning migration. Combs (1979) found that adult striped bass migrated through waters with TDS levels as high as 1,920 mg/l in Keystone Reservoir, Oklahoma.

3.4 Movement and Migration

Striped bass movement is typically associated with foraging, physiological demands, and reproduction. Pearson (1938) divided striped bass movements into three distinct groups he identified as: 1) coastal, 2) seasonal, and 3) spawning but may not have recognized the need of striped bass to find thermal optima. Directly and indirectly, environmental factors dictate to a great extent all aspects of these movements.

Striped bass tag return data from Gulf Coast rivers indicate relatively limited movement between release site and recapture location. The average distance reported in the coastal tributaries of Mississippi was 24 km, and the maximum distance between release point and recapture site was 170 km (Nicholson 2001b). Rarely did the tagged fish move outside the system in which released. Wooley and Crateau (1983) stated 82% of the recaptures in their study occurred within the initial tagging zone of the upper Apalachicola River. They did report 9% moved downstream to the lower river.

Pearson (1938) indicated that Gulf of Mexico striped bass populations were confined to fresh or brackish coastal rivers and generally not found in salt water. Raney et al. (1952) concurred with Pearson regarding the Gulf striped bass. He found the fish along the Gulf and at both extremes of their range on the Atlantic Coast to be primarily freshwater-oriented and rarely make coastal migrations. Those fish might be more appropriately be described as "potadromous," denoting that most migrations they undertake for feeding, spawning, or over-summering occurs within their resident river system.

Tagging and telemetry studies (Barkuloo 1961b, McIlwain 1967, Wooley and Crateau 1983, Crateau 1984, Nicholson et al. 1986, Jackson et al. 2001, and Long 2001) of striped bass in tributaries of the northern Gulf of Mexico substantially agree with Raney et al. (1952) and Pearson (1938). However, there are documented occurrences of individual striped bass entering the Gulf. Wooley and Crateau (1983) reported that two individuals moved through Apalachicola Bay and Sound or through the Gulf and into the Ochlockonee River system. Similarly, individual fish tagged in Lake Talquin, Florida, on the Ochlockonee River were captured by anglers from the Suwannee River and Tampa Bay (FWC unpublished data). Eight striped bass taken on rod and reel from the boat harbor in Buras, Louisiana, apparently moved through the Empire navigation locks on the Mississippi River into the saltwater bay area (P. Cooper personal communication). These fish were caught from January 1993 through November 1994 and ranged in size from 908 g and 457 mm to 3.3 kg and 648 mm. During winter 2003, salinity in the Buras boat harbor ranged from 16 to 19 ppt after a period of no rainfall (P. Cooper unpublished data). A striped bass was captured on hook-and-line at Louisiana's West Delta Block 25 petroleum platform approximately a mile off the mouth of Tiger Pass in the late 1980s (P. Cooper personal communication). A tagging study in 1982-1985 by Lantz (1986) found three striped bass that left the Sabine River. One fish was recaptured north of Lake Charles in the Calcasieu River. The second fish was recaptured in Galveston Bay, and the third was taken in a shrimp trawl in the Gulf of Mexico near Cameron, Louisiana. Butler and Stelly (1993) also reported movement of a striped bass from Toledo Bend Lake on the Sabine River to Galveston Bay. J. Barkuloo (unpublished data) documented one individual captured by a recreational angler and observed another during scuba surveys at the Panama City, Florida, jetties in 35 ppt salinity water. Tagged striped bass have been reported by recreational anglers surf fishing at Mississippi's barrier islands and Louisiana's Chandeleur Islands in the early spring (L. Nicholson personal communication).

Clark (1936) reported on marking experiments that indicated no regular or definite coastal movement of striped bass occurred on the Pacific Coast. The fish appeared to disperse randomly from the point of release. The length of time between release and recapture ranged from four to 477 days and averaged 111 days. The distance traveled by these fish varied from zero to 74 km. Clark (1936) interpreted these data as indicative of limited coastal movement. In subsequent tagging studies, Calhoun (1952) concurred with Clark's assessment.

Seasonal movements of striped bass are very distinct along the Atlantic seaboard where they generally move, after spring spawning in coastal rivers, from mid-Atlantic estuaries north into New England coastal waters and the Bay of Fundy during the early summer and make the return trip during the late fall. Most migratory striped bass winter in the near-shore Atlantic Ocean from New Jersey south to North Carolina (A. Kahnle personal communication, USFWS unpublished data). Some fish, however, may leave the sea and move into bays or rivers where they remain until the spring. Known historic inshore wintering areas include lower Delaware and Chesapeake Bays (R. Miller personal communication), the Hudson River (Clark 1968), the New York Bight apex, and heated effluent plumes from various electric generating plants (V. Vecchio personal communication).

South of the Roanoke River in North Carolina, the distribution and movement of striped bass are strongly influenced by water temperature, especially in hot-weather months (Kerby 1993). During the summer, adult striped bass seek refuge in cool water areas and remain in these locations, if undisturbed, until the fall. The average distance moved during the spring and winter was significantly higher than for summer, early fall, and late spring (Crateau et al. 1982, Cheek et al. 1985, Wooley and Crateau 1983, Minton 1985, Forester and Frugé 1996, Jackson et al. 2001, Nicholson 2001a, Rogillio and Rabalais 2001). Long (2001) used ultrasonic and radio transmitter tags to track striped bass in the lower Apalachicola River and the Intracoastal Waterway. The study demonstrated that some striped bass in the lower river migrated to thermal refuges in the upper Apalachicola River or to the Chipola River to over-summer. Forester and Frugé (1996) found extensive fish movements during the fall (October-November), winter (December-February), and spring (March-May) in the Sabine River below the Toledo Bend Dam. They speculated that transmitter signal loss over an extended time period might be an indication that a fish had left the river. They also found that movements were extensive in many cases. The distance traveled by one tagged fish was estimated at 483 km in less than 51 days.

There is little data to indicate whether YOY fish make deliberate downstream migrations. In the Apalachicola River, the abundance of YOY striped bass in the fall is always greater in the JWLD tailrace and declines rapidly downstream through the upper, middle, and lower river (Long 2001). This trend indicates that by the fall of their first year, YOY striped bass are not actively moving downstream but may be moved a considerable distance via discharge of flood waters.

Adult striped bass in the ACF are more likely to actively make downstream migrations. Striped bass, ranging in size from 2.0 to 5.4 kg, were surgically implanted with radio transmitters and released into the Chipola River, a tributary of the Apalachicola River with thermal refuges (FWC unpublished data). These fish were telemetered from May through December 1989. Several of the surviving fish demonstrated downstream movement beginning in late October and early November. Fish were located as far down the Apalachicola as navigation mile 7.0, where salinity limited tracking capability. Striped bass in Lake Seminole also exit thermal refuges by late October, and many migrate downstream to the lower end of the reservoir (Van Den Avyle and Evans 1990). It is likely that downstream migrations are results of foraging.

Spawning migration of striped bass is essentially the movement of adult fish from brackish, salt, or freshwater upstream to where they spawn. Sexually mature adults require rather specific riverine reproductive habitat and typically make annual spawning migrations (Crance 1984). Generally, spawning takes place within the lower 40 km of the river. However, Raney (1954) and Talbott (1966) found that some populations migrate over 320 km. The Albemarle Sound population in North Carolina is an example of the latter. Depending on latitude, spawning migration has occurred as early as February in the Apalachicola River and as late as July in the St. Lawrence River, Canada. Striped bass found along the southeastern Atlantic Coast have migrated as much as 160.9 km upstream to spawn. In the Santee-Cooper river system, Scruggs and Fuller (1955) found the striped bass population to be landlocked and still capable of successfully spawning without returning to brackish or salt water. Adults in reservoir systems exhibit variable migration and distribution patterns (Cheek et al. 1985, Crance 1984). In the tributaries of the northern Gulf of Mexico, spawning migration may begin in February in the Apalachicola River (Barkuloo 1961b) and continue disjunctively until April. Crateau (1984) found Gulf race striped bass began their spawning run in the lower Apalachicola River in February and spawned in late April and early May depending on water temperature. Jackson et al. (2001) found a general upstream migration of striped bass in the Pascagoula River the second week in February 1997-1999.

Dams and water control structures block the upstream movement and spawning migration of striped bass. The spawning fish move upriver to the JWLD on the Apalachicola River (which impedes further upstream migration) and spawn. The same scenario exists on the Chattahoochee River below Columbia L&D and the Flint River at the Albany Dam. In Alabama, the Neely Henry Dam on the Coosa River is a barrier to upstream spawning migration of striped bass and consequently serves as a broodfish collection site (W. Nichols personal communication). Since 2001, C. Summerlin (personal communication) has collected broodfish below the Ross Barnett Reservoir Dam on the Pearl River. Forester and Frugé (1996) found the largest concentration of fish in their radio-telemetry study on the Sabine River at the upper end of the tailrace below the Toledo Bend Dam during the spring months. The concentration of fish below the dam may have been due to blockage of spawning migration or the fish may have been attracted to the area for other reasons (i.e., flow regime, feeding, etc.). See Section 4.4.4 for additional discussion of the effects of structural impediments on movement of striped bass.

Although dams serve as effective barriers to striped bass movement, occasional reports indicate that fish can move both upstream and downstream through locks and dams. Wooley and Crateau (1983) found 7% of the fish tagged in the upper Apalachicola River entered Lake Seminole through Jim Woodruff L&D. E. Long (personal communication) stated a single, tagged striped bass from the Chipola River migrated down to the Apalachicola River and then traveled upstream through the Jim Woodruff L&D and continued up the Flint River to Albany, Georgia. Downstream movement through dams has been documented on many rivers (Red River, Zale and Jacks 1988; Apalachicola River, Mesing et al. 1990; Ohio River, Henley 1996; Apalachicola River, Long and Rousseau 1996; Alabama River, Smith and Catchings 1998; Sabine River, Lantz 1986).

Mesing et al. (1990) demonstrated downstream through-dam movement of YOY striped bass in the ACF is limited during low flow periods. However, young fish are readily discharged through floodgates during periods of high flow. Their finding that *Morone* hybrids moved 320 km downstream through two reservoirs, Lakes Walter F. George and Seminole, and traversed the length of the Apalachicola River to the Gulf of Mexico demonstrated that downstream movements of YOY can be extensive.

3.5 Feeding, Prey, and Predators

The prey of striped bass has been well studied. Striped bass are adaptable to a variety of habitat conditions from the headwaters to the sea, and their diets reflect this. Juvenile striped bass feed on larval clupeids in freshwater reservoirs (Van Den Avyle et al. 1983, Wilde and Paulson 1989). Mysid shrimp (Cooper et al. 1998), insect larvae (Markle and Grant 1970), polychaetes, and amphipods are prey items in estuaries (Boyton et al. 1981). Sand shrimp are the principle food item of juveniles in the Bay of Fundy, Canada (Rulifson and McKenna 1987). Piscivory increases in importance as striped bass grow (Markle and Grant 1970, Manooch 1973, Rulifson and McKenna 1987, Cooper et al. 1998).

Raney et al. (1952) described striped bass as generalists, feeding on a variety of fishes and crustaceans. Dew (1988) described striped bass feeding as compensatory, in that predation changes in response to prey availability. Principle food items of adult striped bass are clupeids (shad, menhaden, herring, anchovies) (Lee and Hassler 1966, Manooch 1973, Crateau et al. 1981, Persons and Buckley 1982, Rulifson and McKenna 1987, Dew 1988, Matthews et al. 1988, Hartman and Brandt 1995, Slipke et al. 2000). Alternate food items include Atlantic croaker (Dovel 1968); insects in the spring and early summer (Matthews et al. 1988); rainbow trout (Wilde and Paulson 1989, Hess and Jennings 2000); amphipods (Dunning et al. 1997); Atlantic salmon smolts (Blackwell and Juanes 1998); crayfish (Hess and Jennings 2000); and blue crabs (Hollis 1952).

McGovern and Olney (1988) considered clupeids, cyprinids, ictalurids, percids, centrarchids, and moronids as predatory to eggs and larvae of striped bass. A predator of striped bass at the larval stage is the free-living copepod (*Cyclops bicuspidatus thomasi*), which attaches and inflicts enough damage to cause death (Smith and Kernehan 1981). McGovern and Olney (1988) list another copepod (*Acanthocyclops vernalis*) and the hydra (*Craspedacusta sowerbyi*) as predators of larval striped bass.

Striped bass are subject to predation from bluefish (*Pomatomus saltatrix)* on the Atlantic coast; vulnerability decreases as striped bass length increases (Scharf et al. 1998). Although there is no documentation of bluefish predation on striped bass in the Gulf, dolphins (*Terciops truncates*) have been shown to prey on stocked striped bass (FWC unpublished data). Juveniles may be subject to predation by gar, bowfin, largemouth bass, sunfish, crappie, and catfish (Nicholson 1986). A commercial hoop net fisherman working the Pascagoula River reported finding striped bass in the stomachs of flathead catfish, *Pylodictus olivaris* (J. Mareska personal communication), although this predation may have occurred within the confines of a hoop net. However, flathead catfish predation on moronids has also been reported in the Apalachicola River (E. Long personal communication). Predators of striped bass in Gulf of Mexico rivers need to be further investigated.

3.6 Population Structure and Dynamics

Sex composition in striped bass populations may be influenced by movement patterns, fishing pressure, and year-class dominance (Setzler et al. 1980). In Chesapeake Bay migratory populations, the vast majority of fish taken in coastal waters were females. Although males tended to dominate on the spawning grounds, when segregated by year class, females were more numerous on the spawning grounds among the older year classes. Fisheries often tend to take more males than females, which may explain why females are more numerous among the older fish. For this reason, sex ratios may fluctuate due to variable year class dominance in striped bass populations. Within Chesapeake Bay, sex ratios appeared to favor males by a slight margin.

Among striped bass populations in Atlantic rivers, ages typically range from 2 to 15 in recreational and commercial catches with ages 3-5 usually dominant (Setzler et al. 1980). Seasonal variation in age composition is minimal; however, annual differences can be significant. Unusually strong year classes tend to dominate striped bass populations cyclically over periods of several years (Grant 1974). Grant (1974) reported evidence in Maryland of a six-year cycle with a dominant class every six years followed by three years of high abundance and three years of relatively low abundance. In the Apalachicola River in 1980 and 1981, Crateau et al. (1981) found striped bass ages 3-12 represented in the fishery, which was primarily supported by 1976 and 1977 year-classes. However, the 1980 year-class became dominant in 1981 samples and was estimated to be the best year-class since 1976. According to Rago and Goodyear (1987), fishing mortality tended to decrease the average age of striped bass populations, which reduced the probability of strong year classes. Older fish tend to produce more viable and larger numbers of eggs (see Section 3.2.4.3). Secor (2000) indicated that spawning behavior might differ among striped bass of different ages, and older fish tend to spawn earlier in the season. These differences may favor the likelihood of eggs and larvae encountering favorable conditions for survival and development in any given year. These ideas were supported by evidence that year-class strength of the Chesapeake Bay stock was positively related to age diversity of mature females (Secor 2000).

Egg production estimates from Atlantic Coast rivers were found to range from 0.001 x 10^9 to 26.9 x 10^9, and in the Potomac River mortality estimates ranged from 63.6% to 99.2% for eggs, 81.7%-96.1% for yolk-sac larvae, and 81.7%-93.9% for fin fold larvae (Setzler et al. 1980). Average egg mortality rates were 68% to 94% per day (Bulak et al. 1993) for several Atlantic Coast rivers. A Lagrangian time-series study (Olney et al. 1991) of striped bass egg abundance in the Pamunkey River, Virginia, provided mortality estimates of 12%-91% per day (mean = 68% per day). Life table calculations by Secor and Houde (1995) indicated only 18% mortality for eggs, but more than 99% for yolk-sac larvae in the Patuxent River, Maryland, during 1991. Utilizing similar data from the Potomac River, Maryland, during 1987-1989, Secor and Houde (1995) calculated yolk-sac larval mortality values of 73%, 96%, and 80% during those years, respectively. They concluded that the magnitude and variability of yolk-sac larval mortality estimates indicated environmental factors have major impacts on recruitment. Uphoff (1989) estimated larval mortality in the Choptank River, Maryland, as 6%-10% per day, and juvenile mortality at 2%-4% per day. Estimated yolk-sac larval mortality for the Potomac River was inversely related to juvenile abundance values for recruitment indices reported by the Maryland Department of Natural Resources in 1992 (Secor and Houde 1995).

Year-class strength in striped bass populations appears to be largely controlled by density-independent environmental factors (Setzler et al. 1980), particularly those affecting the earliest life stages (Karas 1993, Stevens 1977). Uphoff (1989) found year-class success in the Choptank River during 1980-1985 was largely determined by the end of the postlarval stage. Goodyear (1985) indicated that environmentally-induced variation in stock size of striped bass may mask effects of stock size on recruitment. Steadily increasing temperatures with minimal fluctuation during the spawning season appear to favor strong year classes (Karas 1993), and Setzler et al. (1980) cited evidence that in some cases successful year classes resulted from spawning that occurred later in the season. Setzler et al. (1980) indicated that subnormal winter temperatures were associated with strong year classes in Chesapeake Bay, and this might be related to higher production of zooplankton important as food for striped bass larvae. Bulak et al. (1997) found that highest recruitment in the Santee-Cooper system, South Carolina, occurred during periods when relatively fewer eggs were spawned and transported to high quality nursery habitat with both temperature and flow rates being important factors. Logan (1984) and Stevens et al. (1985) indicated that sublethal effects of pollutants might be important in determining recruitment as well. Stevens et al. (1985) also proposed that larval food availability and loss of eggs and larvae through entrainment and diversions were probably important factors in declines of striped bass in the Sacramento-San Joaquin estuary, California, in the 1970s. Coutant (1985a) proposed that striped bass populations were also limited by availability of suitable thermal refuge habitat for adults, which he defined as areas having temperatures between about 18º and 25ºC and DO above about 2-3 mg/l. Uphoff (1989) working in the Choptank River, Maryland, during 1980-1985 found the best year class occurred during a year of a warm peak spawning period followed by a relatively dry post-larval period. Poorer year classes occurred in years during which a cool peak spawning period was followed by drought or moderate rainfall or when moderate temperatures occurred during the peak spawning period followed by periods of moderate to high rainfall. He postulated that poor water quality conditions and poorer food supply were associated with higher rainfall, negatively affecting postlarval survival, and lower temperatures during the spawning period negatively affected egg and prolarval survival.

Strongest relationships of recruitment to environmental variables appear to involve water flow. Setzler et al. (1980) stated that strong year classes were associated with higher and relatively stable river discharges, though if flows are too high this can also be detrimental, as eggs and larvae may be transported into habitats unfavorable to survival (Karas 1993, Manooch and Rulifson 1989). Stevens (1977) found that highest survival and subsequent recruitment to the fishery in California occurred at moderately high flows up to a point, but flows higher than that level provided little increase in recruitment. Zincone and Rulifson (1991) reported years of good recruitment in the Roanoke River were associated with a moderate discharge plateau in March and early April followed by a drop to a lower plateau; poorer recruitment occurred in years with higher flows throughout March-June, though poorest recruitment occurred when flows were very low (Rulifson and Manooch 1990).

Total annual mortality (A) of 25%-50% was estimated for striped bass populations in Atlantic Coast rivers, and instantaneous total mortality rates (Z) for Atlantic Coast and California populations ranged from 0.29 to 1.14 (Setzler et al. 1980). For the latter estimates, instantaneous fishing mortality (F) ranged from 0.036 to 0.63. Crateau et al. (1981) found that A = 31% in the Apalachicola River with exploitation (E) of 22% in 1981. Instantaneous total mortality for the

Apalachicola River population was 0.37 with F = 0.22; thus fishing mortality made up the majority of total mortality at that time.

With respect to population genetic structure, analyses by Diaz et al. (2000) indicated that only a small fraction of the adult population in the Santee-Cooper rivers population in South Carolina was actually involved in producing the next generation of fish. They also found that high adult mortality tended to change the genetic structure of the population by minimizing the number of age classes involved in reproduction. Because of this, extremely poor recruitment in some years may accelerate the loss of alleles in the population.

Numerous mathematical models have been developed to predict effects of power plant operations on striped bass populations in Atlantic Coast rivers (Setzler et al. 1980). A result of one of those models was that any reduction in fishing mortality in one or several age classes between 3 and 20 would permit a higher tolerance for additional mortality in YOY stages. One model developed for the San Francisco Bay population determined that recruitment was not closely related to parent stock size, and stock sizes below equilibrium may favor production of dominant year classes (Karas 1993).

Other models have been used to assess effects of various management alternatives on striped bass populations. Modeling by Goodyear (1985) showed that a decrease in fishing mortality in the Chesapeake Bay striped bass population could be used to reverse a population decline even if an environmental factor (e.g., contaminant toxicity) was the primary cause of the decline. While studying striped bass in California, Chadwick (1969) concluded that angling regulations could be varied within wide limits without endangering a stock and that declines in striped bass populations in the 1940s and 1950s were more likely due to environmental changes than to excessive fishing mortality. Goodyear (1985) argued that despite the strongly density-independent nature of recruitment in striped bass, management measures that increase fecundity would likely increase the numbers of survivors that are ultimately recruited under a given set of conditions. Analyses by Stevens et al. (1985) corroborated this in their finding that egg production in the Sacramento-San Joaquin Rivers, California, was probably inadequate to maintain strong recruitment during the 1970s. Bulak et al. (1993) cited the importance of maintaining a "critical density of adult stock" in sustaining striped bass populations. In modeling the Hudson River population, Dunning and Ross (1986) found fishing mortality was more detrimental to population growth when the mortality was shifted to older age classes and could neutralize any positive contributions of stocking to the population.

Because recruitment of striped bass is strongly density-independent, it is virtually impossible to determine a proper level of sustained harvest (Cooper and Polgar 1981). Most classical population dynamics models for managing harvest for maximum sustainable yield were developed for populations with density-dependent recruitment. Cooper and Polgar (1981) proposed striped bass harvest be managed through a special application of optimum sustainable yield by trying to optimize the harvest of the dominant year classes. They proposed doing this through controlling mortality rates in these year classes during their first few years by selectively limiting the harvest of younger fish, thus conserving the reproductive potential of the population. Regulations should be set based on the results of juvenile indices, from which dominant year classes are predicted. In this optimization approach, regulations should be flexible and not necessarily uniform from year to year or across different jurisdictions. Their approach emphasized that managing habitat and environmental conditions conducive to strong year class formation should be pursued.

In Atlantic Coast striped bass populations, both recruitment and growth overfishing were responsible for population declines that occurred during the 1970s primarily by reducing the size of the spawning stock (Rago et al. 1990, 1992). Habitat factors probably exacerbated the effects of the reduced spawning populations (Richards and Rago 1999). Harvest restrictions were intensified during the mid-1980s and focused on preventing directed fishing mortality on 1982 year class females and all subsequent year classes of Chesapeake Bay stocks until 95% of the females of these year classes were able to spawn at least once. This involved total closure of some fisheries, minimum size limits, seasonal closures, and control of bycatch (Rago et al. 1992). Minimum size limits were progressively increased to 38 in (97 cm) through 1990 (Richards and Rago 1999). A transitional target F was set as 0.25 with adaptive management used to re-evaluate regulations and F if monitoring indicated the target was exceeded (Rago et al. 1992). By the late 1980s, populations and recruitment improved significantly. Based on the results of a juvenile abundance index, closed fisheries were reopened in 1990, and regulations began relaxing in subsequent years though they remained more restrictive than before the mid-1980s (Richards and Rago 1999). New FMP objectives were based primarily on maintaining spawning stocks and secondarily on providing fishery yield. Based on a number of population indices, the Chesapeake Bay stock was declared fully recovered in 1995 with a new maintenance target F being set at 0.40. Based on recruit per spawning stock biomass ratios, protection of the spawning population was determined to have played an important role in the recovery, though favorable environmental conditions were very important in some years. Stocking of fingerlings to supplement the spawning populations may have accelerated recovery but the benefits of this were far outweighed by those of controlling harvest (Richards and Rago 1999).

In summary, striped bass are long-lived, produce an extremely large number of eggs, and (ideally) individual fish reproduce over multiple years (Rago and Goodyear 1987). Recruitment is highly variable on an annual basis, and one or some large year classes usually dominate populations at any given time. Recruitment is also strongly density-independent, with environmental conditions usually dictating year-class success. Longevity of the species normally provides an opportunity for dominant year classes to spawn over a number of years, thus dampening the effects of poor year classes resulting from unfavorable environmental conditions for egg and larval survival (Rago and Goodyear 1987). Striped bass populations are also quite sensitive to fishing mortality, which tends to decrease the average age of the population and the likelihood of forming strong year classes (Rago and Goodyear 1987). Limited summer thermal refuge habitat may be responsible for high adult striped bass mortality in Gulf rivers.

3.7 Stock Enhancement

Stock enhancement of striped bass populations in the United States has a long history (Whitehurst and Stevens 1990). As early as 1879 and 1881, wild-caught yearling striped bass were transported from New Jersey to California and released into San Francisco Bay resulting in the establishment of a striped bass population and fishery on the Pacific Coast (Whitehurst and Stevens 1990). Striped bass culture began at Weldon, North Carolina, on the Roanoke River in

1884 at a hatchery established by the U.S. Fish Commission, and until the 1960s fry produced at this hatchery were used almost exclusively to stock the Roanoke and other North Carolina rivers. In 1937 fry produced at Weldon were first successfully reared to fingerling size at Edenton National Fish Hatchery in North Carolina.

The introduction of striped bass into inland reservoirs began in the 1930s. By the 1950s landlocked reproducing populations of striped bass supporting significant fisheries had developed in Santee-Cooper river system, South Carolina, and Kerr Reservoir, North Carolina-Virginia (Whitehurst and Stevens 1990). Establishment of these landlocked populations expanded the interest in stocking striped bass into other reservoirs, and by the 1960s most of the southeastern states had initiated programs for stocking striped bass into inland waters. Stocking programs were developed to provide additional recreational fishing opportunities and to control expanding reservoir populations of gizzard shad (*Dorosoma cepedianum*).

Striped bass stocking programs were further expanded following development of techniques for hormone-induced spawning (first successfully accomplished at Moncks Corner, South Carolina, in the mid-1960s) and refinement of pond culture techniques at Edenton NFH for producing fingerlings (Whitehurst and Stevens 1990). Striped bass hybrids were first produced in South Carolina in 1965 (Kerby and Harrell 1990). These developments significantly increased both the availability of striped bass fry and the effectiveness of stocking programs. Early efforts, which had relied primarily on stocking fry directly, were only marginally successful. Utilization of fingerlings greatly increased the survival of stocked fish. By 1981 it was estimated that there were either striped bass or hybrid stocking programs in 279 lakes in the United States. McCabe (1989) reported 34 states engaged in stocking striped bass and/or hybrids. In addition to the stocking of reservoirs on rivers within the striped bass' native range, the species was also introduced into reservoirs of the Arkansas, Colorado (western), Lower Mississippi, Missouri, Ohio, Red, and Tennessee rivers, as well as numerous Texas rivers, including the Rio Grande (Lee et al. 1980 et seq.). Stocking rates in 61 reservoirs ranged from one to 136 fingerlings (sizes unspecified) per acre, averaging 14 per acre (White 1988).

Although stock enhancement of anadromous striped bass populations on the Atlantic Coast has occurred since at least the 1880s following establishment of the hatchery at Weldon, North Carolina, coastal stocking programs there expanded greatly during the 1980s following declines in several populations in Atlantic river systems (Whitehurst and Stevens 1990). Stock enhancement of coastal populations was practiced on the Pacific Coast as well. Success in stocking coastal rivers has been variable. In a stock enhancement study in the Ogeechee River, Georgia, Hornsby (1981) found that stocked Phase II fingerlings comprised at least 20% of harvestable size striped bass in the river. Stocking of the fish, however, did not increase the total harvestable population size as reflected in angler catch-rates, which declined during the four-year study despite the stocking program. In the Savannah River, Georgia, adult striped bass abundance declined about 95% in the 1980s, apparently due to habitat changes (Van Den Avyle et al. 1995), and a stocking program utilizing wild Ogeechee River broodstock began in 1990. Abundance indices increased following the stocking program, with released fish comprising the majority of the population in the river, but success in restoring a self-sustaining population has not yet occurred (M. Thomas personal communication). Chesapeake Bay populations of striped bass declined precipitously during the 1970s and early 1980s (Richards and Rago 1999) prompting an intensive restoration program. Although stocking assisted in population recovery on a localized basis, such as in the Patuxent River (Rulifson and Laney 1999), the reduced fishing mortality resulting from recreational and commercial regulation changes was far more important.

Artificial spawning techniques have been utilized by all Gulf coastal states to produce striped bass fry for either stocking directly or growing out to Phase I or II fingerlings for stock enhancement. Stock enhancement activities in Gulf coastal rivers began during the late 1960s when state fisheries agencies recognized that the native striped bass populations experienced severe declines or were extirpated. Prior to that, striped bass had been stocked into reservoirs in Gulf Coast drainage basins beginning in Arkansas in the mid to late-1950s (Gray 1958, Bailey 1974). Early stock enhancement efforts in Gulf reservoirs and coastal rivers utilized Atlantic race fry or fingerlings because of their ready availability, and most Gulf rivers have been stocked at times with Atlantic origin fish. In the early 1980s, the importance of protecting the genetic integrity of the Gulf race was recommended (Wooley 1982). Since then efforts have been made to shift Gulf coastal stock enhancement programs in rivers east of the Mississippi to the use of Gulf race fish, particularly in the ACF and MAT systems. The USFWS artificially spawned Gulf race striped bass for the first time in 1980 (Hollowell 1980). Although the ACF system has been stocked predominantly with Gulf race fish since 1980, stocking of Atlantic race fish or mixtures of Gulf and Atlantic races continues in other rivers through the present time. See Section 3.8 for more detailed information on striped bass stocking in Gulf rivers.

Stock enhancement programs typically capture wild broodstock, spawn them in hatcheries, and return the spent fish to the wild (Yeager et al. 1990). Although there has been some experimentation with using captive domestic broodstock (notably Mammoth Spring NFH in Arkansas and Warm Springs NFH in Georgia) such efforts have so far not proven to be consistently successful. Eggs sampled from prospective female broodfish are examined and staged immediately following capture to determine eligibility. Those considered eligible are injected with hormone(s), which may be of various types and combinations, to accelerate egg maturation and induce ovulation (Rees and Harrell 1990). Females with marginal eggs, referred to as 15 hr eggs (hormone latency period plus 15 hrs prior to ovulating) by Bayless (1972) and Rees and Harrell (1990), are usually released. Striped bass culturists prefer female broodfish with stage-3 or -4 eggs (hormone latency period plus 10 to 12 hrs prior to ovulation), although females with stage-1 or -2 eggs (13 to 15 hr eggs) can be induced to ovulate.

Following injection the eggs are sampled again, at least once, to predict ovulation time (Rees and Harrell 1990). When a female is ready to ovulate, hatchery workers dispense the eggs into a container by rubbing the abdomen (stripping) while simultaneously stripping the milt from multiple males into the same container. The fertilized eggs are placed into hatching jars with water circulating through them to keep the eggs in suspension. At hatch, the fry are transferred to containers such as aquaria, troughs, or circular tanks.

Another spawning technique, called tank spawning, typically involves placing a hormone-injected female into a circular holding tank with one or two males, and the fish are allowed to spawn naturally (Smith and Whitehurst 1990). Advantages of this method include: being less labor intensive, requiring less expertise in predicting ovulation time, more complete spawn, better fertilization rates, better post-spawning condition of broodfish, and better conservation of broodfish (L. Nicholson personal communication). Disadvantages include: larger hatchery space requirements, higher water volume needed, and reduced control over developing eggs and larvae. Despite the advantages of tank spawning, broodfish from Gulf rivers are usually strip spawned.

Fry are usually stocked into culture ponds as soon as they are ready to begin feeding (about five days), but they may be held a few days in containers and fed a diet of brine shrimp nauplii or zooplankton (Rees and Harrell 1990). Fry can be shipped in plastic bags to other hatcheries for grow-out. Although fry are usually grown out in hatcheries to fingerling size before stocking, Secor and Houde (1998) demonstrated that stocking larvae directly into rivers significantly contributed to recruitment of striped bass in years of poor egg production or unfavorable nursery conditions. Secor and Houde (1998) cited evidence that larval stocking was more advantageous than stocking juveniles because juveniles reared in hatcheries may develop behaviors that are not favorable to survival in the natural environment.

In some cases, fry may be grown to fingerling size in tank systems and fed prepared foods (intensive culture). This technique is frequently plagued by problems of cannibalism, non-inflation of the swim bladder, and diseases (Nicholson et al. 1990). However, it offers a number of advantages, such as less space requirements than traditional hatcheries, greater control over culture conditions, and therefore, greater opportunities for experimentation. The feasibility of growing striped bass from hatch to maturity on prepared foods in intensive culture systems and then spawning them in captivity has also been demonstrated (Woods et al. 1992).

Most typically, fry are stocked into culture ponds in which zooplankton populations are carefully managed. Pond management techniques involve fertilization, "seeding" of culture ponds with zooplankton, and monitoring zooplankton populations and water quality in the ponds (Geiger and Turner 1990). If Phase I fingerlings are to be grown beyond 38.5 mm in length (typically longer than 21-26 days) (Brewer and Rees 1990) or to Phase II or III sizes (Smith et al. 1990), supplemental feeding with prepared foods is required. Additional information on culture and propagation of striped bass can be found in Section 6.4.

In most cases fingerlings being raised for stock enhancement are harvested from ponds and stocked at Phase I size (Smith et al. 1990). However, there are situations where stocking of Phase II fish is preferred such as in coastal areas where predators may be more abundant (Smith et al. 1990). Considerations include whether to stock more fish at a smaller size, which may have a lower survival rate, or to stock fewer fish at a larger size, which may have a higher survival rate. At least one study (Rogillio and Rabalais 2001) indicated that stocking Phase II size might be more efficient in terms of staff time and number of broodstock required. However, producing a given number of Phase II fish is more expensive than producing an equal number of Phase I fish. Dorazio et al. (1991) attempted to compare cost effectiveness of Phase I versus Phase II stocking but found the range of survival from Phase I to Phase II in hatcheries was too broad to support any generalizations. Wallin et al. (1992) found the stocking of Phase II fish to be more cost effective than the stocking of advanced Phase I fish, provided the cost of producing

Phase II fish does not exceed 15 times the cost of producing advanced Phase I fish. There are cases, however, where the use of Phase I fish may be the more cost-effective option, as shown by Slack and Yeager (1993).

Secor and Houde (1998) compared the cost effectiveness of stocking larvae, Phase I fingerlings, and Phase II fingerlings through a modeling approach. They found that stocking Phase I fish would be the most cost-effective strategy if hatchery larval mortality rates were low and wild larval survival was poor or intermediate. Ideally a comprehensive assessment of fisheries restoration programs should involve not only the relative costs of regulation, habitat restoration, and other actions versus the economic values of the fisheries being restored or enhanced, but also the ecological values accrued from any restoration of habitat, biodiversity, or community structure. According to Rulifson and Laney (1999), no such comprehensive assessment has been conducted for any anadromous striped bass restoration program. Holder (1975) recommended stocking at least 20 Phase II fingerlings per acre in the Ogeechee River, Georgia, in order to supplement the native population and monitor the stocked fish through successive age groups.

Other considerations in stock enhancement programs involve handling stress and the characteristics of receiving waters. Wallin and Van Den Avyle (1995) found that, in general, minimally handled striped bass fingerlings tended to have higher short-term (48 hrs) post stocking survival rates, and striped bass shorter than 50 mm TL had higher short-term survival when stocked into brackish water than in freshwater regardless of the amount of handling. For fish longer than 50 mm TL, stocking into brackish water did not appreciably increase short-term survival for minimally handled fish but significantly increased short-term survival for routinely handled or tagged fish. Dorazio et al. (1991) found mortality rates for wild and hatchery-reared Phase I fingerlings were similar in the Patuxent River, Maryland.

Differences in behavior and other biological characteristics of stocked versus naturally spawned striped bass fingerlings are not well documented. However, Wells et al. (1991) found that late Phase I fingerlings stocked into the Hudson River, New York, during August-October dispersed slowly from the release sites, averaging only 4 km after 100 days.

Finally, the potential effects of stocking programs on the genetics of wild populations should be addressed. Major concerns have developed in recent years regarding loss of genetic diversity and reduced fitness in wild salmonid populations as a result of stocking programs (Rulifson and Laney 1999). Tringali and Bert (1998) described similar concerns as applied to non-salmonid species. Effects such as reduced ability to adapt to environmental conditions have been studied extensively in salmonids but not in striped bass. Problems most often are due to the use of limited numbers of adults for broodstock to produce hundreds of thousands of fish used to supplement wild populations. If broodstock are repeatedly obtained from the same supplemented populations, inbreeding effects such as reduced growth rate, lower survival, poor food conversion, and higher proportions of deformed larvae can result. Reduced population fitness may also occur through a phenomenon known as out breeding depression. This can occur when individuals from one population are "cross-stocked" into other genetically different populations. Interbreeding among individuals from different populations may alter the native gene pools by disrupting co-adapted gene complexes. In addition, fish that are cross-stocked to a different river system may not be as ecologically fit to reproduce and survive critical life stages as are fish native to that river. However, if stocked as hatchery-reared fish, the non-native fish may be able to survive to maturity and interbreed with native individuals, thus reducing the overall genetic fitness of the population for the river's environment (Tringali and Bert 1998).

3.8 Stock Status and Stocking

No substantial data exist on the status and sizes of native striped bass populations in Gulf rivers prior to the 1960s. Jordan and Evermann (1896) stated striped bass were "rather rare in the Gulf of Mexico." Throughout their range, striped bass have historically been most common on the Atlantic Coast between Cape Cod and coastal North Carolina (Jordan and Evermann 1923). According to Pearson (1938) striped bass were "found in small numbers" in Gulf of Mexico streams between St. Marks, Florida, and Lake Pontchartrain, Louisiana. However, he acknowledged reliable reports of the "occurrence of considerable numbers of striped bass" in coastal streams of Louisiana, Mississippi, and Florida. In an early 1950s study of striped bass in Florida Gulf rivers, McLane (1958) interviewed commercial fishermen, some of whom had been fishing for up to 60 years. They indicated that population levels of striped bass in Florida Gulf rivers had always been extremely low during that time period. Inferences to relative abundance of striped bass in the Gulf may be made from commercial fishery landings. Fiedler et al. (1934) reported over 226,798 kg of striped bass landed in North Carolina but only 224 kg in the Gulf in 1932, and that amount may have been erroneous, as perhaps were the landings data reported from Texas. During 1936-1938, Fiedler (1938, 1940, 1941) reported striped bass commercial harvest was 237,095-348,272 kg from North Carolina but none from the Gulf.

Despite the lack of quantitative data, anecdotal evidence suggests that severe depletions of Gulf striped bass populations occurred during the 1950s (Barkuloo 1979). Reasons for these declines have not been determined conclusively; however, contaminants (primarily pesticides) are thought to have been a major factor. Although dam construction on rivers may have destroyed or prevented access to key habitat areas, most Gulf rivers did not have dams on them by the time their striped bass populations were either extinct or seriously depleted.

During the course of developing this FMP revision, anecdotal evidence suggested an inadvertent release of Atlantic race striped bass fingerlings may have occurred into a Gulf river during transport by train from the Navasink River in New Jersey to the San Francisco Bay in the late 1800s; however, subsequent investigation did not support that claim. Deliberate stocking of striped bass into some reservoirs on Gulf rivers began as early as the mid-1950s, and these efforts accelerated in succeeding years (Bailey 1974). By the late 1960s Alabama, Florida, Louisiana, and Mississippi had embarked on coastal striped bass stock enhancement programs (Minton and Lukens 1990), as did Texas in 1975 (Matlock et al. 1984).

Stocking data provided in this section are as close approximations as possible based on information obtainable with reasonable effort. These figures are conservative, since information on some rivers may be missing. Stocking numbers were rounded to the nearest 100 fish. The data reported below cover stocking activities through the year 2002.

3.8.1 Texas

Stocking of striped bass into Texas reservoirs began in 1960 when 800 fingerlings from California had been stocked into Lake Diversion on the Red River (McCabe 1981), though intense efforts did not begin until 1967 with stocking of Lakes Bardwell and Navarro Mills on the Trinity River. Fry had been stocked into Toledo Bend Reservoir on the Sabine River by the state of Louisiana in 1965 (Bailey 1974, Hein and Shepard 1982), and fingerlings had been stocked into the reservoir by Louisiana in 1967 (Lantz 1970, Bailey 1974). One goal of the Texas stocking program was to establish one or more self-sustaining populations in inland waters (Bonn 1972). In 1975, Texas also initiated a three-year stocking program in three coastal bays (San Antonio and Corpus Christi bays and Sabine Lake) in an attempt to establish a coastal striped bass fishery (Matlock et al. 1984). Stocking of fry and fingerlings into Galveston and Matagorda bays occurred during 1983-1988 (Dailey 1989), and the stocking of striped bass in waters of the upper Texas coast continued through 1994, at which time the effort was discontinued (N. Boyd personal communication). Between 1965 and 1986 approximately 33,305,400-fingerling Atlantic race striped bass had been stocked into Texas waters (including coastal) (Nicholson et al. 1986), and reservoir stocking with Atlantic race fish continues at present. The numbers of fingerlings stocked into Texas waters are as follows:

Rio Grande	3,847,200
Nueces	442,200
Colorado	4,148,000
Brazos	2,845,800
Trinity	5,869,300
Sabine-Neches	13,004,700
Other coastal rivers	34,400

During 1965-1986, an additional 2,173,300 fingerlings were stocked into reservoirs located on Red River tributaries, which flow into the Mississippi River system (see Section 3.8.2.1). Primary sources of fry for stocking in Texas were the states of Maryland, South Carolina, and Virginia, although some fry were obtained from out-of-state national fish hatcheries or produced from fish stocked into Toledo Bend Reservoir (McCabe 1981), which had been stocked predominantly were striped bass of a South Carolina strain. However, a relatively small number of Gulf race striped bass have been stocked into Texas waters (Nicholson et al. 1986, USFWS unpublished data):

Toledo Bend Reservoir (Sabine River)

1980	500 Phase I fingerlings (unknown haplotype)
1996	78,800 Phase I fingerlings (mtDNA haplotype C2)
1997	7,900 Phase I fingerlings (mtDNA haplotype CD1)
1998	6,900 Phase I fingerlings (mtDNA haplotype D1)

Twin Buttes Lake (Colorado River)

1995	25,600 Phase I fingerlings (mtDNA haplotypes C1, C2)

Waco Lake (Brazos River)

1995	58,200 Phase I fingerlings (mtDNA haplotypes C1, C2)
1996	22,500 Phase I fingerlings (mtDNA haplotypes C2)

Gulf race striped bass stocked into Twin Buttes and Waco Lakes were part of an unsuccessful effort to establish an alternative Gulf race broodstock source. Although not deliberate stocking efforts, both Atlantic and Gulf race striped bass fingerlings have been reared at Uvalde and Inks Dam NFHs in the Nueces and Colorado River systems, respectively, and some may have escaped.

As of 2002 striped bass had been stocked into at least 68 reservoirs on 11 Texas river systems (Nicholson et al. 1986, TPWD 2002) in what McCabe (1989) described as one of the largest freshwater striped bass stocking programs in the nation, although stocking is not currently on-going in all of these reservoirs. Successful and popular fisheries were established in many of these lakes, including Toledo Bend Reservoir, shared with Louisiana. Reproduction by striped bass in Texas has been documented in the Brazos River above Lakes Granbury and Whitney (Guest 1985) and in the Trinity River below Livingston Dam (Kurzawski and Maddux 1991), but the species is not known to have established self-sustaining populations anywhere in the state's waters. Recruitment of naturally spawned striped bass into the adult population has not been determined.

The initial bay-stocking program in Texas failed to establish a fishery, although the capture of striped bass in unstocked bays indicated that striped bass stocked into reservoirs migrated downstream to coastal areas (Benefield et al. 1977, Matlock et al. 1984). Dailey (1988) failed to collect YOY striped bass by seine in Trinity Bay while assessing three consecutive years of stocking fry into the bay (1983-1985). In assessing coastal striped bass populations during 1983-1992, Butler and Stelly (1993) found sport angler harvest was 17 times greater than reported during 1975-1983. However, there were no effort data available; thus a statistically valid comparison was not possible. Catch per unit effort data in bay gill net sampling during 1983-1993 indicated striped bass were approximately 1,000 times less abundant than red drum (*Sciaenops ocellatus*) or spotted seatrout (*Cynoscion nebulosus*). Highest striped bass abundance was found in the Galveston Bay system. Fishery-independent sampling using trawls, gill nets, and bag seines in Texas coastal waters resulted in capture of only 64 striped bass between 1983 and 2003 (TPWD unpublished data). No significant directed striped bass fisheries have been developed in the free-flowing portions of Texas rivers or coastal waters, though striped bass are taken incidentally to fishing for other species.

3.8.2 Louisiana

Gowanlach (1933) indicated the presence of striped bass "in considerable numbers in Louisiana, especially in the region of the Tchefuncta River." He reported the presence of schools of over 100 fish during April and May, apparently following prey (reported as "sardines," but probably Alabama shad) up the river. Raney et al. (1952) reported a 11.3 kg striper taken from the Tickfaw River in 1951 as one of the largest reported from Louisiana in years. The last documented occurrences of native striped bass in Louisiana were from the Bogue Chitto-Pearl Rivers and Bogue Falaya-Tchefuncte Rivers in 1956 (Chipman 1956 as reported by Nicholson et al. 1986). Davis et al. (1970) stated the area of southeastern Louisiana east of the Mississippi River historically supported a striped bass fishery, but those authors captured no striped bass in their collection efforts in drainages of Lakes Maurepas, Pontchartrain, and Borgne during 1967-1969. Based on information from the *Louisiana Conservation Review* and *Louisiana Conservationist* (no dates provided) striped bass in Louisiana were most abundant in the Tchefuncte River with fishable populations also in the Bogue Chitto, Bogue Falaya, Tickfaw, Natalbany, Amite, and Pearl rivers. No reason for the demise of striped bass populations in Louisiana was determined; however, Davis et al. (1970) speculated environmental perturbations (e.g., extensive channeling) might have extirpated populations.

The first known stocking of striped bass in Louisiana occurred when fry were introduced into Toledo Bend Reservoir and D'Arbonne Reservoir in 1965 (Bailey 1974, Hein and Shepard 1982, see Section 3.8.2.1). However, major introductions of striped bass into Louisiana did not begin until 1967 when Atlantic race fingerling striped bass were stocked into these two lakes (Walker 1979). In 1972, the Louisiana striped bass program expanded to include stocking of several coastal rivers and estuarine areas in an attempt to establish anadromous or coastal populations (Hein and Shepard 1982). Other reservoirs were stocked with striped bass in succeeding years. During 1965-1986, 2,202,100 striped bass fingerlings were stocked into Louisiana waters (Nicholson et al. 1986) as follows, with origin of stocks indicated:

Calcasieu	1,192,000	(South Carolina, Virginia stocks)
Mermentau	711,000	(South Carolina, Maryland stocks)
Bayou Teche	213,000	(South Carolina stock)
Terrebonne Bay	55,000	(South Carolina stock)
Barataria Bay	5,500	(South Carolina stock)
Intracoastal Waterway	25,600	(South Carolina stock)

Since 1987, stocking of reservoirs and coastal portions of the rivers west of the Mississippi has continued, including stocking 150,000 fingerlings into the Vermilion River (LDWF unpublished data). Except for a relatively small number of Gulf race striped bass stocked into two lakes in recent years, all striped bass stocked into Louisiana rivers west of the Mississippi have been of Atlantic origin. Exceptions involved unsuccessful efforts to establish Gulf race brood stock sources in the state. These efforts involved stocking as follows (USFWS unpublished data):

Indian Creek Lake (Bayou Teche)

1995	35,000 Phase I fingerlings (mtDNA haplotype C2)
1996	39,900 Phase I fingerlings (mtDNA haplotype C2)
1997	20,800 Phase I fingerlings (mtDNA haplotype C2)

False River (lower Mississippi River)

2000	30,200 Phase I fingerlings (haplotype unknown)

One goal of the Louisiana inland striped bass stocking program was to establish landlocked reproducing populations. A directed put-grow-and-take striped bass fishery developed in Toledo Bend Reservoir (see Section 3.8.1) though natural reproduction in

Louisiana reservoirs or rivers other than the Mississippi has not been documented. No significant riverine or coastal fisheries have been successfully established in Louisiana, although some striped bass are caught incidentally in these rivers and coastal waters.

3.8.2.1 Mississippi-Atchafalaya River

The earliest known striped bass stocking in the Mississippi River system may have been in Arkansas where about 1,100 adult through fingerling size striped bass were stocked in Lake Ouachita between 1956 and 1960, and 33 adults were stocked in Lake Greeson in 1957 (Gray 1958, Bailey 1974). Within the state of Louisiana approximately 3,702,100 Atlantic race striped bass fingerlings (South Carolina and Maryland stocks) were stocked into Mississippi River tributaries, reservoirs, oxbow lakes, or adjacent coastal marshes during 1965-1987 (Nicholson et al. 1986). Very few (approximately 1,300) striped bass have been stocked within Louisiana into the Mississippi River system since 1987 (LDWF unpublished data). The state of Texas stocked 2,173,300 Atlantic race fingerlings into reservoirs on Red River tributaries during 1965-1987 and continues to stock these waters. The state of Mississippi stocked Atlantic race striped bass into the Mississippi River, three lakes located along the river, and on tributaries during 1970-1985 (MDWFP unpublished data):

Mississippi River	232,500
Lake Mary (Mississippi River oxbow)	99,500
Grenada Lake (Yazoo River basin)	1,565,800
Sardis Lake (Yazoo River basin)	1,421,800

Upstream of Louisiana, striped bass have been stocked into many reservoirs throughout much of the drainage basin. According to Clay (1975), striped bass stocking began in Kentucky in 1957, and the species was later stocked into Barkley, Cumberland, Dewey, Green River, Herrington, and Kentucky reservoirs as well, though Cumberland Lake eventually became the primary stocking site in that state (Kinman 1995). Etnier and Starnes (1993) noted striped bass stocking in many reservoirs throughout Tennessee began in the mid-1960s, and Pflieger (1975) noted striped bass stocking began in Missouri in 1966. According to Henley (1991), over ten million fingerlings were stocked into navigation pools of the Ohio River between 1975 and 1991. Fremling et al. (1989) stated that the introduction of striped bass and hybrids was controversial in the upper Mississippi River because of potential competition with walleyes, and neither Minnesota nor Iowa successfully introduced striped bass. As far as is known all striped bass stocked into the Mississippi-Atchafalaya Rivers system have been of Atlantic origin.

Natural reproduction by striped bass has been documented in Lake Texoma on the Red River (Schorr et al. 1995); Keystone Reservoir, Oklahoma; and Dardanelle Reservoir on the Arkansas River, Arkansas (Combs 1980, Hogue et al. 1977). The Lake Texoma population is self-sustaining and supports a robust striped bass fishery. In the Tennessee River, evidence of striped bass reproduction has also been found below Cheatham and Pickwick Dams (Hogue et al. 1977) and in the Ohio River near the Tanners Creek and W.C. Beckjord power plants (ESE 1989). According to Kinman (1995), significant put-grow-and-take striped bass fisheries have developed in a number of reservoirs in the Mississippi basin (e.g., Lake Cumberland, Kentucky). In others, such as Lakes Grenada and Sardis in Mississippi, successful striped bass fisheries never developed, and *Morone* stocking shifted to hybrids or was discontinued (Thompson and Knight 1983, MDWFP unpublished data).

Based on anecdotal accounts striped bass were first observed in the lower Mississippi River in the 1960s, and by the early 1990s, striped bass were relatively plentiful in the system at least locally (Cooper 1992, Montgomery 1991). It was speculated that these fish were downstream migrants from stocking areas far up in the basin. Horst (1976) found that striped bass were uncommon in the Atchafalaya River basin, though increasing in abundance. Two YOY striped bass were collected in the basin, but it was uncertain whether they resulted from natural spawning or stocking. Rogillio et al. (1994) documented natural reproduction by striped bass in both the lower Mississippi and Atchafalaya rivers, but whether or not and the degree to which this spawning may be helping to sustain striped bass populations in this part of the system is uncertain due to the probable downstream migration of striped bass from stocked reservoirs upstream.

Striped bass abundance in the lower Mississippi River appeared to have peaked during the late 1980s and early 1990s but has declined substantially since (S. Montgomery personal communication, P. Cooper personal communication). An unusually successful natural spawn occurred in the Ohio River in 1988. Striped bass catch rates in electrofishing sampling in the Ohio River in 1988 were anomalously high compared to previous and subsequent years (D.T. Henley personal communication). Electrofishing catch rates in the Ohio River during 1988 were up to 483 times higher than in the previous year (Henley 1987, 1988). Stocking rates were not substantially different between the two years, and the higher abundance was considered too great to have resulted simply from higher survival of stocked fish. Flow rates in the Ohio were substantially lower than normal in 1988. Etnier and Starnes (1993) noted that striped bass populations in some areas of Tennessee seriously declined "in recent years." Striped bass in the lower Mississippi River continue to enter creels incidentally; no substantial directed fishery has developed.

3.8.2.2 Lake Pontchartrain

A total of 21,800 Atlantic race (South Carolina and Virginia stocks) striped bass fingerlings were stocked into Lake Pontchartrain in 1974 and 1983 (LDWF unpublished data).

3.8.2.3 Amite River

According to Davis et al. (1970), the Amite River at one time had a fishable population of striped bass. There have been no striped bass stocked in the Amite River.

3.8.2.4 Tangipahoa River

Bean (1885) reported an account of "great schools" of rather small, four to six pound striped bass observed in the Tangipahoa River at Osyka, Mississippi, in the late 1800s. A total of 143,100 striped bass fingerlings (140,000 Phase I; 3,100 Phase II) have been stocked in the

Tangipahoa River since 1987 (LDWF unpublished data, USFWS unpublished data; race and mtDNA haplotype indicated):

102,500	(race unknown, haplotype unknown)
10,000	(Atlantic, haplotype unknown)
30,600	(Gulf, haplotype unknown)

There is no information regarding the current presence or status of striped bass in the Tangipahoa River. Striped bass occasionally occur in creels as incidental catch in this river.

3.8.2.5 Tchefuncte River

Historically, native striped bass abundance in Louisiana is reported to have been highest in the Tchefuncte River, and the last documented occurrence of native striped bass in the state was in this river (Gowanlach 1933, Davis et al. 1970). Striped bass stocking in the Tchefuncte began in 1967. Through 1986, 103,400 Atlantic race striped bass fingerlings were stocked (Nicholson et al. 1986). During 1987-2002, a total of 176,000 fingerlings (147,700 Phase I; 28,300 Phase II) were stocked in the system as follows (LDWF unpublished data, USFWS unpublished data; race and mtDNA haplotype indicated):

59,900	(race unknown, haplotype unknown)
10,000	(Atlantic, haplotype unknown)
15,800	(Gulf, B2)
32,200	(Gulf, C1)
12,500	(Gulf, C2)
45,600	(Gulf, D1)

During a total of 1,798 m-days of gill net sampling in the Tchefuncte River in 1997-2000, Monzyk et al. (2001) captured only six striped bass. No striped bass in spawning condition were collected. Although anglers fishing in the Tchefuncte River catch the species incidentally, the striped bass population appears to be minimal with no evidence of reproduction.

3.8.2.6 Bayou Lacombe

Bayou Lacombe is a small stream tributary to Lake Pontchartrain between the Tchefuncte and Pearl rivers. A total of 47,300 Atlantic race (South Carolina and Maryland stocks) striped bass fingerlings were stocked into Bayou Lacombe between 1971 and 1981 (LDWF unpublished data). There is no information on the current presence or status of striped bass in this stream.

3.8.3 Mississippi

McIlwain (1967) reported striped bass were present in all major Mississippi coastal rivers during a survey in 1967. The largest population was in the Pascagoula River, which supported a small recreational fishery, though striped bass were incidentally caught in other rivers. Less than 25 anglers were estimated to target striped bass in Mississippi at that time.

Stocking in the Pearl River began in 1968 (MDWFP unpublished data), and stocking of other coastal rivers began in 1969 (McIlwain 1971). In addition to the rivers discussed in the following sections, approximately 600 advanced fingerlings were stocked into Davis Bayou, a small coastal stream in Ocean Springs in spring 1969 (McIlwain 1971).

Numbers of striped bass caught by anglers and reported annually from Mississippi coastal rivers began increasing a few years following the initiation of stocking efforts and indicated successful recruitment of stocked fish (McIlwain 1976, 1980a; Nicholson 1983; Nicholson 1986; Nicholson 2001b). After peaking in the early 1980s, the annual number of these reports stabilized:

1974	5
1975	6
1976	21
1977	55
1978	260
1979	373
1980	289
1981	508
1982	89
1983	253
1984	257
1985	329
1998-1999	482
1999-2000	229
2000-2001	151

Likewise, the numbers of tagged striped bass captured and reported annually by anglers indicated a similar trend (Nicholson 1989, 1990, 1993, 1995, 2001b):

1986	57
1987	162
1988	234
1989	156
1990	162
1991	212
1992	256
1992-1993	169
1993-1994	160
1994-1995	58
1998-1999	119
1999-2000	80
2000-2001	90

Before stocking, a sampling program during 1967-1968 used a variety of gear in coastal Mississippi rivers, but no striped bass were collected (McIlwain 1968). However, a continuation of sampling a number of years into stocking yielded seven striped bass (330-495 mm TL) from Mississippi coastal rivers during 1976-1979 (McIlwain 1980a). Robinson and Rich (1977) sampled 24 lake, bayou, and river habitats in coastal Jackson County, Mississippi, in 1976-1977 and did not collect any striped bass. To date, natural reproduction by striped bass in Mississippi coastal rivers has not been demonstrated through either collection of eggs and larvae or collection of YOY in the absence of stocking. Striped bass was included on a preliminary list of rare and threatened vertebrates of Mississippi (Clemmer et al. 1975), but it is not presently on the state's official list of endangered species (MDWFP 1994).

3.8.3.1 Pearl River

McIlwain (1967) reported the presence of striped bass in the Pearl River in 1967 but not in numbers sufficient to support a fishery. Striped bass stocking in the Pearl River began in 1968 when fingerlings were stocked into Ross Barnett Reservoir (Bailey 1974, MDWFP unpublished data). Through 1985, 1,698,900 Atlantic race (South Carolina stock) striped bass fingerlings were stocked into the Pearl River system (Nicholson et al. 1986). From 1987 through 2002 a total of 1,537,900 striped bass fingerlings (1,435,000 Phase I; 102,900 Phase II) were stocked into the Pearl (Nicholson 1994; GCRL unpublished data, MDWFP unpublished data, USFWS unpublished data; race and mtDNA haplotype indicated):

185,000	(race unknown, haplotype unknown)
2,900	(race unknown, C?)
15,600	(race unknown, D1)
289,700	(Atlantic, haplotype unknown)
35,800	(Atlantic, C1)
99,500	(Atlantic, D1)
516,200	(Gulf, haplotype unknown)
30,000	(Gulf, AA2)
34,700	(Gulf, B2)
55,400	(Gulf, C1)
273,100	(Gulf, C2)

Robinson and Rich (1983) did not collect striped bass in monthly electrofishing sampling in the Pearl River along the Old River State Wildlife Management Area during March-November 1982. In fall 1991, Nicholson (1992) collected two striped bass (1.8 kg/540 mm and 384 g/373 mm) by electrofishing in the Pearl River. Monzyk et al. (2001) collected 61 striped bass by angling below low-head sills in the Pearl River during 1997-2000. However, no striped bass were collected in 1,655 m-days of gill netting in the Pearl River in that same study. No female fish in gravid condition were found in the Pearl, and there was no other indication of reproduction occurring in the system, although fecundity, condition indices, growth and mortality rates were found to be similar to other striped bass populations in the Southeast. In a creel survey conducted in 1988, there was no directed fishery for striped bass in the Pearl River and apparently no recorded catches (Holman 1988). As indicated in Section 3.8.3 above, the striped bass population in the Pearl River probably increased as a result of stocking activities, but population levels remain low; the population is not self-sustaining, and a directed fishery has not been established although striped bass enter creels incidentally (Nicholson 2001b). Since 1992, only Gulf race striped bass have been stocked into Ross Barnett Reservoir in efforts to establish that water body as a Gulf race broodstock source.

3.8.3.2 Jourdan and Wolf Rivers

McIlwain (1967) reported the presence of striped bass in the Wolf River in 1967 but not in numbers sufficient to support a fishery. Striped bass were first stocked into the Jourdan and Wolf rivers in 1974 (McIlwain 1976). A total of 1,814,000 striped bass fingerlings were stocked into these two rivers through 1986 (Nicholson et al. 1986, GCRL unpublished data). Stocks utilized to produce these fingerlings were from Maryland, New York, North Carolina, and Virginia. During 1988-1993 a total of 531,100 striped bass fingerlings (500,000 Phase I; 31,100 Phase II) were stocked into the Jourdan and Wolf rivers as follows (GCRL unpublished data, MDWFP unpublished data, USFWS unpublished data; race and mtDNA haplotype indicated):

24,600	(race unknown, haplotype unknown)
506,500	(Atlantic, haplotype unknown)

In an investigation of Jourdan River fisheries during August 1977-July 1978, Lorio and Dakin (1979) did not collect any striped bass in sampling by electrofishing and seine nor did they report striped bass in the creel of recreational anglers. Robinson and Rich (1984) collected one striped bass (0.23 kg) from the Wolf River in a rotenone sample in 1983 but did not collect any striped bass in monthly electrofishing at three sites on the river during April 1983-March 1984. As indicated in Section 3.8.3, striped bass populations in these rivers probably increased because of stocking activities through 1993, but population levels remained low, and a directed fishery has not been established although striped bass enter creels incidentally (Nicholson 2001b). No evidence of natural reproduction in the Jourdan or Wolf rivers was found in 1980-1984 seine sampling of YOY striped bass (Lukens et al. 1991), and all fish collected appeared to be Atlantic race. Because stocking has not been conducted since 1993, it is doubtful many striped bass remain in the system except for migrants from nearby rivers that are still being stocked. Because of habitat limitations, self-sustaining populations in either river are not likely to become established.

3.8.3.3 Biloxi Bay Rivers

McIlwain (1967) reported the presence of striped bass in the Biloxi and Tchoutacabouffa Rivers in 1967 but not in numbers sufficient to support a fishery. Striped bass were first stocked into this system as advanced fingerlings that went into the Tchoutacabouffa River and Fort Bayou in 1969 (McIlwain 1971). A total of 3,505,400 Atlantic race (Maryland, North Carolina, and South Carolina stocks) striped bass fingerlings were stocked into the Biloxi and Tchoutacabouffa rivers and Fort Bayou through 1986 (Minton and Powell 1986, Nicholson et al. 1986, Powell 1989, GCRL unpublished data). During 1987-2002 a total of 352,400 striped bass fingerlings (288,400 Phase I; 64,000 Phase II) were stocked into these streams as follows (GCRL unpublished data, MDWFP unpublished data; race and mtDNA haplotype indicated):

Biloxi River (231,600 Phase I; 43,800 Phase II)
16,600 (Atlantic, haplotype unknown)
93,200 (Atlantic, C1)
108,500 (Atlantic, D1)
57,100 (Gulf, C2)

Tchoutacabouffa River (51,500 Phase I; 10,100 Phase II)
1,400 (race unknown, D1)
10,800 (Atlantic, haplotype unknown)
14,300 (Atlantic, D1)
3,500 (Gulf, haplotype unknown)
31,600 (Gulf, C2)

Fort Bayou (5,300 Phase I; 10,100 Phase II)
1,000 (race unknown, haplotype unknown)
1,800 (race unknown, D1)
3,200 (Atlantic, haplotype unknown)
7,000 (Gulf, haplotype unknown)

Robinson and Rich (1980) did not collect any striped bass using rotenone and electrofishing in the Tchoutacabouffa River and Tuxachanie Creek, a tributary, in 1979-1980. The GCRL sampling by electrofishing in 1983 collected 13 striped bass (1.3-9 kg) in the Tchoutacabouffa River; however, similar sampling in 1984 yielded only one striped bass (3 kg, 935 mm TL) (Nicholson 1986) and none in 1985 (Minton and Powell 1986). Eight striped bass were collected in GCRL gill net sampling, and the MDWFP collected an additional 41 striped bass (330-381 mm TL) in the Biloxi Bay system (Nicholson 1986) in 1983. Robinson and Rich (1984) collected 76 striped bass (average 0.28 kg) in a rotenone sample on the Biloxi River in 1983. During April 1983-March 1984, Robinson and Rich (1984) collected one striped bass (0.27 kg) in monthly electrofishing sampling from one site in the Biloxi River but did not collect striped bass in similar sampling at two other sites in the river. As indicated in Section 3.8.3, striped bass populations in these rivers probably increased because of stocking activities, but population levels remain low, and a substantial directed fishery has not been established although striped bass enter creels mostly incidentally (Nicholson 2001b). No evidence of natural reproduction in the Biloxi or Tchoutacabouffa rivers was found in 1980-1984 seine sampling of YOY striped bass (Lukens et al. 1991), and all fish collected appeared to be Atlantic race. Because of habitat limitations, self-sustaining populations in these streams are not likely to become established.

3.8.3.4 Pascagoula River

McIlwain (1967) documented a minor recreational fishery for striped bass in the west branch of the Pascagoula River in 1967. This was the only coastal Mississippi stream judged to consistently yield fish from year to year. Striped bass were first stocked into Okatibbee Reservoir as well as the lower Pascagoula River in 1969 (Bailey 1974, McIlwain 1971). Through 1986, 1,550,000 Atlantic (South Carolina) and Gulf race striped bass fingerlings were stocked into the Pascagoula River system (Nicholson et al. 1986, GCRL unpublished data). During 1987-2002, 1,496,600 striped bass fingerlings (1,429,600 Phase I; 67,000 Phase II) were stocked into this system as follows (Nicholson 1994, ADCNR unpublished data, GCRL unpublished data, MDWFP unpublished data, USFWS unpublished data; race and mtDNA haplotype indicated):

715,400	(race unknown, haplotype unknown)
8,900	(race unknown, D1)
461,600	(Atlantic, haplotype unknown)
14,900	(Atlantic, C1)
116,600	(Atlantic, D1)
111,400	(Gulf, haplotype unknown)
67,800	(Gulf, C2)

Robinson and Rich (1980) did not collect any striped bass using rotenone and electrofishing in Black Creek and the Chickasawhay River, tributaries to the Pascagoula, in 1979-1980. In approximately 14,000 hr-ft of gill net sampling during summer and fall 1981, the USFWS collected one striped bass but did not collect any striped bass in electrofishing efforts on five separate days during fall-winter 1983-1984 (USFWS unpublished data). In 1983, gill net sampling by GCRL personnel yielded one striped bass from the lower West Pascagoula River (Nicholson 1986), and Robinson and Rich (1984) collected two small (average 0.03 kg) striped bass in rotenone sampling in the Escatawpa River that same year. Robinson and Rich (1984) also collected one striped bass (0.23 kg) in monthly electrofishing sampling from one site in the Escatawpa River during April 1983-March 1984 but did not collect striped bass in similar sampling at two other sites in the river. Holman (1988) reported neither a directed fishery nor incidental hook-and-line catches of striped bass in a creel survey of the Pascagoula, Leaf, and Chickasawhay rivers in 1988 but did report minor catches of striped bass in hoop nets and on trot lines.

Jackson et al. (2001) collected six adult striped bass in the Pascagoula River during winter and spring 1998 and 1999 in a sampling program using angling (99.2 hrs), electrofishing (39.9 hrs), gill net (33.2 hrs), hoop net (26,160 hrs), and trotline (560 hrs). Four of the six fish collected were female. Though the sample size was small, this sex ratio is not typical of a reproductive striped bass population, which should be male-dominated. However, one of the females appeared to have recently spawned, and the others were gravid. In a creel survey conducted during 1998 and 1999 in which 250 anglers were interviewed, no anglers reported targeting striped bass. There were 82 reports of incidental catches of striped bass, though some of these were from recollections as far back as 12 years before the survey (Jackson et al. 2001). Nicholson (2001b) reported an unspecified number of striped bass captured in electrofishing sampling in the Pascagoula River in 1999 and 2000. Based on these data and as indicated in Section 3.8.3, the striped bass population in the Pascagoula River increased as a result of stocking activities since 1969, but population levels remain low, the population is not self-sustaining, and a substantial directed fishery has not been established.

3.8.4 Alabama

As most of Alabama falls within the MAT rivers drainage, that system has been the major focus for striped bass management within the state. Although some attention was focused on the Perdido River, most of the data available on striped bass in Alabama pertain to the MAT. The coastal striped bass restoration program discussed below involved the MAT and Perdido.

3.8.4.1 Mobile-Alabama-Tombigbee Rivers System

Based on interviews with commercial fishermen and seafood dealers, Shell and Kelley (1968) reported a modest commercial fishery for striped bass in the Mobile Bay region during the 1940s and 1950s. In other studies of the Mobile Bay region, Swingle and Kelley (1969) and Spencer (1969) interviewed numerous anglers and commercial fishermen and documented the existence of modest to substantial recreational striped bass catch, as well as commercial catch of striped bass during the 1930s through the 1950s. Raney et al. (1952) reported "a considerable sport fishery" taking striped bass weighing 2.25-18 kg in the Coosa and Tallassee rivers. According to Bryce (1982), the recreational fisheries in dam tailwaters on the Coosa and Tallapoosa rivers attracted numerous out-of-state anglers. However, catches declined considerably by the 1960s when few striped bass were caught. The last significant native spawning migration in the system occurred in 1961. Native striped bass were "virtually extinct" in the Mobile Bay region by the late 1960s, though a remnant population remained based on the capture of a few specimens in the Tallapoosa River and Mobile Bay in 1967 (Shell and Kelley 1968). The factors responsible for the decline of striped bass were not found; however, it was hypothesized that industrial and/or agricultural pollution affected populations (Swingle 1968, Shell and Kelley 1968). The construction of numerous dams in the lower MAT undoubtedly also played a role in the eventual demise of the native population (Bryce 1982).

The ADCNR/WFF began a striped bass stocking program in 1965 (Bailey 1974) and stocked striped bass into at least 15 lakes and reservoirs in the MAT (Claiborne, Coffeeville, East, Inland, Jones Bluff, Lagoon Park, Lay, Lewis Smith, Logan Martin, Martin, Miller's Ferry, Neely Henry, Thurlow, Walker, Yates) as well as the Mobile River delta. In 1967 the ADCNR/MRD initiated a stocking program to restore striped bass fisheries in the lower Mobile River system, particularly the estuarine portions (Shell and Kelley 1968, Swingle 1968, Swingle and Kelley 1969, Swingle 1970). Prior to 1981 most of the stocked fish were Phase I, but that year the ADCNR/MRD began stocking only tagged Phase II fingerlings (Powell 1989). The ADCNR/MRD program was discontinued in 1995 (ADCNR/MRD unpublished data), but the ADCNR/WFF program continues through the present. In the upper Coosa River the GDNR initiated striped bass stocking (most likely Atlantic race) in Allatoona Reservoir in 1973 (Davin et al. 1999) and in Carters Reservoir in 1983 (Beisser 1987).

During 1965-1986, 8,968,200 striped bass fingerlings (mostly Atlantic race, North and South Carolina and Georgia stocks and perhaps others, a few Gulf race) were stocked into the MAT (Nicholson et al. 1986; Duffy 1993; Minton 1979, 1980; Minton and Powell 1986; Powell 1989; Shell and Kelley 1968; Swingle 1970; GDNR unpublished data). From 1987 through 2002, 8,530,200 striped bass fingerlings (8,407,600 Phase I; 122,600 Phase II) were stocked into the system (ADCNR/WFF, MDWFP, and USFWS unpublished data; Duffy 1993; Powell 1989; Powell 1990; Tatum et al. 1994; race and mtDNA haplotype indicated):

2,091,700	(race unknown, haplotype unknown)
100,000	(race unknown, C1)
365,500	(Atlantic, haplotype unknown)
59,000	(Atlantic, C1)
2,080,700	(Gulf, haplotype unknown)
2,430,500	(Gulf, B2)
48,200	(Gulf, B(A)2)
178,000	(Gulf, B(C)2)
1,037,300	(Gulf, C2)
120,300	(Gulf, D1)
19,000	(Gulf, D2)

Gulf race fingerlings were first stocked into the system in 1983. Particular attention was focused on Lewis Smith Lake for stocking Gulf race striped bass, and it became an important source of broodfish. Between 1994 and 2002 mostly Gulf race striped bass were stocked into the MAT system. The only exceptions were in 1999 and 2001 when some Atlantic fish were stocked due to insufficient availability of Gulf race.

Sampling following initiation of the stocking program indicated a growing striped bass population in the lower MAT, although varying effort levels and river hydrological conditions partially accounted for the trends. Powell (1972, 1973) did not capture striped bass broodfish below Claiborne L&D on the Alabama River in 1971 and 1972. Sampling in 1973 occurred in areas of the river downstream of Claiborne L&D and in Mobile Bay due to high water conditions which prevented sampling immediately below Claiborne L&D and Coffeeville L&D on the Tombigbee River; however, no broodfish were collected that year either. Minton (1979) captured one immature female and one male striped bass in 1977 in sampling at various sites in the lower MAT during broodfish collection efforts. In 1978 during similar sampling, Tatum and Powell (1978) collected three male striped bass in the Bon Secour River but none at Claiborne L&D. Minton (1980) reported capture of 70 adult striped bass in broodfish collection efforts in the lower MAT in 1979 and 69 in 1980, but only 15 were collected in 1981 due to low water conditions (Minton 1982).

Similar trends were shown in results of fishery independent sampling for striped bass in the lower MAT (Tatum and Powell 1978; Minton 1979, 1980, 1982, 1984; Minton and Powell 1986; Powell 1989):

1976	1
1977	1
1978	0
1979	87
1980	17
1982	46
1983	28

1984	45
1985	33
1986	82
1987	46
1988	42

Striped bass caught in the wild were marketed commercially in south Alabama in 1978, the first time since the 1950s (Tatum and Powell 1978). In 1979, three or four striped bass identified as Gulf race were found among 250 striped bass collected by the ADCNR/MRD (Crateau ND). The Gulf race fish were identified based on LLSC; the other striped bass were introductions of Atlantic origin. In 1981 five of 61 striped bass collected by ADCNR/MRD personnel were Gulf race (Minton 1982). A 1983 recreational angler mail survey conducted in Alabama indicated that almost 7,000 of the licensed anglers in Alabama reported catching striped bass in the state's coastal areas (Minton 1984).

Bryce (1982) evaluated the striped bass population and fishery in the Tallapoosa River below Thurlow Dam in 1980. No Gulf race fish were found in the population. Atlantic origin striped bass displayed rapid growth and high natural mortality. However, fishing mortality was low despite striped bass composing over 40% of the fishing effort and 60% of the catch in the study area. Beisser (1989) found a directed striped bass fishery developing in Allatoona Lake on the Coosa River in Georgia by 1983.

Natural reproduction by striped bass in the Alabama River between Miller's Ferry L&D and Claiborne L&D and also below Claiborne L&D was documented by collection of eggs and larvae in 1989 (Powell 1990). During 1990, eggs were also collected, but no larvae (Powell 1991). Striped bass eggs were collected in 1991 and 1992, and larvae were collected in 1992 below Claiborne L&D (Duffy 1993). Spawning by striped bass was documented in the Oostanaula and Conasauga rivers above Weiss Reservoir on the Coosa River during 1997 and 1998 (Davin et al. 1999). Evidence indicated that spawning activity resulted in recruitment into river reaches below Weiss Reservoir; the spawning activity has been assumed to involve Atlantic race fish (Davin and Smith 2001, Smith and Catchings 1998) but diagnostic genetic evaluations have not been made.

In summary, with the ADCNR/WFF stocking program, striped bass have become an important component of the fisheries in many reservoirs and tailwater areas of the MAT. A very limited directed fishery for striped bass had likely developed in coastal Alabama by 1992, though it was a "less preferred" species by most anglers in that area (Duffy 1993). The coastal stocking program was discontinued by the AMRD, and that fishery may have declined considerably since that time. Although the WFF continued to stock striped bass into the lower Mobile River, no assessment has been made of the coastal fishery or population since the mid-1990s. There appears to be substantial natural reproduction by striped bass in the upper Coosa River above the fall line, which is assumed to involve primarily or exclusively Atlantic race fish, and there is good evidence for recruitment from this spawning activity into striped bass populations downstream. Some striped bass spawning occurs in the lower portions of the MAT, but it is unknown whether this activity involves Atlantic or Gulf race fish or both, or whether any recruitment results from this activity. It has not been determined whether striped bass populations or fisheries in any portions of the MAT can be sustained through natural reproduction. Striped bass populations in the MAT are a mixture of Atlantic and Gulf races except possibly for those portions of the Black Warrior River upstream of Warrior Dam, which may be populated primarily by Gulf race due to the focus on maintaining Lewis Smith Lake as a Gulf race broodstock source in that tributary.

3.8.4.2 Perdido River

McLane (1958) did not find any substantial striped bass fishery in the Perdido River in a study conducted in the early 1950s. Interviews with commercial fishermen, some of whom had been fishing for up to 60 years, indicated that population levels of striped bass in Florida Gulf rivers had always been extremely low during that time period, with "slight suggestions of fluctuations in abundance." There are no data available on the status of striped bass in the Perdido River from the mid-1950s through the 1960s, though one may assume that the population probably became extinct before or concurrently with that in the MAT.

From 1971 to 1986, 1,494,500 striped bass fingerlings (Atlantic race, South Carolina stock and possibly others) were stocked into the Perdido (Minton 1979, 1980; Minton and Powell 1986; Nicholson et al. 1986; Powell 1972, 1973, 1989). From 1987 through 1994, 51,200 striped bass fingerlings (33,700 Phase I; 17,500 Phase II) were stocked into the system (Powell 1989, USFWS unpublished data; race and mtDNA haplotype indicated):

17,500	(race unknown, haplotype unknown)
10,900	(Atlantic race, haplotype unknown)
22,800	(Gulf race, haplotype unknown)

During 1978 confirmed striped bass fishery catches were documented from the Perdido River system (Tatum and Powell 1978). In fishery independent sampling in the Perdido River, 26 adult striped bass were captured in 1986, 46% of which carried tags inserted during previous years of stocking (Powell 1989). In 1987 sampling, 12 striped bass were captured, 33% of which had been tagged; in 1988, 38 were captured with 92% carrying tags. There have been no subsequent assessments of the stock status in the Perdido River. Since 1994, stocking has not occurred and habitat likely limits development of a self-sustaining population in the Perdido, so very few striped bass may remain in the system today.

3.8.5 Florida

Interviews with fish camp operators indicated that native striped bass populations in northwest Florida declined rapidly or became extinct during the 1950s (Barkuloo 1979). In an early 1950s study, McLane (1958) did not find any substantial striped bass fisheries in the Gulf rivers that he focused upon (Perdido, Escambia, Yellow, Choctawhatchee, Chipola, and Ochlockonee). Interviews with commercial fishermen, some of whom had been fishing for up to 60 years, indicated that population levels of striped bass in Florida Gulf rivers were always extremely low during that time period, with "slight suggestions of fluctuations in abundance." Fewer than 50 avid striped bass anglers were estimated to exist in northwest Florida in the late 1950s (Barkuloo 1961a). McErlean (1961) quoted J. Barkuloo as stating his belief that the few striped bass found in most of the Florida Panhandle rivers were stragglers from the Apalachicola River spawning population.

The reasons for the drastic decrease of native striped bass in Florida rivers are unknown. However, heavy pesticide and herbicide use during the 1950s and 1960s, along with construction of dams on the larger rivers are suspected factors (Barkuloo 1979).

The first striped bass stocked into Florida Gulf rivers, 307-461mm sub-adults, came from Chesapeake Bay and were released into Lake Talquin in 1961 (J. Barkuloo personal communication). In the early 1970s, striped bass were introduced into small lakes and reservoirs of the Florida Peninsula to control shad populations and provide a supplemental fishery. Although shad control was successful, establishment of fisheries was less so (Bailey 1974; Ware 1970, 1974b).

3.8.5.1 Escambia/Conecuh River

Bollman (1887) reported a 461mm striped bass taken by a fisherman at the mouth of the Escambia River. Bailey et al. (1954) stated that striped bass, if present in the Escambia, were there in small numbers since none were collected in sampling efforts during 1929-1953, and resident fishermen near the mouth of the river were unfamiliar with the species. J. Barkuloo (personal communication) collected young striped bass as early as 1957 from the Escambia River before any stocking efforts took place. McLane (1958) found no substantial striped bass fishery in the Escambia River. Stocking records indicate that striped bass fingerlings were released in the Escambia/Conecuh system in 1976 (16,400 Atlantic race) and 2002 (204,600 Phase I; Gulf mtDNA haplotype BC2 and CD2) (Nicholson et al. 1986, FWC unpublished data, Yeager 1988b). Striped bass were also stocked into the Escambia in 1987, though stocking numbers were not given. Evaluation of YOY from that stocking, however, indicated good to excellent survival with catch and growth rates higher than those for YOY striped bass in the Apalachicola River. Striped bass were not noted in creel surveys of the Escambia River during 1983-1993 (Yeager 1988a, Slack and Yeager 1993). In the absence of recent stocking or other data, the status of striped bass in the Escambia/Conecuh system is uncertain.

3.8.5.2 Blackwater River

There is no specific documentation of striped bass status in the Blackwater River prior to initial stocking efforts in 1987. Between 1987 and 2001, 1,427,300 (1,394,300 Phase I; 33,000 Phase II) striped bass fingerlings were stocked into the river (Slack and Yeager 1996, Slack and Yeager 1993, FWC unpublished data, USFWS unpublished data; race and mtDNA haplotype indicated):

59,800	(race unknown, haplotype unknown)
197,500	(Gulf, unknown haplotype)
78,000	(Gulf, A(A)2)
96,300	(Gulf, B2)
347,300	(Gulf, C1)
300,600	(Gulf, C2)
347,800	(Gulf, D1)

Striped bass population sampling during 1987-1993 to evaluate stocking efforts revealed that fish age-2 and younger made up 98% of the population (Slack and Yeager 1993). Growth rates and condition factors were similar to those found for striped bass in other Gulf rivers. Tag returns indicated movement of striped bass between the Blackwater and Yellow Rivers (Slack and Yeager 1993). A female striped bass broodfish was successfully collected from the Blackwater River and artificially spawned in 1995 (USFWS 1996). Increased striped bass angler effort was noted in 1996 (USFWS 1997), though total catch declined in succeeding years through 2002 (USFWS 2003). Striped bass were not stocked into the Blackwater River in 1999 in order to evaluate natural reproduction through YOY collection efforts; however, no YOY were collected (USFWS 2000). The striped bass population in the Blackwater River is probably being maintained through annual stocking.

3.8.5.3 Yellow River

McLane (1958) did not find any substantial striped bass fishery in the Yellow River. Striped bass were first stocked into this river in 1990, and through 2001 a total of 967,800 striped bass fingerlings (957,900 Phase I; 9,900 Phase II) were stocked into the Yellow River (FWC unpublished data; race and mtDNA haplotype indicated):

83,100	(Atlantic)
24,500	(Gulf, haplotype unknown)
25,000	(Gulf, A(B)2)
27,300	(Gulf, B2)
122,000	(Gulf, B(AC)2)
266,400	(Gulf, C1)
210,400	(Gulf, C2)
209,300	(Gulf, D1)

Tag return data indicated mixing of Blackwater and Yellow River striped bass (Slack and Yeager 1993). Striped bass angler effort increased in 1996 (USFWS 1997) though total catch declined in succeeding years through 2002 (USFWS 2003). Striped bass were not stocked into the Yellow River in 1999 in order to evaluate natural reproduction through YOY collection efforts, and no YOY were collected (USFWS 2000). The striped bass population in the Yellow River is probably being maintained through annual stocking.

3.8.5.4 Choctawhatchee River

Smith et al. (1975) stated the last historical record of native striped bass in the Choctawhatchee River as the early 1950s. An "early" rotenone study in the Choctawhatchee River resulted in the capture of Gulf sturgeon and skipjack herring, but no striped bass (no date was given for this study). McLane (1958) did not find a substantial striped bass fishery in the Choctawhatchee. Smith et al. (1975) also referenced a 1958-1959 survey that did not result in collection of striped bass in the river.

According to Smith et al. (1975), the first stocking of striped bass in the Choctawhatchee River was by the state of Alabama, which stocked 4,818 fingerlings into Lake Tholocco, a 607-

acre reservoir in the upper basin during 1967-1971. Through 1987, 3,683,100 striped bass fingerlings (Atlantic race, South Carolina and Hudson River stocks) were stocked into the Choctawhatchee (Nicholson et al. 1986, Smith et al. 1975). From 1993 through 2002, 1,282,800 striped bass fingerlings (1,279,500 Phase I; 3,300 Phase II) were stocked into the river (FWC unpublished data, USFWS unpublished data; race and mtDNA haplotype indicated):

488,000	(Gulf, unknown haplotype)
36,000	(Gulf, A(A)2)
36,000	(Gulf, C1)
98,400	(Gulf, C2)
85,500	(Gulf, C(D)2)
538,900	(Gulf, D1)

Smith et al. (1975) conducted studies to evaluate 1968-1975 stocking efforts. Reproduction at a very low level was documented in the Choctawhatchee River in 1975 by collection of one striped bass egg. In addition three female and five male fish in spawning condition were collected during the study, but sampling gear used did not effectively sample older fish. Condition of stocked striped bass up to 150 mm TL in the Choctawhatchee was better than that for fish of comparable size in other Florida rivers and the Ogeechee River, Georgia. However, Choctawhatchee River striped bass in larger size ranges were found to be in poorer condition. The oldest striped bass found was age-6. Growth of striped bass in the Choctawhatchee was equal to or better than for those in Atlantic and Pacific rivers. Relative abundance of striped bass age-3 and younger in the Choctawhatchee Bay and delta was comparable to other recreational fish species. Angler interviews indicated that striped bass of all sizes were caught infrequently (largely on an incidental basis) throughout the river system. Although very few anglers targeted striped bass, those who did were usually successful. Young and Crew (1982, 1983) reported striped bass were present in low numbers throughout the system in 1981-1983. A total of 88 striped bass were reported in a creel survey on the river in spring 1982 but none in 1983 (Young and Crew 1983). No striped bass were collected in fall 1983 and 1984 electrofishing surveys of the Choctawhatchee River (Young and Crew 1984, 1985). No recent data on striped bass populations in the Choctawhatchee exist, and the population status is uncertain. However, the population is probably being maintained at a low level through recent stocking efforts.

3.8.5.5 Apalachicola-Chattahoochee-Flint Rivers

An anecdotal account was given of as many as three dozen relatively large striped bass in a spring along the Chipola River, an Apalachicola River tributary, during the 1920s and similar large schools in the same area during the 1880s (Chason 1987). There was a historic striped bass commercial fishery in Apalachicola Bay with the largest catches being made before the 1950s (Barkuloo 1979), and a successful recreational fishery existed in the Flint River before construction of the Warwick and Albany Power Dams (Gennings 1970). Populations in the ACF gradually declined through the 1950s along with those of other Florida rivers. Shortly following the filling of Lake Seminole in 1957, however, a significant increase in sport catches of striped bass in the tailrace was noted, and YOY were collected during 1957-1961 (Barkuloo 1960, 1961b, 1970). At that time, the population was determined to be sufficient to withstand existing fishing pressure but not a commercial fishery (Barkuloo 1961a, 1967). Recreational fishing for striped bass remained good through 1963 (Barkuloo 1960, 1979). However, by 1967 sampling in the Apalachicola River did not yield any striped bass, though recreational catches were still being made. Abundance of striped bass in Lake Seminole also declined by 1964, attributed to uncontrolled gill net take, and plans were made to stock striped bass in the lake the following year (Holder 1969) in order to restore the population.

The first known stocking of striped bass into the ACF was in 1966 when the state of Georgia released an estimated 25,000-50,000 fingerlings of a South Carolina stock (probably Santee-Cooper) into Lake Seminole (Wyatt et al. 1966). These fish were grown in a rearing pond constructed on the shore of the lake. Atlantic striped bass stocking also began in Lake Blackshear in 1968 (Holder 1969). Through 1986, 529,400 striped bass fingerlings were stocked into the system (Gennings 1970, Holder 1969, Keefer 1981, McIlwain 1971, Nicholson et al. 1986, Pasch 1973, Wyatt et al. 1966). This total included at least 205,100 Atlantic race fingerlings stocked prior to 1980. These were of South Carolina and Georgia (probably Savannah River) derivation. Beginning in 1980 efforts were made to stock Gulf race fingerlings into the system, although the state of Georgia continued to stock Atlantic race fish into some upstream reservoirs until at least 1990 (Barkuloo 1990). The state of Georgia continues stocking Atlantic race (Savannah River stock) striped bass into Lake Lanier through the present time (R. Ober personal communication) as they have determined that escapement is impossible due to the extremely deep water release system at the dam creating that reservoir. Despite the introduction of Atlantic race fish into the system, recent genetic analyses have indicated that, although significant introgression of Atlantic nDNA alleles has occurred, a high frequency of unique Gulf mtDNA haplotypes and nDNA alleles remain in the population (Section 3.2.4.2). During 1987-2002, 11,614,100 Gulf race fingerlings (10,539,300 Phase I; 1,074,800 Phase II) were stocked (FWC unpublished data, GDNR unpublished data, USFWS unpublished data; race and mtDNA haplotype indicated):

3,238,330	(Gulf, haplotype unknown)
13,400	(Gulf, A(A)2)
346,700	(Gulf, A(B)2)
1,187,600	(Gulf, B2)
48,500	(Gulf, B(A)2)
32,000	(Gulf, B(AC)2)
70,000	(Gulf, B(C)1)
59,500	(Gulf, B(CD)2)
5,500	(Gulf, B(CD)2)
1,520,200	(Gulf, C1)
2,386,200	(Gulf, C2)
70,100	(Gulf, C(B)2)
2,600	(Gulf, C(D)1)
7,700	(Gulf, C(D)2)
2,496,500	(Gulf, D1)
129,300	(Gulf, D(E)1)

Sampling for striped bass in the Flint River during 1970-1972 was unsuccessful, though a few striped bass were found in creel surveys, and anecdotal reports of angler catches continued to be received (Gennings 1970, Pasch 1973). However, a few striped bass (average 0.5 kg/ha) were collected in rotenone samples in 1973-1974 (Pasch 1976). Despite the stocking program, a very limited striped bass fishery existed in Lake Seminole by 1981. Rotenone sampling by Keefer (1981) yielded 0.1 kg/ha of striped bass in Lake Seminole during 1977-1980. However, the appearance of fingerlings in the absence of any stocking since 1974 indicated that some natural reproduction occurred. Harvest of striped bass in Lake Seminole during 1978-1979 was minimal, estimated at 73 kg annually. In Lake Blackshear, Keefer (1984) did not find any indication of a striped bass fishery and did not collect any striped bass in a fishery independent sampling program. Collection of striped bass eggs in the Flint River in 1985 (Keefer 1986) demonstrated that spawning occurred in the Flint River between Lake Seminole and Albany, Georgia. Keefer (1986) reported the striped bass population in the Flint River and Lake Seminole contained an estimated 100 to 200 adults. Keefer (1988) indicated striped bass were collected in Lakes Blackshear and Seminole but not in Lakes Walter F. George or Bartlett's Ferry on the Chattahoochee River; no significant striped bass fisheries were found in any of these four reservoirs. A small recreational fishery developed for striped bass in Lake Blackshear and the tailrace below the lake in 2000 (USFWS 2001).

In an aggressive 1976-1977 sampling program using gill nets, trawls, and seines; the USFWS collected low numbers of striped bass in the Apalachicola River (USFWS 1977). The following year a revised sampling program was initiated by the USFWS utilizing mark-recapture, and in 1981 the striped bass population of the upper Apalachicola River was estimated at approximately 2,000 adults (>381 mm TL) with the dominant 1980 year class consisting of 51% Atlantic race, 43% Gulf race, and 6% intermediates (Wooley and Crateau 1983). The presence of a range of year classes among the Gulf race indicated that natural reproduction occurred; the Gulf race population segment had significantly greater numbers of older fish than the Atlantic segment, and the Gulf fish expressed better average annual condition factors than Atlantic fish among adults >600 mm TL. The exploitation rate on the population was estimated at 22%.

Hill et al. (1990) found striped bass to be rare in all habitats sampled in the Apalachicola River. A striped bass fishery in JWLD tailwaters continued during 1985-1990. While catch increased over that time so did effort, but angler success remained low. No substantial striped bass fishery was documented in the lower Apalachicola, though some incidental catch was documented. Mesing et al. (1993) and Long and Rousseau (1996) found similar results during 1990-1996 striped bass fisheries in the tailwaters and lower Apalachicola River. During 1997-2000, harvest and success rates for striped bass fishing in the upper Apalachicola River, including the dam tailwaters, increased significantly to the point that striped bass had become the most sought species in the tailrace fishery (Long 2001). Nevertheless, a directed striped bass fishery did not exist in the lower Apalachicola, and few legal-size fish were caught. Creel surveys of the Columbia L&D (Chattahoochee River) and Albany Dam (Flint River) tailwater fisheries in 1995-1996 indicated relatively low catches and success rates for striped bass compared to hybrids and white bass (GDNR 1996).

Natural reproduction by striped bass in the Apalachicola River was documented by the collection of striped bass eggs in 1976 (Smith ND, Barkuloo 1989), and nine YOY were collected in the Apalachicola River during October 1976 through October 1977 in the absence of stocking (Miller 1977). In 1985 Mesing et al. (1990) again reported the collection of YOY in the absence of stocking, more than half of which were determined to be Gulf race based on genetic analyses (Mesing 1990). Foster et al. (1988) collected a single striped bass egg in the lower Apalachicola River in 1987, and higher levels of YOY than found in 1985 were collected during 1997 (Long 2001), again in the absence of stocking, with indications that most or all of the spawning activity occurred upstream of JWLD. The level of natural reproduction was considered unlikely to support a sport fishery, as YOY catch rates were significantly lower than during years when stocking occurred.

Hess and Jennings (2000) estimated the striped bass population in the trout waters of the upper Chattahoochee River to be approximately 300 individuals during 1998 and documented limited natural reproduction by striped bass in that part of the river.

In summary, stocking efforts in Lake Seminole resulted in expanding the fishery and likely the spawning population of striped bass in the upper Apalachicola River. Genetic analyses indicate that the striped bass population in the ACF is probably still substantially Gulf race in character, although there has been some introgression of Atlantic race genes into the population. Although limited natural reproduction occurs above Lake Seminole, continued stock enhancement is probably necessary to support the existing fisheries in the system.

3.8.5.6 Ochlockonee River

There are no data available on the population status of striped bass in the Ochlockonee River before stocking. Before 1960, striped bass were frequently caught in the river below the Jackson Bluff Dam (Lake Talquin) with a few as large as 20-23 kg, although fishing success declined sharply in the 1960s (Swift et al. 1977). Although an initial stocking occurred in 1961 (J. Barkuloo unpublished data), consistent stocking efforts began in 1968 in Lake Talquin and subsequently in the tailwaters. Through 1985, 2,437,000 striped bass fingerlings were stocked into the Ochlockonee (Nicholson et al. 1986; Young and Crew 1982, 1983, 1984, 1985). During 1987-2002, approximately 2.3 million striped bass fingerlings (2,284,100 Phase I; 4,300 Phase II) were stocked (Mesing 1993, 1994, 1995; FWC unpublished data, USFWS unpublished data; race and mtDNA haplotype indicated):

149,000	(Atlantic, haplotype unknown)
412,000	(Atlantic, C1)
40,000	(Atlantic, D1)
219,300	(Gulf, haplotype unknown)
94,300	(Gulf, A(A)2)
37,600	(Gulf, A(B)2)
362,900	(Gulf, B2)
15,000	(Gulf, B(D)1)
30,000	(Gulf, B(DC)2)
64,000	(Gulf, C1)

643,500	(Gulf, C2)
39,400	(Gulf, C(A)2)
30,000	(Gulf, C(B)2)
115,000	(Gulf, D1)
36,400	(Gulf, D(C)1)

In a study of the fish populations and fisheries of Lake Talquin during 1974-1982, Dobbins and Rousseau (1982) found a small, short-lived striped bass population. The vast majority were age-4 or younger and being maintained by annual stocking (Dobbins et al. 1988). No striped bass were stocked in 1987 in order to evaluate natural reproduction, and presumably no evidence of this was found in the lake (Mesing 1993). The lack of older year classes was attributed to thermal stress (Dobbins and Rousseau 1982), and although YOY were fast growing, adults were typically in fair to poor condition. Population estimates of adult (age-2 or greater) striped bass in the Oklawaha Creek thermal refuge area were approximately 1,300 in 1983 and 1,800 in 1985 (Dobbins et al. 1988). Only one striped bass was collected in a survey of the river above Lake Talquin in 1987-1989 (Cailteux et al. 1990). No striped bass were collected in a related survey of river floodplain habitats (Leitman et al. 1990).

Lake Talquin was found to support a small, erratic striped bass fishery by Dobbins and Rousseau (1982). During February through June 1986-1990, total striped bass harvest estimates ranged from 36 to 887 (Cailteux et al. 1990, Cailteux 1992). Although a fairly substantial tailwater striped bass fishery developed in the years immediately following initiation of stocking (Dobbins and Rousseau 1982), the fishery varied, with catch strongly related to discharge from the Jackson Bluff Dam (Dobbins et al. 1988).

Although some 1986 year-class Phase II Gulf race striped bass have been stocked into the Ochlockonee River in 1987, Phase I striped bass were not stocked that year in order to evaluate natural reproduction. Sampling resulted in YOY being collected below Jackson Bluff Dam indicating that some natural reproduction was taking place (Mesing 1989). More than 90% of the YOY fish sampled were determined to be Atlantic race based on mtDNA analyses (Mesing 1990). However, it is not known whether this spawning activity resulted in recruitment to the fishery or population. During 1988-1995 roughly equal numbers of Gulf and Atlantic race striped bass fingerlings were stocked into Lake Talquin in order to evaluate potential differences in survival and growth between the two races (Mesing 1996). However, since 1996 only Gulf race fingerlings have been stocked into the lake in order to establish a Gulf race broodstock source. In summary, the minimal striped bass population and fishery in the Ochlockonee River are likely supported by stock enhancement.

3.8.5.7 Suwannee River

No data are available on striped bass population status in the Suwannee River, and there is doubt whether the system historically supported a reproducing population. No substantial numbers of striped bass have been stocked into the system.

3.8.5.8 Small Florida Gulf Coast Rivers

There are no data available on status of striped bass or fisheries in smaller Gulf Coast rivers of Florida. Approximately 1,000 Gulf race striped bass fingerlings were stocked into St. Marks National Wildlife Refuge impoundments adjacent to the St. Marks River in 1984 (Nicholson et al. 1986). There are occasional reports of recreational catches in the St. Marks River, a spring-fed stream that serves as a thermal refuge.

4.0 DESCRIPTION OF THE HABITAT OF THE STOCK(S) COMPRISING THE MANAGEMENT UNIT

4.1 Description of Essential Habitat

The GSMFC has endorsed the definition of essential fish habitat (EFH) as found in the NMFS guidelines for all federally-managed species under the revised Magnuson-Stevens Act of 1996. The NMFS guidelines define EFH as:

> "those waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity. For the purpose of interpreting the definition of essential fish habitat: 'Waters' include aquatic areas and their associated physical, chemical, and biological properties that are widely used by fish, and may include aquatic areas historically used by fish where appropriate; 'substrate' includes sediment, hard bottom, structures underlying the waters, and associated biological communities; 'necessary' means the habitat required to support a sustainable fishery and the 'managed species' contribution to a healthy ecosystem; and 'spawning, breeding, feeding, or growth to maturity' covers a species' full life cycle."
>
> -*Federal Register* 67(12):2343-2383. Final Rule.

For the purposes of describing those habitats that are critical to striped bass in this FMP, this definition was utilized; however, these areas are referred to as "essential habitat" to avoid confusion with EFH mandates in the Magnuson-Stevens Act. These mandates include the identification and designation of EFH for all federally managed species, development of conservation and enhancement measures including those that address fishing gear impacts, and require federal agency consultation regarding proposed adverse impacts to those habitats. Essential habitats identified in the striped bass FMP are not associated with the federal mandate since the species in the Gulf is not federally managed under the Magnuson-Stevens Act.

4.2 Preferred Habitats

Striped bass are considered an anadromous fish throughout most of the species' native range. On the Atlantic coast from North Carolina to New England, adult striped bass are known for their long oceanic migrations. Many fisheries managers consider these movement patterns a response to migrations by pelagic forage species, while others associate the migrations with seasonal and temperature changes (Coutant 1985b). Following spawning, some Atlantic Coast striped bass migrate northward during the spring and summer and return southward in the fall; this corresponds to warming and cooling water temperatures along the Atlantic Coast.

In the southern extreme of their range, including the Atlantic Coast south of North Carolina and the Gulf Coast, striped bass are a riverine species that rarely migrate into salt water. This might be a function of water temperature due to the relatively high spring and summer temperatures of bays, estuaries, and adjacent coastal waters along the south Atlantic and Gulf of Mexico, and upstream portions of rivers being more likely to provide suitable temperatures for striped bass in these areas during summer (Dudley et al. 1977).

In oceans, bays, and reservoirs, sub-adult and adult striped bass are pelagic and schooling. However, in bays and reservoirs, schools may break into smaller groups or individuals and become associated with structures such as submersed channels, points, rock or riprap, tree trunks and stumps, or bridge and pier pilings. In rivers, striped bass may occupy deeper banks and bends where submersed tree trunks and logs accumulate, along points, rock or riprap, and at the junction of tributaries or distributaries (Yeager et al. 1990). Habitat features that break river current or provide cover where prey species might escape from current are often utilized.

Striped bass not only tolerate moderate to high turbidities, they seem to prefer these conditions. Talbot (1966) stated that most of the streams where striped bass spawn could be characterized as turbid. Worth (1884) mentioned that the Roanoke River at Weldon was "muddy." Scruggs (1957) stated that the Congaree River in South Carolina is "very turbid." Tresselt (1952) mentioned Virginia striped bass rivers had "a high turbidity due to silt." Mansueti (1962) pointed out that the striped bass egg is preadapted to "silt-laden and turbid waters."

Hanson and Walton (1990) studied the potential relationship between exposure to increased concentrations of suspended sediment and striped bass hatching success, larval foraging, and adult migration and spawning in the San Francisco Bay and the Sacramento-San Joaquin Delta. Limited information suggested that striped bass were not affected adversely by exposure to increased suspended sediments at the concentrations encountered. This conclusion was consistent with the observation that striped bass were able to establish an abundant population in San Francisco Bay and the Sacramento-San Joaquin Delta system, an environment characterized by high, naturally-occurring concentrations of suspended solids and high turbidity conditions.

There is little published information concerning the utilization of vegetated habitat by striped bass. Price et al. (1985) hypothesized that declines in Chesapeake Bay striped bass populations were related to nutrient enrichment that resulted in severe shading of nearshore submerged aquatic vegetation (SAV). They referred to Orth and Heck (1980), who found that striped bass ranked eighteenth in abundance among 48 species collected from eelgrass (*Zostera marina*) meadows. They further cited that Schaefer (1970) described important prey species consumed by striped bass in coastal New York waters and observed these species ranked second, third, fourth, and fifth in abundance in Chesapeake Bay eelgrass meadows. Price et al. (1985) concluded that loss of vegetated habitat resulted in diminished prey populations that may have negatively affected striped bass populations.

Tupper and Able (2000) compared striped bass utilization of a restored salt marsh with a reference salt marsh in Delaware Bay. Approximately 90% of both marshes contained *Spartina alterniflora* and were bordered by large natural creeks connecting them with the bay. They found that juvenile and adult striped bass (421-610 mm FL) utilized both marshes similarly, but fish tended to move farther into the main creek channel of the restored marsh compared with the reference marsh. This movement was probably related to more favorable DO concentrations in the creeks of the restored marsh. Striped bass were located at the mouths of the main creek channels associated with the marshes, or in the bay adjacent to the marshes, primarily due to the abundance of prey within the marshes. Stomach analysis indicated that striped bass were feeding at an ebb tide or early flood tide when the predominant prey species would be flushed out of the vegetation.

Critical habitats for striped bass stocks, particularly along the Gulf Coast, include adequate free-running rivers providing suitable habitat for reproduction and thermal refuge. Construction of dams along many Gulf Coast rivers has either blocked migration to spawning areas or limited river length required for egg transport until hatching occurs. Dams may also block access to springs and cool water creeks.

4.2.1 Spawning Habitat

Accounts cited by Raney et al. (1952) indicated spawning by striped bass in Atlantic Coast rivers occurred near the mouths of rivers all the way up to the fall line, and although a preference for rocky areas was indicated, spawning over sand and mud areas in tidewater was also mentioned. Even though spawning may occur in the tidal portions of rivers, it apparently occurs only in water that is essentially fresh or only very slightly brackish. However, low salinity may provide optimal conditions for egg water hardening (Albrecht 1964, Morgan et al. 1981, Bain and Bain 1982). Bain and Bain (1982) referenced successful striped bass spawning in salinities as high as 1.5 ppt, but striped bass may not spawn where salinity exceeds 5 ppt. Salinities in excess of 10 ppt cause physical deformities to striped bass eggs (Minton and Harrell 1990), although Crateau (ND) cites Hardy (1978) as finding live eggs in water up to 11.3 ppt.

Pearson (1938) described spawning areas in the Roanoke and Susquehanna rivers as "rock strewn" and "characterized by rapids and strong currents," with the principal area in the Roanoke River being "100 miles above tidewater." Manooch and Rulifson (1989) refined these generalities in describing anadromous striped bass populations along the Atlantic Coast utilizing two distinct spawning substrategies. The first and more common substrategy depends on movement of tidal waters to keep eggs suspended. The second Atlantic Coast substrategy appears to be utilized uniquely by populations in the Roanoke, Tar, and Neuse rivers of North Carolina and depends solely on riverine flow with no role being played by tidal waters in keeping the eggs suspended. Tidal influence is minimal in the estuaries of all three of these rivers due to the presence of the Albemarle and Pamlico sounds barrier islands complex. In the case of the Roanoke, striped bass travel significantly further upstream to spawn (up to 130 km) than in most other Atlantic rivers. It is believed that striped bass populations in Gulf rivers also primarily utilize this second substrategy as tidal energy in Gulf estuaries also tends to be quite low.

Locations of major spawning grounds may change from year to year within an individual river system (Rulifson et al. 1982). Crance (1984) stated generally that striped bass spawning areas should be at least 52 km (32.7 miles) upstream of a river's mouth depending on temperature and current velocity to assure that eggs and larvae are transported to suitable nursery habitat concurrent with larvae being motile and ready to feed. In some Atlantic Coast rivers, spawning occurs much closer to estuaries (see Section 3.2.6.4). McErlean (1961), citing a personal communication by J. Barkuloo, stated that approximately 50 miles or more of large stream is required for spawning in north Florida. In the Tar River, North Carolina, the major area of spawning was approximately between RM 30 and 67 (Humphries 1966). Murawski (1969) found spawning taking place in the lower Delaware River, New Jersey, from approximately RM 58 to 125. Scruggs (1957) reported spawning in the Congaree River 17 km (10.5 miles) above Lake Marion, South Carolina, in the Santee-Cooper river system. In the Brazos River, Texas, Mulford (1979) found striped bass spawning areas approximately 51 and 109 km (31.6 and 67.5 miles) upstream of Lake Whitney and 151-164 km (93.6-101.7 miles) above Lake Granbury. Two of the latter sites were located just below dams on the river. Hogue et al. (1977) also speculated that eggs and larvae collected in Barkley and Kentucky reservoirs on the Cumberland and Tennessee rivers were spawned just below Cheatham and Pickwick dams, respectively, in that system.

Lukens (1988) stated that a minimum stream velocity of approximately 0.3 m/sec is generally necessary to keep striped bass eggs and larvae suspended in the water column long enough to survive. Albrecht (1964), Regan et al. (1968), and Beasley and Hightower (2000) indicated that striped bass eggs tolerate current velocities of 0.31-5.00 m/sec, and below 0.31 m/sec settling occurs and survival drastically decreases. Marcy (1971, 1973) and Morgan et al. (1976) indicated velocities ≥2.4 m/s may be detrimental to striped bass eggs and larvae. In the Roanoke River, a sustained minimum flow was necessary for spawning, and rapid fluctuations in flow were detrimental to spawning (Bain and Bain 1982, Fish and McCoy 1959).

In the Neuse River, North Carolina, striped bass selected areas for spawning where water velocities were significantly higher (0.22-0.73 m/sec) than at randomly selected sites (Beasley and Hightower 2000). Those authors (citing several other references) indicated striped bass eggs were collected in water velocities of 0.12-2 m/sec. In many cases where successful spawning occurs in water velocities lower than the general threshold of 0.30 m/sec, higher salinity may be a factor. The salinity may increase egg buoyancy and reduce the velocity required for egg suspension as reported by Mulford (1979) in the Brazos River, Texas. Beasley and Hightower (2000) also found striped bass spawned at sites with significantly larger substrates than observed at randomly selected sites, but this may have been a function of a correlation between water velocity and substrate size.

Contrary to the above general characterization of typical striped bass spawning habitat, Enamait et al. (1991) documented successful striped bass reproduction in two small Maryland impoundments that apparently lack tributaries of sufficient length or flow velocity to provide suitable spawning or egg incubation habitat. In both cases the higher egg buoyancy of the Chesapeake strain of striped bass was hypothesized as a major reason for reproductive success in these lakes, allowing enough eggs to remain suspended in the absence of high stream flows. Highly-oxygenated bottom water in one of the lakes was also thought to contribute to hatching success and larval survival.

4.2.2 Eggs and Larvae

Striped bass eggs require water current to prevent them from settling to the bottom and dying from suffocation at the substrate interface. Albrecht (1964) concluded a minimum velocity of 0.3 m/sec was required to keep striped bass eggs suspended and deduced that two days developmental time would require a minimum of 48 km of river for successful hatching. Crance (1984) calculated the minimum length of river required for successful spawning by striped bass as approximately 53 km, a similar value to that found by Albrecht (1964) (see Section 3.2.6.4). Albrecht (1964) reported that at a surface velocity of 0.2 m/sec in the San Joaquin River, California, 57% of eggs were collected near the bottom (4.6-7.6 m) of the water column. At a surface velocity of 0.3 m/sec, eggs were more evenly distributed throughout the water column, with 7% to 74% of eggs collected near the bottom and 0% to 81% of eggs collected at the surface (0.01.5 m). At higher velocities, egg densities were generally greater at the surface or mid-column.

River current is also essential to prevent newly-hatched striped bass from settling to the bottom and suffocating until the larvae are able to swim on their own, unless they were hatched in brackish waters and able to float (>3.0 ppt). Soon after hatching, the larvae begin spasmodic swimming and drifting and respond to contact with the substrate by swimming up. Larvae are unable to keep themselves off the substrate, maintain a horizontal position, or overcome minor water currents until four days post hatch (Bayless 1972). To ensure survival and ultimately recruitment into the juvenile population, it is critical that larvae encounter a nursery habitat with an abundance of suitable prey by day-7 post hatch (Bayless 1972). If larvae are not feeding by day-10, they will never accept food regardless of the quality or the quantity of food available. The yolk and oil globule, however, apparently provide sufficient nutritional reserve to allow larvae to survive and grow without feeding for at least that long (Tsai 1991). It is difficult to establish a minimum prey density requirement for striped bass larvae due to the wide range of variation in this characteristic. In general, the higher the prey density, the greater the recruitment success for striped bass larvae (Tsai 1991).

4.2.3 Juveniles

As postlarvae increase in size and age to juveniles (>15 mm), they move from channels to inshore habitats (Kernehan et al. 1981, Uphoff 1989). Young juvenile striped bass tend to utilize beach, sand bar, and shoal areas of lakes, rivers, and bays where food availability and ambient temperatures are most conducive to rapid growth. Larger juveniles and subadults become more pelagic and often move offshore or into deeper channels. This is likely the result of changes in diet or preferred temperature.

4.2.3.1 Substrate

Most of the reported habitat preferences for striped bass are artifacts of where sampling took place and, therefore, may reflect sampling biases by the researchers. Many of these studies (particularly those in riverine and estuarine areas) reported collecting juvenile striped bass with trawls and beach seines, inferring that the habitats sampled were either shallow, sandy beaches or shoals, or deeper areas with firm, clean substrates (Wallace 1975, Dey 1981, Price et al. 1985, Bettross 1991, Dorazio et al. 1991). Setzler et al. (1980) described areas in which juvenile striped bass were collected as generally having bottom types characterized by sand, sand and gravel, or sand and mud. Dey (1981) separated Hudson River estuary sampling locations into shoals (<6 m deep), river channels (>6 m deep), and inshore areas (<3 m deep).

Boynton et al. (1981) estimated that 15 times more juvenile striped bass were collected per unit effort in beach seines on nearshore habitats (depth <1.5 m) than with a high speed bottom sled trawl in offshore habitats (depth to 5 m). Greater abundance and feeding success of juvenile striped bass (25-100 mm TL) in nearshore areas (i.e., beaches) led Boynton et al. (1981) to conclude that this was the preferred habitat for this life stage. Merriman (1941) referred to work by Curran and Reis (1937) who described seining YOY striped bass in the Hudson River and concluded that gravel beaches were the preferred habitat since few fish were taken over other bottom types. Merriman further reported seining YOY striped bass from the Parker River, Massachusetts, over a substrate that was “mostly mud and sand, with little gravel and a few scattered rocks.” Kernehan et al. (1981) found that habitats which yielded the highest catches of postlarval striped bass were shallow, with slow to moderate current, and sand or fine gravel substrates. They found very few fish on riprap shorelines and concluded that beach areas are critical habitat for very young striped bass. Kernehan et al. (1981) further concluded that survival in a particular year might be proportional to the number of postlarvae and early juveniles that migrate to beach habitats. Van Den Avyle and Higginbotham (1979) and Van Den Avyle et al. (1983) found that electrofished YOY striped bass stocked into Watts Bar Reservoir, Tennessee, showed no difference in substrate preference among sand, clay, or rock/gravel habitats through August but demonstrated a significant affinity for sandy shoreline habitats by September, a trend which continued through November. Ager et al. (1983), Mesing and Ager (1987), and Long and Rousseau (1996) reported nocturnal utilization of sandbars and dredge disposal sites by striped bass in the Apalachicola River, Florida. However, mean electrofishing catch rates of YOY striped bass on disposal sites of recently dredged material in the middle Apalachicola River were lower than on older sites in the upper and lower river (Long 2001) indicating that unstable sand is less suitable habitat.

4.2.3.2 Vegetation

Long and Rousseau (1996) evaluated Phase I striped bass stocking in Lake Seminole (Florida and Georgia) and concluded that expansive hydrilla (*Hydrilla verticillata*) coverage in the reservoir had deleterious effects on stocking success. During 1991-1994, when estimated hydrilla coverage expanded to 75% of the lake area, electrofishing results indicated juvenile survival was negatively affected during the first six months after stocking. The extensive hydrilla coverage restricted primary productivity (Carter et al. 1988, Jones 1990) and reduced preferred sandy bottom habitat. Reduction in phytoplankton, in turn, reduced zooplankton populations, thus decreasing feeding efficiency (Maceina and Shireman 1982) and ultimately limiting important prey species such as threadfin shad (*Dorosoma petenense*), gizzard shad (*D. cepedianum*), and skipjack herring (*Alosa chrysochloris*).

4.2.4 Adults

Adult striped bass seasonally utilize a variety of habitats in inshore coastal, estuarine, and large river freshwater systems (Setzler et al. 1980) and in inland reservoirs where they have been introduced or landlocked (Henley 1991, Lantz 1986). Although some Atlantic Coast populations of striped bass undertake extensive coastal migrations, those from about North Carolina southward, including the Gulf, are more riverine in nature and enter coastal and marine waters less extensively (see Section 3.4). Within these rivers, habitat use shifts may occur, with seasonal movements usually associated with spawning, feeding, or thermal refuge needs. The latter is of prime importance to survival of striped bass in Gulf rivers as explained in the next section.

4.2.4.1 Cool Water Refuges

Cool water refuges are one of the most critical habitats for striped bass survival in Gulf rivers and are probably the most important factor limiting abundance (Lukens 1988). Striped bass actively seek out springs and river sections with dense overstory riparian habitat to reduce thermal stress during the summer months (Section 3.3.3.2). Coutant (1985a) used the term thermal niche to describe the temperature range to which adult striped bass are optimally suited, generally 18-25°C. He used the term refuges to describe areas where these water temperature conditions are met when the general ambient conditions in their environment are mostly outside this range. Coutant indicated that these refuges are a critical factor for striped bass survival when they attain a larger size, and they may not reach maturity if oxygenated, cool water habitat is not accessible. Van Den Avyle and Evans (1990) reported that striped bass (63-113 cm) moved into springs in the Flint River, Georgia, apparently to avoid water temperatures exceeding about 23 °C and generally showed a preference for temperatures averaging about 21.6ºC. Coutant (1985a) described striped bass as 'squeezed' between their thermal and DO preferences or requirements. He also reported that crowding due to temperature preferences alone, or coupled with avoidance of low oxygen, can lead to stress-induced pathology and overfishing, both of which can contribute to population declines.

Weeks and Van Den Avyle (1996) found that striped bass use differed among eight thermal refuges studied on the Flint River between Lake Seminole and the Albany Power Dam in Georgia. Striped bass abundance was highest at the site farthest upstream and was positively correlated with potassium concentration and negatively correlated with pH and dissolved oxygen concentrations. They found no significant correlation of striped bass abundance with ambient river temperature or the difference between ambient and refuge temperature.

The importance of thermal refuges to striped bass in Gulf rivers is illustrated by the amount of time they tend to spend in these areas. In their 18-month telemetry study of striped bass in the Flint River, Van Den Avyle and Evans (1990) found 79% of the individual locations determined for telemetered fish to be in thermal refuge areas. Over the course of their study, individual fish spent from 137 to 182 days in thermal refuges.

4.2.4.2 Other Adult Habitats

Other than thermal refuges during summer, the primary habitats of adult striped bass are presumably the pelagic portions of nearshore coastal waters, bays, estuaries, rivers, and reservoirs where they may form schools (Raney 1954) as this is where their principal prey species, clupeids, generally occur (see Section 3.5). In coastal waters, striped bass may be found along sandy beaches, in shallow bays, along rocky shores, among rocks or boulders, in troughs and submerged gullies, under floating vegetation or over sand bars (Setzler et al. 1980). They may also be associated with gravel, muck, detritus, moss, mussel beds (Hardy 1978), oyster reefs, eelgrass beds, and tidal rips (H. Rogillio personal communication). In Lake Pontchartrain, Louisiana, they are known to use drop-offs adjacent to tidal creeks and flats as feeding or holding areas since these offer cover and supply food organisms carried out with the tide (H. Rogillio personal communication). In Atlantic coastal areas, striped bass are usually found relatively close to shore, generally within 8 km (Bigelow and Schroeder 1953) and few beyond 16 km (Raney 1954).

In rivers and reservoirs, striped bass are found, at times, in association with piers, weirs, pilings, bridges, and trestles and in deep holes (Rogillio and Rabalais 2001, Long 2001). They use pelagic areas near dams and the inlet channels of water outlets and submerged river channels (Lantz 1986, Combs and Peltz 1982), as well as the shallower portions of open water pelagic areas and tail waters of dams (Henley 1991, 1996). In J. Percy Priest Reservoir in Tennessee, they inhabited broad open areas of the reservoir usually near creek beds or coves and also island and mud flats where they could drop into the submerged river bed during inactive periods (Stooksbury 1979). Henley (1996) found general habitat types used most commonly by striped bass in portions of the Ohio, Tennessee, and Cumberland rivers were (in order of preference) channel borders, dam tailwaters, and heated discharges. Major specific habitats within these included open bottom substrates, tailwater boils, and woody debris and trees. In Keystone Reservoir on the Arkansas River in Oklahoma, Combs and

Peltz (1982) found that striped bass used staging areas in the upstream portions of the reservoir during the winter and early spring before spawning. They moved upstream to spawning areas in headwater streams during April and May, but in June moved back down into the lower portions of the reservoir near the confluence of the major tributaries and remained there for the summer. In the fall, they dispersed back to the staging areas.

4.3 General Descriptions of Available Habitats in the Gulf of Mexico Region

Striped bass found in the river systems that drain into the Gulf of Mexico primarily utilize coastal habitats associated with estuaries and bays, with minimal use of open Gulf habitat (see Sections 3.3.3.1 and 4.2.4).

In general, the Gulf is a semi-enclosed basin connected to the Atlantic Ocean and Caribbean Sea by the Straits of Florida and the Yucatan Channel, respectively. The Gulf has a surface water area of approximately 1,600,000 km^2 (GMFMC 1998); a coastline measuring 2,609 km; one of the most extensive barrier island systems in the United States; and is the receiving basin for 33 rivers and 207 estuaries (Buff and Turner 1987). These estuaries include some 3.2 million ha of open water and 2.43 million ha of emergent tidal vegetation. Submerged vegetation covers nearly 324,000 ha of bay bottom (Lindall and Saloman 1977).

Tide cycles vary widely throughout the Gulf with diurnal tides (one high tide and one low tide each lunar day of 24.8 hrs) existing from St. Joseph Bay, Florida, to western Louisiana. The tide is semidiurnal in the Apalachicola Bay area of Florida and mixed (diurnal, semidiurnal, and combinations of both) in Louisiana and Texas. Gulf tides are small and noticeably less pronounced than along the Atlantic or Pacific coasts. The normal tidal range at most places is <0.6 m. Despite the small tidal range, tidal current velocities are occasionally high, especially near the constricted outlets that characterize many of the bays and estuaries.

4.3.1 Estuaries

Most of the following estuary descriptions were taken, with permission, directly from the *Gulf of Mexico Fishery Management Council's Generic Essential Fish Habitat (EFH) Amendment* (GMFMC 1998), which provides a comprehensive review of all the literature pertaining to estuarine and marine habitats of particular concern in the Gulf of Mexico. In this section, estuarine habitats are described by state. Where information readily exists, it is presented on individual bays and bay systems.

4.3.1.1 Texas

Texas has approximately 612 km (367 mi) of open Gulf shoreline and contains 3,528 km (2,125 mi) of bay-estuary-lagoon shoreline. This is the most biologically rich and ecologically diverse region in the state and supports more than 247,670 ha (611,760 acres) of fresh, brackish, and salt marshes. Henderson (1997) described the Gulf Coast as containing a diversity of salt, brackish, intermediate, and fresh wetlands. Of the marshes described, saline and brackish marshes are most widely distributed south of Galveston Bay, while intermediate marshes are the most extensive marsh type east of Galveston Bay. The lower coast has only a narrow band of emergent marsh but has an extensive system of bays and lagoons.

From the Louisiana border to Galveston, the coastline is comprised of marshy plains and low, narrow beach ridges. From Galveston Bay to the Mexican border, the coastline consists of long barrier islands and large shallow lagoons. Within this estuarine environment are found the profuse seagrass beds of the Laguna Madre, a rare hypersaline lagoon, and Padre Island, the longest barrier island in the world (TGLO 1996). The Intracoastal Waterway, a maintenance-dredged channel, extends from the Lower Laguna Madre to Sabine Lake. Dredging of the channel has created numerous spoil banks on islands adjacent to the channel.

The major bay systems from the lower-to-upper coast are Lower and Upper Laguna Madre; Corpus Christi and Aransas bays; San Antonio, Matagorda and Galveston bays; and Sabine Lake. In 1992, these estuaries contained 627,560 ha of open water (estuarine subtidal areas), and 1,576,823 ha of wetlands existed along the Texas coast. About 85.3% of the total wetlands were palustrine, 14.5% estuarine and 0.1% marine. There were 711,576 ha of deepwater rivers (24,356 ha); reservoirs (59,661 ha); and estuarine bays (627,560 ha) (Moulton et al. 1997). Climate ranges from semiarid on the lower coast (where rainfall averages 635 mm) to humid on the upper coast where average annual rainfall is 1,397 mm (Diener 1975). Detailed information on temperature, salinity, DO, and turbidity collected from Texas estuaries during routine trawl samples from 1983 to 1996 is available from the Texas Parks and Wildlife Department (TPWD unpublished data).

Texas estuaries support a number of species of emergent vegetation consisting of shoregrass (*Monanthochloe littoralis*), glasswort (*Salicornia bigelovii*), seacoast bluestem (*Schizachyrium scoparium*), salt meadow cordgrass (*Spartina patens*), rush saltwort (*Batis maritima* and *B. maritima*), glasswort (*Salicornia bigelovii*), smooth cordgrass (*Spartina alterniflora*), coastal dropseed (*Sporobolus virginicus*), seashore saltgrass (*Distichlis spicata*), seablite (*Suaeda linearis*), sea oats (*Uniola paniculata*), seashore saltgrass (*Distichlis spicata*), rush (*Juncus roemerianus*), shoregrass (*Monanthochloe littoralis*), bulrush (*Scirpus maritimus* and *S. olneyi*), and gulfdune paspalum (*Paspalum monostachyum*) (Diener 1975). Common reed (*Phragmites communis*) is reported in a few areas as well.

Submergent vegetation includes a number of species with the dominants consisting of turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*). In addition, shoal grass (*Halodule wrightii*), clover grass (*Halophila*), and widgeon grass (*Ruppia maritima*) also occur (Diener 1975, Pulich et al. 1997, Pulich 1998).

4.3.1.2 Louisiana

Coastal Louisiana is predominately a broad marsh indented by shallow bays containing innumerable valuable nursery areas. Total estuarine area in 1970 encompassed more than 2.9 million ha; over 1.5 million ha in marsh vegetation, and more than 1.3 million ha of surface water area (Perret et al. 1971). These waters are generally shallow with over half between zero and 1.8 m in depth. Sediments consist of mud, sand, and silt and are very similar across the coast ranging from coarse near the Gulf and barrier islands to fine in the upper estuaries (Barrett et al. 1971). Extensive wetlands loss is occurring in coastal Louisiana. By 1990, Louisiana had only 1.53 million ha of coastal wetlands remaining; only 1.02 million ha were marsh and only 0.43 million ha were non-fresh marsh (USGS 1997).

Emergent marsh amounts to more than 1.58 million ha and is made up of four main types (USGS 1997):

1. Saline (349,231 ha), consisting of smooth cordgrass (*Spartina alterniflora*), glasswort (*Salicornia* sp.), black needlerush (*Juncus roemerianus*), black mangrove *(Avicennia nitida*), saltgrass (*Distichlis spicata*), and saltwort (*Batis marina*)
2. Brackish (487,174 ha), made up of wiregrass (*Spartina patens*), threecorner grass (*Scirpus olneyi*), and coco (*Scirpus robustus*).
3. Intermediate (263,288 ha), consisting of wiregrass (*Spartina patens*), deer pea (*Vigna repens*), bulltongue (*Sagittaria* sp.), wild millet (*Echinochloa walteri*), bullwhip (*Scirpus californicus*), and sawgrass (*Cladium jamaicense*).
4. Fresh (482,939 ha), consisting of maiden cane (*Panicum hemitomon*), pennywort (*Hydrocotyle* sp.), pickerelweed (*Pontederia cordata*), alligator weed (*Alternanthera philoxeroides*), bulltongue (*Sagittaria* sp.), and water hyacinth (*Eichhornia crassipes*).

Average annual stream discharge is 19,208 m^3/s (678,736 CFS); more than 90% discharges from the Mississippi and Atchafalaya rivers. Peak discharge usually occurs in April and May; low flow occurs typically in September and October. During floods, freshwater is carried far into the Gulf and into neighboring estuaries resulting in lower salinities there.

Live oyster beds amount to more than 53,825 ha. More than 46,945 ha are in private leases; of which the largest are in St. Bernard (14,949 ha), Plaquemines (15,239 ha), and Terrebonne (8,234 ha) parishes. Some 486 ha of public reefs occur in Cameron Parish and are open seasonally to oyster harvest. The remaining 6,659 ha are in the Seed Ground Reservation managed by the state and are in Jefferson, Plaquemines, and Terrebonne parishes.

More than 1,610 km of navigation channels designed and/or maintained by the U.S. Army Corps of Engineers are in the estuarine zone. The longest is the Gulf Intracoastal Waterway (GIWW) (486 km) from Lake Borgne to the Sabine River. Navigation channels account for nearly all of the more than 10,522 ha of fill.

Barrett et al. (1971) provided abundant data on the hydrological aspects of Louisiana's estuaries. In general, the estuaries and near offshore waters are low in salinity and high in nutrients compared with the other Gulf States. High rainfall and large volume of river discharge account for these characteristics. The Mississippi and Atchafalaya rivers are the main contributors of nutrients to the estuaries and are responsible for the large dilutions in salinity within the coastal area. See Barrett et al. (1971) for details on the hydrological aspects of Louisiana's estuaries.

Perret et al. (1971) reported that the only significant area of SAV on the Louisiana coast was on the northern shore of Lake Pontchartrain and encompassed approximately 8,100 ha of grass beds consisting of widgeon grass (*Ruppia maritima*) and wild celery (*Valliseria* sp.). Cho and Poirrier (2004) reported SAV in Lake Pontchartrain had declined by more than 50% since the mid-1950s. No grass beds were found along the south shore of the lake between 1996 and 1998 (Penland et al. 2002). By the early 1990s, most of the extensive beds of wild celery had disappeared, but there was an increase in widgeon grass during 1996-2000 (Cho and Poirrer 2004). Darnell (1958) noted heavy rainfall during spring or fall produced nutrient-rich waters which drained into the lake causing a floating phytoplankton (*Anabaena* sp.) to become so abundant that it literally formed mounds of scum on the water's surface. Large mats of duckweed (*Lemna minor*) followed heavy rainfall (Darnell 1958).

4.3.1.3 Mississippi

Mississippi Sound is a relatively shallow estuary aligned in a generally east-west direction along Mississippi and Alabama bounded on the east by Mobile Bay and the west by Lake Borgne. Barrier islands form a partial boundary separating the sound from the Gulf of Mexico. Numerous marsh isles in southeast Louisiana complete the southern boundary. Unless otherwise noted, the following information on Mississippi estuaries was condensed from Christmas (1973) and Eleuterius (1976a, 1976b) as summarized in GMFMC (1981).

Mississippi Sound is a system of estuaries adjoining a lagoon. The sound, separated from the Gulf of Mexico by a chain of barrier islands, acts as a mixing basin for freshwater discharge from rivers and seawater entering through the barrier island passes. The complexity of the system does not readily lend itself to concise hydrological classification. Both north-south and east-west salinity gradients exist in addition to vertical gradients. Overall, positive salinity gradients exist from the mainland seaward and vertically, surface to bottom. In periods of peak river discharge, the water column may be homogeneous.

Seasonally, salinities are lowest in the early spring, rise sporadically through the summer, and peak in the fall. Temperatures follow expected seasonal trends, with lowest averages in January or February and highest averages in July or August. Levels of dissolved oxygen are usually above lethal limits. Temporary oxygen depletion may occur in deep holes and behind sills in river channels. Anoxia, resulting from excessive biological oxygen demand, occurs periodically in waters near heavily populated areas and in waters subject to industrial outfalls.

The salinity regime of eastern Mississippi Sound is determined largely by the influx of Gulf waters through Petit Bois, Horn, and Dog Keys passes and the outflow of waters from Mobile Bay, the Pascagoula River, and Biloxi Bay. Water from Mobile Bay appears to exit Mississippi Sound entirely through Petit Bois Pass; thus, the west branch of the Pascagoula River becomes the major source of freshwater into the Sound. The outflow from this branch moves westward along the shoreline to Belle Fountaine Beach where it turns and eventually exits through Dog Keys Pass. During periods of high river flow, waters from the Biloxi Bay drainage area join with the outflow from the West Pascagoula River. The discharge from the East Pascagoula River is directed toward the Gulf by dredge spoil deposited along its channel, and this spoil disrupts the westerly flow of water in the eastern sound. A persistent saltwater wedge remains in this channel extending many miles above the river mouth. These waters exhibit a highly stable density structure, and bottom salinity at the mouth of the river can reach 35.0 ppt. Larvae and postlarvae of commercially - important fish and shellfish occur routinely in this channel.

The western end of Mississippi Sound is heavily influenced by drainage from the Pearl River, the Lake Borgne-Lake Pontchartrain complex, and St. Louis Bay. Depressed surface salinity is a natural occurrence for short periods. During periods of high river flow, Ship Island Pass becomes the main passage for the entrance of saltwater into the sound. Tides in Mississippi Sound are diurnal with an average range of 46 cm.

The Pascagoula and Pearl rivers, Bayou Casotte, and Biloxi Bay are the primary sources of nutrients entering Mississippi Sound. Waters adjacent to industrial areas or subject to effluent discharge and associated BOD loadings exhibit greater variability in nutrient levels. Consequently, high levels of phosphorus and nitrogen are found in the Bayou Casotte area where fertilizer-manufacturing plants are located. Coast-wide, there is a general decline in nutrient concentrations from the mainland to the barrier islands and southward into the Gulf (F. Deegen personal communication).

Silty clay is the dominant sediment in Mississippi Sound. Coastal bays receive large volumes of sandy and silty-sandy sediments from the surrounding mainland. In addition, these embayments and the sound proper receive clay-silt sediments from the rivers. Fine sediments are also carried into the sound via tidal currents from Lake Pontchartrain and Mobile Bay. The central portion of the sound is composed of silt and clay mud. In some areas these sediments grade into fine and very fine sands. Medium and coarse sands characterize the barrier islands and are also found along the mainland beach west of the Pascagoula River. Medium to coarse sands extend from Round Island in Mississippi Sound to Horn Island.

The shallowness of the sound (average depth at mean low water is 2 m), its sediments, and wave action are responsible for the turbidity of the water. In most months, nearshore waters are brown in color due to suspended fine sediment in the water column. In periods of peak river flow, these muddy waters may reach and extend beyond the barrier islands.

There were approximately 26,237 ha of mainland marsh identified in south Mississippi in 1968, of which 24,853 ha were dominated by black needlerush (*Juncus roemerianus*). Smooth cordgrass (*Spartina alterniflora*), wiregrass (*Spartina patens*), and threecorner grass (*Scirpus olneyi*) comprised the remaining acreage. Tidal marsh is most extensive in the Pascagoula and Pearl rivers, with areas of 5,400 ha and 3,522 ha, respectively. Saltmarsh on the barrier islands covered 860 ha.

4.3.1.4 Alabama

Crance (1971) divided the Alabama coastal zone into five estuarine systems: Mississippi Sound, Mobile Bay, Mobile Delta, Perdido Bay, and Little Lagoon. Combined, these estuaries contain an open-water surface area of 160,809 ha plus 14,008 ha of tidal marsh. Total acreage of submerged vegetation is unknown, but an estimated 2,024 ha are in Mobile Bay. There are some 2,039 ha of live oyster beds, with more than 1,214 ha of public beds and nearly 809 ha in private leases. More than 850 ha of estuarine habitat have been filled for various purposes.

Mean tidal range is small, varying from about 0.3 m at the head of Mobile Bay to about 0.5 m at the entrance. Annual mean discharge of gauged streams in the Mobile River system is 1,659 m^3/s (58,636 CFS). Salinity is highly variable with oceanic levels occurring at the Gulf passes at times, and freshwater at the upward end of the estuary is often present.

In higher salinity areas, the major emergent species are black needlerush (*Juncus roemerianus*), smooth cordgrass (*Spartina alterniflora*), big cordgrass (*S. cynosuroides*), wiregrass

(*S. patens*), and saltgrass (*Distichlis spicata*). Submerged vegetation includes patches of shoal grass (*Halodule wrightii*), widgeon grass (*Ruppia maritima*), and slender pondweed (*Potamogeton pusillus*) (Crance 1971).

In lower salinity areas, alligator weed (*Alternanthera philoxeroides*) and *Phragmites communis* are more abundant. The major species of submerged vegetation are southern naiad (*Najas guadalupenis*), wild celery (*Vallisneria spiralis*), horned pondweed (*Zannichellia spiralis*), slender pondweed (*Potamogeton pusillus*), and *Nitella* spp. (Crance 1971).

4.3.1.5 Florida

McNulty et al. (1972), in conducting the Florida portion of the Gulf of Mexico Estuarine Inventory (GMEI), provided a comprehensive description of the natural and man-made features of the estuaries on the Florida Gulf Coast. The report covers some 40 estuarine areas from Perdido Bay at the Florida/Alabama border to Florida Bay. Unless otherwise noted, the following information is from McNulty et al. (1972).

The total area of Florida west coast estuaries is 1,215,440 ha, including open water, tidal marsh, and mangroves. Open water amounts to 824,393 ha. Tidal marshes cover 213,895 ha and extend northward the full length of the coast, first as a transition zone between mangroves and freshwater marshes, then as the predominant plant community of the north shore of Tampa Bay. Black needlerush (*Juncus roemerianus*) predominates, but several species are locally abundant, among them saltmarsh cordgrass (*Spartina alterniflora*), saltmeadow cordgrass (*Spartina patens*), seashore saltgrass *(Distichlis spicata*), *Salicornia perennias*, sea-oxeye (*Borrichia frutescens*), *Batis marina*, and *Limonium carolinianum*. Mangroves occupy 159,112 ha. The three common mangroves in their order of abundance and zonation landward are the red (*Rhizophora mangle*), black (*Avicennia germinans*), and button wood (*Conocarpus erectus*). A fourth and less abundant species, the white mangrove (*Laguncularia racemosa*), generally grows landward of the black mangrove.

Submerged vegetation covers 210,618 ha. Shoal grass (*Halodule wrightii*) and widgeon grass (*Ruppia maritima*) are abundant intertidally, whereas turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), *Halophila decipens*, and star grass (*H. engelmannii*) are found only below low water levels. In most of Florida's estuaries, seagrasses are found at depths to about 2.1 m, except where water is exceptionally clear (e.g., portions of Pensacola Bay) where they are found to about 3.6 m.

There are nearly 5,666 ha of live oyster beds (2,074 ha in private leases and 3,529 ha in public beds) in the panhandle estuaries of Apalachicola Bay and St. George Sound. More than 71,066 ha of estuarine bottom have been closed to shell fishing because of unacceptable levels of coliform bacteria.

Stream discharge in north Florida estuaries is much greater than that in central and south Florida. Mean stream discharge for the west coast is 1,988 m^3/s (70,251 CFS). More than 70% of the runoff is from the Apalachicola, Suwannee, Choctawhatchee, and Escambia rivers. The Apalachicola River accounts for about 35%, and the Suwannee River accounts for nearly 15%.

4.3.2 Watersheds and River Systems

The native historical distribution of striped bass in Gulf rivers (Section 3.1; Figure 3.1) is believed to have been restricted to those portions of rivers within the Coastal Plain physiographic province. The province is underlain by sedimentary layers formed during the Cretaceous, Tertiary, and Quarternary periods (Isphording and Fitzpatrick 1992). Tertiary sediments predominate in areas traversed by most of the Gulf rivers (Felley 1992). Geologically, this province is considered to extend seaward to the edge of the continental shelf, and the lower portions of most streams that drain to the Gulf are drowned river valleys resulting from recent (within the last 50,000 years) sea level rise. Land forms include gentle rolling hills, sharp ridges, prairies, and broad, alluvial floodplains (Mettee et al. 1996).

The Coastal Plain province is separated from those provinces to the north by the fall line (Figure 3.1), which is the zone of contact between the hard rocks of the interior provinces and the unconsolidated sediments of the Coastal Plain (Mettee et al. 1996) and associated with rapids and steep gradients in streams. In the Gulf drainages, the fall line probably formed a natural barrier that restrict, but may not have totally prevented upstream movement of striped bass in the MAT and ACF systems. Although the Mississippi-Atchafalaya system also extends north of the fall line, that system lacks steep gradients that would have otherwise limited migration of striped bass (Isphording and Fitzpatrick 1992).

Except for the large alluvial rivers mentioned above, most Coastal Plain lotic systems within the Gulf striped bass native range are sometimes referred to as blackwater streams (Smock and Gilinsky 1992). These streams typically have higher dissolved organic carbon (5-50 ppm) and higher acidity than do their larger counterparts. The dissolved organics often impart a dark color to these streams, hence the term "blackwater." Many of the generalizations made in the succeeding paragraphs apply generally to the blackwater streams and may not hold as true for mainstem portions of the larger alluvial systems which, arising in higher gradient areas outside of the Coastal Plain, are typically higher energy and may differ also in physicochemistry, suspended load, and channel morphology. The description may also not accurately characterize most streams in Texas. As a group, the rivers of the Gulf Coastal Plain are diverse and much remains to be learned about them (Livingston 1992); the general descriptions below should be read with that caveat in mind.

The Mississippi Embayment divides the Gulf Coastal Plain province into west and east regions. The Mississippi Embayment, which generally defines the present lower Mississippi River floodplain area, was formed by regional down-warping of the continental margin during the Cretaceous and Tertiary periods (120 million to 12 million years ago). This basin was submerged by seawater during the late Cretaceous Period after which it was filled in by sedimentation during succeeding periods. These sediments are up to 12,100 m thick in places (Isphording and Fitzpatrick 1992). The Mississippi Embayment extends from near Cairo, Illinois, approximately 800 km to the Gulf and varies in width from 80 to 160 km (Isphording and Fitzpatrick 1992). The native Gulf striped bass range is almost entirely restricted to the East Gulf Coastal Plain.

The climate for Alabama, as described by Mettee et al. (1996), can probably be applied to the entire native range of striped bass in the Gulf Coastal Plain, encompassing the area between 31° and 35° north latitude. The climate is subtropical and humid. Summer high and low temperatures average 32°C and 21°C, respectively. Winter highs average 7°-10°C, and winter lows average 1°-4°C. Rainfall and river discharge are generally greatest during December-March, usually associated with cold front passage, and lowest during late summer and fall. Summer thunderstorms, primarily in July, also account for a considerable amount of rainfall, particularly in the extreme eastern portion of the striped bass' native range. In this area, rainfall may actually be highest in summer and fall (Felley 1992). Average annual precipitation is about 152 cm (Smock and Gilinsky 1992).

All streams within the native range of the Gulf striped bass are warmwater (Felley 1992). Stream gradients are moderate to low (Isphording and Fitzpatrick 1992), usually less than 0.1% (Smock and Gilinsky 1992) with moderate to high discharges; low turbulence; and rubble, sand, and mud substrates (Felley 1992). The presence of woody debris (snags) is important in determining channel morphology and ecological characteristics of these streams (Felley 1992, Smock and Gilinsky 1992). Suspended sediment load differs considerably among streams and also varies temporally, generally highest and most variable during the wet season due to runoff and erosion. Temperatures tend to increase downstream during the dry season but are typically higher in upstream areas during periods of high rainfall during winter and spring (Felley 1992). Except for the streams draining over limestone deposits of the Florida peninsula, nutrient levels, pH, conductivity, and hardness generally tend to be low, and dissolved oxygen relatively high – normally not dropping below 70%. Exceptions tend to occur in low-order streams during the dry season, in streams receiving municipal or industrial effluents, and in freshwater portions of tidal streams or in spring-fed streams (Felley 1992). It should be noted that many of the Gulf rivers where native striped bass were known to occur historically contained springs. The waters from these springs tend to be higher in pH and harder with higher levels of phosphate and chloride ions than in waters that are not spring-fed. This higher hardness has been credited with allowing marine species to more easily invade such streams (Swift et al. 1977).

As described by Felley (1992), submerged vegetation tends to be sparse in most Gulf Coastal Plain rivers and streams. Upstream primary production occurs mostly in riparian forests or swamp areas bordering the streams. Algae, periphyton, and diatoms growing on branches and snags in the water also contribute to primary production. Submerged vegetation is more commonly found in the lower reaches with more stable substrates, in oxbows, and in adjacent canals and sloughs. Generally, submerged plants occurring in Gulf rivers include water nymph (*Najas guadalupensis*); coontail (*Ceratophyllum demersum*); cabomba (*Cabomba caroliniana*); bladderwort (*Utricularia vulgaris*); pondweed (*Potamogeton* sp.); eelgrass, also known as wild celery (*Vallisneria americana*); bogmoss (*Mayaca fluviatilis*); and water hyssop (*Bacopa monnieri*). Other commonly-found species in some rivers include parrot-feather (*Myriophyllum aquaticum*) and waterweed (*Elodea canadensis*) (Peterson et al. 1996). Vascular plants and other substrates can be carpeted with epiphytic macroalgae and microalgae. Unicellular forms include various diatoms (*Achnanthes* spp., *Cymbella* spp., *Epithemia* spp., *Gomphonema* spp., *Navicula* spp., *Nitzshia* spp.) and phytoflagellates (*Chlamydomonas* spp., *Euglena* spp., *Trachelomonas gibberosa*) (Felley 1992). A common freshwater macroalga is *Batrochspermum*, most often attached to snags in flowing water.

Felley (1992) stated that emergent plant species found in coastal plain streams tend to be forms that can grow in flooded conditions as well as on saturated or drying soil, conditions which are typical of the water level and flow characteristics of these streams. Upstream portions typically flow through pine (*Pinus* sp.) and mixed hardwood forest. Trees such as bald cypress (*Taxodium* *distichum*) and water tupelo (*Nyssa aquatica*) grow along the edges of many of these streams and help to stabilize banks. Other emergent species include saw grass (*Cladium jamaicense*), pickerelweed (*Pontederia cordata*), alligatorweed (*Alternanthera philoxeroides*), watershield (*Brasenia schreberi*), water lily (*Nymphea* spp.), buttonbush (*Cephalanthus occidentalis*), water hyacinth (*Eichornia crassipes*), arrowhead (*Sagittaria* spp.), spike rush (*Rynchospora* sp.), golden club (*Orontium aquaticum*), yellow-eyed grass (*Xyris* sp.), rush (*Juncus* spp.), cow-lily and spatterdock (*Nuphar* sp.), St. John's wort (*Hypericum fasciculatum*), burr-reed (*Sparganium americanum*), and cattail (*Typha* sp.). Another commonly found species in some rivers is wild rice (*Zizania aquatica*) (Peterson et al. 1996). Emergent plant communities in the tidally-influenced coastal plain rivers are typically dominated by black rush (*Juncus romerianus*) and smooth cordgrass (*Spartina alterniflora*) (Christmas 1973, Patrick 1994).

The invertebrate communities of Gulf Coastal Plain streams tend to be diverse with species composition changing from headwater to downstream areas (Felley 1992). Extreme headwaters, which may include ephemeral streams and ponds with a mostly detrital trophic base, are typically inhabited by rotifers, copepods (primarily *Diaptomus* spp.), cladocerans, amphipods, isopods, odonates, and culicids. Moving downstream to permanent water areas, oligochaetes and chironomids tend to dominate the invertebrate community. Other groups include ephemeropterans, ceratopogonids, gastropods, and crayfish. In sand-bottomed streams, riffle beetles (Elmidae) and trichopterans are abundant but tend to decrease in abundance further downstream. Downstream reaches include isopods, amphipods, phantom midge larvae (Chaoborinae), various pelecypods, and freshwater shrimp such as *Palaemonetes paludosus*. The most abundant pelecypod in many streams is the non-indigenous Asiatic clam *Corbicula* sp.

The most productive habitats for invertebrates tend to be those with vegetation or fine sand/mud substrates and little current velocity. Substrates of sand and sand/litter, which are most typical of smaller stream segments, are less productive. Snags and woody debris are important productive habitats in many of these systems (Marzolf 1978, Meffe and Sheldon 1990, VanderKooy 1994). Smaller, sand-bottomed streams typically experience lowest production during the low-flow season, while downstream habitats in larger rivers typically have peak production during that same period (Felley 1992).

Felley (1992) listed 72 species characteristic of the freshwater fish fauna of Coastal Plain streams in the native Gulf striped bass range, though this list is not exhaustive. Fish communities tend to be dominated by minnows (Cyprinidae), sunfishes (Centrarchidae), darters (Percidae), and suckers (Catostomidae). Estuarine and freshwater species can occur together at the saltwater/freshwater interface. Predatory species are usually not abundant numerically, but they may account for significant biomass with the more important species being black bass (*Micropterus* spp.), spotted gar (*Lepisosteus oculatus*), and bowfin (*Amia calva*). Longnose gar is also common in the Gulf systems (J. Barkuloo personal communication). Although some are endemic, most species occurring in the Gulf systems are widely distributed. Floodplains are critically important components of Coastal Plain streams as they relate to overall productivity and ecological function (Smock and Gilinsky 1992). While substantial variation exists between streams, physicochemistry (conductivity, total dissolved solids, total nitrogen) strongly influences invertebrate and fish production. However, the lower reaches of larger rivers exhibit less between-stream production variability. These lower reaches have higher levels of in-stream primary production and are less reliant on allochthonous input from the watershed.

4.3.2.1 Reservoirs

Reservoirs result from impounding river waters behind a dam and are common throughout the Southeast. Typically, they are developed for flood control, hydropower, navigation, and water supply (Livingston 1992). Many are now also used for recreation. Approximately 144 major reservoirs have been constructed on rivers in the Southeast (Soballe et al. 1992). The USACOE and the Tennessee Valley Authority (TVA) constructed most of these dams during the middle portion of the 20th Century. Most suitable sites for major dams were utilized by the 1970s, and dam construction has declined drastically since (Soballe et al. 1992).

Soballe et al. (1992) reported that Southeast reservoirs encompass a wide range of hydrological and limnological conditions. They are typically large (median surface area 52 km^2), deep (mean depth 7.7 m), and morphologically complex. Many Southeast reservoirs tend to be linear, exhibiting both lotic (flowing water) and lentic (non-flowing water) characteristics (i.e., both vertical and longitudinal gradients in limnological and biological conditions). Some limnologists have referred to them as river/lake hybrids with upstream portions typically more riverine, a transitional zone toward the middle, and more lacustrine at the lower end. These reservoir zones are dynamic and tend to change in response to inflow, stratification, and dam operation.

A major factor influencing southeastern reservoir ecology is morphometry (physical dimensions and shape). Most exhibit a dendritic (branching) shape with numerous coves, islands, and embayments resulting in high shoreline development ratios (SDR, ratio of shoreline length to that of a circle of the same area). Reservoirs constructed by the USACOE in the Southeast have a median SDR of 12. By comparison, most natural lakes have an SDR of less than three. Reservoirs with a higher SDR generally have a larger watershed than most natural lakes of comparable surface area and tend to be more strongly influenced by watershed conditions than are natural lakes of similar size (Soballe et al. 1992).

Soballe et al. (1992) grouped reservoirs in the Southeast into two major categories based on stream location and water residence time:

1. Tributary reservoirs generally have watersheds of less than 10,000 km^2 and mean water residence times of 263 days.
2. Mainstem reservoirs have watersheds greater than 10,000 km^2 and mean water residence time of 51 days.

The mainstem reservoirs constitute the majority in the Southeast. Mainstem reservoirs typically have less dramatic water level fluctuations, greater nutrient loads, and better-developed littoral communities than do tributary reservoirs. Tributary reservoirs tend to stratify during most of the growing season, but many mainstem reservoirs may stratify intermittently or not at all.

Nutrient inputs tend to be higher for reservoirs on a per unit basis than for natural lakes. However, lower water residence times, generally higher turbidities, and a relatively small contribution to production by rooted littoral vegetation provide for lower average productivity in reservoirs of the Southeast when compared to natural lakes (Soballe et al. 1992). This is a significant difference from these rivers in their natural state, where much stream productivity comes from the floodplain during seasonal over bank flooding (Power et al. 1988), a phenomenon that is generally prevented by dams and impoundments. Primary productivity tends to be lowest in the riverine zone of reservoirs, peaks in the transitional zone, and may decline in the lacustrine zone due to nutrient depletion through hypolimnetic discharge. In some reservoirs, periphyton is a significant source of productivity due to snags and standing timber left in the reservoir basin when it was filled. This initially produces high levels of productivity which stabilize at lower levels after five to ten years (Soballe et al. 1992). In some reservoirs, particularly those with relatively stable water levels, rooted and floating aquatic vegetation, such as *Hydrilla* sp., may become a nuisance (Soballe et al. 1992) and actually reduce pelagic productivity (Carter et al. 1988, Jones 1990).

Soballe et al. 1992 reported that the benthic community is quite important to fish productivity in reservoirs of the Southeast. In DeGray Reservoir, Arkansas, for instance, benthos account on average for 36% of the fish standing crop, compared to only 10% being supported by zooplankton. Benthic communities change dramatically following inundation, with increases in some forms (e.g., chironomids and oligochaetes) and decreases in others (e.g., Ephemeroptera, Tricoptera, and Plecoptera). The effects on pelecypod molluscs were particularly profound, and many species became extinct or are now imperiled due to extensive impoundment. Fluctuating water levels in reservoirs also affect benthos due to stranding and desiccation, burial by sedimentation, changes in substrate size and absence of littoral macrophytes. Maximum benthic invertebrate abundance in reservoirs tends to occur in the upper or riverine zone, and decreases toward the lacustrine zone.

According to Soballe et al. (1992), fishes inhabiting reservoirs tend to be food generalists, feeding at various trophic levels depending on season and age. A strong correlation was found between fish production in reservoirs and the morphoedaphic index (MEI, total dissolved solids/mean depth). Fish abundance in reservoirs was generally found to be highest in the riverine zone and lowest in the lacustrine.

Dam operations can substantially affect reservoirs as well as downstream habitats. Of most significance are quantities, timing, and depths from which water is released. Typical operations for hydropower and flood control result in substantial fluctuations in water depth in the reservoir. Since mainstem reservoirs often are operated as part of navigational systems, water level fluctuations in those bodies tend to be less extreme than in tributary reservoirs, though still substantial (Soballe et al. 1992). Timing of water releases has significant effects on downstream conditions. Although reservoirs tend to dampen the natural seasonal fluctuations in flow, they, particularly hydropower dams, often result in dramatic short-term changes. These changes can result in daily flooding and de-watering cycles that may strongly affect downstream aquatic habitats (Soballe et al. 1992).

Depth of water release also significantly affects reservoir and downstream aquatic habitats, particularly if the reservoir stratifies. Stratification occurs when warmer, well-oxygenated epilimnetic (upper water column) waters sit atop a cooler hypolimnion (lower water column), which is less oxygenated through the summer and fall. Most hydropower reservoirs in the Southeast release water from the bottom of the dam, resulting in discharge of cooler, less-oxygenated hypolimnetic water during summer and fall. As nutrients also tend to accumulate in the hypolimnion, these reservoirs may become nutrient deficient in the lower ends and nutrient enriched in tailwaters (Soballe et al. 1992). Approximately 75% of the reservoirs in the Southeast are arranged in series on rivers; for example, the Mobile River system has 19 impoundments in series. Hypolimnetic discharges from reservoirs in series may facilitate the transport of nutrients and contaminants through the reservoirs, thus amplifying effects on downstream habitats. The ecological effects of series impoundments on some rivers can be substantial (Soballe et al. 1992).

Benthic habitats downstream of dams are particularly affected by temperature and flow fluctuations that are radically different from that in natural streams due to hypolimnetic discharges. Major effects include scouring of downstream channels due to lack of bed load in the discharge waters; changes in the quality and quantity of particulate food sources available to downstream benthos; and release of water that may be anoxic, nutrient enriched, and/or contaminated with toxic materials (Soballe et al. 1992).

While some fish species common in riverine habitats can survive in reservoirs, many cannot and soon disappear following inundation. Also, the cold waters of hypolimnetic discharges may eliminate most native fish species for considerable distances downstream of reservoirs. Consequently, fishery managers have stocked a variety of game and forage fish species (often non-native) such as striped bass, rainbow trout (*Onchyrincus mykiss*), northern pike (*Esox lucius*), yellow perch (*Perca flavensces*), and walleye (*Stizostedion vitreum*) in reservoirs and tail waters to maximize sport fishery benefits. In many cases these measures have produced beneficial sport fisheries but in some instances have contributed to declines in native species. In situations where reservoirs were built in series on a river, overall fish species diversity may decline such as in the case of West Point Reservoir on the Chattahoochee River of Alabama and Georgia. Before impoundment in 1975, there were 53 fish species in the river, but there were only 32 fish species by 1979, a number that included six non-native species that had not occurred in the stream before impoundment (Soballe et al. 1992). Water level fluctuations in reservoirs most affect fish populations if they: are large (i.e., several meters); long term (i.e., several months); occur during the growing season; or inundate or eliminate productive littoral or terrestrial vegetation.

A number of reservoirs have been established within the native striped bass range in the coastal plain portions of some Gulf rivers. Dams and reservoirs have had the obvious effects of producing physical barriers to migration of striped bass and other diadromous species (Soballe et al. 1992). At the same time, these physical barriers may also have eliminated historical spawning habitats and other critical areas for these species. Many of these reservoirs were stocked with striped bass and/or hybrid striped bass (hybrids, striped bass×white bass) for recreational fisheries enhancement or to more effectively utilize large forage fishes. In addition, some reservoirs located above the fall line on tributaries of the Mississippi/Atchafalaya River system (i.e., the Ohio, Red, and Missouri) and in coastal plain rivers farther west (i.e., western Louisiana and Texas) that are outside of the native range of striped bass in the Gulf, have been stocked with striped bass and hybrids. In addition to providing certain types of habitat important for striped bass within their reservoirs (i.e., thermal refuges, nursery habitat, and pelagic food sources), dams may also provide within their tail waters important thermal refuge habitats for striped bass in some rivers (Coutant 1985a). A major factor in managing coastal anadromous striped bass populations in rivers where striped bass have been stocked in reservoirs is the escapement of striped bass that contributes to downstream populations. Most of these stocking programs historically utilized and still use Atlantic race striped bass. While most of these reservoir populations do not reproduce, strongly reproductive populations of Atlantic race striped bass have become established in Lake Texoma on the Red River (Schorr et al. 1995), and Keystone Reservoir on the Arkansas River in Oklahoma (Mensinger 1970). What are believed to be Atlantic race striped bass are also reproducing in Lake Weiss, a reservoir on the Coosa River in northern Georgia (Davin and Smith 2001, Smith and Catchings 1998).

4.3.3. Rivers

In the following sections, major Gulf river systems of relevance to striped bass are described from west to east. Lukens (1988) conducted an analysis of various habitat suitability criteria for striped bass during spawning, egg/larval, juvenile, and adult stages. Criteria assessed included water temperature, DO, pH, food availability, water quantity and velocity, and contaminants for the free-flowing portions of major river systems across the Gulf of Mexico. The conclusions of that assessment were whether a river was a high, medium, or low priority for maintenance of a striped bass population; those conclusions are mentioned in the following sections. It should be noted, however, that Lukens (1988) did not address availability of thermal refuge habitat.

In some of the following subsections, reference is made to the stocking of striped bass and/or hybrids. This is done simply to indicate that striped bass habitat may potentially exist in some of these rivers as a consequence of introductions outside the native range of the species. References are not made in these subsections to striped bass introductions within the historic native range. A more detailed discussion of striped bass stocking is given in Section 3.8.

4.3.3.1 Texas

While Texas is outside the historic range of striped bass as defined in this document, Atlantic race striped bass and hybrids have been introduced to provide sport fisheries in numerous reservoirs on Texas rivers, and escapees from these reservoirs have resulted in small striped bass populations downstream.

In general, Texas river systems drain regions that are significantly more arid than rivers farther east, receiving an average of 38-72 cm of rainfall per year (Livingston 1992). The floodplains of these rivers tend to be disproportionately wide relative to flow volumes due to generally higher rainfall in the region 10,000 to 18,000 years ago (Livingston 1992). Although the Sabine-Neches River system resembles neighboring streams to the east in Louisiana, the rivers to the west are quite different ecologically from the other Gulf river systems.

Stelly (1993) ranked 18 Texas coastal streams for their suitability to support various life stages of striped bass using water velocity, DO, temperature, and length of unobstructed river below the farthest downstream obstruction as parameters. No river system ranked particularly high for any life stage. Rankings were assigned with one (1) being the highest suitability.

4.3.3.1.1 Rio Grande

The Rio Grande forms the border between Texas and Mexico and drains portions of Mexico, southwest Texas, most of New Mexico, and portions of the eastern slopes of the Sangre de Cristo Mountains of southern Colorado. With a total watershed area of 867,650 km^2, the Rio Grande is the second largest river system in North America (Isphording and Fitzpatrick 1992). The lowermost major dam on the river is Falcon Dam, located approximately 442 km from the mouth (Stelly 1993). At least four other major dams are located on the mainstem, and another 27 are located on tributaries (Hitt 1984). The river discharges near the lower Laguna Madre; however, due to a combination of upstream water withdrawals and arid conditions in the drainage basin, it does not have a discharge at times. Lukens (1988) did not assess striped bass habitat criteria for this river; Stelly (1993) ranked this river 17 out of 18 with respect to suitability to support striped bass (highest ranking = 1). Except for the Falcon and Amistad reservoirs, located on the mainstem and in which striped bass have been stocked (TPWD 2002), there is no documentation of striped bass habitat areas in this river. Hybrids have been stocked in Lake Casa Blanca and Red Bluff Reservoir located on Rio Grande tributaries (TPWD 2002).

4.3.3.1.2 Nueces River

The Nueces drains portions of south Texas and discharges to Nueces and Corpus Christi bays. The lowermost dam (Wesley E. Sealy) forms Lake Corpus Christi and is located 76 km upstream from the mouth (Lukens 1988, Stelly 1993). Two other dams occur farther upstream on the main stem and include Choke Canyon Dam/Reservoir (Hitt 1984). This river was given a high potential rating for supporting striped bass populations by Lukens (1988), although it has no known areas of important striped bass habitat. Stelly (1993) ranked the river 9 out of 18 (highest ranking = 1) for suitability to support striped bass. However, he considered the river length below the lowermost reservoir to be insufficient for successful striped bass spawning.

4.3.3.1.3 San Antonio-Guadalupe River System

These two rivers drain the southern portion of the Edwards Plateau region of Texas and discharge into San Antonio Bay. The lowermost dam on the San Antonio River is on a tributary, Arroyo Seco, forming Victor Braunig Lake approximately 349 km from the coast (Stelly 1993). A major dam on the Guadalupe is Canyon Dam, located approximately 485 km from the mouth (Stelly 1993). Both rivers were rated high by Lukens (1988) with respect to ability to support striped bass. Stelly ranked the San Antonio and Guadalupe rivers 2 and 4, respectively, out of 18 (highest ranking = 1) for their suitability to support striped bass. However, there are no known areas of important striped bass habitat in these rivers other than in Canyon Lake on the Guadalupe where striped bass have been stocked (TPWD 2002). Hybrids have been stocked into Coleto Creek Reservoir in the Guadalupe basin and in Victor Baunig Lake, Calavaras Lake, and Medina Lake in the San Antonio basin (TPWD 2002).

4.3.3.1.4 Colorado River

The Colorado River drains portions of west central Texas and the northern portion of the Edwards Plateau and discharges to the Gulf of Mexico with some contribution also to Matagorda Bay. The lowermost major dam on the Colorado main stem, Longhorn Dam forming Town Lake, is located about 470 km upstream from the coast (Lukens 1988, Stelly 1993). In addition to at least 18 dams on tributaries, there are at least six farther upstream on the main stem, and another located near the lower end of the river, which is bypassed by a maintained navigation channel (Hitt 1984). This river was rated high by Lukens (1988) with respect to ability to support striped bass, though there are no known areas of important striped bass habitat in the free-flowing portions of the river. Stelly (1993) ranked the Colorado 5 out of 18 (highest ranking = 1) for ability to support striped bass. Striped bass have been stocked into Lakes Travis, Buchanan, and E.V. Spence on the main stem and into Twin Buttes Reservoir on a tributary (TPWD 2002). Hybrids have been stocked into Lakes Brownwood, Coleman, Walter E. Long, and Nasworthy, all located on tributaries (TPWD 2002).

4.3.3.1.5 Brazos River

The Brazos River drains the extreme southwestern portion of the Texas panhandle and a considerable portion of north central Texas and discharges into the Gulf of Mexico south of Houston. A major dam, Lake Brazos Dam forming Lake Whitney, is located 713 km from the coast (Lukens 1988, Stelly 1993). At least three other major dams are located on the main stem upstream of Lake Whitney, and at least 30 others are located on tributaries (Hitt 1984). Lukens (1988) rated the Brazos high with respect to ability to support striped bass. Stelly (1993) ranked the Brazos 7 out of 18 (highest ranking = 1) for ability to support striped bass. Striped bass spawning areas have been identified at three sites in this river approximately 51 and 109 km upstream of Lake Whitney and 151-164 km above Lake Granbury (Mulford 1979). Two of the sites were located just below dams on the river. Striped bass have been stocked into Lakes Whitney, Granbury, and Possum Kingdom (all on the main stem), and hybrids have been stocked into Lakes Belton, Fort Phantom Hill, Graham, Millers Creek, Proctor, and Somerville, which are on tributaries (TPWD 2002). Striped bass have also been stocked into Buffalo Springs Lake (R. Weller personal communication).

4.3.3.1.6 Trinity River

The Trinity River drains the Blackland Prairie region in the western portion of northeastern Texas and discharges into Trinity Bay at the head of the Galveston Bay system. Livingston Dam, located 208 km from the coast, is the lowermost dam (Stelly 1993), and there are at least four more dams located farther upstream on the mainstem and at least 23 other dams on tributaries (Hitt 1984). This river was rated high by Lukens (1988) with respect to potential for supporting striped bass. Stelly (1993) ranked the Trinity 8 out of 18 (highest ranking = 1) for its ability to support striped bass and considered the Trinity to have insufficient length below Livingston Dam for striped bass to spawn successfully. However, striped bass spawning has occurred below the dam based on collection of eggs and larvae (Kurzawski and Maddux 1991). Annual variations in water velocity and temperature might explain this apparent contradiction. Striped bass in the Trinity River system have been noted to use most extensively those habitat areas immediately below the outfall of Livingston Dam and in the Houston Power and Light cooling water outfall in Trinity Bay (Butler and Stelly 1993). Striped bass have been stocked in Lake Livingston; both striped bass and hybrids have been stocked in Lewisville and Lavon Lakes. Hybrids have been stocked into Lakes Arlington, Bardwell, Benbrook, Bridgeport, Cedar Creek, Ray Hubbard, and Richland Chambers; all are on tributaries except for Livingston (TPWD 2002).

4.3.3.1.7 Sabine-Neches River System

The Sabine and Neches Rivers drain the mixed pine/hardwoods region of eastern Texas and discharge to a relatively large (22,614 ha) (White and Perret 1973) estuarine basin known as Sabine Lake that connects to the Gulf of Mexico through a relatively short, channeled entrance (Sabine Pass). The lowermost dam on the Neches is Town Bluff Dam, which creates B.A. Steinhagen Lake about 183 km from the coast (Lukens 1988, Stelly 1993). There is one more major dam on the Neches main stem and at least eight other dams on tributary streams including Sam Rayburn Dam on the Angelina River, creating Lake Sam Rayburn, the state's second largest reservoir (Hitt 1984). The lowermost dam on the Sabine is Toledo Bend Dam creating Toledo Bend Reservoir approximately 252 km from the coast (Lukens 1988, Stelly 1993). The Sabine forms most of the boundary between Louisiana and Texas, and Toledo Bend Lake is the largest reservoir in the Southeast at 74,000 ha (Forester and Frugé 1996). There is one other major dam located on the Sabine main stem forming Lake Tawakoni near the river's headwaters, and there are at least ten other dams on tributary streams. Lukens (1988) rated both the Sabine and Neches high with respect to potential to support striped bass. Stelly (1993) ranked the Sabine 1 and the Neches 10 out of 18 Texas streams (highest ranking = 1) for ability to support striped bass. While no areas of important striped bass habitat have been documented in the Neches, Forester and Frugé (1996) found that the tailrace channel of Toledo Bend Dam apparently served as important thermal refuge habitat for striped bass in the free-flowing portion of the Sabine River. Several other spring-fed sandy streams tributary to the Sabine River may also provide thermal refuge habitat for striped bass farther downstream from Toledo Bend Dam, though no striped bass have been documented using any of these areas. These include Toro Bayou and Sandy, Pearl, Forker, and Mill creeks (B. Reed personal communication). Temperatures in these streams may range from approximately 20ºC to 23ºC during summer. Striped bass have been stocked into Lake Palestine on the Neches River and into Lakes Toledo Bend and Tawakoni on the Sabine (TPWD 2002). Hybrids have been stocked into Lake Sam Rayburn located on a Neches tributary, as well as into Lake Tawakoni on the Sabine (TPWD 2002).

4.3.3.1.8 Small Coastal Rivers

There are a number of relatively small river systems draining Texas coastal plain areas between the larger river basins. These include a number of streams that drain into Baffin Bay on the lower Texas coast – Copano Creek and the Aransas and Mission Rivers draining into Copano Bay between the Nueces and San Antonio Rivers; Arenosa Creek and the Lavaca and Navidad Rivers draining into Lavaca Bay between the Guadalupe and Colorado Rivers; Linville Bayou and the San Bernard River which drain into East Matagorda Bay and the Gulf of Mexico between the Colorado and Brazos Rivers; and the San Jacinto River draining into Trinity Bay between the Brazos and Trinity Rivers. Lukens (1988) evaluated some of these streams for potential to support striped bass and found the Aransas River to have low potential; the Mission River, Copano Creek, and Lavaca River moderate potential; and the San Bernard River to have high potential. Stelly (1993) ranked the San Bernard River 6 out of 18 (highest ranking = 1) for ability to support striped bass, although the length of river below the lowermost obstruction was considered insufficient for successful striped bass spawning. Other small coastal rivers were ranked as follows: Lavaca (11); Aransas (12); Mission (13); and Copano Creek (16) out of 18 (highest ranking = 1). No important striped bass habitat areas have been documented in any of these systems, although hybrids have been stocked into Alice City Lake located on a stream in the Baffin Bay drainage, Lake Texana on the Navidad River, and into Lake Conroe on the San Jacinto River (TPWD 2002).

4.3.3.1.9 Red River

A number of reservoirs are located on tributaries of the Red River in Texas, and these are discussed in the next section in a broader discussion of the Red River as a tributary of the Mississippi-Atchafalaya River system which discharges into the Gulf of Mexico in Louisiana.

4.3.3.2 Louisiana

Even though the Sabine River forms part of the western border of Louisiana with Texas, that river is discussed under Texas, where the majority of the watershed is located. There are four major river systems in Louisiana west of the Mississippi River, which is effectively the western limit of the historical native range of striped bass. All major tributaries of the Mississippi including the Red River are discussed in this section even though they may be outside of Louisiana. Rivers in Louisiana that are east of the Mississippi are tributary to Lake Pontchartrain. The Pearl River, which forms the boundary between Louisiana and Mississippi in its southernmost reach, is discussed under Mississippi, where most of the watershed occurs.

4.3.3.2.1 Calcasieu River

The Calcasieu River drains an area of predominantly mixed pine/hardwoods and portions of coastal prairie in southwestern Louisiana. The watershed area measures roughly 440,300 ha with an average discharge of 72 m^3/s (2,574 CFS) as measured over 27 years between 1938 and 1967 at Kinder, Louisiana (Perret et al. 1971). Land use is predominantly timber, rice, cattle, and sugar cane production. A major metropolitan area, Lake Charles (2000 Census population 17,757) is within the basin. A number of oil and petrochemical refineries occur near Lake Charles and discharge to the Calcasieu River. The Calcasieu River drains into a relatively large enclosed estuarine basin, Calcasieu Lake, which connects to the Gulf through a channeled entrance (Calcasieu Pass). A flood control bypass structure and associated navigational lock is located on the river at Two-O’clock Point just above Lake Charles. There are no other dams located on the main stem, although one reservoir occurs on a tributary stream (Bundick Lake). A navigation channel for ocean vessels is maintained to Lake Charles, approximately 65 km inland from the Gulf. Lukens (1988) estimated the Calcasieu River to have moderate potential to support striped bass, though no important striped bass habitat areas have been documented in the system. Atlantic race striped bass have been stocked into this system intermittently. Hybrids have been stocked into Bundick Lake (Nicholson et al. 1986).

4.3.3.2.2 Mermentau River

The Mermentau River drains an area of coastal prairie in southwestern and south central Louisiana. Land use is predominantly rice, cattle, and sugar cane production; although a riparian zone of bottomland hardwood forest typically borders the river and several tributary bayous. The Mermentau River drains into an enclosed inland estuarine basin known as Grand Lake, and the river exits the southwestern end of Grand Lake and resumes an approximately 12 km route to the Gulf of Mexico. The Gulf Intracoastal Waterway (ICW) crosses the upper end of Grand Lake. A water control structure used primarily as a salinity barrier is located at Catfish Point where the Mermentau River exits Grand Lake. Atlantic race striped bass were stocked into the Mermentau River before 1987 (Nicholson et al. 1986). Lukens (1988) found the Mermentau River to have a moderate potential to support striped bass, though there has been no documentation of important striped bass habitat areas in this system.

4.3.3.2.3 Vermilion River

The Vermilion River drains an area of coastal prairie in south central Louisiana and discharges to the western end of Vermilion Bay south of Lafayette. Land use is predominantly rice, cattle, and sugar cane production. The City of Lafayette (2000 Census population 110,257) is located within the basin. No major contaminant point sources other than municipal are located in the basin. Atlantic race striped bass have been stocked into the Vermilion River (LDWF unpublished data). Lukens (1988) did not evaluate this system for potential to support striped bass, nor have any important striped bass habitat areas been documented in the system.

4.3.3.2.4 Bayou Teche

Headwaters of Bayou Teche drain areas of pine and hardwood south of Alexandria. Most of this stream's length runs through and drains a relatively narrow strip of Mississippi River alluvial floodplain between the eastern edge of the Louisiana coastal prairie and the western edge of the Atchafalaya River basin. The drainage basin covers 3,965 km^2, and during 1949-1967 had an average discharge of 21.4 m^3/s (822 CFS) at the town of Arnaudville (Perret et al. 1971). Bayou Teche is an abandoned channel of the Mississippi River. Land use in the drainage area is predominantly cotton, sugar cane, and soybean production. This stream has little elevation change and exhibits sluggish stream flow. Although Bayou Teche historically connected with the Atchafalaya River in the vicinity of Morgan City, today it drains predominantly to East Cote Blanche Bay via an artificial channel (Charenton Canal) near the town of Baldwin. A smaller canal (Hanson Canal) near the town of Franklin connects it with an interconnecting series of artificial canals and natural streams lacing the coastal marshes to the south. An artificial distributary channel of the Atchafalaya River Basin (Wax Lake Outlet) and associated levee interrupts Bayou Teche's historical meandering course toward Morgan City. Two small reservoirs are located in the headwaters – Chicot Lake on Bayou Chicot and Indian Creek Lake on Bayou Boeuf. Atlantic race striped bass were stocked into the Bayou Teche system before 1987 (Nicholson et al. 1986). Indian Creek Lake, a small headwater reservoir located on Bayou Boeuf, was stocked with Gulf race striped bass fingerlings for several years during the 1990s in an attempt to establish a broodstock source, but this effort was discontinued (USFWS unpublished data).

4.3.3.2.5 Mississippi-Atchafalaya River System

The Mississippi River is the largest river in North America (Fremling et al. 1989). The headwaters of the main stem are in Lake Itasca, Minnesota. From there, the river flows south 3,731 km to the Gulf of Mexico, and the mouth is located approximately 129 km southeast of New Orleans and about an equal distance south of Gulfport, Mississippi. The river system has four major tributaries – the Missouri, Ohio, Arkansas, and Red Rivers. The river system has hundreds of lesser tributaries and a total drainage area of 475.9 billion ha (Fremling et al. 1989). The basin covers one-eighth of the North American continent including parts of 32 states of the U.S. and portions of Canada.

The Red River, the southernmost large Mississippi River tributary, is 1,222 mi (1,967 km) long (Columbia Encyclopedia 2004). The river originates in the Texas Panhandle and flows southeast between Texas and Oklahoma and then between Texas and Arkansas to Fulton, Arkansas, and then turns south and enters Louisiana near Shreveport. The river crosses Louisiana diagonally toward the southeast and joins the Atchafalaya River near the town of Simmesport, Louisiana. Near its headwaters in Texas, the river flows rapidly through a canyon in semi-arid plains, but farther downstream, the river courses through a red-clay agricultural zone that imparts the river's characteristic red color. A major dam, Denison Dam (completed in 1943), created Lake Texoma between Oklahoma and Texas. A series of L&Ds provide navigability for small ships as far upstream as Shreveport, Louisiana; the lowermost is L.C. Boggs L&D located at RM 44 just upstream from the mouth of the Black River, a Red River tributary. There are a number of floodplain lakes along the lower part of the river, and numerous reservoirs exist on tributaries.

Today, the Atchafalaya River (an older, abandoned channel of the system) functions as a controlled distributary of the Mississippi River. The Atchafalaya River begins near where the Red River joins the system in east central Louisiana and flows 225 km southward to the Atchafalaya Bay. Flow in the Atchafalaya River is regulated by the Old River Control Structure (ORCS, begun by the USACOE in 1951 and completed in 1964) to carry approximately 28%-29% of the combined flow of the Red and Mississippi rivers (Bryan et al. ND). If the ORCS had not been put in place, the Atchafalaya River would now be the dominant Mississippi River distributary.

The range and diversity of aquatic habitats within the Mississippi River system probably span most of the types available in the temperate zone of North America. Main channel habitats in the middle and lower sections of the river, where striped bass in the main stem are most likely to be found, include the main river channel, secondary channels, sandbars, gyres below bars, tributary mouths, natural banks, and structures such as rock dikes and revetted banks. While most of these habitats are lotic, slack water areas may occur during periods of low flow. Many of these habitats are subject to extreme changes in water depth over the course of the year due to the annual flood cycle (Fremling et al. 1989).

The Mississippi River mainstem and most of its tributary habitats have been subjected to substantial human modification, mainly for navigation and flood control. The upper portion of the Mississippi mainstem is routinely dredged, and a series of 29 navigational L&Ds were constructed, the lowermost just above the mouth of the Missouri River near St. Louis, Missouri. From that point southward, the river flows freely to the Gulf with the exception of the ORCS on the Atchafalaya River distributary. However, at least 90% of the river's historic floodplain, which in places is over 160 km wide, below the mouth of the Ohio River (Lower Mississippi River or LMR) has been isolated from the river by an extensive levee system begun in 1727 (Fremling et al. 1989). This isolation has had substantial effects on the LMR's hydrology and aquatic ecology. In addition to the levees, a program of armoring with concrete, rock, or asphalt revetments is used to stabilize bends. Through channelization, the LMR has been shortened by 229 km, and a system of dikes is used to "train" the river to maintain the navigation channel (Fremling et al. 1989). Some dredging is still needed in localized areas, particularly at the mouth of the river. A consequence of the levee system in the LMR is reduction in sediment being deposited in coastal wetlands of Louisiana, resulting in ongoing wetland loss due to subsidence and erosion. A levee system has confined the Atchafalaya River to a floodplain approximately 32 km wide (Atchafalaya Basin); the Atchafalaya system still functions somewhat as a natural floodplain river, though substantial sedimentation and basin filling have occurred (Sabo et al. 1999).

The first structural blockage on the Red River occurs at the L.C. Boggs L&D at RM 44. The lowermost L&D on the Arkansas River is approximately 32 km upstream from the Mississippi, and on the Ohio River, the first L&D is a similar distance upstream from its mouth. On the Missouri system, the lowermost dam is at Gavin's Point on the border between Nebraska and South Dakota in the northeastern and southeastern portions of those states, respectively (Hitt 1984).

Although striped bass were probably not native to the Mississippi River system above New Orleans, native populations from Gulf rivers farther east likely utilized habitats at least in the extreme lower portions of the river. Atlantic race striped bass and hybrids have been widely stocked into reservoirs throughout the Red, Ohio, and Missouri rivers (see Section 3.8). In the state of Texas, striped bass have been stocked into Lakes Kemp and Diversion on Red River tributaries, as well as Lake Texoma, a Red River main stem impoundment between Texas and Oklahoma. Hybrids have been stocked into Texas in Lake o'the Pines as well as Lakes Cooper, Lone Star, Mackenzie, Pat Mayse, Nocona, Pauline, Wichita, and Wright Patman, all on Red River tributaries (TPWD 2002). Significant escapement of striped bass to downstream waters in the Mississippi River system has been well established (Zale and Jacks 1988, Henley 1996).

Lake Texoma is of special significance for striped bass in the Mississippi River system. Atlantic race striped bass were stocked into this 36,000 ha reservoir from 1965 through 1974 (Schorr et al. 1995). Successful reproduction by this population has resulted in a strong sport fishery; striped bass have become the most sought after fish in the lake, and the lake is now nationally-recognized for its striped bass fishery (Schorr et al. 1995). Successful reproduction has also been documented in Keystone Reservoir on the Arkansas River in Oklahoma (Mensinger 1970) and in Dardanelle Reservoir on the Arkansas River in Arkansas (Bailey 1974). Striped bass spawning has also been documented in the Tennessee River below Cheatham and Pickwick dams (Hogue et al. 1977), in Kentucky Lake (Davis and Freeze 1977), and in the Ohio River near the Tanners Creek and W.C. Beckjord power plants (ESE 1989).

Sampling has documented the presence of juvenile striped bass in the Mississippi River in Louisiana and in the Atchafalaya River (Mesing 1989). Except for the spawning areas associated with reservoirs far upriver, no other specific spawning areas are known in the system. Horst (1976) studied the species in the Atchafalaya Basin and found striped bass to be uncommon but widely distributed and found in virtually all habitat types including the main channel, flowing and non-flowing canals and bayous, lakes, backwater areas, and shallow marsh sloughs, though they were less relatively abundant in the latter habitats. Further, he found that the area met the spawning, nursery, and forage needs for the species and speculated that striped bass in the Atchafalaya Basin were likely descendants of or escapees from fish stocked upstream in the Mississippi system and were likely of Atlantic origin based on lateral line scale counts. The Mississippi-Atchafalaya system was not assessed by Lukens (1988) regarding suitability to support striped bass. There is no other documented information on important striped bass habitat areas in the free-flowing portions of this river system.

Gulf race striped bass fingerlings were stocked into False River, a Mississippi River oxbow lake near the town of New Roads, Louisiana, during the late 1990s in an effort to establish a broodstock source, but this effort was later abandoned. Hybrids have also been stocked in this lake, as well as in a number of other Mississippi River oxbow lakes.

4.3.3.2.6 Amite River

The Amite River originates in southwestern Mississippi and flows south into Louisiana through an area of mostly mixed pine and hardwood uplands. It skirts the eastern Baton Rouge, Louisiana, metropolitan area and drains into Lake Maurepas, which is connected by a relatively short and wide channel (Pass Manchac) to Lake Pontchartrain. Average discharge, as measured at Denham Springs, Louisiana, between 1938 and 1967 was 51.8 m^3/s (Perret et al. 1971). There are no dams on this river's main stem nor was it assessed by Lukens (1988) with respect to potential support of striped bass. There are no habitat areas known to be of particular importance to striped bass in this river.

4.3.3.2.7 Tickfaw River

The Tickfaw River has its headwaters approximately 15 km southwest of McComb, Mississippi; flows 151 km southward; drains into Lake Maurepas (Rogillio et al. 2002); and drains an area of mostly mixed pine and hardwood uplands. There are no dams on this river's main stem and it was not assessed by Lukens (1988) with respect to potential support of striped bass. There are no areas known to be of particular importance to striped bass in this river.

4.3.3.2.8 Tangipahoa River

The Tangipahoa River heads approximately 14 km northwest of McComb, Mississippi, and flows 179 km south into Louisiana and drains into Lake Pontchartrain (Rogillio et al. 2002). Its watershed is mostly mixed pine and hardwood uplands. Average annual discharge, as measured at Robert, Louisiana, was 31 m^3/s (Perret et al. 1971). There are no dams on this river's main stem and it was not assessed by Lukens (1988) with respect to potential support of striped bass. There are no areas known to be of particular importance to striped bass in this river.

4.3.3.2.9 Tchefuncte River

The Tchefuncte River's watershed is entirely within Louisiana, originating about 16 km southeast of Kentwood, Louisiana, and flowing 99 km southward to Lake Pontchartrain (Rogillio et al. 2002), an area of mostly mixed pine, hardwoods, and agricultural lands. The drainage area is 116,600 ha (Monzyk et al. 2001). There are no dams on this river's main stem, though it was subjected to some channelization beginning in 1956 (Monzyk et al. 2001). This river was not assessed by Lukens (1988) with respect to potential support of striped bass. Davis et al. (1970) indicated the river was historically one of the least polluted of the Lake Pontchartrain rivers and apparently was the stream where striped bass were historically most prevalent among these rivers. Those authors also reported that forage fish populations were sufficient in Lake Pontchartrain rivers to support striped bass. Investigations by Monzyk et al. (2001) and Rogillio and Rabalais (2001) did not indicate any areas known to be of particular importance to striped bass in this river, and no thermal refuge areas were documented. However, Rogillio and Rabalais (2001) speculated that shaded portions of the headwaters of the Tchefuncte River might offer such habitat, and striped bass were usually found associated with structures, such as fallen trees, bridge pilings, etc., in the river that offered some shade during the summer. They also speculated that deep waters of Lake Pontchartrain might provide limited thermal refuge below the thermocline.

4.3.3.3 Mississippi

As indicated previously, the Pearl River forms part of the boundary between Louisiana and Mississippi but is discussed under Mississippi where the majority of the drainage basin occurs.

4.3.3.3.1 Pearl River

The Pearl River drains approximately 2.27 million ha (Rogillio et al. 2002) in east central Mississippi and southeastern Louisiana and drains into Lake Borgne, which is contiguous with the western end of Mississippi Sound. The river extends approximately 788 km from its headwaters to the mouth (MDEQ 2000). A major tributary, the Bogue Chitto River, enters the lower portion of the river. At 75 km upstream from the mouth, the Pearl River divides into two distributaries, the East and West Pearl rivers (Monzyk et al. 2001). The East Pearl River is a boundary between Louisiana and Mississippi. Hydrologic changes have caused the West Pearl (entirely within Louisiana) to become the dominant distributary, and water quality and access problems result in the East Pearl during low flow periods (MDEQ 2000). One major dam and reservoir (the Ross Barnett Reservoir) on the main stem is located 486 km upstream. A number of human modifications have occurred in the lower river as a result of the Pearl River Navigation Project, completed in 1956 by the USACOE (Rogillio et al. 2002). The navigation system consists of three locks and three low water sills. One of the sills is located at Pools Bluff on the Pearl River main stem at about RK 783; another is on the Bogue Chitto River south of Lock 3, and another on Talisheek Creek between Locks 1 and 2. Because of the Pools Bluff sill, access to 408 km of Pearl River riverine habitat between Pools Bluff and Ross Barnett Dam is prevented for up to 280 days per year (Rogillio et al. 2002). The sill on the Bogue Chitto River prevents access by migratory fish to 91% of the river areas upstream (Rogillio et al. 2002). Although the navigation system is now non-functional, the sills and locks remain in place. Other channel modifications include various activities related to flood control and sand/gravel extraction. Predominant land use in the basin is commercial forestry, livestock production, and some row crop agriculture (MDEQ 2000). One significant metropolitan area, Jackson, Mississippi, is located near Ross Barnett Reservoir. Monticello and Columbia are located near the river in southwest Mississippi, and Bogalusa is located near the river in southeast Louisiana. All of these factors have resulted in various impacts to the river and its aquatic resources.

The Pearl River was assessed by Lukens (1988) as having a medium potential to support striped bass. Investigations by Monzyk et al. (2001) and Rogillio and Rabalais (2001) did not indicate any habitat areas known to be of particular importance to striped bass in this river, and no thermal refuges were documented. Rogillio and Rabalais (2001) found striped bass usually associated with structures in the river that offered some shade during the summer. Ross Barnett Reservoir and its tail waters are the only areas known to be of particular importance as striped bass habitat in the Pearl River system. Nicholson (1992) determined that zooplankton abundance in the lower Pearl River was sufficient to sustain juvenile striped bass.

4.3.3.3.2 Pascagoula and Escatawpa Rivers

The Pascagoula-Escatawpa River basins drain portions of southeastern Mississippi and southwestern Alabama. The drainage basins together cover about 2.43 million ha, and the two streams join just upstream from where they discharge into Mississippi Sound. The lower ends of both basins contain extensive areas of coastal estuarine marsh. Two major sub-basins of the Pascagoula are the Leaf and Chickasawhay rivers. Annual average discharge is about 397.8 m^3/s (15,300 CFS). The basins of the Pascagoula-Escatawpa are relatively sparsely populated and contain three moderate sized cities in Mississippi – Laurel, Hattiesburg, and Pascagoula. The Escatawpa basin borders the extreme western portions of the metropolitan area of Mobile, Alabama. Substrates of mud, clay, and silt with some sand predominate in these systems. Predominant land usage in the basin is commercial forestry and livestock production, and there have been some impacts to stream habitats resulting from these activities. There are several point source contaminant discharges to the river, primarily from paper mills and other forest products facilities. Other impacts have occurred from dredging and industrial development near the mouth of the Pascagoula River. Chevron USA is permitted to withdraw up to 100 million gallons per day of water from the lower river to supply an oil refinery located near Pascagoula, Mississippi (Pierson et al. 2002). Although there is a dam and reservoir on a tributary of the Escatawpa River in Alabama (Big Creek Lake), the Pascagoula River is notable in that it is the largest remaining free-flowing (i.e., no obstructions in the main channel) river in the temperate zone of North America (Dynesius and Nilsson 1994). Lukens (1988) rated the Pascagoula River high in potential to support striped bass, though the Leaf and Chickasawhay tributaries were rated low and medium, respectively.

In a study conducted on the Pascagoula River and major portions of the Leaf and Chickasawhay rivers during summer 1998, the USGS found water temperatures ranging from 28.9ºC to 33.0ºC during August and 25.0ºC to 29.2ºC during September. The coolest water during August was at the mouth of Black Creek and during September in the Leaf River about eight miles upstream of its confluence with the Chickasawhay River. Jackson et al. (2001) speculated that two areas were used by striped bass for spawning – just above the junction of the east and west forks (distributaries) of the Pascagoula River (approximately 28.5 km upstream from the river mouth) and in the vicinity of the mouth of Ward Bayou. Jackson et al. (2001) documented two thermal refuges in tributaries of the lower portion of the river: Cedar Creek and its immediate outflow area and Bluff Creek. Jackson et al. (2001) speculated that gravel pits in the Bouie River, a tributary of the Leaf River near Hattiesburg, Mississippi, might also provide some thermal refuge habitat. Other refuges were believed to be present in the river and warrant further investigation. The existing refuges are relatively small, and there is a crowding problem with striped bass when ambient river water temperatures are high. Temperature/DO squeeze conditions exist in some refuges when striped bass are subjected to low DO while in the thermal refuge (Jackson et al. 2001). Nicholson (2001b) reported conditions suitable for thermal refuge in Cedar Creek, Bluff Creek, and at Gibson's Landing on the Pascagoula River.

4.3.3.3.3 Small Coastal Rivers

A number of relatively minor coastal rivers enter Mississippi Sound between the major river basins in Mississippi. As reported by Christmas (1973), these include (drainage areas in ha and average discharge in m^3/s) from east to west, Old Fort Bayou (11,600/2.5), Biloxi and Tchoutacabouffa rivers (142,500/31.2), and Bayou Bernard (19,400/4.2), which drain into Biloxi Bay, and the Wolf River (98,400/21.5) and Jourdan River (88,000/19.8), which drain into St. Louis Bay. Other smaller, coastal streams drain approximately an additional 6,170 ha with a combined average annual discharge of 9 m^3/s. Lukens (1988) assessed the Biloxi and Wolf rivers as high in potential to support striped bass. None of these streams have dams on their main stems.

4.3.3.4 Alabama

The major river system in Alabama is the Mobile-Alabama-Tombigbee (MAT). Another, the Perdido forms the north/south boundary between Alabama and Florida. Because the majority of its drainage basin lies within Alabama, it is discussed here.

4.3.3.4.1 Mobile-Alabama-Tombigbee (MAT) Rivers

The Mobile River basin drains 4.37 million ha in the states of Alabama, Georgia, Mississippi, and Tennessee (Mettee et al. 1996). The western part of the drainage consists of the lower Tombigbee River, which flows entirely through the Coastal Plain province in northeast Mississippi and western Alabama. It also includes the Black Warrior River, which drains portions of the Cumberland Plateau in north central Alabama (Mettee et al. 1996). The Black Warrior River drops across the fall line onto the Coastal Plain near Tuscaloosa, Alabama, and joins the Tombigbee River. The eastern portion of the drainage consists of the Alabama, Coosa, Tallapoosa, and Cahaba rivers. The Coosa River drains an area of the Valley and Ridge province in Alabama and Georgia, while the Tallapoosa drains an area of the Piedmont province in both states. These two rivers cross the fall line near Wetumpka and Tallassee, Alabama (respectively), and then join to form the Alabama River just above Montgomery. The Cahaba River drains a portion of the Valley and Ridge province in Alabama, crosses the fall line near Montevallo, Alabama, and then joins the Alabama River near Selma. The Alabama and Lower Tombigbee rivers join near Mt. Vernon, Alabama, to form the Mobile River. The Mobile River splits into four distributaries in the lower portion of the delta – the Mobile, Middle, Tensaw, and Blakely rivers and delivers an average of 155.2 billion liters of water per day to the Mobile Bay estuary (Mettee et al. 1996). The rivers in the eastern portion of the drainage have a higher mineral content and clarity than those in the western portion of the drainage.

A major navigation project, the Tennessee-Tombigbee Waterway, was constructed in the western part of the drainage and connects the MAT and Tennessee River systems; consequently, introduction of non-native species has occurred in these systems (Soballe et al. 1992). The waterway also has the potential to allow passage of striped bass between the Tennessee and Tombigbee rivers. A series of 11 L&Ds have been built on the Tombigbee beginning at the lower end with Coffeeville L&D and proceeding up the river through Demopolis, Aliceville, and Gainesville L&Ds in Alabama, and Columbus and Aberdeen L&D, Locks B, C, D, and E, and then Bay Springs L&D in Mississippi (Hitt 1984). On the Black Warrior River, there are three L&Ds below the fall line – Warrior, WM Bacon Oliver, and Holt L&Ds and one above the fall line – John Hollis Bankhead L&D (Hitt 1984). Several other dams exist on tributaries, including those creating Lakes Tuscaloosa and Lewis Smith (Mettee et al. 1996).

There are three L&Ds on the Alabama River beginning with Claiborne, the lowermost, and proceeding upward through Miller's Ferry and Jones Bluff which extend barge navigation to Montgomery, Alabama (Hitt 1984). In addition to these, there are hydropower and flood control dams on both the Coosa and Tallapoosa rivers. On the Tallapoosa River, these include (downstream to upstream) dams creating Lakes Thurlow, Yates, Martin, and RL Harris in Alabama (Mettee et al. 1996), and there is at least one additional dam on a tributary in Georgia (Hitt 1984). On the Coosa, beginning downstream, there are dams creating Lakes Jordan/Bouldin, Mitchell, Lay, Logan Martin, Neely Henry, and Weiss in Alabama (Mettee et al. 1986) and Lakes Allatoona and Carters on tributaries in Georgia (Hitt 1984).

A major habitat issue in the system is the challenge in maintaining adequate flows due to upstream water use, primarily in the northern Atlanta, Georgia metropolitan area (CWRS 1995). Negotiations continue between the states of Alabama and Georgia regarding water allocation in the system. Insufficient instream flow can have direct effects on striped bass but can also indirectly affect certain habitats due to changes in river bed hydrography and freshwater inflow to estuarine areas.

Lukens (1988) assessed both the Alabama and Tombigbee rivers as having high potential to support striped bass but did not assess the Mobile River itself. Smith and Catchings (1998) concluded that Atlantic race striped bass have been reproducing, possibly since 1988, in the upper Coosa River and have established a fishery in Lake Weiss. They also found a significant downstream migration of these fish from Lake Weiss into Neely Henry, Logan Martin, and Lay Lakes. Therefore, habitat conditions are suitable for striped bass spawning somewhere between Lake Weiss and Allatoona and Carters Lakes, Georgia, well above the fall line. Evidence of striped bass spawning has also been documented in the Alabama River below Claiborne L&D and between Claiborne and Miller's Ferry L&Ds (Powell 1990, 1991; Duffy 1993). Moss (1985) identified four thermal refuges in the Coosa River between Mitchell Dam and the upper end of Jordan Lake. In the Alabama River, four thermal refuges were found between approximately 2 and 30 km below Jones Bluff L&D, and one was found approximately 2 km below Miller's Ferry L&D (Moss 1985).

4.3.3.4.2 Perdido River

The Perdido River forms the north/south boundary between the states of Alabama and Florida. It has a relatively small watershed with a drainage area of approximately 217,500 ha (Mettee et al. 1996), a total length of 105 km, and average discharge of 21.8 m^3/sec (Bass and Cox 1985). It is relatively undisturbed with no dams on the system, and land uses are primarily forest and agriculture (Bass and Cox 1985). It has relatively cool water by Florida standards and very low hardness (Bass and Cox 1985). Lukens (1988) assessed this river as having a medium potential to support striped bass.

4.3.3.5 Florida

As mentioned in the previous section, the lower reach of the Perdido River forms the north/south boundary between Alabama and Florida and is discussed in Section 4.3.4.2.

4.3.3.5.1 Escambia River

The Escambia River is the largest of three major tributaries to Pensacola Bay (Wakeford 2001). It originates in Alabama as the Conecuh River, becomes the Escambia River as it enters Florida, and flows 148 km from its headwaters to the bay. It drains a watershed of 1.09 million ha (Wolfe et al. 1988) with an average flow of 180.7 m^3/sec (Bass and Cox 1985). Point and non-point source pollution, sedimentation, and gravel mining have led to decline in aquatic habitat conditions and fish populations in the river, though signs of recovery have been evident over the past 20 years (Wakeford 2001). Two dams are located on the Conecuh River. Lukens (1988) assessed the

Escambia River as high in potential to support striped bass. The only area documented as being of particular importance as habitat for the species is Pine Barron Creek, which flows into the river north of Molino, Florida (D. Yeager, USFWS, personal communication). Water temperatures in the creek are normally 5ºC cooler than in the Escambia River during summer, and striped bass can be collected there.

4.3.3.5.2 Blackwater River

The Blackwater River, another Pensacola Bay tributary, is a relatively unpolluted stream draining a sand and gravel aquifer. It originates in Alabama and flows 107 km from its headwaters to Blackwater Bay, part of the Pensacola Bay system, draining a watershed of 159,400 ha (Wakeford 2001) with an average flow of 9.8 m^3/sec (Bass and Cox 1985). The watershed is heavily forested, and much is protected by state and national forests in Alabama and Florida. Water quality is relatively good, though biological productivity is not high (Livingston 1992), and there are contaminant problems from agricultural pesticides. Sedimentation has been a significant problem (Wakeford 2001). Temperatures in the river tend to be moderate since most of the river's flow comes from groundwater (Wakeford 2001). There are no dams on the Blackwater River's main stem. Lukens (1988) assessed the river as low in potential to support striped bass populations; however, this rating was primarily due to a lack of data. Striped bass have been collected at a known thermal refuge area, the mouth of Clear Creek (D. Yeager personal communication).

4.3.3.5.3 Yellow River

The Yellow River is another Pensacola Bay stream in relatively natural condition that is generally characterized by cooler temperatures and sandy bottoms, though generally low nutrient levels tend to limit fish biomass and productivity (Livingston 1992). It originates in Alabama and flows 150 km to Blackwater Bay. The total drainage basin is 356,000 ha (Wolfe et al. 1988). A relatively high gradient in the Yellow River produces a swift flow (65 m^3/sec) compared to other streams of similar size in the area (Wakeford 2001, Isphording and Fitzpatrick 1992). The Shoal River is a major tributary (Yeager 1988b). The Yellow River has some of the most pristine water in the state of Florida, although it is subject to impacts from non-point source runoff with consequent DO, nutrient, and bacteria problems locally, particularly in the Alabama portion (Wakeford 2001, Wolfe et al. 1988). There are no dams on the river's main stem and Lukens (1988) assessed its potential to support striped bass as high. Several smaller tributaries and Boiling Creek, which enters the Yellow River six to seven miles from its mouth in Blackwater Bay, provide thermal refuge habitat for striped bass in this river (D. Yeager personal communication).

4.3.3.5.4 Choctawhatchee River

The Choctawhatchee River with a drainage basin of 1.20 million ha (Wolfe et al. 1988) originates in Alabama and flows 280 km southward (Wakeford 2001) with an average discharge of about 200 m^3/sec into Choctawhatchee Bay (Livingston 1992). It is considered a major alluvial river, the third largest in Florida, and probably the most turbid in the state (Wakeford 2001). Major tributaries are the Pea River in Alabama, and Pinelog, Holmes, Wrights, and Sandy creeks in Florida (Wigfall and Barkuloo 1975). Although water quality is good (Livingston 1992), it has been affected by point and non-point source pollution in the form of sediments, nutrients, and bacteria, the latter of which have prompted fish consumption advisories (Wolfe et al. 1988, Wakeford 2001).

Winger (1989) conducted field toxicity tests on water from the Choctawhatchee, Apalachicola, and Ochlockonee rivers and found the Choctawhatchee River water toxic to larval fathead minnows. Full-strength Choctawhatchee River water had 40% higher mortality than control water or in dilutions of the river water. Mortalities of larva in different solutions of Apalachicola and Ochlockonee river water did not differ significantly from the controls. Cause of toxicity of the Choctawhatchee River water was not determined.

The Choctawhatchee River faunally resembles the Escambia River more so than the Apalachicola River system to the east or the Yellow and Blackwater River systems to the immediate west (Livingston 1992). There are no dams on the river's main stem, and Lukens (1988) assessed it as high in potential to support striped bass. One striped bass egg was collected and verified in the lower Choctawhatchee River during plankton net tows, indicating there was some striped bass spawning in the river during 1975 (Smith et al. 1975).

Several springs, some relatively large, are located in Holmes, Washington, and Walton counties that flow into the Choctawhatchee River. There are many large and deep depressions (springs) reported at the mouth of the Choctawhatchee River and the east end of Choctawhatchee Bay that extend 40 feet or more below normal channel bottom (Pascale 1974). Holmes Creek, a major tributary to the Choctawhatchee River, is fed from a number of springs (Rosenau et al. 1977). Another potential thermal refuge is Pine Log Creek, which may be spring fed, receive cool-water seepage, or be protected thermally by extensive canopy (E. Long personal communication).

4.3.3.5.5 Apalachicola-Chattahoochee-Flint Rivers

The ACF river system is the third largest within the historic range of striped bass in the Gulf. It is about 205 km in length (Bass and Cox 1985) and drains an area of 5.08 million ha (Livingston 1992) with three major tributaries – the Chattahoochee, Flint, and Chipola rivers.

The Chattahoochee River is 701 km long with a drainage area of 2.27 million ha in Alabama and Georgia and an average flow rate of 346 m^3/sec (Livingston 1992). The Chattahoochee River originates in north Georgia, above Atlanta, in the Blue Ridge physiographic province. It enters the Coastal Plain province at the fall line near Columbus, Georgia, at approximately the Eagle-Phoenix Dam (Hitt 1984, Livingston 1992, Metee et al. 1996). In-stream habitats within the Chattahoochee River include shoal areas with steep gradients and rocky substrates above the fall line in the upper portions, grading to areas of moderate gradient and sandy substrate in the Coastal Plain, becoming siltier with little gradient in the lower reaches (Livingston 1992). The headwaters north of Atlanta are mostly mixed pine/hardwood forest, and between Atlanta and Columbus, loblolly pine dominates. In the Coastal Plain, the river runs through a landscape dominated by agriculture, and little of the area is in natural condition (Livingston 1992). There are a total of 13 dams on the Chattahoochee River for the purposes of flood control, navigation, hydropower, recreation and/or water supply. The following dams (moving downstream) are above the fall line: Buford Dam, Morgan Falls Dam, West Point Dam, Langdale Dam, Riverview Dam, Bartletts Ferry Dam, Goat Rock Dam, North Highlands Dam, City Mills Dam, and Eagle-Phoenix Dam (Livingston 1992). Walter F. George L&D and Columbia (Andrews) L&D are below the fall line (Livingston 1992).

The Flint River, with a 1.58 million ha drainage area entirely within the state of Georgia, is 600 km long with an average flow of 244 m^3/sec. This river originates in the Piedmont Plateau physiographic province just south of Atlanta and enters the Coastal Plain at the fall line at a point approximately on a line between Columbus and Macon. The upper Flint River is in a relatively natural state and mostly bordered by loblolly pine forest. The Coastal Plain portion of the drainage is mainly agricultural, and the river is characterized by sandy substrates and alternating shallow and deeper areas (Livingston 1992). Two major hydropower dams occur on the Flint, both below the fall line: Warwick Dam creates Lake Blackshear and Flint River Dam (Albany Power Dam) creates Lake Worth further downstream (Livingston 1992, Baker and Jennings 2001a).

The Chattahoochee and Flint rivers join near the Florida/Georgia border to form the Apalachicola River, producing an average flow of 690 m^3/sec at Chattahoochee, Florida (Livingston 1992). The two rivers actually now enter a reservoir, the 37,500-acre (15,176 ha) Lake Seminole, created by the Jim Woodruff L&D, which is now the origin of the Apalachicola River (Ager et al. 1986). The Apalachicola River then flows another 171 km to Apalachicola Bay. The Chipola River joins the Apalachicola about 45 km upstream from the bay (Livingston 1992). The Apalachicola and Chipola rivers lie entirely within the Coastal Plain and run through a mostly forested area (E. Long personal communication). The lower portion of the Apalachicola River is bordered by an extensive bottomland hardwood forested floodplain and coastal marshes (Livingston 1992). Water quality in the Apalachicola is generally considered good, though elevated levels of turbidity, bacteria, and nutrients create eutrophication and sedimentation problems (Wakeford 2001). In-stream habitats in the Apalachicola are mostly sand, silt, and clay (Livingston 1992). The Apalachicola River can be divided into three physiographic segments: 1) the upper river, JWLD downstream to near Blountstown, is characterized by long, straight stretches and wide bends, and passes through an area of steep bluffs on the east and rolling hills on the west; 2) the middle river, near Blountstown to the mouth of the River Styx near Wewahitchka, contains numerous bends meandering through an area of gentle slopes and lowlands; 3) the lower river, characterized by long, straight reaches courses through lowlands with a wide floodplain (Ager et al. 1986). Three major distributaries are the St. Marks River (Note: There is another St. Marks River a little further east that is not associated with the Apalachicola), Little St. Marks River, and East River (Hill et al. 1990). The Apalachicola River contains the largest number of freshwater fish species of any Florida river (Ager et al. 1986).

The Chipola River is the largest tributary of the Apalachicola River in Florida with an average annual discharge of 34 m^3/sec (Hill et al. 1990). It flows 140 km from near the Florida/Alabama state line and joins the Apalachicola River 44.6 km upstream from the latter's mouth. Approximately 32 km above the confluence with the Apalachicola River, the Chipola River is joined by Chipola Cutoff, a distributary of the Apalachicola River, which diverts about 25% of the Apalachicola River's flow to the Chipola (Wolfe et al. 1988). Historically, water flowing through the Chipola Cutoff backed up flow of the Chipola River, naturally forming Dead Lake, a 1,465-ha cypress swamp in a wide portion of the floodplain. A sheet-pile and rock dam was constructed at the mouth of Dead Lake in 1960 to stabilize water levels. The sheet-pile and rock were removed in 1987 and the remaining supporting rock in 1989, restoring unimpeded flow to the Chipola River. However, Dead Lake remains a feature of this tributary system. The Chipola River generally has good water quality (Wolfe et al. 1988).

The upper Chipola River is characterized by numerous limestone outcrops and shoals with clear cool water (<26°C in summer) from the many natural springs located in this part of the river

(Hill et al. 1990). Prior to 1960, anecdotal evidence indicated striped bass were utilizing the upper portions of the river (Hill et al. 1994). Barkuloo observed adult striped bass in the Chipola near Marriana and collected striped bass in the lower Chipola before the dam was constructed (J Barkuloo personal communication). Barkuloo (1967) listed the area below Dead Lake Dam as a principal striped bass fishing location. Striped bass were presumably congregating below the dam in an attempt to migrate up the Chipola River to spawn or seek thermal refuge (Hill et al. 1994). Hill et al. (1994) and Long (2001) reported limited numbers of striped bass utilizing thermal refuges in the upper river following removal of Dead Lake Dam. Long (2001) listed nine springs and creeks utilized as thermal refuges, although ambient temperature in the upper 85 km of the stream is cool enough to sustain striped bass through hot summer months. The low numbers of striped bass utilizing the upper Chipola River during the summer months indicate that Dead Lake may act as a thermal barrier by warming up faster than the Apalachicola River. An 18.5-mile long canal runs from the Chipola River to the town of Port St. Joe for water supply (Ryan et al. 1998). Up to 1.82 m^3/s (70 CFS) (48 million gallons per day) may be pumped from the canal.

Congress originally authorized navigational modifications for the ACF in 1824, and construction of the navigation system occurred between 1834 and 1975 (Livingston 1992). Lake Seminole was formed when JWLD was completed in 1957. The navigation channel (2.7 m deep, 30 m wide) extends upstream to Columbus, Georgia, on the Chattahoochee River and Bainbridge, Georgia, on the Flint River (Livingston 1992). Maintenance dredging continues, and a series of groins was installed in the upper Apalachicola River to reduce sedimentation in the channel. The navigation system also includes a number of bend-way cutoffs (Livingston 1992). Removal of gravel and rocky shoals in the river to create the navigation channel may have removed areas important for striped bass spawning, and sedimentation may have affected others (Wakeford 2001). Disposal of material from maintenance dredging has negatively affected overall sport fish productivity in the river (Ager et al. 1986) and may have negatively affected some habitats important to striped bass. Lower river stages resulting from the navigational modifications (Wolfe et al. 1988) have affected thermal refuge habitats for striped bass in the upper Apalachicola (C. Mesing personal communication).

A major habitat issue in the ACF system is the challenge in maintaining adequate flows due to upstream water use, primarily in the Atlanta, Georgia metropolitan area and for agricultural irrigation (CWRS 1995). There are conflicts between the states of Alabama, Georgia, and Florida regarding water allocation in the ACF system. Insufficient in-stream flow can have direct effects on striped bass but can also indirectly affect certain habitats due to changes in riverbed hydrography and freshwater inflow to estuarine areas.

Lukens (1988) assessed the Apalachicola River as having a high potential to support striped bass. Some reservoirs in the watershed above the fall line have been stocked with Gulf and Atlantic race striped bass, as well as hybrids. Based on the presence of YOY striped bass in the absence of stocking, spawning has occurred upstream of Lake Seminole (Long 2001), and limited natural reproduction was documented in the ACF system in 1985 (Mesing 1989). Keefer (1986) found striped bass eggs and larvae in plankton samples from the Flint River between Lake Seminole and the Albany Power Dam. Although there is no direct evidence, the presence of specific year classes of striped bass above West Point Reservoir indicate striped bass may spawn (at a relatively low level) in the Chattahoochee River above that lake (Hess and Jennings 2001). Striped bass have been stocked into West Point Lake, which is above the fall line. Striped bass eggs were found during one of three years in which sampling for eggs and larvae was conducted in the Apalachicola River (Mesing 1989).

There are striped bass thermal refuge habitat areas in Lake Blackshear, a reservoir on the Flint River. In a study involving 33 radio-tagged striped bass, 5% were successful in locating these primarily spring-fed areas (Baker and Jennings 2001b). However, severe drought conditions contributed to high mortality among the tagged fish and affected the availability, extent, and conditions of refuge habitat. Weeks and Van Den Avyle (1996) identified 22 springs with potential to serve as thermal refuges in the Flint River between the Albany Power Dam and JWLD. Five of these springs were within Lake Seminole, and 17 others were along the river. Striped bass abundance differed among the eight refuge areas that were studied in detail; the highest abundance was found at the spring located farthest upstream. Since completion of their study, the GDNR has annually sampled these springs to assess striped bass abundance.

Jim Woodruff Lock and Dam was constructed on top of a honeycomb of underground channels that now flow into the Apalachicola at the location of the dam and just below. These are important thermal refuge; however, water withdrawal from these aquifers by agricultural operations (especially in Southwest Georgia) has greatly reduced flow from these springs and underground channels. Other thermal refuges in the upper Apalachicola River were Flat Creek, Selman's ditch, and several other spring fed creeks or creeks with a heavy overstory of trees. During normal to high

water levels, striped bass used the mouths of these creeks extensively during the warmer months as refuges (J. Barkuloo personal communication).

Dredging of the navigation channel and destruction of rock ledges for navigation has severely entrenched the channel of the upper river and lowered the water stage. This resulted in the mouths of these tributaries becoming inaccessible by striped bass.

A few thermal refuges exist in the lower river and adjacent Intracoastal Waterway; however, these refuges are not well known or documented (J. Barkuloo personal communication). In addition, there are areas in the Chipola River and the upper portion of the Apalachicola River that provide thermal refuge habitat for striped bass. Striped bass from the Apalachicola may have difficulty locating such areas in the Chipola due to the Dead Lake thermal barrier (Long 2001).

4.3.3.5.6 Ochlockonee River

The Ochlockonee River originates in Worth County, Georgia; flows 257 km to Ochlockonee Bay; and is fed predominantly by surface runoff rather than groundwater (Wakeford 2001). The drainage basin is approximately 588,000 ha and extends through five southwest Georgia counties and five Florida counties (Swift et al. 1977) with an annual flow of approximately 26.8 m^3/s (1,030 CFS) (Leitman et al. 1990). The watershed is mostly forested and agricultural land (Dobbins and Rousseau 1982). This system has one major dam and reservoir, Jackson Bluff Dam; forming Lake Talquin (Cailteux et al. 1990) located 106 km upstream from the mouth. The system is predominantly sand-bottomed and in relatively natural condition (Livingston 1992). Toxic levels of copper were found in the middle portion (Wakeford 2001), and high concentrations of mercury were found in fish from Lake Talquin (Livingston 1992). Inflow to Lake Talquin is turbid, and the lake is eutrophic (Dobbins and Rousseau 1982). The lower portion of the river has good water quality

(Wakeford 2001), and the extreme lower portion of the river flows through an area of coastal marsh before emptying into Ochlockonee Bay (Swift et al. 1977). Lukens (1988) rated the Ochlockonee as having a high potential to support striped bass. The lower Ochlockonee River has limited thermal refuge habitat (R. Long, personal communication). Natural reproduction by Atlantic race striped bass has been documented below the dam (Mesing 1989).

4.3.3.5.7 Suwannee River

The Suwannee River is 394 km long with a drainage basin of approximately 2.5 million ha and an average discharge of 305 m^3/sec (Livingston 1992), the second-largest water volume of rivers in Florida (Wakeford 2001). The river originates in the Okefenokee Swamp, Georgia; major tributaries include the Withlacoochee, the Alapaha, and Santa Fe rivers. The upper portion of the river tends to be acidic, highly colored, and low in nutrients and turbidity except for some portions that drain phosphate-mining areas. Groundwater influences water quality farther downstream where pH tends toward neutrality. Hardness of water in the lower Suwannee is quite high (Bass and Cox 1985). Biological diversity and productivity tend to increase downstream. Habitat diversity is high with extensive limestone shoals (Livingston 1992). Despite its pristine appearance, the Suwannee River has been affected significantly by non-point source pollution creating increased levels of nutrients, bacteria, and turbidity (Wakeford 2001). There are no dams on the Suwannee River, and Lukens (1988) assessed it as having a high potential to support striped bass.

4.3.3.5.8 Small Florida Panhandle Rivers

Several small streams drain areas between the watersheds of the major rivers in the Florida panhandle. These include Econfina Creek (Bay County), Wakulla/St. Marks River system (Wakulla and Leon counties), Wacissa/Aucilla River system (Jefferson and Taylor counties), and Fenholloway River (Taylor County). The Econfina Creek drains an area of 77,400 ha and flows 56 km from its headwaters into St Andrews Bay. It is in relatively natural condition with a rich fauna (Livingston 1992) and may be one of the most pristine in Florida (Wakeford 2001). A dam was constructed in the bay in 1962 forming Deer Point Lake, and prevents movement of fish upstream on the Econfina Creek (J. Barkuloo personal communication). The St. Marks is spring fed and provides some thermal refuge habitat. The Aucilla River is spring fed, originates in Georgia, and flows partially underground in karst topography 111 km to the Gulf. Although the Aucilla is in a relatively natural state (Livingston 1992), it is highly tannic and does not have as many springs as the Wacissa, a tributary, which is more likely to provide striped bass thermal refuge habitat (E. Long personal communication). The Econfina River (Taylor County) is probably not suitable striped bass habitat due to low hardness and highly tannic, acidic water. The Fenholloway River has been strongly affected by waste from a pulp paper mill. None of these rivers were assessed by Lukens (1988) for potential to support striped bass.

4.4 Habitat Quality, Quantity, Gain, Loss, and Degradation

Factors that affect striped bass populations are complex, and interactions between many of them make their effects difficult to identify. A general overview of these multi-faceted factors is provided and includes positive and negative effects on striped bass.

The populations of striped bass suffered a substantial decline in Gulf rivers during the 1950s and 1960s, and some have speculated that widespread contamination by organochlorine compounds, heavy metals, and other agricultural chemicals may have been responsible (Davis et al. 1970). During this time period, dichlorodiphenyl trichloroethane (DDT) was responsible for decimating bald eagle and brown pelican populations of the northern Gulf Coast. Dams also greatly reduced access to spawning habitats and thermal refuges in many river systems. By the late 1960s, only a small striped bass population remained in the ACF (Wooley and Crateau 1983), and striped bass populations became extirpated in other Gulf Coast rivers.

4.4.1 El Niño/La Niña

El Niño [also referred to as the El Niño Southern Oscillation (ENSO)] is a change in the eastern Pacific Ocean's surface water temperatures that contributes to major changes in global weather. It is a periodic phenomenon caused by changes in surface trade wind patterns. The tropical trade winds normally blow east to west piling up water in the western Pacific and causing upwelling of cooler water along the coast of South America. El Niño occurs when this "normal" wind pattern is disrupted. El Niño generally produces cooler and wetter summer weather in the southern United States and warmer than normal weather in the northern part of the country. In addition, there seems to be reduced (though no less severe) tropical activity during El Niño years (NAS 2000). The resulting increased summer rainfall can significantly increase river discharge, flow rates, water clarity, and other physicochemical parameters, which may impact striped bass but may also provide cooler water temperatures due to increased rainfall during critical summer months.

The effects of La Niña are nearly opposite those of El Niño. La Niña is characterized by unusually cold ocean temperatures in the eastern equatorial Pacific Ocean. La Niña periods are characterized by wetter than normal conditions across the Pacific Northwest and very dry, hot summer conditions in the Southeast. In addition, a greater than average number of tropical storms and possibly hurricanes are likely in the Gulf from June through October during La Niña. As Gulf striped bass need cool water for thermal refuge, La Niña tends to be the less favorable pattern based on temperature, although increased tropical activity may offer infrequent relief.

4.4.2 Coastal Development

The nation's coastlines continue to be among the most popular areas in which to live. Coastal areas across the United States have population increases five times the national average. According to the USGS (Williams et al. 1991), 50% of the nation's population lives within 75 km of a coast, and this figure was projected to increase to 75% by the year 2010. Both direct and indirect effects from urban development impact the quality and quantity of estuarine habitat utilized by striped bass. Hopkinson and Day (1980) suggest that processes occurring at the uplands-estuary interface have direct ecological effects, such as nutrient runoff and eutrophication. While some of the direct impacts to estuaries have abated in recent years due to coastal zone management regulations, indirect and cumulative impacts continue to be major concerns that are in direct proportion to human population growth.

4.4.3 Riparian Habitat Alterations

The clearing of overstory on tributary streams of Gulf rivers has had a profound effect on water temperatures in those streams and receiving rivers. Thermal refuges required by striped bass can be altered or eliminated by such activities. In some states, floodplains of larger streams are protected from residential developments, but silvicultural and agricultural activities are often allowed down to the river's edge. Water temperature can increase several degrees during the summer if the forest canopy is removed (Tarplee et al. 1971).

4.4.4 Barriers and Impediments to Migration

Structures that block migratory movements of anadromous fish are important factors that have contributed to declines of striped bass and other anadromous fish populations (CBF 1991, Orth and White 1993). Besides dams, barriers may also include such structures as navigational locks, pipeline crossings, culverts, and beaver dams (Odom et al. 1988), although the last two types probably do not significantly affect striped bass as they typically occur on smaller streams not usually used by striped bass (Collier and Odom 1989). In addition to upstream movements, dams may also restrict downstream movement, and fish attempting to move downstream through hydroelectric dams may be injured or killed by turbines (Orth and White 1993). Although allowing for some movement by striped bass, navigation locks severely restrict it (Scruggs 1957). Numerous dams, locks, and sills occur in Gulf rivers and impede movement of striped bass (see Sections 4.3.2.1 and 4.3.3). However, most Gulf rivers did not have dams on them by the time their striped bass populations were either extinct or seriously depleted (Barkuloo 1979).

The most effective method for restoring migratory movements interrupted by a dam is to simply breach or remove the structure (CBF 1991). Other strategies for facilitating upstream passage may involve structural features and operation of locks. Structural features include ladders, which are passive structures that fish must actively negotiate in order to move above a dam. One variation of the ladder, a bypass channel, has moderate gradients that allow fish to move around a dam. Lifts are essentially elevators that fish are attracted into by appropriate water flow. The lifted fish are released on the upstream side of the dam. Another strategy involves attraction of fish into locks with subsequent release of the fish through the upstream lock gate. Some of these strategies (primarily ladders) have successfully facilitated upstream passage of large numbers of clupeids in some Atlantic Coast rivers (CBF 1991). Striped bass do not generally utilize ladders; although somewhat better success has been had using locks and lifts (CBF 1991). Bypass channels are relatively new features, which have not been extensively used and evaluated. Screens and other guiding devices may prevent fish from entering turbines or other downstream passageways that pose a hazard to fish (Orth and White 1993). There is no information regarding downstream passage as a problem affecting striped bass in Gulf rivers.

In addition to blocking spawning migrations and preventing access to spawning or thermal refuge habitat, dams that create large impoundments may actually destroy such habitats through inundation (Collier and Odom 1989). Another important effect of dams may be to shorten the effective length of river available for striped bass eggs and larvae to hatch and develop (Lukens 1988). This may be of particular concern in rivers with multiple dams in series. In cases where suitable habitats have been reduced in quantity or quality above dams, the benefits of upstream fish passage may be limited even if successful (Collier and Odom 1989).

Some dams, particularly those used for hydroelectric power generation, may cause a general reduction in discharge along with more frequent and precipitous river stage/discharge fluctuations downstream from the dam (Fish and McCoy 1959). Fish and McCoy (1959) demonstrated that such changes reduced utilization of primary spawning areas by striped bass and spawning success in the Roanoke River, North Carolina. Water releases from dams may also affect other habitat factors downstream of dams as described by Manooch and Rulifson (1989). Temperature regimes may be altered, affecting seasonal timing or location of spawning or preventing spawning activities altogether. Prolonged abnormally high flows may increase turbulence and sediment load, transport eggs or larvae laterally into floodplain areas, or wash them directly into open coastal waters, all of which may interfere with successful hatching or larval survival. Under conditions of abnormally low flow, eggs may hatch too far upstream of nursery areas where food supplies are not adequate to support newly hatched larvae. Sudden temperature changes may shock eggs resulting in death or deformed larvae. Other water quality factors (hardness, alkalinity, pH, and DO) change quickly during water discharges. High flows tend to lower pH and increase concentrations of some heavy metals, which under lower pH conditions can become more highly toxic to fish larvae. Prolonged high flows can result in lower phytoplankton and zooplankton concentrations in estuarine nursery areas affecting the feeding success and nutrition of striped bass larvae in those areas.

In Gulf rivers, the only removal of a dam that is documented to have benefited striped bass was the removal of the Dead Lake Dam on the Chipola River, Florida, during 1987-1989. Following removal of the dam, striped bass began using thermal refuge areas of the upper Chipola River in limited numbers (Hill et al. 1994). However, warm water in the Dead Lake area still acts as a thermal barrier to striped bass movement to the upper river (USFWS 1992, Long 2001).

4.4.5 Dredge and Fill

4.4.5.1 Estuarine Impacts

Shallow water dredging for sand, gravel, clam shell, and oyster shell not only alters the bottom directly but may also change local current patterns leading to erosion or silting of productive habitats. Destruction of wetlands by development of waterfront properties results in loss of productive habitat and reduction of detritus. Channelization or obstruction of watercourses emptying into estuaries can result in loss of wetlands and change salinities in the estuaries. Lowered flow rates of drainage systems may reduce the amount of nutrients washed into estuaries or permanently alter the composition of shoreline habitats.

Degradation of estuarine habitats in the Gulf from human impacts can be traced as far back as the early 1900s (GMFMC 1998). The quality of many wetlands continues to decline due to urban and agricultural run-off and oil and gas development. Exploration for and production of oil and gas, with its concomitant development of infrastructure, began along the northern Gulf (Texas and Louisiana) in the 1930s and 1940s (GMFMC 1998). Alterations of marshes and coastal waters for oil exploration result from seismic exploration, dredging canals, construction of storage tanks and field buildings, and other types of development. Estuarine habitat loss may cause a number of problems for striped bass through saltwater intrusion into brackish water areas and directly reduce low salinity (5-15 ppt) nursery habitat, thus reducing availability of important prey. Levees built to protect urban and agricultural areas from flooding along the Mississippi River deprive marshlands of water and sediments (GMFMC 1998).

4.4.5.2 Riverine Impacts

Maintenance of the navigation channel has been particularly damaging to the Apalachicola River. Discharge of water through JWLD scours the riverbed, resulting in entrenchment of the river channel in the tailrace and upper river area by as much as two meters. Loss of bedload in upstream reservoirs results in increased scouring and entrenchment downstream of the dam as the bedload is replenished. Entrenchment of the river channel contributes to disconnection of tributary streams, including thermal refuge tributaries and spring runs at lower flows, rendering them ineffective during drought years. Maintenance dredging, bendway easing, and rock removal may locally exacerbate channel entrenchment and disconnection of tributary streams (Light et al. 1998).

Within-bank disposal of dredged material also impacts thermal refuges when flood stage flows redistribute spoil from disposal sites into the lower reaches of tributary streams. These sand deposits create berms that reduce connectivity and block access to tributary streams during lower flows.

Thermal refuge streams and spring runs that were disconnected by the deposition of spoil material or by channel entrenchment have been successfully rejuvenated by excavating sand from the creek mouths. Over-excavating the creek mouths, creating enlarged depressions where cool water aggregates, thereby increasing the available volume of thermal refuge area, has also been successful in enhancing these critical habitats. However, the life expectancy of rejuvenated refuge habitats has been as short as one to two years, depending on river conditions.

The practice of disposing dredged material onto natural sandbars reduces the quality of this habitat for young striped bass. Aquatic invertebrates, which provide forage for YOY striped bass, or for other YOY striped bass prey, are buried during dredged material disposal. Coarse sand and fine sand ranked sixth and seventh, respectively, out of eight Apalachicola River substrate habitat types in terms of macroinvertebrate productivity (mean organisms/m2, Ager et al. 1983). Coarse sand ranked seventh in terms of diversity. On older disposal sights, unconsolidated, shifting sand substrate, which is typical on these areas, is less likely to support colonies of invertebrates than stable substrates.

4.4.6 Thermal Discharge

Thermal discharge can be a major factor contributing to habitat alteration. Industrial wastewater often produces large quantities of heated effluent. Nuclear or fossil fuel electrical generation plants produce large quantities of heated water, especially if the plant has no cooling towers. This can cause significant increases in stream temperatures during the summer months and especially during drought conditions. For instance, Roessler and Zieman (1970) found all aquatic plants and animals were greatly reduced near a nuclear plant outflow within the +4°C isotherm. Conversely, the warm water discharge may become a preferred habitat when water temperatures become depressed during winter months. Van Den Avyle and Evans (1990) found that telemetered striped bass moved back into springs in the Flint River when ambient river temperature declined to 5-8°C for about two weeks during January 1985. They speculated this behavior may have indicated avoidance of cold water and suggested more study was necessary. Coutant and Carroll (1980) also found that subadult striped bass sought the warmest available water when surface temperature fell below 21°C in reservoirs. The effects of thermal pollution may be especially important during summer on the Gulf Coast for striped bass, where ambient temperatures alone may be high enough to cause stress.

Of special concern are situations where high temperature water in streams result in blockage of migration or movement of striped bass to important habitats. In the Chipola River, warm water in the Dead Lakes area acts as a thermal barrier preventing or reducing access to thermal refuge habitat farther up the Chipola (USFWS 1992, Long 2001). Cooling water discharge from a coal-fired electric power plant located on the upper Mobile River near Mt. Vernon, Alabama, has resulted in elevated temperatures in the river during some periods (Isphording and Enright 1997). The thermal plume from the discharge canal at times also extends both up and down the river and may act as a thermal barrier to fish, although this has not been documented.

4.4.7 Freshwater Diversions

Water withdrawals for municipal, industrial, and agricultural use may reduce water flow in springs, and in some cases, flow may be interrupted or reversed during droughts. Increases in water withdrawals and subsequent reduction in cool water may seriously affect the carrying capacity for larger striped bass in some rivers.

Changes in the amount and timing of freshwater inflow may affect all life history stages of striped bass that use estuaries. These habitats rely on freshwater inflow to transport nutrients critical for productivity. Activities affecting freshwater inflow include river levees (eliminating overflow into surrounding marshes), river dams, channelization, and water withdrawal.

Wildfires and clear-cutting resulting from poor silvicultural practices may lead to increased erosion rates, increased sediment load downstream, and decreased ground water recharge due to increased runoff and increased evaporation rates of sun baked soil (J. Mareska personal communication). It has also been hypothesized that replacement of natural stands of mixed pine-hardwood with pine monoculture in some parts of the southeastern United States may have had an effect on shallow aquifers and spring flow in some areas. Because pine species have active photosynthesis and corresponding transpiration throughout the year, in contrast to hardwoods that exhibit winter dormancy, there is potential for greater annual water withdrawal from the soil when landscapes are dominated by pine forest. This could affect recharge rates of shallow aquifers and springs, particularly during years of drought, including spring upwelling within river channels that serve as summer thermal refuges for striped bass. However, there have been no studies conducted to test this hypothesis (D. Jackson personal communication).

4.4.8 Point and Non-point Source Pollution

The discharge of pesticides and other toxic substances into Gulf of Mexico rivers is increasing as anthropogenic activity increases. Point sources for the introduction of these contaminants include discharge from industrial facilities, municipal wastewater treatment plants, and accidental spills. Non-point sources include urban storm water runoff, air pollutants, and agricultural activities. Approximately 5.9 million kg of toxic substances are discharged annually into the Gulf's watersheds, and approximately 2.3 million kg of pesticides were applied to agricultural fields bordering Gulf Coast counties in 1990 (USEPA 1994). The effects of these substances on aquatic organisms include: 1) interruption of biochemical and cellular activities, 2) alterations in populations dynamics, and 3) sub-lethal effects on ecosystem functions (Capuzzo et al. 1988). Lethal effects on ecosystems and individual organisms may occur with high levels of certain contaminants.

Agricultural pesticides are a major concern in striped bass management along the Gulf Coast. Most of the rivers that historically supported Gulf striped bass are in watersheds that are largely forested and agricultural. These rivers receive non-point source pollution as storm-water runoff from rural and urban areas, and roadways, which add heavy metals, polychlorinated biphenyls (PCBs), organochlorines, and other contaminants. Other sources of pollution include point source discharges from municipal wastewater treatment plants and industries, non-point contributions from airborne pollutants, and barge/boat traffic.

An example of point source pollution in known striped bass habitat is a study of largemouth bass taken from the Escambia River (contaminated site) and the Blackwater River (reference site) near Pensacola, Florida. Escambia River bass were collected downstream of the effluent from two identified point sources of pollution, including a coal-fired electric power plant and a chemical company (Orlando et al. 1999). Reference site largemouth bass were collected in the more pristine upper regions of the Blackwater River. Blood plasma was assayed for the concentration of 17ß-estradiol (E2) and testosterone using validation. No differences in plasma concentrations of E2 or testosterone were observed in females from the two sites (Orlando et al. 1999). Similarly, males exhibited no difference in plasma E2. However, plasma testosterone was lower in the males from the contaminated site, as compared to the reference site. Vitellogenic males occurred only at the contaminated site. Additionally, liver mass was proportionately higher in males from the contaminated site, as compared to males from the reference site (Orlando et al. 1999). These data suggest that reproductive steroid levels may have been altered by increased hepatic enzyme activity, and the presence of vitellogenic males indicates that an exogenous source of estrogen was present in the Escambia River.

Contaminant studies on striped bass were conducted along the Atlantic Coast in conjunction with the Emergency Striped Bass Research Study (Rago et al. 1990). Indications were that salinity levels of 2 to 5 ppm were effective in buffering the effects of insecticides when striped bass were exposed to up to four times the estimated environmental concentrations of those contaminants. A major cause of mortality to striped bass reported by those studies was aluminum toxicity. Another important finding was that low pH values play a significant role in intensifying the lethal effects of aluminum and other inorganic contaminants.

The primary contaminants in fish flesh in the Rago et al. (1990) analysis were chlorinated hydrocarbon pesticides; however, for 83% of those contaminants reported there was either no residue or no detectable residue in at least one sample. This would indicate that in the majority of cases listed by Rago et al. (1990), survival of striped bass was not threatened by those contaminants. In cases where salinity was encountered, the margin of safety would be even higher. Aluminum was not listed as a contaminant found in the fish flesh from those rivers sampled. Other inorganic pollutants appeared to be at relatively low concentrations. The pH level of the rivers studied played a role in lessening the severity of those inorganic pollutants.

The U.S. Fish and Wildlife Service in Panama City, Florida, reported relatively high levels of organochlorines, especially toxaphene and PCBs, were present in striped bass from the Flint and Apalachicola rivers in samples taken during 1986-1989 (Bateman and Brim 1994). Additional fish were collected in 1993 by Brim et al. (2001) and analyzed for organochlorine pesticides and metals in muscle and ovarian tissues. Six organochlorine pesticides were found in muscle and ovarian tissues. The concentrations found may not be deleterious to survival of adults; however, they could affect striped bass reproduction. For a detailed listing of the toxicity of certain chemicals to striped bass, see Bonn et al. (1976) and Hall (1991).

Wirgin et al. (2005a) studied pollution effects on Hudson River, New York, biota including striped bass and found that despite chronic exposures to record high levels of diverse toxicants and their bioaccumulation, only a very few taxa displayed observable gross aberrations that could be of consequence to the success of its populations. They concluded that this might frequently result from an acquired resistance of highly challenged populations to toxicants either through genetic adaptations or by physiological acclimation.

4.4.8.1 Methyl-Mercury

Mercury is found naturally in the environment as a result of volcanic activity. Mercury is also added to the environment through human activities, including incineration of solid waste, combustion of fossil fuels, and other industrial activities. Elemental inorganic mercury in the environment is converted into methyl-mercury (MeHg) by bacteria in the water. Through feeding on aquatic organisms, fish absorb MeHg. The higher on the food chain and the older the fish are, the higher the concentration of MeHg in the tissues. In the 1970s, the U.S. Food and Drug Administration (USFDA) established a standard of 0.5 ppm for the substance, in part as a result of industrial poisonings in Japan in the 1950s. In the late 1970s, the courts overturned that standard, and an action level of 1.0 ppm was established. This level was based on new data, partly contributed by the National Marine Fisheries Service, which indicated that exposure levels would not increase significantly by consumption of seafood at 1.0 ppm. The USFDA issued a fish consumption advisory for MeHg in 1995 and revised the advisory in 2001. The revision warned that pregnant women and women who may become pregnant should not eat shark, swordfish, king mackerel, and tilefish. Further, the consumption of all other fish should average no more than about 12 ounces per week, since high, prolonged exposure to MeHg can cause neurological damage (B. Collette personal communication).

There is little Gulf data on MeHg levels in striped bass. Each of the five Gulf States test recreationally and commercially harvested fish for mercury on a routine basis but have sampled very few striped bass. Those that were tested indicate low levels of MeHg or total mercury (another measure of contamination) with only a few individual exceptions (T. Atkeson , F. Leslie, M. Tennant, and C. Piehler personal communications).

Striped bass and several other fish species were collected by Lowe et al. (1985) in the Apalachicola River during 1978-1979 and 1980-1981 during the National Contaminant Biomonitoring Program. Concentrations of mercury in muscle were higher (0.855 μg/g) than in gonads or ovaries. Every sample in this study exceeded Florida's limited consumption advisory of 0.5 μg/g fresh weight edible portion. One sample exceeded the FDA level for mercury in fish for human consumption (1 ppm). Comparisons of 1993 data with data from 1986 to 1989 indicated that mercury levels had almost doubled in muscle and tripled in ovarian tissue of striped bass from the Apalachicola River by 1993.

4.4.9 Introduction of Non-native Flora and Fauna

According to ISFT (2000) the terms "non-native" and "introduced" are synonyms for "nonindigenous." That reference defines nonindigenous species to include:

> any individual, group, or population of a species, or other viable biological material, that is intentionally or unintentionally moved by human activities, beyond its natural range or natural zone of potential dispersal, including moves from one continent or country into another and moves within a country or region; includes all domesticated and feral species, and all hybrids except for naturally occurring crosses between indigenous species.

Further, nonindigenous aquatic species are defined as those that must live in a water body for part or all of their lives.

As of September 2000 a total of 399 amphibians, bryozoans, coelenterates, fishes, and aquatic crustaceans, mammals, mollusks, plants, and reptiles were considered nonindigenous aquatic species in four of the Gulf states within the striped bass' native range (ISFT 2000). Some of these species have established reproducing populations, and many probably have no adverse effects on native ecosystems. However, some do have serious impacts on native fauna and/or flora. While the effects of a few nonindigenous species on striped bass have been documented, others may be speculative.

From another perspective, striped bass have been introduced extensively throughout the U.S. in areas where they were not native, including some Gulf Coastal plain rivers (see Section 3.1). Although there have been assessments of potential effects of introduced striped bass on native fauna, few serious negative impacts have been reported on other recreational fish species (Bailey 1974, Axon and Whitehurst 1985), although potentially problematic predation on trout was reported (Axon and Whitehurst 1985, Hess and Jennings 2000). At times, reductions in standing crops of shad have followed striped bass introduction to reservoirs, generally without effects on other recreational fish populations (Combs 1980). However, in some reservoirs with limited clupeid prey, populations of other predatory fish species may expand somewhat in the absence of striped bass (Miranda et al. 1998). Introduction of Atlantic race striped bass into Gulf rivers that have or at one time had striped bass native populations may also be considered a non-native introduction (USGS 2003).

4.4.9.1 Aquatic Plants

Several nonindigenous aquatic plants found in Alabama, Florida, Georgia, Louisiana, and Mississippi (Benson et al. 2001) may impact striped bass. The most problematic of these is hydrilla (*Hydrilla verticillata*). Effects on fisheries by submerged macrophytes such as hydrilla have been well documented (Maceina and Shireman 1982, Carter et al. 1988, Jones 1990, Long and Rousseau 1996). Extensive infestations by these plants had deleterious effects on Phase I fingerling stocking success and reduced juvenile survival during the first six months after stocking. The negative effects were likely due to restricting primary productivity and reducing access to sandy bottom nursery habitat. Reduced phytoplankton populations decrease feeding efficiency of important striped bass prey species such as threadfin shad, gizzard shad, and skipjack herring, with subsequent trophic effects manifested in the striped bass population (see Section 4.2.3.2).

Other plants with potential effects similar to hydrilla include Brazilian waterweed (*Egeria densa*), which is similar in appearance and growth to hydrilla (Benson et al. 2001). This aggressive plant may be out-competed only by hydrilla in southern regions.

Water hyacinth (*Eichhornia crassipes*) is a floating plant with thick, glossy leaves, mats of which often cover large areas of standing water; and giant salvinia (*Salvinia molesta*) is a free floating fern with large leaves that may form impenetrable monoculture covering the water surface. Eurasian water milfoil (*Myriophyllum spicatum*) is a submerged aquatic species found throughout the Southeast. In the striped bass' historic range it has become established in reservoirs of the Alabama and Tombigbee rivers. It is somewhat tolerant of brackish conditions and has been found in some Gulf Coast estuaries. Although it is most problematic in the northern United States, it may have impacts similar to hydrilla in reducing primary productivity.

4.4.9.2 Zebra Mussels (*Dreissena polymorpha*)

Zebra mussels (*Dreissena polymorpha*) are native to Eastern Europe (USGS 2003). They first appeared in North America in the Great Lakes in 1988, probably transported by ship ballast water. They now inhabit much of the Mississippi River drainage, including the LMR all the way to the mouth, as well as the Tennessee River system in northern Alabama and Mississippi. They have also been found in the Mississippi Sound. Although large zebra mussel populations are not found within the historic range of striped bass, they have the potential to spread to other freshwater areas of the Southeast.

Zebra mussels can attain lengths of up to about 50 mm and live four to five years. Although normally inhabiting fresh water, they can tolerate brackish water of 1-2 ppt. They are filter feeders; each individual is capable of filtering approximately 1 liter of water per day, straining out the algae.

Despite the ability of large zebra mussel populations to filter significant quantities of algae from the water column, no negative fisheries impacts have been documented. The mussels dramatically increased water clarity in Lake Erie (4-6 fold difference). Higher light penetration led to increases in submerged rooted macrophyte beds that provide nursery habitat for some species of fish. If they became established in waters important to striped bass there could conceivably be effects on planktonic algae populations with trophic effects on striped bass similar to those of hydrilla.

4.4.9.3 Fishes

Two large non-native predatory fishes may directly compete with and feed upon striped bass in Gulf rivers – the flathead catfish (*Pylodictis olivaris*) and blue catfish (*Ictalurus furcatus*). The two species are native to the rivers from the MAT westward but have been introduced into the ACF system and other rivers in the eastern portion of the striped bass' native range. Flathead catfish are known to prey upon shad (USGS 2003). Although both flathead catfish and striped bass have historically co-existed in the western portion of the striped bass' native range in the Gulf, problems could occur if nonindigenous populations significantly expand beyond densities normally seen in their native range. Predation on juvenile striped bass would be the most probable issue.

Grass carp *(Ctenopharygodon idella*), native to eastern Asia, have been stocked extensively for aquatic vegetation control, especially in reservoirs, and are known to occur in some Gulf rivers, including the Mississippi, some western Lake Pontchartrain rivers, and the MAT and ACF systems (USGS 2003). Although they may compete with striped bass for thermal refuge (FWC unpublished data), their presence is sometimes associated with increases in phytoplankton abundance due to nutrient enrichment effects. The actual impact of this species on striped bass is not known.

Bighead carp (*Hypophthalmichthys nobilis*), native to central and southern China, have been established in the Mississippi River and reported from the lower Pascagoula River and portions of the MAT Rivers system (USGS 2003). Bighead carp are planktivorous and become quite large, so they have the potential to reduce zooplankton populations and thus affect prey species of striped bass.

4.4.9.3.1 Hybrid Striped Bass

Many Gulf Coast rivers and reservoirs have been stocked with hybrid striped bass, which could be considered a non-native species. According to Axon and Whitehurst (1985) the number of hybrid fisheries surpassed the number of striped bass fisheries in reservoirs by 1981. The effects of these introductions on striped bass populations have not been fully evaluated. Axon and Whitehurst (1985) noted that striped bass in mixed (i.e., with hybrids) reservoir fisheries tended to be larger than in fisheries with striped bass alone. In Texas, stocking of striped bass and hybrids improved habitat utilization and did not negatively affect other sport species (McCabe 1984). However, the view of many fisheries professionals is that stocking hybrids may present problems in systems where the goal is restoration of a self-sustaining striped bass population (USFWS 2003).

Because hybrids do not maintain self-sustaining populations, they must be restocked periodically (McCabe 1989). Hybrids do not usually live longer than age 4-5 (Holman et al. 1998, Keefer 1981), although individuals age 6-7 have been found in the Apalachicola River (Mesing et al. 1997).

Hybrids are currently (within the last four years) stocked into numerous reservoirs throughout Texas (TPWD 2002). In Louisiana hybrids are stocked into a number of lakes in various parts of the state but not into any of the rivers within the striped bass' native range east of the Mississippi (H. Rogillio, personal communication). Hybrids have been stocked into numerous reservoirs in the Mississippi River system (Kinman 1995) and into some Mississippi River oxbow lakes (MDWFP unpublished data). In Mississippi, hybrids are currently being stocked into Ross Barnett Reservoir on the Pearl River (MDWFP unpublished data) and into Big Creek Lake on the Escatawpa River branch of the Pascagoula River system (ADCNR/WFF unpublished data). In addition, an aquaculture facility in the Pascagoula basin produced hybrid striped bass in the 1990s. In Alabama, Florida, and Georgia, hybrids are currently being stocked into various areas of the MAT system (ADCNR/WFF unpublished data), as well as into the Escambia, Choctawhatchee, ACF, and the Ochlockonee systems, although not on an annual basis (FWC, GDNR unpublished data). Hybrids were first stocked into the ACF system in 1975 (Young and Crew 1979).

Since hybrids are generally not as dependent on thermal refuges as are striped bass (McCabe 1989), they are sometimes stocked in shallower eutrophic reservoirs that have limited cool water habitat. However, Muncy et al. (1990) found that hybrids prefer relatively cooler water (21°-27°C) than what is ambient during summer months, and movements were restricted and condition declined during July and August in Ross Barnett Reservoir, Mississippi. Although there is potential for thermal refuge competition between striped bass and hybrids, observations of both species in thermal refuge areas in the ACF system indicated that striped bass are found in the coolest temperature zones with the hybrids in the peripheral areas, and the striped bass appear to effectively compete for the coolest water (USFWS 2003).

Patrick and Moser (2001) documented diet overlap, co-occurrence in estuarine habitats and possible co-occurrence in spawning habitats by striped bass and hybrids in the Cape Fear River, North Carolina. Over the same period, striped bass populations in other North Carolina rivers experienced strong recovery, and the authors postulated that if food, habitat, or mates were limited, the presence of hybrids could hinder the recovery of the population within the system. They also noted that introgression may be a problem. While they did not document reproduction by hybrids, the presence of hybrids with well-developed gonads was noted during the pre-spawning season, and one spent hybrid was captured. They indicated that striped bass and hybrids in the system are difficult to distinguish and pointed out that this may be due to backcrossing. Yeager (1982) determined that hybrids preferred lower river estuarine habitats in the Escambia River and found no upstream spring migration by hybrids. However, an upstream spring migration was documented by Muncy et al. (1990) in Ross Barnett Reservoir, Mississippi. Thompson and Knight (1983) determined that clupeids composed 65%-85% of the adult diets for both striped bass and hybrids in Sardis Reservoir, Mississippi, and Ott and Mavestuto (1981) found shad comprised over 90% of the diet of hybrids in West Point Reservoir, Alabama-Georgia.

While co-stocking striped bass and hybrids in the ACF system, Mesing (1990) found growth of YOY striped bass declined significantly when combined stocking densities were >35 fish/ha, although YOY hybrid growth did not decline until stocking densities reached 85 fish/ha. The poor growth probably contributed to reduced recruitment of striped bass. These effects were attributed to declines in shad populations, possibly in part due to the high *Morone* stocking rates, although the effects of hydrilla in Lake Seminole were also probably partly responsible for the decline in shad. These growth effects might be less problematic or perhaps even non-existent in systems with higher primary productivity (USFWS 2003).

Hybrids are known to spawn and can successfully reproduce (McCabe 1989, Karas 1993). In Lake Palestine, Texas, 29% of *Morone* spp. collected in 1985-1986 was non-F1 hybrids (Forshage et al. 1986). Possible natural hybridization has been reported in Arkansas (Crawford et al. 1984). Natural backcrossing of hybrids to striped bass has also been observed. Avise and Van den Avyle (1984) found evidence of limited backcrossing or hybrid reproduction in the Savannah River, but they found significant evidence of backcrossing in Cherokee Reservoir in the Tennessee River system in Tennessee. Harrell et al. (1993) found 3% of hybrids in Chesapeake Bay were the result of backcrosses with striped bass. There is also evidence of backcrossing between striped bass and hybrids in the Tombigbee River (Powell 1990). The potential outcomes of such mating may include deformed progeny, loss of genetic integrity of the parental species, and consequent contamination of wild broodfish sources (Avise and Van den Avyle 1984, Forshage et al. 1986).

Among the positive aspects of stocking hybrids may be a possible reduction in fishing pressure on striped bass in some systems. Hybrid striped bass are generally more aggressive (Heidinger 1983) and easier to catch than are striped bass (Karas 1993). Tucker and Johnson (1989) found that at age-1 hybrid catch rates were higher than for striped bass, but the reverse was true at age-2 and age-3 in the lower Mobile River. Mesing (1990), however, found higher hybrid to striped bass catch rate ratios at ages 1-4 in the Apalachicola River. On the other hand, many anglers have difficulty distinguishing between hybrids and striped bass, and the lack of size limit regulations on hybrids may result in undersize striped bass being taken (USFWS 2002).

4.4.10 Global Warming and Sea Level Rise

Increasing atmospheric levels of carbon dioxide and other gases released by human activities are believed to contribute to the greenhouse effect whereby more of the sun's radiant heat is retained within the atmosphere. It is expected that the earth's average temperature will rise by several degrees in the next century and that, while most of the U.S. is expected to warm, there is likely to be an overall trend toward increased precipitation and evaporation, more intense rainstorms, and drier soils (Titus and Narayanan 1995). Some of the potential impacts of global warming include stronger and more frequent tropical storms, changes in rainfall patterns that may affect agriculture, spreading of tropical diseases, melting of glaciers and land-based ice caps causing sea level rise, and increases in pollution levels.

Estimates of rising sea level rates vary considerably and are extremely controversial (Titus 1987). As sea level rises, wetland habitats may be impacted by inundation, erosion, and saltwater intrusion. Such impacts could contribute to serious wetland losses along the relatively flat coastlines of the Gulf of Mexico, depending on the magnitude of the sea level rise and the amount of shoreline hardening, which would retard wetland retreat inland. The effects of global warming and sea level rise could both positively and negatively impact striped bass in the Gulf of Mexico.

Increased global temperatures would likely increase water temperatures in rivers and streams, and increased rainfall may not significantly reduce those temperatures. Alternatively, increased water levels could provide both access to, and additional areas of, thermal refuge and increase the "recharge" of the aquifers, significantly increasing the amount of cool water upwelling into existing springs. The true impacts of such events on Gulf striped bass are uncertain.

4.4.11 Liquefied Natural Gas (LNG) Plants

Natural gas is a limited resource in the United States. In recent years as demand grew, the U.S. supply declined substantially. The chemical properties of natural gas allow it to be cooled and held in insulated tanks as a liquid. In this form, it is able to be transported long distances. The two most common systems to warm LNG back into its gaseous form are a closed loop system and an open loop system. Regardless of the system design, the super cooled liquid must be warmed after transport back into a gaseous form. Most open loop systems use ambient water to warm the liquefied gas resulting in decreases in water temperatures of -13º to -30º F below normal. In a closed loop system, the LNG plant recycles and warms the cooled outfall water back up to ambient temperatures using heat from the burning of natural gas and reuses the warmed water. The open loop system continuously pumps new water into the plant and releases the chilled water into the environment.

The first commercial inland LNG plant in the U.S. was built in 1941 in Cleveland, Ohio, and the first marine-based plant in the Gulf was built in Lake Charles, Louisiana, in 1971 (CLNG 2004). A total of 113 LNG facilities exist in the country, but only four terminals operate in a marine/estuarine environment. The plants currently operating in these nearshore areas are closed-loop systems due to the large amount of water required for heating the LNG. Open loop systems have the potential to negatively impact marine fisheries. The estimated 100 million gallons of water taken from the estuary each day by an open loop system would result in billions of fish eggs and larvae becoming impinged and entrained annually. In addition, the super-cooled outfall water from an open loop system could decrease the ambient temperatures in the estuary and pose a thermal shock to the early juvenile to adult fish that escaped entrainment. Offshore LNG terminals also have the same potential to impact recreational and commercial fisheries. Striped bass could be affected by open loop systems located in estuarine habitats.

5.0 FISHERY MANAGEMENT JURISDICTIONS, LAWS, AND POLICIES AFFECTING THE STOCK(S)

Striped bass are native to rivers and estuaries of the northern Gulf of Mexico at least as far west as Lake Pontchartrain, Louisiana, and eastward to the Suwannee River, Florida. Although these fish historically supported recreational and commercial fisheries until the early 1950s, population declines have eliminated all commercial endeavors in the Gulf States. The following is a partial list of some of the more important fishery management entities and a brief description of the laws and regulations that could potentially affect striped bass and their habitat. Contact individual states and federal agencies for specific and up-to-date state laws and regulations.

5.1 Federal

5.1.1 Management Institutions

The striped bass fishery in the northern Gulf of Mexico is conducted exclusively in state management jurisdictions; consequently, laws and regulations of federal agencies primarily affect striped bass populations by maintaining and enhancing habitat, preserving water quality and food supplies, and abating pollution. Federal laws may also be adopted to protect consumers through the development of regulations to maintain the quality of striped bass as seafood.

5.1.1.1 Regional Fishery Management Councils

With the passage of the Magnuson Fishery Conservation and Management Act (MFCMA), the federal government assumed responsibility for fishery management within the exclusive economic zone (EEZ), a zone contiguous to the territorial sea and whose inner boundary is the outer boundary of each coastal state. The outer boundary of the EEZ is a line 200 nautical miles from the (inner) baseline of the territorial sea. Management of fisheries in the EEZ is based on FMPs developed by regional fishery management councils. Each council prepares plans for each fishery requiring management within its geographical area of authority and amends such plans as necessary. Plans are implemented by federal regulation through the U.S. Department of Commerce (USDOC).

The councils must operate under a set of standards and guidelines, which to the extent practicable, call for an individual stock of fish to be managed as a unit throughout its range. The standards also call for management to, where practicable, promote efficiency, minimize costs, and avoid unnecessary duplication (MFCMA Section 301a).

The GMFMC has not developed a management plan for striped bass, as there is no fishery for striped bass in the EEZ of the United States Gulf of Mexico.

5.1.1.2 National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), USDOC

The Secretary of Commerce, acting through the NMFS, has the ultimate authority to approve or disapprove all FMPs prepared by regional fishery management councils. Where a council fails to develop a plan, or to correct an unacceptable plan, the Secretary may do so. The

NMFS also collects data and statistics on fisheries and fishermen and comments on all projects that affect marine fishery habitat. It performs research and conducts management authorized by international treaties. The NMFS has the authority to enforce the MFCMA and Lacey Act and is the primary federal trustee for most living and nonliving natural resources in coastal and marine areas.

The NMFS exercises no management jurisdiction other than enforcement with regard to striped bass in the Gulf of Mexico; however, the NMFS interacts with the states and the GSMFC through the funding of interstate fishery management plans under the MFCMA (Section 5.1.3.1) and the Interjurisdictional Fisheries Act (Section 5.1.3.2). In addition, the NMFS can provide programmatic funding for activities under the Anadromous Fish Conservation Act (AFCA) (Section 5.1.3.5).

The USDOC, in conjunction with coastal states, administers the National Estuarine Research Reserve and National Marine Sanctuaries Programs as authorized under Section 315 of the Coastal Management Act of 1972. Those protected areas serve to provide suitable habitat for a multitude of estuarine and marine species and serve as sites for research and education activities relating to coastal management issues.

Under the Fish and Wildlife Coordination Act and through its Habitat Conservation Division, the NMFS reviews and comments on activities that may adversely affect habitat. Dredging, filling, and marine construction are examples of projects that could affect striped bass habitat.

5.1.1.3 Office of Ocean and Coastal Resource Management (OCRM, NOAA)

The OCRM asserts management authority over marine fisheries through the National Marine Sanctuaries Program. Under this program, marine sanctuaries are established with specific management plans that may include restrictions on harvest and use of various marine and estuarine species. Harvest of striped bass could be directly affected by such plans, though there are currently no national marine sanctuaries within the striped bass' range in the Gulf of Mexico.

The OCRM may influence fishery management for striped bass indirectly through administration of the Coastal Zone Management Program and by setting standards and approving funding for state coastal zone management programs. These programs often affect estuarine habitat on which striped bass depend.

5.1.1.4 National Park Service (NPS), U.S. Department of the Interior (USDOI)

The NPS under the USDOI may regulate fishing activities within park boundaries. Such regulations could affect the harvest of striped bass if implemented within a given park area.

5.1.1.5 United States Fish and Wildlife Service (USFWS), USDOI

The USFWS has no direct management authority over striped bass harvest except on some national wildlife refuges (NWR). This harvest is restricted to within recreational limits developed by the respective states. On certain NWRs, the USFWS may directly regulate fishery harvest through the National Wildlife Refuge Administration Act (Section 5.1.3.17). Special use permits may be required if commercial harvest is to be allowed in refuges.

The USFWS may affect the management of striped bass through the Fish and Wildlife Coordination Act, under which the USFWS and the NMFS review and comment on activities that may adversely affect habitat. Dredging, filling, dam construction, navigation projects, and marine construction are examples of projects that could affect striped bass habitat.

Under the AFCA and the Federal Aid in Sport Fish Restoration Act (FASFRA) the USFWS is authorized to provide grant funding to the states for anadromous fish management activities. In addition, the USFWS fisheries resource offices provide assistance to the states in carrying out and coordinating management and restoration activities for striped bass, and the national fish hatcheries produce fry and fingerlings for stock enhancement of striped bass populations and develop and refine propagation techniques to assist the states in striped bass management and restoration.

5.1.1.6 United States Environmental Protection Agency (USEPA)

Through its administration of the Clean Water Act and the National Pollutant Discharge Elimination System (NPDES), the USEPA provides protection for striped bass and their habitat. Applications for permits to discharge pollutants into estuarine waters may be disapproved or conditioned to protect marine resources.

The USEPA and a local sponsor administer the National Estuary Program jointly. This program evaluates estuarine resources, local protection and development of policies, and develops management plans. Input is provided to these plans by a multitude of user groups including industry, environmentalists, recreational and commercial interests, and policy makers. National Estuary Programs in the Gulf include those in Sarasota, Tampa, Mobile, Barataria/Terrebonne, Galveston, and Corpus Christi bays.

5.1.1.7 United States Army Corps of Engineers (USACOE)

Striped bass populations are directly influenced by the USACOE's responsibilities pursuant to the Clean Water Act and Section 10 of the Rivers and Harbors Act. Under these laws, the USACOE issues or denies permits to individuals and organizations for proposals to dredge, fill, and construct in wetland areas and navigable waters. The USACOE is also responsible for planning, constructing, and maintaining navigation channels, locks and dams, and other water development projects in aquatic areas, and these projects may affect striped bass, their habitat, and food sources.

5.1.1.8 United States Coast Guard

The United States Coast Guard is responsible for enforcing fishery management regulations adopted by the USDOC pursuant to management plans developed by the GMFMC. The Coast Guard also enforces laws regarding marine pollution and marine safety and assists commercial and recreational fishing vessels in times of need.

Although no regulations have been promulgated for striped bass in the EEZ, enforcement of laws affecting marine pollution and fishing vessels could influence striped bass populations.

5.1.1.9 United States Food and Drug Administration (USFDA)

The USFDA may directly regulate the harvest, sale, and processing of fish through its administration of the Food, Drug, and Cosmetic Act and other regulations that prohibit the sale and transfer of contaminated, putrid, or otherwise potentially dangerous foods.

5.1.2 Treaties and Other International Agreements

No treaties or other international agreements affect the harvest or processing of striped bass in the northern Gulf of Mexico. No foreign fishing applications to harvest striped bass in the Gulf of Mexico have been submitted to the United States.

5.1.3 Federal Laws, Regulations, and Policies

The following federal laws, regulations, and policies may directly or indirectly influence the quality, abundance, and ultimately the management of striped bass.

5.1.3.1 Magnuson Fishery Conservation and Management Act of 1976 (MFCMA); Magnuson-Stevens Conservation and Management Act of 1996 (Mag-Stevens); and Sustainable Fisheries Act of 1996 (P.L. 94-265)

The MFCMA mandates the preparation of FMPs for important fishery resources within the EEZ. It sets national standards to be met by such plans. Each plan attempts to define, establish, and maintain the optimum yield for a given fishery. The 1996 reauthorization of the MFCMA set three new additional national standards to the original seven for fishery conservation and management, included a rewording of standard number five, and added a requirement for the identification of EFH and definitions of overfishing. Striped bass in the Gulf are not subject to any of these laws at this time, though the species may benefit from EFH habitat protection measures.

5.1.3.2 Interjurisdictional Fisheries (IJF) Act of 1986 (P.L. 99-659, Title III)

The IJF Act established a program to promote and encourage state activities in the support of management plans for interjurisdictional fisheries and to promote and encourage management of these resources throughout their range. The enactment of this legislation repealed the Commercial Fisheries Research and Development Act (P.L. 88-309).

5.1.3.3 Federal Aid in Sport Fish Restoration Act (FASFRA); the Wallop-Breaux Amendment of 1984 (P.L. 98-369)

The FASFRA has been amended several times and is commonly called the Dingell-Johnson Act or Wallop-Breaux Act. It provides federal grant funding to the states for managing and restoring fish populations having "material value in connection with sport or recreation in the marine and/or fresh waters of the United States." Grant funding can also be provided to the states for aquatic education, wetlands restoration, boat safety, and recreational vessel sewage pump-out stations.

5.1.3.4 Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA), Titles I and III and The Shore Protection Act of 1988 (SPA) (P.L. 92-532)

The MPRSA provides protection of fish habitat through the establishment and maintenance of marine sanctuaries. The MPRSA and the SPA regulate ocean transportation and dumping of dredged materials, sewage sludge, and other materials. Criteria for issuing such permits include consideration of effects of dumping on the marine environment, ecological systems, and fisheries resources.

5.1.3.5 Anadromous Fish Conservation Act (AFCA) of 1965 (P.L. 89-304)

The AFCA (as amended) authorizes the Secretaries of the Interior and Commerce to initiate cooperative programs with states for the conservation, development, and enhancement of the nation's anadromous fish. This Act authorizes the conduct of such investigations, engineering and biological surveys, and research as may be desirable to protect fishery resources. The act authorizes the construction, installation, maintenance, and operation of devices and structures for the improvement of feeding and spawning conditions and to facilitate the migration of anadromous fish.

5.1.3.6 Federal Water Pollution Control Act of 1948 (FWPCA), as amended, and the United Nations Treaty from the Convention for the Prevention of Pollution from Ships, MARPOL (Marine Pollution), Annexes I and II (P.L. 845)

Also referred to as the Clean Water Act (CWA), the FWPCA requires that a USEPA approved NPDES permit be obtained before any pollutant is discharged from a point source into waters of the United States, including waters of the contiguous zone and the adjoining ocean. Discharges of toxic materials into rivers and estuaries that empty into the Gulf of Mexico can cause mortality or other harm to freshwater and marine fishery resources and may alter habitats.

Under Section 404 of the CWA the USACOE is responsible for administration of a permit and enforcement program regulating alterations of wetlands as defined by the act. Dredging, filling, bulk-heading, and other construction projects are examples of activities that require a permit and have potential to affect fish populations. Pursuant to the CWA, the FWS and NMFS are the federal trustees for living and nonliving natural resources in waters under United States jurisdiction.

Discharge of oil and oily mixtures is governed by the FWPCA through Title 40 of the Code of Federal Regulations, Part 110, in the navigable waters of the United States. MARPOL Annex I governs discharge of oil and oily substances by foreign ships or domestic ships operating or capable of operating beyond the United States territorial sea.

MARPOL Annex II governs the discharge at sea of noxious liquid substances primarily derived from tank cleaning and deballasting. Most categorized substances are prohibited from being discharged within 22 km of land and at depths of less than 25 m.

5.1.3.7 MARPOL Annex V and United States Marine Plastic Research and Control Act of 1987 (MPRCA)

MARPOL Annex V is a product of the International Convention for the Prevention of Pollution from Ships, 1973/1978. Regulations under this act prohibit ocean discharge of plastics from ships; restrict discharge of other types of floating ship's garbage (packaging and dunnage) within 46 km of any land; restrict discharge of victual and other recomposable waste up to 22 km from land; and require ports and terminals to provide garbage reception facilities. The MPRCA of 1987 and 33 CFR, Part 151, Subpart A, implement MARPOL V in the United States.

5.1.3.8 Coastal Zone Management Act of 1972 (CZMA), as amended (P.L. 92-583)

Under the CZMA, states receive federal assistance grants to maintain federally-approved planning programs for enhancing, protecting, and utilizing coastal resources. These are state programs, but the act requires that federal activities must be consistent with the respective states' CZM programs. Depending upon the individual state's program, the act provides the opportunity for considerable protection and enhancement of fishery resources by regulation of activities and by planning for future development in the least environmentally damaging manner.

5.1.3.9 Endangered Species Act of 1973, as amended (P.L. 93-205)

Administered by the USFWS and NMFS, the Endangered Species Act provides for the listing of plant and animal species, subspecies, or certain populations as threatened or endangered and as critical, certain habitats upon which these species or populations depend. Endangered means a species or population is in danger of becoming extinct throughout all or a significant portion of its range. A threatened species or population is one that is likely to become endangered in the near future. Once listed as threatened or endangered, a species may not be taken, possessed, harassed, or otherwise molested. It also provides for a review process to ensure that projects authorized, funded, or carried out by federal agencies do not jeopardize the continued existence of these species or result in destruction or modification of habitats that are determined by the Secretary of the USDOI or USDOC to be critical. The Gulf race of striped bass could potentially be listed as an endangered or threatened population under the act if it was determined to be an evolutionarily significant unit meeting the conditions for listing as defined in the act.

5.1.3.10 National Environmental Policy Act of 1970 (NEPA) (P.L. 91-190)

The NEPA requires that all federal agencies recognize and give appropriate consideration to environmental amenities and values in the course of their decision-making. In an effort to create and maintain conditions under which man and nature can exist in productive harmony, the NEPA requires that federal agencies prepare environmental impact statements (EIS) prior to undertaking major federal actions that significantly affect the quality of the human environment. Within these statements, alternatives to the proposed action that may better safeguard environmental values are to be carefully assessed.

5.1.3.11 Fish and Wildlife Coordination Act of 1934, as amended (P.L. 325)

Under the Fish and Wildlife Coordination Act, the USFWS and NMFS review and comment on fish and wildlife aspects of activities sanctioned, permitted, assisted, funded, or conducted by federal agencies. The reviews focus on potential damage to fish, wildlife, and their habitat; therefore, they serve to provide some protection to fishery resources from activities that may alter aquatic habitats. The act is important because federal agencies must give due consideration to the recommendations of the USFWS and NMFS.

5.1.3.12 Fish Restoration and Management Projects Act of 1950 (P.L. 81-681)

Under this act, the USDOI is authorized to provide funds to state fish and wildlife agencies for fish restoration and management projects. Funds for protection of threatened fish communities that are located within state waters could be made available under the act.

5.1.3.13 Lacey Act Amendments of 1981, as amended (P.L. 81-681)

The Lacey Act prohibits import, export, and interstate transport of illegally taken fish and wildlife. As such, the act provides for federal prosecution for violations of state fish and wildlife laws. The potential for federal convictions under this act with its more stringent penalties has probably reduced interstate transport of illegally possessed fish and fish products.

5.1.3.14 Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or "Superfund") (P.L. 96-510)

The CERCLA names the USFWS and NMFS as the federal trustees for living and nonliving natural resources in freshwater coastal and marine areas under United States jurisdiction. It could provide funds for "clean-up" of fishery habitat in the event of an oil spill or other polluting event.

5.1.3.15 Fish and Wildlife Act of 1956

This act, as frequently amended, established a comprehensive national fish, shellfish, and wildlife resources policy with emphasis on the commercial fishing industry but also with a direction to administer the act with regard to the inherent right of every citizen and resident to fish for pleasure, enjoyment, and betterment and to maintain and increase public opportunities for recreational use of fish and wildlife resources. Among other things, it directs a program of continuing research, extension, and information services on fish and wildlife matters, both domestically and internationally. Although the responsibilities for commercial fisheries were transferred to the USDOC in 1970, this act and its amendments essentially established the USFWS as it currently exists.

5.1.3.16 National Wildlife Refuge Administration Act of 1966 (P.L. 89-669)

The National Wildlife Refuge System Administration Act, as amended, consolidated the various categories of lands administered by the Secretary of the Interior through the USFWS into a single National Wildlife Refuge System. The act created a refuge system for the purpose of protection and conservation of fish and wildlife, including species threatened with extinction, wildlife ranges, game ranges, wildlife management areas, or waterfowl production areas; and to ensure opportunities for compatible wildlife-dependent uses.

5.1.3.17 Clean Vessel Act of 1992 (P.L. 102-587)

The Clean Vessel Act established a recreational boater sewage disposal program which was authorized through 2003 and amended the Federal Aid in Sport Fish Restoration Act in providing grants to coastal and inland states for building and maintaining pump-out stations and waste reception facilities to dispose of recreational boater sewage. Funding was provided to states during 1993-1997 and 1999. There is currently no authorization for Clean Vessel Act funding.

5.1.3.18 Estuary Protection Act of 1968 (PL 90-454)

This Act highlights the values of estuaries and the need to conserve their natural resources. It authorizes cooperative studies between the USDOI, other federal agencies, and the states to study and inventory estuaries of the United States and to determine areas the federal government should acquire for protection. It also authorizes cost-sharing agreements between the USDOI, states, and subdivisions for management of estuarine areas in their possession. Federal agencies are also required to assess the impacts of commercial and industrial developments on estuaries. It also requires the USDOI to encourage state and local governments to consider the importance of estuaries in their planning activities related to federal natural resource grants.

5.1.3.19 Estuaries and Clean Waters Act of 2000 (P.L. 106-457)

This act encourages restoration of estuarine habitats through more efficient project financing and coordination of federal and non-federal restoration programs. It created a federal interagency council (composed of the directors of the USFWS, the Secretary of the Army for Civil Works, the Secretary of Agriculture, the Administrator of the USEPA and the Administrator of the NOAA) charged with developing a national estuary habitat restoration strategy and providing grants to restore and protect estuarine habitat.

5.1.3.20 Fish and Wildlife Improvement Act of 1978 (P.L. 95-616)

This act authorizes the Secretaries of the USDOI and USDOC to establish, conduct, and assist with national training programs for state fish and wildlife law enforcement personnel. It also authorized funding for research and development of new or improved methods to support fish and wildlife law enforcement and strengthens the law enforcement operational capability of the USFWS by authorizing the disbursement and use of funds to facilitate various types of investigative efforts.

5.1.3.21 Oil Pollution Act of 1990 (P.L. 101-380)

The Oil Pollution Act set up new requirements and substantially amended the Federal Water Pollution Control Act to enhance capabilities for oil spill response and natural resource damage assessment by the USFWS. Under the Act, consultation is required with the USFWS in developing a fish and wildlife response plan for the National Contingency Plan, which authorizes the USFWS to provide input to Area Contingency Plans. The Act also authorizes the USFWS to review Facility and Tank Vessel Contingency Plans and to conduct damage assessments associated with oil spills. The Act also provides for identifying ecologically sensitive areas and preparing scientific monitoring and evaluation plans.

5.1.3.22 Outer Continental Shelf (OCS) Lands Act of 1953 as amended (P.L. 212, P.L. 93-627, P.L. 95-372, P.L. 98-498)

This statute defines the OCS as all submerged lands lying seaward of state coastal waters (generally beyond three miles offshore) which are under U.S. jurisdiction and sets up a program for leasing these areas for oil and gas production. It provides for assessing the effects of oil and gas exploration, development, and production on biological resources. The law also provides a channel for comments on federal approval of leasing OCS areas for exploration and development. Oil and gas leasing activities could be of concern for coastal anadromous fish habitat, particularly regarding transportation of crude oil to shore, as well as potential pollution from on-shore processing facilities.

5.1.3.23 Resource Conservation and Recovery Act (RCRA) of 1976 as amended (P.L. 94-580)

This act regulates the treatment, transportation, storage, and disposal of solid and hazardous wastes.

5.1.3.24 Rivers and Harbors Appropriation Acts of 1899 and 1938

Section 9 of this act prohibits construction of bridges, dams, dikes, or causeways over or in navigable waters of the U.S. without a federal permit. The Coast Guard administers Section 9. Section 10 of the act prohibits building wharfs, piers, jetties and other structures, and excavation or fill within navigable waters without a permit from the USACOE. The Act of 1938 specifies that fish and wildlife conservation be given "due regard" in planning federally authorized water resources projects.

5.1.3.25 Water Resources Development Acts (WRDA)

These legislative actions authorize the USACOE to study and/or construct individual water resource projects. Prior to 1974 such acts were known as the "Flood Control Act of (year)," the "River and Harbor Act of (year)," or commonly called the "Omnibus Bill" (Hardy and Dawson 1977). Beginning in 1974 these laws were referred to as the "WRDA of (year)." Numerous projects may be authorized under these acts in any given year. Many of these acts contain provisions for mitigation of fish and wildlife damages associated with these projects and/or enhancement of fish and wildlife habitat in conjunction with projects. Of particular relevance to anadromous fish are the: WRDA of 1976 which authorized the USACOE to plan and create wetlands from placement of dredged material in conjunction with water resources development projects; the 1986 WRDA which provided that fish and wildlife enhancement features be 100% federally-funded for species of national significance, such as anadromous fish; and provided authority for the USACOE to repair fish and wildlife damages due to existing projects. The WRDA of 1990 identified environmental protection as one of the missions of the USACOE and established an interim goal for the USACOE of "no overall net loss of the Nation's remaining wetland base as defined by acreage and function" and a long-term goal "to increase the quality and quantity of the Nation's wetlands."

5.1.3.26 Wild and Scenic Rivers Act of 1968 (P.L. 90-542)

The Wild and Scenic Rivers Act establishes a National Wild and Scenic Rivers System designed to protect and preserve the natural character of river corridors. Under this act, the Secretaries of the USDOI and U.S. Department of Agriculture may study areas and submit proposals to the President and Congress for addition to the system. The act also describes procedures and limitations for control of lands in federally administered components of the system and for dealing with disposition of lands and minerals under federal ownership. Rivers are classified as wild, scenic, or recreational, and hunting and fishing are permitted in components of the system under applicable federal and state laws.

5.1.4 Federal Programs

5.1.4.1 USACOE Civil Works Program

The USACOE administers the federal program for maintaining navigable waterways and flood control. This program can and has had major impacts on anadromous fish habitat. The program also has potential for reversing past damages or enhancing existing habitats.

5.1.4.2 USACOE Permit Program

The USACOE has primary responsibility for administering permit programs involving Section 10 of the Rivers and Harbors Act and Sections 103 and 404 of the Clean Water Act.

5.1.4.3 Coastal America

This initiative originated in the Office of the President. Its purpose is to provide a coordinated effort among the principal federal departments responsible for coastal resources in developing a series of demonstration projects under existing authorities to address coastal problems. Principal focus of the program is on habitat alteration and loss, non-point source pollution, and contaminated sediments.

5.1.4.4 U.S. Environmental Protection Agency (USEPA) Gulf of Mexico Program

This intergovernmental program was established to develop and implement management strategies for protecting, restoring, and maintaining the health and productivity of the Gulf of Mexico. The main function of the program is to provide a focal point for better coordination, cooperation, communication, public outreach, and data management among all state and federal agencies, other entities, and the public in working toward protecting the Gulf of Mexico environment.

5.1.4.5 USEPA National Estuary Program (NEP)

This program sets up special coordination groups, known as National Estuary Programs (NEP) to develop comprehensive plans for nationally significant estuaries. There are 28 of these

NEPs in existence including seven in the Gulf of Mexico. The NEPs primarily assess the principal factors adversely impacting estuarine water quality and direct and coordinate management measures to address them. Other functions include improving data collection and storage and enhancing coordination between agencies with water quality and resource management responsibilities.

5.1.4.6 USEPA Office of Wetlands, Oceans, and Watersheds (OWOW)

The OWOW exists to help promote a watershed approach to managing, protecting, and restoring water resources and both marine and freshwater aquatic ecosystems. The OWOW provides technical and financial assistance and guidance to support the watershed approach. Some of the key OWOW functions include wetlands regulation (in coordination with the USACOE), wetlands restoration, managing the National Estuary Program, water quality monitoring, and building watershed partnerships.

5.1.4.7 Federal Energy Regulatory Commission (FERC) Hydropower Licensing Program

The FERC licenses dams containing electric generating equipment. In its licensing program, the agency must consider the needs of fish and wildlife affected by the projects, particularly with respect to downstream flow requirements and fish passage. License documents contain provisions allowing for conservation of fish and wildlife resources through construction and operation of facilities associated with dams or modification of dam operations. The USFWS or state fish and wildlife agencies may recommend such facilities or modifications. The FERC must then make a finding concerning the necessity of the recommended facilities or modifications and consistency with primary project purposes.

5.1.4.8 Minerals Management Service (MMS) Outer Continental Shelf (OCS) Leasing Program

This program was set up to lease OCS areas for oil and gas exploration and development. The program is also charged with protecting the human, marine, and coastal environments in conjunction with leasing activities.

5.1.4.9 NMFS Habitat Conservation Division

The NMFS Habitat Conservation Division reviews and makes recommendations to other federal and state agencies regarding programs, policies, and projects with respect to effects on fishery habitat. Purview may include any activities affecting marine, estuarine, or riverine systems important to marine species.

5.1.4.10 NMFS Habitat Restoration Center

The Habitat Restoration Center is a NMFS unit that works closely with the NOAA Office of the General Counsel in conducting damage assessments, bringing claims against potentially responsible parties, and restoring injured resources. Most of the effort relates to damages due to oil and other hazardous substance spills.

5.1.4.11 National Ocean Service (NOS) Damage Assessment Center

A NOS unit works closely with the NOAA Office of the General Counsel in conducting damage assessments, bringing claims against potentially responsible parties, and restoring injured resources. Most of the effort relates to damages due to oil and other hazardous substance spills.

5.1.4.12 U.S. Coast Guard Marine Pollution Program

This program works to reduce the potential for marine pollution and ensures that effective countermeasures and cleanup activities are initiated in the event of hazardous spills.

5.1.4.13 USFWS Fisheries and Habitat Conservation and Endangered Species Programs

The Fisheries and Habitat Conservation Program operates through its Washington and Regional offices, Ecological Services field offices (ESFOs), national fish hatcheries (NFHs), fish technology centers (FTCs), fish health centers (FHCs), and fisheries resource offices (FROs) nationwide. The ESFOs carry out agency efforts in habitat conservation and improvement, especially with respect to water resources development activities.

The NFHs produce fry and fingerlings for stocking to enhance and restore fish populations. The FROs provide technical and coordination assistance to states and the GSMFC in fisheries restoration and management. The FTCs conduct management studies to develop and refine fish propagation and other fisheries management techniques, and FHCs work to protect the health of wild and captive fish populations.

The Endangered Species Program functions through the Washington and Regional offices and numerous field offices of various types. These offices implement the Endangered Species Act for species the agency has the lead for.

5.2 State

Table 5.1 outlines the various state management institutions and authorities.

5.2.1 Florida

5.2.1.1 Fisheries Resource Agency(ies)

Florida Fish and Wildlife Conservation Commission (FWC)
620 South Meridian Street
Tallahassee, FL 32399
Telephone: (850) 487-0554

The Florida Fish and Wildlife Conservation Commission (FWC) is charged with the administration, supervision, development, and conservation of natural resources. This commission is not subordinate to any other agency or authority of the executive branch. The administrative head of the FWC is the executive director. Within the FWC, the Division of Marine Fisheries is empowered to conduct research directed toward management of marine and anadromous fisheries in the interest of all people of Florida. The Division of Freshwater Fisheries develops and manages community-based fisheries and is responsible for selection of fish stocks and species of freshwater fish released into Florida's public waters and carries out applied research on fishery issues. The Division of Law Enforcement is responsible for enforcement of marine resource-related laws and all rules and regulations of the department.

The FWC, a seven-member board appointed by the governor and confirmed by the senate, was created by constitutional amendment in November 1998, effective July 1, 1999. This commission was delegated rule-making authority over marine and freshwater life in the following areas of concern: gear specification, prohibited gear, bag limits, size limits, quotas and trip limits, species that may not be sold, protected species, closed areas, seasons, and quality control codes.

Florida has habitat protection and permitting programs and a federally approved CZM program.

5.2.1.2 Legislative Authorization

Prior to 1983, the Florida Legislature was the primary body that enacted laws regarding management of striped bass in state waters. Chapter 370 of the Florida Statutes, annotated, contained the specific laws directly related to harvesting, processing, etc. both statewide and in specific areas or counties. In 1983, the Florida Legislature established the Florida Marine Fisheries Commission and provided the commission with various duties, powers, and authorities to promulgate regulations affecting marine fisheries. On July 1, 1999, the Florida Marine Fisheries Commission (including the Florida Marine Patrol) and the Florida Game and Fresh Water Fish Commission were merged into one commission. Marine fisheries rules of the new Florida Fish and Wildlife Conservation Commission are now codified under Chapter 68B, Florida Administrative Code (FAC), and rules relating to freshwater fish are codified under Chapter 68A, FAC.

5.2.1.3 Reciprocal Agreements and Limited Entry Provisions

5.2.1.3.1 Reciprocal Agreements

Florida statutory authority provides for reciprocal agreements related to fishery access and licenses. Florida has no statutory authority to enter into reciprocal management agreements.

5.2.1.3.2 Limited Entry

Florida has no statutory provisions for limited entry in the striped bass fishery.

5.2.1.4 Commercial Landings Data Reporting Requirements

There is no commercial harvest of striped bass in any Florida waters. Commercial sale was prohibited in 1963 by Section 370.112, Florida Statutes, and striped bass was designated as a gamefish in 1989.

Table 5.1. State management institutions - Gulf of Mexico.

	Administrative body and its responsibilities	Administrative policy-making body and decision rule	Legislative involvement in management regulations
FLORIDA	**FISH AND WILDLIFE CONSERVATION COMMISSION** administers management programs enforcement conducts research	creates rules in conjunction with management plans ten member commission	responsible for setting fees, licensing, and penalties.
ALABAMA	**DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES** administers management programs enforcement conducts research	Commissioner of department has authority to establish management regulation Conservation Advisory Board is a thirteen- member board and advises the commissioner has authority to amend and promulgate regulations authority for detailed management regulations delegated to commissioner statutes concerned primarily with licensing	
MISSISSIPPI	**DEPARTMENT OF MARINE RESOURCES** administers management programs conducts research enforcement	**COMMISSION ON MARINE RESOURCES** seven-member board establishes ordinances on recommendation of executive director (MDMR)	authority for detailed management regulations delegated to commission statutes concern licenses, taxes, and some specific fisheries laws
LOUISIANA	**DEPARTMENT OF WILDLIFE AND FISHERIES** administers management programs enforcement conducts research makes recommendations to legislature	**WILDLIFE AND FISHERIES COMMISSION** seven-member board establishes policies and regulations based on majority vote of a quorum (four members constitute a quorum) consistent with statutes	detailed regulations contained in statutes authority for detailed management regulations delegated to commission
TEXAS	**PARKS AND WILDLIFE DEPARTMENT** administers management programs enforcement conducts research makes recommendations to Texas Parks & Wildlife Commission (TPWC)	**PARKS AND WILDLIFE COMMISSION** nine-member body establishes regulations based on majority vote of quorum (five members constitute a quorum) granted authority to regulate means and methods for taking, seasons, bag limits, size limits and possession	licensing requirements and penalties are set by legislation

5.2.1.5 Penalties for Violations

Penalties for violations of Florida laws and regulations are established in Florida Statutes, Section 370.021. Additionally, upon the arrest and conviction of any license holder for violation of such laws or regulations, the license holder is required to show just cause as to reasons why his license should not be suspended or revoked.

5.2.1.6 Annual Recreational License Fees

Recreational Freshwater Fishing License

· Resident	
Annual	$13.50
Seniors Hunting and Fishing (Includes freshwater fishing and hunting licenses; and Type I WMA, archery, muzzle-loading gun, turkey permits, and waterfowl permit)	13.50
Sportsman's License (annual) (Includes hunting, freshwater fishing, and permits for WMA, archery, muzzle-loading gun, turkey, Florida waterfowl)	67.50
· Nonresident	
Seven day	16.50
Annual	31.50

Recreational Saltwater Fishing License

· Resident	
Ten day	11.50
Annual	13.50
· Nonresident	
Three day	6.50
Seven day	16.50
Annual	31.50

5.2.1.7 Laws and Regulations

Florida's laws and regulations regarding the harvest of striped bass are regional. The following discussions are general summaries of laws and regulations, and the FWC should be contacted for more specific information. *The restrictions discussed in this section are current to the date of this publication and are subject to change at any time thereafter.*

5.2.1.7.1 Size Limits

In an area of the state north and west of the Suwannee River (including in the Suwannee River and in any tributary river, creek, or stream of the Suwannee River), fishermen can only have a daily bag of three striped bass as part of a daily aggregate of 20 striped bass, hybrids, and white bass. There is a minimum size limit of 18" TL for striped bass [68A-23.005(7)(b)] with the exception of Lake Seminole which has no minimum size.

In an area of the state south and east of the Suwannee River a daily aggregate bag limit of striped bass and sunshine bass of no more than twenty, no more than six of which may be more than 24" TL [68A23.005(8)(b)].

Special regulations for Lake Seminole: striped bass, striped bass-white bass hybrid, and white bass, a daily aggregate bag limit of fifteen, only two of which may be 22" or greater in TL and no minimum size limit.

5.2.1.7.2 Quotas and Bag/Possession Limits

In an area of the state north and west of the Suwannee River (including in the Suwannee River and in any tributary river, creek, or stream of the Suwannee River), no person shall kill or possess more than three striped bass in one day [68A-23.005(7)(b)].

Special regulations for Lake Seminole: striped bass, striped bass-white bass hybrid, and white bass, a daily aggregate bag limit of fifteen.

5.2.1.7.3 Gear Restrictions

As a freshwater game fish, striped bass may only be taken by hook and line or rod and reel [68A-23.002(2)].

5.2.1.7.4 Closed Areas and Seasons

There are no closed areas for the harvest of striped bass in Florida with the exception of Everglades National Park, the sanctuary preservation areas (SPA) within the Florida Keys National Marine Sanctuary, and other state and national parks and reserves.

5.2.1.7.5 Other Restrictions

Pursuant to Chapter 68A-1(31)(e) Florida Administrative Code, striped bass are considered freshwater game fish and may not be possessed for commercial purposes. Sale of striped bass was prohibited by Section 370.112 of the Florida Statutes that designated striped bass a game fish in 1989.

The use of dip nets for taking freshwater game fish or catfish is prohibited except that landing nets may be used for boating fish caught by rod and reel or hook and line.

Possession of any freshwater fish together with any device that is prohibited for taking such freshwater fish is unlawful, except that game fish may be possessed together with bait catching devices.

5.2.2 Alabama

5.2.2.1 Fishery Resource Agency(ies)

Alabama Department of Conservation and Natural Resources (ADCNR)
Marine Resources Division (MRD)
P.O. Box 189
Dauphin Island, AL 36528
(251)-861-2882

Alabama Department of Conservation and Natural Resources (ADCNR)
Division of Wildlife and Freshwater Fisheries (WFF)
Folsom Administrative Building
64 North Union Street
Montgomery, AL 36130
(334)-242-3467

The Alabama Department of Conservation and Natural Resources (ADCNR) Commissioner holds management authority for fishery resources in Alabama. The Commissioner may promulgate rules or regulations designed for the protection, propagation, and conservation of all natural resources and may prescribe the manner of taking, times when fishing may occur, and designate areas where fish may or may not be caught. All regulations are directed to protect fisheries resources while allowing use of these resources by the public.

Most regulations are promulgated through the Administrative Procedures Act approved by the Alabama Legislature in 1983; however, bag limits and seasons are not subject to this act. The Administrative Procedures Act outlines a series of events that must precede the enactment of any regulation other than those of an emergency nature. Among these series of events are: (a) the advertisement of the intent of the regulation; (b) a public hearing for the regulation; (c) a 35-day waiting period following the public hearing to address comments from the hearing; and (d) a final review of the regulation by the Joint House and Senate Review Committee.

Alabama also has the Alabama Conservation Advisory Board (ACAB) that is endowed with the responsibility to provide advice on policies and regulations of the ADCNR. This board consists of the Governor, the ADCNR commissioner, the Director of the Auburn University Agriculture and Extension Service, and ten board members.

The Marine Resources Division (MRD) and the Division of Wildlife and Freshwater Fisheries (WFF) have the responsibility of enforcing state laws and regulations, for conducting biological research, and for serving as the administrative arm of the commissioner with respect to marine and freshwater fisheries resources. The divisions recommend regulations to the commissioner.

Alabama has a habitat protection and permitting program and a federally approved CZM program.

5.2.2.2 Legislative Authorization

Chapters 2 and 12 of Title 9, Code of Alabama, contain statutes that affect marine fisheries. Chapter 11 contains statutes that affect wildlife and freshwater fisheries.

5.2.2.3 Commercial Fishery

There is no commercial striped bass fishery in Alabama.

5.2.2.4 Penalties for Violations

Violations of the provisions of any statute or regulation are considered Class A, Class B, or Class C misdemeanors and are punishable by fines up to $2,000 and up to one year in jail.

5.2.2.5 Annual Recreational License Fees

The following is a list of license fees current to the date of publication; however, they are subject to change at any time. Nonresident fees for commercial hook and line licenses, recreational licenses, and seafood dealers licenses may vary based on the charge for similar fishing activities in the applicant's resident state.

5.2.2.5.1 Residents

Annual Freshwater	$ 9.50
Combination Hunting and Freshwater	24.50
Seven-Day Trip Freshwater	6.00
Lifetime Freshwater	150.00
Lifetime Hunting and Freshwater	450.00
Annual Saltwater	16.00
Seven-Day Trip Saltwater	6.00
Annual Combination	24.50
Saltwater and Freshwater	
Lifetime Saltwater	250.00
Lifetime Hunting and Saltwater	550.00
Combination Lifetime Hunting, Freshwater, and Saltwater	700.00
Annual Saltwater Pier	6.00

5.2.2.5.2 Nonresidents

Annual Freshwater	$ 31.00
Annual Saltwater	31.00
Annual Combination	61.00
Freshwater and Saltwater	
Seven-Day Trip Freshwater	11.00
Seven-Day Trip Saltwater	11.00

Special fishing license fees may apply to residents of Florida, Louisiana, and Tennessee due to reciprocal license costs.

5.2.2.6 Laws and Regulations

Alabama's laws and regulations regarding creel limits, possession limits, and size limits vary throughout the state. The following are general summaries of laws and regulations.

Contact the ADCNR for more specific information. *The restrictions in this section are current to the date of this publication and are subject to change at any time thereafter.*

5.2.2.7 Game Fish

All members of the bass family including white bass, yellow bass, saltwater striped bass, and hybrid striped bass (a cross between the white bass and the saltwater striped bass) are game fish (*Regulation 220-2-34*).

It is a violation of Alabama law for any person to transport more than one day's creel limit of any species of game fish beyond the boundaries of this state.

There is no closed season on any game fish.

5.2.2.8 Daily Creel Limits, Possession Limits, and Size Limits

5.2.2.8.1 Fresh Water

White bass, yellow bass, saltwater striped bass, and hybrids or combinations – 30. No more than six of the 30 can exceed 16 inches TL; no more than two of the six may be saltwater striped bass.

Exceptions:

Lake Martin: It is illegal to possess more than two white bass, yellow bass, saltwater striped bass, and hybrids or combinations over 16 inches TL in the daily creel limit.

Neely Henry Lake and Logan Martin Lake: It is legal to possess a maximum of six white bass, yellow bass, saltwater striped bass, and hybrids or combinations over 16 inches TL in the daily creel limit.

Weiss Reservoir: It is legal to possess 30 white bass, yellow bass, saltwater striped bass, and hybrids or combinations of any size.

5.2.2.8.2 Salt Water

It is legal to possess two striped bass per person over 16 inches in total length in a daily creel limit.

5.2.2.9 Gear Restrictions

WFF jurisdiction (freshwater): It shall be unlawful to use nets of any type for fishing purposes in all impounded public waters and tributaries thereto of Alabama in which saltwater striped bass were stocked. The following lakes were stocked: Lake Martin, Lake Mitchell, Lay Lake, Jones Bluff, Logan Martin, Neely Henry, and Weiss Lake. *Regulation 220-2-47*.

MRD jurisdiction (saltwater): It shall be unlawful to possess game fish in conjunction with the use or possession of any net, seine, or purse seine; required to be licensed or permitted under Alabama Code 9-12-113; or required to be licensed under Alabama Code 9-12-123. Commercial hook and line fishermen in possession of over the limit of species regulated by a bag limit shall not possess game fish. *Regulation 220-3-03(21)*.

5.2.2.10 Closed Season

There is no closed season on striped bass.

5.2.2.11 Other Restrictions

It shall be unlawful for any person to take, catch, or kill or attempt to take, catch, or kill any game fish by any other means than ordinary hook and line, artificial lure, troll, or spinner in any of the public waters of this state (*Law 9-11-87*).

5.2.3 Mississippi

5.2.3.1 Fisheries Resource Agencies

Mississippi Department of Marine Resources (MDMR)
1141 Bayview Avenue, Suite 101
Biloxi, Mississippi 39530
(228) 374-5000

Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP)
1505 Eastover Drive
Jackson, MS 39211-6374
(601) 432-2400

The Mississippi Department of Marine Resources (MDMR) administers coastal fisheries and habitat protection programs. Authority to promulgate regulations and policies is vested in the Mississippi Commission on Marine Resources (MCMR), the controlling body of the MDMR. The commission consists of seven members appointed by the Governor. One member is also a member of the Mississippi Commission on Wildlife, Fisheries, and Parks (MCWFP) and serves as a liaison between the two agencies. The MCMR has full power to "manage, control, supervise, and direct any matters pertaining to all saltwater aquatic life not otherwise delegated to another agency" (Mississippi Code Annotated 49-15-11).

The mission of the Mississippi Department of Wildlife, Fisheries, and Parks is to conserve and enhance Mississippi's natural resources, to provide continuing outdoor recreational opportunities, to maintain the ecological integrity and aesthetic quality of these resources, and to ensure socioeconomic and educational opportunities for present and future generations.

Mississippi has a habitat protection and permitting program and a federally approved CZM program. The MCMR is charged with administration of the Mississippi Coastal Program (MCP), which requires authorization for all activities that affect coastal wetlands. Furthermore, the state has an established a Coastal Zone Management Plan (CZMP) approved by the NOAA.

The CZMP reviews activities that would potentially and cumulatively impact coastal wetlands located north of tidal areas. The Executive Director of the MDMR is charged with administration of the CZMP.

5.2.3.2 Legislative Authorization

Title 49, Chapter 15 of Mississippi Code of 1972, annotated, contains the legislative regulations as related to the harvest of marine species in Mississippi. Chapter 15 also describes the regulatory duties of the MCMR and the MDMR regarding the management of marine fisheries. Title 49, Chapter 27 involves the utilization of wetlands through the Wetlands Protection Act and is also administered by the MDMR.

Title 49, Chapter 15 of Mississippi Code of 1972, §49-15-2, "Standards for fishery conservation and management; fishery management plans," was implemented by the Legislature on July 1, 1997 and sets standards for fishery management as related to the Magnuson-Stevens Act (1996).

Mississippi Code of 1972 defines game fish to include all bream (red ear, bluegill, long ear, warmouth, green sunfish); all crappie (white, black); all black bass (largemouth, smallmouth, spotted); shadow bass; walleye; sauger; yellow perch; hybrid striped bass; striped bass; white bass; yellow bass; and all pickerel (redfin, grass, and chain).

5.2.3.3 Reciprocal Agreements and Limited Entry

5.2.3.3.1 Reciprocal Agreements

Section 49-15-15 (h) provides statutory authority to the MDMR to enter into or continue any existing interstate and intrastate agreements in order to protect, propagate, and conserve seafood in the state.

Section 49-15-30 (1) gives the MCMR the statutory authority to regulate nonresident licenses in order to promote reciprocal agreements with other states.

5.2.3.3.2 Limited Entry

Section 49-15-16 gives the MCMR authority to develop a limited entry fisheries management program for all resource groups.

Section 49-15-29 (3) directs the MCMR to determine whether a vessel or its owner complies with all applicable federal and/or state regulations when a license of any kind is applied for. If it is determined that a vessel or its owner is not in compliance with applicable federal and/or state regulations, no license will be issued for a period of one year.

5.2.3.4 Commercial Landings Data Reporting Requirements

No commercial harvest of striped bass is allowed in Mississippi waters.

5.2.3.5 Penalties for Violations

Section 49-15-63 provides penalties for violations of Mississippi laws and regulations regarding finfish in Mississippi.

5.2.3.6 Annual Recreational License Fees

The license fees that are required for the harvest of striped bass in Mississippi waters are below. Nonresident fees may vary based on the charge for similar fishing activities in the applicant's state of residence. A saltwater license is required south of U.S. Highway 90, and a freshwater or saltwater license is valid between I-10 and U.S. Highway 90. The saltwater license is not valid north of I-10. All license fees listed below are subject to change at any time.

Resident Sportsman's License (Not including saltwater fishing)	$ 33.00
Resident All Game Hunting/Freshwater Fishing (Not including archery/primitive weapon)	18.00
Resident Small Game Hunting/Freshwater Fishing	14.00
Freshwater Fishing	
Resident	9.00
Nonresident	33.00
Three-Day Freshwater Fishing	
Resident	4.00
Nonresident	17.00
Saltwater Fishing	
Resident	5.00
Nonresident	33.00
Nonresident Three-Day Saltwater Fishing	17.00

Louisiana residents must purchase both the freshwater and saltwater license to fish in the marine waters of Mississippi.

5.2.3.7 Laws and Regulations

Mississippi laws that regulate the harvest of striped bass primarily apply to recreational size and possession limits in freshwater and prohibition of commercial harvest in any Mississippi waters.

5.2.3.7.1 Size limits

A minimum 15 inch (381 mm) size limit is placed on striped bass and hybrids caught in freshwater. There are no size limits for striped bass in saltwater.

5.2.3.7.2 Closed Areas and Seasons

There are no area or seasonal closures to the recreational harvest of striped bass in Mississippi waters. Commercial harvest of striped bass is prohibited in Mississippi.

5.2.3.7.3 Quota and Bag and Possession Limits

There is a statewide freshwater bag limit for striped bass of three fish per day. Striped bass in freshwater are considered a game fish in Mississippi; consequently, they may be taken only by hook and line with one or more hooks or by trotlines or trolling or dip net. There is a statewide freshwater bag limit of three fish per day for sea-run striped bass and hybrid striped bass. There are no catch and possession limits in saltwater. Creel limits for striped bass and hybrids in waters adjoining adjacent states shall be that of the adjacent states or shall be the Mississippi limit (whichever is greater).

5.2.3.7.4 Other Restrictions

Game fish may be taken only by hook and line with one or more hooks (including rod and reel with artificial bait), trolls or trotlines. Each person having a valid fishing license using trotlines or throw lines may use no more than 100 hooks per person with the hooks tied securely at least three feet apart.

An individual may not fish with more than 25 set hooks and/or limb lines, jugs, and yo-yos with no more than two single hooks on each of these devices. If these devices are attached to a line, they must be tied securely at least three feet apart.

Effective July 1, 2001, all yo-yos, jugs, and free-floating fishing devices placed in Lake Washington and Sardis Lake must be tagged with the angler's full name and residence address including zip code. Anglers shall furnish the tags, and the information must be legibly written with waterproof ink or legibly inscribed or stamped on the tag.

Effective July 1, 2001, yo-yos, jugs, and free-floating fishing devices must be attended on borderline waters between Arkansas and Mississippi, Lake Washington, and Sardis Lake. Attended means these gears must remain in sight of the angler during daylight hours.

Only buffalo, carp, gar, and bowfin may be taken year-round by use of the bow and arrow by persons with a hunting and/or fishing license.

There is no open season for snagging game fish. Illegally snagged fish (hooked further back than the gill covers) must be returned to the water immediately.

It is unlawful to take any fish species by muddying and by the use of lime, poison, explosives, electrical devices, wire baskets, fish traps, or dip net. It is unlawful to take game fish with minnow seines for use as bait and to fail to return to the water any game fish taken by net, seine, or other commercial fishing gear.

It is unlawful for any person to buy or sell, offer for sale or exchange any game fish taken within Mississippi or coming from another state. It is also illegal for any restaurant or public eating establishment to possess or offer for sale any game fish. However, they may prepare and serve game fish for any person who has taken the fish legally.

5.2.3.7.5 Restrictions On State Reservoirs

Anglers fishing from spillway outlet to the end of rip rap of Barnett, Grenada, Enid, Arkabutla, and Okatibbee reservoirs may use no more than one pole or rod per person with no more than two single hooks or one artificial lure with no more than three treble hooks (no larger than #2). Anglers fishing spillways of the following lakes and/or locks may use no more than one pole or rod per person with no more than two single hooks or one artificial lure with no more than three treble hooks (no larger than #2):

- Bay Springs lock downstream to the Mississippi Highway 4 overpass,
- Lock “E” spillway downstream to mile marker 405,
- Lock “D” spillway downstream to mile marker 397,
- Lock “C” spillway downstream to mile marker 388,
- Lock “B” downstream to mile marker 375,
- Lock “A” spillway downstream to the Mississippi Highway 6 overpass,
- Aberdeen Lake spillway downstream to the U.S. 45 overpass, including auxiliary spillway and Tombigbee River cutoff below the dam, and
- Columbus Lake spillway downstream to mile marker 332, including auxiliary spillway and Tombigbee River cutoff below the dam.

Sport fishing trotlines, throw lines, set hooks, limb lines, yo-yos, and jugs may be fished in all waters except:

- The portion of Ross Barnett Reservoir north of the main dam and south of a line between the point where Twin Harbors channel enters the main lake under the Natchez Trace in Madison County and Fannin Landing boat ramp in Rankin County; that portion of Pelahatchie Bay south and westward of the navigational channel from the causeway crossing to Hwy 471 and within 100 yards of any residence on the northern side of navigational channel; also, within 100 yards of any sandbar or in any marked navigational channel between Hwy 43 and Ratliff’s Ferry,
- Sardis Lower Lake (known as Barrow Lake) is closed from the outlet structure to Spaulding Creek; however, jugs are permitted, and
- All state parks and state fishing lakes.

5.2.4 Louisiana

5.2.4.1 Fisheries Resource Agency(ies)

Louisiana Department of Wildlife and Fisheries
P.O. Box 98000
Baton Rouge, Louisiana 70898-9000
Marine Fisheries: (225) 765-2384
Law Enforcement: (225) 765-2989
Inland Fisheries: (225) 765-2330

The Louisiana Department of Wildlife and Fisheries (LDWF) is one of 21 major administrative units of the Louisiana government. The Governor appoints a seven-member board, the Louisiana Wildlife and Fisheries Commission (LWFC). Six of the members serve overlapping terms of six years, and one serves a term concurrent with the Governor. The commission is a policy-making and budgetary-control board with no administrative functions. The legislature has authority to establish management programs and policies; however, the legislature has delegated certain authority and responsibility to the LWFC and the LDWF. The LWFC may set possession limits, quotas, places, seasons, size limits, and daily take limits based on biological and technical data. The Secretary of the LDWF is the executive head and chief administrative officer of the department and is responsible for the administration, control, and operation of the functions, programs, and affairs of the department. The Governor with consent of the Senate appoints the Secretary.

Within the administrative system, an Assistant Secretary is in charge of the Office of Fisheries. In this office there are two divisions, the Marine Fisheries Division and the Inland Fisheries Division (both headed by a Division Administrator) which perform:

> "the functions of the state relating to the administration and operation of programs, including research relating to oysters, water bottoms and seafood including, but not limited to, the regulation of oyster, shrimp, and marine fishing industries." (Louisiana Revised Statutes 36:609).

> "the functions of the state relating to the administration, operation and law enforcement of programs relating to freshwater fisheries and other aquatic life, including the regulation of sport and commercial fishing. . ."

The Enforcement Division, in the Office of the Secretary, is responsible for enforcing all fishery statutes and regulations. The Inland Fisheries Division is responsible for managing striped bass.

Louisiana has habitat protection and permitting programs and a federally approved CZM program. The Department of Natural Resources is the state agency, which monitors compliance with the state Coastal Zone Management Plan and reviews federal regulations for consistency with that plan.

5.2.4.2 Legislative Authorization

Title 56, Louisiana Revised Statutes (L.R.S.) contains statutes adopted by the Legislature that govern fisheries in the state and that empower the LWFC to promulgate rules and regulations regarding fish and wildlife resources of the state. Title 36, L.R.S. created the LDWF and designated the powers and duties of the department. Title 76 of the Louisiana Administrative Code contains the rules and regulations adopted by the LWFC and the LDWF that govern fisheries.

Sections 320, 325.4, and 326.3 of Title 56 (L.R.S.) authorize the LWFC to promulgate rules for the harvest of finfish including seasons, daily take and possession limits, permits, and other aspects of harvest, and provide authority to adopt interim rules until the LWFC can implement permanent rules. Additionally, Sections 325.4 and 326.3 of Title 56 (L.R.S.) give the LWFC the legislative authority to set possession limits, quotas, places, seasons, size limits, and daily take limits for all freshwater and saltwater finfishes based upon biological and technical data.

5.2.4.3 Reciprocal Agreements and Limited Entry Provisions

5.2.4.3.1 Reciprocal Agreements

The LWFC is authorized to enter into reciprocal management agreements with the states of Arkansas, Mississippi, and Texas on matters pertaining to aquatic life in bodies of water that form a common boundary. The LWFC is also authorized to enter into reciprocal licensing agreements.

Residents of Texas 65 years of age or under 17 years of age may fish in all Louisiana/Texas border waters without a Louisiana fishing license. Reciprocally, Louisiana residents 60 years of age or older or those under 16 years of age may fish in all Texas/Louisiana border waters, excluding the Gulf of Mexico, without a Texas fishing license. Louisiana also has a reciprocal agreement with Mississippi.

5.2.4.3.2 Limited Entry

Louisiana does not have a commercial harvest for striped bass. No limited entry currently is in effect for the recreational fishery.

5.2.4.4 Commercial Landings Data Reporting Requirements

There is no commercial harvest of striped bass in Louisiana waters.

5.2.4.5 Penalties for Violations

Violations of Louisiana laws or regulations for illegal commercialization of striped bass are a Class 5-B violation. The following penalties shall be imposed for a Class 5-B violation:

- A Class 5-B violation shall, for the first offense, be a fine of not less than $350 and not more than $500 and imprisonment for 30 days,
- For the second offense, the violator shall be fined not less than $500 and not more than $1,000 and imprisoned for 60 days, and
- For the third and all subsequent offenses, the violator shall be fined not less than $1,000 and not more than $2,000 and imprisoned for 90 days.

In addition to the above fines and jail sentences and for Classes 5-A and 5-B of Class 5 violations, the license under which the violation occurred shall be revoked and shall not be reinstated at any time during the period for which it was issued and for one year thereafter.

The above penalties in all cases shall include forfeiture to the department of anything seized in connection with the violation.

Violation of laws or regulations concerning the illegal recreational harvest of striped bass is a Class 4 violation. The following penalties shall be imposed for a Class 4 violation:

- For the first offense, the fine shall be not less than $400 nor more than $750, or imprisonment for not more than 120 days, or both,
- For the second offense, the fine shall be not less than $750, nor more than $3,000, and imprisonment for not less than 90 days nor more than 180 days, and
- For the third and all subsequent offenses, the fine shall be not less than $1,000, nor more than $5,000, and imprisonment for not less than 180 days nor more than two years.

The above penalties in all cases shall include forfeiture to the commission of anything seized in connection with the violation.

Violation of over limit or undersize regulations of striped bass is a Class 2 violation. The following penalties shall be imposed for a Class 2 violation:

- For the first offense, the fine shall be not less than $100 nor more than $350, or imprisonment for not more than 60 days, or both,
- For the second offense, the fine shall be not less than $300, nor more than $550, and imprisonment for not less than 30 days nor more than 60 days, and
- For the third and all subsequent offenses, the fine shall be not less than $500 nor more than $750, and imprisonment for not less than 60 days nor more than 90 days, and forfeiture to the commission of anything seized in connection with the violation.

5.2.4.6 Annual Recreational License Fees

The following list of recreational license fees is current to the date of this publication. They are subject to change any time thereafter.

Basic Recreational Fishing	
Resident	$9.50
Nonresident	60.00
Saltwater Angling License	
Resident	5.50
Nonresident	30.00
Basic Recreational Fishing (Four Day)	
Nonresident	15.00
Saltwater Recreational Fishing (Four Day)	
Nonresident	45.00
Basic Recreational Fishing (One Day)	
Nonresident	5.00
Temporary Saltwater Recreational Fishing (One Day)	
Nonresident	15.00

Striped bass in Louisiana are considered a freshwater fish. Anglers are only required to purchase a basic fishing license to fish for striped bass; however, anglers fishing in saltwater areas of the state are required to also have a saltwater license if possessing saltwater species.

5.2.4.7 Laws and Regulations

Louisiana laws and regulations regarding the harvest of striped bass are primarily related to freshwater recreational fishing. There is no commercial harvest of striped bass allowed in Louisiana waters. The following is a general summary of these laws and regulations. They are current to the date of this publication and are subject to change at any time thereafter. The LDWF should be contacted for specific and up-to-date information.

5.2.4.7.1 Size Limits

Striped bass, hybrid striped bass, or any combination thereof: five daily, of which no more than two may exceed 30 inches in length.

5.2.4.7.2 Gear Restrictions

Licensed recreational anglers may take striped bass recreationally with hook and line and rod and reel.

5.2.4.7.3 Closed Areas and Seasons

No areas are closed to recreational harvest of striped bass.

5.2.4.7.4 Quotas and Bag/Possession Limits

Not more than two striped bass in the possession of a fisherman may exceed 30 inches. The same limits apply no matter where the fish is caught. No person shall have in possession more than twice the daily bag limit of any kind of freshwater game fish.

5.2.4.7.5 Other Restrictions

Striped bass caught in the saltwater areas of Louisiana must be landed "whole" with heads and tails attached; however, they may be eviscerated and/or have the gills removed. For the purpose of consumption at sea aboard the harvesting vessel, a person shall have no more than two pounds of finfish parts per person on board the vessel, provided that the vessel is equipped to cook such finfish. The provisions shall not apply to bait species.

No person shall purchase, sell, exchange, or offer for sale or exchange, or possess or import with intent to sell or exchange any freshwater game fish including striped bass and hybrid striped bass (striped bass-white bass cross or striped bass-yellow bass cross).

5.2.4.8 History of Regulations

1950 - Listed as a game fish
1966 - Limit of five fish with no more than two fish to exceed 30" TL

5.2.5 Texas

5.2.5.1 Fisheries Resource Agency(ies)

Texas Parks and Wildlife Department
Coastal Fisheries Division
4200 Smith School Road
Austin, Texas 78744
(512) 389-4863

Texas Parks and Wildlife Department
Freshwater Fisheries Division
4200 Smith School Road
Austin, Texas 78744
(512) 389-4800

The Texas Parks and Wildlife Department (TPWD) is the administrative unit of the state charged with management of the fishery resources and enforcement of legislative and regulatory procedures under the policy direction of the Texas Parks and Wildlife Commission (TPWC). The commission consists of nine members appointed by the Governor for six-year terms. The commission selects an Executive Director who serves as the administrative officer of the department. Directors of Coastal Fisheries, Inland Fisheries, Wildlife, and Law Enforcement Division are named by the Executive Director. The Coastal Fisheries Division, headed by a Division Director, is under the supervision of the Deputy Executive Director, Operations.

Texas has habitat protection and permitting programs and a federally approved CZM program. The Texas General Land Office (TGLO) is the lead agency for the Texas Coastal Management Program. The Coastal Coordination Council monitors compliance with the state Coastal Management Program and reviews federal regulations for consistency with that plan. The Coastal Coordination Council is an eleven-member group whose members consist of a chairman (the head of TGLO) and representatives from Texas Natural Resource Conservation Commission, TPWC, the Railroad Commission, Texas Water Development Board, Texas Transportation Commission, and the Texas Soil and Water Conservation Board. The remaining four places on the council are appointed by the Governor and are comprised of an elected city or county official, a business owner, someone involved in agriculture, and a citizen. All must live in the coastal zone.

5.2.5.2 Legislative Authorization

Chapter 11, Texas Parks and Wildlife Code, established the TPWC and provided for its make-up and appointment. Chapter 12, Texas Parks and Wildlife Code, established the powers and duties of the TPWC; Chapter 61, Texas Parks and Wildlife Code, provided the commission with responsibility for marine fishery management and authority to promulgate regulations. Chapter 47, Texas Parks and Wildlife Code, provided for the commercial licenses required to catch, sell, and transport finfish commercially; Chapter 66, Texas Parks and Wildlife Code, provided for the sale, purchase, and transportation of protected fish in Texas. All regulations pertaining to size limits, bag and possession limits, and means and methods pertaining to finfish are adopted by the TPWC and included in the Texas Statewide Hunting and Fishing Proclamations.

5.2.5.3 Reciprocal Agreements and Limited Entry Provisions

5.2.5.3.1 Reciprocal Agreements

Texas statutory authority allows the TPWC to enter into reciprocal licensing agreements in waters that form a common boundary, i.e., the Sabine River area between Texas and Louisiana. Texas has no statutory authority to enter into reciprocal management agreements.

5.2.5.4 Commercial Landings Data Reporting Requirements

No commercial harvest of striped bass is allowed in Texas waters.

5.2.5.5 Penalties for Violations

Penalties for violations of Texas' proclamations regarding striped bass are provided in Chapter 61, Texas Parks and Wildlife Code, and most are Class C misdemeanors punishable by fines ranging from $25 to $500. Under certain circumstances, a violation can be enhanced to a Class B misdemeanor punishable by fines ranging from $200 to $1,000; confinement in jail not to exceed 180 days; or both.

5.2.5.6 Annual License Fees

There is no provision in Texas law to allow a person to catch and sell striped bass from the public waters of Texas. Only farm-raised striped bass may be sold, and they must have been fed a prepared feed containing at least 20% plant protein or grain by-product.

The following is a list of recreational licenses and fees applicable to striped bass harvest in Texas. They are current to the date of this publication and are subject to change at any time thereafter.

General Fishing License	
Resident	$19.00
Nonresident	30.00
Temporary Fishing License (Three Day)	
Resident	10.00
Temporary Fishing License (14 Day)	
Resident	12.00
Temporary Fishing License (Five Day)	
Nonresident	20.00
Lifetime Fishing License	600.00
Saltwater Sportfishing Stamp[1]	7.00
Special Resident Fishing[2]	6.00
Combination Hunting and Fishing	32.00
“Super Combo” License Package Resident[3]	49.00
“The Texan” All-purpose License Package	
Resident[4]	100.00
Lifetime Combination Hunting and Fishing License	
Resident	1,000.00

[1]Required in addition to recreational licenses when fishing in saltwater.
[2]Required of residents who reach 65 years of age after September 1, 1995, who are legally blind, or are resident commercial fishermen fishing for sport.
[3]Package includes Resident Combination Hunting and Fishing License and seven state stamp fees (five hunting, two fishing) at a discount price ($82.00 value if purchased separately).
[4]Package adds free park entry (Gold Texas Conservation Passport) to Super Combo above and may include preferred customer opportunities.

5.2.5.7 Laws and Regulations

Various provisions of the Statewide Hunting and Fishing Proclamation adopted by the TPWC affect the harvest of striped bass in Texas. The following is a general summary of these laws and regulations. They are current to the date of this publication and are subject to change at any time thereafter. The TPWD should be contacted for specific and up-to-date information.

5.2.5.7.1 Size Limits

Statewide minimum length limit for striped bass is 18" but there are several exceptions to this regulation on specific bodies of water.

5.2.5.7.2 Gear Restrictions

Striped bass may be legally taken by pole and line only.

5.2.5.7.3 Closed Areas and Seasons

There are no closed areas or seasons for the taking of striped bass in Texas.

5.2.5.7.4 Quotas and Bag/Possession Limits

Recreational Daily Limit – five striped or hybrid (in any combination)
Recreational Possession Limit – ten striped or hybrid (in any combination)

5.2.6 Georgia

5.2.6.1 Fisheries Resource Agency(ies)

Georgia Department of Natural Resources
Wildlife Resources Division
Fisheries Management Section
2070 U.S. Hwy. 278, S.E.
Social Circle, Georgia 30279
(770) 918-6418

The Georgia Department of Natural Resources (GDNR) is the administrative unit of the state of Georgia charged with the management of fish, parks, and wildlife. The GDNR is made up of seven divisions: the Coastal Resources Division (CRD); the Environmental Protection Division (EPD); the Historic Preservation Division (HPD); the Parks, Recreation and Historic

Sites Division (PRHSD); the Pollution Prevention Assistance Division (PPAD); the Program Support Division (PSD) and the Wildlife Resources Division. The Wildlife Resources Division (WRD) regulates hunting, fishing, and the operation of watercraft in Georgia, protects non-game and endangered wildlife, and maintains public education and law enforcement programs to ensure that Georgia's natural resources will be conserved for present and future generations. The Coastal Resources Division (CRD) has primary responsibility for managing Georgia's marshes, beaches, and marine fishery resources. Unless otherwise noted, only information pertinent to regulation of striped bass fisheries in rivers draining into the Gulf of Mexico in Georgia is provided in this section. Regulations governing take of striped bass in Atlantic rivers may differ.

5.2.6.2 Legislative Authorization

Chapter 4 of Title 27 of the Georgia Conservation Code contains statutes that affect fisheries in Georgia. Chapter 391-4-3 contains freshwater fishing regulations of the Georgia Department of Natural Resources.

5.2.6.3 Reciprocal Agreements and Limited Entry Provisions

Georgia statutory authority allows the GDNR to enter into reciprocal licensing and management agreements with its bordering states, which share common waters.

5.2.6.4 Annual License Fees

There is no commercial fishing for striped bass in the fresh waters of Georgia. The following is a list of recreational licenses and fees that are applicable to striped bass harvest in Georgia. They are current to the date of this publication and are subject to change at any time thereafter.

General Fishing License	
Resident	$9.00
Nonresident	24.00
Temporary Fishing License (One Day)	
Resident	3.50
Temporary Fishing License (One Day)	
Nonresident	3.50
Temporary Fishing License (Seven Day)	
Nonresident	7.00
Lifetime License[1]	
Resident infants (under 2 years old)	200.00
Residents (2-15 years old)	350.00
Residents (16 years and older)	500.00
Resident senior citizens (65 years and older)	0.00
Resident Sportsman's License[2]	60.00
Combination Resident Fishing and Hunting	17.00

[1]Georgia lifetime licenses cover all sport hunting and fishing licenses, except for the Federal Duck Stamp and the free Federal Harvest Information Program Permit. Deer hunters also must pick up a Deer Harvest Record from a license dealer before hunting each year. Lifetime licenses are valid for the life of the person, even if they move out of Georgia.

[2]Package includes all sport hunting and fishing privileges except the federal duck stamp.

5.2.6.5 Laws and Regulations

The following is a general summary of the laws and regulations affecting striped bass harvest in Georgia. They are current to the date of this publication and are subject to change at any time thereafter. The GDNR should be contacted for specific and up-to-date information.

5.2.6.5.1 Size Limits

There is no minimum size limit for striped bass in Georgia Gulf of Mexico rivers except on the ACF. The size restrictions for striped bass and hybrid striped bass in the ACF are a two fish limit for fish greater than 22 inches. A total of 15 fish combined (stripers and hybrids) is allowed but only two over 22 inches may be harvested. There is no minimum size limit for stripers or hybrids.

5.2.6.5.2 Gear Restrictions

It is illegal to use any fishing gear in Georgia that is not specifically mentioned as being legal. The only legal fishing gear for game fish is a pole and line, which includes rod and reel as well as cane poles.

5.2.6.6 Closed Areas and Seasons

There is no closed season for striped bass fishing in Georgia with the following exceptions. The Flint River and its tributaries from the Georgia Power Company dams at Albany to the U.S. Highway 84 bridge; the Chattahoochee River and its tributaries from the Columbia L&D to the Georgia Highway 91 bridge; and Spring Creek and its tributaries downstream to Georgia Highway 253 are closed to striped bass fishing and spear fishing from May 1 through October 31.

All fishing, including spear fishing, for any species in the marked areas around five fish refuges in Lake Seminole and in three fish refuges in Lake Blackshear, is prohibited from May 1 through October 31.

5.2.6.7 Quotas and Bag/Possession Limits

No game fish, including striped bass, may be taken from the fresh waters of Georgia by commercial fishing.

The recreational combined bag/possession limit for striped bass, white bass, and/or hybrid white-striped bass is 15 fish per fisherman per day, only two of which can be 22 inches or longer.

5.3 Regional/Interstate

5.3.1 Gulf States Marine Fisheries Compact (P.L. 81-66)

The Gulf States Marine Fisheries Commission (GSMFC) was established by an act of Congress (P.L. 81-66) in 1949 as a compact of the five Gulf States. Its charge is

> "to promote better utilization of the fisheries, marine, shell and anadromous, of the seaboard of the Gulf of Mexico, by the development of a joint program for the promotion and protection of such fisheries and the prevention of the physical waste of the fisheries from any cause."

The commission is composed of three members from each of the five Gulf States. The head of the marine resource agency of each state is an ex-officio member, the second is a member of the legislature, and the governor appoints the third, a citizen who shall have knowledge of and interest in marine fisheries. The chairman, vice chairman, and second vice chairman of the commission rotate annually among the states.

The commission is empowered to make recommendations to the governors and legislatures of the five Gulf States on actions regarding programs helpful to the management of the fisheries. The states do not relinquish any of their rights or responsibilities in regulating their own fisheries by being members of the commission.

Recommendations to the states are based on scientific studies made by experts employed by state and federal resource agencies, advice from law enforcement officials, and commercial and recreational fishing industries. The commission is also authorized to consult with and advise the proper administrative agencies of the member states regarding fishery conservation problems. In addition, the commission advises the U.S. Congress and may testify on legislation and marine policies that affect the Gulf States. One of the most important functions of the commission is to serve as a forum for the discussion of various problems, issues, and programs concerning marine fisheries management.

5.3.2 Interjurisdictional Fisheries Act of 1986 (P.L. 99-659, Title III)

The Interjurisdictional Fisheries (IJF) Act of 1986 established a program to promote and encourage state activities in support of management plans and to promote and encourage management of IJF resources throughout their range. The enactment of this legislation repealed the Commercial Fisheries Research and Development Act (P.L. 88-309).

5.3.2.1 Development of Management Plans (Title III, Section 308(c))

Through P.L. 99-659, Congress authorized the USDOC to appropriate funding in support of state research and management projects that were consistent with the intent of the IJF Act. Additional funds were authorized to support the development of interstate FMPs by the Gulf, Atlantic, and Pacific States Marine Fisheries Commissions.

5.4 History of Management

Striped bass management predated the establishment of the United States as an independent nation. The Massachusetts Bay Colony passed the first legislation in what is now the United States to protect a fish species in 1639 in prohibiting the use of striped bass as fertilizer. A tax levied on the Atlantic Coast striped bass fishery in 1670 partially funded the first public schools in the United States (Whitehurst and Stevens 1990). Introduction of striped bass outside their native range occurred as early as 1879, and efforts at culture began in 1884. Stocking of striped bass in freshwater impoundments began in the 1930s.

5.4.1 Management Activities

Stocking of striped bass in reservoirs of some Gulf rivers began in the mid-1950s (Bailey 1974). By the late 1960s, the Gulf states of Alabama, Florida, Louisiana, and Mississippi had initiated coastal striped bass stock enhancement programs to restore or establish anadromous populations (Minton and Lukens 1990) as did Texas in 1975 (Matlock et al. 1984). Coastal striped bass restoration programs have been generally supported through federal funds authorized by the Anadromous Fish Conservation Act of 1965 (P.L. 89-304). Funding under the act became available in 1966 (ADC 1967).

Anadromous striped bass management in Gulf rivers has predominantly focused on stock enhancement, management studies, research, and enforcement of laws and regulations. Although not specifically focused on striped bass, consultation efforts by state and federal agencies have slowed the loss of habitat resulting from dredge and fill and other water resource development activities. Point and non-point source contaminant regulatory programs of state and federal governments have resulted in measurable water quality improvements in most Gulf rivers, which have benefited striped bass. Specific studies to identify striped bass thermal refuge and spawning habitat areas have occurred in the Sabine, Tchefuncte, Pearl, Pascagoula, Blackwater, Yellow, Flint, Apalachicola, and Ochlockonee rivers (Baker and Jennings 2001b, Dobbins and Rousseau 1982, FGFFC 1989, Frugé 1998, Lukens and Barkuloo 1990, Van Den Avyle and Evans 1990, Slack and Yeager 1993, Forester and Frugé 1996, Jackson et al. 2001, Long 2001, Monzyk et al. 2001). Monitoring of thermal refuge habitat usage by striped bass and specific actions to restore or enhance thermal refuge habitats has occurred in the Apalachicola and Flint rivers (USFWS 1994, 1996, 1997, 2002, 2003). A dam was removed from the Chipola River (Apalachicola River system) in 1988-1989 that facilitated use of thermal refuge habitat upstream of the dam by striped bass (Hill et al. 1994).

Morphological differences between Gulf and Atlantic striped bass were recognized by the mid-1960s (Raney and Woolcott 1955, Brown 1965). However, early stock enhancement efforts in Gulf rivers, including the ACF, utilized Atlantic race fingerlings (see Section 3.10). Formal recognition of the Gulf race was not yet established, and Atlantic race fingerlings were readily available due to the development of hatchery facilities in the Atlantic States. Barkuloo (1970) concluded that the population in the ACF was racially distinct from Atlantic populations based on meristics. In 1979 significant numbers of Gulf race striped bass still existed in the ACF (Crateau ND), and the following year the USFWS successfully produced Gulf race fry for the first time through artificial spawning (Hollowell 1980). Since that time primarily Gulf race fingerlings have been stocked into the ACF. Although stocking of Atlantic race fish has continued in Lake Lanier, these stocked fish are unable to escape downstream due to the method of water release from the dam (Barkuloo 1990, FWC unpublished data, GDNR unpublished data, USFWS unpublished data, R. Ober personal communication).

Between 1994 and 2002, only Gulf race fish were stocked into the MAT except for 1999 and 2001 when stocking numbers were augmented with Atlantic fish due to insufficient Gulf race fingerling availability (ADCNR/WFF unpublished data). Although efforts were made to shift stock enhancement activities in other Gulf rivers to exclusive use of Gulf race fish, the ability to produce sufficient numbers of Gulf race fry and fingerlings annually has continued as a limiting factor. Captive broodstock programs were initiated at Mammoth Spring NFH in Arkansas, Warm Springs NFH in Georgia, and at the GCRL in Mississippi to provide additional broodstock. However, these efforts have been marginally successful to date.

In 1984, efforts began to determine whether polymorphisms existed in the striped bass mtDNA genome, which would differentiate Gulf and Atlantic race striped bass (Mesing 1990a). In 1988 more than 50% of the striped bass in the ACF were found to have unique mtDNA genotypes not found in Atlantic populations (Wirgin et al. 1989, Dunham et al. 1988). In 1993, over 90% of the ACF striped bass were found to have nDNA fingerprints not observed in Atlantic populations (Wirgin et al 1991). Also in 1988, a study was initiated in Lake Talquin, Florida, to evaluate potential differences in survival and growth between co-stocked Gulf and Atlantic races (Mesing 1996), genetic screening of all ACF striped bass broodstock began, and Gulf race fry were first produced from Lewis Smith Lake (MAT) broodstock.

The last year that a significant amount of funding was available under the AFCA to support anadromous fish management in the Gulf was 1991. Since then funding under the act has not been available through USDOI appropriations. Although some AFCA funding has continued to be appropriated through the USDOC, only a small amount of this funding has been utilized in the Gulf (approximately $50,000 annually). Subsequent to loss of AFCA funding through the USDOI, coastal striped bass stocking programs terminated in Texas (1994) and Alabama (1993).

In 1991 the USFWS established a new office in Ocean Springs, Mississippi, to focus on better state-federal coordination and cooperation in Gulf of Mexico anadromous fish restoration activities. The office is co-located with the GSMFC.

A total of $888,000 was provided by the USFWS for work on striped bass restoration in Gulf river systems during 1997-1999 through the agency's Fisheries Stewardship Initiative (Frugé 2001). This funding was utilized for management studies by state and federal agencies in the ACF, Pascagoula, Pearl, and Tchefuncte rivers (Baker and Jennings 2001a, Baker and Jennings 2001b, Hess and Jennings 2001, Jackson et al. 2001, Long 2001, Monzyk et al. 2001, Rogillio and Rabalais 2001) and hatchery and riverine evaluation of growth and survival differences between Gulf and Atlantic race striped bass (Nicholson 2001). This was the last significant amount of funding specifically dedicated to striped bass restoration in Gulf rivers.

5.4.2 Management Planning

The American Fisheries Society, Southern Division (AFS/SD) established a Striped Bass Subcommittee of its Reservoir Committee in 1967 (Whitehurst and Stevens 1990). In 1970 the subcommittee was elevated to full technical committee status. Although the committee provided an important forum for information exchange among entities working with striped bass, its focus was primarily on culture techniques for striped bass and hybrids with an emphasis primarily on reservoirs – not coastal anadromous stocks.

Cooperative striped bass management began in Gulf rivers in 1980 with a meeting at Eufaula, Alabama between representatives of the states of Alabama, Georgia, Florida, and the USFWS (Barkuloo 1990). The purpose of that meeting was to discuss cooperative management of striped bass in the ACF in light of discussions within the USFWS to propose listing the Gulf race as a threatened species under the Endangered Species Act (see Section 6.3.3).

In 1980, the USFWS established a Gulf Coast Striped Bass Advisory Group to guide development of agency policy and activities regarding striped bass in the Gulf (USFWS 1980c). That group developed a Gulf Coast Race Striped Bass Management Plan in 1981, the goal of which was to "restore the Gulf coast race striped bass (STB-G) to biologically suitable areas of its former range, consistent with state management programs" (Crateau ND). The advisory group disbanded after developing the plan.

In 1982, a report contracted by the USFWS (Rulifson et al. 1982) recommended that an interagency coordination committee for anadromous species management be established in the Gulf region to include representation of the USFWS and NMFS, as well as the Gulf States. It also recommended that each state have marine and freshwater representatives on the committee.

The USFWS issued a draft Fish and Wildlife Objective document in January 1983 (USFWS 1983). Two objectives addressed striped bass in the Gulf:

> 1) "Reestablishing self-sustaining populations of 2,000 adult striped bass in each of the Apalachicola and Pascagoula Rivers by 1988, and reestablishing self-sustaining populations of the Gulf race of striped bass in all other Gulf of Mexico river systems, that are suitable and that historically supported striped bass, by 1988"; and 2) "In cooperation with the States, establish fishable populations of striped bass in inland lakes and rivers in accordance with mitigation responsibilities of the Fish and Wildlife Service."

Under the leadership of the Florida Game and Freshwater Fisheries Commission, a workshop for field level personnel involved in management of *Morone* species (including hybrids) in the ACF system was held at Chattahoochee, Florida, in September 1983. Subsequent gatherings (commonly referred to as the *Morone* Workshop) have since been held annually. These meetings provide an important forum to share information on agency activities and coordinate cooperative efforts in restoration of striped bass in the ACF, and in recent years for other Gulf rivers as well. The second *Morone* Workshop (1984) was regarded as an important turning point in state-federal cooperation in restoring striped bass in the Gulf (USFWS 1984). Important decisions made at that meeting included the establishment of Lewis Smith Lake in Alabama as a Gulf race broodstock source and a decision to not stock striped bass fingerlings in the ACF in 1985 in order to evaluate natural reproduction.

In 1984, the GSMFC established an Anadromous Fish Subcommittee to serve as "a focal point for coordination of restoration, research, and management activities" for anadromous striped bass in Gulf of Mexico rivers (Minton and Lukens 1990). One of the first actions of the subcommittee was completion of the *Striped Bass Fishery Management Plan, Gulf of Mexico* (Nicholson et al. 1986). The goals of that management plan were to:

1. Achieve and maintain optimum sustainable yield (OSY) for striped bass throughout their former range; and
2. Determine the validity of the Gulf race striped bass. If applicable, restore and maintain Gulf race striped bass populations at levels where sufficient stock are available for reestablishment efforts Gulf-wide should states desire to use them.

The Alabama Department of Conservation and Natural Resources/Division of Game and Fish, the Florida Department of Natural Resources/Division of Marine Resources, the Florida Game and Freshwater Fisheries Commission, the Georgia Department of Natural Resources, and the USFWS signed the *Cooperative Agreement for Striped Bass Restoration in the Apalachicola Chattahoochee/Flint River Basin System* in 1987. The Cooperative Agreement established a Technical Committee to review progress and plan striped bass restoration activities in the ACF basin.

In 1987, the USFWS Assistant Regional Director appointed a committee to review the agency's Gulf of Mexico striped bass restoration efforts (USFWS 1987). In 1988, the committee concluded that USFWS efforts involving striped bass in Gulf rivers were poorly coordinated and incoherent (USFWS 1988). Specific recommendations called for, among numerous others: 1) finalization of a draft agency policy on Gulf striped bass restoration; 2) establishment of a coordinator's position for the central Gulf of Mexico area; 3) better tracking and record keeping of broodfish collection, fry and fingerling production, and stocking; and 4) increased production and stocking of Gulf race fish outside of the ACF system.

In 1988, the GSMFC developed criteria for rating river systems based on habitat suitability for all life stages of striped bass (Lukens 1988). In 1992 the GSMFC also completed *A Strategic Plan for Restoration and Management of Gulf of Mexico Anadromous Fisheries* (GSMFC 1991). This plan identified high priority activities and fiscal resources needed for restoration of anadromous fish, including striped bass, in Gulf rivers. Preparation of the strategic plan was prompted by the extremely low (3%) share of AFCA funding historically received by the Gulf States and was intended to support efforts to increase that funding share.

The *Striped Bass Fishery Management Plan Amendment 1* (GSMFC 1992) modified the FMP goal as follows: "The goal of this interstate FMP is to restore and maintain striped bass throughout the Gulf of Mexico region, and to establish self-sustaining populations of striped bass in at least ten coastal river systems." Amendment 1 formally recommended that states prohibit sale and/or purchase of striped bass, recommended a six-fish daily bag limit and minimum size limit of 18 inch TL, and set a stocking goal of ten million fish per year, including at least 500,000 Phase II fingerlings. The Amendment also incorporated the elements contained in the strategic plan.

An *ACF Striped Bass Restoration and Evaluation Plan* was developed in 1995 by the ACF Striped Bass Technical Committee. The goal of that plan was to "Restore the native Gulf striped bass within the ACF river system and address Gulf-wide restoration opportunities by meeting or exceeding in 1999 an annual average of 0.7-1.0 broodfish collected per hour of electrofishing" (USFWS 1995). This plan was revised and updated in 2004.

The GSMFC and USFWS jointly sponsored two striped bass workshops (1998 in Pensacola Beach, Florida, and 2001 in New Orleans, Louisiana) in order to prepare for the revision of the 1986 striped bass FMP. Until 2001 the GSMFC Anadromous Fish Subcommittee normally met twice annually in conjunction with the GSMFC semi-annual meetings. In 2001, the subcommittee was functionally integrated into the *ad hoc* Striped Bass Technical Task Force, which was organized specifically to revise the 1986 striped bass FMP. Consequently the subcommittee has not met as such since March 2001.

5.4.3 Legal Management Framework

Striped bass harvest restrictions have been enacted by each of the Gulf States for coastal waters and rivers (Section 5.2).

In 1977, reflecting a growing consensus among field level fishery biologists involved with striped bass in the Gulf, the USFWS field office at Panama City, Florida, made formal inquiries to the USFWS regional office in Atlanta, Georgia, regarding the appropriateness of listing the Gulf race of striped bass as threatened or endangered under the Endangered Species Act. The Gulf race appeared to meet criteria required for such a listing (USFWS 1977, 1978a, 1978b).

The USFWS Southeast Regional Director inquired with the USFWS Director as to whether the Office of Endangered Species would pursue a proposed threatened listing for the Gulf race (USFWS 1978c). Discussions within the agency determined that a proposed threatened listing, with special regulations to allow take, might be a feasible approach.

A status report on the Gulf race was prepared in June 1980 (Hollowell 1980). Comments on the status report by the USFWS Area Manager in Jackson, Mississippi, included recommendations against an Endangered Species Act listing due to the potential for a detrimental impact on striped bass restoration efforts in the long term (USFWS 1980a). The concern centered on the possible implications of Section 7 consultations on the stocking of Atlantic race fish. It was thought that stocking of Atlantic race striped bass could result in a Section 7 jeopardy opinion, the consequence of this would likely be that the states could no longer be able to stock the Atlantic race fish in their reservoirs and rivers. Based on conversations with state fisheries chiefs, it was felt that the states would likely refuse to allow the federal government to continue stocking of the Gulf race in such a case, since if the Gulf race were no longer present in a river, there would no longer be a jeopardy situation and thus no further restrictions on their striped bass stocking programs. Such ramifications were viewed as potentially negating efforts to restore the Gulf race.

A meeting was held at Eufaula, Alabama, on August 19, 1980, between the USFWS Regional Director and staff and the fisheries agency chiefs and staff from Alabama, Georgia, and Florida to discuss the striped bass listing issue (USFWS 1980b). At that meeting the USFWS Regional Director emphasized that the Gulf race striped bass had not been proposed for listing, nor was it a candidate for listing, and since the agency had not been petitioned to list the Gulf race, the USFWS was under no time constraint for any potential listing action decision. He emphasized that the agency's review of the Gulf race's status was continuing and was concerned solely with the biological status, and that no further steps would be considered without full communication with the states.

In fall 1980, the Striped Bass Committee of the AFS/SD prepared a draft resolution in opposition to listing the Gulf race striped bass as threatened or endangered (AFS/SD 1981, USFWS 1981a). Although the resolution was not passed at the November 1980 AFS/SD meeting due to a technicality, many members of the Striped Bass Committee strongly supported it and intended to try again to get it passed at the following year's AFS/SD meeting. The opposition centered on potential effects on state striped bass management flexibility as well as the merits of whether listing was necessary. At the 1981 meeting of the Striped Bass Committee, the resolution was reconsidered but tabled indefinitely in light of assurances from the USFWS that listing was not being actively considered at that time, and since recent field activities that focused on restoration of the Gulf race appeared to be making considerable progress (USFWS 1981a). A letter from the USFWS Regional Director to the Striped Bass Committee chairman stated that if, in the future, it appeared the outlook for the Gulf race striped bass or its habitat was deteriorating, the USFWS would immediately notify each of the affected states to discuss possible solutions at that time (USFWS 1981b).

Georgia enacted laws in 1991 to prohibit fishing in striped bass thermal refuge habitats in the Flint and Chattahoochee rivers and Lake Seminole.

6.0 DESCRIPTION OF FISHING ACTIVITIES AFFECTING THE STOCKS OF STRIPED BASS IN THE UNITED STATES GULF OF MEXICO

Striped bass have probably always been a relatively minor component of the species complex of the Gulf of Mexico; however, they historically supported limited commercial and recreational fisheries. Highly prized, striped bass are considered a delicacy by many. In the Gulf, as elsewhere throughout their range, they have been taken almost exclusively within state jurisdictions due to their close association with rivers. The historical range of the native Gulf race of striped bass extended from the Suwanee River in Florida to the Lake Pontchartrain rivers of Louisiana and Mississippi. Highest population concentrations were probably in the Apalachicola-Chattahoochee-Flint (ACF) rivers system. This section discusses the fishery in coastal waters and free-flowing portions of rivers.

6.1 Recreational Fishery

6.1.1 History

The historical recreational fishery for anadromous striped bass ranged from the Gulf of St. Lawrence to the St. Johns River in Florida and in the Gulf of Mexico from northern Florida to Louisiana, but the center of abundance was always from Massachusetts to South Carolina. As early as 1859, striped bass were taken on hook and line in Massachusetts Bay. The largest reported stripers weighed 125 lbs; however, few fish over 70 lbs are taken today. The existing International Game Fish Association's (IGFA 2000) all-tackle world record is a 78½ lb fish taken off New Jersey in 1982. Since some Atlantic coast stripers are migratory, the fishery is distinctly seasonal in that portion of the range, but stripers may be taken in the Chesapeake Bay during all seasons.

While striped bass are not a major species for nearshore saltwater sportfishing in the Gulf of Mexico, striped bass and their hybrids have been stocked extensively into inland reservoirs, lakes, and streams in the Gulf region due to their potential as sport fish and as non-competing, biological controls of shad populations (Moss and Lawson 1982). Since their first introductions in South Carolina in 1965, hybrid striped bass have been attractive to anglers and managers because of their higher survival and growth rates (Logan 1967, Ware 1974a). Popular recreational fisheries have developed in some areas as a result of these introductions and contribute to downstream striped bass populations through escapement.

6.1.2 State Fisheries

The National Marine Fisheries Service's (NMFS) Marine Recreational Fisheries Statistics Survey (MRFSS) and the Texas Parks and Wildlife Department's (TPWD) Marine Sport-Harvest Monitoring Program provide the most current recreational fishing information available. The Texas monitoring program has been in place since 1974 and the MRFSS since 1979. Together they provide the best estimates of landings and effort by recreational anglers in each state. Although striped bass are predominantly captured in freshwater in the Southeast, they occasionally show up in marine surveys; therefore, when available, catch data from the MRFSS was used in the following sections.

6.1.2.1 Georgia

Considerable recreational fisheries exist in the Georgia portions of the Flint and Chattahoochee rivers for striped bass. Creel surveys were conducted in 1996, 1997, and 1998 at the Albany Dam on the Flint River and the Columbia L&D on the Chattahoochee River during the open season for striped bass (November 1-May 1) (GDNR 1998). Angler effort directed toward striped bass at the Albany Dam ranged from 7% to 11% over the three-year study. Striped bass comprised only 1% of the total harvest, and catch rates ranged from 0.010 fish per hour in 1997 to 0.073 fish per hour in 1998. Columbia L&D anglers were less successful at catching striped bass, which comprised less than 1% of the total catch. Angler-directed effort could only be calculated in 1996 due to the low number of anglers in 1997 and 1998. A harvest rate of 0.063 fish per hour (15.8 hours effort per fish) was achieved that year (GDNR 1998).

6.1.2.2 Florida

Historically, Florida had very few dedicated striped bass recreational anglers. Barkuloo (1961a, 1967) estimated that less than 50 individuals in Northwest Florida were avid striped bass fishermen, and only following the completion of Jim Woodruff L&D in 1957 could anglers successfully target striped bass with any consistency. Today, the Jim Woodruff L&D tailrace remains the primary location for most Florida anglers pursuing striped bass.

It is accepted that the ACF holds the last remnant of a naturally reproducing population of Gulf race striped bass. As a result, all broodfish or their progeny used for restocking the Gulf race originated from the ACF. Likewise, the largest recreational fishery for striped bass along the Gulf Coast occurs in this system. Along the entire west coast of Florida, estimated landings of striped bass from the MRFSS database vary greatly for reasons similar to those for the other states (Table 6.1). The data indicate that the ability of samplers to intercept striped bass landings is strongly influenced by the location and time of day fish are landed; therefore, these estimates probably do not reflect biological changes in the populations.

> **Note:** Recreational landings in this document are Type A and B1 and actually represent total harvest as designated by the NMFS. Type A catch is fish that are brought back to the dock in a form that can be identified by trained interviewers and type B1 catch is fish that are used for bait, released dead, or filleted (i.e., they are killed but identification is by individual anglers). Type B2 catch is fish that are released alive, identified by individual anglers, and is excluded from the values in this FMP.

Most of the recreational fishery in Florida exists in its reservoirs and rivers. One such reservoir is Lake Talquin that was formed in 1927 when Jackson Bluff Dam was completed on the Ochlockonee River just west of Tallahassee to produce hydroelectric power. The best striped bass fishing is in the spring and fall, using deep diving, minnow-type lures, and casting spoons.

Table 6.1. Total number of striped bass caught and total released from West Florida coastal waters from 1981 to 2003 (NMFS/MRFSS personal communication). Empty lines indicate that no striped bass were intercepted by surveyors.

Year	TOTAL CATCH (TYPE A + B1 + B2)	RELEASED ALIVE (TYPE B2)
1981	192	192
1982		
1983		
1984		
1985	32,574	0
1986	5,335	5,335
1987	4,027	4,027
1988	16,840	0
1989	6,772	6,772
1990	85,689	43,117
1991	27,621	18,066
1992	72,273	60,310
1993	1,064	1,064
1994	4,049	0
1995		
1996		
1997		
1998		
1999	4,620	4,620
2000		
2001	1,510	1,015
2002		
2003	1,174	0

In the fall, anglers locate schools of stripers by watching birds congregate to prey on shad pushed to the top by feeding stripers.

Creel census surveys were conducted on Lake Talquin during the spring in 1981 (Dobbins and Rousseau 1982), 1985-1990 (Dobbins et al. 1988, Cailteux et. al 1990), 1992-1996 (Cailteux et al. 1993, FWC unpublished data), and 1999-2000 (Cailteux et al. 1999, FWC unpublished data; Table 6.2A). Anglers were surveyed during April-June 1981 and 1985 and from February to June 1986-2000. Estimated striped bass angling effort ranged from 0 to 1,777 hours and was less than 250 hours during nine of the 14 years surveyed. Striped bass harvest estimates ranged from 21 to 1,163 fish and was less than 100 fish during seven years.

Table 6.2. Estimates of fishing success for striped bass on Lake Talquin, Florida, from FFWCC annual A.) spring and B.) fall creel surveys. Empty lines indicate no survey conducted, NE indicates insufficient data to estimate.

A. Spring

Year	Effort (hrs)	Harvest	Success
1981	142	81	0.57
1982			
1983			
1984			
1985	25	52	NE
1986	0	42	0.00
1987	838	349	0.15
1988	114	36	0.00
1989	70	116	0.81
1990	254	887	2.12
1991			
1992	199	97	0.32
1993	71	33	0.57
1994	250	112	0.20
1995	790	369	0.14
1996	232	21	0.00
1997			
1998			
1999	1777	470	0.17
2000	549	1163	0.27
2001			
2002			

B. Fall

Year	Effort (hrs)	Harvest	Success
1980	3309	426	0.13
1981	1137	38	0.03
1982	1750	138	NE
1983			
1984	1134	275	NE
1985			
1986	311	109	0.00
1987	122	129	0.46
1988	107	146	0.00

Creel surveys were also conducted on Lake Talquin during fall 1980-1982 (Dobbins and Rousseau 1982, Dobbins et al. 1988), 1984 (Dobbins et al. 1988), and 1986-1988 (Dobbins et al. 1988, FWC unpublished data; Table 6.2B). Anglers were surveyed from October through December. Estimated angler effort ranged from 107 to 3,309 hours and was greater than 1,000 hours during four of the seven years surveyed. Striped bass harvest estimates ranged from 38 to 426 fish, and angler success was low, ranging from 0.00 to 0.46 fish per angler hour and averaging 0.12 fish per hour. No success estimates (insufficient data) or 0.00 fish per hour estimates were calculated during four years, indicating that only a few anglers participated in the fishery, or that the majority of striped bass harvested were taken incidentally by anglers targeting other species.

Creel surveys were also conducted on the Ochlockonee River in the tailrace below Jackson Bluff Dam in 1981-1983 (Dobbins and Long 1985). Estimates of angler effort ranged from 2,015 to 848 hrs with 1982 representing the lowest year for success but the median year for effort (Table 6.3).

Table 6.3 Estimates of fishing success for striped bass on the Lower Ochlockonee River, Jackson Bluff Dam tailrace from the FWC annual spring creel survey.

Year	Effort (hrs)	Harvest	Success
1981	2015	298	0.15
1982	1328	50	0.04
1983	848	86	0.10

In a recent study by Long (2001), anglers were interviewed during creel census surveys on the upper Apalachicola River in the Jim Woodruff L&D tailrace, and also on the lower river and Intracoastal Waterway. In the tailrace, surveys were conducted for 66 weeks during February-May (14 weeks) 1998-2000 and October-December (12 weeks) 1998-1999. For all five surveys combined, a total of 3,454 anglers were interviewed including 633 who reported they were targeting striped bass. Information collected from striped bass anglers resulted in an estimate of 15,966 hours of effort expended fishing for striped bass during the five survey periods. Striped bass angling effort averaged 4,142 hours during the three spring surveys, and 1,770 hours during the two fall surveys. The total estimated striped bass catch over the course of the study was 2,501 fish, of which an estimated 1,801 were harvested. Angler success ranged from 0.1 to 0.19 fish per hour during spring surveys, and from 0.03 to 0.39 fish per hour during fall surveys.

During the same study by Long (2001), creel census surveys were conducted during October-December (12 weeks) 1998-1999 and March-June (16 weeks) 1999-2000, on the lower Apalachicola River and Intracoastal Waterway. For all surveys combined, 2,180 anglers were interviewed, including 11 who fished for striped bass. Data collected from anglers on the lower Apalachicola River and Intracoastal Waterway resulted in an estimate of 346 hours spent fishing for striped bass. An estimated 3,369 striped bass were caught during the course of the study, but only 133 were harvested. Nearly all striped bass reported were incidentally caught by anglers fishing for other species and released because of size (18 inch minimum size restriction).

Angler's willingness to expend time and effort in pursuit of striped bass was clearly greater on the upper reaches of the Apalachicola River. The reasons are many and varied. There are greater expectations of harvestable-sized and trophy-sized fish in the tailrace. Peak striped bass fishing seasons are more clearly identifiable in the tailrace. Many lower river anglers fish for saltwater species, and striped bass were not acceptable to many of these anglers. In any case, the striped bass fishery was negligible in the lower Apalachicola River and Intracoastal Waterway, while striped bass fishing, at times, was the largest component of the tailrace fishery (Long 2001).

A 14-week, spring peak season creel survey in the Jim Woodruff L&D tailrace was conducted annually from 1979 to 2004 (FWC unpublished data). Striped bass harvest increased from an estimated 152 fish in 1982 to 1,505 fish in 1992, following a decade of restoration efforts. Striped bass harvest and catch have varied widely in the years since, resulting from changes in habitat quantity, habitat quality, year class stocking success, rainfall, and alterations in water management throughout the ACF, particularly as it affects discharge at Jim Woodruff L&D. Angler effort was also highly variable during the period of study, ranging from a low of 629 hrs in 1981 to a high of 9,485 hrs in 1991 (Table 6.4). However, angling effort for striped bass appears to have remained at or above estimated levels at the time restoration efforts began. Striped bass angling effort may also be affected, directly or indirectly, by the variables listed above. E. Long (personal communication) noted that the recreational fishery in the tailrace of

Table 6.4. Angler effort and estimated value of the Jim Woodruff Dam spring tailrace striped bass fishery. Values based on 2004 dollar equivalents using $27.66/angler hour average (US Fish & Wildlife Service).

Year	Effort Estimate (hrs)	Value Estimates ($)
1980	1,480	32,175
1981	629	13,674
1982	1,954	42,480
1983	750	16,305
1984	1,098	23,871
1985	919	19,979
1986	6,145	133,592
1987	3,272	71,133
1988	3,300	71,742
1989	5,519	119,983
1990	9,108	198,008
1991	9,485	206,204
9992	9,255	201,204
1993	3,163	68,764
1994	5,876	127,744
1995	5,951	129,375
1996	2,609	56,720
1997	4,180	90,873
1998	1,593	34,632
1999	4,250	92,395
2000	6,583	143,114
2001	968	21,044
2002	3,505	76,199
2003	4,275	92,939

Jim Woodruff L&D was described as an "artisanal" fishery where anglers developed techniques to increase success. Anglers with proper weight and lure setups consistently caught more striped bass than those without the proper setup. The skill level of the anglers surveyed clearly contributed to the overall success rate at Jim Woodruff L&D.

6.1.2.3 Alabama

A directed recreational fishery existed in the Tallapoosa, Coosa, Alabama, Tombigbee, and Mobile rivers until 1962 when populations declined rapidly and striped bass were more often caught incidentally while anglers targeted other species (Brown 1965, Shell and Kelley 1968, Swingle 1968, Minton 1980). In contrast, most of the reservoirs along the Black Warrior and Tombigbee rivers, Lewis Smith Lake, Lake Martin, Jones Bluff Lake, and reservoirs along the Coosa River including Neely-Henry, Logan Martin, and Lay Lakes continued to support recreational striped bass fisheries due to stocking efforts. In Alabama, stripers are taken throughout the Mobile River and bay systems, as well as the Perdido and Conecuh rivers (Table 6.5).

Table 6.5. Total number of striped bass caught and total released from Alabama coastal waters from 1981 to 2003 (NMFS/MRFSS personal communication). Empty lines indicate that no reported striped bass were intercepted by surveyors.

YEAR	TOTAL CATCH (TYPE A+B1+B2)	RELEASED ALIVE
1981		
1982		
1983		
1984		
1985		
1986		
1987		
1988	1,775	0
1989		
1990		
1991		
1992	477	0
1993	926	467
1994	2,096	0
1995	8,400	6,991
1999	923	923
2000	701	395
2001		
2002	3,191	3,191
2003	20,775	12,038

As part of a fish consumption study (FIMS and FAA 1993), field interviews of anglers were conducted from 1992-1993 following fishing trips in eleven Alabama drainages and included 23 tailwaters and six reservoir locations across the state. Moronids including striped bass, white bass (*Morone chrysops*) and their hybrids, and yellow bass (*M. mississippiensis*) were the third most frequently encountered species group recorded by the surveyors.

6.1.2.4 Mississippi

Recreational fishermen have historically caught striped bass incidentally across coastal Mississippi. Jackson et al. (2001) surveyed anglers on the Pascagoula River system in eastern Mississippi regarding striped bass. No angler identified striped bass as a target species, and several indicated striped bass were undesirable. Most of the fish reported were characterized as being small (<3 lb). Incidental catches of small striped bass were actively angled (60%) or captured on trotlines (38%). Jackson et al. (2001) referred to an anecdotal report that a population of striped bass historically existed in a tributary of the Pascagoula River in such numbers that dip nets were used to collect them. No directed effort estimates exist for striped bass with which to assign CPU or relate to angler expenditure; therefore, no fishery value was determined in Mississippi. L. Nicholson (personal communication) indicated that while limited, there have been a few anglers who specifically target striped bass on the Pascagoula River. The MRFSS database captured a few landings since 1981 (Table 6.6). Several years indicated no reported recreational landings, but a peak occurred in the mid-1980s when 14,154 fish were caught in 1986.

6.1.2.5 Louisiana

Recreational fishermen catch striped bass incidentally across coastal Louisiana. A few charter boats and guides target striped bass opportunistically around the Mississippi River delta at certain times of the year (P. Cooper personal communication); however, most of the landings are probably not intercepted by NMFS survey personnel. Also, a limited recreational fishery targeting striped bass exists in Lake Pontchartrain (H. Rogillio personal communication). The MRFSS database has existed since 1981 and captured some recreational landings from the marine environment (Table 6.7.). The reported recreational landings have fluctuated widely and probably do not accurately reflect true landings. Only those fish intercepted at public boat launches have been reported in the MRFSS database; therefore, a greater number of fish could have been landed. Fishing at night may have also caused landings to be missed by interviewers who primarily sample during daylight hours.

6.1.2.6 Texas

Although stocking began in Texas waters in 1967 (McCabe 1981), all efforts including extensive stocking activity from June 1975 through April 1983 in coastal rivers failed to establish a coastal fishery (Butler and Stelly 1993). In 1991 most stocking of striped bass focused on the Galveston/Trinity and Sabine Lake bay systems. While some natural reproduction occurred in the Trinity River below Lake Livingston (Kurzawski and Maddux 1991), no significant fishery developed. Butler and Stelly (1993) reported that:

Table 6.6. Total number of striped bass caught and total released from Mississippi coastal waters from 1981 to 2003 (NMFS/MRFSS personal communication). Empty lines indicate that no reported striped bass were intercepted by surveyors.

YEAR	TOTAL CATCH (TYPE A+B1+B2)	RELEASED ALIVE
1981		
1982		
1983		
1984	2,586	2,586
1985		
1986	14,154	0
1987	2,833	0
1988	1,137	535
1989	3,687	2,341
1990	1,480	476
1991	3,621	2,050
1992	8,318	8,318
1993	1,237	1,237
1994		
1995	840	0
1996	2,059	2,059
1997	539	539
1998		
1999	342	342
2000		
2001	3,210	2,573
2002	905	0
2003	983	0

"It is without doubt that the Galveston bay system is the site on the Texas coast where striped bass are concentrated. Striped bass within this system congregate mainly in Trinity Bay near the HLP cooling water discharge. A second congregation of striped bass is found below the dam at Lake Livingston."

Based on recent TPWD creel data, there is no substantial fishery targeting striped bass anywhere along the Texas coast, although a few individuals in the Galveston and Sabine Lakes area target stripers (N. Boyd personal communication). In addition, striped bass are rarely intercepted in the MRFSS sampling (Table 6.8). A targeted fishery occurs just below the Lake Livingston Dam on the Trinity River. Striped bass also congregate around the Houston Light & Power outfall in Trinity Bay, and TPWD fisheries biologists occasionally collect them while

Table 6.7. Total number of striped bass caught and total released from Louisiana coastal waters from 1981 to 2003 (NMFS/MRFSS personal communication). Empty lines indicate that no reported striped bass were intercepted by surveyors.

YEAR	TOTAL CATCH (TYPE A+B1+B2)	RELEASED ALIVE
1981		
1982	47,521	43,477
1983		
1984	5,255	4,608
1985	2,880	1,013
1986	12,298	1,775
1987		
1988	15,227	8,707
1989	4,604	4,604
1990	69,858	36,985
1991	63,571	31,012
1992	28,544	22,101
1993	10,867	8,965
1994	5,752	3,636
1995	15,336	14,449
1996	14,480	3,296
1997	20,051	14,003
1998	1,884	881
1999	2,125	1,192
2000	615	0
2001		
2002		
2003	542	0

conducting fishery-independent sampling in this area. An unconfirmed state record striped bass was reportedly caught at the Houston Light & Power outfall near San Leon several years ago. The only directed fishery for striped bass in Galveston Bay is at the outfall in Trinity Bay and is particularly popular around March in that area.

6.2 Commercial Fishery

6.2.1 History

Numerous references to striped bass fishing appear in early American literature. Records indicate that the Plymouth colonists fished for striped bass along the Atlantic Coast during

Table 6.8. Total number of striped bass caught and total released from Texas coastal waters from 1981 to 2003 (NMFS/MRFSS personal communication). Empty lines indicate that no reported striped bass were intercepted by surveyors.

YEAR	TOTAL CATCH (TYPE A+B1+B2)	RELEASED ALIVE
1981		
1982		
1983	1,245	0
1984	1,679	1,679
1985		
1986		
1987		
1988		
1989		
1990		
1991		
1992		
1993		
1994		
1995		
1996		
1997		
1998		
1999		
2000		
2001		
2002		
2003		

summer 1623, although records for the Gulf are sketchy at best. Today, there is no commercial fishing for striped bass in the Gulf; all commercial activities are restricted to the Atlantic Coast.

6.2.2 State Fisheries

The only NMFS records of commercial landings of striped bass in the Gulf of Mexico are for coastal Alabama in 1951 (NMFS unpublished data).

6.2.2.1 Georgia

Commercial landings for striped bass in Georgia existed through 1972 (Table 6.9); although these landings include both Atlantic coast and inland records. At present, all game fish caught by commercial fishermen must be released into Georgia state waters; therefore, the only commercial fisheries consist of American Shad, shrimp, crab, welk, and several offshore species. Before 1973, shad fisherman could retain stripers captured in their gill nets as bycatch. However, that practice is no longer allowed. Historical commercial landings from 1956 to 1973 averaged 1,566 lbs per year with a high of 6,500 lbs in 1973 and a low of 100 lbs in 1956 and 1962.

Table 6.9. Georgia commercial striped bass landings (NMFS various years; includes Atlantic coast and inland landings).

Year	Landings (lbs)	Year	Landings (lbs)
1920	125	1957	300
1923	360	1958	700
1927	5,355	1959	200
1928	740	1960	1,000
1929	0	1961	1,400
1930	500	1962	100
1931	0	1963	1,400
1932	0	1964	3,100
1933	0	1965	1,800
1934	0	1966	1,300
1936	0	1967	200
1937	0	1968	600
1938	0	1969	1,100
1939	0	1970	1,800
1940	0	1971	1,600
1945	0	1972	5,000
1950	0	1973	6,500
1956	100		

6.2.2.2 Florida

There has been no documented commercial striped bass catch in Florida waters since 1939 when Fiedler noted commercial landings of 45.5 kg (100 lbs). J. Barkuloo (personal communication) indicated that large numbers of striped bass were harvested in the Apalachicola Bay until the late 1940s although no documentation or estimate of these landings exist.

> 'His mullet nets (beach seine) catch striped bass occasionally every fall and winter, most of the catches were on the mainland side of the islands, but he has picked up a few on the outside of the island. They were always following large schools of mullet. His largest catch was twelve or fifteen years ago at which time they caught a very large haul of mullet and included in the catch was 1,200 pounds of striped bass'.
>
> *J. Barkuloo interview with George Kirvin, September 14, 1961*

6.2.2.3 Alabama

Commercial landings in Alabama were reported occasionally from 1899 to 1963 but never in large numbers. Shell and Kelley (1968) surveyed commercial operators on Mobile Bay and determined a few large purchases of striped bass were made in the late 1940s and early 1950s but a significant run has not occurred since 1961. A limited harvest existed in 1978 after substantial stocking efforts by the state of Alabama but not since then (Tatum and Powell 1978). The NMFS has no estimates for striped bass landings in Alabama other than 400 lbs reported in 1951 (NMFS various years). Striped bass were declared a game fish in 2004, eliminating any chance for commercial fishery development in the future.

6.2.2.4 Mississippi

While a small fishery is believed to have existed, there is no documented commercial catch from Mississippi (NMFS various years).

6.2.2.5 Louisiana

Although the historical occurrence of striped bass west of the Mississippi River in Louisiana has not been documented, reported commercial landings in Texas (Collins and Smith 1893, Townsend 1900, Fiedler et al. 1934) suggested their former presence in western Louisiana; however, see Sections 3.1.1 and 3.1.2 for further discussion. The last documented occurrences of native striped bass in Louisiana were from the Bogue Chitto-Pearl Rivers and Bogue Falaya-Tchefuncte Rivers in 1956 (Chipman 1956). Lake Pontchartrain drainages supported a commercial fishery with reported landings of 33,105 kg (72,830 lb) from 1892 to 1899 (Collins and Smith 1893, Townsend 1900). Striped bass were declared a game fish in Louisiana in 1950 eliminating it from any commercial harvest; therefore, no landings data exist in the NMFS commercial landings database after 1950 (NMFS various years).

6.2.2.6 Texas

There are reports of commercial striped bass harvest from Texas waters (Collins and Smith 1893, Stevenson 1893, Townsend 1900, Fiedler et al. 1934, Butler and Stelly 1993). However, these data appear to conflict with the lack of documentation in the classical ichthyological literature of striped bass occurring historically as a native species in rivers or coastal waters west of the Mississippi River. It is possible that the striped bass reported in the coastal commercial fisheries of Texas by fishermen being interviewed for these fisheries surveys were actually yellow bass or white bass, or perhaps even some serranids. See Section 3.11 for further discussion of this issue.

6.3 Catch and Release Mortality

Several studies have been conducted to evaluate catch-and-release mortality of striped bass in freshwater rivers and impoundments and in saltwater. Individual studies examined blood sera concentrations that relate to stress (Ridley and Isley 1997, Tomasso et al. 1996); the effects of water temperature or season (Harrell 1987, Hysmith et al. 1992, Bettoli and Osborne 1998, Nelson 1998, Wilde et al. 2000); salinity (Diodati and Richards 1996); fish length (Hysmith et al 1992, Wilde et al. 2000); playing and handling time (Tomasso et al. 1996, Bettoli and Osborne 1998); artificial lures or natural bait (Harrell 1987, Nelson 1998, Wilde et al. 2000); hooking location and injury (Diodati and Richards 1996, Nelson 1998); and supplemental feeding (Ridley and Isley 1997). Striped bass size in these studies ranged from 10 to 84 cm. Mortality varied within and among studies, but generally ranged from 3% to 75%, with greatest mortality occurring within the first 24 hrs.

Tomasso et al. (1996) played subadult striped bass (<36 cm TL) from 6.0 sec to exhaustion (<6.05 min) at water temperatures of 26°-32°C (summer) and 16°-19°C (fall). They observed elevated plasma cortisol concentrations only in fish caught during summer, and only in fish played >2.5 min. Hyperglycemia was also only evident in summer-caught fish and was proportional to playing time. Plasma lactate concentrations and osmolality increased with playing time during both summer and fall. The increase in plasma osmolality during both seasons indicated impaired osmoregulatory function as a result of angling stress. They concluded that mortality was not related to playing time, but rather that the physiology of striped bass is severely disturbed during capture by angling, and that the degree of disturbance is greater during summer than in fall.

In similar experiments, Ridley and Isely (1997) studied the effects of supplemental feeding or fasting on blood chemistry of caught-and-released striped bass (mean TL = 38.7±1.3 cm [subadult]) played 20±8 sec or 180±8 sec at 23°-30°C (ambient summer temperatures). They found that plasma glucose concentrations increased significantly, both in fed and unfed fish, with long play. On average, glucose concentrations were higher in fed fish for both short and long-play groups. Plasma lactate concentrations increased significantly in response to play time and were significantly higher among the fed group than the unfed group played 180 sec during July and August. Plasma osmolalities were similar between fed and unfed fish and significantly higher for the long-play group than for the short-play group. These results led Ridley and Isley to conclude that the physiological responses to angling of undernourished fish could have an effect on survival by increasing angling-induced mortality of caught-and-released fish during summer months.

Tomasso et al. (1996) and Harrell (1987) found that mortality rates of caught-and-released striped bass were higher during the summertime (ambient temperature >25°C) than during fall and winter periods when water temperatures were cooler (11.5% and 32% mortality, respectively). Bettoli and Osborne (1998) concluded that air temperature (time of year) was significantly related to mortality and found that mortality was highest (54%-67%) during July-

September. Hysmith et al. (1992) determined that mortality rates were highest during spring (69%) and summer (47%) and lowest during fall (8%) and winter (13%). Nelson (1998) found an increase in mortality rates above 21°C and concluded that the odds of hooking mortality increased 103% with each 1°C increase in water temperature. Harrell (1987) also found that secondary bacterial and fungal infections were present during summer but not manifested during other times of the year.

Salinity may play a key role in the effect of hooking on mortality. Experiments with wild fish caught, tagged, and held in saltwater (31‰) at temperatures less than 25°C resulted in overall mortality of 9%, much less than values generally reported for fish caught in freshwater (Diodati and Richards 1996). Diodati and Richards (1996) and Harrell (1987) speculated that salt water might ameliorate the effects of hooking, playing, and landing stress.

Results were inconsistent among investigators who examined fish length as a variable related to catch-and-release mortality. Nelson (1998) found no significant relationship between fish size and hooking mortality. However, among angled wild fish in the size range 229-762 mm TL, Hysmith et al. (1992) found hooking mortality greater for large fish during spring through fall, but the relationship was reversed during the winter. Seasonal differences in mortality were greater for larger fish than for smaller fish. In modeling compiled catch-and-release data reported by other investigators, Wilde et al. (2000) concluded there was no significant relationship between fish size and hooking mortality.

Harrell (1987), Hysmith et al. (1992), Diodati and Richards (1996), Bettoli and Osborne (1998), Nelson (1998), and Wilde et al. (2000) examined the effects of natural bait and artificial lures on hooking mortality. All agreed that gear type was directly or indirectly important in catch-and-release mortality. In general, natural baits were more likely to be swallowed or deeply penetrated into the oral cavity than artificial lures, and single hook lures were more likely to be deeply penetrated than artificial lures with multiple or treble hooks. Deeply penetrated hooks and lures were generally located in more critical and deleterious areas than other artificial lures, and mortality was 30 times greater for striped bass hooked in esophagus, pharynx, or gills than in the mouth, jaw, or externally (Nelson 1998). Degree of bleeding because of hooking was also a critical factor affecting catch-and-release mortality, and heavy bleeders died at significantly higher rates (75%) than non-bleeders (9%, Nelson 1998). Diodati and Richards (1996) also found that angler experience played a significant role in catch-and-release mortality, reporting that survival was higher with more experienced anglers.

These studies led several researchers to conclude that catch-and-release mortality may be counterproductive to minimum size limits and prompted some to recommend fisheries managers consider alternative regulations to minimum sizes, such as closed seasons or suspended regulations during summer.

6.4 Striped Bass Aquaculture

Development of striped bass aquaculture techniques began in 1884 with the construction of the Weldon, North Carolina, hatchery on the Roanoke River (Worth 1884) (see Section 3.7). Techniques were further refined with the development of hormone induced spawning in the mid-

1950s at the Moncks Corner, South Carolina, striped bass hatchery (Stevens 1966). Bayless (1972) further refined the process and by doing so stimulated the construction of striped bass hatcheries and aquaculture facilities across the United States.

The aquaculture of striped bass was initially developed and promoted primarily for stock enhancement of wild populations and establishment of striped bass fisheries in inland reservoirs (See Section 3.7). Private aquaculture production of striped bass, however, has not been as successful. Consequently the private sector has turned to hybrid striped bass for most production efforts. Hybrids have proven to be more adaptable than striped bass to both intensive and extensive culture environments, and their “hybrid-vigor” is very evident. They are amenable to culture in a wide variety of salinities from freshwater to 30 ppt (Kerby and Joseph 1979), and an equally wide range of temperatures that allows culture in a wide geographical area (Harrell et al. 1990). Private industry in the southeast region has an ongoing hybrid striped bass aquaculture program with most of the production concentrated in Mississippi, North Carolina, Texas, Florida, Louisiana, and South Carolina. The total regional production in 1997 was estimated to be five million pounds with a pond-side value of approximately $12.5 million. The hybrid striped bass industry has been growing at 10%-15% per year for the last five years (Mississippi State University Extension Service 2004).

7.0 SOCIOECONOMIC CHARACTERISTICS OF THE FISHERY

Characterizing the social and economic aspects of the striped bass fishery in the Gulf of Mexico was problematic. The historic contribution to both commercial and recreational fisheries was difficult to isolate since low numbers of fish are landed and even fewer are encountered in creel census surveys. When the minimum number of landings for a certain species is not achieved in the summary landings data, the fish are typically lumped into a miscellaneous category by both the NMFS and states. In addition, early fisheries accounts included both Atlantic and Gulf race as well as hybrid striped bass in the landings. Considering the difficulty in distinguishing among these, the category "striped bass" in fisheries data has represented a mixture of all three in Gulf rivers and coastal areas. Also, see the caveats regarding some commercial fisheries data as discussed in Sections 3.1.1, 3.1.2, 6.2.2.5, and 6.2.2.6.

Further confounding the socioeconomic profile, no commercial harvest for striped bass has been recorded by NMFS since the 1930s in Texas and Florida and since the 1960s in Alabama (GSMFC 1992). Therefore traditional economic indicators such as dockside values and market price do not exist in the Gulf for striped bass. Likewise, very few recreational anglers, with the exception of a few reservoir fisheries, specifically target striped bass, making that sector equally difficult to identify and characterize. The following attempts to summarize what is known regarding the economic aspects of and participants in the Gulf's striped bass fisheries.

7.1 Commercial Sector

There are no current commercial harvests of striped bass in the Gulf States. Anecdotal reports indicated that a small commercial fishery persisted in the Gulf of Mexico until the early 1960s. Notwithstanding, a total of 53,888 kg (118,554 lb) striped bass valued at $7,031 was reported in the Gulf States between 1887 and 1963 (Collins and Smith 1893, Townsend 1900, Fiedler 1940, Anderson and Peterson 1951, Shell and Kelly 1968).

7.1.1 Georgia

No sociologic data exist for the striped bass commercial fishermen in Georgia. Likewise, little economic data has been reported for the commercial fishery as a whole. Table 7.1 summarizes the values associated with the reported historical landings.

7.1.2 Florida

No sociologic data exist for the striped bass commercial fishermen in Florida. Likewise, little economic data has been reported for the commercial fishery as a whole. Reported commercial landings of 45.5 kg (100 lb) valued at $10 were made in 1939 (Fiedler 1939).

Table 7.1. Georgia commercial striped bass landings (NMFS various years; includes Atlantic coast and inland landings). Empty lines indicate that no striped bass landings were reported.

Year	Landings (lbs)	Value ($)
1920	125	10
1923	360	29
1927	5,355	490
1928	740	107
1929		
1930	500	100
1931		
1932		
1933		
1934		
1936		
1937		
1938		
1939		
1940		
1945		
1950		
1956	100	20
1957	300	60
1958	700	140
1959	200	40
1960	1,000	200
1961	1,400	270
1962	100	16
1963	1,400	210
1964	3,100	509
1965	1,800	310
1966	1,300	242
1967	200	30
1968	600	173
1969	1,100	264
1970	1,800	297
1971	1,600	405
1972	5,000	1,373
1973	6,500	2,100

7.1.3 Alabama

Historically, commercial striped bass landings in Alabama were not high. The NMFS only reported landings in 1951 valued at $48 (NMFS unpublished data). In April 1967, the Alabama Department of Conservation conducted a survey of commercial operators on Mobile Bay to determine the status of striped bass in coastal Alabama (Shell and Kelley 1968). The last large purchase by seafood processors was in the late 1940s and early 1950s. Alabama waters were officially closed in 2004 to commercial fishing for striped bass.

7.1.4 Mississippi

The NMFS commercial landings database has no documented commercial catch of striped bass from Mississippi waters (NMFS various years).

7.1.5 Louisiana

The Lake Pontchartrain drainage supported a commercial fishery with reported landings valued at $4,499 from 1892 to 1899 (Collins and Smith 1893, Townsend 1900). Goode and Bean (1880) quoted a letter from Mr. Silas Sterns, stating that "at New Orleans it [striped bass] is found in the market quite often."

7.1.6 Texas

Fiedler (1939) and Butler and Stelly (1993) reported the most recent commercial landings of striped bass in Texas were in 1932 and 1945-46, respectively. Stevenson (1893) reported that a number of striped bass were landed commercially in 1890 from Galveston, Aransas, and Corpus Christi bays and were valued at $391 in total. No information was available on the fishermen themselves. See Sections 3.1.1 and 6.2.2.6 for discussions of possible problems with the reports of striped bass commercial harvest from Texas waters.

7.2 Recreational Sector

Striped bass are not a major species in the nearshore saltwater sport fishery in the Gulf of Mexico. In contrast, efforts by states to stock striped bass in freshwater lakes and rivers have resulted in popular recreational fisheries for native, non-native, and/or hybrid striped bass in some inland rivers. Because of the relatively low occurrence of striped bass in coastal fisheries, very little effort has been put forth by researchers to assign an economic value to a "saltwater recreational striped bass fishery."

7.2.1 Saltwater and Coastal Rivers

Maharaj and Carpenter (1997) explored economic activities associated with saltwater angler expenditures in the United States. The initial expenditures by anglers set in motion a series of spending in local economies that resulted in the provision of economic output and products, secondary purchases of goods and services by associated businesses, the generation of wages and salaries, and the creation of jobs. True economic "impact" occurs when these economic consequences are associated with the expenditures by nonresident anglers. Maharaj and Carpenter (1997) found economic activities associated with saltwater angling are substantial. The annual economic output associated with saltwater angling expenditures in the Gulf (excluding Florida) was estimated at $2.9 billion in 1996. The total output for Florida (Atlantic and Gulf Coasts) was estimated at $4.1 billion. This economic activity resulted in total annual wages and salaries of $1.17 billion and generated 56,000 jobs, although very little of this saltwater angling activity targeted striped bass.

With the steady trend in migration of the human population to coastal areas, the number of participants in recreational saltwater fishing is expected to increase (VanderKooy and Muller 2003). Nearly half the U.S. population lives within 45 km of a coast, and recent studies show coastal populations are growing faster than other populations (Culliton et al. 1990, Cohen et al. 1997). In 2000, nearly 50 million people lived along the Atlantic Coast from Maine to Virginia and comprised almost a quarter of the total U.S. population; 16 million people lived along the coastline of the Gulf of Mexico (Culliton et al. 1990). Coastal population growth, coupled with increased numbers of tourists and vacationers, is increasing demands on aquatic habitats and fishery resources. Between 1990 and 2025 in Texas, the projected rates of growth in the number of saltwater anglers (60%) will trail population growth (66%) but will exceed the rate of growth among freshwater anglers (42%), placing additional pressure on all recreational fisheries (Murdock et al. 1992).

7.2.1.1 Georgia (ACF)

While a few studies have looked at the sociologic profile of recreational anglers in Georgia (Slipke et al. 1998, Responsive Management 2004), none focus specifically on those anglers that target Gulf striped bass. Consequently there is little or no information on the value of the recreational Gulf striped bass fishery in Georgia.

7.2.1.2 Florida

The Apalachicola River tailrace striped bass fishery is important to the local economy. Utilizing economic data collected by the U.S. Census Bureau (USDOI et al. 1996), as analyzed by Southwick Associates (www.southwickassociates.com) for the American Sportsfishing Association (www.asafishing.org), FWC (www.myFWC.com) calculated an average value of $18.20 per hour for freshwater angling effort. Adjusted for inflation to a value of $21.74 per hour in 2004-dollar equivalents (U.S. Bureau of Labor Statistics, www.bls.gov/cpi/), the FWC determined the tailrace striped bass fishery provided an estimated range of $13,674 to $206,204 of revenue annually to area businesses during the 14-week peak fishing seasons between 1980 and 2003 (Table 6.4).

7.2.1.3 Alabama

There is no current information on a directed recreational fishery for striped bass in coastal Alabama waters today, although anglers do catch a few incidentally.

7.2.1.3 Mississippi

There are no directed effort estimates for a recreational striped bass fishery in coastal Mississippi although a few anglers target them. Most are caught as incidental catch.

7.2.1.4 Louisiana

Virtually no recreational fishery targeting striped bass exists in coastal Louisiana. Currently, no expenditure, effort, or participation data exists for a recreational striped bass fishery on the Louisiana coast.

7.2.1.5 Texas

There are no data on anglers or value of a striped bass recreational fishery in Texas.

7.2.2 Inland Reservoirs, Lakes, and Streams

A characterization of the inland recreational striped bass angler is difficult because this sector represents a true crosscut of American culture. Every educational level, income level, age level, and ethnic group participate in recreational fishing in the U.S. Because striped bass are accessible from shore, dock, and boat, there is nothing to limit participation in the recreational fishery. However, limited information exists in the form of creel surveys, especially in and around reservoirs.

The inland angler typically targets striped bass during fall when adults disperse from thermal refuges throughout reservoirs, feeding voraciously on shad to replenish fat reservoirs and store energy for gamete production, and during spring spawning runs (H. Barkley personal communication as cited in Nicholson 1986) when both natural and man-made barriers concentrate fish at specific locations. The inland component of the recreational fishery tends to target striped bass during the fall and spring peak seasons; though these fish are caught year-round in many reservoirs.

7.2.2.1 Georgia

While considerable recreational fisheries exist along the Flint and Chattahoochee rivers (see Section 6.1.2.1), there is virtually no information on expenditures by these anglers or their sociologic makeup.

7.2.2.2 Florida

Lake Talquin was formed in 1927 when Jackson Bluff Dam was completed on the Ochlockonee River just west of Tallahassee to produce hydroelectric power. Because the best striped bass fishing was in the spring and fall, the FWC conducted creel census surveys on Lake Talquin during those peak fishing seasons between 1980 to 2000 (Table 7.2A and B). Striped bass angling effort, harvest, and success were estimated. No angler expenditure estimates were

Table 7.2. Estimates of fishing effort and value for the striped bass fishery on Lake Talquin, Florida, based on the FWC annual A.) spring and B.) fall creel surveys. Empty lines indicate no survey conducted, NE indicates insufficient data to estimate. Values based on 2004 dollar equivalents using $27.66/angler hour average (USFWS).

A. Spring

Year	Effort (hrs)	Value ($)
1981	142	3,087.08
1982		
1983		
1984		
1985	25	543.50
1986	0	0
1987	838	18,218.12
1988	114	2,478.36
1989	70	1,521.80
1990	254	5,521.96
1991		
1992	199	4,326.26
1993	71	1,543.54
1994	250	5,435.00
1995	790	1,717.46
1996	232	5,043.68
1997		
1998		
1999	1777	38,631.98
2000	549	11,935.26
2001		
2002		

B. Fall

Year	Effort (hrs)	Value ($)
1980	3309	71,937.66
1981	1137	24,718.38
1982	1750	38,045.00
1983		
1984	1134	24,653.16
1985		
1986	311	6,761.14
1987	122	2,652.28
1988	107	2,326.18

in those surveys; however, by applying USFWS average angler expenditures, values can be estimated. These values ranged from $543.50 in spring 1985 to $71,937.66 in fall 1980.

Creel surveys were also conducted on the Ochlockonee River in the tailrace below Jackson Bluff Dam in 1981-1983. Estimates of angler effort ranged from 2,015 to 848 hrs with 1982 representing the lowest year for success but the median year for effort (Table 7.3), with expenditures ranging from $18, 435.52 to $43,806.10.

Table 7.3. Estimates of fishing success for striped bass on the Lower Ochlockonee River, Jackson Bluff Dam tailrace from the FWC annual spring creel survey. Values based on 2004 dollar equivalents using $27.66/angler hour average (USFWS).

Year	Effort (hrs)	Value ($)
1981	2015	43,806.10
1982	1328	28,870.72
1983	848	18,435.52

7.2.2.3 Alabama

Most of the reservoirs along the Black Warrior and Tombigbee rivers, Lewis Smith Lake, Lake Martin, Jones Bluff Lake, and reservoirs along the Coosa River including Neely-Henry, Logan Martin, and Lay Lakes support recreational striped bass fisheries. A statewide study of fish consumption among freshwater anglers was conducted for the Alabama Department of Environmental Management from August 1992 to July 1993 (FIMS and FAA ND). This study was conducted to further evaluate statewide water quality criteria. Field interviews of anglers were performed following fishing trips in eleven Alabama drainages and included 23 tailwaters and six reservoir locations across the state. *Moronids* including striped bass, white bass (*Morone chrysops*) and their hybrids, and yellow bass (*M. mississippiensis*) were the third most frequently encountered species group recorded by the surveyors.

Fourteen states were represented among the anglers interviewed (FIMS and FAA ND). Eighty-eight percent of those encountered were Alabama residents, and 88% were male. Most (55%) of the anglers interviewed were between the ages of 30 and 50 years. The ethnic makeup of anglers was as follows: 79% white, 18% black, and less than 1% each were Native American, Asian American, or Latin American. The annual household income of the majority of those surveyed (78%) was greater than $15,000; however, 22% were below poverty level.

7.2.2.4 Mississippi

There is no information available on the socioeconomic characteristics of state reservoir striped bass fisheries in Mississippi. A substantial fishery exists in the Ross Barnett Reservoir in central Mississippi but little to no research has been done to characterize this fishery or the fishery participants.

7.2.2.5 Louisiana

A substantial striped bass fishery exists in the Toledo Bend reservoir but virtually no data exist on the anglers participating or the fishery itself.

7.2.2.6 Texas

In 1978, a statewide creel survey began to determine fishing pressure and harvest trends in several fisheries including striped bass and hybrid striped bass in inland waters. The survey concentrated on reservoirs across Texas and was conducted from March through August 1978-1980. Striped bass were the most sought after sport fish in at least one reservoir and the second or third most popular sport species on several others (McCabe 1981). Lake Texoma is one of the premier Texas reservoirs for recreational striped bass fishing; additional lakes and reservoirs that support recreational striped bass fisheries include the Whitney, Buchanan, Possum Kingdom, and Granbury.

Lake Texoma on the Oklahoma-Texas border was created on the Red River in the 1940s. The 36,000-hectare reservoir was stocked with Atlantic striped bass during 1965-1974 and quickly established a reproducing population (Schorr et al. 1995). More than 60% of the fishing pressure on Lake Texoma is directed toward striped bass, and in 1989, Mauck (1990) estimated that anglers spent $16.1 million on striped bass fishing trips there. Schorr et al. (1995) reported that in 1990, 415,128 striped bass anglers (40% regional and 60% non-regional) fished 1.33 million hours on Lake Texoma. Striped bass anglers on Lake Texoma fished an average of 3.2 hours per day with the majority of the trips (>80%) lasting one day for regional anglers and two or more days for non-regional. Regional anglers spent $10.40 per hour fishing for striped bass while non-regional anglers spent $31.10 on average. Non-regional striped bass anglers in Lake Texoma in 1990 contributed $19.8 million to the regional economy through fishing expenditures.

7.3 Costs and Benefits of Stock Enhancement Programs

Striped bass in Gulf of Mexico rivers are unique in that there is little measurable directed effort toward a coastal fishery, yet there are substantial stocking efforts. In most fisheries, the cost of production is tempered by the economic benefits generated by a large directed fishery. For example, in the state of Texas considerable money and effort goes into the production of red drum (*Sciaenops ocellatus*) while the economic rewards in fishery-related jobs and tourism continue to surpass production costs. The economic benefits of Gulf race striped bass hatchery operations are not as clear. While millions of Gulf striped bass have been hatched and released over the last 24 years, the economic return from sport fishing is probably quite low.

A summary of the estimated total hatchery production of striped bass, both Phase I and Phase II fingerlings, has been provided each year by the USFWS in a report from the Annual *Morone* Workshop. Approximately 8.6 million fry were expected to be produced in 2002 to meet Gulf-wide stocking requests of 1,667,000 Phase I fingerlings (USFWS 2002). Phase II fingerling production for Gulf wide distribution that year was estimated at 120,000 fish. Utilizing striped bass production cost values provided by GDNR of $0.05 per fish for Phase I fingerlings and $1.00 per fish for Phase II fingerlings, production cost of Gulf striped bass for the

2002-year class was $203,350. Production efforts included broodfish collection, transportation, and hatchery operations and were shared by many state and federal agencies; the cost to any individual entity was only a fraction of the total cost.

In 1978, the program costs for stocking striped bass in Texas rivers and reservoirs were estimated at $143,356. Recreational benefits derived from the program had an estimated value of $4.5 million, and the value of the striped bass harvested was approximately $2.7 million. The fishery had an estimated total value of $19.4 million in 1979 with a program cost of $124,697. Program costs in 1980 were the lowest for the three years of the survey ($66,814), and the total value of the striped bass fishery for the state was estimated at $15.7 million (McCabe 1981). The average combined value of the striped bass and hybrid striped bass fishery over the three-year period resulted in an estimated cost-benefit ratio of 1:111 (McCabe 1981).

The appearance of striped bass in previously unstocked bays and in the Gulf indicated that a coastal striped bass fishery along the Texas Coast might be feasible (Matlock et al. 1984). By stocking more and larger fingerlings per hectare in an area subject to heavy fishing pressure (i.e., Galveston Bay), Matlock et al. (1984) believed the stocking effort could be successful. However, after limited indications of success in establishing a coastal striped bass fishery, coastal stocking of striped bass in Texas waters was discontinued in 1994.

7.4 Organizations Associated with the Fishery

7.4.1 National

National Coalition for Marine Conservation
Ken Hinman
3 West Market Street
Leesburg, VA 22075

National Striped Bass Association
Warren Turner
403 2nd Loop Road
Suite #3
Florence, SC 29505

National Fisheries Institute
1901 North Ft. Myer Drive
Suite 700
Arlington, VA 22209

American Sportfishing Association
Mike Hayden
1033 North Fairfax Street
Suite 200
Alexandria, VA 22314

Coastal Conservation Association (CCA)
Walter Fondren, Chairman
4801 Woodway, Suite 220W
Houston, TX 77056

7.4.2 Regional

Gulf and South Atlantic Fishery
Development Foundation
Judy L. Jamison
Lincoln Center, Suite 997
5401 West Kennedy Boulevard
Tampa, FL 33609

Southeastern Striped Bass Foundation
Warren Turner
403 2nd Loop Road
Suite #3
Florence, SC 29505

Southeastern Fisheries Association
Robert Jones, Executive Director
1118B Thomasville Road
Mt. Vernon Square
Tallahassee, FL 32303

7.4.3 Local (State)

The following organizations are concerned with finfish-related legislation and regulations. Consequently, they are potentially interested in the effects of these regulations on striped bass in the Gulf of Mexico region.

7.4.3.1 Georgia

Georgia Wildlife Federation
Jerry McCollum
11600 Hazelbrand Rd.
Covington, GA 30014

Coastal Conservation Association of Georgia
(CCAGA)
515 Demark St.,
Suite 300,
Statesboro, GA 30458

7.4.3.2 Florida

Florida Conservation Association
(Florida CCA)
Dave Lear
905 East Park Avenue
Tallahassee, FL 32301-2646

Florida Department of Agriculture &
Consumer Services/Bureau of Seafood
& Aquaculture
2051 East Dirac
Tallahassee, FL 32310

Florida League of Anglers
534 North Yachtsmen
Sanibel, FL 33957

Organized Fishermen of Florida
Jerry Sansom, Executive Director
P.O. Box 740
Melbourne, FL 32902

7.4.3.3 Alabama

Coastal Conservation Association - Alabama
David Dexter
P.O. Box 16987
Mobile, AL 36616
(334) 478-3474

Alabama Seafood Association
Pete Barber
P.O. Box 357
Bayou LaBatre, AL 36509

7.4.3.4 Mississippi

Mississippi Charter Boat Association
Jim Twigg
3209 Magnolia Lane
Ocean Springs, MS 39564

Mississippi Gulf Coast Fishermen's Association
Eley Ross
176 Rosetti Street
Biloxi, MS 39530

Mississippi Gulf Fishing Banks
Paul Kensler
P.O. Box 223
Biloxi, MS 39533

7.4.3.5 Louisiana

Louisiana Seafood Management Council
Peter Gerica, President
Rt. 6 Box 285 K
New Orleans, LA 70129
(504) 254-0618
(504) 254-6185 (fax)

Concerned Finfishermen of Louisiana and Louisiana Fishermen for Fair Laws
Henry Truelove
P.O. Box 292
Charenton, LA 70523

Coastal Conservation Association - Louisiana
Jeff Angers, Executive Director
P.O. Box 373
Baton Rouge, LA 70821-0373

Louisiana Association of Coastal Anglers
Susan Vuillemot
P.O. Box 80371
Baton Rouge, LA 70818

Louisiana Coastal Fishermen's Association
Terry Pizani
P.O. Box 420
Grand Isle, LA 70354

Louisiana Seafood Processors Council
Mike Voisin
P.O. Box 3916
Houma, LA 70361-3916
(504) 868-7191
(504) 868-7472 (fax)

Louisiana Wildlife Federation
Randy Lanctot, Executive Director
P.O. Box 65239
Baton Rouge, LA 70896-5239

7.4.3.6 Texas

Coastal Conservation Association - Texas
Kevin Daniels, Director
4801 Woodway, Suite 220 W
Houston, TX 77056

Finfish Producers of Texas
Carroll and Ruth West
P.O. Box 60-B
Riviera, TX 78379

Tournament Directors Foundation of Texas
Pam Basco
P.O. Box 75231
Houston, TX 77034

Sportsmen Conservationists of Texas
Alan Allen, Director
807 Brazos Street
Suite 311
Austin, TX 78701

8.0 MANAGEMENT GOALS AND RECOMMENDATIONS

The primary goal of this interstate FMP is to restore and maintain self-sustaining Gulf race striped bass populations in suitable rivers within their native range. A secondary goal is to maintain optimum sustainable yield (OSY) from riverine, recreational striped bass fisheries within that range.

These goals generally apply to the free-flowing portions of rivers below the fall line or farthest downstream obstruction, unless otherwise stated. The river systems to which these goals apply are the lower Mississippi, Tangipahoa, Tchefuncte, Pearl, Wolf, Jourdan, Biloxi, Tchoutacabouffa and Old Fort Bayou, Pascagoula, Mobile-Alabama-Tombigbee (MAT), Perdido, Escambia, Blackwater, Yellow, Choctawhatchee, Apalachicola, and the Ochlockonee. These goals do not apply to rivers west of the Mississippi because evidence does not indicate that striped bass were native to those rivers, nor to the Suwannee, as it is not considered likely that this river historically supported a reproducing population of striped bass. In addition, there has not been a significant history of stock enhancement of striped bass in the Suwannee River. The range-wide goals specified above are further tailored to specific river systems, and these river-specific goals are detailed in Section 8.5.

The general management recommendations described in Section 8.3 are those which may apply individually to all or selected rivers within the management unit. Recommendations listed in Section 8.4 are considered global recommendations for the Gulf striped bass management program as a whole. The general recommendations as they apply to specific rivers and those that may be unique to those rivers are listed in Section 8.5. All recommendations in this FMP are proposed to the individual states for their adoption and implementation. However, states may elect to implement additional measures and regulations that are more restrictive if situations within the fishery warrant such action. Regulations which are less restrictive than those recommended are discouraged, although the states at no time relinquish any of their rights or responsibilities to regulate their own fisheries. Since striped bass populations are affected by factors outside the jurisdiction of coastal fishery management agencies, many of the recommendations made within this FMP are directed toward inland fishery agencies and states outside the GSMFC Compact.

In cases where future state goals and objectives for striped bass management may come into conflict with recommendations made in this FMP, the Striped Bass TTF or the Anadromous Fish Subcommittee of the GSMFC will serve as a forum for discussion and resolution of such concerns. If necessary the TTF will develop amendments to this FMP to address these concerns.

8.1 Management Unit

The management unit under this interstate FMP is striped bass (*Morone saxatilis* Walbaum), which includes both Gulf and Atlantic races. Both races currently exist within the native range of striped bass in the Gulf.

8.2 Management Area

The management area for this interstate FMP is the state jurisdictional waters (inland and coastal) of the Gulf of Mexico region within the historical native range of striped bass. This includes the states of Louisiana, Mississippi, Alabama, and Florida. Because the *Cooperative Agreement for Striped Bass Restoration in the Apalachicola/Chattahoochee/Flint River System* includes Georgia among participatory states establishing the ACF Technical Committee, Georgia is also included in the management area. Striped bass fisheries exist within Texas reservoirs and their tailwaters because of reservoir stocking efforts. However, Texas is not included in the management area because it is outside the accepted native range of striped bass in the Gulf.

8.3 General Management Recommendations

The recommendations included in this section are those that generally apply to the entire management area or to two or more specific river systems. Table 8.1 summarizes applicability of recommendations by river system.

8.3.1 Harvest Regulation

8.3.1.1 Sale and/or Purchase

Sale and/or purchase of striped bass harvested from public waters should continue to be prohibited.

It is accepted that striped bass populations in the Gulf of Mexico region were in severe decline for several decades, and stocking efforts by the states and federal agencies are primarily responsible for those that exist. The abundance of striped bass in this region remains too low to support viable commercial fisheries, and commercial harvest of the species has not occurred since the 1970s. Current state laws for the region prohibit the sale and/or purchase of striped bass harvested from public waters; therefore, it is counterproductive to restoration goals to encourage development of commercial fisheries.

8.3.1.2 Bag Limits and Size Limits

Size and bag limits should be established for striped bass on all public waters within the management area. Those regulations should appropriately support the management goals for rivers or river systems within each state. A maximum daily bag limit of three fish per person with a minimum size restriction of 18 inches TL is recommended.

Striped bass can occur in large aggregations, particularly in early year classes. This, coupled with the aggressive nature of the species, indicates a high probability that a three-fish bag limit could be exceeded once an angler locates an aggregation of fish. Anecdotal information indicates that individual daily catches of 20 fish are not unusual once an aggregation of fish is found, especially in warmer months when they aggregate in known thermal refuges. In view of extremely low population levels of striped bass in Gulf rivers, a conservative bag limit is necessary.

Table 8.1. Summary of general management recommendations by river.

General Recommendation	Lower Mississippi	Tangipahoa	Tchefuncte	Pearl	Wolf/ Jordan	Biloxi/ Tchoutacabouffa/ Old Fort Bayou	Pascagoula	Mobile/ Alabama/ Tombigbee
Sale/Purchase Regulations(8.3.1.1)	X	X	X	X	X	X	X	X
Bag/Size Limits (8.3.1.2)	X	X	X	X	X	X	X	X
Other Harvest Regulations (8.3.1.3)				X			X	X
Stocking (8.3.2.1)		X	X	X	X	X	X	X
Genetic Diversity (8.3.2.2)		X	X	X			X	X
Genetic Integrity (8.3.2.3)		X	X	X			X	X
Evaluation of Stocking Success (8.3.2.4)		X	X	X	X	X	X	X
Fishery Independent Data (8.3.3.1)	X	X	X	X	X	X	X	X
Fishery Dependent Data (8.3.3.2)	X	X	X	X	X	X	X	X
Critical Habitat Identification (8.3.4.1)				X			X	X
Comprehensive Habitat Assessment (8.3.4.2)		X	X	X			X	X
Critical Habitat Management (8.3.4.3)	X			X			X	X
Migration and Movement (8.3.4.4)				X				X
Riverine Habitat Integrity (8.3.4.5)		X	X	X			X	X
Population and Habitat Modeling (8.3.5)				X			X	X
Enforcement (8.3.6)	X	X	X	X	X	X	X	X

Table 8.1. General recommendations (Con't).

General Recommendation	Perdido	Escambia/ Conecuh	Blackwater	Yellow	Choctawhatchee	Apalachicola/ Chattahoochee/ Flint	Ochlockonee
Sale/Purchase Regulations(8.3.1.1)	X	X	X	X	X	X	X
Bag/Size Limits (8.3.1.2)	X	X	X	X	X	X	X
Other Harvest Regulations (8.3.1.3)		X			X	X	
Stocking (8.3.2.1)	X	X	X	X	X	X	X
Genetic Diversity (8.3.2.2)		X		X	X	X	X
Genetic Integrity (8.3.2.3)		X		X	X	X	X
Evaluation of Stocking Success (8.3.2.4)	X	X	X	X	X	X	X
Fishery Independent Data (8.3.3.1)	X	X	X	X	X	X	X
Fishery Dependent Data (8.3.3.2)	X	X	X	X	X	X	X
Critical Habitat Identification (8.3.4.1)		X			X	X	
Comprehensive Habitat Assessment (8.3.4.2)		X			X	X	
Critical Habitat Management (8.3.4.3)		X			X	X	
Migration and Movement (8.3.4.4)		X				X	
Riverine Habitat Integrity (8.3.4.5)		X			X	X	
Population and Habitat Modeling (8.3.5)		X			X	X	
Enforcement (8.3.6)	X	X	X	X	X	X	X

Stress-related mortality related to catch-and-release increases with temperature and to a lesser extent size (see Section 6.3), and large striped bass hooked in the summertime are less likely to survive catch-and-release practices. Size and bag limit recommendations are intended to serve as a general rule for the Gulf of Mexico region; however, different, more specific recommendations may be made for certain rivers. States are encouraged to enact regulations that are more restrictive as appropriate based on the management goals for the fisheries within their jurisdiction.

For instance, modeling assessments by Bulak et al. (1995) indicated that restricting harvest to age-4 or greater produced population growth under all mortality rates evaluated. They found that even with supplemental stocking, growth potential of the population was severely restricted if high rates of harvest were permitted on age-2 fish. Similarly, Cooper and Polgar (1981) recommended decreasing mortality on dominant year classes during the first few years of life. They advised that regulations be flexible, tailored to specific populations, and not necessarily uniform from year to year. High adult mortality in striped bass tends to truncate the age structure of populations, which can reduce the likelihood of strong year class formation (Rago and Goodyear 1987) and genetic diversity (Diaz et al. 2000).

8.3.1.3 Other Harvest Regulations

Enact or promulgate additional harvest laws or regulations as appropriate to support river-specific goals for striped bass.

To achieve river-specific goals, the need for other regulations (closed seasons, slot limits, prohibition of fishing in specific areas such as thermal refuges) should be considered. Specific gear types should be prohibited where appropriate. In rivers where a goal includes restoration of self-sustaining populations, complete harvest moratoria should be considered if beneficial to achieve that goal. Jensen (1993) viewed the imposition of moratoria as being critical to dramatic increases in Chesapeake Bay populations of American shad and striped bass. A moratorium can serve as an important first step in obtaining commitments needed to correct habitat problems that may be the basis for population declines. In the Chesapeake Bay striped bass fishery, the decision to impose a moratorium was based on projections that recovery of stocks and fisheries would be achieved more quickly with the moratorium. An important element, however, is a clear definition of conditions under which to lift a moratorium. Successful moratoria and fishery restoration requires meaningful involvement of the fishing public. Information developed under recommendations 8.3.3 and 8.3.4.2 may help determine whether more restrictive regulations are needed.

8.3.2 Stock Enhancement

8.3.2.1 Stocking

States within the management area should continue to stock striped bass fingerlings either in the free-flowing portions of rivers or in upstream reservoirs on an annual basis if considered essential to support management goals. Genetic diversity of the fish stocked should be maximized, and genetic integrity of the Gulf race should be maintained in specific rivers.

Continued existence of striped bass in most Gulf of Mexico rivers is probably dependent upon stocking efforts. Stocking programs should be critically evaluated to determine necessity and appropriate stocking rates. Specific preliminary recommendations on the numbers, sizes, and races to stock are given by individual river system in Section 8.5. However, these recommendations should be evaluated and modified as necessary in accordance with adaptive management strategies. Stocking efforts should follow accepted protocols and standards as found in *Culture and Propagation of Striped Bass and its Hybrids* (Harrell et al. 1990) and *Striped Bass Handling Survey* (Parauka 1993). An annual stocking rate of one million Phase I fingerlings was recommended by USFWS (1975) for rivers the size of the Choctawhatchee River, Florida, in order to establish a successful year class. Alternative stocking strategies should be considered. For instance, Bulak et al. (1995) found through modeling of the Santee-Cooper population that stocking every other year in combination with restricting harvest to age-4 or older fish was a viable strategy to increase population size while minimizing negative genetic effects of stock enhancement. Rulifson and Laney (1999) recommended a conservative approach in stock enhancement programs for striped bass, and such programs should be used in conjunction with sufficient regulation of fishing mortality to ensure adequate protection of spawning stock. In general, they recommended against stocking solely for the purpose of put-and-take fisheries for striped bass, but rather relying on natural reproduction to maintain stocks. Restoration stocking programs should also monitor natural egg production and recruitment. In the Savannah River, Georgia, restoration was to be considered successful when survival from natural spawning provided enough spawning adults to maintain the population, and stocking was to continue until rates of natural recruitment at age-2 were equal to or exceeded those resulting from stocking efforts (Van Den Avyle et al. 1995). In systems where habitat conditions that support the adult population are limiting (i.e., thermal refuge habitat), the availability of those habitats should be considered when determining stocking rates (Weeks and Van Den Avyle 1996).

8.3.2.2 Genetic Diversity

The following general recommendations are provided as ways to help maintain and/or increase genetic diversity in Gulf of Mexico striped bass populations (the position in the list in no way reflects a prioritization.

- *a) Protect, enhance, or create critical habitats so that self-sustaining populations can be recovered from wild stocks to the extent possible.*
- *b) Periodically monitor striped bass genetic diversity in river systems where restoration of self-sustaining populations is a goal.*
- *c) Determine and periodically monitor Gulf striped bass effective population sizes in rivers where maintenance of self-sustaining populations are goals.*
- *d) Protect each year class long enough to allow its gene pool to be passed on proportionately to the next generation.*
- *e) To the extent possible, manage stocks without any kind of captive production or supplementation.*
- *f) Where necessary, rebuild natural spawning populations while minimizing genetic risks through captive propagation and supplemental stocking to augment declining populations or to restore extirpated populations or stocks.*

Supplemental stocking programs should incorporate the following features.

a) *As many broodfish as practicable should be used each year in producing fingerlings for stocking. An ideal broodfish population would be 100-200 fish.*
b) *Multiple hatcheries should be utilized for artificial spawning in order to increase the ability to hold and spawn ideal numbers of broodfish.*
c) *To the extent practicable, an equal sex ratio should be maintained within broodfish populations. Where this is not practicable, mating females with multiple males or vice versa should be utilized to maximize genetic variation in progeny.*
d) *Ideally, eggs from a mature female should be divided into equal aliquots prior to fertilization. A single male should be used to fertilize each aliquot. Males should be used to fertilize eggs only once.*
e) *Larvae of several females should be stocked into individual grow-out ponds. Monitor the genetic diversity of individual ponds prior to harvesting and releasing.*
f) *Family sizes of stocked fish should be as equal as possible. The number of progeny stocked from individual matings in any given year should be within 50% of each other to avoid gene swamping from small numbers of breeding pairs.*
g) *To the extent practicable, entire families of progeny should not be exported to grow out facilities which stock river systems outside the ACF.*
h) *An equal portion of each family should be maintained for stocking back into the ACF system.*
i) *Ideally, fingerlings restocked into hatchery ponds for Phase II grow-out should come from as many families as possible and in equal proportions.*
j) *Size-at-age keys for each broodfish population should be developed. Broodfish should be paired across year classes, but within generational intervals (three years).*
k) *The effects of stocking Phase II fingerlings on genetic diversity of wild populations should be investigated and a determination made on whether the practice should be continued in the Gulf of Mexico striped bass restoration program.*

Genetic variation is the basis for evolutionary change in populations (Allendorf and Luikart 2004). Genetic diversity is an expression of the numbers of and frequency of occurrence of specific heritable features in a population. Such features can include phenotypic expression of physical characteristics (such as color), variant forms of specific proteins, or variant forms of nucleotide sequences (alleles) at specific sites (loci) in DNA molecules. Genetic diversity can be measured in various ways. For instance, heterozygosity measures the relative proportion of individuals in a population that are heterozygous (i.e., have different alleles) at a locus. Another measure is allelic richness, or the total number of different alleles that may be found at a locus in a population.

According to the Hardy-Weinburg equilibrium principle, the relative frequency of alleles in a population remains constant unless affected by factors such as natural selection, differential mutation rates, random genetic drift, or meiotic drive (Gardner 1975). An important factor in reducing genetic diversity in a population is genetic drift (Allendorf and Luikart 2004). The rate of genetic drift is generally inversely related to population size, with smaller isolated populations tending to become homozygous for specific alleles more rapidly than larger populations.

Inbreeding depression increases homozygosity in a population (Busack and Currens 1995) and generally results in the loss of rare alleles. In some instances these rare alleles may be very important to fitness of a population, and reduction of overall fitness is likely to result from increased homozygosity for these alleles (Kerby and Harrell 1990). Fixation of higher-frequency alleles may also result from the loss of heterozygosity of rare alleles, which can also reduce variability and fitness (Kerby and Harrell (1990). Reduction in heterozygosity may result in decreased growth or survivorship, increased incidence of deformities, or loss of reproductive viability (Meffe 1986, Kincaid 1995). Inbreeding may also increase from one generation to the next (St. Pierre et al. 1996).

Most of the recommendations in this section are summarized from Appendix 12.2 (Gulf Striped Bass Genetics Management Plan) of this document. The appendix should be referred to for more detailed information and background.

8.3.2.3 Genetic Integrity

The following general recommendations are provided as ways to help protect genetic integrity in Gulf of Mexico striped bass populations.

a) Analyze and monitor nDNA markers in the ACF striped bass population if needed in order to better assess introgression by Atlantic alleles into the ACF population.
b) Conduct a comprehensive statistical analysis of genetics data on striped bass in the ACF, if needed, in order to better determine the degree of introgression of Atlantic alleles into the ACF striped bass population.
c) Develop a morphologically and/or genetically-based definition of Gulf race striped bass on which to base selection of broodstock for stock enhancement efforts.
d) If determined necessary, initiate a genetics restoration program for the ACF population of striped bass.

In a species such as striped bass, in which subpopulation structure exists, outbreeding depression may result if individuals from two distinct, differentiated populations are mixed. Outbreeding may initially increase genetic diversity, but long-term increased fitness will generally not be the result (Leary et al. 1995). The first generation of hybrids may be more fit, but over the long-term reduced fitness generally occurs (Meffe 1986, Leary et al.1995). Outbreeding depression results in an erosion of adaptations to local habitats through the loss of co-adapted gene complexes (Leary et al. 1995, Czapla 1999). Individual genes evolving in response to other genes result in co-adapted gene complexes in reproductively isolated populations. These gene complexes function as a unit in phenotypic expression of characteristics that may be important in the local population. Hybridization tends to break down co-adapted gene complexes resulting in a general loss in fitness of the endemic population (Leary et al. 1995).

Even though striped bass of Atlantic origin have been stocked into the ACF and genetic introgression into the native population has occurred, studies have demonstrated that the native striped bass population in the ACF is still genetically distinct from Atlantic Coast populations Wirgin et al. 2005b). A high percentage of individual fish from the ACF exhibit mtDNA haplotypes and nDNA genotypes not seen in populations along the Atlantic Coast or elsewhere on the Gulf Coast.

Most of the recommendations in this section are summarized from Appendix 12.2 of this document. The appendix should be referred to for more detailed information and background.

8.3.2.4 Evaluation of Stocking Success

Both short and long-term stocking success should be evaluated. Short-term evaluation should assess mortality associated with transport and initial introduction into receiving waters, and long-term evaluation should assess growth and survival to age-1.

Short-term evaluation may include holding a subsample of stocked fish in cages in receiving waters, transport containers, or aquaria for at least 48 hrs or seine sampling from two days to a month after release. Long-term evaluation may include sampling by seine, trawl, electrofishing, gill net, hook-and-line, or subsurface visual assessment.

Because maintenance of striped bass populations in the Gulf is heavily dependent on stock enhancement at present, it is necessary to evaluate stocking success. This assures maximum efficiency and makes the best use of financial resources available for restoration. Short-term evaluation may assist in adaptive management to avoid repeating previous unsuccessful practices, allowing adjustment of subsequent stocking efforts, and in making predictions of recruitment and future year-class strength. Dunning and Ross (1986) recommended that evaluation of stocking programs should include assessing age-specific fishing mortality if the objective of the program is to maintain or enhance a self-sustaining stock.

8.3.3 Population Data

Fishery independent and dependent data should be collected on striped bass populations in rivers where restoration of self-sustaining populations is a goal in order to evaluate the status of individual striped bass populations and gauge the success of restoration efforts.

Collection of pertinent data may provide information on population parameters such as age and size structure, condition, relative abundance, population size, genetic composition, mortality rates, exploitation rates, maturity schedules, length-at-age and growth rates, reproduction and recruitment, movements, interspecific competition, and sex ratios. In addition to providing an indication of success in establishing self-sustaining populations, these data may help determine the need for adjustments in management strategies.

8.3.3.1 Fishery Independent Data

Fishery independent sampling programs for striped bass should be conducted using methodologies and on a schedule appropriate to the goals established for specific rivers and the currently known or suspected population status.

Since most Gulf striped bass populations are extremely limited and fishery dependent data may be very difficult to obtain, fishery independent sampling may be the most important source of population data. Methodologies should be tailored to goals and population status in the specific river under consideration but may include techniques such as electrofishing, trawling, seining, plankton sampling, gill netting, mark and recapture, and angling. Uphoff (1993, 1997) indicated that a modest presence-absence egg-sampling program could provide a reliable indicator of striped bass spawning stock status. Annual sampling programs should at least monitor YOY and adult relative abundance and condition. In rivers where populations are extremely limited, reconnaissance-level relative abundance monitoring may be sufficient. In rivers where populations are more substantial and/or expanding, comprehensive sampling should be conducted in order to refine management measures. In rivers where a mixture of Atlantic and Gulf races co-exists, genetic composition should be periodically assessed.

8.3.3.2 Fishery-Dependent Data

Fishery-dependent data sampling programs for striped bass should be conducted using methodologies and on a frequency appropriate to the goals established for specific rivers and the currently known or suspected catch rates.

Fishery dependent data are essential for determining fishing mortality rates in those systems where goals include maintaining a striped bass fishery while attempting to restore a self-sustaining population. Since fishing activity and catch rates for striped bass in Gulf rivers are currently minimal, many routine creel surveys have failed to intercept anglers catching striped bass and have not provided needed fishery-dependent data for striped bass. Targeted creel surveys (e.g., site-specific or peak season) and/or angler diary surveys may be more likely to provide needed data. Tag return programs may also be a potential source of fishery-dependent data.

8.3.4 Habitat Management

8.3.4.1 Critical Habitat Identification

Identify, describe, and quantify functional and potential thermal refuge, spawning, and nursery habitats in selected rivers in the management area.

In rivers where the goal is to restore self-sustaining populations of striped bass, it is important that areas currently serving as thermal refuge and spawning and nursery habitats are identified and mapped. In addition, areas that provided for those functions in the past or lend themselves to creation or enhancement of such habitats should be identified.

A variety of methods may be used to identify current and potential thermal refuge habitats including direct field observations and water quality monitoring; telemetry of tagged fish; review of historical water resource data; consultation with river specialists, fishermen, and other knowledgeable individuals; and advanced techniques such as aerial thermal imagery. Areas likely to serve as thermal refuge habitat include areas of spring outflow, deep holes, areas in tributaries shaded by overstory vegetation, and discharge from reservoirs. See Section 4.2.4.1 for a detailed discussion of thermal refuge habitat.

Current and potential spawning habitat may be identified by a variety of methods including direct field observations, telemetry of tagged fish, review of historical water resources data, and consultation with river specialists, fishermen and anglers, and other knowledgeable individuals. See Section 4.2.1 for a detailed discussion of spawning habitat.

Methods for identifying current and potential nursery habitats may include direct field observations, consultation with river specialists, or referral to river substrate maps. Nursery habitats are generally described as sandy or silty shoal areas with relatively low flow velocity. See Section 4.2.3 for a discussion of juvenile striped bass habitat.

8.3.4.2 Comprehensive Habitat Assessment

Develop comprehensive assessments for selected rivers that integrate information on important habitats and other environmental and anthropogenic factors that may positively or negatively affect striped bass populations.

It is important that availability of functioning and potentially important critical habitats is assessed in rivers where a goal is to restore self-sustaining populations of striped bass. The assessments should consider other environmental factors such as water quality that may affect striped bass populations. Data on levels of contaminants determined to be problematic as identified in Recommendation 8.4.4 should be compiled from federal and state point and non-point source contaminants programs. The assessments would provide insight into the degree of success that might be expected in a restoration program and what population levels could be supported, as well as assist with prioritizing efforts to enhance, restore, or create critical habitat areas for striped bass.

8.3.4.3 Critical Habitat Management

Design and implement projects to restore, enhance, and create thermal refuge, spawning, and nursery habitat in selected rivers in the management area.

In rivers where a goal is to restore self-sustaining populations of striped bass, it is important that sufficient thermal refuge, spawning, and nursery habitat are available. Where availability of such habitats is not sufficient, projects should be designed and implemented to maximize the availability of such habitats through restoration, enhancement, or creation.

The lack of thermal refuge habitat is likely the most important factor limiting striped bass populations in most Gulf rivers. Potential projects to increase availability of such habitats include deepening or enlarging areas that may hold cool water, enhancing spring flow into suitable areas, and improving overstory shading in tributary streams through restoration of riparian vegetation. In protecting spring-fed thermal refuge habitat, consideration should also be given to the role groundwater conservation may play in supporting such habitats, and all possible actions taken to support groundwater conservation where indicated (Weeks and Van Den Avyle 1996).

Projects should be designed and implemented to provide conditions that would be suitable for spawning by striped bass at the appropriate time and located far enough upstream to allow eggs to hatch before reaching slack water areas such as estuaries or reservoirs. These projects should consider factors such as river stage, discharge, depth, substrate, water temperature, and other appropriate water quality factors. In some systems, conditions for spawning and larval survival may be optimized by managing water releases from dams upstream of spawning areas (Bulak et al. 1997, Zincone and Rulifson 1991). See Section 3.2.5 for the effects of river flow on recruitment.

Nursery habitat may be created by projects that restore, enhance, or create sandy beach and other shallow water habitats where currents are low. For example, carefully designed and managed dredge disposal projects may offer opportunities to develop suitable areas. Instream flow factors such as depth, timing, and duration of stage changes may also be important factors for stable nursery areas, and control of such factors through management of discharge from reservoirs offer opportunities to protect or enhance available nursery habitat. Protection and maintenance of natural river channels and flow regimes should allow sufficient nursery habitat to develop in the most cost effective manner.

8.3.4.4 Migration and Movement

Take advantage of opportunities to cooperatively remove obstructions and implement projects that would facilitate movement of striped bass upstream and downstream of structures blocking access to important habitats.

Considering that the presence of obstructions such as dams, locks, and sills contributed to the loss of native striped bass populations in some rivers, opportunities that arise for removal of such structures should be supported, particularly in rivers where the goals include restoration of self-sustaining populations. In addition, modifications in operation of locks and installation of features to facilitate passage of striped bass at obstructions should be advocated and supported.

8.3.4.5 Riverine Habitat Integrity

Foster the protection and/or restoration of naturally functioning riverine habitats.

Based on the information resulting from recommendation 8.3.4.2, state and federal fish and wildlife agencies should take actions, in cooperation with the appropriate regulatory authorities, to address problems involving water quality (e.g., dissolved solids, suspended solids, turbidity, silting, pH, temperature); contaminants; in-stream flow; water diversions (including groundwater); physical habitat structure and diversity in rivers where goals include restoration of self-sustaining populations of striped bass. Effective use of existing authorities for consultation with responsible entities involving new or operation of existing projects should be made. In addition, adequate mitigation should be sought for new and existing projects and modifications in operation of existing projects advocated where benefits to striped bass may ensue. New laws and regulations for protecting habitats should be advocated, supported, enacted, or promulgated where necessary. Acquisition of critical habitat areas by resource agencies should be sought where necessary to effectively protect those habitats. Use of best management practices in forestry, agriculture, and land development should be advocated, and local efforts to protect and restore watersheds should be supported where such efforts may result in benefits to striped bass populations.

8.3.5 Population and Habitat Modeling

Develop population models for selected rivers in the management unit incorporating population dynamics, conservation biology, and habitat factors.

Data developed under recommendations 8.3.3 and 8.3.4.2 should be utilized in developing striped bass population models for rivers where goals include restoration of self-sustaining populations. Such models may involve classical stock assessment analyses, conservation biological assessments such as minimum viable population analysis, and habitat analyses such as habitat suitability indices. Such models should help in providing a greater understanding of population response to restoration and management actions, developing realistic and justifiable restoration goals, and guiding development of future management actions.

8.3.6 Enforcement

Vigorously enforce harvest and other regulations affecting striped bass populations.

Commercial harvest of striped bass in Gulf rivers and coastal waters is prohibited by all states within the management unit, and all states have restrictive regulations in place for recreational harvest of the species. Each state should continue to enforce these provisions, and federal agencies should vigorously prosecute Lacey Act violations involving striped bass. Particular attention should be placed on enforcement of closures in areas closed to protect critically important habitats and of regulations intended to reduce incidental take of striped bass. Laws and regulations to protect habitat in rivers and/or watersheds should also be enforced.

8.4 Global Management Recommendations

The following recommendations relate to the striped bass management program in the Gulf of Mexico region as a whole and do not specifically apply to any particular watershed or river basin.

8.4.1 Program Coordination

Maintain a standing Anadromous Fish Subcommittee (AFS) under the Interjurisdictional Fisheries Program of the GSMFC which, with appropriate augmentation, will serve as the technical task force for developing, revising, or amending FMPs for Gulf anadromous fish including striped bass, Gulf sturgeon, and Alabama shad. In addition, the AFS should be convened as needed to address issues important to the conservation of Gulf anadromous species.

As in any interjurisdictional cooperative fishery management program, a structured framework for on-going coordination is essential to avoid duplication of effort and provide for efficient use of fiscal and staff resources. Such on-going coordination is also necessary for maintaining focus on management objectives, jointly developing yearly work plans and goals, developing and advocating budget initiatives to fund the program, resolving conflicts, and maintaining a high level of interest among the participants. An important component of program coordination should be periodic assessments of the success and direction of Gulf striped bass restoration and management efforts. In defining the composition of the AFS and TTF, consideration should be given to assuring that appropriate inland state fishery agencies are represented, even if these agencies are not normally represented on GSMFC committees or their respective states not involved in the GSMFC Compact.

8.4.2 Funding

Seek adequate funding to support Gulf of Mexico striped bass restoration and management programs.

The program for restoration and management of anadromous striped bass in Gulf rivers has been severely under-funded for many years. Efforts should be made to restore appropriations under the federal Anadromous Fish Conservation Act and other legislation. Specific budget initiatives should be pursued to provide a dedicated source of funding for state and federal entities involved in the Gulf striped bass program. Other potential funding through grants and private sources should be sought as appropriate.

8.4.3 Information and Education Program

Develop and implement a coordinated information and education program for Gulf striped bass in cooperation with existing programs.

Informed and involved public support is essential for success of a striped bass restoration program. An active public information and education program should be implemented involving all agency partners in the striped bass restoration program with the cooperation of other organizations and entities. Potential tools to develop include attractively designed brochures, World Wide Web sites, videos, news releases, media events, letters to the editor, and specific articles written for outdoor and environmental media. Opportunities to directly interact with the public, such as at fishing rodeos, Earth Day events, and other public functions should be utilized to the extent possible. Presentations at meetings of civic and conservation organizations should be made.

8.4.4 Contaminant Effects

Investigate the effects of river-borne contaminants on early life stage success of striped bass.

Certain chemical contaminants can affect reproductive success of some fish species. A comprehensive assessment should be made of the role contaminants played in the near-extinction of striped bass in the Gulf and the roles they may continue to play in limiting restoration in these rivers. Existing information on contaminant effects on striped bass and other fish species should be used in the assessment. Additional data on contaminant levels in the environment and in striped bass tissue should be gathered as needed.

8.4.5 Taxonomic Investigation

Investigate the biological significance of the Gulf race of striped bass from a taxonomic standpoint.

While the Gulf race is recognized as distinct from Atlantic populations, the taxonomic significance of this distinction has never been systematically evaluated. If differences between Gulf and Atlantic populations are indicated to be significant enough to warrant subspecies or species designation, such information could have significant implications for the conservation priority and status of Gulf of Mexico populations of striped bass, with potential benefits for conservation and management programs established by this FMP.

8.4.6 Historic Population Levels

Investigate the relative abundance of striped bass in the management unit during pre-colonial times using archeological evidence.

Because quantitative data do not exist on population levels of striped bass in Gulf rivers prior to their extirpation, it has been difficult to develop restoration goals for the species in these rivers. The use of archaeological evidence from midden and other human aboriginal sites may provide insight into the historic levels of striped bass populations in Gulf rivers through comparison of the abundance of striped bass remains at these sites with the abundance of remains of other fish species for which there is reliable historic population level data. Support for such work should be sought and initiated in order to develop this information. Such data could have significant implications for the future development of the Gulf striped bass restoration and management program.

8.4.7 Conservation Status

Assess the conservation status of Gulf race striped bass populations in Gulf rivers and recommend to management agencies whether special conservation designation(s) should be made, such as listing under the Endangered Species Act, either throughout the Gulf race's range or in specific rivers.

As reported in Section 5.4.3, the question of whether the Gulf race of striped bass should be listed under the ESA was considered internally within the USFWS in the late 1970s, but the decision was made in 1980 not to pursue listing at that time. Major opposition to its listing centered on the potential restrictions that may have been imposed on stocking of Atlantic race striped bass into Gulf river drainages. The USFWS decided against pursuing a listing on the premise that significant progress was being made in restoration of the Gulf race in the ACF. Since that time, significant progress has been made in gathering data on the status of striped bass populations, genetics, movement, and availability and use of thermal refuge habitats in the ACF and other Gulf rivers. In addition, a program of stock enhancement utilizing Gulf race striped bass has been established for the ACF and a number of other Gulf rivers. However, no Gulf race striped bass population in a Gulf river is believed to be currently able to support fisheries without stock enhancement, and it is uncertain whether any population would be able to avoid extinction without stock enhancement, even if take was completely eliminated. Therefore, the utility of listing the Gulf race throughout its range or within individual river systems should be re-visited.

Under the ESA, the term "species" is defined to include "any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature" (Nehlsen et al. 1991). Waples (1991) proposed the concept of ESU as a criterion in defining a "distinct population segment." Wirgin et al. (2005b) recommended that the Gulf race population in the ACF warranted designation as an ESU (see Section 3.2.1.1.1). The NOAA Fisheries and USFWS jointly published a policy defining "distinct population segment" in 1996 (61 FR 4722). Three elements to be considered in determining whether to list a distinct population segment under the ESA include: 1) discreteness of the population segment from other populations of the species, 2) significance of the population segment to the species, and 3) conservation status.

In evaluating the conservation status of wild salmonid stocks in the Pacific Northwest, Nehlsen et al. (1991) determined that an effective population size of at least 50 fish was necessary to minimize inbreeding problems, though the actual census population of a stock may be at least twice that size or more. They generally considered stocks in which the spawning populations numbered 200 or less to warrant listing as endangered. Spawning populations above 200 to around 1,000 were considered to warrant listing as threatened. However, these criteria were not rigidly applied. In some cases total populations of 400-1,000 might be more realistic minimum populations needed for population stability and the level that should trigger an endangered listing. Wooley and Crateau (1983) estimated the size of the striped bass population in the upper Apalachicola River below JWLD to be approximately 2,000 in 1981. Of this total, only 860 were estimated to be Gulf race; the remainder were Atlantic. Their estimate did not include the portion of the ACF population above JWLD. Since that time no comparable estimate has been made, and no striped bass population estimate has been made in any other Gulf river.

In considering the above discussion, it should be kept in mind that the population dynamics of salmonid species are much different from those of striped bass. Furthermore, minimum population estimates must factor in the size of the watershed, genetic diversity in the stock, and stock history (Nehlsen et al. 1991). Decisions on conservation status also must take into account the nature and extent of various threats on a population and the probable benefits that may result from a particular conservation designation. Because Gulf race striped bass populations are likely close to or below levels needed to maintain viability and sustainability, it is recommended that assessments of conservation biology should be applied to striped bass populations in Gulf rivers to determine effective population sizes, minimum viable populations, and other factors relevant to sustainability. Based on these analyses, recommendations should be made as to whether the Gulf race as a whole or in selected rivers should be listed under the ESA.

8.5 River Specific Management Goals and Recommendations

The goals and recommendations contained in this section are specific to river systems within the native range of striped bass in the Gulf of Mexico region (Figure 8.1). The applicable general recommendations and more detailed recommendations that apply are listed for each river. Additional recommendations unique to the river system are also listed.

8.5.1 Lower Mississippi River

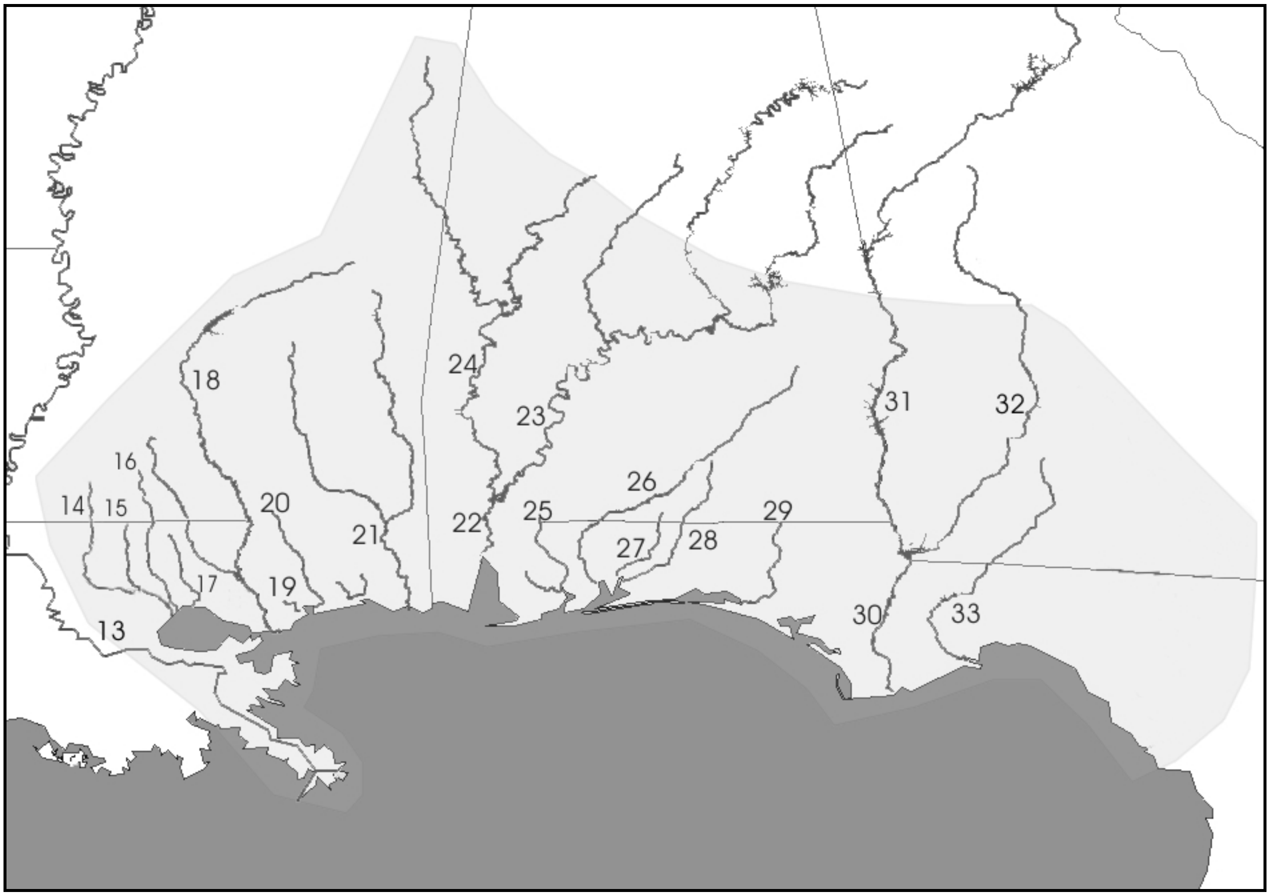
The river-specific goal for the lower Mississippi River (LMR) is to maintain a striped bass recreational fishery at an optimum yield level, based on available and enhanced habitat, that is supported by natural reproduction and escapement from upstream tributaries.

General management recommendations that apply to the LMR are indicated below as modified by more specific recommendations.

- Sale and/or Purchase (8.3.1.1)
- Bag Limits and Size Limits (8.3.1.2)
- Fishery-Independent Data (8.3.3.1)
  - Monitor abundance of YOY.
  - Monitor abundance of adult striped bass.
  - Determine the extent of escapement by striped bass from the river into the surrounding estuarine areas downstream of New Orleans through freshwater diversion projects and natural passages.
  - Determine the contribution of upstream escapement to the LMR striped bass population.
  - Determine the contribution of local natural reproduction to recruitment in the LMR striped bass population.
- Fishery-Dependent Data (8.3.3.2)
  - Conduct creel surveys that include striped bass.
- Habitat Management (8.3.4)
  - Advocate and support projects that improve habitat for striped bass in the Mississippi River and adjacent oxbow lakes.
- Enforcement (8.3.6).

8.5.2 Tangipahoa River

The river-specific goal for the Tangipahoa River is to maintain a Gulf race striped bass put-grow-take recreational fishery and develop a broodstock source.



13 Mississippi River
14 Amite River
15 Tickfaw River
16 Tangipahoa River
17 Tchefuncte River
18 Pearl River
19 Jourdan River
20 Wolf River
21 Pascagoula River
22 Mobile River
23 Alabama River
24 Tombigbee River
25 Perdido River
26 Escambia/Conecuh River
27 Blackwater River
28 Yellow River
29 Choctawhatchee River
30 Apalachicola River
31 Chattahoochee River
32 Flint River
33 Ochlockonee River

Figure 8.1 Rivers within the native range of Gulf race striped bass for which recommendations are made considering striped bass management.

General management recommendations that apply to the Tangipahoa River are indicated below as modified by more specific recommendations.

- Sale and/or Purchase (8.3.1.1)
- Bag Limits and Size Limits (8.3.1.2)
- Stocking (8.3.2.1)
  - Stock at least 7,000 and up to 25,000 Phase II genetically diverse Gulf race striped bass annually.
- Genetic Diversity (8.3.2.2)
- Genetic Integrity (8.3.2.3)
- Evaluation of Stocking Success (8.3.2.4)
- Fishery-Independent Data (8.3.3.1)
- Fishery-Dependent Data (8.3.3.2)

- Comprehensive Habitat Assessment (8.3.4.2)
  - Evaluate water quality and tissue burdens of contaminants in introduced striped bass populations.
- Riverine Habitat Integrity (8.3.4.5)
- Enforcement 8.3.6

8.5.3 Tchefuncte River

The river-specific goal for the Tchefuncte River is to maintain a Gulf race striped bass put-grow-take recreational fishery and develop a broodstock source.

General management recommendations that apply to the Tchefuncte River are indicated below as modified by more specific recommendations.

- Sale and/or Purchase (8.3.1.1)
- Bag Limits and Size Limits (8.3.1.2)
- Stocking (8.3.2.1)
  - Stock at least 7,000 and up to 25,000 Phase II genetically diverse Gulf race striped bass annually.
- Genetic Diversity (8.3.2.2)
- Genetic Integrity (8.3.2.3)
- Evaluation of Stocking Success (8.3.2.4)
- Fishery Independent Data (8.3.3.1)
- Fishery Dependent Data (8.3.3.2)
- Comprehensive Habitat Assessment (8.3.4.2)
  - Evaluate water quality and tissue burdens of contaminants in introduced striped bass populations.
- Riverine Habitat Integrity (8.3.4.5)
- Enforcement (8.3.6)

8.5.4 Pearl River

The river-specific goals for the Pearl River are to: 1) maintain a put-grow-take Gulf race recreational fishery and 2) develop a Gulf race broodstock source in the Ross Barnett Reservoir in the short term; and 3) establish a self-sustaining population of Gulf race striped bass that can support a recreational fishery at an optimum yield level consistent with the carrying capacity of available, restored, and enhanced habitat in the long term.

General management recommendations that apply to the Pearl River are indicated below as modified by more specific recommendations.

- Sale and/or Purchase (8.3.1.1)
- Bag Limits and Size Limits (8.3.1.2)
- Other Harvest Regulations (8.3.1.3)
- Stocking (8.3.2.1)
  - Stock at least 14,000 and up to 50,000 Phase II genetically diverse Gulf race

striped bass annually into the river.
    - Stock at least 100,000 and up to 300,000 Phase I or at least 20,000 to 60,000 Phase II genetically diverse Gulf race striped bass annually into the Ross Barnett Reservoir.
- Genetic Diversity (8.3.2.2)
- Genetic Integrity (8.3.2.3)
- Evaluation of Stocking Success (8.3.2.4)
- Fishery-Independent Data (8.3.3.1)
- Fishery-Dependent Data (8.3.3.2)
- Critical Habitat Identification (8.3.4.1)
    - Evaluate the potential of Pushepatapa Creek, Washington Parish, Louisiana, as thermal refuge.
- Comprehensive Habitat Assessment (8.3.4.2)
    - Determine the impacts of sand and gravel dredging operations on striped bass populations.
- Critical Habitat Management (8.3.4.3)
- Migration and Movement (8.3.4.4)
    - Remove or modify low-water sills near Bogalusa, Louisiana, to allow for fish passage.
    - Discourage construction of additional dams on the Pearl River and its major tributaries.
- Riverine Habitat Integrity (8.3.4.5)
    - Discourage future channel dredging within the Pearl River and its major tributaries.
    - Investigate the effects on striped bass of maintaining historic flows in the East Pearl River and take appropriate action to restore flows if warranted.
- Population and Habitat Modeling (8.3.5)
- Enforcement (8.3.6)

8.5.5 Wolf and Jourdan Rivers (St. Louis Bay Drainage)

The river-specific goal for the Wolf and Jourdan rivers is to maintain striped bass put-grow-take recreational fisheries.

General management recommendations that apply to the Wolf and Jourdan rivers are indicated below as modified by more specific recommendations.

- Sale and/or Purchase (8.3.1.1)
- Bag Limits and Size Limits (8.3.1.2)
- Stocking (8.3.2.1)
    - Stock at least 7,000 and up to 25,000 Phase II striped bass annually per river.
- Evaluation of Stocking Success (8.3.2.4)
- Fishery Independent Data (8.3.3.1)
- Fishery Dependent Data (8.3.3.2)
- Enforcement (8.3.6)

8.5.6 Biloxi and Tchoutacabouffa Rivers and Old Fort Bayou (Biloxi Bay Drainage)

The river-specific goal for the Biloxi and Tchoutacabouffa rivers and Old Fort Bayou is to maintain striped bass put-grow-take recreational fisheries.

General management recommendations that apply to the Biloxi and Tchoutacabouffa rivers and Old Fort Bayou are indicated below as modified by more specific recommendations.

- Sale and/or Purchase (8.3.1.1)
- Bag Limits and Size Limits (8.3.1.2)
- Stocking (8.3.2.1)
    - Stock at least 7,000 and up to 25,000 Phase II striped bass annually per river.
- Evaluation of Stocking Success (8.3.2.4)
- Fishery Independent Data (8.3.3.1)
- Fishery Dependent Data (8.3.3.2)
- Enforcement (8.3.6)

8.5.7 Pascagoula River

The river-specific goals for the Pascagoula River are to: 1) maintain a put-grow-take Gulf race recreational fishery in the short term and 2) establish a self-sustaining population of Gulf race striped bass that can support a recreational fishery at an optimum yield level consistent with the carrying capacity of available, restored, and enhanced habitat in the long term.

General management recommendations that apply to the Pascagoula River are indicated below as modified by more specific recommendations.

- Sale and/or Purchase (8.3.1.1)
- Bag Limits and Size Limits (8.3.1.2)
- Other Harvest Regulations (8.3.1.3)
    - Close Bluff Creek and Cedar Creek thermal refuges to fishing during May through September.
    - Consider prohibiting the use of live bait on trotlines and limblines during February through May to minimize bycatch and hooking mortality of striped bass.
- Stocking (8.3.2.1)
    - Stock at least 100,000 Phase I and 50,000 Phase II genetically-diverse Gulf race striped bass annually into the river.
- Genetic Diversity (8.3.2.2)
- Genetic Integrity (8.3.2.3)
- Evaluation of Stocking Success (8.3.2.4)
- Fishery-Independent Data (8.3.3.1)
- Fishery-Dependent Data (8.3.3.2)
- Critical Habitat Identification (8.3.4.1)
- Comprehensive Habitat Assessment (8.3.4.2)
    - Evaluate groundwater withdrawal in and around the Cedar Creek refuge.

- Critical Habitat Management (8.3.4.3)
- Riverine Habitat Integrity (8.3.4.5)
  - Support efforts to maintain the free-flowing nature of the Pascagoula River and its major tributaries.
- Population and Habitat Modeling (8.3.5)
- Enforcement (8.3.6)

8.5.8 Mobile-Alabama-Tombigbee (MAT) Rivers System

The river-specific goals for the MAT rivers system are to: 1) maintain a striped bass recreational fishery at an optimum yield level that is supported by natural reproduction and escapement from upstream waters and supplemental stocking of Gulf race striped bass, 2) maintain Gulf race striped bass broodstock sources in Lewis Smith Lake and Lake Martin in the short term, and (3) establish a self-sustaining population of Gulf race striped bass that can support a recreational fishery at an optimum yield level consistent with the carrying capacity of available, restored, and enhanced habitat in the Tallapoosa River between R.L. Harris Dam and Lake Martin in the long term.

There is a reproducing population of what are probably Atlantic race striped bass in the Coosa River. In addition, there is a direct connection between the Tombigbee and Tennessee rivers (Mississippi River drainage) through the Tennessee-Tombigbee Waterway. In both of these instances Atlantic race striped bass are able to move downstream through locks and dams to the lower portions of the MAT, thus producing a mixture of Atlantic and Gulf race striped bass in most of the system. The only exception may be the portion of the Tallapoosa River between R.L. Harris Dam and Lake Martin, which may contain only Gulf race striped bass. If suitable minimum continuous flows through R.L. Harris Dam can be obtained in the future, it may be possible to obtain limited striped bass spawning and recruitment in that reach of the river. That is the only portion of the MAT system where consideration should be given to efforts to establish a self-sustaining population and fishery for Gulf race striped bass. Further genetics investigation should be conducted on the reproducing population in the Coosa River to confirm genetic identity. Depending on the results of this investigation, the goals for this system may warrant revision in the future.

General management recommendations that apply to the MAT rivers system are indicated below as modified by more specific recommendations.

- Sale and/or Purchase (8.3.1.1)
- Bag Limits and Size Limits (8.3.1.2)
- Other Harvest Regulations (8.3.1.3)
- Stocking (8.3.2.1)
  - Stock at least 450,000 and up to 550,000 Phase I Gulf race striped bass in reservoirs and riverine portions of the MAT annually.
- Genetic Diversity (8.3.2.2)
- Genetic Integrity (8.3.2.3)
- Evaluation of Stocking Success (8.3.2.4)
- Fishery-Independent Data (8.3.3.1)

- Fishery-Dependent Data (8.3.3.2)
  - Verify genetic identity of striped bass spawning in the Coosa River system.
- Critical Habitat Identification (8.3.4.1)
  - Evaluate Hastie Lake as a potential thermal refuge on the Tensaw River.
- Comprehensive Habitat Assessment (8.3.4.2)
- Critical Habitat Management (8.3.4.3)
  - Seek minimum continuous flows in the reach of the Tallapoosa River between R.L. Harris Dam and Lake Martin that would be suitable to support striped bass spawning and recruitment.
- Migration and Movement (8.3.4.4)
- Riverine Habitat Integrity (8.3.4.5)
- Population and Habitat Modeling (8.3.5)
- Enforcement (8.3.6)

8.5.9 Perdido River

The river-specific goal for the Perdido River is to maintain a Gulf race striped bass put-grow-take recreational fishery.

General management recommendations that apply to the Perdido River are indicated below as modified by more specific recommendations.

- Sale and/or Purchase (8.3.1.1)
- Bag Limits and Size Limits (8.3.1.2)
- Stocking (8.3.2.1)
  - Stock at least 50,000 and up to 100,000 Phase I Gulf race striped bass annually.
- Evaluation of Stocking Success (8.3.2.4)
- Fishery-Independent Data (8.3.3.1)
- Fishery-Dependent Data (8.3.3.2)
- Enforcement (8.3.6)

8.5.10 Escambia/Conecuh River

The river-specific goals for the Escambia/Conecuh River are to: 1) maintain a put-grow-take Gulf race recreational fishery in the short term and 2) establish a self-sustaining population of Gulf race striped bass that can support a recreational fishery at an optimum yield level consistent with the carrying capacity of available, restored, and enhanced habitat in the long term.

General management recommendations that apply to the Escambia/Conecuh River are indicated below as modified by more specific recommendations.

- Sale and/or Purchase (8.3.1.1)
- Bag Limits and Size Limits (8.3.1.2)
- Other Harvest Regulations (8.3.1.3)
- Stocking (8.3.2.1)

    - Stock at least 100,000 and up to 400,000 Phase I genetically diverse Gulf race striped bass annually into the river.
- Genetic Diversity (8.3.2.2)
- Genetic Integrity (8.3.2.3)
- Evaluation of Stocking Success (8.3.2.4)
- Fishery-Independent Data (8.3.3.1)
- Fishery-Dependent Data (8.3.3.2)
- Critical Habitat Identification (8.3.4.1)
- Comprehensive Habitat Assessment (8.3.4.2)
- Critical Habitat Management (8.3.4.3)
- Migration and Movement (8.3.4.4)
- Riverine Habitat Integrity (8.3.4.5)
- Population and Habitat Modeling (8.3.5)
- Enforcement (8.3.6)

8.5.11 Blackwater River

The river-specific goal for the Blackwater River is to maintain a Gulf race striped bass put-grow-take recreational fishery and broodstock source.

General management recommendations that apply to the Blackwater River are indicated below as modified by more specific recommendations.

- Sale and/or Purchase (8.3.1.1)
- Bag Limits and Size Limits (8.3.1.2)
- Stocking (8.3.2.1)
    - Stock at least 50,000 Phase I genetically diverse Gulf race striped bass annually.
- Genetic Diversity (8.3.2.2)
- Genetic Integrity (8.3.2.3)
- Evaluation of Stocking Success (8.3.2.4)
- Fishery-Independent Data (8.3.3.1)
- Fishery-Dependent Data (8.3.3.2)
- Critical Habitat Management (8.3.4.3)
- Enforcement (8.3.6)

8.5.12 Yellow River

The river-specific goal for the Yellow River is to maintain a Gulf race striped bass put-grow-take recreational fishery and broodstock source.

General management recommendations that apply to the Yellow River are indicated below as modified by more specific recommendations.

- Sale and/or Purchase (8.3.1.1)
- Bag Limits and Size Limits (8.3.1.2)
- Stocking (8.3.2.1)

    - Stock at least 50,000 Phase I genetically diverse Gulf race striped bass annually.
- Genetic Diversity (8.3.2.2)
- Genetic Integrity (8.3.2.3)
- Evaluation of Stocking Success (8.3.2.4)
- Fishery-Independent Data (8.3.3.1)
- Fishery-Dependent Data (8.3.3.2)
- Critical Habitat Management (8.3.4.3)
- Enforcement (8.3.6)

8.5.13 Choctawhatchee River

The river-specific goals for the Choctawhatchee River are to: 1) maintain a put-grow-take Gulf race recreational fishery in the short term and 2) establish a self-sustaining population of Gulf race striped bass that can support a recreational fishery at an optimum yield level consistent with the carrying capacity of available, restored, and enhanced habitat in the long term.

General management recommendations that apply to the Choctawhatchee River are indicated below as modified by more specific recommendations.

- Sale and/or Purchase (8.3.1.1)
- Bag Limits and Size Limits (8.3.1.2)
- Other Harvest Regulations (8.3.1.3)
- Stocking (8.3.2.1)
    - Stock at least 100,000 and up to 400,000 Phase I genetically diverse Gulf race striped bass annually.
- Genetic Diversity (8.3.2.2)
- Genetic Integrity (8.3.2.3)
- Evaluation of Stocking Success (8.3.2.4)
- Fishery-Independent Data (8.3.3.1)
- Fishery-Dependent Data (8.3.3.2)
- Critical Habitat Identification (8.3.4.1)
- Comprehensive Habitat Assessment (8.3.4.2)
- Critical Habitat Management (8.3.4.3)
- Riverine Habitat Integrity (8.3.4.5)
- Population and Habitat Modeling (8.3.5)
- Enforcement (8.3.6)

8.5.14 Apalachicola-Chattahoochee-Flint Rivers System

Restore and maintain a population of native Gulf race striped bass in the Apalachicola-Chattahoochee-Flint River system leading to a self-sustaining population that will: 1) provide a broodfish source for the ACF and other Gulf state restoration programs, 2) support recreational fishing opportunities at optimum yield levels consistent with the carrying capacity of available, restored, and enhanced habitat, and 3) maximize natural reproduction and recruitment of Gulf race striped bass into the reproducing population.

The river-specific goal for the ACF and the general recommendations below are (in part) adapted from the *ACF Striped Bass Restoration and Evaluation Five Year Plan* (ACF Plan) as revised May 21, 2004 and adopted December 21, 2004 (ACF Technical Committee 2004). As the five-year plan is subject to revision at a more frequent interval than this FMP, refer to the most recent version of the five-year plan for the most up-to-date action items.

- Sale and/or Purchase (8.3.1.1)
- Bag Limits and Size Limits (8.3.1.2)
    - In 2007, evaluate management strategies (e.g., closed seasons, length limits, bag limits, etc.) for the striped bass fishery on the ACF (Task 3.3 ACF Plan).
- Other Harvest Regulations (8.3.1.3)
- Stocking (8.3.2.1)
    - Review, and modify as necessary, stocking strategies for the ACF at the annual *Morone* Workshops (Task 1.3 ACF Plan).
    - Continue to use Smith Lake, Alabama, and Lake Talquin, Florida, as broodstock repositories for the ACF (Task 1.4 ACF Plan).
    - In 2005, compile a database of all striped bass and hybrids stocked into the ACF and update annually (Task 1.5 ACF Plan).
    - Continue to evaluate harvest and handling techniques that may reduce stress or injury to fingerlings (Task 1.6 ACF Plan).
    - Annually produce and stock striped bass in accordance with Objectives 1.0 and 2.0 of the ACF Plan (Task 2.2 ACF Plan). This will generally entail stocking of 850,000-1,250,000 Phase I and 70,000-175,000 Phase II genetically-diverse Gulf race striped bass annually into the system.
    - Annually ensure that fry and fingerling production capacities at the primary state and federal hatcheries are not diminished (Task 2.3 ACF Plan).
- Genetic Diversity (8.3.2.2)
    - Collect 15-25 female broodfish and sufficient males from the ACF annually and transport them to federal and state hatcheries for artificial propagation; if available, ACF lineage broodfish may also be used from Lake Talquin, Florida; Blackwater River, Florida; Smith Lake, Alabama; Ross Barnett Lake, Mississippi; and other reliable sources (Task 2.1 ACF Plan).
    - Continue to collect mtDNA and nDNA microsatellite genetic data from broodfish and continue to evaluate the need for cataloging genetic information (Task 1.7 ACF Plan).
    - Conduct genetic analysis of broodfish annually to document genetic composition of progeny used for stocking (Task 2.4 ACF Plan).
- Genetic Integrity (8.3.2.3)
    - In 2005, fund an assessment of all genetics and meristics data to date that address conservation management of the Gulf race striped bass and the need for any additional data (Task 4.8 ACF Plan).
    - Annually record LLSC (or other meristics) from as many ACF striped bass as possible and minimally from all fish that have had otoliths removed (Task 4.9 ACF Plan).
- Evaluation of Stocking Success (8.3.2.4)
    - Continue marking Phase I fingerlings with oxytetracycline (OTC) so that released fish may be identified and numbers of known stocked fish may be compared with

numbers of wild (unmarked) fish during annual YOY sampling (Task 1.1 ACF Plan).

- By 2008, complete the Phase II evaluation study to determine the relative contribution of Phase I and Phase II stocked fish to the broodstock source (Task 1.2 ACF Plan).
- Annually conduct a 48-hour post stocking survival evaluation of stocked striped bass by holding a subset of acclimated fish in receiving waters; develop a study design to evaluate Phase II post-stocking survival (Task 4.1 ACF Plan).
- Annually monitor the relative survival of Phase II fingerlings marked with decimal coded wire tags; remove coded wire tags from all fish collected in order to evaluate relative stocking location success and the need for continued Phase II stocking (Task 4.4 ACF Plan).
- By 2009, complete an analysis of survival of Phase II fish and the proportion that enter the broodstock (Task 4.11 ACF Plan).

▪ Fishery-Independent Data (8.3.3.1)
  - Annually during the fall, monitor relative abundance of YOY striped bass in Lake Seminole using standardized electrofishing; sample standard stations on sand habitat at night for ten minutes per site; calculate relative abundance value for each year class (Task 4.2 ACF Plan).
  - Annually during the fall, monitor growth, condition, and abundance of age-1 and older striped bass using standardized experimental gill nets in Lake Seminole; set gill nets at fixed sampling locations prior to nightfall and fish overnight; remove nets from the water the following morning; determine length-frequency distribution, coefficients of condition or relative weight, and CPUE (Task 4.3 ACF Plan).
  - Annually remove otoliths and fin clips from a subsample of fish collected under Tasks 4.2, 4.3, and 4.4 (ACF Plan); analyze otoliths for OTC marks and determine age of fish; calculate percent composition of stocked (marked) and wild (unmarked) fish to estimate the relative contribution of each year class; take fin clips according to standard procedures and store for potential future analyses (Task 4.5 ACF Plan).
  - Collect striped bass broodstock by electrofishing from the ACF each spring; determine average CPUE (f/h) of adult (>18 in TL) fish for each sampling effort over the course of the broodfish season to evaluate relative abundance of adult fish and year class contribution to the reproductive population; starting in spring 2005, provide additional labor in order to collect and check smaller fish for any tags that normally are not assessed during broodfish season (Task 4.6 ACF Plan).
  - In 2005 and 2006, evaluate relative condition of age-1 and age-2 fish to develop a trend analysis to determine if additional assessments of stocking location, habitat availability, or forage resources are needed (Task 4.7 ACF Plan).

▪ Fishery-Dependent Data (8.3.3.2)
  - Conduct a standardized creel census survey through 2008 below the JWLD and the upper Apalachicola River and provide creel clerks with equipment to check fish for coded wire tags (Task 3.1 ACF Plan).
  - In 2006, reevaluate the need for creel census surveys on the lower Apalachicola River and other locations in the ACF (Task 3.2 ACF Plan).
  - In 2006, mark 10% of Phase II striped bass released into the ACF with external tags identifiable by anglers (e.g., internal anchor tags) (Task 3.4 ACF Plan).
  - By 2005, initiate a program with anglers and local bait shops/marinas/fish camps to

provide a depository for striped bass heads to be checked for coded wire tags (Task 3.5 ACF Plan).

- Critical Habitat Identification (8.3.4.1)
  - By 2006, complete a GIS database on all known coolwater refuges in the ACF river system (Task 5.1 ACF Plan).
- Comprehensive Habitat Assessment (8.3.4.2)
  - By 2006, complete a study plan to evaluate the contaminant levels in striped bass populations, implement the plan by 2007, and determine by 2008 the need for a long-term monitoring plan (Task 5.5 ACF Plan).
- Critical Habitat Management (8.3.4.3)
  - By 2008, develop a strategy that protects important coolwater refuges in the ACF river system (Task 5.2 ACF Plan).
  - Conduct four projects by 2009 with the COE or other partners to maintain and restore/enhance/rehabilitate coolwater refuges in the ACF river system (Task 5.3 ACF Plan).
  - Participate in the COE operations planning that may benefit or affect striped bass (Task 5.4 ACF Plan).
- Migration and Movement (8.3.4.4)
  - By 2005, initiate research to determine suitability of using the JWLD for fish passage; by 2006, make recommendations to the COE regarding usage of the locks for passage of striped bass and other species (Task 5.6 ACF Plan).
  - Work with partners to achieve fish passage at dams in the Flint River system (Task 5.7 ACF Plan).
- Riverine Habitat Integrity (8.3.4.5)
- Population and Habitat Modeling (8.3.5)
  - By 2008, use existing and historic data to prepare a stock assessment and population model for the ACF population of striped bass; identify significant data gaps (Task 4.10 ACF Plan).
- Enforcement (8.3.6)
- Other Recommendations
  - Annually provide information about conservation efforts to the public through brochures, formal programs, and news releases (Task 6.1 ACF Plan).
  - Send a reward to anglers when tagged fish are reported (Task 6.2 ACF Plan).
  - By 2008, identify two partnerships with anglers, local governments, and/or the private sector to help achieve the objectives of the ACF five-year plan (Task 6.3 ACF Plan).
  - In 2005, complete a summary of the previous 20 years of conservation and partnership successes to be distributed via flyer to anglers, conservation groups, and the general public via an internet site and partners' links via area-wide news releases, and via PowerPoint presentations (Task 6.4 ACF Plan).
  - Annually sponsor the ACF Morone Workshop for the partners and others to share information about striped bass and the objectives and tasks in this plan (Task 6.5 ACF Plan).

8.5.15 Ochlockonee River

The river-specific goal for the Ochlockonee River is to maintain a Gulf race striped bass put-grow-take recreational fishery and maintain a Gulf race striped bass broodstock source in Lake Talquin.

General management recommendations that apply to the Ochlockonee River are indicated below as modified by more specific recommendations.

- Sale and/or Purchase (8.3.1.1)
- Bag Limits and Size Limits (8.3.1.2)
- Stocking (8.3.2.1)
  - Stock up to 100,000 Phase I genetically-diverse Gulf race striped bass annually into Lake Talquin.
- Genetic Diversity (8.3.2.2)
- Genetic Integrity (8.3.2.3)
- Evaluation of Stocking Success (8.3.2.4)
- Fishery-Independent Data (8.3.3.1)
- Fishery-Dependent Data (8.3.3.2)
- Enforcement (8.3.6)

9.0 REGIONAL RESEARCH PRIORITIES AND DATA REQUIREMENTS

Research and data needs of the Gulf striped bass fishery encompass a wide range of biological, social, and environmental studies. Additional research and data collection programs are needed, and the following is a partial list of some of the more important needs. They are not prioritized or ranked in any way.

9.1 Biological/Ecological

- Investigate the various anecdotally-observed biological/physiological differences between Gulf and Atlantic races of striped bass (i.e., egg buoyancy, size at hatching, yolk sac absorption rates, age at first feeding, and color of stripes on adults). Determine the heritability of these features and assess their status in the current ACF striped bass population. Investigate whether any of these features are associated with specific genetic markers.
- Formally assess whether the Gulf race of striped bass constitutes a Distinct Population Segment as defined under the Endangered Species Act (ESA).
- Determine whether the Gulf race of striped bass constitutes an Evolutionarily Significant Unit as used for determining need for listing under the ESA.
- Determine whether the Gulf race of striped bass should be considered a separate taxon (i.e., species or subspecies) from other populations.
- Determine nDNA genotypes of striped bass reproducing in the Coosa River.
- Determine nDNA genotypes of striped bass reproducing in the ACF system.
- Develop technical definitions for Gulf race striped bass populations and individuals, using morphological characteristics or genetics or a combination of both.
- Determine important predators of striped bass in Gulf of Mexico rivers and their importance in terms of affecting striped bass populations.
- Determine the relative contributions of downstream escapement from tributaries and local natural reproduction to recruitment into the lower Mississippi River striped bass population.
- Determine the significance of the differences observed in levels of introgression by Atlantic striped bass population alleles into the ACF population as indicated by current mtDNA and nDNA analyses.
- Analyze and monitor additional nDNA markers in the ACF and other Gulf striped bass populations as appropriate and conduct additional genetic statistical analyses as appropriate.
- Determine minimum viable population size for Gulf striped bass.
- Determine and monitor effective population size of striped bass populations in rivers where self-sustaining populations is a goal.
- Determine what factors are enabling striped bass to successfully spawn in the upper Coosa River system as compared to river systems within the Gulf race striped bass' native range where spawning is less successful.
- Determine the forage base for Phase I and Phase II striped bass fingerlings in specific rivers in order to evaluate stocking sites and the subsequent survival of stocked fish.
- Conduct aging studies on striped bass using otoliths in all of the Gulf river systems.
- Determine whether Atlantic origin striped bass are escaping Lake Lanier and contributing to the population/natural reproduction in the Chattahoochee River/West Point Reservoir.

- Determine the feasibility of a genetics restoration propagation program for the ACF using current genetics information.

9.2 Habitat

- Determine effects of water withdrawal on aquifers and the flow of springs important as striped bass thermal refuge habitat in Gulf rivers.
- Evaluate the effects water control structures (i.e., locks and dams) have on striped bass in rivers of the northern Gulf of Mexico and the potential effects of their removal or implementation of fish passage measures.
- Delineate the characteristics of specific thermal refuges for striped bass (i.e., time of entry, carrying capacities, etc).
- Investigate the feasibility of creation or expansion of thermal refuge habitat.
- Determine the effects of riparian habitat along rivers (canopy cover, water flow, land use patterns, etc.) on refuge quality (water volume, temperature, dissolved oxygen).
- Determine locations of the most suitable spawning habitat sites in Gulf rivers where maintenance of self-sustaining striped bass populations are goals.
- In rivers where maintenance of self-sustaining striped bass populations are goals, determine locations of striped bass critical habitats and determine priorities among them based on suitability for protection and/or enhancement actions.
- Investigate the effects of pine silviculture activities on aquifers that support springs providing or potentially providing critical thermal refuge habitat for striped bass.

9.3 Fisheries Related

- Determine fishing mortality in relation to total mortality for striped bass in rivers where restoration of self-sustaining populations is a goal.
- Assess the impacts static fishing gear (i.e., trotlines, limblines, and hoopnets) have on striped bass populations and on hook and line recreational fisheries for striped bass.
- Investigate the potential benefits and consequences of closing thermal refuges to fishing during the summer.

9.4 Economic/Social

- Investigate the social characteristics (age, race, ethnicity, education, income, etc.) of anglers targeting Gulf race striped bass in each river or system in which a viable fishery currently exists.
- Investigate the economic contribution by anglers targeting Gulf race striped bass in each river or system where a viable fishery currently exists.

10.0 REVIEW AND MONITORING OF THE PLAN

10.1 Review

The State-Federal Fisheries Management Committee of the Gulf States Marine Fisheries Commission will review, as needed, the status of the stock, condition of the fishery and habitat, the effectiveness of management regulations, and research efforts. Results of this review will be presented to the GSMFC for approval and recommendation to the management authorities in the Gulf States.

10.2 Monitoring

The GSMFC, the USFWS, the NMFS, states, and universities should document their efforts at plan implementation and review these with the S-FFMC.

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12.0 APPENDIX

12.1 Glossary

(Modified from Cowardin et al. 1979, Wetzel 1983, and Wallace et al. 1994)

A

Abundance - See relative abundance.

Acidic - Term applied to water with a pH below 6.6 and low in calcium.

Age Frequency or Age Structure - A breakdown of the different age groups or individuals in a population.

Alkaline or "Basic" - Term applied to water with a pH greater than 7.4.

Allele - One of two alternate forms of a gene that can have the same locus on homologous chromosomes and is responsible for alternative traits

Allozyme – An isozyme which differs from other variants of the enzyme as result of an allelic difference.

Alluvial - Increased sediment deposition at the junction of a tributary to its mainstem.

Anadromous - Fish that migrate from saltwater to fresh water to spawn.

Anchylosis – The consolidation of bones or their parts to form a single unit. The stiffening and immobility of a joint as the result of disease, trauma, surgery, or abnormal bone fusion.

Angler - A person catching fish or shellfish with no intent to sell and typically implies a recreational fishermen. This includes people releasing the catch.

Annual Mortality (A) - The percentage of fish dying in one year due to both fishing and natural causes.

Aquaculture - The raising of fish or shellfish under some controls, for either commercial sale or stock enhancement. Ponds, pens, tanks, or other containers may be used. Feed is often used. When used for stock enhancement the fish are usually released before harvest size is reached.

B

Bag Limit - The number and/or size of a species that a person can legally take in a day or trip. This may or may not be the same as a possession limit.

Benthic - Refers to animals and fish that live on or in the water bottom.

Biomass - The total weight or volume of a species in a given area.

Blackwater – Water rich in humic acids and with low nutrient concentrations.

Brackish - Marine and estuarine waters which mix at intermediate salinities ranging from 5-15 ppt.

Broodstock – A group of organisms which are set aside as the source for reproductive materials in propagation.

Bycatch - The harvest of fish or shellfish other than the species for which the fishing gear was set. Examples are blue crabs caught in shrimp trawls or sharks caught on a tuna longline. Bycatch is also often called incidental catch. Some bycatch is kept for sale.

C

Catadromous - A freshwater fish that goes into saltwater to spawn; ex. *Anguilla*

Catch - The total number or poundage of fish captured from an area over some period of time. This includes fish that are caught but released or discarded instead of being landed. The catch may take place in an area different from where the fish are landed. Note: Catch, harvest, and landings are different terms with different definitions.

Catch Per Unit of Effort (CPUE) - The number of fish caught by a specific amount of effort. Typically, effort is a combination of gear type, gear size, and length of time gear is used. Catch per unit of effort is often used as a measurement of relative abundance for a particular fish.

Charter Boat - A boat available for hire, normally by a group of people for a short period of time. A charter boat is usually hired by anglers.

Cohort - A group of fish spawned during a given period, usually within a year.

Commercial Fishery - A term related to the whole process of catching and marketing fish and shellfish for sale. It refers to and includes fisheries resources, fishermen, and related businesses directly or indirectly involved in harvesting, processing, or sales.

Condition - A mathematical measurement of the degree of plumpness or general health of a fish or group of fish.

Confidence Interval (CI) - The probability, based on statistics, that a number will be between an upper and lower limit.

Coefficient of Variation (CV) – A measure of the amount of variation within a population, calculated as the standard deviation (s) expressed as a percentage of the mean ($\bar{x}$); C. of V. = $s \times 100/\bar{x}$. .

D

Dam - A barrier on a river or stream resulting in the artificial creation of a lake or reservoir.

Deltaic - The process of sediment deposition due to the reduction of water velocity resulting in delta formation.

Demersal - Describes fish and animals that live near water bottoms. Examples are flounder and croaker.

Dendritic - "tree-like," branching greatly.

Directed Fishery - Fishing that is directed at a certain species or group of species. This applies to both sport fishing and commercial fishing.

Discharge - The volumetric measure of water passing a channel typically reported as a volume per unit of time.

Diurnal - Refers to a 24-hr cycle.

DNA - Deoxyribonucleic acid; the molecule is a double-stranded molecule held together by weak bonds between base pairs of nucleotides that encodes the genetic information of an organism.

Dysplasia - Abnormal growth or development of cells, tissue, bone, or an organ.

E

Effort - The amount of time and fishing power used to harvest fish. Fishing power includes gear size, boat size, and horsepower.

Emergent Vegetation - Erect, rooted, herbaceous plants that may be temporarily to permanently flooded at the base but do not tolerate prolonged inundation of the entire plant.

Endonuclease - Any of a group of enzymes that degrade DNA or RNA molecules by breaking linkages within the polynucleotide chains.

Epilimnion - The uppermost layer of water in a stratified lake consisting of warm, circulating, turbulent water which "floats" on a cooler, stable layer of water called the hypolimnion.

Essential Habitat - The habitats deemed critical to the survival and persistence of a species.

Estuarine - Water bodies consisting of deepwater habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land.

Euryhaline – Condition of or living in a wide range of salinities.

Exvessel - Refers to activities that occur when a commercial fishing boat lands or unloads a catch. For example, the price received by a captain for the catch is an exvessel price.

F

FMP - See fishery management plan.

Fall-line - The zone of demarcation between the coastal plain province and the interior provinces. It is generally identified by unconsolidated rock outcrops and rapids in streams crossing it.

Fecundity - A measurement of the egg-producing ability of a fish. Fecundity may change with the age and size of the fish.

Fishery - All the activities involved in catching a species of fish or group of species.

Fishery Dependent Data - Data collected on a fish or fishery from sport fishermen, commercial fishermen, and seafood dealers.

Fishery Independent Data - Data collected on a fish by scientists who catch the fish themselves, rather than depending on fishermen and seafood dealers.

Fishery Management Plan (FMP) - A plan to achieve specified management goals for a fishery. It includes data, analyses, and management measures for a fishery.

Fishing Effort - See effort.

Floodplain - A flat expanse of land bordering a river which floods during high water periods.

Fork Length (FL) - The length of a fish as measured from the tip of its snout to the fork in the tail.

G

Genome - A full set of chromosomes; all the inheritable traits of an organism.

Genotype – A particular set of alleles at specified loci present in the genes of an organism that may determine the expression of a trait.

Gynogenesis – The process in which an egg develops parthenogenetically after the egg has been activated by sperm or pollen; pseudogamy.

H

Haplotype - A combination of alleles (for different genes) which are located closely together on the same chromosome and which tend to be inherited together.

Hardness - Total concentration of calcium and magnesium ions, expressed as the equivalent concentration (mg/L) of calcium carbonate.

Harvest - The total number or poundage of fish caught and kept from an area over a period of time. Note that landings, catch, and harvest are different.

Hatchery - A facility with the primary function of spawning, hatching, and rearing fish.

Head Boat - A fishing boat that takes recreational fishermen out for a fee per person. Different from a charter boat in that people on a head boat pay individual fees as opposed to renting the boat.

Hermaphroditism - The condition of being a hermaphrodite. An individual in which reproductive organs of both sexes are present.

Homostasis - The tendency of a system, especially the physiological system of higher animals, to maintain internal stability, owing to the coordinated response of its parts to any situation or stimulus tending to disturb its normal condition or function.

Hyperostosis - Abnormal development of bony tissue.

Hypolimnion - The lower layer of water in a stratified lake that is cooler and undisturbed relative to the upper layers.

I

Incidental Catch - See bycatch.

Isozyme - Any of a group of related enzymes that catalyze the same reaction but have different structural, chemical, or immunological characteristics.

J

Juvenile - A young fish or animal that has not reached sexual maturity.

L

Lacustrine - This system includes permanently flooded lakes and reservoirs, intermittent lakes, and tidal lakes with ocean-derived salinities below 0.5 ppt.

Landings - The number or poundage of fish unloaded at a dock by commercial fishermen or brought to shore by recreational fishermen for personal use. Landings are reported at the points at which fish are brought to shore. Note that landings, catch, and harvest define different things.

Landlocked – Those organisms that are confined to a fresh-water lake or section of river by reason of waterfalls or dams.

LC 50 – Lethal concentration, fifty percent; the concentration of a toxin or pollutant that kills half the organisms in a test population per unit time.

Length Frequency - A breakdown of the different lengths of individuals in a population or sample.

Lentic- That which is of or relating to or living in still waters (as lakes or ponds).

Limited Entry - A program that changes a common property resource like fish into private property for individual fishermen. License limitation and the ITQ are two forms of limited entry.

Littoral - All wetland habitats in a lacustrine system from the shoreline to a depth of 2 meters below low water or to the maximum extent of nonpersistent emergent vegetation.

Lock - Enclosure consisting of a section of canal that can be closed to control the water level on a river or stream; used to raise or lower vessels that pass through it.

Locus (Loci - Pl.) - The position on a chromosome of a gene or other chromosome marker. The use of locus is sometimes restricted to mean regions of DNA that are expressed.

Lotic – That which is of or in running water such as a stream or river.

M

mtDNA – Mitochondrial deoxyribonucleic acid; the genetic material found in mitochondria, the organelles that generate energy for the cell, which is inherited only from the mother.

Mariculture - The raising of marine finfish or shellfish under some controls. Ponds, pens, tanks, or other containers may be used, and feed is often used.

Mark-Recapture - The tagging and releasing of fish to be recaptured later in their life cycles. These studies are used to study fish movement, migration, mortality, growth, and to estimate population size.

Meristics – Physical characteristics (usually scale counts, spine counts, or fin ray counts) of fish in a population. Studies of meristics are often used to differentiate populations or races of fish.

Metalimnion – The zone of steep temperature gradient (thermocline) between the epilimnion and the hypolimnion in a lake.

Microsatellite - A short sequence of repeated nucleotides in a genome.

Morphometrics – Measurements of the physical features of fish, for example, body length to depth. Studies of morphometric differences are sometimes used to differentiate between fish populations.

N

nDNA – Nuclear deoxyribonucleic acid; genetic material found within the nucleus of the cell and inherited from either parent.

National Standards - The Fishery Conservation and Management Act requires that a fishery management plan and its regulations meet seven standards. The seven standards were developed to identify the nation's interest in fish management.

Natural Mortality (M) - A measurement of the rate of removal of fish from a population from natural causes. Natural mortality can be reported as either annual or instantaneous. Annual mortality is the percentage of fish dying in one year. Instantaneous mortality is and integral expression of the rate of mortality at a specific point in time. The rates of natural mortality may vary from species to species.

Navigational Mile (NM) – A Navigation Mile differs from **River Mile (RM)** in that it takes into account navigation improvements such as bend easing and navigational cutoffs.

Nucleotide - Any group of molecules that, when linked together, form the building blocks of DNA or RNA: composed of a phosphate group, the bases adenine, cytosine, guanosine, and thymine, and a pentose sugar, in RNA the thymine base being replaced by uracil.

O

Overfishing - Harvesting at a rate greater than which will meet the management goal.

P

Pelagic - Refers to fish and animals that live in the open sea, away from the sea bottom.

Physoclistic – Having the air bladder closed off from the mouth.

Physotomous – Physotomous fish possess a pneumatic duct that connects the gut and swimbladder throughout their entire life. Physotomes inflate their swimbladder by gulping surface air and forcing it through their pneumatic duct.

Polygamous – Pertaining to the condition in which a single male has many female mates at one time.

Polymorphism – The co-occurrence of several different forms.

Population - Fish of the same species inhabiting a specified area.

Possession Limit - The number and/or size of a species that a person can legally have at any one time. Refers to commercial and recreational fishermen. A possession limit generally does not apply to the wholesale market level and beyond.

Potadromous - Species that migrate within a river system or between lakes and rivers.

Primary Productivity - A measurement of plant production that is the start of the food chain. Much primary productivity in marine or aquatic systems is made up of phytoplankton that are tiny one-celled algae that float freely in the water.

Protogyny - Pertaining to a hermaphroditic organism that assumes a functional female condition first during development before changing to a functional male state.

R

Race - A taxonomic group that is below the level of subspecies. Races may develop as a consequence of geographical isolation of populations within a species. Racial differences may represent the beginning of species divergence.

Recreational Fishery - Harvesting fish for personal use, fun, and challenge. Recreational fishing does not include sale of catch. The term refers to and includes the fishery resources, fishermen, and businesses providing needed goods and services for fishing activities.

Recruit - An individual fish that has moved into a certain class, such as the spawning class or harvestable-size class.

Recruitment - A measure of the number of fish that enter a class during some time period, such as the spawning class or harvestable-size class.

Recruitment Overfishing - When fishing pressure is too heavy to allow a fish population to replace itself.

Relative Abundance - An index of population abundance used to compare a population from year to year. This does not measure the actual numbers of individuals but shows changes in the population over time.

Reservoir – An artificial water body resulting from a dam, sill, weir, or lock for the purpose of holding water for hydropower, controlling flow, or enhancing navigation.

Riparian - On, or pertaining to, the banks and other adjacent, terrestrial environments of freshwater bodies, watercourses, and surface-emergent aquifers.

Riverine - A system which includes all wetlands and deepwater habitats contained within a channel that does not exceed 0.5 ppt salinty; additional characteristics typically include flowing water and low tidal influence.

River Mile (RM) – A geographic location designation based on linear measurement of a stream starting at the mouth and proceeding upstream, calculated by planimetric measurements on the largest scale maps available (thus can change over time as natural meanders and oxbow lakes change the length of the stream). River Mile is <u>not</u> synonymous with **Navigational Mile**.

S

Scoliosis - An abnormal lateral curvature of the spine.

Size Distribution - A breakdown of the number of fish of various sizes in a sample or catch. The sizes can be in length or weight. This is most often shown on a chart.

Slot Limit - A limit on the size of fish that may be kept. Allows a harvester to keep fish under a minimum size and over a maximum size but not those in between the minimum and maximum. Can also refer to size limits that allow a harvester to keep only fish that fall between a minimum and maximum size.

Snag - A tree, or a branch of a tree, that is all of mostly submerged in a body of water.

Socioeconomics - A word used to identify the importance of factors other than biology in fishery management decisions. For example, if management results in more fishing income, it is important to know how the income is distributed between small and large boats or part-time and full-time fishermen.

Species - A group of similar organisms that can freely interbreed.

Spring - A natural flow of water coming from underground.

Stocking - The activity of adding fish to a body of water.

Stock - A grouping of fish usually based on genetic relationship, geographic distribution, and movement patterns. Also, a managed unit of fish.

Stock Enhancement – The stocking of fish into a water body to augment a population if natural recruitment is limited.

Strain - A group of individuals within a species are distinguished from similar groups. Sometimes used synonymously with race or stock. Often connotes a hatchery population. Distinction may or may not be based on actual differences between groups.

Submergent Vegetation - A rooted or non-rooted plant which lies entirely beneath the water's surface except for the flowering parts in some species.

T

Teratogenic – A drug or other substance capable of interfering with the development of a fetus, causing birth defects.

Thermal Niche – A range of temperatures within which a species' physiological processes or requirements are optimally suited and which it selects, if available in a gradient.

Thermal Refuge - An area in which the temperature requirements of an organism are met when ambient temperatures are outside the physiological tolerance limits or optimum range.

Turbidity - A measurement of the extent to which light passing through water is reduced due to suspended materials.

W

Weir - A low dam built across a stream to raise its level or divert its flow.

Y

Year-Class – A group of individuals in a population that were born or hatched in a given year; a "generation" of fish. This is often used synonymously with the term "cohort".

Young-of-the-Year (YOY) - A juvenile fish less than 1 year old.

12.2 Gulf Striped Bass Genetics Management Plan

12.2.1 Introduction

Striped bass, *Morone saxatilis*, is native to Gulf of Mexico (Gulf) rivers, with a historical range from the Florida Panhandle to Louisiana (Barkuloo 1970, Wooley and Crateau 1983). Striped bass in the Gulf region are riverine, as are other populations in the southern extent of the species' range, completing their life cycle generally without leaving rivers or estuaries to mature in the open ocean (Dudley et al. 1977). Striped bass along the Gulf coast require cool water thermal refuges to survive during hot summer months, and this critical habitat may be a limiting factor for populations in many Gulf coastal rivers.

Striped bass populations declined along the Gulf of Mexico during the 1950s and 1960s, most likely from anthropogenic influences including widespread use of pesticides and construction of dams. In many river systems, dams impeded migration to natural spawning grounds, shortened river-runs required for egg incubation, and blocked passage to thermal refuges. Within the Georgia portion of the Apalachicola-Chattahoochee-Flint river system (ACF), gill netting of striped bass was legal until 1966, which drastically reduced the striped bass population (Gennings 1970). It is accepted that reproducing populations were extirpated from all but the ACF in Florida, Georgia, and Alabama.

Raney and Woolcott (1955) reported that striped bass stocks along the Gulf are distinct from Atlantic coast stocks. Brown (1965) and Barkuloo (1970) described meristic characteristics of striped bass from the ACF and Alabama River (Gulf) which separated them from Atlantic race fish collected from the St. Johns (Florida), Cooper (South Carolina), Delaware (New Jersey), Hudson (New York), and St. Lawrence river systems, Lake Marion (South Carolina), Albemarle Sound (North Carolina), and Chesapeake Bay. Although there is probably ample evidence to support the determination, Gulf race striped bass are not recognized as a subspecies separate from Atlantic race fish, and are not listed as threatened or endangered by state or Federal conservation agencies.

Gulf coast state conservation agencies began striped bass stocking programs during the 1960s and 1970s to mitigate population declines and to introduce a pelagic species into man-made reservoirs that utilized overabundant forage species such as gizzard shad, (*Dorosoma cepedianum*) and threadfin shad (*D. petenense*). Broodfish sources of fry and fingerlings for stocking were of Atlantic origin, primarily from the Santee-Cooper river system, South Carolina, the Roanoke River, North Carolina, and the Chesapeake Bay system, Virginia and Maryland. Put-grow-and-take fisheries were created in many reservoirs and rivers, while self-sustaining populations were established in other systems. Atlantic origin (Santee-Cooper system) fry and fingerling introductions included the ACF. Atlantic race fingerlings were introduced into Lake Seminole, Florida-Georgia, in 1966 (60,000), 1968 (1,800), and 1974 (27,000), and into the Apalachicola River in 1976 (34,000, USFWS unpublished data). Approximately 1,750,000 Atlantic race fry were released into Lake Seminole from 1965 to 1968. A total of 1,000,000 four-day sac fry were released into a renovated 15.7 hectare nursery pond adjacent to the lake in 1968. Gill net and trammel net sampling during November 1968, prior to reconnecting the nursery pond with the lake, resulted in the collection of one 11.8-inch striped bass and numerous predator fish, indicating that survival was probably low (Pasch et al. 1973). In addition, approximately 131,000 fish, ranging in size from phase I fingerlings to large (11 kg) adults were released into Lake Blackshear, on the Flint River, between 1967 and 1972 (Pasch et al. 1973). A lack of striped bass in subsequent electrofishing, netting, and rotenone samples in the Flint River and in lakes Blackshear, Worth (Flint River) and Seminole, led Pasch et al. to conclude that stocked striped bass had failed to establish a population. Currently Lake Lanier, on the upper Chattahoochee River, is the only location on the ACF where Atlantic origin fish are stocked. Lake Lanier was established as a broodfish repository for depleted Savannah River stocks, and fingerlings are introduced annually. However, die to deep release of water from this reservoir, downstream escapement of striped bass is considered unlikely (R Ober personal communication).

Barkuloo (1967) described the striped bass fishery in the Apalachicola River as being limited to areas below Jim Woodruff Lock and Dam (JWLD), which forms Lake Seminole and the headwaters of the Apalachicola River, and the outfall of Dead Lake on the Chipola River, a tributary of the Apalachicola River, and the discharge of other tributary creeks. Creel surveys conducted during the peak spring fishing season on the Apalachicola River, in the tailrace of JWLD, from 1979 to 1981 resulted in estimates of harvested striped bass ranging from 152 (SE = 130) to 182 (SE = 60) over the span of the annual 14-week surveys (FWC unpublished data).

Wooley (1982) proposed adoption of the stock concept by Gulf Coast striped bass fisheries managers; however, he voiced concerns that insufficient attention was directed towards the impacts of introduced conspecifics on native Gulf populations and too much attention focused on the survival and harvest of stocked fish. During the early 1980s the population of striped bass greater than 381 mm total length in the Apalachicola River was estimated at 1,986 individuals (95% confidence interval = 1,288 – 2,711; Wooley and Crateau 1983). Conservatively using meristics described by Barkuloo (1970), Wooley and Crateau concluded that 43% of the population was comprised of Gulf race fish, 51% of Atlantic race fish, and 6% of intermediates. Using age data provided by Wooley and Crateau to partition the population estimate and assuming average sexual maturity of females at age-4, the potential broodfish population of Gulf striped bass in the upper Apalachicola River at that time could have been calculated as 384 fish (Long personal communication). Wooley and Crateau's population estimate did not include fish upstream of JWLD inhabiting Lake Seminole or the Flint and Chattahoochee rivers.

12.2.2 Initial Recovery Efforts

In 1980, biologists from the U.S. Fish and Wildlife Service (USFWS) collected striped bass broodfish from the Apalachicola River below JWLD and produced 100,000 fingerlings at Welaka National Fish Hatchery for restocking into the ACF. Strict guidelines using conservative lateral line scale counts (LLSC) above 65, as described by Barkuloo (1970), were utilized to provide the best assurance that broodfish were native Gulf race. Subsequent year classes were produced and released during 1983 (132,500 fingerlings) and 1984 (41,000 fingerlings). In 1985, striped bass stocking in the ACF was suspended for one year so that natural reproduction could be evaluated. Egg, larval, and fingerling sampling indicated that successful natural reproduction was most likely occurring in the Flint River, between Lake Seminole and Albany Dam, and that recruitment from egg to fingerling was probably very limited (Keefer 1986).

The extremely low number of broodfish, one to two wild females, used to produce each of the first three year classes raised concerns that inbreeding depression would result in loss of fitness of progeny. LLSC guidelines were relaxed in the late 1980s to include fish with scale counts of 63 or higher, which would provide reasonably high certainty that broodfish were Gulf race fish. LLSC guidelines were eventually suspended to insure maximum genetic variability of wild-caught broodfish.

In 1986, the Gulf States Marine Fisheries Commission (GSMFC) published a range-wide *Striped Bass Fishery Management Plan* for the Gulf of Mexico region (Nicholson et al. 1986), which called for restoration of striped bass in rivers across the northern Gulf of Mexico. In 1987, the USFWS and the states of Florida, Georgia, and Alabama established a Cooperative Agreement to "restore a self-sustaining stock of striped bass to the maximum extent possible" in the ACF. A technical advisory committee was organized to determine restoration needs and guide restoration efforts. The ACF Technical Committee developed the ACF Striped Bass Management Plan, which supported efforts to stock native striped bass throughout its historic range along the Gulf coast. The goal of the SBMP was to "restore the native Gulf striped bass within the Apalachicola-Chattahoochee-Flint river system." That goal was amended in 2004 to "restore and maintain a population of native Gulf race striped bass in the Apalachicola-Chattahoochee-Flint river system leading to a self-sustaining population that will: 1) provide a broodfish source for the ACF and other Gulf state restoration programs; 2) support recreational fishing opportunities at optimum yield levels consistent with the carrying capacity of available, restored, and enhanced habitat; and 3) maximize natural reproduction and recruitment of Gulf race striped bass into the reproducing population. To that extent, striped bass progeny of ACF river descent are restocked into the ACF on an annual basis. Non-self-sustaining Gulf striped bass broodfish populations, of ACF descent, have also been established in Lake Talquin and the Blackwater-Yellow river system, Florida, and Lewis Smith Lake, Alabama. Additionally, striped bass fingerlings of ACF descent have been released into the Choctawhatchee (FL), Escambia (FL), Tallapoosa (AL), Coosa (AL), Mobile-Alabama-Tombigbee (AL), Pascagoula (MS), Pearl (MS), Tchefuncte (LA), Tangipahoa (LA), Mississippi (LA), Bayou Teche (LA), Sabine (LA), Brazos (TX), and Colorado (TX) river systems.

12.2.3 Criteria For Identification And Characterization Of Gulf Striped Bass

12.2.3.1 General Characterization

The ACF Technical Committee has preliminarily defined the Gulf race striped bass as: 1) the populations of fish inhabiting the Apalachicola-Chattahoochee-Flint river system, except for the population found in Lake Lanier, Georgia; 2) populations derived exclusively from broodfish collected from the ACF river system, exclusive of Lake Lanier; 3) individual striped bass found in rivers outside the ACF system that exhibit a LLSC of at least 65 or higher; or 4) individual striped bass found in rivers outside the ACF system that exhibit mtDNA and nDNA markers that are considered unique to the ACF. Hatchery personnel often described the eggs of putative native Gulf striped bass as being much heavier than eggs of Atlantic (Santee-Cooper system and St. Johns River) origin fish (Dave Yeager, personal communication; Chuck Starling, personal communication), and have used this characteristic to differentiate between the two races. However, Barkuloo (personal communication) suggested that differences in egg density are related to stream gradient rather than racial origin. Bergey et al. (2003) described similar egg density variation among populations along the Atlantic coast, demonstrating that this characteristic may not be diagnostic in differentiating Gulf fish from all Atlantic fish. There is some indication that introduced Atlantic striped bass spawn earlier than native Gulf fish, which may serve to reproductively isolate the two populations to some extent where they coexist.

Waldman et al. (1988) provided a review of techniques used to discriminate striped bass stocks along the Atlantic and Gulf coasts. These techniques included differentiation based on meristic, morphometric, biochemical, and genetic applications. None of the techniques reviewed, or combinations thereof, have been unequivocal in discerning mixed stocks from the major spawning areas of the Atlantic Coast, but some techniques have been, or may be, useful in discriminating between Gulf and Atlantic races in mixed stocks along the Gulf coast.

12.2.3.2 Meristics

Brown (1965) and Barkuloo (1970) reported the range and average LLSC of Gulf striped bass collected from Alabama-Coosa-Tallapoosa, Alabama, and ACF river systems, respectively. Mean LLSCs of striped bass from these rivers were significantly different from those from the Atlantic Coast. More recent collections from the ACF indicated that the average LLSC has decreased, which may have resulted from introgression of Atlantic characteristics, environmental factors, or a combination of the two. Progeny of conservatively high (>65) LLSC broodfish spawned and reared at Welaka National Fish Hatchery in 1983 and 1984 (FWC unpublished data, USFWS unpublished data) had scale counts that ranged from 60 to 67 (mean = 64.0) and 60 to 71 (mean = 63.8), respectively (Table 12.1). LLSC of ACF striped bass collected by Barkuloo

Table 12.1 Lateral line scale counts of Gulf striped bass collected from the Apalachicola River (1957-62 R) by Barkuloo (1970) prior to any stocking, progeny of high scale count Gulf (Apalachicola River) striped bass broodfish spawned at Welaka National Fish Hatchery during 1983 and 1984 (1983 H, FWC unpublished data; 1984 H, USFWS unpublished data), and young-of-year striped bass collected from the Apalachicola River (1984 R, USFWS unpublished data) during 1984.

	Lateral Line Scale Count																
Sample	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	**Mean**	**N**
1957-62 R						4	11	15	13	12	11	10	9	3	1	66.7	87
1983 H			1	1	2	8	7	6	4	2						64.0	31
1984 H			1	8	20	14	17	17	12	5	1			1		63.8	96
1984 R	2	5	6	26	18	18	15	15	9	9	2	1				61.6	129

Barkuloo (1970) also found significant differences in soft dorsal ray counts, soft anal ray counts, pectoral ray counts, and a character index comprised of the sum of all counts, between (1970) from 1957 to 1962 ranged from 63 to 72 (mean = 66.7). LLSC is still the best physical characteristics for field identification of Gulf and Atlantic race fish. It may be desirable to reestablish acceptable LLSC values for identifying potential broodfish for restoration of native Gulf striped bass populations.fish from the Apalachicola River and most Atlantic populations reported by Raney and Woolcott (1955). Although these meristic counts are not unequivocal, they may be useful, combined with other techniques, in discriminating Gulf and Atlantic race fish.

12.2.3.3 Morphometrics

Lund (1957) used body depth, caudal peduncle depth, prepelvic distance, predorsal distance, and head length to differentiate four Chesapeake Bay populations from the James, York, Rappahannock, and Potomac rivers, Virginia, from that in the Hudson River, New York. Bayless (1972) provided morphometric measurements, including fork length/body depth, second anal spine length/third anal spine length, and head length/second anal spine length, which were descriptive of striped bass from the Santee-Cooper system, South Carolina, and other moronids (*Morone chrysops* and *M. americana*) and their hybrids. Barkuloo (1970) measured morphometric proportions of striped bass from the ACF similar to Lund (1957), but proportions similar to those provided by Bayless have not been reported.

Merriman (1941), Taub (1975), and Riley and Margraf (1983), cited in Waldman et al. (1988) used scale morphology to differentiate Atlantic coast stocks with varying degrees of success (Waldman et al. 1988). Scale morphology is not fixed and changes throughout the lifespan, limiting its use among mixed migratory Atlantic coastal stocks. The same limitations would likely apply to mixed Gulf and Atlantic race fish in Gulf coastal streams. However, Ross and Pickard (1990) and Humphreys et al. (1990) were able to discriminate hatchery-reared and wild striped bass using scale morphology with up to 95% accuracy in California and New York, respectively.

12.2.3.4 Genetic Characterization of Gulf Striped Bass

Morgan et al. (1973) examined juvenile and adult striped bass from five rivers in the upper Chesapeake Bay using discontinuous polyacrylamide gel electrophoresis and found five serum proteins that aided them in discerning populations from the Elk, Choptank, Nanticoke/Patuxent, and Potomac rivers. Using similar techniques, Sidell et al. (1980) examined 52 enzyme loci from liver samples of adult fish from six rivers in the upper Chesapeake Bay and the Chesapeake and Delaware Canal. They found only two polymorphisms and concluded that striped bass was one of the least genetically variable species of teleost fish. Sidell et al. (1980) also examined serum proteins and did not observe the serum transferrin polymorphisms reported by Morgan et al (1973). Their data suggested that river-specific populations do not occur in the middle and upper Chesapeake Bay. However, Sidell et al. (1980) did concede that while significant differences in gene frequencies at a small number of gene loci within the entire genome "allow confidence in predicting genetically separate breeding groups, the lack of differences does not form a sound basis for the alternative conclusion."

Rogier et al. (1985) used isozyme electrophoresis to assess genetic variation in landlocked spawning striped bass from the Dan and Roanoke rivers, tributaries of Kerr Reservoir, Virginia-North Carolina. They found only three of 56 scoreable protein loci that were polymorphic and estimated heterozygosity at 1.6%; results similar to those found by Otto (1975) and Grove et al. (1976, cited in Rogier et al. 1985) in their examinations of other Atlantic coast stocks. Rogier et al. also concluded that the low degree of electrophoretically detectable variation in protein loci may indicate low genetic diversity within the striped bass genome.

Fabrizio (1987a and 1987b) used isoelectric focusing of eye lens proteins and morphometric characters to correctly identify up to 90% of Hudson River and Chesapeake Bay-Roanoke River striped bass from the mixed-stock commercial fishery along the Atlantic Coast between New Jersey and Massachusetts. This technique, which measured relative abundance of eye lens proteins, is largely a phenotypic rather than a genetic approach to stock discrimination (Waldman et al. 1988).

Restriction endonuclease analysis of mitochondrial DNA (mtDNA) has been used more recently to differentiate populations and races of striped bass. Low levels of diversity have been observed in the base sequence of striped bass mtDNA, but there is considerable variability in the size of the mtDNA molecule (Waldman et al. 1988). Wirgin et al. (1990) found significant differences in frequencies of five major length variants useful in distinguishing between Hudson River and Chesapeake Bay populations, and between Chesapeake Bay and Roanoke River populations. Wirgin et al. (1990) also found minor length variants and base pair substitutions (restriction site polymorphisms), which allowed identification of ancestry of individual fish from the Chesapeake Bay and Roanoke River. They reported mtDNA sequence diversity ($p = 0.0004$) of striped bass as being among the lowest reported of any animal species. Stellwag et al. (1994) found additional restriction site polymorphisms among Roanoke River striped bass collected over a two-year period.

Mitochondrial DNA from wild striped bass from the 1985 ACF year class, along with wild broodfish with high LLSC, and hatchery reared descendents of wild broodfish was collected over a five-year period. The mtDNA was analyzed and compared with specimens collected from the St. Johns River, Florida, hatchery-reared individuals from the Santee-Cooper system (Moncks Corner Fish Hatchery, South Carolina), and approximately 200 fish from the Atlantic coastal migratory stock (Wirgin et al. 1989). Treatment with the restriction enzymes *Rsa* I and *Xba* I revealed base pair substitutions not observed in striped bass from Atlantic coast collections. Approximately 57% of 200 striped bass from the ACF exhibited an *Xba* I haplotype that was unique to the Gulf population. Four discrete mtDNA molecule length polymorphisms, differing by approximately 200, 300, and 400 base pairs, were also detected. The largest genotype was also unique to the ACF. Dunham et al. (1988) found similar differences between Gulf and Atlantic striped bass mtDNA.

Mitochondrial DNA from archived specimens, collected from the ACF prior to any introductions of Atlantic race fish, was also examined (Wirgin et al. 1997). No significant difference in the frequency of the unique *Xba* I haplotype between archived and extant fish from the ACF was observed, indicating that significant maternally derived introgression of Atlantic mtDNA genomes into the Gulf race in the ACF has not occurred. Additionally, no evidence of the unique Gulf genotype was observed in specimens from extant striped bass populations in Texas, Louisiana, and the Mississippi River, where Atlantic–origin fish have been stocked extensively.

Mitochondrial DNA is maternally inherited and is transmitted separately from nuclear DNA (nDNA), so that a fish exhibiting a unique Gulf mtDNA genotype may carry a considerable complement of Atlantic race nDNA (Wirgin et al. 1990). Nuclear DNA fingerprints of broodfish collected from three locations in the ACF during 1989 and 1990 were compared with nDNA fingerprints of striped bass from the Santee-Cooper system, Albemarle Sound and the Pamlico River, North Carolina, the Rappahannock and York rivers, and the Hudson River (Wirgin et al. 1991). Striped bass nDNA digested with single restriction enzymes and hybridized to two DNA fingerprinting probes generated DNA fragments shared by 71 of 75 ACF fish, but not observed in any of 51 Atlantic fish. Using polymerase chain reaction-restriction fragment length polymorphism assays to examine three anonymous single-copy nuclear loci, Diaz et al. (1997) also found significantly different allele frequencies between Gulf and Atlantic striped bass populations.

In contrast with earlier mtDNA studies, analysis of three nDNA microsatellite loci, diagnostic in distinguishing between Gulf and Atlantic race striped bass, demonstrated that introgression of Atlantic nDNA genomes has occurred (Wirgin et al. 2005). Using nDNA isolated from archived scale samples of ACF and St. Johns River striped bass, fixed differences in allelic identity were found at two loci and significant frequency differences at a third locus, demonstrating that the ACF population was historically distinct from its nearest Atlantic population. Significantly different allele frequencies at two other microsatellite loci were highly informative in distinguishing archived ACF fish from St. Mary's River (Florida-Georgia, Atlantic Coast) striped bass and from most extant Santee-Cooper system fish. However, significant allelic frequency differences were observed between archived and extant ACF samples at all three loci. The degree of introgression of Atlantic (Santee-Cooper system) alleles into the extant ACF population was estimated to be 0.515. Although these results suggest that significant introgression of Atlantic Coast alleles has occurred in striped bass from the ACF, the ACF population is still highly genetically distinct from those in all the Atlantic Coast rivers.

12.2.4 Genetic Risks In Stock Restoration and Augmentation

Recovery of populations, races, or species at risk should emphasize preserving and enhancing natural habitats so that self-sustaining populations can be recovered from wild stocks to the extent possible. Recovery of wild stocks via natural processes will always be preferable to artificial manipulation through propagation and augmentation.

Williamson and Wydoski (1994, and references therein) outlined three strategies that can be used in the recovery of depleted populations:

> "1. All Natural. Establish a refuge or genetic conservation area to manage a natural or naturalized population or stock without any kind of captive production or supplementation.

2. Supplementation. Rebuild natural spawning while minimizing genetic risks through captive propagation and supplemental stocking to augment declining populations or stocks or to restore extirpated populations or stocks.

3. All Captive-Reared. Maximize hatchery contribution to maintain populations with little or no expectation of restoring natural production."

Strategy 1 is the preferred course of action and strategy 3 is adopted as the last resort. Gulf striped bass restoration has relied almost exclusively on strategy 2.

Long-term conservation of populations, races, or species, if not based within a genetics framework, will likely fail (Kerby and Harrell 1990 citing Frankel and Soulé 1981). This genetic framework must consider total population size, effective population size, inbreeding, introgression, propagation and supplementation, genetic swamping, and artificial selection.

Population size is the most important factor in maintaining a high degree of genetic variation (Meffe 1986). A large total population, in itself, is not an assurance of a genetically effective population, since many individuals may be reproductively immature, senescent, or may contribute disproportionately to the next generation (Meffe 1986). Additionally, during spawning, many more gametes are produced and dispersed than actually become progeny, such that quantity and variety of alleles in the F1 generation is not an exact copy, but only a subsample, of the parental generation (Busak and Currens 1995). The principle of effective population size is used to model the number of individuals in the parent generation transferring genetic material to the progeny generation (St. Pierre et al. 1996). The effective population is almost always less than the total population because of an unbalanced sex ratio, unequal progeny distribution, or population fluctuation (Meffe 1986, Busak and Currens 1995). The effective population size is defined as "the size of an ideal population that would experience genetic drift and inbreeding at the same rate as the real population under consideration" (Czapla 1999). In small populations, such as Gulf striped bass, effective population size and genetic diversity can be increased or maintained by utilizing equal sex ratios among broodfish, equalizing the family size of random or pedigreed matings, and avoidance of directed selection (Williamson and Wydoski 1994).

Modde et al. (1995) suggested that if a natural population is larger than 250 individuals and is successfully reproducing and recruiting, that genetic variation should be sufficient to prevent inbreeding depression and a stocking program should not be initiated. Using the formula,

$$N_e = \frac{4(N_m \bullet N_f)}{(N_m + N_f)}$$

Ne = calculated effective population size for broodfish,
Nm = broodfish males, and
Nf = broodfish females (Falconer 1981 as cited in Meffe 1986, Kincaid 1995, Kincaid 1999);

they selected a threshold of 250 (equal males and females) individuals, assuming that an effective population size (N_e) is approximately 0.2 of a natural stock, so that a population of 250 would approximate an effective population size of 50 fish. Using the formula,

$$\Delta F = \frac{1}{2N_e}$$

ΔF = the calculated increase in inbreeding, and
N_e = the effective population size (Falconer 1981 cited in Meffe 1986, Kincaid 1995, Kincaid 1999);

an effective population of 50 results in an inbreeding rate of 1% per generation (Meffe 1986, Williamson and Wydoski 1994). Modde et al. (1995) added that if a population larger than 250 individuals is not recruiting, but maintains a locally adapted genetic stock, that augmentation should not be initiated unless genetic risk has been assessed and appropriate actions, such as habitat restoration needs, defined.

Utilizing the age data presented by Wooley and Crateau (1983), Long (personal communication) calculated that 384 adult striped bass in the Apalachicola River were of Gulf origin. Using the assumption proposed by Modde et al. (1995), Long determined the effective population size for Gulf race striped bass in the Apalachicola as approximately 77 fish at the time that Wooley and Crateau conducted their study. The calculated rate of inbreeding for an effective Gulf population of 77 fish equals 0.6% per generation, which is less than the value of 1% projected by Meffe (1986) and Williamson and Wydoski (1994) as being acceptable during the short term. The total and effective population sizes of native Gulf fish in the ACF are underestimated because of the unknown number of mature Gulf fish inhabiting waters upstream of JWLD.

In species that are long-lived or in which individuals spawn in multiple years, numerous year classes will contribute to the same progeny generation. The generation N_e is calculated as the sum of all males (N_m) and females (N_f) spawning each year for the number of years in the generation interval ($N_{e,GI}$) for the population (St. Pierre et al. 1996, Kincaid 1999). The generation N_e must be adjusted by any difference in sex ratio and by the number of individuals that spawn multiple times per generation (Kincaid 1999). The generational interval (GI) is the average age that females reach reproductive maturity (St. Pierre et al. 1996, Kincaid 1999). The generation N_e is the total number of spawners over the generation interval, and can be calculated as,

$$N_{e(GEN)} = \Sigma\ (N_{e,1} + N_{e,2} + N_{e,3} + \ldots\ldots N_{e,GI})$$

(St. Pierre et al. 1996). The assumptions are that "1) individuals spawn once per generation, 2) matings occur randomly within each year class, 3) survival across year classes is equal, and 4) there is no migration, mutation, or selection" (St. Pierre et al. 1996). The generation N_e is very important for populations such as Gulf striped bass since the relatively small numbers of broodfish mated each year (in the hatchery and in the wild) are additive to future year pairings. For example, if only five females and five males are crossed each year over the course of a generation (four years), the year class N_e would only be 10 with an inbreeding rate (ΔF) of 5%. However, over the course of a generation interval N_{eGEN} would be 50 and $\Delta F = 1\%$.

The occurrence of overlapping generations violates the assumptions outlined by St. Pierre et al. noted above and can create difficulties in measuring N_e when year class and family size are variable and generation intervals are long (Kincaid 1995). The effects of overlapping generations are minimized when year class and family sizes are kept uniform. At this time, overlapping generations generally do not pose a serious problem for Gulf striped bass in the wild since natural reproduction appears to be limited and relatively few fish survive to an age that they are likely to mate with fish from the succeeding generation. Artificial propagation of overlapping generations may be more likely to occur in the hatchery.

Inbreeding is a major concern of native Gulf striped bass restoration efforts within the ACF. Inbreeding depression results in increased homozygosity (Busack and Currens 1995), producing genotypic frequencies which depart from the Hardy-Weinburg equilibrium. The Hardy-Weinburg equilibrium mathematically describes the principle that the relative frequency of alleles in a randomly reproducing population remains constant unless affected by factors such as natural selection, differential mutation rates, random genetic drift, or meiotic drive (Gardner 1975). Inbreeding is generally manifest in the loss of heterozygosity among rare alleles, those with a frequency less than 0.01 first. In general, rare alleles are neutral and contribute little to the genetic variation of a population (Kerby and Harrell 1990). However, in some instances rare alleles may be extremely important to the fitness of a population, and increased homozygosity for such low-frequency alleles will likely be accompanied by a reduction in overall fitness (Kerby and Harrell 1990). In the long-term, the loss of heterozygosity of rare alleles may result in fixation of higher-frequency alleles further reducing variability and fitness (Kerby and Harrell (1990). In a depressed population, the reduction in heterozygosity may culminate in a loss of fitness characters manifested as decreased growth or survivorship, increased incidence of deformities, or loss of reproductive viability (Meffe 1986, Kincaid 1995). Inbreeding may be cumulative, increasing from one generation to the next (St. Pierre et al. 1996). Once inbreeding has occurred within a population, increasing the number of breeding individuals will not reverse the loss of heterozygosity, but it will prevent the rate of inbreeding from increasing as rapidly (Tave 1984). The larger the effective population becomes, the smaller the increase in the rate of inbreeding and change in gene frequency due to genetic drift (Tave 1984).

Campton (1995) describes only one situation where introgression might result in increased fitness of an indigenous population. This scenario may occur when habitat becomes so perturbed that the indigenous population becomes no longer locally adapted. Under these circumstances, hybridization may be more advantageous biologically than loss of variation due to decreasing effective population size or extinction of the indigenous gene pool.

The introduction of Atlantic race fish to the Gulf of Mexico region, particularly the ACF, also presented the potential for outbreeding of the endemic population. Although outbreeding may increase genetic diversity in a depressed population, increased fitness is generally not achieved when genetically divergent genomes are hybridized (Leary et al. 1995). Even though the first generation of hybrids may be robust, the long-term result of introgression is usually intermediate or reduced fitness (Meffe 1986, Leary et al.1995). The mechanisms of outbreeding depression are the subsidence of adaptation to specific habitats and the dilution of coadapted gene complexes (Leary et al. 1995, Czapla 1999). Coadapted gene complexes form in reproductively isolated populations as individual genes evolve in response to other genes in the genome, creating groups which function as a unit to regulate physiological or developmental processes. Hybridization of divergent genomes breaks down these complexes, and may result in the loss of fitness parameters such as growth, survival, fertility, thermal tolerance, or homing (Leary et al. 1995).

Artificial propagation and stocking may be useful tools in restoration efforts where wild stocks are low in number or absent. When utilized in a recovery effort, a propagation program should prevent: (1) "extinction of the species" or population; (2) "loss of genetic diversity within the species, stock, or population; (3) loss of genetic diversity among stocks or populations; and (4) inadvertent artificial selection that may lead to directional succession from inbreeding or genetic swamping of wild stocks" (Williamson and Wydoski 1994).

Several adverse effects often associated with supplemental stocking arise when the hatchery product: "1) competes with wild fish for food and rearing space resulting in reduced survival of the wild fish, 2) competes with wild fish for spawning habitat resulting in reduced reproduction of the wild fish, 3) interbreeds with wild fish resulting in the introduction of hatchery-adapted genes which dilute the genetic attributes and gene complexes that enhance 'wild' survival, growth, and reproductive performance" (Kincaid 1999). Many of the negative impacts associated with hatchery production can be reduced significantly by employing simple precautions in the culture program (Kincaid 1999). These precautions include: "1) stock fish at the earliest possible life stage, 2) maintain fish at low rearing densities during the culture, 3) maintain high number of brood fish (effective population numbers), 4) limit and equalize the genetic contribution of all parental fish to the next generation, 5) recover brood fish from throughout the fishery and spawning season, 6) spawn all mature adults available, and 7) avoid selection of brood fish based on physical appearance and captive performance" (Kincaid 1999).

Ryman and Laikre (1991, as cited in Campton 1995) mathematically modeled the consequences of population admixture resulting from the random mating of two populations with different effective population sizes using the equation,

$$\frac{1}{N_e} = \frac{x^2}{N_c} + \frac{(1-x)^2}{N_w}$$

N_e = the effective population size of the introgressed (total) population,
N_c = the effective population size of the donor population,
N_w = the effective population size of the recipient population,
x = the fraction of N_e comprised of donors, and
$1 - x$ = the fraction of N_e comprised of recipients.

If N_c is greater than $0.5N_w$, interbreeding of the two populations may increase the effective population size of the recipient population over the range of values for x ($0 < x < 0.6$). In general, the effective donor population (N_c) would be expected to be smaller than the effective recipient population (N_w), except where threatened or endangered populations might be involved.

When the effective donor population is very small ($N_c < 0.1N_w$), as may occur in a hatchery broodfish population, then the effective size of the recipient population will be substantially reduced over a wide range of values for x ($x > 0.2$). The mechanism of reduction, referred to as genetic swamping, results from the introduction of a large number of progeny from a small parental stock, as may occur from the introduction of hatchery-reared fish. When this circumstance occurs, the genetic contribution of the introduced fish becomes a large component of the indigenous gene pool. The theoretical results of admixture described by Ryman and Laikre assume equal survivability between the donor and recipient populations.

Kerby and Harrell (1990) describe a case history in which the donor effective population (N_c) was small compared to the recipient effective population (N_w) while the value of x was large. In a South Carolina study where Phase I and Phase II fingerlings were co-stocked into a system having a natural population, Phase II fish comprised 50% of YOY sampled in the fall during three years of a five-year study. The predominance of Phase II fish raised concerns among fisheries managers since these fish were the product of only a few crosses at the hatchery. Greater survivability of Phase II fingerlings, many of which are siblings, may have resulted in swamping the native population with the genetic component of only a few individual parental fish. Kerby and Harrell cautioned that if genetic integrity of a naturally reproducing population is to be maintained, fisheries managers should consider eliminating the practice of stocking Phase II fingerlings where wild populations exist.

A small number of broodfish producing a year class (female striped bass may produce 100,000 eggs per pound of body weight) results in a large potential for inbreeding and reduction in population fitness (Kerby and Harrell 1990). In their discussion, Kerby and Harrell (1990) stressed that the consequence is an inordinately low donor effective population size (N_c) and loss of genetic variability among the hatchery produced progeny. The impact of stocking such a year class on the gene pool of a recipient population is difficult to measure. The relative contribution of the donor effective population to the total effective population (N_e) becomes an extremely important factor. If the introduced hatchery progeny survive to maturity and comprise a sizable proportion of that year class, the genetic influence can be significant. Kerby and Harrell (1990) stated "the impact of hatchery releases on natural stocks can be stated to be most severe when hatchery fish are more numerous than wild fish of the same age." Williamson and Wydoski (1994) cautioned that if hatchery progeny originated from only a small number of parents they should not be stocked into a natural population to prevent genetic swamping of the wild stock.

Propagation and grow-out within the hatchery environment results in artificial selection for improved hatchery performance, even when new broodstock are collected from the wild for each generation (Doyle et al. 1995). Hatchery performance selection occurs because not all progeny survive within the hatchery. The degree of selection is determined by the proportion of fertilized eggs that survive to release and by the proportion of mortality within the hatchery that is selective (Doyle et al. 1995). This domestication selection during propagation and grow out may result in the reintroduction of fish that are less fit than native fish. For example, studies of salmonids have demonstrated that the relative condition of hatchery fish often declines rapidly following release which may contribute to increased mortality, and that the decline may result from less flexibility among hatchery fish, compared with native fish, in switching to alternative food items as they become available (Ersbak and Haase 1983); hatchery fish are more aggressive, more mobile, and less efficient feeders, at a higher energy cost, than native fish (Bachman 1984, Mesa 1991); hatchery fish are less successful at producing offspring (Chilcote et al. 1986); and hatchery fish biochemically react to physiological stressors differently, and maybe less adaptively, than native fish (Woodward and Strange 1987).

Limiting grow-out time in rearing ponds is one method of reducing domestication selection (Kincaid 1999). Using wild caught broodfish each year also mitigates hatchery performance selection (Doyle et al. 1995). However, domestication selection may accumulate over time when stocked fish or their progeny are returned to the hatchery for production after maturing in the wild. In general, it is preferable to use naturally spawned native fish as the brood source if possible. The use of native fish reduces domestication selection and increases genetic diversity. However, as noted by Doyle et al. (1995), under some circumstances it may be preferable to recapture released hatchery produced fish, or their progeny, since selection has acted upon these fish in both the hatchery and in the wild.

Introgression of an indigenous population may occur by the introduction of hatchery progeny that have undergone domestication selection just as readily as through the introduction of non-native conspecifics. However, as St. Pierre et al. (1996) pointed out, in some instances stocked fish may out-compete wild fish of the same age for food because of their larger average size, but the advantage may be negated by a relative lack of fitness for survival in the wild.

12.2.5 Current Genetics Management of Gulf Striped Bass

Striped bass stocks within river systems along the Gulf of Mexico were likely localized self-sustaining populations. Wooley and Crateau (1983) reported that 82% of striped bass recaptured during a four-year tagging study on the upper Apalachicola River were recovered within the initial tagging area. Less than 1% of the recaptured fish left the Apalachicola River system and migrated to adjacent river systems. Individuals that did emigrate from the ACF were identified, using LLSC, as introduced Atlantic fish rather than native Gulf striped bass. Tagging studies in the adjacent Ochlockonee River system also demonstrated little movement out of that system (FWC unpublished data) to other rivers along the Florida Panhandle.

In general, extinction of indigenous stocks is preceded by the loss of genetic diversity within the population (Czapla 1999). Extirpation of localized populations from individual river drainages of the Gulf of Mexico may have ensued from diminished stock size that resulted in constriction of the gene pool. It is unknown whether the native population of striped bass in the ACF had dwindled to the point that inbreeding resulted in loss of genetic diversity prior to the introduction of nonnative Atlantic striped bass. Inbreeding within the endemic population, particularly among hatchery broodfish, has been a concern among fisheries managers involved in the restoration of striped bass in the ACF.

Although there are many strategies involved in the restoration of native Gulf striped bass, hatchery propagation and stocking has been most prominent. Gulf striped bass broodfish are collected from the wild on an annual basis from the ACF, Ochlockonee, and Blackwater river systems, as well as Lewis Smith Lake. However, since stocking success has been best using Phase I fingerlings (25-50 mm total length), a size too small to mark with an externally visible tag, it is difficult, if not impossible, to determine whether an eligible broodfish is a stocked or naturally spawned fish in a timely fashion without sacrificing the fish. Since naturally spawned fish appear to contribute very little to recruitment in the ACF (Mesing 1986, Long 2001, Long 2002, Long 2003), it is likely that the majority of broodfish are hatchery-reared fish that have matured in the wild. Captive and domestic broodfish have only rarely been used for experimental purposes in the Gulf striped bass restoration effort.

The Gulf striped bass spawning season is short, with gravid females generally located in spawning areas from the last week of March through the third week of April, depending on the water temperature and river system. In general, only ripe females that can be induced to ovulate within 36 to 48 hours of capture are transported to hatcheries. Not all females captured are spawned successfully each year. Hatchery managers prefer that each female be mated with a minimum of two males, although males may be mated with more than one female if fresh males are not available. Eggs from one female and sperm from two to three males are usually wet-mixed in a single vessel during fertilization.

At the time of capture, fin clip samples are taken from broodfish for mtDNA and nDNA analysis. Fin clips are shipped, overnight, to the genetics laboratory within one to three days of collection, depending on the frequency that broodfish are captured. Mitochondrial DNA results are normally returned within a week, although nDNA results generally take longer.

Striped bass males normally become reproductively mature at age-3 and females at age-4. Broodfish populations are usually comprised of three to five year classes and dominated by one to two year classes. Generational overlap is normally not a problem since few fish survive in the wild to an age that risk of mating parent with progeny would be commonplace. Accurate ages are unknown at the time of spawning at the hatchery, although age may be estimated based on size. Since so few fish are available to the hatchery manager at a given time, age (*i.e.* year class) is not a consideration during the broodfish collection and spawning process. Otoliths are removed from fish that are sacrificed or die at the hatchery, and ages are determined at the end of the spawning season. Since age and genetic analysis results are not available prior to spawning at the hatchery, it is impossible to determine whether siblings are being crossed during the spawning season.

Since 1991 the number of females successfully spawned annually at Welaka NFH and contributing to stocked year classes has averaged 11.2 and ranged from 6 to18. During that same time span, an average of 5.8 additional females (range 4-18) was spawned at Blackwater Fisheries Research and Development Center (FRDC). Depending on the number of fingerlings produced, progeny from 11 to 29 females are typically used to augment the ACF population annually. From 1991 to the present, the number of males used annually at the two hatcheries ranged from 10 to 40 (average = 26.9). Each year at least some males were used to fertilize ova from multiple females.

In order to minimize the rate of inbreeding accumulation and reduce the probability that rare alleles (frequency less than 0.01) will be lost from the population, the ideal broodfish stock should be as large as possible (Kincaid 1995). A large broodfish population would more likely simulate a random mating population. With an effective broodfish population of 100 (50 females and 50 males), an inbreeding accumulation of 0.5% per generation could be expected (Kincaid 1995). Utilizing a broodfish population of 200 would reduce inbreeding accumulation to 0.25% and maintain a high probability that rare alleles would not be eliminated from the gene pool. However, the logistics of broodfish collection, holding and spawning facilities, and rearing space are factors that limit the effective Gulf striped bass broodfish population to less than desirable. Utilization of several hatcheries increases the ability to hold and spawn an ideal broodfish population, but this creates its own set of logistical problems in terms of transportation and timing.

To maximize the effective population size and genetic contribution of one generation to the next, an equal sex ratio should be maintained within the broodfish population (Williamson and Wydoski 1994). In a population with unequal numbers of males and females, the limiting sex contributes genetic material disproportionately to the next generation (Kincaid 1995). Although the sex ratio of the Gulf striped bass population in the wild is unknown, females have generally been the limiting sex during hatchery production. To offset the reduction in genetic variation caused by the low number of females, each female is spawned with a minimum of two males, creating at least two families of half siblings rather than one family of full siblings. This type of breeding system is a mechanism used to increase genetic diversity when the breeding population is small (St. Pierre et al. 1996), but when the sex ratio becomes too skewed the effective population is reduced (Tave 1984). Late in the spawning season, ripe striped bass females may become more abundant than males, and males become the limiting sex. When this occurs, males are then mated with multiple females.

Ideally, in a mating system such as used at Gulf striped bass hatcheries, eggs from a mature female should be divided into equal aliquots prior to fertilization (Rees and Harrell 1990, Kerby and Harrell 1990). Separation of eggs reduces the risk of sperm from one male out-competing sperm from other males and fertilizing the majority of the eggs, as might happen when milt from multiple males are mixed with eggs in a single vessel (Campton 2004). A single male should be used to fertilize each aliquot, and the number of males available determines the number of half-sibling families produced. Males should be used to fertilize eggs only one time.

Genetic diversity may be improved by pooling the larvae of several females prior to stocking into growout ponds (Kerby and Harrell 1990). Pooling prevents differential artificial selection among growout ponds. Pooling may also be one mechanism to increase the number of families stocked into water bodies such as lakes Talquin, Blackshear, or Bartlett's Ferry, that do not receive large numbers of fish. However, pooling relies upon multiple females spawning during a very short time frame, which occurs infrequently during Gulf striped bass production.

Preferably, family size of stocked fish should be equal (Williamson and Wydoski 1994, Kincaid 1999). The number of progeny stocked from individual crosses in any given year should be within 50% of each other to avoid gene swamping from small numbers of breeding pairs (St. Pierre et al. 1996). To reduce the loss of genetic variation within the Gulf striped bass hatchery system, the practice of exporting entire families of progeny from spawning facilities to hatcheries used to stock river systems outside the ACF should be eliminated. An equal portion of each family should be maintained for stocking back into the ACF system. Likewise, the practice of setting aside entire families for Phase II production should be eliminated. Ideally, fingerlings restocked into hatchery ponds for Phase II grow-out should come from as many families as possible and in equal proportions.

In many river systems where they are stocked, the number of Gulf striped bass families and half-families produced and released each year is generally low. Since striped bass broodfish are collected from the wild in spawning condition, it is impossible to determine whether individuals are related using genetic analysis prior to propagation in the hatchery. It is also impossible to accurately determine the age of an individual broodfish without sacrificing the fish and removing the otoloiths. While it is preferable to avoid overlapping generations among broodfish, it is more important to avoid crossing siblings. To reduce the risk of mating siblings or half-siblings, size-at-age keys for each broodfish population should be developed. Although there may be some overlap of growth among year classes, assigning broodfish ages by size-class and pairing fish across year classes, but within generational intervals, will eliminate most chances of crossing siblings. Pairing fish across year classes will also serve to increase the effective population. Pairing broodfish across generational intervals will be less likely since few striped bass in Gulf systems survive in the wild to an age that there is a large risk of mating siblings of parental fish with progeny of those parents.

Fingerlings from different parents are generally not mixed prior to stocking, and in any given year class, fish from only one to two crossings have been used to stock various lakes within the ACF such as lakes Blackshear, Bartletts Ferry, or Walter F. George, or one of the other broodfish repositories such as Lake Talquin or the Blackwater-Yellow river system. Significant natural reproduction above these reservoirs or in the Blackwater-Yellow river system has not been documented. Within the ACF, fish are discharged from upstream reservoirs during flood events, and mixing of progeny increases downstream to some extent.

In 1997, no Phase I fingerlings were stocked into Lake Seminole or the Apalachicola River. Fingerlings were stocked only into lakes Blackshear and Bartlett's Ferry, upstream on the Flint and Chattahoochee rivers, respectively. Analysis of mtDNA from 83 YOY fish collected from the Flint River, Lake Seminole, and the Apalachicola River revealed 16 haplotypes, indicating that as many as 16 females may have successfully reproduced in the ACF. The number may have been greater since more than one female with a given haplotype may have reproduced successfully. Assuming each female spawned with one male, the effective breeding population would have been a minimum of 128. However, as a result of procedural vagaries (Waldman and Wirgin 1994), it is possible that YOY striped bass exhibiting similar heteroplasmic haplotypes [e.g., A′(B)2 and A′(B)(A)2] were siblings, reducing the estimated number of females that successfully spawned to a minimum of 14 ($N_e \geq 112$). Two other haplotypes in the YOY sample may have occurred as a result of stocking in upstream reservoirs, further reducing the estimated effective breeding population to a minimum of 96.

Historically, three hatcheries have been the primary producers of Gulf striped bass for restoration programs in the ACF and other Gulf of Mexico drainages. Phase I and Phase II fingerlings are reared at seven to nine hatcheries depending on availability and needs. Because of geographic locations and climatic conditions, the two southernmost hatcheries generally produce the majority of the fish stocked into Georgia, Florida, Mississippi, and Louisiana systems. Broodfish collection begins as early in the season as possible, and when enough fry are produced to fill grow-out ponds, production ceases. When gravid females are plentiful early in the season, hatcheries may be filled during the first few weeks of the season, while production needs may not be met during other years. When gravid females are scarce, production may be discontinued prior to the end of the season because harvesting and stocking temperatures will become too warm to harvest and handle progeny of late-spawned fish. There are occasions when an entire family of fry or fingerlings is shipped to grow-out facilities and ultimately stocked into a river system other than the broodfish source. When this occurs, whole families are lost from broodstock populations, which contributes to a loss of diversity. Likewise, the receiving populations may suffer from a paucity of genetic diversity.

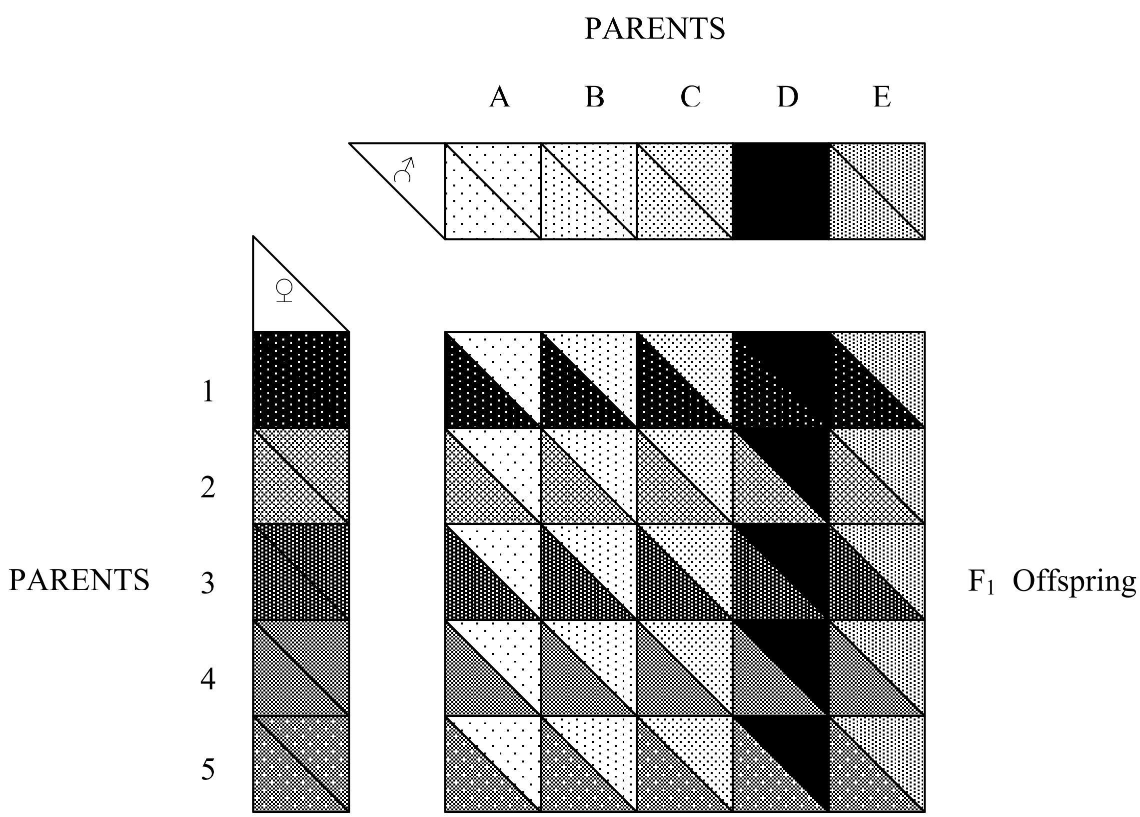
Phase I fingerlings from one to two females are restocked into grow-out ponds each year for Phase II fingerling production. The practice of setting aside entire families for Phase II production should be eliminated. Ideally, fingerlings restocked into hatchery ponds for Phase II grow-out should come from as many families as possible and in equal proportions. Grow-out of Phase II fingerlings generally occurs at several facilities, which may help alleviate some problems with domestication selection since selection pressures will vary among hatcheries.

To the extent possible, based on known genetic differences between Gulf and Atlantic striped bass races, initiating a genetics restoration program for Gulf striped bass may be desirable. In such a program, the introgressed population is converted to one that is nearly a genetically pure population of the indigenous taxon by stocking genetically pure conspecifics (Leary et al. 1995). Each generation of stocked fish that survives and reproduces reduces the proportion of non-native genes in the host population. While it is unlikely that genetically pure Gulf striped bass exist, it may be possible to reduce Atlantic introgression by selecting broodfish that are characterized by the fewest Atlantic markers among mtDNA and nDNA microsatellite loci which distinguish Gulf and Atlantic races. If a genetic restoration program is undertaken, broodfish must be maintained at the hatchery until genetic analysis has been completed. Once broodfish have been screened, only those that meet genetic criteria to be founders need to be housed at the hatchery or other holding facility. At every opportunity, additional fish meeting genetic requirements should be added to the founding population. Artificial gynogenesis may be a useful tool in a genetics restoration program since homozygosity of indigenous markers can be achieved in fewer generations (Kerby and Harrell 1990). The need to acquire and maintain broodfish with specific allele markers for selective breeding would be alleviated. However, the risk of homozygosity for other alleles may also be increased, and the risks of genetic restoration and the use of gynogenesis should be carefully weighed against the benefits.

Williamson and Wydoski (1994) recommended several strategies to maximize effective population size in a captive breeding population, which are particularly adaptive to a genetics restoration breeding program. These include: 1) mating one male with one female until an effective population of 50 is achieved; 2) breeding as many adult pairs as feasible in a given year, and continue into the next year until an effective population of 50 is attained; 3) if the number of adults is low, utilize a 5 x 5 di-allele matrix (basic minimal breeding strategy model) to develop a broodstock population; 4) when wild fish are extremely rare and sex ratios are unequal, use a factorial mating system; and 5) additional wild adults should be obtained to supplement the captive broodstocks developed from the 5 x 5 or factorial breeding system.

The di-allele crossbreeding system has been widely used in recovery and augmentation programs when the total number of adults is small and the contribution of each individual is important to maintaining population characteristics (Kincaid 1995). This type of mating strategy ensures that every genetic combination among the broodfish utilized is passed to the next generation so that genetic diversity is maintained. In a di-allele mating system, an equal number of females and males are crossbred with all fish of the opposite sex. In the example matrix (Figure 12.1), five males are each crossed with five females to produce 25 half-sibling families. The families along the diagonals are unrelated. In a domestic breeding program, the five unique families along the diagonal A1 – E5 become the core of the matrix, and the remaining families provide a genetic refuge in the event that a unique family lot is lost. The core F_1 generation becomes the broodfish population, and substituting wild fish to supplement the genetic component of the original founders over time increases genetic diversity.

Figure 12.1 An example of a factorial breeding system in which five males are each crossed with five females to produce 25 half-sibling families.



12.2.6 Recommendations for Genetic Management of Gulf Striped Bass Restoration Programs

12.2.6.1 Emphasize preservation and enhancement of natural habitats so that self-sustaining populations can be restored from wild stocks to the extent possible.

12.2.6.2 Protect each year class long enough to allow its gene pool to be passed on proportionately to the next generation.

12.2.6.3 Collect wild broodfish throughout the fishery and spawning season.

12.2.6.4 Avoid selection of broodfish based on physical appearance or captive performance.

12.2.6.5 Develop size-at-age keys to reduce the incidence of hatchery crosses within year classes, which will eliminate the potential for crossing siblings.

12.2.6.6 During hatchery production, utilize a large broodfish (effective) population to maintain genetic diversity and minimize the rate of inbreeding and loss of rare alleles. Spawn all mature adults available.

12.2.6.7 Maintain an equal sex ratio within the broodfish population.

12.2.6.8 Divide eggs from ovulating females into equal aliquots prior to fertilization.

12.2.6.9 Utilize individual males to fertilize eggs only one time.

12.2.6.10 Limit the genetic contribution of all parental fish to the next generation. Family sizes of stocked fish should be equal and the number of progeny stocked from individual crosses should be within 50% of each other to reduce the potential of gene swamping that may result from a small number of breeding pairs.

12.2.6.11 When feasible, improve genetic diversity of stocked fish by pooling offspring of several females prior to stocking into growout ponds.

12.2.6.12 Maintain fish at low rearing densities during the growout period.

12.2.6.13 Exporting entire families of progeny from spawning facilities to hatcheries supplying river systems outside the parental source should be avoided. A portion of progeny produced from individual crosses should be stocked back into the body of water where the broodfish were collected.

12.2.6.14 Stock fish into the wild at the earliest possible life stage to reduce artificial selection within the hatchery system.

12.2.6.15 To the extent feasible, utilizing known genetic differences between Gulf and Atlantic striped bass, initiate a genetics restoration program for Gulf striped bass.

12.2.6.16 Establish one or more genetic conservation refuges for Gulf striped bass.

12.2.6.17 To the extent feasible, evaluate, develop, or refine the use of cryogenics and artificial gynogenesis to support genetics restoration.

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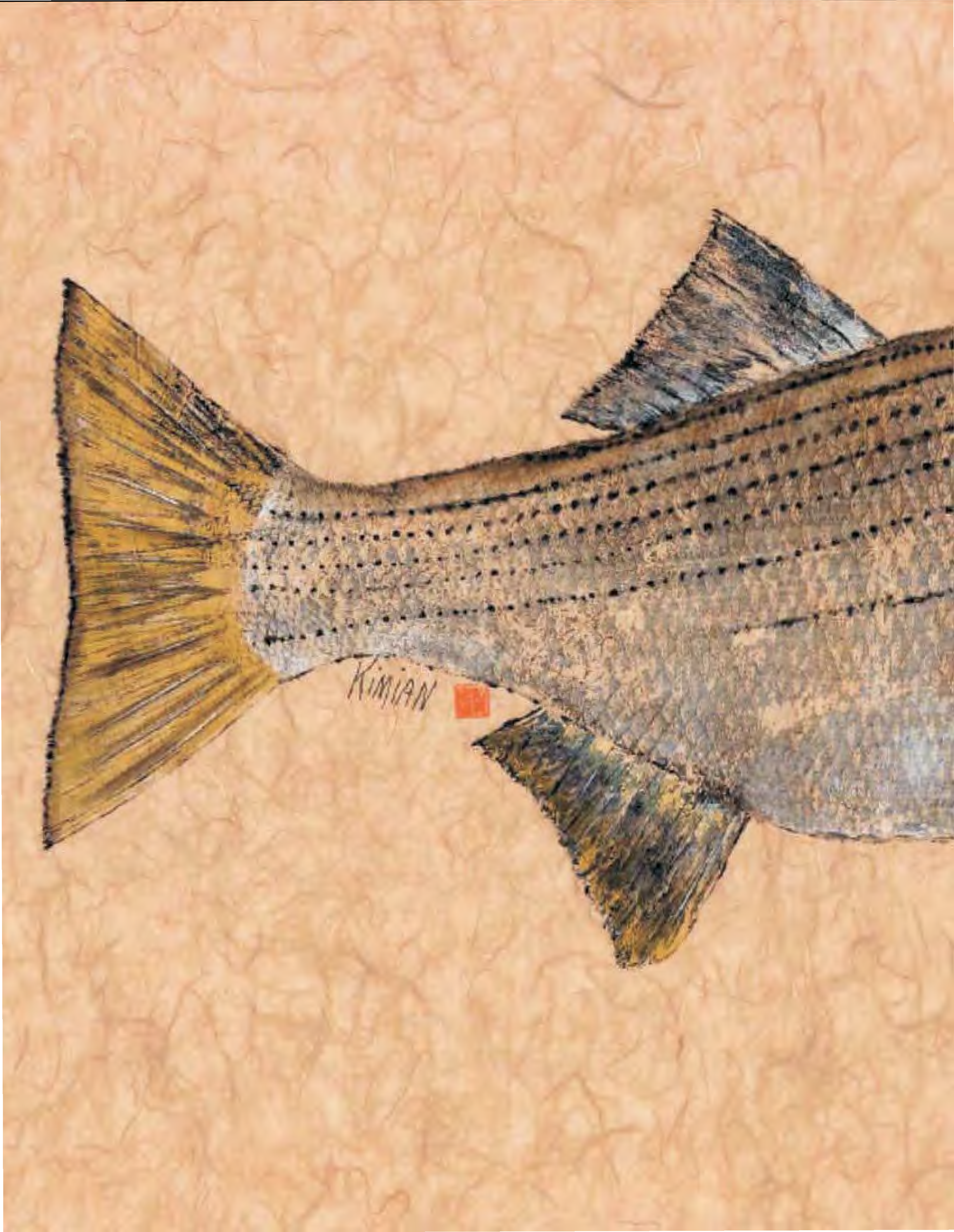
On the cover

"Striped Bass on Rice Paper" – by KIMIAN

About the Artists

Their love of the water and marine life lured Kim and Ian Workman to the Florida Keys from Mississippi in the mid 1990s. Kim was born in Biloxi, Mississippi where, as a child, she spent her summers exploring the barrier islands on the Gulf of Mexico and later moved to the coast of South America. Kim is a self-taught artist, and experiences from her childhood have greatly influenced her artistic expression. Starting at an early age she received several awards for her work. Ian was born in Lawford, England and has been a marine biologist for over 30 years. While he studied art in college, Ian's primary interest in art was for scientific purposes. Ian used photography including still, movie and video to document his studies. His photographs appear in several books and publications and are on display in the Smithsonian Institute and the Monterey Bay Aquarium.

Gyotaku (gee-o-tah-ku) or fish rubbing originated in Japan, where fishermen initially used it to document the size of their catch. Together, Kim and Ian have combined their talents, creating art from their fish rubbings. Using black ink or acrylic paint, Ian prints the fish onto handmade paper or canvas, and both artists employ their own techniques in coloring the fish rubbings. Their collaborate work is signed using a combination of their first names — KIMIAN, and have received several honors and Best of Show awards for their work. In the Florida Keys, their work may be viewed at Kennedy Studios in Key West, Artist in Paradise in Big Pine, and Bougainvillea House Gallery in Marathon.


Kimian