The Striped Mullet Fishery of the Gulf of Mexico, United States:

A Regional Management Plan

Gulf States Marine Fisheries Commission

December 1995 No. 33

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

A REGIONAL MANAGEMENT PLAN

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GULF STATES MARINE FISHERIES COMMISSION
P.O. Box 726
Ocean Springs, Mississippi 39566-0726

December 1995

Number 33

A publication of the Gulf States Marine Fisheries Commission pursuant to National Oceanic and Atmospheric Administration Award Numbers NA16FI0034-01, NA26FI0026-01, NA26FI0026-02, NA26FI0026-03, and NA56FI0085. This paper is funded by a grant from the National Oceanic and Atmospheric Administration. The views expressed herein are those of the author(s) and do not necessarily reflect the views of NOAA or any of its sub-agencies.

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Acknowledgements

The Gulf States Marine Fisheries Commission (GSMFC) would like to thank the Striped Mullet Technical Task Force (TTF) for their many hours of work and dedication in developing this striped mullet fishery management plan (FMP). The Commission would also like to extend special thanks to former members of the TTF who took up other pursuits prior to the completion of the FMP including Mr. Patrick Anglada (enforcement), Mr. Jim Lane (recreational advisory), and Mr. Brandt Savoie (Louisiana Department of Wildlife and Fisheries). The GSMFC also thanks the Stock Assessment Team (SAT) for their review, critique, and guidance in the development of the stock assessment, a critical component of this FMP.

The Striped Mullet TTF would like to express its appreciation for the use of the FMP previously developed for state waters in Louisiana and to its authors (Mr. Brandt Savoie, Mr. Richard Bejarano, Mr. John Burdon, Mr. Karl Mapes, Mr. Joe Shepard, Mr. Harry Blanchet, and Mr. Dave Johns), and the FMP previously developed for Alabama's state waters and its authors (Mr. Walter Tatum, Mr. Stevens Heath, Dr. Henry G. Lazauski, and Mr. Mark S. Van Hoose). The TTF also gratefully acknowledges present and former members of the National Marine Fisheries Service for their timely and courteous development and distribution of both commercial and recreational data used in this plan including: Mr. Josh Bennett, Dr. Al Jones, Mr. Steve Koplin, Mr. Lee Usie, Dr. Dave Van Voorhees, Dr. Gerry Gray, and others.

Finally, the Striped Mullet TTF and the GSMFC extend their most heartfelt thanks to Mrs. Cynthia B. Yocom for her special talents, effort, and dedication to ensure the quality of this document.

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 was 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 mullet 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 NMFS, the GSMFC funded travel for state agency representatives and consultants other than federal employees.

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1.0 SUMMARY

Striped mullet, *Mugil cephalus*, is the largest and most abundant species of mullet found in the Gulf of Mexico. Mullet are highly fecund, and spawning occurs offshore in large aggregations following mass spawning migrations from early to mid-winter. Larvae return to estuaries to grow and usually complete their life cycle by their second or third year. Because mullet are a schooling fish, they are easy prey for a wide variety of other fish, birds, and mammals, and they may be subjected to numerous pollutants as they feed on bottom sediments.

Mullet range throughout the Gulf and are found in a wide variety of habitats. They are most common in estuaries with moderate salinities and temperatures; however, juveniles and adults can tolerate salinities ranging from 0.0‰ to in excess of 35‰ and temperatures from 5.0° to 34.9°C (Perret *et al.* 1971).

Because mullet range throughout state and federal coastal waters, they are subject to the jurisdictions of numerous state and federal agencies. Mullet are most abundant in state territorial waters and the fishery is primarily conducted here; consequently, direct management of mullet populations has historically been the responsibility of the Gulf States and not the Gulf of Mexico Fishery Management Council. Other federal agencies that may exercise some direct or indirect management of mullet include the National Oceanic and Atmospheric Administration (National Marine Fisheries Service, Office of Ocean and Coastal Resource Management); the National Park Service; the U.S. Army Corps of Engineers; the U.S. Fish and Wildlife Service; the U.S. Food and Drug Administration; and the Environmental Protection Agency. These agencies along with various state agencies administer programs that regulate land and water use, pollution control, wetlands protection, public health and safety, and other activities that could affect mullet populations.

The mullet fishery in the Gulf has historically been a commercial fishery, and to a lesser extent a subsistence fishery, in part because mullet are not easily captured with hook and line gear. The fishery has primarily been conducted in Florida where approximately 80% to 90% of the total Gulf landings were taken until the early 1990s when Louisiana's fishery increased significantly. Mullet have historically been caught for both their flesh and roe, year-round and seasonally, and in approximately equal percentages. Flesh has most often been marketed in the United States for human consumption and bait; roe has almost exclusively been sold to foreign markets. The expansion of the fishery in Alabama, Mississippi, and Louisiana in recent years has occurred primarily during the roe season to take advantage of the increased catchability and significantly greater value of the fish during this period.

The predominant gear used to take mullet has been the gill net; however, purse seines, haul seines, and trammel nets have also been used. The efficiency of these gears has caused concern for the mullet stock in recent years as the roe fishery has expanded. A potential problem of overfishing mullet populations in Florida was noted and addressed by the adoption of additional regulations from 1990 through 1993. Recent stock assessments for individual state's populations which included data through 1994 showed that mullet populations in Florida were recovering, and estimates of spawning potential ratio (SPR) were expected to exceed 30% by the year 2000. In Alabama and Louisiana, SPR estimates were calculated at 34% and 31%,

respectively, and these estimates were considered to be adequately meeting established conservation standards despite increases in roe-season landings in these states. Estimates of SPR were not available for Mississippi and Texas.

In 1994, increasing concerns particularly from recreational fishermen led to the passage of a constitutional amendment in Florida that eliminated gill nets and other entangling nets in the fishery. These concerns also prompted the passage of legislation in Alabama and Louisiana and regulatory actions in Mississippi that produced much more stringent restrictions on the use of gill nets and other nets used to harvest finfish. The effects of these restrictions on fishing mortality and subsequent estimates of SPR are unknown and cannot be evaluated until future data are collected.

The limited database for management and habitat reduction and degradation are perhaps the most serious problems facing mullet populations and fishery managers in the Gulf. Other problems and perceived problems are primarily social and economic including transient fishing, illegal harvests, waste of product during the roe season, and inconsistent regulations among states. The extent to which these problems and perhaps others affect the mullet fishery in the Gulf is unknown.

Data to evaluate the status of striped mullet stocks in the Gulf are limited; however, based on available data, a "threshold" SPR of 30% is considered to be an acceptable conservation standard for maintaining a healthy stock of striped mullet in the Gulf at the present time. Present and future data collection efforts may disclose better estimates of appropriate conservation standards. States should closely monitor population abundance indices, catch and effort from the commercial and recreational fisheries, and other factors in both state and federal waters. They should also attempt to determine the effects of habitat changes, recently enacted regulations/legislation, and other phenomena that could negatively affect optimum yield from the fishery. States should enact additional restrictions such as quotas and trip limits, size limits, bag/possession limits, gear restrictions, area and seasonal closures, and limited access regulations as needed to maintain the equivalent of a 30% "threshold" SPR conservation standard until such time as a more appropriate standard is determined.

2.0 INTRODUCTION

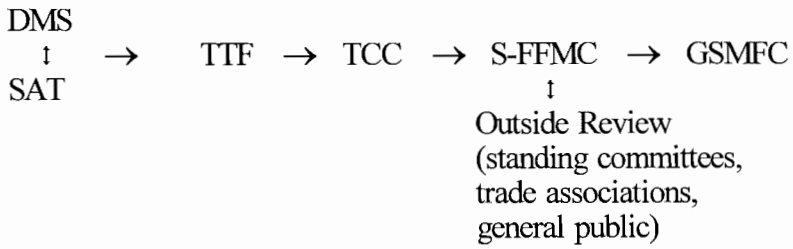
On March 17, 1991, the State-Federal Fisheries Management Committee (S-FFMC) of the GSMFC met in New Orleans, Louisiana, to consider Gulf fisheries in need of a fishery management plan (FMP). Other interjurisdictional plans for Spanish mackerel, menhaden, blue crab, and oysters had previously been completed, and a plan for black drum was in progress. After discussing potential efforts for spotted seatrout, red drum, and striped mullet, the S-FFMC concluded that a striped mullet FMP was of the highest priority because of a number of accumulating concerns regarding the fishery.

The primary concern expressed by the S-FFMC was the potential for overharvesting of spawners during the roe season. This concern was prompted by the belief that effort in this fishery had significantly increased in recent years because: (1) restrictions were placed on numerous traditional fisheries, and (2) the value and marketability of mullet roe had likewise increased. Also, there was concern that a portion of the resource was being wasted by discarding fish after the more valuable eggs were stripped.

2.1 IJF Program and Management Process

The Interjurisdictional Fisheries Act of 1986 (Title III, Public Law 99-659) was established 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 the other marine fishery commissions. The Commission decided to pattern its plans after those of the Gulf of Mexico Fishery Management Council 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 council.

After passage of the act, the GSMFC initiated the development of a FMP planning and approval process. This process has been modified as various plans have been developed, and its current form is outlined as follows:



DMS = Data Management Subcommittee
GSMFC = Gulf States Marine Fisheries Commission
SAT = Stock Assessment Team
S-FFMC = State-Federal Fisheries Management Committee
TCC = Technical Coordinating Committee
TTF = Technical Task Force

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. 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, Commercial Fisheries Advisory, and Recreational Fisheries Advisory) is appointed by the respective committee. In addition, the TTF may include other experts in economics, sociology, anthropology, population dynamics, or other specialty areas when needed.

Once the TTF completes the plan it may be approved or modified by the 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 this approval 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 recommended to the individual states for consideration of adoption and implementation.

2.2 Striped Mullet Technical Task Force Members

Terry Bakker	Mississippi Department of Wildlife, Fisheries and Parks (law enforcement)
Harry Blanchet	Louisiana Department of Wildlife and Fisheries
Mike Buchanan	Mississippi Department of Marine Resources
Christopher Dyer	Aguirre International (sociology/anthropology)
Walter Keithly	Coastal Fisheries Institute, Louisiana State University (economics)
Henry "Skip" Lazauski	Alabama Department of Conservation and Natural Resources, Division of Marine Resources
Behzad Mahmoudi	Florida Department of Environmental Protection
Gene Raffield	Raffield Fisheries, Inc. (commercial advisory)
Kyle Spiller	Texas Parks and Wildlife Department, Coastal Fisheries Division
Ray Lenaz	Biloxi, Mississippi (recreational advisory)

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Larry B. Simpson	Executive Director
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Cynthia B. Yocom	Staff Assistant

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Section 6.0 - Leard, Keithly
Section 7.0 - Keithly, Leard
Section 8.0 - Dyer, Leard
Section 9.0 - Leard, Mahmoudi, Blanchet
Section 10.0 - Leard
Section 11.0 - Leard
Section 12.0 - Leard, Blanchet, Mahmoudi, Lazauski, Keithly, Spiller, Buchanan
Section 13.0 - Leard
Section 14.0 - All
Section 15.1 - All
Section 15.2 - Dyer
Section 15.3 - Mahmoudi

2.5 FMP Management Objectives

The objectives of the Mullet FMP are:

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

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3.0 DESCRIPTION OF STOCK COMPRISING THE MANAGEMENT UNIT AND THEIR HABITAT

3.1 Biological Description and Geographic Distribution

Striped mullet are distributed throughout the coastal area of the U.S. Gulf of Mexico. They are most common in estuarine areas where they are very abundant and sometimes constitute the majority of the total finfish biomass (Gunter 1941, Joseph and Yerger 1956, Hellier 1962). Mullet are also found in open Gulf waters and many miles inland in totally fresh waters.

Striped mullet were perhaps first described by Linnaeus (1758). Numerous biological descriptions, taxonomic distinctions, and other studies have followed.

3.1.1 Classification and Morphology

3.1.1.1 Classification

The accepted classification of striped mullet is that of Greenwood *et al.* (1966):

Phylum: Chordata
Subphylum: Vertebrata
Class: Osteichthyes
Superorder: Acanthopterygii
Order: Perciformes
Suborder: Mugiloidei
Family: Mugilidae
Genus: *Mugil*
Species: *cephalus*

The valid name for the striped mullet is *Mugil cephalus* Linnaeus (1758). The following synonymy is adapted from Jordan and Everman (1896):

Mugil cephalus, Linnaeus, 1758
Mugil alba, Linnaeus, 1766
Mugil tang, Bloch, 1794
Mugil plumieri, Bloch, 1794
Mugil lineatus, Mitchill, MS; Cuvier and Valenciennes, 1836
Mugil rammelsbergii, Tschudi, 1845
Mugil berlandieri, Girard, 1859
Mugil guntheri, Gill, 1863
Mugil mexicanus, Steindachner, 1875
Mugil albula, Jordan and Gilbert, 1883
Mugil cephalus, Jordan and Swain, 1884
Querimana gyrans, Jordan and Gilbert, 1884

Striped mullet is the preferred common name recognized for *M. cephalus* by the American Fisheries Society (Robins *et al.* 1991). Other common names include common mullet, grey

mullet, black mullet, jumping mullet, whirligig mullet, popeye mullet, molly, callifavor, menille, mulle (Louisiana French, phonetic spelling), cefalo, macho, machuto, liza, lisa, and lisa cabezuda (Spanish of various regions) (Jordan and Evermann 1896, Gowanloch 1933, de Sylva *et al.* 1956, Hoese and Moore 1977, Collins 1985). Throughout this document, the terms striped mullet or simply mullet are used to refer to this species.

Striped mullet is the most abundant species of the family Mugilidae found in waters of the U.S. Gulf of Mexico (Hoese and Moore 1977). Other species found in the Gulf are white mullet, *Mugil curema*, mountain mullet, *Agonostomus monticola*, and fan-tail mullet, *Mugil gyrans* (Robins and Ray 1986). Relationships within the family have been outlined by Ebeling (1957, 1961).

3.1.1.2 Morphology

Various authors have described the life history stages of striped mullet including Anderson (1958), Scotton *et al.* (1973), Lippson and Moran (1974), Russell (1976), Martin and Drewry (1978) and Fahay (1983). Figure 3.1 shows various developmental stages of striped mullet.

Descriptions of fertilized *M. cephalus* eggs in the Gulf of Mexico have not been reported possibly because of the difficulty in distinguishing the eggs of *M. cephalus* from other species of fish. Russell (1976) noted that the only certain descriptions of *M. cephalus* were provided by Sanzo (1936) and Tung (1973) for artificially fertilized eggs.

The following description of *M. cephalus* eggs was developed from Martin and Drewry (1978) and Fahay (1983) and includes contributions from numerous studies in various parts of the world:

> Fertilized eggs - Nonadhesive, spherical, transparent, straw-colored with unsegmented, homogeneous yolk; pelagic, often boyant with one (1) oil droplet 0.3-0.36 mm in diameter, colorless or yellowish; egg diameter 0.60-0.99 mm, but usually 0.88 to 0.99 mm with a narrow perivitelline space.

Ditty and Shaw (1996) discussed characteristics used to separate *M. cephalus* (>6 mm SL) from *M. curema*, *M. gyrans*, and *A. monticola*; these were illustrated in Ditty *et al.* (1996). Martin and Drewry (1978) reported descriptions of a larval stage and a prejuvenile stage for *M. cephalus* with size ranges of 4-11 mm TL and 11-52 mm TL, respectively. Anderson (1958), however, considered fish as larvae until the formation of the third anal spine at 35-45 mm SL. The following descriptions are based on the differentiation of larval and juvenile stages by Anderson (1958) and are derived from descriptions presented by Anderson (1958), Martin and Drewry (1978), and Fahay (1983):

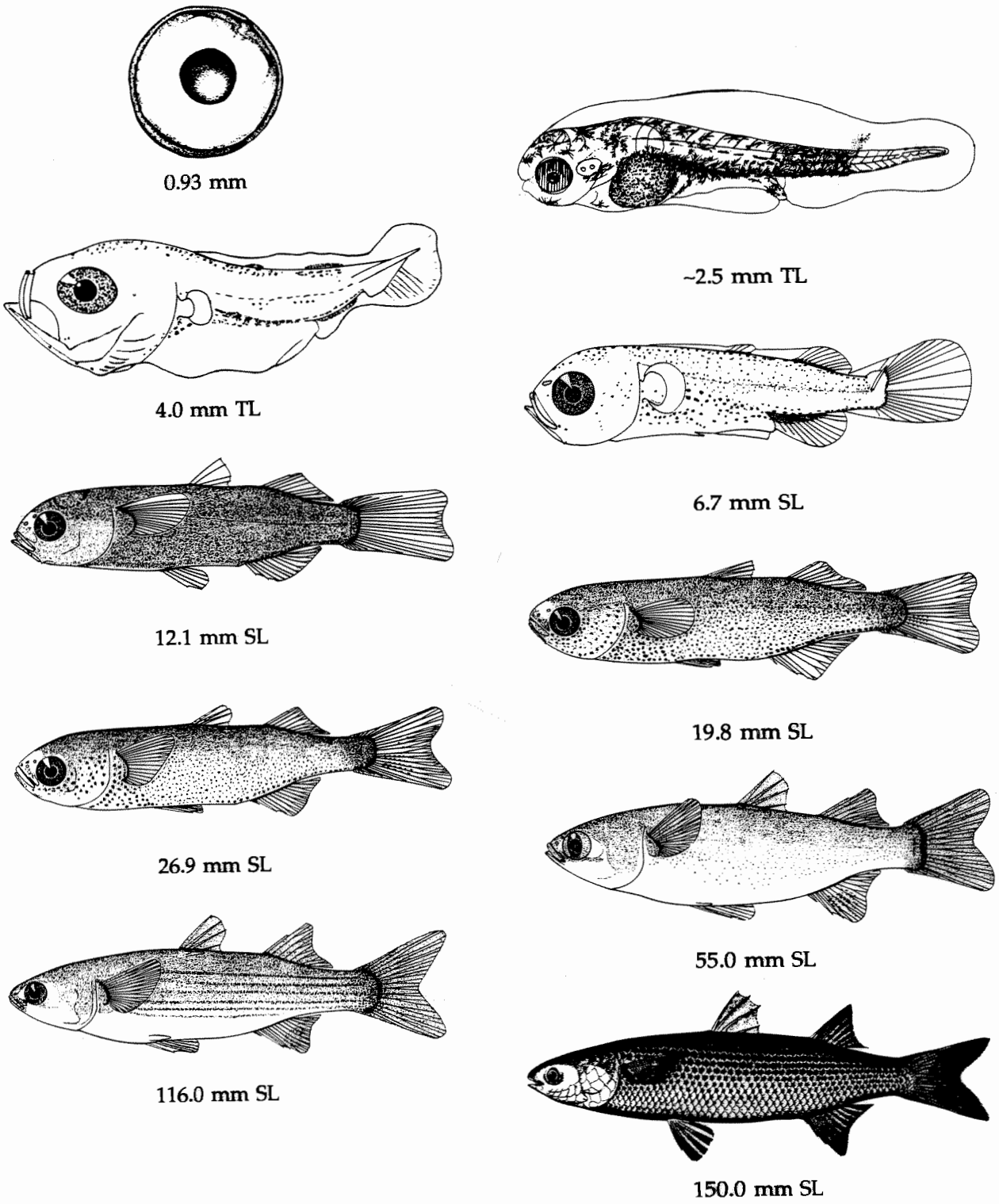

Figure 3.1. Typical egg, larvae, and juvenile stages of striped mullet at specified lengths. (A. Kuo *et al.* 1973 [from Martin and Drewry 1978], B. Sanzo 1936 [from Martin and Drewry 1978], C.-I. Anderson 1958, J. Goode 1884 [from Martin and Drewry 1978]).

Larvae - Caudal rays first to form increasing from seven (7) at ca. 4.0 mm TL to fourteen (14) principle and about three secondary at 5.4 mm TL; rays complete at approximately 10.0 mm TL (14 principle and 15 secondary). Dorsal rays separate and posterior at 4.0 mm TL; first dorsal with four (4) ray bases and second dorsal with all nine (9) bases and rays by 5.4 mm TL; four first dorsal spines complete by 6.7 mm TL and finfold disappears by 7.9 mm TL. Pectoral fins high on trunk; noticeable at 4.0 mm TL; 9-10 rays visible at 7.9 mm TL; all rays formed (16-17) at 9.7 mm SL. Ventral fins present at 5.4 mm TL; rays distinguishable at 7.9 mm TL and complete (6) rays at 9.7 mm SL.

Growth and branching of fins and fin rays continues through the end of the larval stage approximately 35-45 mm SL. Pigment spots begin to develop at 4.0 mm FL, spreading and intensifying to 27 mm TL. Anderson (1958) notes: "One of the striking characteristics is the large, less-numerous melanophores on the central aspect of the body as compared with the smaller, more-numerous ones on the dorsal aspect. In some specimens (9.7 and 12.1 mm SL) the more typical pigmentation described gives way to pigmentation so dense as to make the specimens almost black." From 16-35 mm SL, dorsal color dusky tan to brownish or greenish with ventral aspects brilliantly silver to about 32 mm TL and dusky thereafter.

Scales appear at about 11.0 mm TL. According to Anderson (1958), Jacot (1920) provided a detailed account of scale development and characteristics for specimens 23 mm TL and larger.

Juveniles - 44-200 mm SL; caudal fin reaching final form at ca. 110 mm FL, other fins same as adult; striped pigmentation increasingly distinct from 44-60 mm SL; scales increasing in size with circuli becoming complete and uninterrupted on the posterior exposed region.

Adult mullet are thick-bodied, blunt-snouted fish with two short-based dorsal fins. The mouth is shaped like an inverted "V" when viewed from the front, and the teeth are minute (Figure 3.2). Most members of the family have a thick-walled, gizzard-like stomach and a very long intestine (Randall 1968).

The following description of adult striped mullet is summarized from Martin and Drewry (1978) and contains contributions from various other authors:

D. IV-I, 7-8; A. III,8; C. 7+7, procurrent rays 7-8+7-8; V. I,5; lateral line scales 37-43, vertebrae 11+13 or 12+12, first interneural bifurcate above seventh vertebra; gill rakers 24-36+50-76, numbers increasing with size; primary teeth uniserial, simple, 57-101 in upper jaw, 97-149 in lower jaw; secondary teeth in bands, bicuspid, numerous, number increasing with size; no teeth on vomer or palatines.

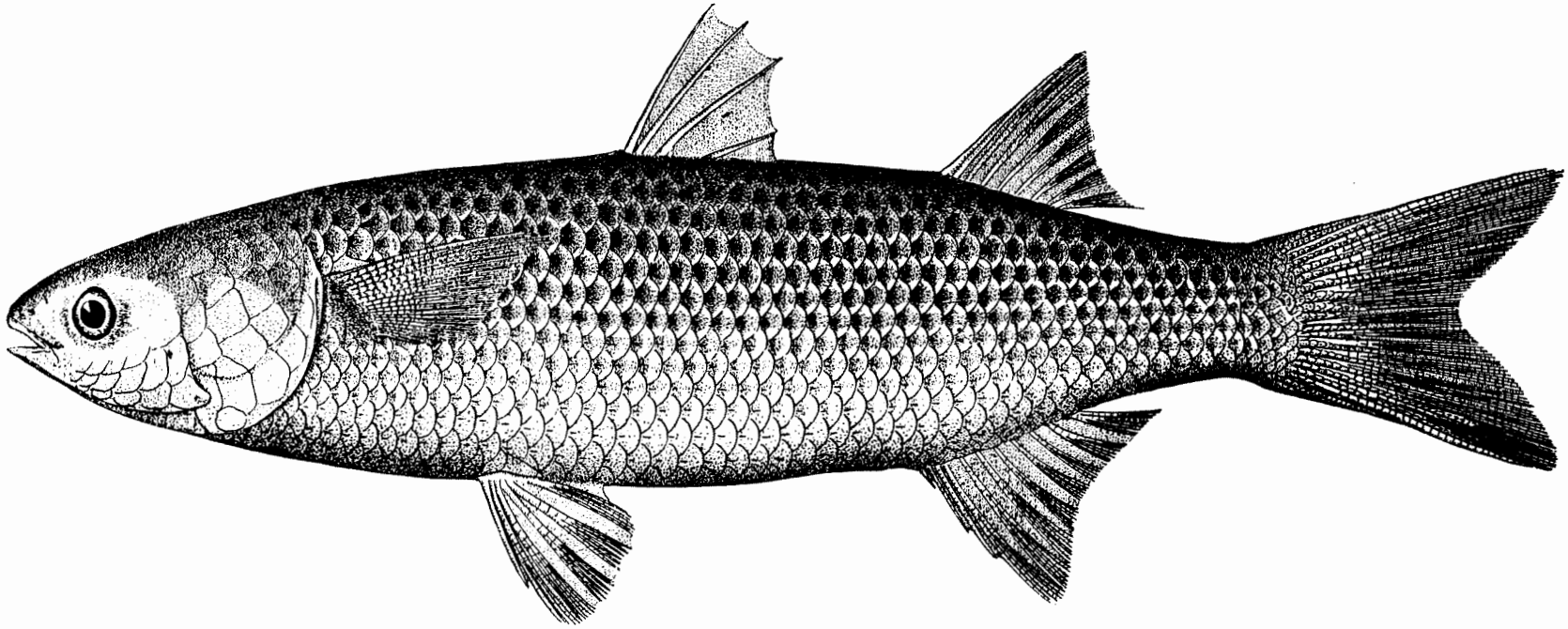

Figure 3.2. Adult mullet (from Goode 1884).

Head 25.4-27.7; maxillary 7.0; interorbital width 9.3-10.4; body depth 25.4-26.0; first predorsal 50.8-57.1; second predorsal 74.6; preanal 73.0-73.5; prepelvic 39.4-39.5; first dorsal base 12.8-13.3; second dorsal base 10.6; second dorsal height 14.3-14.4; anal fin height 15.0-15.5; pectoral length 17.3-17.6; pelvic length 15.2-15.3; all being % standard length (SL) means for 2 samples of 25 specimens (de Sylva *et al.* 1956).

Body robust, moderately elongate, compressed; lower profile curved from snout to caudal peduncle, upper profile less curved, but arched slightly from snout to first dorsal fin origin; body oval in cross section; caudal peduncle rather strongly compressed. Head massive, somewhat broader than deep; interorbital flat, short, and broad, its width more than twice eye diameter; snout shorter than eye, blunt or rounded anteriorly with a strong taper in dorsal view; some scales on top of head slightly enlarged; anterior and posterior nostrils widely separated. Mouth moderate, oblique, jaws weak; lower jaw included; maxillary hidden when jaws closed, its posterior end moving forward when mouth opened; lower lip with a thin edge directed horizontally forward or nearly so. Gape somewhat broader than deep. Gill openings wide, gill membranes free of the isthmus; gill rakers numerous, long, slender, and close-set; pseudobranchiae large. A prominent adipose eyelid almost obscuring eye, covering preorbital anteriorly and extending almost twice as far posteriorly, leaving a narrow slit over pupil. Scales moderate, cylcoid or feebly ctenoid. Lateral line inconspicuous. Pectoral fins above midline, at level of eye; originating about length of head behind eye; tips pointed, not reaching first dorsal origin; a distinctly enlarged scale in pectoral axil; pelvic fins subabdominal; origin of first dorsal fin over pelvics; first dorsal spine longest, others graduated, last spine about half as long as first; origin of second dorsal fin slightly behind anal origin; upper margin concave, longest ray nearly same length as longest spine of first dorsal; anal fin about same size and shape as second dorsal but margin less concave; caudal deeply forked, longest rays nearly as long as head, shortest about half as long. Fine scales extending onto caudal fin and some on anterior rays of second dorsal and anal.

Pigmentation: Color varies with habitat and salinity, in fresh water very dark dorsally with overlay of dirty brown or bluish color, dull white ventrally; in marine waters dorsum olive green, sides silvery, venter off-white. In general, dorsum grayish olive, grayish blue, grayish brown, bluish brown or dark blue; shading to silvery white on sides and white or pale yellow ventrally; many brown spots on sides, organized into rows along scale centers on upper half, forming 5 to 10 dark longitudinal stripes on upper scale series down to about the tenth, lower band not extending behind anal origin. Sometimes a terminal caudal bar in migrating adults. Fins dusky, minutely dotted with black, except pelvics, that are a pale yellowish color; pectoral black at base of upper rays and distally, with a narrow pale margin, inner surface almost black; margin and last few rays of anal fin pale. A dark blue streak or spot in the axil of pectoral. A golden ring around the iris.

3.1.2 Biological Description

The life cycle of striped mullet is typical of many estuarine-dependent species. Adults spawn offshore (Arnold and Thompson 1958), and larvae and postlarvae are transported to estuaries by various mechanisms (Ditty and Shaw 1996). Juveniles generally mature in estuarine or nearshore waters and complete the cycle when they reach maturity.

3.1.2.1 Age, Growth, and Maturation

According to Rivas (1980), mullet may live four or more years. Thompson *et al.* (1991) reported a maximum age of approximately nine years, but noted that mullet rarely live more than six years. Thomson (1963) stated the maximum age as 13 years.

Age validation of striped mullet in Louisiana waters suggested that a single annulus is formed annually between April and August (Thompson *et al.* 1989); however, the first annulus is not formed until the age of approximately 16 to 18 months (Thompson *et al.* 1991). Thompson *et al.* (1991) described annual otolith formation and noted that yearly otolith growth occurs between July and November. They hypothesized that following this somatic growth period energy levels were focused on reproduction (November and December) and post-spawning recovery (January to March). Afterwards (April), growth of the next year's otolith began. Using scale analyses, Cech and Wohlschlag (1975) found similar trends in the winter and early spring, but they also observed a slow growth period in June and July. Rivas (1980) reported that growth of striped mullet during the spring and summer was more than double the growth during the fall and winter, and he believed the phenomenon was related to temperature.

Futch (1966) reported that larval mullet (approximately 2.5 mm long) grew into postlarvae in about 7 days, and K. Peters (unpublished data) noted that upon reaching inshore areas, prejuveniles were approximately 22 mm TL. Within 5 months mullet grew to 50 mm juveniles, and at 1 year they were about 185 mm (Futch 1966). In their second year they were approximately 265 mm and became available to the commercial fishery.

Table 3.1 shows size at age for various studies. Thompson *et al.* (1989) compared size at age data for Louisiana striped mullet and found a near-linear growth rate to age 3. Their length at age data indicated that in the Gulf of Mexico, growth in length gradually slowed as the fish became larger and reached an asymptote at approximately 350 mm FL, 3-5 years of age. Thompson *et al.* (1991) also found a faster growth rate in striped mullet taken east of the Mississippi River than west of the river. Broadhead (1958) and Cech and Wohlschlag (1975) noted that females were most often bigger and grew a little faster than males of identical age. Mahmoudi (1990) and Thompson *et al.* (1991) also observed significantly faster growth rates and correspondingly greater lengths at age and weights at age for female mullet than for males.

Table 3.1. Size at age for striped mullet (various investigations and locations).

Author	Area	Aging Method	Fork Length at Formation of Annuli (cm)								
			1	2	3	4	5	6	7	8	9
Jacot (1920)	North Carolina	Scale	12-20	22-23							
Kesteven (1942)	East Australia	Scale	14.9	23.1	31.7	39.7	47.7	53.7			
Thomson (1951)	West Australia	Scale	14.0	24.5	33.6	40.5	46.7	50.5	53.7		
Morovic (1954)	Italy	Scale	16.6	24.6	31.8	38.4	42.6	45.1			
Broadhead (1958)	West Florida (a)	Scale	14.2	20.7	26.3						
	West Florida (b)	Scale	13.4	20.7	27.1						
	West Florida (c)	Scale	17.5	25.8	30.7						
	West Florida (d)	Scale	17.8	26.9	31.9	36.6					
Cech & Wohlschlag (1975)	Texas	Scale	12.7	18.6	22.5	25.8	28.6				
Pafford (1983)	Georgia	Scale	12.3	21.2	25.7	29.4	33.5	36.3	39.8		
Denizci (1958)	Turkey	Otolith	4.7	14.5	21.6	30.0	41.8	51.5			
Erman (1959)	Sea of Marmara	Otolith		17.1	25.3	33.3	42.6	50.3	55.0	59.0	62.0
Pafford (1983)	Georgia	Otolith	14.1	21.2	24.3	27.4	32.0	36.2	39.7	43.4	
Mahmoudi (1990)	Florida	Otolith-male	18.6	24.5	29.3	31.8	33.7	35.6			
		Otolith-female	18.7	23.9	30.3	34.1	37.2	40.3	42.9	45.2	
Tatum *et al.* (1993)	Alabama	Otolith		21.4	29.5	34.7	38.3	41.0	42.7	43.5	
Thompson *et al.* (1989)	Louisiana 1986 Louisiana 1987	Otolith Otolith			37.0 34.2	38.1 35.9	40.4 38.9	41.1 39.3	40.0		

(a) Pensacola, (b) Apalachicola, (c) Cedar Keys, (d) Homosassa

Futch (1966) found a rough correlation between average water temperature and size/age at maturity. Individuals from higher-temperature areas matured faster than those from lower-temperature areas. Jhingran and Mishra (1962) suggested that portions of some populations of mullet can become mature by one (males) to two (females) years of age. Thompson *et al.* (1991) observed that both male and female striped mullet were generally mature at age two; however, some females were not mature until age three. Collins (1985), using data from Broadhead (1953, 1958) and Rivas (1980), reported that mullet mature between 200 and 300 mm SL with the females maturing at a slightly larger size than males. Some fish matured in their second year, and most matured by three years. Table 3.2 shows length/weight relationships for various studies.

Table 3.2. Length-weight relationships of *Mugil cephalus*.

Authors	Region	Length-Weight Relationship
Classen *et al.* (1988)	Texas	$W = 0.000015\ L^{2.93}$
Pafford (1983)	Georgia	$W = 0.00020\ L^{2.943}$
	female	$W = 0.000065\ L^{2.943}$
	male	$W = 0.000082\ L^{2.694}$
	juvenile	$W = 0.000020\ L^{2.946}$
Thompson *et al.* (1989)*	Louisiana male female	 $W = 0.0000096\ L^{3.06}$ $W = 0.000026\ L^{2.85}$
Thompson *et al.* (1991)**	Louisiana	$W = 0.000021\ FL^{2.93}$
Mahmoudi (1989)	Florida	
	spawning season	$W = 0.0000052\ FL^{3.17}$
	post spawning season	$W = 0.000083\ FL^{2.677}$
	summer season	$W = 0.0000066\ FL^{3.14}$
Mahmoudi (1990)	Florida male female	 $W = 0.000008794\ FL^{3.09}$

*from fishery-dependent data
**from fishery-independent data

Thompson *et al.* (1991) noted that maturity (50% of the population with functional gonads) was reached at approximately 200 to 220 mm FL (males) and 220 to 230 mm FL (females). They also found that regardless of sex, mullet <160 mm FL were immature, while all males >280 mm FL and all females >290 mm FL were mature. Mahmoudi (unpublished data) noted that mullet from the west coast of Florida reached maturity at 290 to 380 mm FL. Table 3.3 shows size and age at maturity for various studies.

Table 3.3. Size and age at maturity for striped mullet (various investigations and locations).

Region	Size/Age at Maturity	Source
Louisiana	280-290 (2-3)	Thompson *et al.* (1991)
Florida West Coast	290-300 (2-3)	Mahmoudi (unpublished data)
Florida East Coast	270-310	Greely *et al.* (1987)
Australia	310-350 (3)	Grant and Spain (1975)

Robins and Ray (1986) reported that mullet reach a maximum size of 910 mm (3 feet) but added that largest individuals are usually less than 510 mm (20 inches) in TL. Gopalakrishnan (1971) reported a 914 mm TL specimen from India; and a striped mullet caught from Florida's west coast was reported to have a fork length of 698 mm, a weight of 4.4 kg (9 lb, 10 oz), and an age of nearly 8 years (Topp and Beaumariage 1971).

3.1.2.2 Reproduction

3.1.2.2.1 Gonadal Development

Thompson *et al.* (1989) stated that oocyte development patterns in Louisiana supported previous reports by Shehadeh *et al.* (1973) and Kuo *et al.* (1974) that striped mullet were isochronal spawners with synchronous oocyte maturation. They also observed initial reproductive development in September with the appearance of some cortical alveolar oocytes among mainly developing primary stage oocytes. They noted continuous development through the spawning season with vitellogenic oocytes being predominate from November through December. Mean egg diameters were 0.21 mm in September and 0.56 mm in November and remained relatively constant to late December (Thompson *et al.* 1989). Greely *et al.* (1987) observed similar growth stages and egg sizes. Thompson *et al.* (1989) observed resting, primary stage oocytes and degenerating, mature oocytes during February indicating that reproduction had ceased. A similar dormant period was reported by Abraham *et al.* (1966).

3.1.2.2.2 Spawning

3.1.2.2.2.1 Season

The spawning season in the northern Gulf of Mexico generally extends from October through March (Anderson 1958, Hoese 1965, Finucane *et al.* 1978, Ditty 1986). Peak spawning occurs in November and December for the northern Gulf (Thompson *et al.* 1989; J. Warren, unpublished data) and slightly later in the more southern areas at the eastern and western Gulf (Mahmoudi 1991). Render *et al.* (1995) reported that spawning was completed by late February off Louisiana, and Ditty and Shaw (1996) confirmed this conclusion based on analyses of larvae from offshore stations. Shireman (1975) found evidence that some females may spawn only in alternate years in Louisiana and implied that this phenomenon could occur in other U.S. waters. This observation has not been confirmed in recent studies.

3.1.2.2.2.2 Courtship and Spawning Behavior

According to Shireman (1975), mature mullet usually swim offshore to spawn in the fall and winter; however, sexually mature fish that are forced to remain in freshwater resorb their gonadal products. Peterson (1976) observed that swimming speed is greater during migrations and is much greater than that predicted to be energetically optimal, possibly because of the augmented hydromechanical efficiency provided by schooling and the selective force of heavy predation during spawning migrations.

Futch (1966) noted that eggs are discharged into the water and nearby males fertilize them. Arnold and Thompson (1958) reported apparent spawning of striped mullet at night in the Gulf of Mexico from visual observation while drifting in 755 fathoms (1,381 meters) of water:

> In a typical group, the males, noticeably smaller and more slender, maintained positions slightly behind what was ostensibly a female. Five or six times while they remained in view, one or more of the males would quickly move up beside or below the female, nudging and pressing against her abdomen with head and body. Often during this action the individuals thus engaged would quiver and cease swimming momentarily, sometimes rising to the surface. The unoccupied males swam rapidly back and forth in the immediate vicinity until they in turn behaved in a similar fashion.

Thompson *et al.* (1991) examined the first record of a hermaphroditic striped mullet taken in U.S. waters (Mississippi) in a spawning condition. They found both functional testicular tissue and vitellogenic oocytes in this mullet and noted the possibility of self-fertilization.

3.1.2.2.2.3 Duration

The duration of spawn seems to be short for individual fish. Broadhead (1953) stated that fishermen reported schools of roe mullet moving offshore during bad weather. Within a week after the spawning migration, fishermen reported seeing spent male and female mullet in their catches. In addition, an unpublished tagging study by the University of Miami revealed that two tagged, mature mullet were collected as spent fish within fourteen days after being tagged at the same location where they were set free. These findings suggest that the spawning process is not long, that the fish may not swim far, and that they may come back to the same place.

3.1.2.2.2.4 Location and the Effects of Temperature, Salinity, and Photoperiod

There have been no reports of water temperatures associated with mullet spawning in the wild; however, mature eggs and yolk sac larvae have been collected from Gulf waters off Texas at average temperatures of 22.2°-22.4°C (Finucane *et al.* 1978). Tung (1970) reported that the best temperatures from which to catch migrating spawners ranged from 21°-25°C. Kuo *et al.* (1974) found that the most effective temperature for the completion of oogenesis in captive mullet was 21°C when combined with a retarded photoperiod of 6 hours of light and 18 hours of dark. A study by Dindo *et al.* (1978) reported that when the natural photoperiod shortens (less than 12 hours) and the temperature falls to approximately 20°C in September and October, there is a concurrent initiation of rapid gonadal growth and reproductive readiness.

Finucane *et al.* (1978) collected fertilized eggs at average salinities of 36.4‰ to 36.5‰ off Texas. Optimum egg development and hatching was reported as 30‰-32‰ salinity (Sylvester *et al.* 1975) and 30‰-40‰ (Lee and Menu 1981). The best larval survival occurred at 26‰ indicating a physiological adaptation for the lower salinity estuarine stage (Sylvester *et al.* 1975).

Spawning location for mullet has been studied by many investigators. Mullet have been reported to spawn inshore (Breder 1940), near passes along outside beaches (Gunter 1945), in the ocean near inlets (Taylor *et al.* 1951), 5-20 miles offshore (Broadhead 1953), over 20 miles from shore (Finucane *et al.* 1978), and in waters from 20 to over 100 fathoms (Anderson 1958, Finucane *et al.* 1978). Most literature supports offshore spawning at night near the surface in deep water (Martin and Drewry 1978; Fischer 1978; Collins 1985; Robins and Ray 1986; Ditty and Shaw 1996; K. Peters, unpublished data).

Histological studies by Thompson *et al.* (1991) also support the contention of offshore spawning. Post vitellogenic oocytes were absent from samples and development appeared to cease inshore at a terminal vitellogenic oocyte diameter until movement offshore occurred. They also did not find post-ovulatory follicles, which can only be observed for a short period after ovulation, in mullet from inshore estuarine waters. Previous reports of inshore spawning could have been erroneously caused by the short duration of the event.

3.1.2.2.3 Fecundity

Broadhead (1953) estimated fecundity between 0.5 to 2.0 million eggs, depending on the size of the female, and Futch (1966) stated that adult females produce from 1.2 to 2.7 million eggs per spawn. Topp and Beaumariage (1971) estimated fecundity for a large fish (698 mm FL, 4.4 kg) at 4.7 x 10^6 ova. Shehadeh *et al.* (1973) calculated a fecundity value of 648 plus or minus 62 eggs per gram of body weight, and Thompson *et al.* (1991) found that mullet ranging from 290 to 568 mm FL contained from 798 to 2,616 eggs per gram of eviscerated body weight.

Render (personal communication) reported fecundity estimates for mullet ranging from 300-550 mm FL (Table 3.4). Greely *et al.* (1987) found similar estimates of fecundity by size expressed in SL. Estimates by Mahmoudi (1990) were generally higher; however, reasons for this difference are unknown. The three studies found that fecundity increased with size, and the greatest increases occurred at the largest sizes.

Table 3.4. Fecundity estimates by size.

Fork Length (FL)	Average Fecundity (Number of Eggs)	
	Mahmoudi (1990)	J. Render (personal communication)
300-350	984,000	551,104
350-400	1,493,000	913,456
400-450	2,152,000	1,077,163
450-500	2,979,000	2,960,897[1]
500-550	3,992,000	2,269,251

[1]Figure may be overestimated because average was obtained from only two samples, 491 and 495 mm FL.

3.1.2.2.4 Incubation

Kuo *et al.* (1973) reported hatching at 36-38 hours after fertilization at 24°C and 48-50 hours at 22°C; salinities were 32‰. They also reported that turbulence reduced hatching time. These salinities and temperatures corresponded with optimum values reported by Martin and Drewry (1978). Hatching time lengthened at reduced temperatures and decreased slightly as temperatures increased; however, survival was reduced (Martin and Drewry 1978). Hatching occurred at 2.2-3.6 mm TL with little growth noted during the yolk-sac larval stage to approximately 4.0 mm TL. This stage lasted from 2-5 days with flexion occurring at 4.0-5.0 mm TL (Martin and Drewry 1978, Fahay 1983).

3.1.2.3 Parasites and Diseases

Mullet are frequent hosts to parasitic infections and infestations. Collins (1985) found that in almost 300 adult mullet taken from saltwater and freshwater habitats on Florida's Gulf coast, all fish had parasites either on the body surface or gills.

Bacteria have been reported to kill striped mullet. Lewis *et al.* (1970) documented deaths caused by a *Pasteurella*-like bacterium in Galveston Bay, Texas, in November 1968. Substantial mucoid material covered the gill filaments, and purulent material was found in abdominal cavities of sick fish. Plumb *et al.* (1974) isolated a species of *Streptococcus* from mullet and other dying fishes from Florida to Alabama in August and September of 1972 and suggested that this bacterium was responsible. Cook and Lofton (1975) infected five species of fishes including *M. cephalus* with the bacteria and observed death as a result of the bacteria. Paperna and Overstreet (1981) stated Donald H. Lewis of Texas A&M University found many mullet near Galveston, Texas, with *Vibrio anguillarum* during early spring. When under the stress of being taken to Mr. Lewis' laboratory, they developed small hemorrhages in and at the base of the fins,

in the oral cavity, and around the vent. Lewis also saw loss of scales and large lesions on the abdominal wall of mullet, and *Pseudomonas* sp. was most often present in the lesions, liver and frequently the blood.

Fungi such as the water mold, *Saprolegnia* sp., infect mullet (Sarig 1971), and deaths have been documented. The parasitic dinoflagellate *Amyloodinium ocellatum* or a closely related species, sometimes infests striped mullet in Mississippi and can easily kill most pond fishes (Paperna and Overstreet 1981). They also found that in Mississippi, *Trypanosoma mugicola* infects the blood of striped mullet, but it appears to have no effect.

Ciliates can also be found in striped mullet. Skinner (1974) noted an unidentified trichodinid on *M. cephalus* from Florida closely resembling *Trichodina halli*. What appear to be two species of trichodinids have been observed in the gill area and on the integument of striped mullet and white mullet from Louisiana to Florida (Paperna and Overstreet 1981). *Scyphidia* sp. has also been observed on the integument and gills. Wilkie and Gordin (1969) found that mullet were vulnerable to *Cryptocaryon irritans* when marine waters were warmer than 15°C.

In Florida, Saunders (1964) observed the haematozoan *Haemogregarina mugili* that infects only mullets. Becker and Overstreet (1979) observed it and *Trypanasoma mugilicola* in striped mullet from Mississippi.

Paperna and Overstreet (1981) found cysts of one or more species of *Kudoa* in mullet from Mississippi. These infections were observed in the musculature and along the alimentary tract.

The parasite *Myxosoma cephalus* was found in striped mullet from south Florida (Paperna and Overstreet 1981). It was discovered in the meninges, gill arches and filaments, buccal cavity, jawbone, crop, esophagus, intestine, liver, and mesentery of the fish. It was thought to have caused the heavy mortality of striped mullet in southern Florida in 1964 (Iversen *et al.* 1971). Material obtained from the brain cavity and elsewhere pointed to this pathogen.

Parasitic copepods also infect striped mullet (Paperna and Overstreet 1981). The ergasilids *Ergasilus lizae*, *E. versicolor*, and two other forms parasitized mullet in the United States (Johnson and Rogers 1973). *E. longimanus* has been reported from Florida (Skinner 1974). Paperna and Overstreet (1981) stated that probably other ergasilid species parasitize mullet. The cyclopoid copepod, *Bomolochus concinnus*, was observed in 20 of 83 fish from Biscayne Bay, Florida, and each fish was infected with between 2 and 25 individuals (Skinner 1974). *Bomolochus teres* and *B. exilipes* parasitized striped mullet in Texas (Pearse 1952, Causey 1953). *Naobranchia lizae* has been found on the gills of striped mullet in the Gulf of Mexico (Pearse 1952, Paperna and Overstreet 1981). The lernaeopodoidids *Clavellopsis robusta*, *Alella longimana*, and *Clavella inversa* have also been observed on striped mullet from the Gulf of Mexico (Pearse 1952, Paperna and Overstreet 1981).

Argulus flavescens and *A. floridensis* have been reported to infest mullet throughout the Gulf coast of the United States (Cressey 1972). The isopods *Ancinus depressus* and *Nerocila acuminata* parasitize striped mullet in Texas (Pearse 1952, Paperna and Overstreet 1981).

Monogenetic trematodes may be found on the gills and body of mullet. Gyrodactylids plague striped mullet in Florida (Skinner 1974). Paperna and Overstreet (1981) reported that the dactylogyrid *Ancyrocephalus vanbenedenii* infests mullet in the Gulf of Mexico. They also stated that of all the helminths parasitizing mullets, digenetic trematodes or flukes usually are the most abundant both in numbers of species and numbers of individuals.

At least two species of cestodes under the group-name *Scolex polymorphus* have been found in striped mullet. One parasite was discovered in the cystic duct of striped mullet from Mississippi and Florida, the other was found in the intestine of young fish from Mississippi (Paperna and Overstreet 1981). A *Rhinebothrium* sp. has also been documented from the mesentery of mullet in Mississippi (Paperna and Overstreet 1981).

The nematode *Contracacecum robustum* parasitizes the liver, kidneys, and adjacent tissues of striped mullet (Paperna and Overstreet 1981). *Hysterothylacim reliquens* and *Hysterothylacium* types MB and MD have been observed in striped mullet in the Gulf (Deardorff and Overstreet 1981).

The acanthocephalan, *Floridosentis elongatus*, has been found in the intestine of striped mullet from Florida to Texas, but it probably does not cause harm to mullet in their natural environment (Paperna and Overstreet 1981).

The leech *Myzobdella lugubris* has been found on *M. cephalus* from estuarine and freshwater habitats in all Gulf states (Sawyer *et al.* 1975). As discussed by Overstreet (1974) and Sawyer *et al.* (1975) leeches may be vectors for the protozoan parasites living in the blood of mullet and other fishes.

Glochidia larvae from freshwater clams (Unionidae) may parasitize striped mullet living in freshwater (Paperna and Overstreet 1981).

Diet deficiencies, the environment (including pollution), and genetic problems can cause atypically shaped mullet (Paperna and Overstreet 1981). Tumors have been observed in striped mullet from the northern Gulf of Mexico and Biscayne Bay, Florida (Sindermann 1972, Lightner 1974, Edwards and Overstreet 1976). Increased pollution was suggested by Edwards and Overstreet (1976) as the cause of these tumors.

Red tide caused by dinoflagellates or dinoflagellates in combination with bacteria have killed fishes along the Gulf of Mexico apparently by lowering the dissolved oxygen level when these organisms decompose. In addition, Ray and Wilson (1957) and Gates and Wilson (1960) noted that unialgal and axenic cultures of *Gymnodinium breve* and cultures of *Gonyaulax monilata* with bacteria produced one or more substances that were deadly to striped mullet.

3.1.2.4 Feeding, Prey, and Predators

According to de Silva (1980) most researchers now agree that larval mullet mainly eat microcrustaceans. Nash *et al.* (1974) grew larvae using cultured phytoplankton, rotifers, natural plankton, and *Artemia* (nauplii) and observed little nutritional use of phytoplankton. In Indian River Lagoon (Florida), stomach-content analyses were performed on nearly 400 mullet larvae

up to 35 mm SL. Larvae up to 15 mm SL ate almost exclusively copepods (70%) and mosquito larvae (30%); those in the 15-25 mm SL range consumed copepods (50%), mosquito larvae (15%), and plant debris (35%); and larvae 25-35 mm SL ingested mainly plant debris (80%) and copepods (10%) (Harrington and Harrington 1961). de Silva (1980) noted that mullet primarily eat phytoplankton at about 40 mm SL and are almost exclusively vegetarian bottom feeders at 50 mm SL. de Silva and Wijeyaratne (1977) discovered that the proportion of sand and detritus in the gut of fry increases with length for fish >25 mm TL indicating that they tend to take more food from the bottom as they grow older. Odum (1968a), however, found that mullet 35-80 mm in length fed on a bloom of the dinoflagellate *Kryptoperidinum* sp., and Futch (1976) stated that if non-toxic plankton blooms are available, mullet will feed almost entirely on the plankton.

Adult striped mullet have been classified as detritivorous, herbivorous, and interface feeders. The diet and feeding behavior of the fish can vary by site, but their predominant food is either epiphytic and benthic microalgae, macrophyte detritus, or inorganic sediment (Odum 1970 and Moore 1974).

Mullet frequently feed by sucking up the uppermost layer of sediment that is rich in detritus and microscopic algae and by ingesting the epifauna, epiphytes, and macrophytic detritus on seagrasses and other substrates (Collins 1981). Sediment may be used to grind food materials and aid digestion. Moore (1974) and Collins (1981) found that sediment, sand, and shell particles made up the majority of the stomach volume. Odum (1968b) reported that mullet select fine sediment less than 10μ when feeding and observed that these particles made up less than 30% of the sediment but 80% of the stomach contents. He suggested that these smaller particles are richer in organic materials, including bacteria, algae, and other microorganisms than larger sediment particles. Marais (1980) also noted selection of fine particles. Mullet also eat surface scum when large amounts of microalgae can be found at the air-water interface (Odum 1970). Bishop and Miglarese (1978) reported that mullet ingest polychaetes (*Nereis succinea*) in the water column. They also cited several observations where mullet consumed earthworms, macerated fish flesh, and benthic fauna. In some freshwater environments mullet were found to eat mostly benthic filamentous green algae, *Hydrodictyon reticulatum* and diatoms (Collins 1981).

Literature is variable regarding the times and stimuli for feeding. Odum (1970) found that in all the Florida habitats of his study, feeding varied with the height of the tide; however, Collins (1981) reported that in the saltwater (Cedar Key, Florida) and freshwater (Crystal River, Florida) locations of the study, feeding was diurnal with a peak around 11:00 a.m. and not related to tidal stage. de Silva and Wijeyaratne (1977) also noted nontide-related diurnal periodicity in feeding activity and peaks at dawn and around midday. Brusle (1970) also stated that striped mullet feed during the day; however, Tabb and Manning (1961) reported that mullet in Florida Bay often fed on flats at night and returned to channels in the daytime.

Thomson (1963) observed that the main predators of juvenile and adult mullet are other fishes and birds. Great blue heron (*Ardea herodias*) has been reported to feed on mullet (M. Van Hoose, personal communication). Bluefish, *Pomatomus saltatrix*, were reported to eat mullet (Olla and Samet 1974). Predation by spotted seatrout, *Cynoscion nebulosus*, has been recorded by Overstreet and Heard (1982), and Breuer (1957) reported that spotted seatrout ate mullet up to ½ to ⅔ their own body length. Sharks, *Eulamia floridanus* and *E. falciformis*, were reported predators of mullet (Springer 1957). Juvenile mullet have been found in the stomachs

of red drum (*Sciænops ocellatus*) and spotted seatrout (H. Blanchet, personal communication; Breuer 1957; Overstreet and Heard 1978).

3.1.3 Behavior

Mullet are known to form large, tightly-bunched schools, especially just prior to and during spawning (B. Mahmoudi, personal communication). School formation may also occur for other reasons. Hellier and Hoese (1962) observed a large school estimated at 335,500 individuals, 90-140 mm SL in Mesquite Bay, Texas, and attributed the school's formation to the onset of a severe cold front. Mahmoudi (1989) observed that large, pre-spawning schools congregated at or near the mouths of rivers, bays, and other tributaries and moved rapidly offshore with the passage of cold fronts. Outgoing tides and rain associated with some cold fronts may increase the size of schools (B. Mahmoudi, personal communication). After spawning offshore, schools have been observed to disperse and move to tributaries during spring and summer months. Thompson *et al.* (1991) reported that striped mullet congregate in increasingly larger schools as they move offshore from estuaries and appear to have "staging" areas where coalescence of schools occurs. Two observed areas of congregation were Lake Borgne and Breton Sound.

Mullet may form smaller schools during feeding. Olla and Samet (1974) studied the propensity for schooling and feeding of individual mullet both in view of and isolated from a school. They observed that mullet were attracted to schools and fed more often and more readily when exposed to a feeding school than any other time. The attraction stimulus for schooling was perhaps stronger than the feeding stimulus because isolated mullet fed more frequently than when exposed to a nonfeeding school.

Breder (1962) observed an apparent "parasite picking" behavior by *Lagodon rhomboides* on *M. cephalus* during a pre-spawning, "staging" period. McFarland and Moss (1967) observed changes in shape and breakups in schools of mullet. They recorded significant reductions in dissolved oxygen in the center/rear portions of large schools (sometimes in excess of 20%) and suggested that structural changes and break-ups were the result of group metabolism resulting in reduced dissolved oxygen.

According to Hoese (1985), *M. cephalus* seemed to have the same "air pumping" behavior as described for *Rhinomugil corsula* by Hora (1938) in which individuals of a school place much of the mouth, eye, and the upper part of the opercle above the surface. This behavior together with rolling or jumping is thought to move air into the posterior portion of the pharynx where it is utilized for aerial respiration. The main evidence for this hypothesis is that jumping frequencies are inversely correlated with dissolved oxygen concentrations, and the pharyngobranchial organ has the ability to hold gas.

Hoese (1985) stated that escape jumps from predators or when frightened can be distinguished from normal jumps because several disturbed fish jump together, and they maintain an upright posture on reentering the water. He stated that "the normal jump is slower and shorter, and the fish usually turns on its side or sometimes completely upside down before entering the water." He also stated that, "such easy jumps would not appear to be effective in

either removing parasites or escaping but would be the only way to irrigate the pharyngeal chamber with air with a small expenditure of energy."

3.1.4 Geographic Distribution and Migration

Striped mullet are found in coastal waters, roughly between 42° North and 42° South (Thomson 1963). They are present in the western Atlantic from Brazil to Nova Scotia (Hoese and Moore 1977) but absent from the Bahamas and most of the West Indies and Caribbean (Robins and Ray 1986). They are also found throughout the northern Gulf of Mexico.

In general mullet do not move or migrate extensively, and the greatest distance moved occurs during the fall and winter spawning migrations. Spawning migrations are triggered by cold fronts (Mahmoudi 1989). Environmental factors delaying and disrupting these migration movements include unseasonably warm waters in the fall and fall hurricanes (Thompson *et al.* 1991). Thomson (1963) reported that the timing of the offshore migration may vary as much as two months. Idyll and Sutton (1951) observed that migrations were not extensive in Florida with 90% of their tagged mullet moving less than 20 miles. Broadhead and Mefford (1956) recorded tagged mullet moving a maximum distance of 349 miles in Florida, but 90% of recaptures occurred within 20 miles. Mahmoudi (1990) noted that at least 9% to 17% of tagged mullet permanently moved from the region of release.

3.2 Description of the Habitat of the Stock Comprising the Management Unit

3.2.1 General Conditions

Striped mullet can be found in rivers, lakes, bays, bayous, and canals along the Gulf Coast and on barrier islands, in fresh, brackish, and saltwater (Franks 1970, Nordlie *et al.* 1982). They are also found in offshore, Gulf waters (Arnold and Thompson 1958). Mullet habitats vary greatly and may change with their particular life history stages. All size and age classes have been reported in Louisiana estuarine waters (Thompson *et al.* 1991). Gunter and Hall (1965) observed young (16-22 mm SL) first appearing outside the estuary in October and noted that they moved into the estuary as size increased peaking in abundance in January at 24-39 mm SL. Collins (1985) and Futch (1966) reported that larvae move inshore to shallow waters of bays and along beaches and later enter salt marshes and grassy areas. Thompson *et al.* 1991 noted that postlarval and juvenile striped mullet moved to lower salinity estuarine waters and became established in estuarine habitats in mid to late winter. Smaller juveniles preferred shallow, protected shorelines; tide pools; and marsh habitats (Collins 1985, Major 1978, Thompson *et al.* 1991). Although juveniles may move offshore with spawning adults, large numbers overwinter in estuaries where they spend most of their first year (Collins 1985). Perret *et al.* (1971) reported that striped mullet in Louisiana were more abundant in shallow waters near the shore. Seine collections produced fish during all months; however, the highest catches included postlarvae and juveniles in January.

3.2.2 Salinity, Temperature, and Other Requirements

Striped mullet are euryhaline and have been collected from salinities ranging from 0‰ to 75‰ in the Gulf (Breuer 1957, Simmons 1957, Franks 1970, Moore 1974, Collins 1981, Nordlie *et al.* 1982). Perret *et al.* (1971) collected mullet (15 to 465 mm TL) from salinities ranging from 0‰ to over 30‰ with largest catches taken from 5.0‰ to 19.9‰.

Survival of eggs appears greatest in full strength seawater (30‰-32‰) based on spawning observations (Arnold and Thompson 1958) and laboratory tests (Sylvester *et al.* 1975). Larvae, however, have shown optimum survival at slightly lower salinities, approximately 26 ppt (Sylvester *et al.* 1975). Juveniles (40-70 mm SL) are able to thrive in salinities similar to adults, *e.g.*, 0‰ to 35‰ (Nordlie *et al.* 1982).

Kilby (1949) collected young striped mullet from temperatures ranging from 13° to 34.5°C, and Franks (1970) reported mullet from 16° to 33°C. Perret *et al.* (1971) collected mullet with trawls and seines from temperatures ranging from 5.0° to 34.9°C. Eggs survived best at 22°C (Nash *et al.* 1974) and 22.7°-23.3°C (Sylvester and Nash 1975). Larvae preferred slightly higher temperatures, 24°-28°C (Babaian and Zaitsev 1964), 24.5°-25.3°C (Sylvester and Nash 1975) and 22.8°-23.5°C (Sylvester *et al.* 1975). Optimum temperatures for juveniles less than 50 mm SL were 30°-32.5°C and 19.5°-20°C for fish 50 to 130 mm SL (Collins 1985). Older juveniles tended to have thermal tolerances similar to adults with a range from about 10.4° to 33.0°C (Sylvester *et al.* 1974, Martin and Drewry 1978). The lowest water temperature from which mullet were reported was 4.5°C (Moore 1976). Moore (1974) collected a striped mullet from 36°C and noted that 37°C was probably their upper critical temperature.

Sylvester *et al.* (1975) observed that mullet eggs and larvae apparently cannot live in waters with dissolved oxygen (DO) levels below 4.0 ppm. Survival was greatest at 5.0 ppm and above for eggs and 7.9 ppm for larvae. They noted that these levels were at or above saturation, but there was no evidence of gas bubble disease. Although sizes were not given, Collins (1985) reported survival of fish in cages at a DO concentration of 4.4 ppm with temperature at 29°C and salinity at 28‰.

3.2.3 Pollution

Because mullet spend the majority of their lives in nearshore and estuarine waters and are bottom feeders, they are highly subject to exposure to numerous pollutants including pesticides, heavy metals, dioxins, and other elements and compounds. Pesticides concentrate in mullet tissues, especially those containing lipids (Paperna and Overstreet 1981). The authors also reported that mullet can die from the rapid release of high levels of pesticides from stored fat into the blood during periods of starvation.

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4.0 FISHERY MANAGEMENT JURISDICTIONS, LAWS, AND POLICIES AFFECTING THE STOCK

4.1 Management Institutions

Striped mullet are found in a wide variety of habitats ranging from freshwater river systems, associated estuaries, and the open Gulf of Mexico. Because of this variance in geographic range, mullet are directly and indirectly affected by numerous state and federal management institutions through their administration of state and federal laws, regulations, and policies. The following is a partial list of some of the more important agencies, laws, and regulations that affect striped mullet and their habitat. These may change at any time; however, individual Gulf States are directly responsible for the management of mullet, and they should be contacted for specific and current state laws and regulations.

4.1.1 Federal

Although mullet are found in the exclusive economic zone (EEZ) of the Gulf of Mexico, they are most abundant in state waters. The commercial and recreational fisheries occur almost exclusively in state management jurisdictions. Consequently, laws and regulations of federal agencies primarily influence mullet abundance by maintaining and enhancing habitat, preserving water quality and food supplies, and abating pollution. Federal laws may also affect consumers through the development of regulations to protect product quality.

4.1.1.1 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 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 miles from the (inner) baseline of the territorial sea. Management of fisheries in the EEZ is based on fishery management plans 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 as federal regulation through the Department of Commerce (DOC).

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

The Gulf of Mexico Fishery Management Council has not developed a management plan for striped mullet. Furthermore, no significant fishery for mullet is known to exist in the EEZ of the U.S. Gulf of Mexico.

4.1.1.2 National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Department of Commerce (DOC)

The Secretary of Commerce, acting through the NMFS, has the ultimate authority to approve or disapprove all fishery management plans 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. It performs research and conducts management authorized by international treaties. The NMFS has the authority to enforce the Magnuson Act and Lacey Act and is the federal trustee for living and nonliving natural resources in coastal and marine areas.

The NMFS exercises no management jurisdiction other than enforcement with regard to striped mullet in the Gulf of Mexico. It conducts some research and data collection programs and comments on all projects that affect marine fishery habitat.

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

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 mullet could be directly affected by such plans.

The OCRM may influence fishery management for mullet 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 mullet depend.

4.1.1.4 National Park Service (NPS), Department of the Interior (DOI)

The NPS under the DOI may regulate fishing activities within park boundaries. Such regulations could affect mullet harvest if implemented within a given park area. The NPS has developed regulations preventing commercial fishing within one mile of the barrier islands in the Gulf Islands National Seashore off Mississippi.

4.1.1.5 Fish and Wildlife Service (FWS), DOI

The FWS has little direct management authority over mullet. The ability of the FWS to affect the management of mullet is based primarily on the Fish and Wildlife Coordination Act, under which the FWS, in conjunction with the NMFS, reviews and comments on proposals to alter habitat. Dredging, filling, and marine construction are examples of projects that could affect mullet habitat.

In certain refuge areas, the FWS may directly regulate fishery harvest. Here the harvest is usually restricted to recreational limits developed by the respective state. Special use permits may be required if commercial harvest is to be allowed in refuges.

4.1.1.6 Environmental Protection Agency (EPA)

The EPA through its administration of the Clean Water Act and the National Pollutant Discharge Elimination System (NPDES) may provide protection to mullet habitat. Applications for permits to discharge pollutants into estuarine waters may be disapproved or conditioned to protect resources on which mullet and other species rely.

4.1.1.7 Corps of Engineers (COE), Department of the Army (DOA)

The abundance of mullet may be influenced by the COE's responsibilities pursuant to the Clean Water Act and Section 10 of the Rivers and Harbors Act. Under these laws, the COE issues or denies permits to individuals and other organizations for proposals to dredge, fill, and construct in wetland areas and navigable waters. The COE is also responsible for planning, construction, and maintenance of navigation channels and other projects in aquatic areas. Such projects could affect mullet habitat and subsequent populations.

4.1.1.8 United States Coast Guard

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

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

4.1.1.9 The United States Food and Drug Administration (FDA)

The FDA may directly regulate the harvest 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.

4.1.2 State

Table 4.1 outlines the various state management institutions and authorities.

4.1.2.1 Florida Department of Environmental Protection and Florida Marine Fisheries Commission

Florida Department of Environmental Protection
Division of Marine Resources
3900 Commonwealth Boulevard
Tallahassee, Florida 32303
Telephone: (904) 488-6058

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Table 4.1. State management institutions - Gulf of Mexico.

	Administrative body and its responsibilities	Administrative policy-making body and decision rule	Legislative involvement in management regulations
FLORIDA	DEPARTMENT OF ENVIRONMENTAL PROTECTION · administers management programs · enforcement · conducts research · makes recommendations to legislature and Marine Fisheries Commission	MARINE FISHERIES COMMISSION · creates rules that must be approved by the governor and cabinet · seven member commission	· can override any rule of the commission · responsible for licensing, management of fishing in man-made canals and limited entry
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 DEPARTMENT OF WILDLIFE, FISHERIES AND PARKS · 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 and commission	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 · granted authority to regulate seasons, bag limits, size limits, and possession limits	· 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

Florida Marine Fisheries Commission
2540 Executive Center Circle West, Suite 106
Tallahassee, FL 32301
Telephone: (904) 487-0554

The agency charged with the administration, supervision, development, and conservation of natural resources is the Florida Department of Environmental Protection (FDEP) headed by the Governor and Cabinet. The Governor and Cabinet serve as the seven-member board that approves or disapproves all rules and regulations promulgated by the FDEP. The administrative head of the FDEP is the Secretary. Within the FDEP, the Division of Marine Resources (through Section 370.02(2), Florida Statutes) is empowered to conduct research directed toward management of marine and anadromous fisheries in the interest of all people of Florida. The Division of Law Enforcement is responsible for enforcement of all marine, resource-related laws and all rules and regulations of the department.

The Florida Marine Fisheries Commission (FMFC), a seven-member board appointed by the Governor and confirmed by the Senate, was created by the Florida legislature in 1983. This commission was delegated rule-making authority over marine life in the following areas of concern: gear specification; prohibited gear; bag limits; size limits; species that may not be sold; protected species; closed areas; seasons; quality control codes, with the exception of specific exemptions for shellfish; and special considerations relating to oyster and clam relaying. All rules passed by the commission require approval by the Governor and Cabinet. The commission does not have authority over endangered species, license fees, penalty provisions, or regulation of fishing gear in residential, saltwater canals.

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

4.1.2.2 Alabama Department of Conservation and Natural Resources

Alabama Department of Conservation and Natural Resources (ADCNR)
Alabama Marine Resources Division (AMRD)
P.O. Box 189
Dauphin Island, Alabama 36528
Telephone: (205) 861-2882

Management authority for fishery resources in Alabama is held by the Commissioner of the Department of Conservation and Natural Resources. The Commissioner may promulgate rules or regulations designed for the protection, propagation, and conservation of all seafood. He may prescribe the manner of taking, times when fishing may occur, and designate areas where fish may or may not be caught; however, all regulations are to be directed at the best interest of the seafood industry.

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 regulations other than those of an emergency nature. Among this series of events are:

(1) the advertisement of the intent of the regulation, (2) a public hearing for the regulation, (3) a 35-day waiting period following the pubic hearing to address comments from the hearing, and (4) a final review of the regulation by a joint house and senate review committee.

Alabama also has the Alabama Conservation Advisory Board (ACAB) that provides advice on policies of the ADCNR. The board consists of the governor, the ADCNR commissioner, and ten board members.

The AMRD has responsibility for enforcing state laws and regulations, for conducting marine biological research, and for serving as the administrative arm of the commissioner with respect to marine resources. The division recommends regulations to the commissioner.

Alabama has a habitat protection and permitting program and a federally approved CZM program.

4.1.2.3 Mississippi Department of Marine Resources

Mississippi Department of Marine Resources (MDMR)
152 Gateway Drive
Biloxi, Mississippi 39531
Telephone: (601) 385-5860

The 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).

Mississippi has a habitat protection and permitting program and a federally approved CZM program.

4.1.2.4 Louisiana Department of Wildlife and Fisheries

Louisiana Department of Wildlife and Fisheries (LDWF)
P.O. Box 98000
Baton Rouge, Louisiana 70898
Telephone: (504) 765-2800

The LDWF is one of 21 major administrative units of the Louisiana government. A seven-member board, the Louisiana Wildlife and Fisheries Commission (LWFC), is appointed by the Governor. 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 Secretary is appointed by the Governor with consent of the Senate.

Within the administrative system, an Assistant Secretary is in charge of the Office of Fisheries. In this office, a Marine Fisheries Division (headed by the Division Administrator) performs "the functions of the state relating to the administration and operation of programs, including research relating to oysters, waterbottoms, and seafood including, but not limited to, the regulation of oyster, shrimp, and marine fishing industries." (Louisiana Revised Statutes 36:609). The Enforcement Division in the Office of the Secretary is responsible for enforcing all marine fishery statutes and regulations.

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

4.1.2.5 Texas Parks and Wildlife Department

Texas Parks and Wildlife Department
Coastal Fisheries Branch
4200 Smith School Road
Austin, Texas 78744
Telephone: (512) 389-4863

The Texas Parks and Wildlife Department is the administrative unit of the state charged with management of the coastal fishery resources and enforcement of legislative and regulatory procedures under the policy direction of the Texas Parks and Wildlife Commission. 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 are named by the Executive Director. The Coastal Fisheries Division, headed by a Division Director, is under the supervision of the Executive Director.

4.2 Treaties and Other International Agreements

There are no treaties or other international agreements that affect the harvesting or processing of mullet. No foreign fishing applications to harvest mullet have been submitted to the United States Government.

4.3 Federal Laws, Regulations, and Policies

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

4.3.1 Magnuson Fishery Conservation and Management Act of 1976 (MFCMA)

The MFCMA mandates the preparation of fishery management plans 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.

4.3.2 Federal Aid in Sport Fish Restoration Act (SFRA); the Wallop-Breaux Amendment of 1984

The SFRA provides funds to states, the USFWS, and the GSMFC to conduct research, planning, and other programs geared at enhancing and restoring marine sportfish populations.

4.3.3 Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA), Titles I and III and The Shore Protection Act of 1988 (SPA)

The MPRSA provides protection of fish habitat through the establishment and maintenance of marine sanctuaries. The MPRSA and the SPA acts 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.

4.3.4 Federal Food, Drug, and Cosmetic Act of 1938 (FDCA)

The FDCA prohibits the sale, transfer, and importation of "adulterated" or "misbranded" products. Adulterated products may be defective, unsafe, filthy, or produced under unsanitary conditions. Misbranded products may have false, misleading, or inadequate information on their labels. In many instances the FDCA also requires FDA approval for distribution of certain products.

4.3.5 Clean Water Act of 1981 (CWA)

The CWA requires that an EPA 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 to marine fishery resources and may alter habitats.

Under Section 404 of the CWA the Corps of Engineers 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 effect marine populations. The NMFS is the federal trustee

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for living and nonliving natural resources in coastal and marine areas under United States jurisdiction pursuant to the CWA.

4.3.6 Federal Water Pollution Control Act of 1972 (FWPCA) and MARPOL Annexes I and II

Discharge of oil and oily mixtures is governed by the Federal Water Pollution Control Act (FWPCA) and 40 Code of Federal Regulations (CFR), Part 110, in the navigable waters of the U.S. Discharge of oil and oily substances by foreign ships or by U.S. ships operating or capable of operating beyond the U.S. territorial sea is governed by MARPOL Annex I.

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 12 nautical miles of land and at depths of less than 25 meters.

4.3.7 Coastal Zone Management Act of 1972 (CZMA), as amended

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.

4.3.8 Endangered Species Act of 1973, as amended

The Endangered Species Act provides for the listing of plant and animal species that are threatened or endangered. 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 existence of these species or result in destruction or modification of habitats that are determined by the Secretary of the DOI to be critical.

4.3.9 National Environmental Policy Act of 1970 (NEPA)

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 an environmental impact statement (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.

4.3.10 Fish and Wildlife Coordination Act of 1958

Under the Fish and Wildlife Coordination Act, the FWS and NMFS review and comment on fish and wildlife aspects of proposals for work and activities sanctioned, permitted, assisted, or conducted by federal agencies that take place in or affect navigable waters, wetlands, or other

critical fish and wildlife habitat. The review focuses on potential damage to fish, wildlife, and their habitat; therefore, it provides protection to fishery resources from activities that may alter critical habitat in nearshore waters. The act is important because federal agencies must give due consideration to the recommendations of the FWS and NMFS.

4.3.11 Fish Restoration and Management Projects Act of 1950

Under this act, the DOI is authorized to provide funds to state fish and game 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.

4.3.12 Lacey Act of 1981, as amended

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.

4.3.13 Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or "Superfund")

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

4.3.14 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, 1973/78. Regulations under this act prohibit ocean discharge of plastics from ships, restrict discharge of other types of floating ship's garbage (packaging and dunnage) for up to 25 nautical miles from any land, restrict discharge of victual and other recomposable waste up to 12 nautical miles 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.

4.3.15 Fish and Wildlife Act of 1956

This act provides assistance to states in the form of law enforcement training and cooperative law enforcement agreements. It also allows for disposal of abandoned or forfeited property with some equipment being returned to states. The act prohibits airborne hunting and fishing activities.

4.4 State Authority, Laws, Regulations, and Policies

Table 4.2 shows a summary of selected regulations for each of the five Gulf States. These are not exhaustive, and each state should be contacted for a complete and up-to-date list of regulations.

4.4.1 Florida

4.4.1.1 Legislative Authorization

Prior to 1983, the Florida Legislature was the primary body that enacted laws regarding management of mullet 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 including mullet.

4.4.1.2 Reciprocal Agreements and Limited Entry Provisions

4.4.1.2.1 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.

4.4.1.2.2 Limited Entry

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

4.4.1.3 Commercial Landings Data Reporting Requirements

On a monthly basis, processors are required to report the volume and price of all saltwater products received and sold. These data are collected and published by the Florida Department of Environmental Protection, Marine Fisheries Information System.

4.4.1.4 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 for violation of such laws or regulations, the license holder is required to show just cause as to reasons why his saltwater license should not be suspended or revoked.

Table 4.2. Summary of Gulf States' striped mullet regulations.

Regulation	Florida	Alabama	Mississippi	Louisiana	Texas
Size Limits					
Commercial	11" FL minimum	none	10" TL minimum	none	12" TL maximum
Recreational	none	none	none	none	12" TL maximum
Gear Restrictions					
Purse seines	prohibited	prohibited		prohibited	prohibited
-minimum mesh size			1" stretched		
-maximum length			1,500 feet		
Gill & Trammel Nets	prohibited				prohibited
(roe season)					
-minimum mesh size		1 7/8" bar	3 1/2" stretched*	3 1/2 stretched*	
-maximum length		2,400 feet	1,200 feet	1,200 feet	
(preroe season)					
-minimum mesh size		1 3/4" bar	3" stretched*		
-maximum length		2,400 feet	1,200 feet		
(nonroe season)					
-minimum mesh size		1 3/4" bar*	3" stretched*		
-maximum length		2,400 feet	1,200 feet		
Possession Limits					
Commercial					
-roe season	none	none	none	none	none
-preroe season*			none	closed	none
-nonroe season			none	closed	none
Recreational	50/person or vessel	25/person or vessel	none	100 lbs/vessel	none
Closed Areas	yes*	yes*	yes*	yes*	no
Closed Seasons	yes*	yes*	no	yes*	no
Data Reporting Required	yes*	yes*	yes*	yes*	yes*
Licenses Required					
Commercial	yes*	yes*	yes*	yes*	yes*
Recreational	yes*	yes*	yes*	yes*	yes*

*see state regulations

4.4.1.5 Annual License Fees

Resident wholesale seafood dealer	
• county	$ 300.00
• state	450.00
Nonresident wholesale seafood dealer	
• county	500.00
• state	1,000.00
Alien wholesale seafood dealer	
• county	1,000.00
• state	1,500.00
Resident retail seafood dealer	25.00
Nonresident retail seafood dealer	200.00
Alien retail seafood dealer	250.00
Saltwater products license	
• resident-individual	50.00
• resident-vessel	100.00
• nonresident-individual	200.00
• nonresident-vessel	400.00
• alien-individual	300.00
• alien-vessel	600.00
Recreational saltwater fishing license	
• resident	
10 day	11.50
annual	13.50
• nonresident	
3 day	6.50
7 day	16.50
annual	31.50
Annual commercial vessel saltwater fishing license (recreational for hire)	
• 11 or more customers	801.50
• 5-10 customers	401.50
• 4 or less customers	201.50
Optional pier saltwater fishing license (recreational users exempt from other licenses)	501.50
Optional recreational vessel license (recreational users exempt from other licenses)	3,001.50

4.4.1.6 Laws and Regulations

Florida's laws and regulations regarding the harvest of mullet vary by region and body of water fished. Variances are most notable for gear, seasons, and daily quotas for the commercial fishery. In discussing these restrictions footnotes are used to describe the regions and waterbodies to which specific regulations apply. These discussions are also general summaries of laws and regulations; therefore, the FDNR or the Florida Marine Patrol should be contacted for more specific information. The restrictions discussed in this FMP are current to the date of this publication and are subject to change at any time thereafter.

4.4.1.6.1 Size Limits

A minimum size of eleven (11) inches FL is established for the commercial mullet fishery; however, 10% of the total whole weight of mullet in possession at any given time may be undersized. There is no maximum size limit for the commercial fishery, and there are no size limits in effect for the recreational mullet fishery.

4.4.1.6.2 Gear Restrictions

Gill nets, trammel nets, pound nets, and other entangling nets are prohibited, and only nonentangling nets of 500 square feet or less (as defined by regulations) may be used in Florida waters. Purse seines are only allowed in nonfood-fish fisheries.

4.4.1.6.3 Closed Areas and Seasons

The commercial harvest of mullet is prohibited in all Florida waters seaward of three nautical miles. Both commercial and recreational fishing is prohibited from the fourth Friday of December for a period of ten days.

In the Lake Okeechobee Region[1] the harvest of mullet is prohibited in all waters of the Okeechobee Waterway in Martin County (South Fork St. Lucie River, St. Lucie Canal) between the State Road 714 bridge at Palm City, Florida, and Lake Okeechobee. It is also prohibited in all waters of the Okeechobee Waterway in Hendry and Glades Counties (Caloosahatchee Canal) between the Lee-Hendry County Line and Lake Okeechobee.

[1]"Lake Okeechobee Region" means all waters of Lake Okeechobee, the Okeechobee Waterway in Martin County (South Fork St. Lucie River, St. Lucie Canal) between the State Road 714 bridge at Palm City, Florida, and Lake Okeechobee, and the Okeechobee Waterway in Hendry and Glades Counties (Caloosahatchee Canal) between the Lee-Hendry County Line and Lake Okeechobee.

In the Collier-Monroe Gulf Region[2] the harvest of mullet for commercial purposes is prohibited offshore of the Everglades National Park Line.[3]

4.4.1.6.4 Quotas and Bag/Possession Limits

A daily bag/possession limit of 50 fish per person or vessel (whichever is less) is established for the recreational fishery in all Florida waters. Commercial fishermen are required to have a "Restricted Species Endorsement"[4] to their saltwater products license in order to possess mullet in excess of the daily bag/possession limit, except in the Panhandle Region where only the saltwater products license is needed. Additionally, a 500 lb/day quota is effective during July, August, and September of each year.

4.4.1.6.5 Other Restrictions

Aircraft may not be used in conjunction with fishing operations for mullet.

4.4.2 Alabama

4.4.2.1 Legislative Authorization

Chapters 2 and 12 of Title 9, Code of Alabama, contain statutes that affect marine fisheries.

4.4.2.2 Reciprocal Agreements and Limited Entry Provisions

4.4.2.2.1 Reciprocal Agreements

Alabama statutory authority provides for reciprocal agreements with regard to access and licenses. Alabama has no statutory authority to enter into reciprocal management agreements.

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[2]"Collier-Monroe Gulf Region" means all state waters of the Gulf of Mexico in Collier and Monroe Counties, shoreward of the three nautical mile line until it intersects the Everglade National Park Line, thereafter shoreward of the Everglades National Park Line until it intersects the three mile line, thereafter shoreward of the three nautical mile line.

[3]The "Everglades National Park Line" means a line commencing at a point on the three nautical mile line due southwest of the West Pass Marker, 81°31'12"W longitude, 25°49'03"N latitude, thereafter going due northeast to the West Pass Marker, thereafter going in a southerly direction following the Western boundary of the Everglades National Park to the lighted buoy #2 at 80°52.9'W longitude, 24°52.3'N latitude, thereafter 240° True (or 242° magnetic) to the three nautical mile line where it terminates.

[4]"Restricted Species Endorsement" requires commercial fishermen to show by *bona fide* means (*i.e.*, trip tickets, sales receipts, etc.) that a minimum of $5,000 of their gross income has come from the sale of "restricted species" during at least one of the past three years.

4.4.2.2.2 Limited Entry

Alabama law provides that commercial net and seine permits shall only be issued to applicants who purchased such licenses in two of five years from 1989 through 1993 and who show proof (in the form of both federal and Alabama state income tax returns) that they derived at least 50% of their gross income from the capture and sale of seafood species in two of the five years; or applicants that purchased such licenses in all five years and who (unless exempt from filing Alabama income tax law) filed Alabama income tax returns in all five years. Other restrictions are applicable, and the ADCNR, MRD should be contacted for details.

4.4.2.3 Commercial Landings Data Reporting Requirements

Alabama law requires that wholesale seafood dealers file monthly reports by the tenth of each month for the preceding month. Under a cooperative agreement, records of sales of seafood products are now collected jointly by NMFS and ADCNR port agents.

4.4.2.4 Penalties for Violations

Violations of the provisions of any statute or regulation are considered Class C misdemeanors and are punishable by fines up to $500 and up to 3 months in jail.

4.4.2.5 Annual 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 dealer licenses may vary based on the charge for similar fishing activities in the applicant's resident state.

Commercial hook and line	
• resident	$ 26.00
• nonresident	51.00
Gill nets, trammel nets, seines* (up to 2,400 feet) Commercial	
• resident	301.00
• nonresident	1,500.00
Roe mullet/Spanish mackerel endorsement**	
• resident	501.00
• nonresident	2,500.00
Recreational gill net	
• resident	51.00
• nonresident	variable
Recreational saltwater fishing license	
• resident	16.00
• nonresident	variable

Seafood dealer***	
• resident	126.00
• nonresident	variable

*Seines 25 feet or less in length are exempt from licensing.
**Required in addition to gill net license.
***Required for cast nets if used commercially.

4.4.2.6 Laws and Regulations

Alabama laws and regulations regarding the harvest of mullet primarily address the type of gear used and seasons for the commercial fishery. 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 ADCNR, MRD should be contacted for specific and up-to-date information.

4.4.2.6.1 Size Limits

Alabama has no minimum or maximum size limit for mullet in either the commercial or recreational fishery.

4.4.2.6.2 Gear Restrictions

Gill nets must be marked every 100 feet with a color contrasting float and every 300 feet with the fisherman's permit number. Recreational nets may not exceed 300 feet in length and must be marked with the licensee's name and license number. Commercial gill nets, trammel nets, and other entangling nets may not exceed 2,400 feet in length; however, depth may vary by area.

During the period January 1 through October 31 of each year, gill nets, trammel nets, and other entangling nets used to catch any fish in Alabama coastal waters must have a minimum mesh size of 1 3/4" bar (knot to knot). A minimum mesh size of 1 7/8" bar is required for such nets used to take mullet during the period October 24 through December 31 of each year for all Alabama coastal waters under the jurisdiction of the MRD as provided in Rule 220-2-42 and defined in Rule 220-3-04(1), and only strike nets may be used in certain waters of Bon Secour Bay during this period. Any person using a 1 7/8" bar net during the period October 24 through December 31 of each year shall be considered a roe mullet fisherman and must possess a roe mullet permit. These net-size restrictions do not apply to coastal rivers, bayous, creeks, or streams. In these areas (with the exception of Delvan Bay, Grand Bay, Polecat Bay, and those portions of the Blakely and Apalachee Rivers south of the I-I0 Causeway), the minimum mesh size shall be 6" stretched mesh. The minimum mesh for nets used in these excepted areas shall be generally the same as previously described by season for other coastal waters.

The use of purse seines to catch mullet is prohibited. Commercial and recreational gill net fishermen may use only one net at any time; however, commercial fishermen may possess more than one such net. No hook and line device may contain more than five hooks when used in Alabama salt waters.

4.4.2.6.3 Closed Areas and Seasons

Gill nets, trammel nets, seines, purse seines, and other entangling nets are prohibited in any marked navigational channel, Theodore Industrial Canal, Little Lagoon Pass, or any man-made canal; within 300 feet of any man-made canal or the mouth of any river, stream, bayou, or creek; and within 300 feet of any pier, marina, dock, boat launching ramp, or certain "relic" piers. Recreational gill nets may not be used beyond 300 feet of any shoreline, and they may not extend into the water beyond the end of any adjacent pier or block ingress or egress from any of the aforementioned structures.

From January 1 through October 1 of each year, gill nets, trammel nets, seines, haul seines, and other entangling nets are prohibited within 0.25 miles of shore, except (and subject to other provisions) waters east of longitude 87°59' which will be open from 6:00 p.m. to 6:00 a.m. each day from March 15 through the Thursday before Memorial Day. From October 2 through December 31 only mullet may be caught with 1 7/8" minimum mesh nets in these waters during these hours.

From January 1 through the day after Labor Day of each year, entangling nets are prohibited in certain waters in and around Dauphin Island. From the first day after Labor Day through October 23 of each year, possession of mullet aboard a boat with net gear is prohibited north of the Intercoastal Waterway, east of the Dauphin Island Bridge, and west of the Bon Secour River Channel.

4.4.2.6.4 Quotas and Bag/Possession Limits

A possession limit of 25 fish per person or vessel (whichever is less) is established for snagging and cast net fishermen during the period October 24 through December 31 of each year and at all times for vessels with entangling nets onboard in areas closed to gill nets.

4.4.2.6.5 Other Restrictions

It is illegal to remove the roe or otherwise process roe mullet aboard any boat or vessel in Alabama. All nets must be constantly attended by the licensee and no dead fish or other dead seafood may be discarded within three miles of the Gulf beaches; within 500 feet of any shoreline; or into any river, stream, bayou, or creek.

4.4.3 Mississippi

4.4.3.1 Legislative Authorization

Title 49, Chapter 15 of the Mississippi Code of 1972, annotated, contains various restrictions regarding the harvest of marine species. This chapter also authorizes the Mississippi Department of Marine Resources to promulgate regulations effecting the harvest of marine fishery resources. Title 49, Chapter 27 contains the Wetlands Protection Act, and its provisions are also administered by the MDMR.

4.4.3.2 Reciprocal Agreements and Limited Entry Provisions

4.4.3.2.1 Reciprocal Agreements

Section 49-15-15 provides statutory authority for the MDMR to enter into interstate and intrastate agreements for the purposes of protecting, propagating, or conserving seafood. Such agreements may provide for reciprocal agreements for licensing, access, or management provided that they do not conflict with other statutes.

4.4.3.2.2 Limited Entry

Section 49-15-29(3) prohibits a nonresident from purchasing a commercial license if the nonresident's state of domicile likewise prohibits the sale of such license to a Mississippi resident. By regulation, the MDMR limits the sale of gill and trammel net licenses to persons, firms, or corporations that previously purchased such a license in any year from May 1, 1990 through April 30, 1995.

4.4.3.3 Commercial Landings Data Reporting Requirements

Ordinance Number 9.001 of the MDMR establishes reporting requirements for various fisheries and types of fishery operations. It also provides for confidentiality of data and penalties for falsifying or refusing to supply such information.

4.4.3.4 Penalties for Violations

Penalties for violations of Mississippi laws and regulations regarding mullet are provided in Section 49-15-63, Mississippi Code of 1972, annotated.

4.4.3.5 Annual License Fees

The following is a list of license fees for activities related to the capture, sale, or transport of mullet. They are currently only to the date of publication and may change at any time. Nonresident fees may vary based on the charge for similar fishing activities in the applicant's state of residence.

Commercial hook and line	$100.00
Charter boats and party boats	200.00
Trammel nets, gill nets and seines*	
• resident	100.00
• nonresident	300.00
Purse seine (other than menhaden)	
• resident	100.00
• nonresident	300.00
Seafood processor	200.00
Wholesale dealers	100.00

*Small mesh beach seines (less than ¼" bar, ½" stretched mesh) that do not exceed 100 feet in length are exempt from licensing.

4.4.3.6 Laws and Regulations

Ordinance Number 5.012 of the MDMR contains regulations regarding the harvest of mullet from Mississippi territorial and inland 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 MDMR should be contacted for specific and up-to-date information.

4.4.3.6.1 Size Limits

A minimum size limit of 10" TL is established for the commercial mullet fishery. There is no maximum size limit, and there are no size restrictions on recreational harvests.

4.4.3.6.2 Gear Restrictions

Gill nets, trammel nets, and seines (other than purse seines) that are used to capture mullet must have a minimum mesh size of 1½" bar, 3" stretched, except that from October 15 to December 15 of each year when said nets must have a minimum mesh size of 3½" stretched. These nets may not exceed 1,200 feet in length, and nets may not be fished within ¼ mile of another such net. Nets must be marked by visible buoys every 100 feet containing the owners license number or full name. No boat or vessel may carry more than one such net. Purse seines must have a minimum mesh size of ½" bar, 1" stretched, and they may not exceed 1,500 feet in length.

4.4.3.6.3 Closed Areas and Seasons

Commercial fishing is prohibited in all waters north of the CSX railroad bridge. Gill nets, trammel nets, purse seines, and other commercial nets may not be used within 1,200 feet of any public pier or hotel/motel pier, and they are prohibited within 300 feet of private piers that are at least 75 feet in length. These nets are also prohibited within 1,200 feet of the shoreline of Deer Island and within 1,500 feet of the shoreline between the U.S. Highway 90 bridge and the north shore of Bayou Caddy in Hancock County. The aforementioned nets are also prohibited in and within 100 feet of the mouth of rivers, bays, bayous, streams, lakes, and other tributaries to Mississippi saltwaters, except as follows:

Point aux Chenes Bay, Middle Bay, Jose Bay, L'Isle Chaude, Heron Bay, South Rigolett, Pascagoula Bay (south of the CSX railroad), and Biloxi Bay (south of a line between Marsh Point and Grand Bayou). They must not be used in a manner that would block any of these bays, bayous, rivers, streams, or other tributaries.

State regulations prohibit the use of gill nets, trammel nets, purse seines, and other commercial nets within 1 mile of the shoreline of Cat Island, Ship Island, Horn Island, Petit Bois Island, Round Island, and the shoals of Telegraphy Keys and Telegraph Reef from

May 15 to September 15 of each year. Federal regulations prohibit any commercial fishing within the Gulf Islands National Seashore (Ship, Horn, and Petit Bois Islands).

Purse seines are prohibited within 1 mile of the shoreline in Harrison and Hancock counties. Recreational cast nets may be used only in waters south of Interstate Highway 10.

There are no closed seasons for mullet fishing in Mississippi; however, various time closures have been implemented. Gill nets and trammel nets may not be used within ½ mile of the shoreline from Bayou Caddy in Hancock County to Marsh Point in Ocean Springs (Jackson County) from 6:00 a.m. to 6:00 p.m. and within ¼ mile from 6:00 p.m. to 6:00 a.m. The use of these nets is also prohibited from 6:00 a.m. to 6:00 p.m. on all legal holidays and from 6:00 a.m. on Saturday to 6:00 p.m. on Sunday in all marine waters of Mississippi.

4.4.3.6.4 Quotas and Bag/Possession Limits

There are no quotas, bag limits, or possession limits in effect for the mullet fishery in Mississippi.

4.4.3.6.5 Other Restrictions

While engaged in "mullet fishing," each set of a commercial net may not produce in excess of 10% by weight of species other than mullet. Commercial nets must be attended with at least one person located within the boat's length of the net at all times while it is in the water.

4.4.4 Louisiana

4.4.4.1 Legislative Authorization

Title 56, Louisiana Revised Statutes (L.R.S.) contains statutes adopted by the Legislature that govern marine fisheries in the state and that empower LWFC to promulgate rules and regulations regarding fish and wildlife resources of the state. Title 36, L.R.S. creates the LDWF and designates the powers and duties of the department. Title 76 of the Louisiana Administrative Code contains rules and regulations adopted by the LWFC and the LDWF that govern marine fisheries.

Section 333 of Title 56, L.R.S. authorizes the LWFC to promulgate rules for the harvest of mullet including daily take and possession limits, permits, and other aspects of harvest. Additionally, the LWFC has authority to set possession limits, quotas, locations, seasons, size limits, and daily take limits for all freshwater and saltwater finfishes based upon biological and technical data.

4.4.4.2 Reciprocal Agreements and Limited Entry Provisions

4.4.4.2.1 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 commission is also authorized to enter into reciprocal licensing agreements.

4.4.4.2.2 Limited Entry

Section 333 of Title 56, L.R.S. as amended by the 1995 Legislative Session provides that mullet permits may only be issued to persons who have held a Louisiana saltwater gill net license in two of the years 1993, 1994, and 1995; has derived more than 50% of his earned income from capture and sale of seafood species in two of those years; and has not applied for economic assistance for training under 56:13.1(C). Any person convicted of any offense involving fisheries law shall be forever barred from receiving any such permit or license.

4.4.4.3 Commercial Landings Data Reporting Requirements

Wholesale/retail dealers who purchase mullet from fishermen are required to report those purchases by the tenth of the following month. Commercial fishermen who sell mullet directly to consumers must report the previous month's sales. As of August 1995, mullet permit holders must report the pounds of mullet taken during the previous month and the dealers to whom these were sold for each month of the open mullet season.

4.4.4.4 Penalties for Violations

Violations of Louisiana laws and regulations regarding mullet are all Class 3. First offenses are punishable by fines of $250-$500 or up to 90 days in jail or both. Second offense convictions carry fines from $500-$800 and 60-90 days in jail with forfeiture of all equipment involved with the illegal activity, and third offense violations have fines ranging from $750-$1,000, 90-120 days in jail and forfeiture of equipment. As of August 1995, any person convicted of any offense involving fisheries law shall forfeit any permit or license to take mullet. They are then forever barred from entering the fishery. Civil penalties may also be imposed, especially for restitution.

4.4.4.5 Annual License Fees

The following is a list of license fees that are current to the date of this publication. They are subject to change any time thereafter. Also, nonresident fees may vary based on the charge for similar fishing activities in the applicant's state of residence.

Commercial	
Commercial fisherman license	
• resident	$ 55.00
• nonresident	400.00
Vessel license	
• resident	15.00
• nonresident	60.00
Special mullet permit*	
• resident	100.00
• nonresident	400.00

Saltwater gill net (for use in the EEZ only)	
• resident	250.00
• nonresident	1,000.00
Mullet strike net**	
• resident	250.00
• nonresident	1,000.00
Traversing permit	
• resident	250.00
• nonresident	1,000.00
Wholesale/retail dealer (business)	
• resident	105.00
• nonresident	405.00
Wholesale/retail dealer (vehicle)	
• resident	105.00
• nonresident	405.00
Wholesale/retail dealer (restaurant & retail grocer)	30.00
Transport license**	30.00

*Required in addition to other fisherman, vessel and gear licenses.
**May be used in lieu of saltwater gill net license and traversing permit in EEZ.
***Allows transport of saltwater gill nets through state waters.

4.4.4.6 Laws and Regulations

Louisiana laws and regulations regarding the harvest of mullet include gear restrictions, seasons, and other provisions. 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.

4.4.4.6.1 Size Limits

Louisiana has no minimum or maximum size limit for mullet in either the commercial or recreational fishery.

4.4.4.6.2 Gear Restrictions

Mullet may only be taken commercially with a mullet strike net that must have a minimum mesh size of 1¾" bar or 3½" stretched mesh. These nets may not exceed 1,200 feet in length, and no more than one net may be used from a vessel. Nets must be properly tagged.

Monofilament nets and purse seines are prohibited for mullet fishing, except that purse seining operations for menhaden or other herring-like species may have a maximum of 5% by weight of other species. Recreational cast nets may have a maximum radius of 8½ feet.

4.4.4.6.3 Closed Areas and Seasons

Commercial netting is prohibited in all waters of Lake Catherine, Lake Charles, Moss Lake, and Prien Lake. Also, portions of Breton Sound, Chandeleur Sound, Lake Pontchartrain, and Sabine Lake are also closed to netting. Commercial netting is prohibited in Calcasieu Lake from sunset on Friday to sunset on Sunday during the period May 1 through September 30 of each year. The LDWF should be contacted for other restrictions regarding the placement of nets in specific areas.

Commercial harvest of mullet is prohibited outside the season that is established from the third Monday in October through the third Monday in January. Commercial harvest is also prohibited at night (sunset to sunrise) and on weekends (5:00 a.m. Saturday to 6:00 p.m. Sunday) during the open season.

4.4.4.6.4 Quotas and Bag/Possession Limits

No quotas have been established for the take of mullet from Louisiana waters. Recreational fishermen are limited year-round to a daily take and possession limit of 100 pounds.

4.4.4.6.5 Other Restrictions

The use of aircraft in any form to assist fishing operations is prohibited except for menhaden and other herring-like fish. Fishermen must be within 200 feet of their net at all times while fishing.

4.4.5 Texas

4.4.5.1 Legislative Authorization

Chapter 11, Texas Parks and Wildlife Code establishes the Texas Parks and Wildlife Commission (TPWC) and provides for its make-up and appointment. Chapter 12 establishes the powers and duties of the TPWC, and Chapter 61 provides the commission with responsibility for marine fishery management and authority to promulgate regulations. All regulations adopted by the TPWC are included in the Texas Statewide Hunting and Fishing Proclamations.

4.4.5.2 Reciprocal Agreements and Limited Entry Provisions

4.4.5.2.1 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.

4.4.5.2.2 Limited Entry

Texas has no specific statutory provisions for limited entry in the mullet fishery.

4.4.5.3 Commercial Landings Data Reporting Requirements

All seafood dealers in aquatic products who purchase directly from fishermen are required to file monthly aquatic products reports with the TPWD. These reports must include species, poundage, gear utilized, and location of fishing activities.

4.4.5.4 Penalties for Violations

Penalties for violations of Texas' proclamations regarding mullet are provided in Chapter 61, Texas Parks and Wildlife Code, and most are Class C misdemeanors punishable by fines ranging from $25 to $500.

4.4.5.5 Annual License Fees

The following is a list of licenses and fees that could be applicable to mullet harvest and processing in Texas. They are current to the date of this publication and are subject to change at any time thereafter.

Commercial	
General commercial fisherman's license	
• resident	$ 20.00
• nonresident	150.00
Commercial finfish fisherman's license	
• resident	75.00
• nonresident	150.00
Commercial fishing boat license	
• resident	15.00
• nonresident	60.00
Wholesale fish dealer (business)	
• resident	525.00
• nonresident	525.00
Wholesale fish dealer (truck)*	
• resident	325.00
• nonresident	325.00
Retail fish dealer (business)	
• resident	46.00
• nonresident	46.00
Retail fish dealer (truck)*	
• resident	86.00
• nonresident	86.00
Recreational	
General fishing license	
• resident	13.00
• special resident***	6.00
• nonresident	30.00
Temporary fishing license (14-day) resident	10.00

Temporary fishing license (5-day) non-resident	20.00
Saltwater sportfishing stamp**	7.00

*Refers to the use of a truck as a place of business.
**Required in addition to fishing license when fishing in saltwater.
***Required of residents exempt from fish licenses to obtain red drum trophy tag.

4.4.5.6 Laws and Regulations

Various statewide hunting and fishing proclamations affect the harvest and use of mullet 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.

4.4.5.6.1 Size Limits

Texas has no minimum size limit for mullet; however, a maximum size limit of 12" TL is imposed during the period October 1 through January 31 of each year and successive year.

4.4.5.6.2 Gear Restrictions

Gill nets, trammel nets, seines, purse seines, and any other type of net or fish trap are prohibited in the coastal waters of Texas for taking mullet. Cast nets that do not exceed 14' in diameter and small mesh beach seines not exceeding 20 feet in length may be used for taking mullet for bait purposes only.

4.4.5.6.3 Closed Areas and Seasons

There are no closed areas or seasons for the taking of mullet.

4.4.5.6.4 Quotas and Bag/Possession Limits

Texas has not established any quotas or bag/possession limits for mullet.

4.4.5.6.5 Other Restrictions

Since there is no directed commercial fishery for mullet using traditional net gear, the harvest is primarily regulated by restrictions on fisheries that take mullet incidentally. Shrimp trawling is the most common incidental capture fishery, and its regulations would to some degree affect the harvest of mullet. Hook and line fisheries could also take mullet; however, since this harvest would be quite happenstance, restrictions are not discussed.

5.0 DESCRIPTION OF FISHING ACTIVITIES AFFECTING THE STOCK IN THE UNITED STATES GULF OF MEXICO

Striped mullet are an important commercial species in the Gulf of Mexico. The fishery includes three major components: the roe fishery, the flesh fishery, and the bait fishery. The roe fishery is the most important component in terms of economic value because of the yellow or red roe (eggs); however, white roe (testes) are also marketed at significantly lower prices than eggs. The flesh fishery is perhaps the staple component because mullet are harvested year-round for food. As a bait species, mullet are used in the spiny lobster, stone crab, blue crab, crawfish, and various finfish fisheries.

The recreational importance of mullet varies among the Gulf States. Since they are not readily taken by hook and line because of their feeding habits, their overall popularity when compared with spotted seatrout, red drum, flounder, and other species is relatively low.

Mullet are almost exclusively caught in state waters. A wide variety of gear ranging in efficiency from hook and line to purse seines are used throughout the year.

Commercial catch data are primarily recorded as landings. Catch by gear type is not available due to disclosure prohibitions, and data on catch locations are limited. Although commercial data are quite limited, recreational data (including the most comprehensive survey available) are less adequate.

5.1 Commercial and Recreational Mullet Fisheries

5.1.1 History

The Gulf of Mexico region ranks first in total U.S. commercial production of mullet with average annual landings of approximately 27,826,000 lbs from 1961 to 1990. From 1991 through 1994 average landings were about 26,682,000 pounds (Table 5.1, Figure 5.1). Gulf landings were approximately 90% of total United States production from 1972-1991 and averaged 93% from 1991 through 1994 (United States Department of Commerce Fisheries of the United States, various issues). Florida landings dominated Gulf production with approximately 91% of the total Gulf during the 1960s, 89% during the 1970s, and 85% during the 1980s. From 1991 through 1994, however, Florida's contributions declined from 79% in 1991 to 46% in 1994 (Figure 5.2).

Although total Gulf landings have remained relatively stable throughout this period (within 5% of the 34 year average [Table 5.1]), changes in percentages of the total catch are indicative of changes in individual state's fisheries. Louisiana's fishery has significantly increased in the last five years, while Florida's landings have sharply declined. Landings for the other Gulf States were generally less than 10% of the total Gulf (Table 5.1, Figure 5.1, Figure 5.2).

Table 5.2 shows monthly commercial landings of mullet from the Gulf during the 1989-1993 period along with the overall monthly average for the five-year period. As indicated, monthly landings are highly cyclical. Lowest monthly production occurs in the spring, and approximately 61% of the total landings are taken in October, November, December, and January.

Table 5.1. Commercial striped mullet landings (lbs x 1000) by Gulf States, 1961-1994.

Year	State FL (west coast)	AL	MS	LA	TX	Gulf
1961	32,964	897	399	366	48	34,674
1962	32,820	1,447	507	8	53	34,835
1963	32,612	1,390	382	19	9	34,412
1964	34,996	1,072	250	22	5	36,345
1965	31,368	1,509	241	7	1	33,126
1966	26,958	1,697	636	10	15	29,316
1967	23,283	3,170	1,705	6	28	28,192
1968	20,363	2,840	947	74	28	24,252
1969	25,476	3,193	388	88	182	29,327
1970	23,139	3,112	162	38	11	26,462
1961-70 avg.	**28,398**	**2,033**	**562**	**64**	**38**	**31,094**
1971	23,818	2,361	177	8	98	26,462
1972	26,863	1,513	221	16	92	28,705
1973	26,654	2,786	482	103	158	30,183
1974	25,120	2,013	452	50	113	27,748
1975	23,167	1,618	285	213	46	25,329
1976	16,752	865	841	57	52	18,567
1977	18,807	877	949	595	9	21,237
1978	24,279	933	1,487	1,992	36	28,727
1979	23,792	649	1,482	1,416	111	27,450
1980	27,230	622	1,990	204	92	30,138
1971-80 avg.	**23,648**	**1,424**	**837**	**465**	**81**	**26,455**
1981	28,384	523	1,301	3,052	123	33,383
1982	23,783	685	460	1,534	141	26,603
1983	22,242	567	800	1,887	120	25,616
1984	17,904	603	764	3,157	84	22,512
1985	18,100	982	46	579	296	20,003
1986	20,533	1,727	1,126	2,278	116	25,780
1987	20,298	729	586	1,439	224	23,276
1988	20,900	1,283	700	2,367	67	25,317
1989	23,780	1,185	253	2,414	170	27,802
1990	23,430	2,028	803	2,646	99	29,006
1981-90 avg.	**21,935**	**1,031**	**684**	**2,135**	**144**	**25,930**
1991	19,870	1,280	439	3,563	66	25,218
1992	18,000	774	474	4,922	42	24,212
1993	17,400	1,372	447	10,847	126	30,192
1994*	12,400	1,213	887	12,560	45	27,105

*preliminary

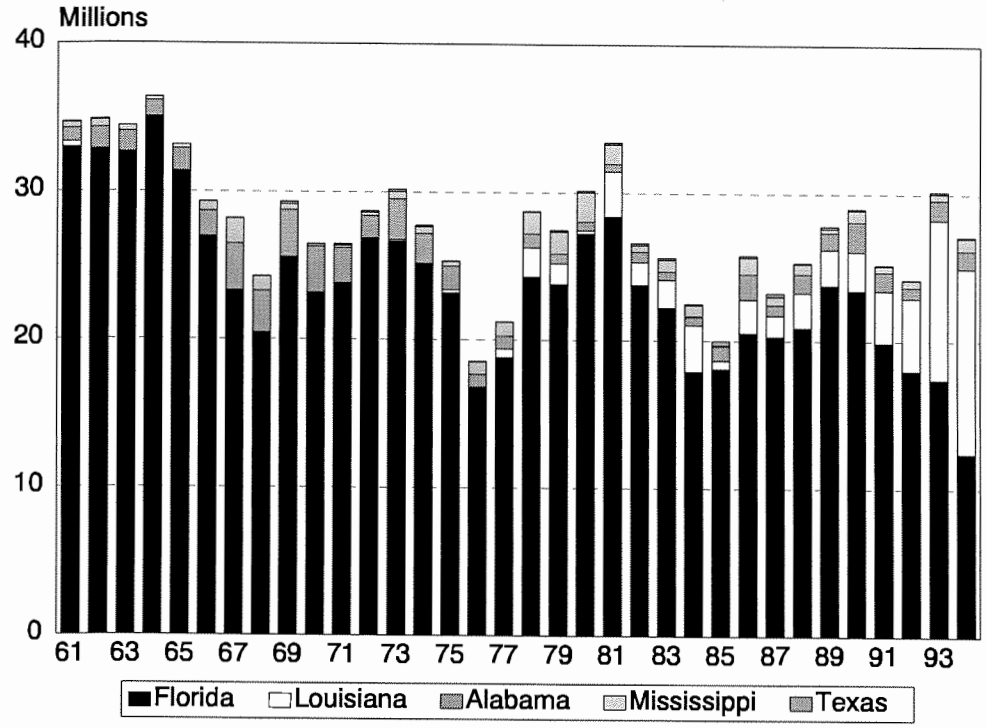

Figure 5.1. Commercial striped mullet landings (millions of pounds) by Gulf States, 1961-1994.

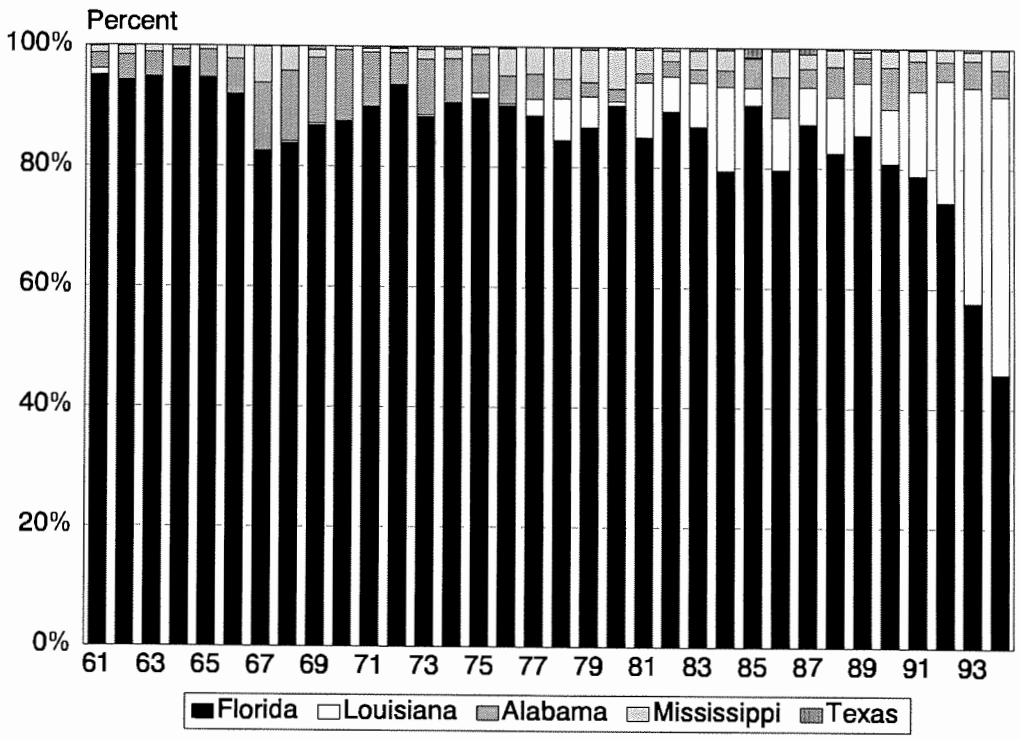

Figure 5.2. Commercial striped mullet landings by Gulf States, percent of total Gulf.

Table 5.2. Monthly landings of striped mullet, 1989 through 1993 (in pounds).

Month/Year	1989	1990	1991	1992	1993	Monthly Average	Average Montly Percentage
January	2,711,315	2,512,452	3,356,211	1,529,289	2,216,449	2,465,143	9.6
February	944,779	914,949	1,112,895	831,976	908,866	942,693	3.7
March	773,626	1,014,188	860,785	983,882	886,556	903,807	3.5
April	873,559	915,165	777,960	810,675	759,082	827,288	3.2
May	1,003,156	1,058,659	807,596	953,718	798,912	924,408	3.6
June	1,173,735	1,224,542	989,258	1,050,860	1,028,772	1,093,433	4.3
July	1,460,047	1,345,561	1,348,981	1,652,862	1,350,259	1,431,542	5.6
August	1,927,032	1,909,883	1,801,137	1,749,960	1,604,641	1,798,531	7.0
September	2,377,264	2,255,554	1,754,869	2,077,794	1,917,568	2,076,610	8.1
October	3,633,199	4,087,799	2,157,002	4,015,237	4,401,542	3,658,956	14.2
November	5,099,835	5,326,817	4,450,775	4,324,203	6,567,788	5,171,884	20.1
December	5,561,517	4,910,170	4,268,876	3,959,653	3,385,603	4,417,164	17.2

Source: Unpublished NMFS data

Florida has an extensive commercial fishery for both flesh and roe that dates to the early 1900s. On the other hand, Texas has historically only harvested mullet for a small bait fishery. Landings for Alabama and Mississippi have fluctuated significantly since 1961; however, Louisiana's landings have increased over ten-fold since the mid 1970s following the development of their roe fishery.

These changes in percentages of total commercial landings among states and by month, the downward trend in Florida's landings, and fluctuations in landings in other states have been caused by various factors. Prior to the mid 1970s, mullet were relatively underutilized in the Gulf, with the exception of Florida. During this period, the ability to market mullet was a primary factor in landings, price, and subsequently fishing effort (Cato *et al.* 1976). With the development of the roe fishery from the mid 1970s to present and particularly during the roe season, market demand and price are no longer significant factors affecting fishing effort and mortality because virtually all fish that are caught can be sold profitably. Consequently, landings and fishing mortality are primarily affected by abundance and catchability. In turn, those factors are affected by year-class strengths, available habitat, environmental perturbations, gear used, fishing pressure, management regulations, and others.

The strength of a given year class, or its percentage of the overall biomass may vary based on a number of factors. Initially, it is based on the spawning potential of the overall spawning stock biomass. Afterwards, it is based on the survivability of that year class through successive ages. Survivability, in turn, is determined by natural mortality (habitat carrying capacity, environmental conditions, predation, disease, etc.) and fishing mortality.

Significant increases in coastal populations, particularly in Florida, have caused losses to habitats that mullet require (Comp and Seaman 1985). These long-term changes may have reduced the overall size of mullet populations. Additionally, short-term effects of hurricanes, floods, droughts, and other environmental anomalies can alter mullet stocks, displace populations, and significantly affect landings.

Without regard to the overall, relative size of mullet stocks, fishing mortality and subsequent landings may vary. Commercial landings may vary based on the size of a given year's fishable population. The catchability of mullet from year-to-year, particularly during the roe season, also appears to be affected by weather patterns. The increased frequency and severity of cold fronts tend to increase the concentration and size of mullet schools as they begin to move offshore to spawn. Larger catches occur during these years, and reduced catches are seen in years with relatively mild winters.

The type of gear used in the commercial fishery, whether voluntarily or by management regulations, may also affect landings. While purse seines and haul seines catch virtually all sizes, larger-mesh gill nets are selective for larger fish. Other management regulations (*e.g.*, size limits, closed seasons, and closed areas) may also alter landings.

Compared to spotted seatrout, red drum, flounder, and some other species, mullet are not often targeted by recreational fishermen, primarily because they are not readily caught with hook-and-line gear. They are perhaps more important as a subsistence fishery component, but they are also widely used by recreational fishermen for bait in other fisheries. Table 5.3 shows

recreational catches of mullet for each of the five Gulf States from 1981 through 1994. Figure 5.3 shows annual catches for the Gulf, and Figure 5.4 shows the average percent of catches for each state from 1981 through 1994.

Table 5.3. Estimated recreational striped mullet catches (numbers of fish) by Gulf States, 1981-1994.[1]

Year	Florida West Coast	Alabama	Mississippi	Louisiana	Texas	Total
1981	366,860	7,725	340,384	346		715,315
1982	769,737	6,838	62,754	9,382		848,711
1983	2,955,952		2,426		6,308	2,964,686
1984	4,568,449		6,781	6,905	257	4,582,392
1985	4,981,473	42,255	85,796	14,589	1,377	5,125,490
1986	3,620,410	28,102	180,768	61,764	605	3,891,649
1987	1,240,947	229	182,884		381	1,424,441
1988	1,748,817	131,822	216,100	74,544	1,673	2,172,956
1989	679,606		23,940	76,874	1,388	781,808
1990	671,549	125,751	117,888	201,213	6,004	1,122,405
1991	1,596,826	65,717	553,241	43,594		2,259,378
1992	906,329	170,646	525,238	145,919	2,062[2]	1,750,194
1993	616,405	90,980	157,914	294,552	2,692[2]	1,162,543
1994	863,479	36,376	112,686	133,718	7,446[2]	1,153,705

[1]does not include recreational gill net and perhaps other gears
[2]estimated from the average of 1983-1991
Source: unpublished NMFS data

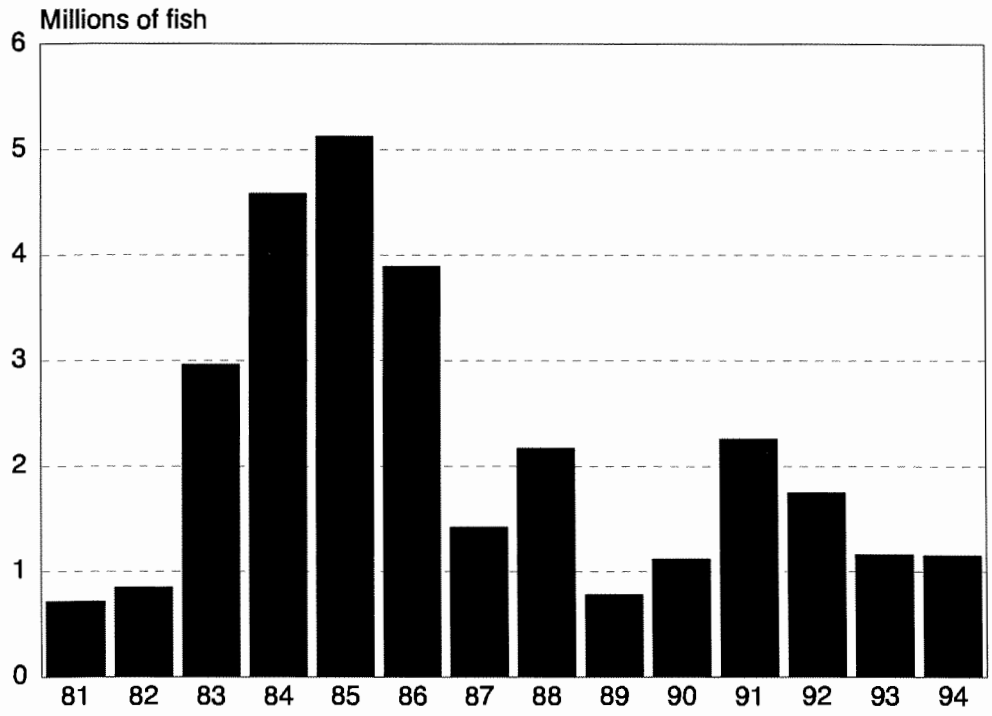

Figure 5.3. Recreational mullet catches for the United States Gulf of Mexico, 1981-1994.

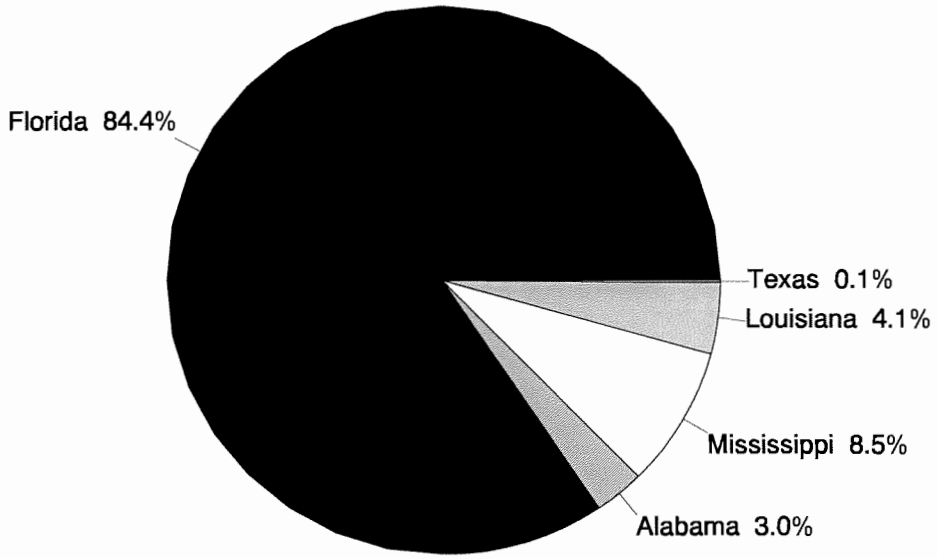

Figure 5.4. Percentage of recreational mullet catches by state, average of years 1981-1994 (years with unreported or zero estimates were not averaged).

5.1.2 State Mullet Fisheries

The commercial and recreational mullet fisheries from Florida to Texas are quite variable with regard to landings, gear, vessels, and uses of the fish.

5.1.2.1 Florida

Most nearshore commercial fishermen in Florida target various species during a fishing year; however, mullet are a major component of their catch (Degner *et al.* 1989). Although the mullet fishery accounts for approximately 20% of total finfish production in Florida, it garners a much larger percentage of the nearshore or estuarine fishery. Average annual commercial landings for the west coast of Florida were approximately 28 million pounds in the 1960s, 24 million pounds in the 1970s, and 21 million pounds in the 1980s. Landings declined steadily in the 1990s to only 12.4 million pounds in 1994 (Table 5.1, Figure 5.5). Historical commercial landings show a short-term, cyclic pattern with cycles occurring at about 8-year intervals and a long-term downward trend (Figure 5.5). These observed fluctuations may be related to several factors previously discussed in Section 5.1.1.

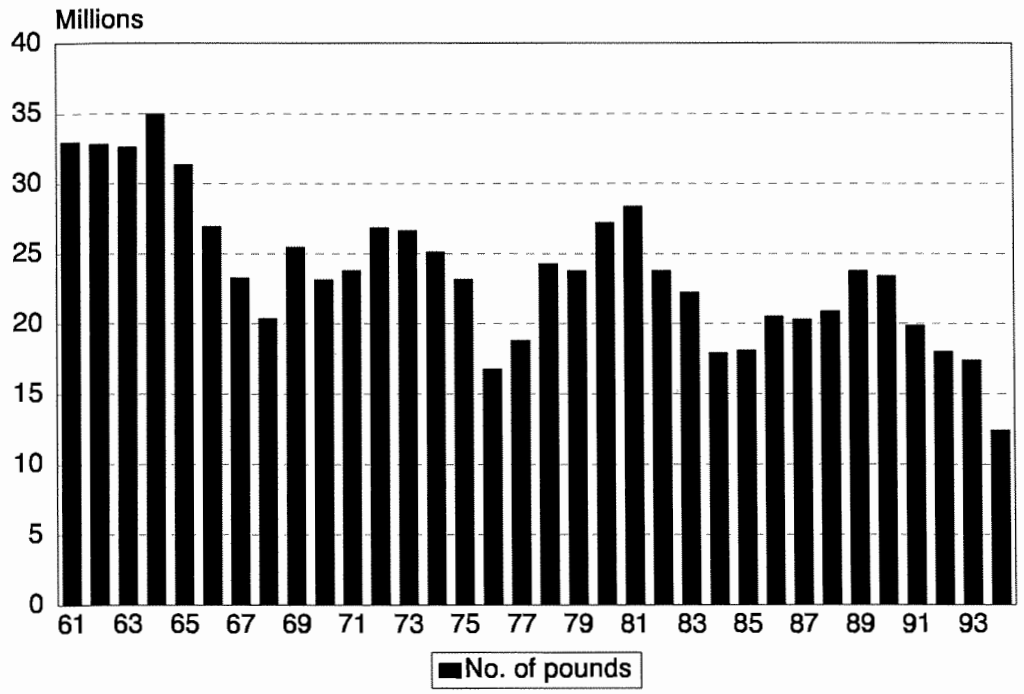

Figure 5.5. Commercial mullet landings in Florida, west coast, 1961-1994.

The most common gears used in the commercial mullet fishery have been runaround gill nets, trammel nets, haul seines, and cast nets. The mesh size of gill nets has varied seasonally to maximize the catchability of the optimum market-size fish. During the "spawning run" many

fishermen switched to large mesh gill nets (4"-4¾" stretched mesh) to target the large, roe-laden female mullet.

In the Florida commercial mullet fishery, vessels (mullet boats) range from 20'-35' with an average size of 23'-25'. The fish holding capacity ranges from 2,000 pounds to 20,000 pounds with an average boat capacity of 4,000 pounds to 6,000 pounds.

Mullet are commercially caught along the east and west coasts of Florida; however, the west coast of Florida produces about 90% of the total landings. The central and southwest coasts' waters are the most productive (Figure 5.6), and the majority of landings occur in Lee, Manatee, Charlotte, and Pinellas counties. Although mullet are caught throughout the year, 50% of the production occurs from October through late January during the roe season, and about 50% are caught in other months for flesh and bait.

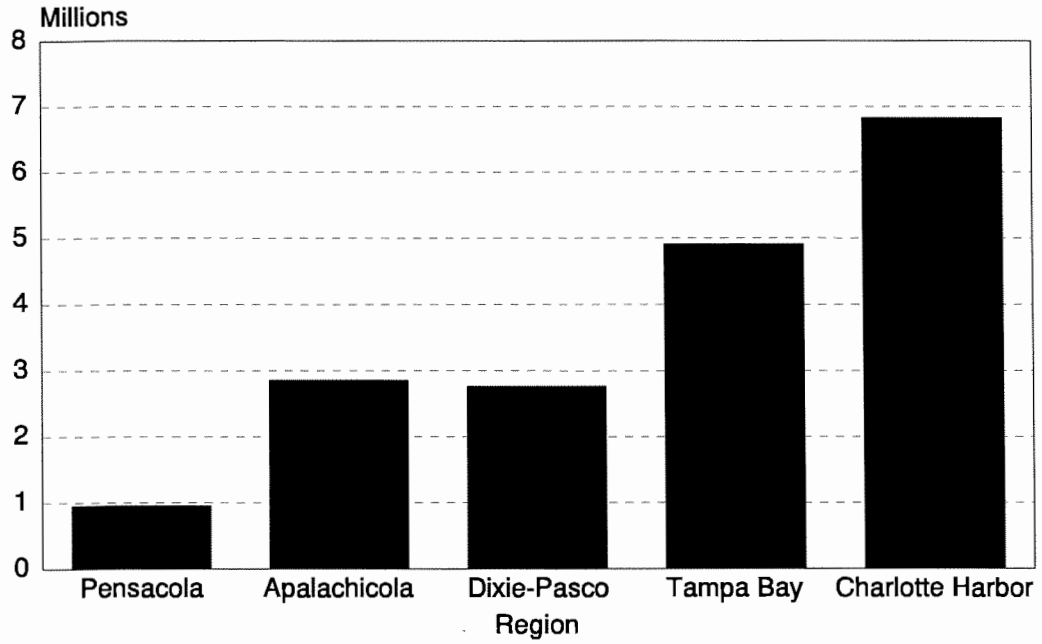

Figure 5.6. Striped mullet commercial landings by region, Florida west coast (annual average 1986-1993).

Table 5.4 shows effort for the commercial mullet fishery from 1986 through 1994 reported as the number of one-day successful trips. The number of trips increased from 1986 to 1990 and declined from 1991 to 1994 probably as a result of management regulations.

Table 5.4. Annual number of one-day successful trips in the commercial mullet fishery, Florida.

Year	West Coast
1986	48,701
1987	49,059
1988	52,835
1989	57,573
1990	61,623
1991	53,404
1992	52,818
1993	47,504*
1994	39,006*

*incomplete

Seasonal distribution of commercial landings expressed as the percentage of total landings by month are shown in Figure 5.7. During the roe season (October-January), mullet are more easily caught due to their schooling aggregation before spawning. There is also an increase in the market demand due to the high price for roe. Consequently, the number of trips, fishermen (part-time entrants), and landings increase significantly. During the spring (after the roe season), landings and trips are at minimum levels, and mullet are scattered and not available in all sizes. With the start of the rainy season (June-July), mullet become more numerous and are larger in size. Landings, trips, and catches then increase steadily until the peak of the spawning season.

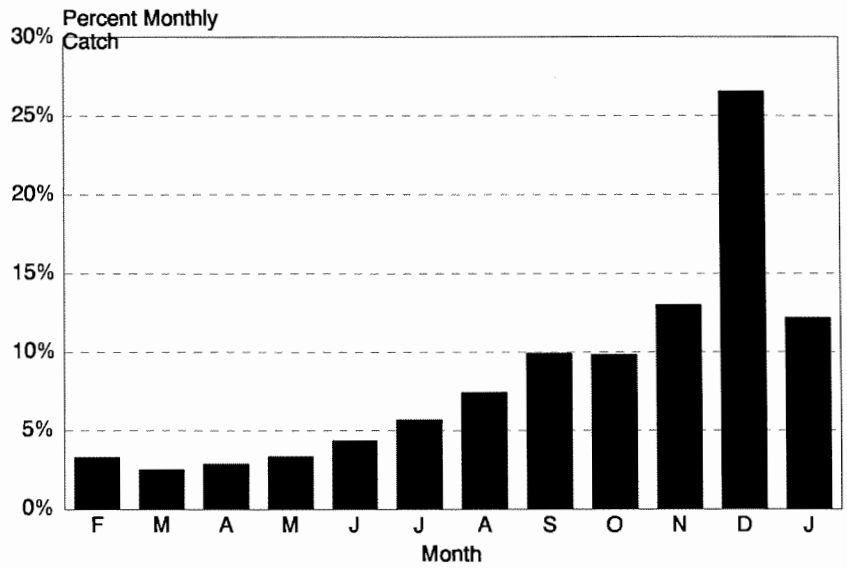

Figure 5.7. Percentage of total commercial landings by month, Florida west coast (annual average 1986-1993).

Mullet are also caught by recreational fishermen primarily with cast nets from piers, bridges, jetties, seawalls, and other shore-based structures as well as boats. Fishing usually occurs nearshore and in bayous, rivers, bays, creeks, and other tributaries.

5.1.2.2 Alabama

Alabama's commercial landings since the early 1960s have averaged approximately 1.5 million pounds per year (Table 5.1, Figure 5.8). Landings showed a substantial increase in the 1960s followed by an equally substantial decline in the 1970s. From 1981 through 1994 landings steadily increased to more historic levels. Alabama ranked second in the Gulf in total production throughout the 1960s and 1970s, yielding to Louisiana in the 1980s.

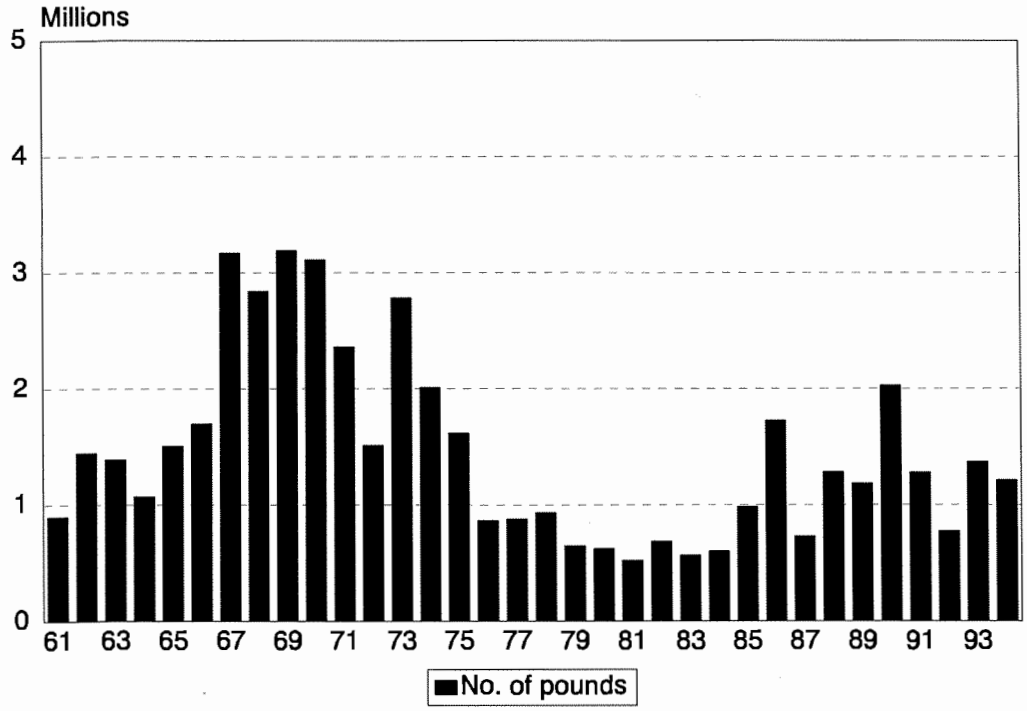

Figure 5.8. Commercial mullet landings in Alabama, 1961-1994.

Alabama commercial fishermen have utilized several methods to capture striped mullet throughout the years. Prior to the development of gill nets, the haul seine fishery predominated catches. Two or more fishermen in a boat with the seine would sight a school of mullet close to the bank, draw the boat close to it, debark with the seine and surround the fish as they dragged the seine to the beach. On some occasions, fishermen from the bank would surround mullet with the seine and no boat would be necessary. Once on the beach, the fish were gutted and transported to a dealership where they were salted and shipped by rail to points north (J.R. Nelson, personal communication).

Currently, mullet are commercially harvested almost exclusively with monofilament gill nets, and a small number of fish are taken with cast nets and snatch hooks. Commercial mullet fishermen work from small net boats that are designed to rapidly deploy nets up to 2,400 feet in length. When a school of mullet is sighted, the net is deployed around the school, and the boat is maneuvered inside the net and noisily guided through the mullet school to scare them into the net. The fish are then boated and transported to a dealership for processing.

The commercial striped mullet fishery in Alabama consists of an inshore and Gulf-beach gill net fishery. Fishing effort for striped mullet is concentrated primarily in Mobile Bay with a few netters working Mississippi Sound and the Gulf beaches off Mobile and Baldwin counties during the roe mullet season. Cast nets and snag hooks are used in areas where mullet schools occur near the shoreline (*e.g.*, the Theodore Industrial Canal).

The commercial mullet fishery in Alabama has two distinct components, a flesh fishery and a roe fishery. During the first nine months of a calendar year, mullet are harvested for flesh that is sold to local wholesale dealers. Beginning in October, striped mullet aggregate in large schools in the delta and river areas of Alabama in preparation for their spawning run to the Gulf. The roe fishery commences as the mullet exit the delta and river areas in large schools. Fishermen from nearby states join Alabama's fleet during this period. The roe fishery is significantly more important than the flesh fishery in both pounds landed and value.

Wade (1977) estimated an annual recreational harvest of 80,500 pounds of mullet. These fish were taken by bank fishermen or from small recreational boats. A more detailed recreational creel survey conducted in 1984-1986 by ADCNR, MRD estimated a harvest of 45,736 pounds with an estimated 29,500 hours of directed effort for the period from October 1984 to September 1985. Over 60% of the harvest and over 98% of the directed effort was from the recreational bank fishery. Most of the effort directed at mullet was in Mobile County where it dominated the spring-summer bank harvest. Mullet was the ninth most sought after species by pier, offshore boat, bank, and inshore boat fishermen in the survey. The survey did not cover recreational cast or gill netting that accounts for a substantial amount of the harvest each year.

5.1.2.3 Mississippi

Commercial mullet fishing has a long and somewhat diverse history in Mississippi. In the coastal area, mullet have been an important food fish. At one time, it was called "Biloxi bacon" and appeared on the menus of many restaurants. Since the mid-1970s, mullet have become more important for their roe and have virtually disappeared from menus.

Prior to 1976, the commercial fishery for mullet in Mississippi waters was dominated by gill and trammel net catches. In 1976, purse seines were introduced into the mullet fishery and landings increased significantly (Table 5.1, Figure 5.9). Landings continued to climb in the late 1970s and peaked at nearly 2.0 million pounds in 1980. Following 1980, strike gill nets became the most prominent gear, and in the early 1990s, pair trawls were used on a limited basis in offshore waters. The bulk of these mullet landings occurred during the roe fishery. A decline in commercial landings after 1980 was due in-part to a decrease in purse seine landings; however, other factors are probably involved, *e.g.*, Hurricane Elena in 1985. Mississippi ranked third in the Gulf in total landing during the 1960s and 1970s and fourth during the 1980s and 1990s.

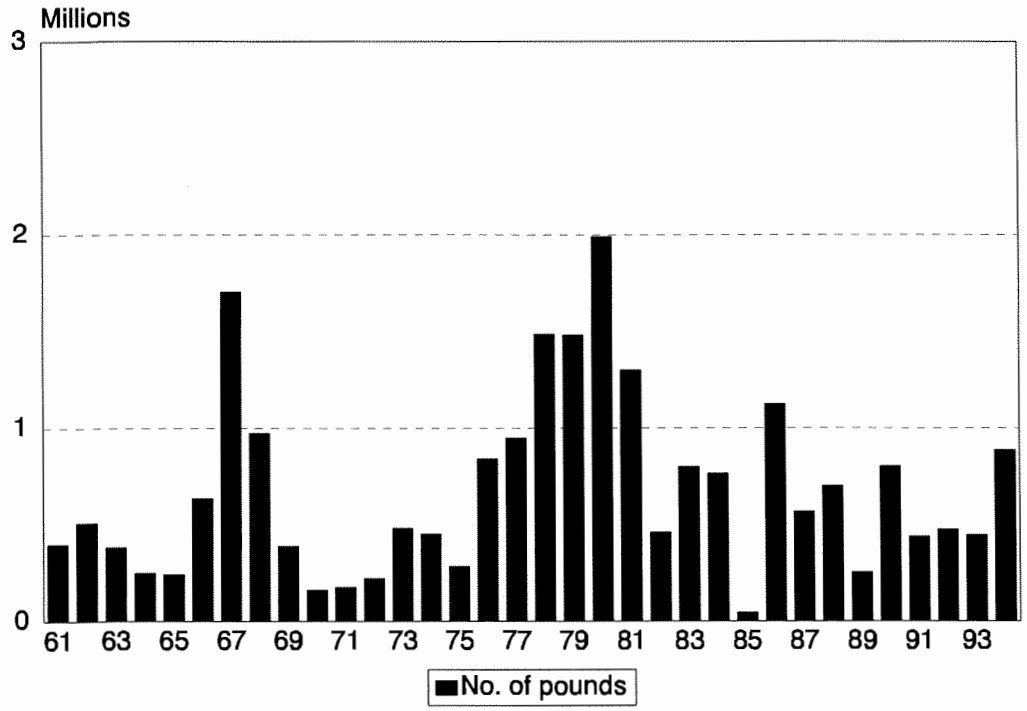

Figure 5.9. Commercial mullet landings for Mississippi, 1961-1994.

The gill net fishery for roe mullet generally concentrates its effort around the mouths of the bays and river systems to catch the mullet as they leave. Weather permitting, gill netters may fish for mullet and other species around the barrier islands during the colder months of the year.

Purse seine vessels are larger than the boats used by most gill netters and can work in rougher seas. Purse seiners tend to work in the more open waters of the Mississippi Sound and around the barrier islands.

Recreational fishing for mullet is very popular in Mississippi, and mullet comprise a substantial portion of the total recreational catch. Striped mullet are generally taken with cast nets in nearshore waters while wading or casting from piers, bridges, jetties, or boats. Other methods include hook and line, usually with red worms or dough balls for bait, and snagging with weighted treble hooks around the effluent of seafood plants.

5.1.2.4 Louisiana

Striped mullet were a relatively unimportant and underutilized commercial species in Louisiana until approximately 1976 when the more valuable roe market developed. Landings throughout the 1960s and from 1970 to 1976 averaged only about 70,000 pounds per year, and they were primarily caught for bait. During this time, Louisiana ranked fourth in the Gulf in total landings (Table 5.1, Figure 5.10). Landings increased in the late 1970s and throughout the 1980s as the roe fishery developed, and during this time Louisiana ranked second in total Gulf production. Landings in 1985 were significantly below the 1980s average as the result of Hurricane Juan and later inclement weather during the roe season. From 1987 to 1992, the harvest of mullet almost exclusively for roe steadily increased, and the 1993 and 1994 harvests were more than double that of 1992. After 1991, a small market for flesh developed, but in 1994 about 70% of the total harvest was during the roe season.

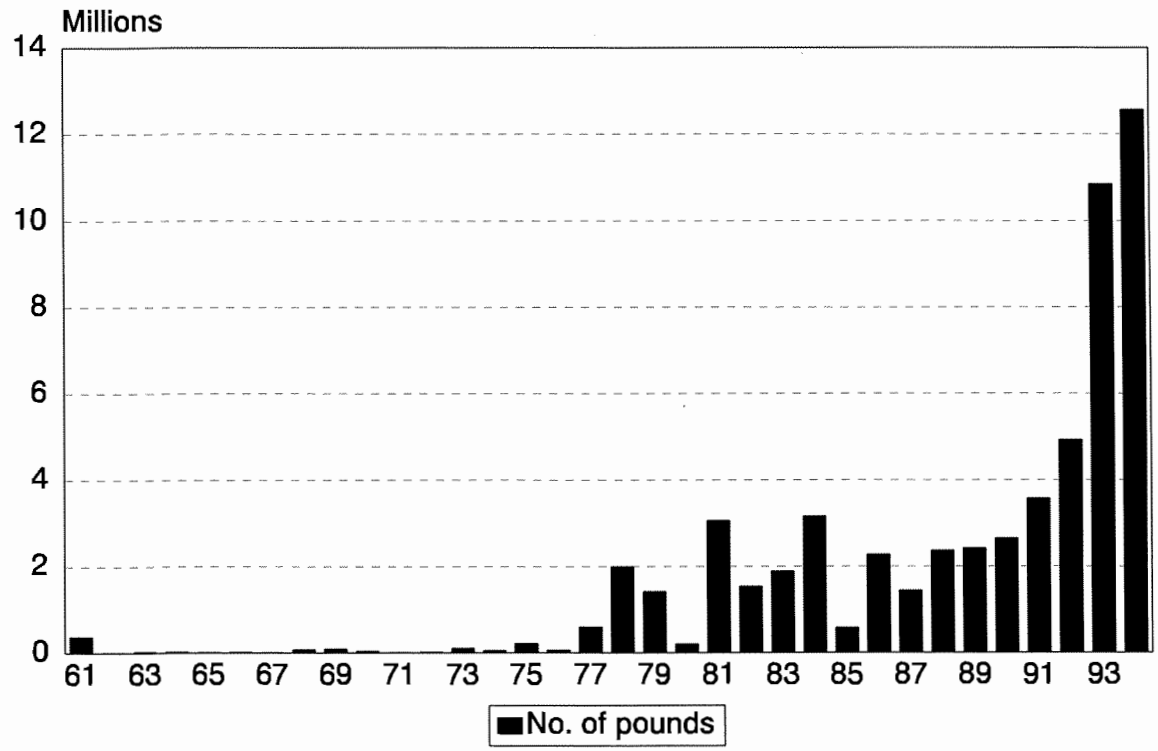

Figure 5.10. Commercial mullet landings for Louisiana, 1961-1994.

The commercial striped mullet fishery in Louisiana consists of an inshore and nearshore fishery. Size of boats, types of fishing gear, and fishery regulations play important roles in the divisional structure of the commercial fishermen and the fishing area of preference.

Commercial fishermen in Louisiana historically have utilized a variety of methods to capture striped mullet for the commercial fishery including mono- and multifilament gill nets, haul seines, trammel nets, and purse seines. Special interest was placed on the use of some of these gear types with the issuance of experimental mullet fishing permits from 1980 through 1986. Trammel net permits were only requested and issued during 1980 and 1981, and haul seine permits were only used in 1980. Purse seine permits were issued from approximately 1980 to 1986; thereafter, additional regulations were implemented that precluded their use.

Haul seines, used in conjunction with spotter planes, were a very efficient gear type for catching large numbers of mullet inshore, and their use did not require the time consuming process of removing individually entangled fish. The relatively small mesh size, however, was not selective and significant quantities of smaller, less desirable fish were often captured. In 1986, airplanes were prohibited other than for spotting menhaden.

Until they were prohibited, purse seines were perhaps the most efficient gear for catching mullet; however, like haul seines, they were relatively nonselective. Purse seines had the capability, depending on the length of the net, of capturing over 100,000 pounds of mullet per set.

Purse seine vessels used in Louisiana's commercial mullet fishery were typically 50-80 feet in length with holding capacities of up to 200,000 pounds (Russell *et al.* 1986). They operated primarily in Breton Sound and other offshore waters due to permit restrictions banning them from inshore waters. In the late 1970s and early 1980s, most purse seine operators transported their catches directly to processors out of state, usually in Alabama, Mississippi, or Florida (Bain *et al.* 1985).

Gill nets are the most widely used commercial gear, and they are usually deployed by one of two methods: (1) as a set net located in an area of high mullet concentration or in a location that has a channelling effect, or (2) as a strike net deployed in a circling manner around a school of mullet. Schooling mullet are mostly taken by strike nets, and they are usually located by spotter planes. Gill nets used in the Louisiana mullet fishery are typically 1,200 feet in length and are made of 3.5 to 4.5 inch stretched monofilament mesh; however, the most common mesh size used is 4 inch stretched. Soak time averages ten minutes (Russell *et al.* 1986).

Florida skiffs are the dominant vessel type used in the commercial mullet fishery. They vary in size from 22 to 28 feet in length and often have specialized gear such as a small flying bridge for spotting, lights for night fishing, and power rollers for net retrieval (Russell *et al.* 1986). They are primarily used to deploy gill nets, trammel nets, and haul seines.

The commercial mullet fishery is concentrated east of the Mississippi River with effort and catch per trip increasing during the spawning months. Fishing effort during the non-roe period is lower due to a lack of market interests in Louisiana. Louisiana areas of concentrated gill net fishing for mullet are Lake Borgne, Mississippi River Gulf Outlet, Breton Sound, and Breton Bay (Bain *et al.* 1985). The Hopedale-Yscloskey area in St. Bernard Parish is the center for mullet roe production in Louisiana. In 1986, over 70 boats from Louisiana, Alabama, Florida, and Mississippi worked St. Bernard Parish and the surrounding area. Out-of-state fishermen were

more experienced at netting mullet than most Louisiana fishermen, but more local fishermen have developed an interest in the fishery due to its obvious profit potential (Russel *et al.* 1987).

In recent years, additional areas in western Louisiana, notably in the Atchafalya Bay area and to a lesser extent in the Barataria Bay and Calcasieu Lake areas, have been harvested primarily during the roe season. Slower growth rates for mullet have been observed in these areas (Thompson *et al.* 1991), and typically, smaller mesh gill nets of 3½" to 4" stretched mesh (mostly around 3¾") have been used.

Recreational harvest of mullet is typically for use as bait using relatively fine-mesh cast nets. Individual fish are usually (<150 mm TL), but larger individuals are taken for use as cut bait. A small portion of the recreational harvest is used for human consumption.

5.1.2.5 Texas

The primary fishery for mullet in Texas is for bait that is used in both sportfishing and commercial crab fishing. Commercial landings of mullet come from Texas bays and the Gulf of Mexico with the greatest landings in most years coming from the bays.

Commercial landings have historically been quite variable from year to year, but these fluctuations are probably not related to abundance (Table 5.1, Figure 5.11). From 1979 to 1989, landings appear to have increased and somewhat stabilized at a higher level than previous years. This change is probably the result of the development of a small roe fishery as these fisheries were also developing in other states. Further development of a roe fishery was probably precluded by the ban on nets in all saltwaters in 1988, and a subsequent maximum size restriction of 12" TL imposed in 1991.

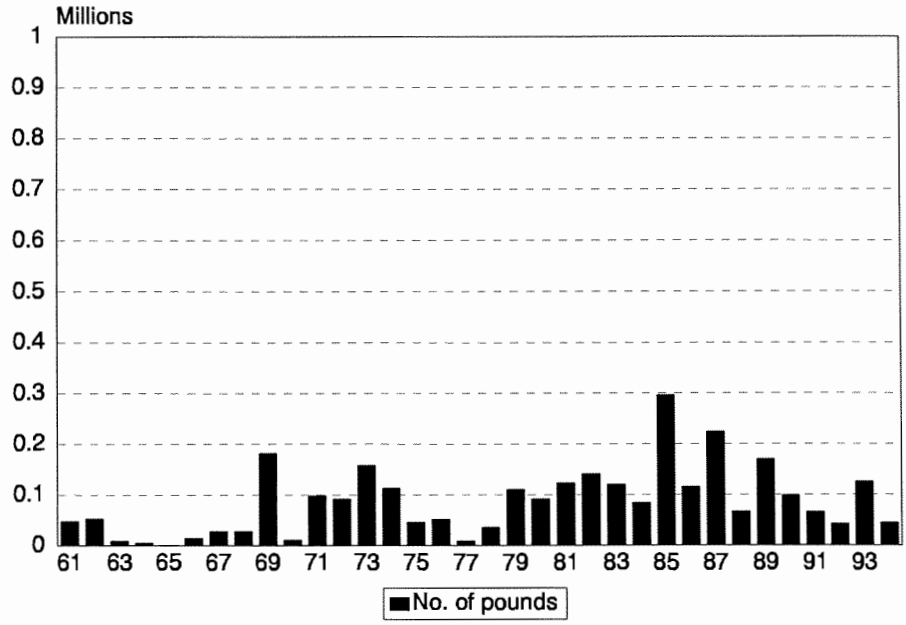

Figure 5.11. Commercial mullet landings for Texas, 1961-1994.

Striped mullet are classified as a nongame fish in Texas, and commercial fishermen use cast nets not exceeding 14 feet in diameter and minnow seines (≤20 ft) to take mullet. Mullet are also taken incidental to legal shrimping operations and sold for bait or food. Shrimp trawl bycatch accounts for most of the commercial landings of mullet in Texas with cast nets producing most, if not all of the remainder.

Mullet are primarily used for bait by Texas recreational anglers. Over 6% of Texas recreational fishermen report using either live or dead fish for bait (Weixelman and Chai 1991). A good portion of these "bait fish" are probably mullet. Recreational landings of mullet occur in Texas bays and Gulf beaches with most coming from the bays. Recreational fishermen may use a wide variety of gear to take mullet in Texas; however, most mullet are caught with cast nets and minnow seines. Other gears include rod and reel and gig.

5.2 Total United States Gulf and Mexico

Figure 5.12 shows commercial mullet landings for the entire Gulf. Since Florida's landings have historically made up over 80% of the total Gulf landings, this figure basically repeats trends in Florida until recent years when Louisiana's landings increased.

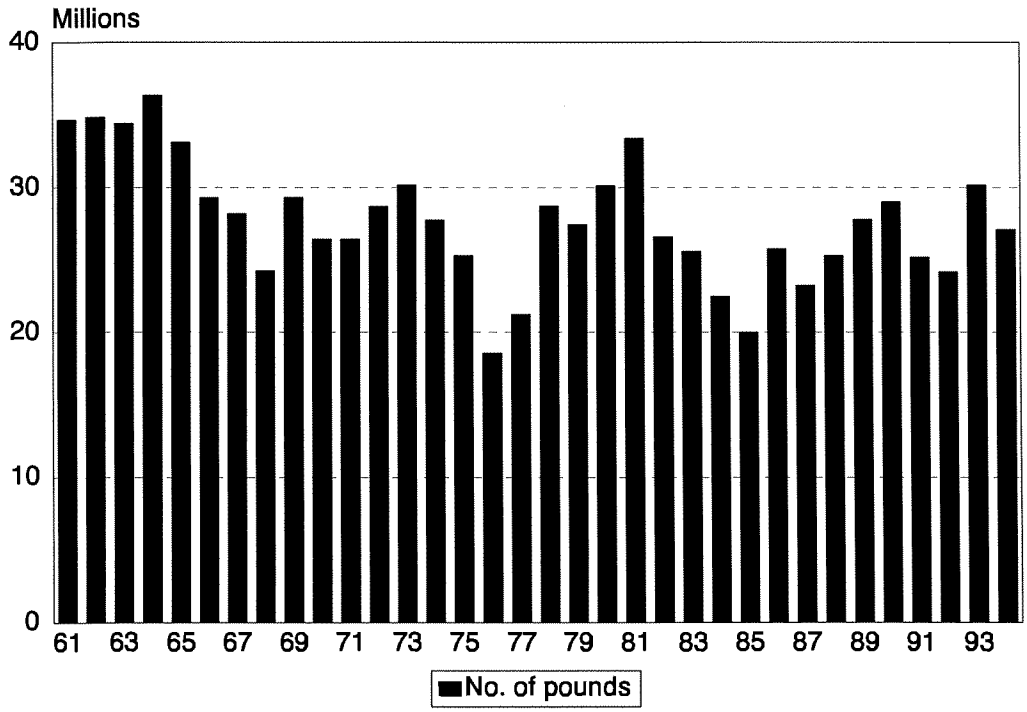

Figure 5.12. Commercial mullet landings in the United States Gulf of Mexico, 1961-1994.

Table 5.5 and Figure 5.13 show commercial landings of mullet from three Mexican states on the Gulf of Mexico and the total Mexican Gulf production from 1982 through 1992. Mexican landings totalled 33% of the combined United States and Mexico production from the Gulf for

the 11 year period. These data are provided for informational purposes only, and they are not included in the stock assessment or any other aspects of this plan because data on these mullet stocks are not available.

Table 5.5. Commercial striped mullet landings for Mexico (by state), 1982-1992.

Year	Tamaulipas	Veracruz	Campeche	Total
1982	5,260,948	1,910,868	229,216	7,401,032
1983	6,014,716	2,770,040	337,212	9,128,968
1984	8,004,928	3,510,972	747,156	12,263,056
1985	5,897,904	1,855,768	850,744	8,604,416
1986	6,770,688	1,857,972	2,237,060	10,865,720
1987	11,337,376	1,518,556	1,461,252	14,317,184
1988	12,503,292	1,366,480	1,595,696	15,465,468
1989	12,822,872	1,214,404	2,001,232	16,038,508
1990	13,741,940	3,797,492	641,364	18,180,796
1991	9,549,932	678,832	1,090,980	11,319,744
1992	10,167,052	3,700,516	469,452	14,337,020

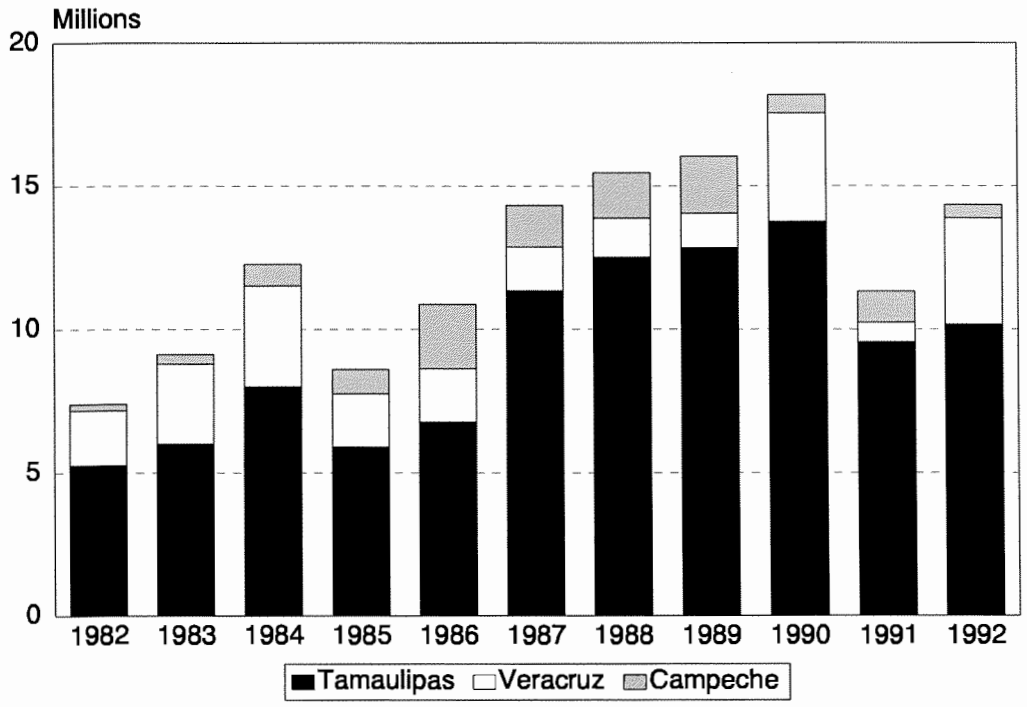

Figure 5.13. Commercial striped mullet landings (lbs) for Mexico (by state), 1982-1992.

5.3 Incidental Catch

Striped mullet may be caught by both commercial and recreational fishermen while directing their efforts toward other finfish species. Those efforts may include haul seining, gill netting, trammel netting, purse seining, hook and line fishing, cast netting, and others. Mullet may also be caught during trawling operations for shrimp; however, catches amount to only a very small fraction of 1% of the total species caught. Because mullet form tight schools during peak fishing periods (roe season), incidental catch of other species during this period is minimal (B. Mahmoudi, personal communication).

Bycatch during the nonroe season is somewhat larger but relatively insignificant. Species that are occasionally caught throughout the year are sheepshead, black drum, red drum, spotted seatrout, sharks, sea catfish, Spanish mackerel, and others (Russell *et al.* 1987, Thompson *et al.* 1989). Since mullet are not readily taken by traditional recreational fishing methods, incidental recreational catches are virtually nonexistent.

5.4 Foreign Activity

Currently, no governing international fishing agreements (GIFAs) have been issued in the fishery for mullet in the U.S. Gulf of Mexico. Additionally, no total allowable level of foreign fishing (TALFF) has been established.

5.5 Potential for Aquaculture

Bardach *et al.* (1972) described experimental aquaculture projects in various countries including Italy, Taiwan, Israel, India, Pakistan, Burma, Cyprus, Yugoslavia, Greece, Tunisia, United Arab Republic, Egypt, France, Indonesia, the Philippines, the Republic of China, Hong Kong, Japan, the United Kingdom, and the United States. He noted that mullet could be one of the most important aquaculture species if problems with spawning and rearing could be solved and that it could help alleviate major shortages of protein in poorly developed countries in Africa and South America. Futch (1966) reported that mullet was a major aquaculture species in the Orient, and he recommended that it be pursued in the United States. Because of the expanded roe fishery in recent years, the increasing value of roe, and the severe restrictions that have been placed on commercial harvest of wild stocks, the future for mullet culture may be great.

Although the potential for mullet culture exists in the United States, there are various reasons why it has not been more aggressively pursued. First, mullet are not widely accepted as a food fish, and most consumption occurs in Hawaii, Florida, and Georgia with lesser use in South Carolina, Alabama, and Mississippi. The demand in these states has easily been met with local supplies of wild-caught fish. Second, there are legal restrictions on construction of ponds in wetlands, and those which do exist or are permitted often are used for more lucrative aquaculture ventures such as shrimp or red drum. Finally, experimental yields are also low compared to other equally desirable food fish, and more research is needed (Bardach *et al.* 1972). If these problems can be solved, mullet could become an important aquacultural species.

6.0 DESCRIPTION OF PROCESSING, PRODUCTS, MARKETING, AND ORGANIZATIONS ASSOCIATED WITH THE FISHERY

6.1 Processing Methods and Products

Striped Mullet are primarily harvested for human consumption in the flesh and roe fisheries of four of the five Gulf States (Florida, Alabama, Mississippi, and Louisiana). Historically, landings both inside and outside the roe season have contributed approximately equal portions of the total; however, in recent years (particularly in Louisiana) the more valuable roe-season fishery has contributed the greatest amount of product. Although the fishery in Texas is technically a bait fishery, it is likely that some fish are consumed, but there is no commercial market for mullet as a food fish. Small amounts of mullet are also caught for direct-bait markets in other Gulf States. Approximately 5%-10% of the total mullet harvest is taken directly for bait. An additional 15%-20% is contributed as split carcasses from the roe fishery. Direct harvest yields mullet for recreational fisheries as well as commercial fisheries for spiny lobster, stone crab, blue crab, and crawfish. Most split carcasses are used as bait for commercial fisheries.

Mullet flesh is sold whole, collared, gutted, and fileted either fresh, frozen, salted, or smoked. The roe fishery yields four major products: red or yellow roe (eggs), white roe (testes), gizzards (the muscular stomachs), and split carcasses. These products are obtained by "stripping" or "splitting" mullet and removing the eggs, testes, and gizzards. The "split" carcasses are then sold for bait or for further processing as food. Although the roe fishery is only conducted during spawning months (primarily late October through January), its products yield the highest value.

6.2 Market Structure and Channels

As noted in Section 5.0, mullet are harvested in three fishery components: roe, flesh, and bait. The markets and product distribution vary among these components. Only limited information exists by which to portray the market structure and channels associated with the Gulf of Mexico mullet industry. The most relevant work, conducted by Degner *et al.* (1989), pertains only to Florida and is somewhat outdated, *i.e.*, the study focused on activities for the year 1986; consequently, findings may be of only limited use in light of recent changes in the industry, especially the growth in production in Louisiana

6.2.1 Market Structure

6.2.1.1 Fishermen

According to Degner *et al.* (1989), the majority (65%) of Florida fishermen producing mullet in 1986 were classified as full-time fishermen. The full-time fishermen accounted for 85% of the mullet landed in the state and an equivalent percentage by value. Other than mullet, these full-time fishermen primarily targeted seatrout.

6.2.1.2 Handlers

Based on analysis of trip ticket data for 1986, Degner *et al.* (1989) reported that 313 Florida firms could be categorized as first handlers (buyers) of mullet. Of these, 224 firms (72%) were Gulf Coast based, and they accounted for 88% of Florida's mullet landings. Of the 224 firms, 31 (14%) purchased in excess of 100,000 pounds of mullet in 1986, and 51 firms (23%) purchased from 20,000 pounds to 100,000 pounds. Of the Gulf Coast based firms, 142 (63%) purchased less than 20,000 pounds. As noted by Degner *et al.* (1989), "...the relatively large numbers of fishhouses handling mullet in practically every [Florida] Gulf Coast county indicates the potential for competitive buying behavior among fishhouses."

Degner *et al.* (1989) reported that, in general, little evidence existed of horizontal integration among the primary buyers (an estimated 9% operated in more than one location); however, about ¼ of the surveyed primary handlers engaged in fishing for mullet with their own boats, suggesting a somewhat higher degree of vertical integration in the primary handling sector. Only 13% of the mullet landings reported by these firms, however, were caught via their own boats.

6.2.2 Market Channels

6.2.2.1 Mullet in the Round

According to Degner *et al.* (1989), all primary handlers surveyed with respect to 1986 activities reported selling mullet in the round. About 80% of the total annual volume of mullet sales among Florida's primary handlers was sold in the round, and 20% was split for roe. This 80% by volume represented about 59% of the total value of mullet sales.

Most of the mullet (92%) sold in the round was for human consumption with the remaining 8% destined for the bait market. Of the mullet product sold in the round by first buyers in Florida, 83% was sold to wholesalers with sales direct to consumers (6%), fishhouses and processors (5%), retailers (4%), and food service establishments (2%) accounting for the remainder. About ⅓ of the product sold in the round to wholesalers was to establishments in Florida while another 54% was to other United States establishments. The remaining 15% of wholesales of in-the-round product constituted purchases by foreign firms.

6.2.2.2 Processed Mullet

Processed mullet enter the human-consumption market from both the year-round flesh fishery and seasonal roe fishery. Most mullet from the flesh fishery are sold in the round. Later, they are processed and sold in decreasing order of significance as dressed, fileted, smoked, and salted product. This fishery is predominantly a directed fishery; however, a small percentage of product is contributed from the roe fishery. The majority of flesh sales ultimately go directly to consumers or retailers in the Gulf. The next two largest buyers include foreign wholesalers and United States wholesalers, outside the Gulf, respectively.

By weight, roe mullet processing yields 84% split carcasses, 16% red roe, and less than 1% white roe and gizzards. Red or yellow roe is the most valuable mullet product, and it is

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almost exclusively sold to foreign markets. Only about 1% remains in the United States and is sold to other wholesalers, retailers, or consumers (Degner *et al.* 1989). On the other hand, the majority of the white roe (56%) are marketed directly to domestic retailers and consumers at 40% and 16%, respectively. Foreign wholesalers are the next largest market (33%) followed by domestic wholesalers (Degner *et al.* 1989). Like yellow or red roe, virtually all of the gizzards are sold to foreign wholesalers. Less than 1% is sold in the United States to other wholesalers, retailers, or consumers. Because the roe fishery is conducted differently from the flesh fishery, the resultant carcasses are mostly poor in quality. Over 90% of all split carcasses are ultimately sold as bait. The remainder is predominantly sold fresh or frozen with increasingly smaller portions being sold smoked or salted. Overall, Degner *et al.* (1989) estimated that ⅔ of primary mullet dealers in Florida sold split carcasses in 1986. On average, split carcasses were sold at an average price of $0.15 per pound compared to $0.35 for product sold in the round.

6.3 Organizations

A list of organizations that may be associated with the mullet fishery are listed in Appendix 15.1.

7.0 DESCRIPTION OF THE ECONOMIC CHARACTERISTICS OF THE FISHERY

7.1 Value and Price

7.1.1 Annual Value and Price

The dockside value of the Gulf of Mexico mullet fishery averaged $2.0 million annually during the 1961-1970 period (Table 7.1). Despite declining poundage produced, the value had advanced to more than $8.0 million annually in 1981-1990 and exceeded $9.0 million annually in 1991-1993. The increased value during the period of study reflects an increased price which in 1961-1970 averaged $0.065 per pound compared to $0.361 per pound in 1991-1993 (Table 7.1).

When adjusted for inflation (1982-1984 consumer price index [CPI]=100), the dockside value of Gulf of Mexico mullet landings advanced from an average of $6.1 million annually in 1961-1970 to $7.4 million annually in 1981-1990, or by about 20%. The average annual deflated value of Gulf of Mexico mullet landings in 1991-1993 ($6.5 million), however, was only marginally above that reported in the 1960s.

The deflated dockside price, as indicated by the information in Table 7.1, averaged about $0.20 per pound in 1961-1970 (1982-1984 CPI=100). When viewed on a long-term basis, it increased steadily through the 1981-1990 period wherein it averaged $0.285 per pound, or approximately 45% above the average annual deflated price of $0.196 during 1961-1970. The 1986-1990 period can be characterized as one of a particularly strong price advancement.[1] Since 1990, the deflated Gulf of Mexico dockside mullet price has fallen sharply with the 1991-1993 price, $0.257 per pound, approximating that observed for the 1971-1980 period.

7.1.2 Monthly Value and Price

The monthly values for Gulf of Mexico mullet landings for the 1989-1993 period along with the overall monthly average value and price for the five-year period are presented in Table 7.2. The monthly values are highly cyclical, as indicated, reflecting the cyclical nature in both pounds landed and price. In general, the average monthly price tends to be positively correlated with pounds landed reflecting the additional price paid for the landed product during roe season when production is highest. In November, for example, the average price received by fishermen equalled $0.505 during the 1989-1993 period - far above the average price received during any other month. Pounds landed also peaked in November, averaging 20% of the yearly total in 1989-1993.

[1]The advancing price during this period likely reflects, in part, the successful development of an export market for the roe product.

Table 7.1. Value and price of Gulf of Mexico striped mullet landings, 1961-1993.

	Value		Price Per Pound	
Year	Current	Deflated	Current	Deflated
1961	1,899,618	6,353,237	$0.055	$0.183
1962	1,935,983	6,410,540	$0.056	$0.184
1963	1,819,764	5,946,941	$0.053	$0.173
1964	1,997,512	6,443,587	$0.055	$0.177
1965	1,857,205	5,895,889	$0.056	$0.178
1966	2,020,361	6,235,682	$0.069	$0.213
1967	2,002,135	6,012,417	$0.071	$0.213
1968	1,885,021	5,416,727	$0.078	$0.223
1969	2,394,370	6,524,169	$0.082	$0.223
1970	2,242,308	5,779,144	$0.085	$0.218
Average	2,004,428	6,102,133	$0.065	$0.196
1971	2,231,428	5,509,699	$0.084	$0.208
1972	2,501,623	5,984,744	$0.087	$0.208
1973	3,202,607	7,213,079	$0.106	$0.239
1974	3,363,596	6,822,710	$0.121	$0.246
1975	3,586,104	6,665,621	$0.142	$0.263
1976	2,986,031	5,247,858	$0.161	$0.283
1977	4,103,043	6,770,698	$0.193	$0.319
1978	5,247,805	8,048,781	$0.183	$0.280
1979	5,000,358	6,887,545	$0.182	$0.251
1980	5,915,864	7,179,447	$0.196	$0.238
Average	3,813,846	6,633,018	$0.144	$0.251
1981	7,684,607	8,453,913	$0.230	$0.253
1982	5,912,973	6,127,433	$0.222	$0.230
1983	6,442,904	6,468,779	$0.252	$0.253
1984	6,057,737	5,830,353	$0.269	$0.259
1985	5,389,811	5,009,118	$0.277	$0.258
1986	8,857,359	8,081,532	$0.344	$0.314
1987	7,637,393	6,723,057	$0.317	$0.289
1988	10,477,408	8,856,642	$0.416	$0.351
1989	11,504,626	9,277,924	$0.418	$0.337
1990	11,458,797	8,767,251	$0.399	$0.305
Average	8,142,361	7,359,600	$0.316	$0.285
1991	9,233,714	6,799,526	$0.381	$0.286
1992	8,365,571	5,962,631	$0.349	$0.249
1993	9,782,622	6,769,981	$0.377	$0.261
Average	9,127,302	6,500,713	$0.370	$0.263

Source: NMFS unpublished data

Table 7.2. Monthly value and price of Gulf of Mexico mullet landings, 1989-1993.

Month/ Year	Value in Dollars						Average Monthly Percentage	Average Price ($/lb)
	1989	1990	1991	1992	1993	Monthly Average		
January	1,764,242	679,537	852,296	461,555	703,557	892,237	9.2	0.362
February	242,359	264,088	349,555	269,226	281,316	281,309	2.9	0.298
March	226,639	296,988	298,456	334,356	308,530	292,994	3.0	0.324
April	259,335	288,217	257,278	304,865	271,967	276,332	2.9	0.334
May	291,933	324,532	291,351	363,030	296,707	313,511	3.3	0.339
June	342,477	383,442	333,670	377,038	382,300	363,785	3.8	0.333
July	418,001	403,472	456,839	545,400	385,199	461,782	4.8	0.323
August	496,762	498,138	532,951	521,983	479,730	505,913	5.3	0.281
September	600,155	573,423	497,918	576,022	559,499	561,403	5.9	0.270
October	1,317,587	1,879,278	775,115	1,591,181	1,851,846	1,483,001	15.4	0.405
November	3,241,771	2,764,973	2,306,828	1,729,529	3,024,886	2,613,593	27.1	0.505
December	2,301,032	1,846,787	1,475,931	1,291,386	1,137,105	1,610,448	16.7	0.365

Source: NMFS unpublished data

7.1.3 Prices of Different Mullet Products

Table 7.3 shows the different prices received by fishermen for whole mullet yielding different products in various markets. As indicated, the red roe mullet harvested during the spawning season traditionally sells at a higher premium. In 1994, for example, the red roe mullet were sold by fishermen to fish houses at an average price of $1.583 per pound. The average price received by fishermen for general mullet was only about a quarter of that established for the red roe mullet ($0.376 per pound). The higher price for roe mullet coupled with aggregation of mullet stocks, results in the potential for higher profitability among fishermen assuming increased effort does not completely offset the increased revenue per trip.

Table 7.3. Estimated prices received by fishermen for whole mullet yielding different products in the state of Florida, 1992-1994.[a]

Year/Products	Number of Observations[b]	Poundage Reported[c]	Weighted Average Price ($/lb)
1992			
Bait	14	15,936	0.481
Black mullet	4,570	1,264,260	0.297
Red roe	3,706	1,038,250	1.262
White roe	3,316	558,875	0.276
1993			
Bait	167	141,169	0.346
Black mullet	12,375	3,094,734	0.306
Red roe	5,223	1,778,363	1.330
White roe	4,212	1,047,897	0.276
1994			
Bait	188	72,516	0.345
Black mullet	10,166	2,170,331	0.376
Red roe	5,468	1,530,175	1.583
White roe	5,719	1,097,700	0.355

[a]To the extent that the samples may not accurately reflect the population, prices may be biased.
[b]Reflects the number of trip tickets with price information.
[c]Reflects poundage reported with price information.

7.2 Exports

Exports of mullet products averaged almost $15 million annually during 1992-1994 (Table 7.4). Frozen mullet roe constituted the primary exported product, accounting for ¾ of the total value of all exported mullet products during the 3-year period.[2] Frozen mullet represented the majority of the remaining exported product, by value, though exports of fresh mullet roe have experienced the greatest relative increase since 1992.

The exported price of the frozen mullet roe averaged $6.74 per pound during the 1992-1994 period with approximately 95% of total exports of this product destined for Taiwan. Similarly, Taiwan was the primary importer of United States fresh mullet roe which was sold at an average price of $5.65 per pound during the 1992-1994 period. The export price associated with frozen mullet averaged $1.21 per pound. While Taiwan was the primary country of destination for exports of frozen mullet, a number of other countries such as Egypt, Italy, and Japan also contributed to the total.

These prices appear low relative to the minimum price expected based on average dockside prices received by mullet fishermen during the roe season. The low exported price may reflect vertical integration practices within the processing sector. For example, if a company in the Gulf also has a subsidiary in Taiwan, the price reported on bills of lading may not actually represent the true export value.

[2]A small amount of other mullet products such as fresh mullet may also be exported.

Table 7.4. United States exports of mullet products, 1992-1994.

	1992		1993		1994		1992-1994 Average	
Product/Country	**1,000 lbs**	**$ thous.**	**1,000 lbs**	**$ thous.**	**1,000 lbs**	**$ thous.**	**1,000 lbs**	**$ thous.**
Mullet Roe Fresh								
Taiwan	18	$38	161	$741	312	$1,739	163	$839
Other[a]	10	$122	8	$96	21	$211	13	$143
Total	28	$160	169	$837	333	$1,950	177	$982
Mullet Frozen								
Egypt	0	$0	531	$159	313	$84	281	$81
Italy	17	$14	0	$0	0	$0	6	$5
Japan	36	$68	360	$911	791	$933	396	$637
Mexico	0	$0	69	$22	221	$40	97	$21
Taiwan	629	$1,732	887	$2,403	1,871	$1,361	1,129	$1,832
Other[b]	42	$22	273	$116	641	$229	319	$122
Total	724	$1,836	2,118	$3,612	3,837	$2,648	2,226	$2,699
Mullet Roe Frozen								
France	19	$280	17	$213	0	$0	12	$164
Italy	4	$24	44	$382	18	$155	22	$187
Taiwan	1,609	$10,125	1,609	$10,552	1,551	$11,361	1,590	$10,679
Other[c]	12	$64	15	$189	86	$246	37	$166
Total	1,644	$10,493	1,684	$11,336	1,655	$11,762	1,661	$11,197

[a]Other countries: China, Egypt, France, Germany, Italy, Japan, and Spain.
[b]Other countries: Brazil, China, Colombia, Hong Kong, Israel, Saudi Arabia, Sweden, United Kingdom, and Venezuela.
[c]Other countries: Belgium, China, Japan, and Spain.

8.0 SOCIAL AND CULTURAL CHARACTERISTICS, ATTITUDES, AND OPINIONS OF MULLET FISHERMEN, DEALERS, AND PROCESSORS

8.1 Introduction

All fisheries management plans must take into account aspects of the changing social and cultural conditions of the user population. A fishery cannot simply be defined as a stock of fish. Fishery managers must take the operational view that a "fishery" is not only the biological resources (stocks) but also the population of resource users, their families, and social and economic support networks interacting with the biological resources (Dyer and McGoodwin 1994). They must also recognize that these assemblages of people and their communities have unique characteristics and may have been identified using the natural resource community (NRC) model (Dyer *et al.* 1992). The NRC is defined as "a population of individuals living in a bounded area whose primary cultural existence depends upon the utilization of renewable natural resources." This model is now well accepted in the discipline (Dyer and McGoodwin 1994) and has been widely used as a means of investigating the relationship between humans and their natural resource base.

Communities that rely on fishery resources to support their economy must adapt to the inevitable fluctuations in abundance caused by natural cycles. In recent years, they have been forced to further adapt to ever-changing regulations most of which have reduced their ability to harvest the available resources. Although many regulations have been adopted to address biological problems with stocks, others have been implemented for political purposes. In both cases, the effects of such measures on the human components of fisheries has been largely ignored. Ignoring potential impacts to users can seriously affect the thrust of a particular management measure because some users may attempt to circumvent the measure either legally or illegally and others may shift effort either within or to other fisheries, potentially causing additional problems. A better knowledge of the human components of fisheries including their interactions, attitudes, and opinions is needed to avoid future crises.

Very little information is currently available regarding the human dimensions of the mullet fishery of the United States Gulf of Mexico. The fishery has historically been predominantly conducted in Florida, and the only scientific studies of users have occurred in this state. The fishery is almost exclusively commercial; however, there is currently a conflict between different factions in Florida over the use of nets that catch mullet and other nearshore species. This conflict led to the passage of a referendum in 1994 that changed Florida's constitution and banned the use of certain nets in most inshore and nearshore waters. Partly because of institution of stricter regulations on fishermen in Florida, Smith and Jepson (1993), Thunberg *et al.* (1994), and Smith (1995) studied commercial fishing families to determine the potential impacts of regulations and disruptions to these multigenerational users. These researchers evaluated the social, economic, and political perceptions of these families as they related to present and potential regulations.

Dyer and Leard (unpublished data) developed a brief questionnaire to survey mullet wholesalers and processors in all five Gulf States to gather information about this segment of the fishery. The questionnaire was used to determine personal characteristics of these groups; economic and social interactions; perceived problems; and consequences of regulations,

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environmental changes, and product availability (see Section 15.2). They also attempted to ascertain which factors might cause these groups to terminate their businesses; their expectations from management; and their past, present, and future characterization of their lives in general.

8.2 Importance of Mullet to Users

Mullet have a relatively long history of use as a food fish in Florida and Mississippi with some use in the other Gulf States. Florida's catch and consumption are, however, orders of magnitude above Mississippi's where the term "Biloxi bacon" has often been used for mullet. Until the development of the roe fishery in the late 1970s, mullet were not heavily fished in the other Gulf States.

Roe mullet have a much higher value, and because the season is very short and unpredictable, annual profitability from catches may vary for some users. This fishery has traditionally been centered in Florida, but landings have increased many fold in Louisiana as this fishery has grown steadily. Although the roe fishery may be more important than the flesh fishery from an economic viewpoint, the flesh fishery and its local and in-state markets in Florida have been a staple for most fishermen, wholesalers, and retailers of mullet (Dyer and Leard, unpublished data).

8.3 Mullet Fishermen

In general, mullet fishermen in the Gulf do not rely solely on catches of mullet for their livelihood. Based on seasons and availability, the nearshore fishermen most often target a variety of species including mullet, seatrout, black drum, sheepshead, and red drum (Degner *et al.* 1989, Thunberg *et al.* 1990). The importance of mullet to these fishermen varies greatly from state-to-state, but Florida fishermen are perhaps the most significant group that has a history of reliance on mullet fishing as a way of life. Also, Florida is the only Gulf state in which empirical, social and economic studies of mullet fishermen have been undertaken.

Florida's nearshore commercial mullet fishing activities are family based, and they are transgenerational. Participants may be characterized as being part of these NRCs. In the mullet NRCs of Florida, cultural values and self-esteem are linked to the occupational activity of resource extraction. For NRC members utilization requires the development of special knowledge which is critical to their success in the fishing and marketing of finfish species. In order to develop the specialized and experimental knowledge needed to succeed as fishermen, formal education and other occupational skills are not stressed in the NRCs. Additionally, because many NRCs are located in rural and poor areas, there are fewer opportunities to diversify employment. In NRCs, men typically serve as harvesters while wives, children, and other relatives complement the fishing effort by managing the household; performing bookkeeping, purchasing, and other administrative tasks; and giving emotional support (Thunberg *et al.* 1994). Wives may also hold nonfishing-related jobs.

As a result of 1991 and 1992 regulations in Florida, commercial fishing families felt that their existence and way of life were threatened and that they were experiencing increased financial burdens and emotional stress that were negatively impacting family relationships (Thunberg *et al.* 1994). These effects were similar to those experienced by the families of

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fishermen in Cordova, Alaska, who underwent years of psychological, cultural, social, and economic trauma stemming from the technological disaster of the Exxon Valdez Oil Spill (Dyer 1993, Dyer *et al.* 1992, and Picou *et al.* 1992).

Most Florida fishermen did not finish high school; consequently, opportunities for other jobs are limited. Many are at or approaching middle age and are reluctant to leave an occupation that they enjoy, and one that is an integral part of their culture. Prior to the passage of the net ban referendum, these families planned to continue fishing with wives taking other jobs and fishermen husbands working longer hours to meet their financial needs. Also, before the passage of the referendum, these families felt that commercial fishing would eventually cease to be a viable source of income, and most were encouraging their children to seek other job opportunities; however, few felt that the virtual end of inshore net fishing was imminent.

Although fishing families believed that present (1991-1992) and proposed (1993) regulations posed the most serious threat to their way of life, they noted that loss of marine habitat to development, pollution, and displacement from the waterfront as a result of a rapidly increasing coastal population would probably destroy their way of life at some future time. They also cited demoralization resulting from misrepresentations and political attacks by recreational and environmental groups (Smith and Jepson 1993, Thunberg *et al.* 1994). Forced transition out of the fishery cannot be viewed as singularly effecting individual numbers of fishermen.

8.4 Mullet Wholesalers

Wholesalers represent part of the socioeconomic network that supports and is supported by mullet fishermen and their families. Very little data are available to characterize wholesalers or to describe their relationships with fishermen, processors, and others. Dyer and Leard (unpublished data) sent questionnaires to nearly 200 businesses in the five Gulf States; however, the only appreciable responses were received from Florida (20 of 100) and Louisiana (3 of 20). The findings from this survey are tentative due to the low response rate. Additionally, some respondents did not answer all of the questions, and some questions were only partially or subjectively answered. The low response rate could be a result of the timing of the survey (just prior to the vote on the net ban amendment in Florida); the fact than an antiquated list of wholesalers was used; or other reasons, *e.g.*, growing apathy of the industry toward scientific inquiry.

The mullet fishery is either well established (Florida) or has grown rapidly in recent years (Louisiana). Respondents ranged from 25-90 years of age with an average age of 49 years. All but one of the respondents were white, and over 70% were state natives. Their years in the business ranged from 4-50 years with an average of approximately 22 years; thus, many have invested most if not all of their occupational history to fish wholesaling.

The majority of respondents chose the business because they liked the work, and approximately 35% indicated that they were following a family tradition. Eighty-five percent of the respondents indicated that this was a family business with relatives involved at all levels (fishing, secretarial roles, bookkeeping, etc.). Of the respondents, 48% reported that family members had taught them the business; however, 29% were self taught, and 24% were taught by others.

All respondents from Louisiana were college graduates; however, only 3 of 19 respondents from Florida were college graduates. Most of Florida's respondents had high school diplomas and/or some college, but 20% had less than 12 years of school.

When asked to rank their top 6 species based on economic importance to their business, 76% (n=19) of the respondents indicated that it was number one. All but one respondent noted that mullet was an important food fish. Almost all respondents indicated that their businesses would be profoundly impacted if mullet were not available, and they also noted that there were sufficient opportunities to sell their products.

Most Florida wholesalers sold mullet as whole fish. Respondents that processed mullet for roe indicated that this product amounted to only about 20% of their sales with the remainder being sold fresh fileted. A few respondents sold gutted and headed or smoked mullet. Louisiana wholesalers sold about 60%-70% of their mullet for roe. The remainder was sold as whole fish.

Most wholesalers reported that they sold their products to other wholesalers followed by retailers and private individuals. Restaurants and other institutions also received 20% to 25% of products from a few wholesalers. Florida wholesalers most often sold their products locally followed by within-the-state sales. Louisiana wholesalers, however, sold nearly 100% of their product out-of-state.

Most wholesalers received mullet from local fishermen, but some respondents indicated that they received from 10% to 30% of their fish from outside the local area but within the same state, and some received 10% to 20% from out-of-state fishermen. Wholesalers estimated that they usually received mullet from 1-4 hours after it was caught and reported that it was almost always in excellent condition. Wholesalers reported paying an average of about $0.60 per pound for mullet entering the flesh markets and about $1.30 for whole mullet for the roe fishery. Whole mullet prices varied from approximately $0.30 to $0.80 per pound (flesh fishery) to $1.10 to $1.65 (roe fishery). Roe prices ranged from $5.00 to $12.00 per pound depending on size and other factors.

All but one respondent believed that mullet stocks were doing well in the Gulf. Most (80%) disagreed that mullet were overfished, and only 3 of 25 respondents felt that stricter regulations were needed. When asked if more fishermen should catch mullet, the majority of wholesalers were neutral; however, 32% (8 of 25) disagreed or strongly disagreed, and only 12% (3 of 25) agreed or strongly agreed.

Wholesalers identified the following potential problems for their businesses based on significance (1 being most significant) as follows:

1. insufficient product
2. too few fishermen suppliers
3. poor prices
4. lack of market outside the region
5. too much product*

6. poor condition of fish*
7. little demand

*ranked equally

Most wholesalers did not feel that numbers 5, 6, and 7 were problems. Other problems most often mentioned by respondents were habitat loss, over-regulation, and pollution. Interestingly, most Louisiana respondents did not feel that habitat loss and pollution were significantly affecting mullet, but the opposite was true in Florida.

Virtually all respondents considered their business as a "way of life" versus just a job, and they wanted their children to have a choice regarding involvement with the fishery. When asked about factors that might cause them to consider leaving or closing their business, wholesalers most often listed practical factors such as operating costs, pollution, lack of product, market prices, and regulations as the most important factors. Family pressures, excessive work and absence from home, and scarce or inexperienced labor were considered the least important. In Florida, the ban on commercial net gear was specifically cited by many respondents as a key threat to the survival of their business.

When asked to characterize their life on a scale of 0 to 10 (0 being extremely bad and 10 being very good) for the period 10 years ago, 5 years ago, 2 years ago, today, in 2 years, and in 5 years, most indicated that their life had improved from 10 years ago until today. Also, approximately 61% indicated that they were currently at a level 8 or above (most were level 10). Only 8 of 23 respondents indicated a decline, and 5 of the 8 were still self ranked at level 5 or above today. Only 3 respondents noted a level below 5. Six respondents graded themselves at 10 for the entire period (10 years ago until 5 years from now). Although most respondents were pleased with their quality of life today, most in Florida indicated uncertainty if the then proposed restrictions on netting were promulgated. Some felt their life would be fine regardless of the proposal. Others felt that it would decline, but the majority were merely uncertain.

8.5 Mullet Processors

Dyer and Leard (unpublished data) also mailed similar questionnaires to approximately 80 processors in the five Gulf States. Processors were separated from wholesalers based on data provided by individual states and the NMFS. Only three surveys were returned, and it is believed that present data cannot be used to adequately separate processors from wholesalers because as previously reported under Section 8.4, some processing is being conducted.

8.6 Conclusions

With the imminent passage of the net ban referendum in Florida, wholesalers believed that as much as 42% of fishermen would go to other Gulf States to fish mullet (Dyer and Leard, unpublished data). This possibility probably influenced subsequent legislation and regulations in Louisiana, Alabama, and Mississippi. How these drastic changes to laws and regulations will ultimately affect the human components of the mullet fishery in the Gulf is unknown; however, various actions are ongoing that signal possible effects. The effect on wholesalers and processors will certainly be a loss of domestic product, but questions of whether or not product from other areas can be acquired and at what price are presently unanswerable.

Changes to state laws and regulations banning the use of certain nets to harvest mullet in Florida, Louisiana, Alabama, and Mississippi reflect a social choice. They were not enacted to address a biological problem with the stocks as indicated in Sections 9.3 and 15.3. In Florida the buy-back program had expended in excess of $16 million to purchase nets from qualified fishermen as of September 1995; consequently, the number of fishermen will probably be reduced in the coming year and into the future. Other Florida fishermen that attempt to go to other states will be hindered by new laws and regulations as well as increased costs for licenses. Some may be precluded from moving because of new laws and the "attachment to place" that is characteristic of NRC residents. To combat the prohibitions on certain net gear in the inshore fishery, some fishermen are developing alternative gears and harvesting techniques (modified cast nets, cast net cannons, modified purse seines, and other gear), and some plan to fish in areas that are not addressed in current laws and regulations, *e.g.*, EEZ.

Current legal challenges to severely restrictive legislation in Louisiana and Florida, the major mullet producing states in the Gulf, and plans to continue fishing in some form by many fishermen are testimony to the fact that mullet fishing is a way of life for many fishermen, wholesalers, and processors. It also supports the earlier contention that some participants in the commercial fishery have few if any alternatives for making a living.

9.0 MANAGEMENT CONSIDERATIONS

9.1 Definition of the Fishery

The fishery includes the harvest activities for the species, *Mugil cephalus*, in the United States Gulf of Mexico.

9.2 Management Unit

The management unit is considered to be the total population of striped mullet, *M. cephalus*, occurring in the United States Gulf of Mexico.

9.3 Stock Assessment

The following subsections summarize the analyses and results of the overall stock assessment (Appendix 15.3). All data and calculations used in this stock assessment are the best available through 1994, and they include the effects of state regulations existing through the same period. The effects of laws and regulations adopted in 1995 that prohibit or further restrict the use of certain gears are unknown, and no attempt has been made in this assessment to predict such effects.

9.3.1 Introduction

Striped mullet is the primary species caught in the commercial and recreational mullet fisheries. The mullet populations in the Gulf are believed to be genetically homogeneous (Tatum *et al.* 1993, Campton and Mahmoudi 1991, Thompson *et al.* 1991); and in this assessment, they are considered to be a unit stock. There are, however, regional morphological differences that are influenced by habitat conditions. Mullet generally remain in the same region all their juvenile and adult life and rarely move long distances. Consequently, the stock may be managed under regional or state-specific management programs in the Gulf of Mexico as long as the overall stock can maintain itself.

Biological and fishery data for mullet were reviewed for the stock assessment. Landings (catch) and effort are key ingredients in the analysis of the relative health of any fish population, because trends in these factors may alert scientists and fishery managers to the potential of overfishing. In general, if landings are decreasing and effort is increasing, the potential for overfishing exists and should be investigated. There are, however, many factors that affect landings and fishing effort (see sections 5.1.1 and 15.3). Although landings data and trends are reasonably known for all Gulf States, fishing effort is virtually unknown except in Florida.

9.3.2 Population Models Considered

Several population models (yield per recruit, surplus production, virtual population analysis [VPA], and spawning stock biomass per recruit [SSB/R]) were considered for the stock assessment. The VPA analysis requires long-term and continuous data on gear-specific age frequencies of the catch and total catch and effort. The surplus production model requires long-term data on annual catch and effort. Long-term data on catch and effort and size/age

frequencies were not available for these analyses. Given available databases (age and growth, mortality rates, reproduction, and maturity schedules), the SSB/R model was selected as the most appropriate method for the assessment of the mullet stock.

9.3.3 Spawning Stock Biomass per Recruit Analysis and Biological Reference Points

Spawning stock biomass per recruit (SSB/R) analysis is a simple extension of the "dynamic pool" model used to calculate yield per recruit (YPR). Beverton and Holt (1957) gave the classic derivation of the model, and Gabriel *et al.* (1989) specified the computational details. The SSB/R model requires estimation of a number of input parameters (growth, age-specific weight, maturity schedule, maximum age, fishing mortality, and natural mortality rates). The SSB/R model calculates the reproductive contribution of females from every age group.

Gabriel *et al.* (1989) suggested that the maximum SSB/R is obtained under conditions of no fishing mortality. Fishing results in a reduction is SSB/R, and the percentage reduction from this maximum SSB/R is expressed by dividing the SSB/R at a given fishing rate (F) by SSB/R under no fishing:

$$\frac{\text{SSB/R at } F>0}{\text{SSB/R at } F=0}$$

This ratio is termed spawning potential ratio (SPR) (Goodyear 1989) and is expressed as a percent. This analysis is one of the most common methods used in recent years to estimate the effects of fishing pressure on the spawning stock.

Biological and fishery data available from Louisiana, Florida, and Alabama were used in various analyses. Estimates of von Bertalanfy growth parameters K, L (inf), and t (0) for female mullet were available for Florida and Louisiana. The K values ranged from 0.28 to 0.36; L (inf) values ranged from 451 to 472 mm FL; and t (0) values ranged 0.05 yr to -0.114 yr. The number of age classes and growth parameters are also similar for the two regions. Data from both Florida and Louisiana showed significant differences in growth rates between sexes. The equations to predict fecundity based on standard length (SL) and fork length (FL) and data on maturity schedules were available for Florida and Louisiana.

Total mortality (Z) is equal to natural mortality (M) plus fishing mortality (F). The annual instantaneous natural mortality rate (M) was estimated based on analysis of the catch curve and/or Pauly's method (Appendix 15.3). These analyses have yielded estimates of M from 0.30 to 0.65. In previous stock assessments for mullet in the Gulf, a range of M = 0.30 to 0.44 has been used in Florida (Mahmoudi 1993), and M = 0.3 has been used for Louisiana (Shepard *et al.* 1992) and Alabama (Lazauski 1993). These values of M were assumed to be constant for all ages and years. If Z=M+F, use of the lower M (0.3) is more conservative because it results in higher estimates of F and lower estimates of SPR. Fishing mortality rates (F) were calculated based on the catch-curve method and/or mark/recapture studies. Fishing mortality on the stock was highly variable among the Gulf States. The most recent estimates of F were 0.5 (females) for Louisiana (Shepard *et al.* 1992), 0.6 (females) for Alabama (Lazauski 1995), and 1.0 (females) for Florida (Mahmoudi 1993) (Appendix 15.3). There were no estimates of F for Mississippi or Texas. Using these mortality estimates, SSB/R and SPR were calculated for stocks

of mullet in Louisiana (Shepard *et al.* 1992), Florida (Mahmoudi 1993), and Alabama (Lazauski 1995).

The SSB/R and SPR for mullet stocks in Louisiana and Alabama were estimated using similar SSB/R models (Shepard *et al.* 1992 and Lazauski 1993). The age at entry to the fishery was adjusted based on a minimum mesh size regulation in each state. Current SPRs were calculated as 31% for Louisiana and 34% for Alabama. There were no analyses of SSB/R and SPR for Mississippi and Texas due to the lack of fishing mortality estimates.

For the assessment of the mullet stock in Florida, biological and fishery data collected during 1988-1989 were used to calculate SSB/R and SPR for the pre-regulation period. The SPR was estimated in the range of 15% to 22% (Mahmoudi 1993). During 1990-1992, management measures including a minimum mesh size for gill nets of 3 inches and week-end closures of 36 and 54 hours (October to January) were adopted by the FMFC. A fishing mortality rate of 1.0 was estimated for 1992, and SPR was calculated at 18% to 25%. In 1993, FMFC adopted additional management measures including extension of the 54-hour week-end closures to 72-hours (July through January), a pre-roe season trip limit of 500 pounds (July through September), and reduction of the maximum gill net length to 600 yards. These measures were intended to reduce catch, increase escapement of spawners during the roe season, and increase SPR to 35%.

Week-end closures should reduce fishing time and catch especially when they occur during the passage of cold fronts because at this time large schools emigrate from the inshore waters to offshore spawning grounds. A time-series model, superposed epoch (Prager and Hoenig 1989) was used to test for an association between cold front passages and catch rates. The results indicated a strong association ($PR>F = 0.01$ for 1986/1987, 0.006 for 1987/1988, and 0.001 for 1988/1989) between cold front events and variabilities in catch. A Monte Carlo model was developed to determine the effectiveness of weekend closures in reducing yield from the fishery under randomized cold front events. The base-line data used in the model included: (1) a probability distribution of the number of days between cold front events, (2) a daily distribution of catch and effort, (3) an effort shifting rate, and (4) a catchability coefficient multiplier. The results of these analyses showed that under these management measures, the SPR was expected to reach the targeted 35% in 5 to 7 years as the spawning stock biomass increased by 90%.

9.3.4 Management Implications

Biological reference points are one of the most commonly used standards to evaluate minimum values of SPR. The most widely used reference points are F0.1, Fmax, F20%, and F35%. In the absence of information on the spawning stock and recruitment, Goodyear (1989) suggested that a working, critical minimum SPR of about 20% was appropriate; whereas, Mace and Sissenwine (1993) suggested that a conservative strategy would be to maintain at least a 30% SPR as a default "threshold," and Clark (1991) recommended a SPR of 35% as a management "target."

In the absence of information on the spawning-stock-recruitment curve for mullet and due to inclusion of other factors such as spatial distribution in fisheries, socio-economic considerations, and ecological parameters, some states have conservation standards based on the

SPR concept ranging from a "threshold" of 20% in Louisiana to a "target" of 35% in Florida. Based on the current estimates of SPR, these actions should be sufficient to rebuild populations in Florida and maintain populations in Alabama and Louisiana. Louisiana's fishery has grown considerably since the 1992 assessment, and a SPR "threshold" of 20% will require monitoring of the fishery to ensure that recruitment is not impacted if fishing mortality rates approach the conservation standard. Louisiana's standard, however, is based primarily on the fished portion of the mullet stock and does not completely consider that portion of the stock in lightly fished areas of the state. Consequently, it more accurately reflects the fishing mortality rates east of the Mississippi River and not the relatively lightly fished areas west of there or the total population of the state. Measured F values, therefore, are likely overestimated for the stock as a whole, and SPR is probably underestimated.

9.4 Problems and Perceived Problems in the Fishery

Although mullet are believed to be a unit stock in the Gulf of Mexico, problems and perceived problems in the fishery vary greatly from state-to-state. Because Florida's fishery accounts for a relatively large percentage of the total Gulf production, and since mullet do not migrate great distances, problems that appear to have the highest priority for consideration by management are more focused in this state. The following is a discussion of problems and perceived problems with indications as to which states they are applicable.

9.4.1 Limited Database for Management

A serious problem with scientifically managing the mullet fishery is the lack of adequate data. Age and growth relationships, reproduction, and fecundity are fairly well known; however, estimates of mortality (both natural and as the result of fishing) are uncertain. Consequently, estimates of spawner/recruit relationships, recruitment, and SPRs are not as accurate as would be desired for management purposes.

Landings are the primary component of the fishery-dependent data collected. Since the area of catch is oftentimes not recorded, transient fishing that results in landings in one state and catch in another may bias data.

Variations in the types of gear used (*i.e.*, purse seines, gill nets, trammel nets, etc.) and minimum legal mesh sizes for commercial gear among the Gulf States contribute to the inaccuracy of population models and stock assessments, particularly size and age structure components. Variations in scientific collection gear may also bias Gulf-wide estimates of recruitment, larval and juvenile abundance, and other factors used in stock assessments.

Another problem stems from the fact that mullet are sold at both wholesale and retail markets, and some may or may not be reported as landings. Since there are no quotas on the fishery, the problem is primarily manifest when fish are caught and sold without being reported. This unknown catch may cause increased uncertainty regarding estimates of SPR.

Additionally, trip tickets only include data from successful trips, and an individual ticket may have a combined number of trips. Unsuccessful trips that are not recorded and combined trips that are recorded as one may cause estimates of CPUE to be inordinately high.

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A reliable, long-term catch and effort database is needed to improve stock assessments. The collection of this data is, however, improving especially since the enactment of the saltwater products license in Florida and increased efforts by the other states to more accurately identify users and their fishing effort.

9.4.2 Habitat Reduction and Degradation

Another serious problem that has probably adversely affected mullet resources through time is the loss of critical estuarine habitat. The human population in coastal areas of the Gulf, especially in Florida, has increased dramatically. To establish human populations in previous uninhabited or sparsely inhabited coastal areas and to provide the "creature comforts" desired; filling, dredging, channelization, and other construction activities were conducted. These activities have been primarily responsible for the loss of habitat. Thousands of acres of vegetated wetlands (critical habitat for larval and juvenile stages of mullet) have been lost and are continuing to be altered at an alarming rate.

Changes caused by natural phenomena such as hurricanes, stream diversions, sea level fluctuations and other weather patterns may also have caused loss of mullet habitat or reduced its productivity; however, these natural changes have usually been short-term and constitute only a small percentage of the overall destruction that has occurred. In Louisiana, and perhaps other areas, erosion and subsidence have been quite significant in recent years, and it is believed that human activities including channelization and leveeing have exacerbated the natural destructive processes.

The extent of habitat loss has not been accurately measured and neither has its affect on mullet resources. The magnitude of wetland habitat alteration and the level of dependence that mullet have for such habitat, however, strongly suggests that this phenomena has at least contributed to declining catches over time and the perception of lower numbers of fish.

9.4.3 Inconsistent Interstate Management

Inconsistent interstate regulations on the mullet fishery have probably caused problems for fishermen and dealers/processors. During the roe season as harvesters move from state to state, they encounter different regulations on fishing seasons, approved gear, closed areas, and other restrictions. These regulations have also changed rapidly over the past few years. Sometimes these inconsistencies cannot be supported by biological or stock assessment data and merely reflect a sociological compromise derived through political and regulatory processes. As a result, users from state-to-state are confused as to why such discrepancies exist. Additionally, the effectiveness of enforcement is reduced. Citations may also be issued to unknowing transient fishermen.

At least two factors have hindered the development of greater consistency. First, there is little communication among neighboring states prior to the enactment of regulations. Regulations are consequently developed primarily from information gathered within each state. Secondly, most states lack legislative authority to enter into interstate cooperative management agreements. Consequently, measures must be adopted singularly by states. This fact may

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diminish a state's ability and willingness to negotiate. These factors may be compounded because when there is no authority to cooperatively manage, desire for communication is reduced or eliminated.

9.4.4 Illegal Sale

Although illegal sale of mullet is not a major problem, it occurs to some degree in all Gulf States. It is perhaps most significant in Florida where the majority of the Gulf harvest has historically been caught and sold, and where regulations on commercial and recreational fishermen are most stringent. The problem is probably least significant in Texas where mullet are primarily used for bait.

The problem is probably most apparent during the roe season in Florida because at this time the per-pound value increases significantly, and mullet are more easily caught in large, compact schools. Both commercial and recreational fishermen make illegal sales as the result of directed, premeditated effort. Commercial fishermen may catch mullet with cast nets from areas closed to commercial gear or during periods when gill nets and other commercial gear are not allowed (*i.e.*, weekends). Recreational fishermen may intentionally and opportunistically (when they unintentionally catch more than they need) sell mullet without the burden of licenses, permits, or reporting requirements.

9.4.5 Transient Fishing

The spawning migration of mullet occurs earliest in the north-central Gulf States (Louisiana, Mississippi, and Alabama) beginning in mid October, and migration occurs latest in south Florida. Problems occurred as the result of the concentration of both transient and local fishermen in particular areas causing conflicts among fishermen as a result of too many people fishing in a limited area.

Transient fishing occurs when fishermen move from one area or state to another to follow migrating fish. In the mullet fishery, most transient fishing has occurred when Florida fishermen moved to other states to harvest roe mullet.

Although the entangling net ban in Florida would probably have increased transient fishing in 1995, legislation in other states has effectively precluded increased entry through stringent licensing requirements and increased fees. Overall problems associated with transient fishing of mullet have been reduced; however, future effects are unknown.

9.4.6 Increased Commercial Harvest of Spawning Stock for Roe

The perception of this problem commenced in the mid to late 1970s when the price and value of mullet roe increased greatly; however, the overall concern that harvests were exceeding the environmental carrying capacity date to at least the late 1940s (Sutton 1950). By the mid 1980s, all Gulf States were receiving testimony from user groups that stocks were being depleted, and this perception was perhaps the most important factor leading to the development of this management plan. Although Florida's landings show a definite declining trend over the past 30 years (Table 5.1) and effort is greatest during the roe season, reduced catches cannot be solely

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attributed to commercial fishing especially for roe. Other factors that are discussed in Section 5.1.1 may be causing or contributing to the observed declines. Further study is needed to determine whether this problem is related to commercial fishing, other factors, or some combination. Also, with the ban on entangling nets in Florida, fishermen may target spawners farther offshore.

9.4.7 Waste of Flesh Discarded After Stripping Roe

Because the roe fishery expanded so rapidly in the mid 1970s, uses for the flesh could not keep pace. Since the value of roe also increased greatly, there was a lack of concern for flesh, and it was sometimes discarded. Additionally, some boats with inadequate refrigeration entered the fishery and could not maintain quality flesh for other uses. Although this problem was not widespread, individual incidences aggravated debates regarding the status of mullet stocks, particularly the spawners. Presently, there are few incidences where flesh is not utilized either for human consumption or bait.

9.4.8 Increased Recreational/Bait Harvest

Although there are isolated reports of increased catches of mullet for bait and recreational/subsistence use, there are no data available to confirm or deny this observation on a Gulfwide or regional basis. Recreational fishing (both inshore and offshore) has undoubtedly increased since the mid 1970s; however, this fact would not of itself prove an increased use of mullet as bait.

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10. 0 POTENTIAL MANAGEMENT MEASURES

Various management measures may be used to accomplish a given management objective or to solve a management problem. The following is a discussion of potential management measures that could be adopted alone or in some combination to address management needs for mullet fisheries in the Gulf.

10.1 Fishing Year

A fishing year could be established to assist agencies in managing quotas, collecting fishery-independent and fishery-dependent data, and other purposes.

10.2 Limitations on Catch

Quotas, trip limits, size restrictions, and possession limits are four ways that have traditionally been used to control catch over a specified period.

10.2.1 Quotas

Quotas have most often been identified as a total allowable catch (TAC) based on an estimate of allowable biological catch (ABC). An acceptable TAC may occur within a range of ABC (sometimes outside the ABC range) depending on the status of the stock and the management goals. Quotas could be implemented for the entire mullet fishery of a given state, or there could be separate quotas for the flesh fishery and the roe fishery. Quotas could be nonmanaged or managed through trip limits or individual quota systems, *e.g.*, individual transferable quotas (ITQs).

10.2.2 Size Restrictions

Minimum size restrictions could be established for recreational and commercial fishermen to ensure adequate recruitment to the spawning stock. Maximum size restrictions could be established for recreational and commercial fishermen to protect spawning populations and increase reproduction. Maximum size limits would not adversely effect recreational and commercial bait fisheries; however, they could preclude continuation or development of roe fisheries. In establishing size restrictions, states should consider uniform minimum and/or maximum size limits based on biological, social, and economic characteristics of the fishery that are appropriate for the entire Gulf with no allowance for undersized fish. These criteria would enhance interjurisdictional enforcement, increase economic yield, promote favorable relationships with users, and maintain viability of stocks.

10.2.3 Bag and Possession Limits

Bag and possession limits could be used to limit catches, allow more fishermen the opportunity to catch fish, and extend fishing over a longer period of time. Bag and possession limits are usually applied to the recreational fishery, and they are especially effective when effort exceeds that which is capable of taking the available supply. If adopted, bag limits and possession limits should be synonymous, and if there is no biological need for variations, states

should work to make them uniform throughout the Gulf States. These criteria would enhance enforcement efforts and reduce conflicts between managers and users.

10.3 Gear Restrictions

Gear restrictions are a very common and popular method used by management to regulate the size and amount of fish harvested. A disadvantage of such restrictions is that they often reduce the efficiency of harvest. Most gear restrictions in the mullet fisheries of the Gulf States pertain to nets used commercially and recreationally. Gill nets have been the most common gear because mesh size can be regulated to catch larger fish, particularly during roe season. Purse seines, haul seines, trammel nets, and fish trawls have also been used to a lesser extent; however, these gears are less size selective.

States could evaluate the use of mesh restrictions on gill nets, trammel nets, seines, and fish trawls especially in the roe fisheries to harvest optimum-sized fish for the market. States could also limit the length, width, and other parameters based on the areas fished, the desires of users, and other criteria. Some gear (*i.e.*, purse seines) could be prohibited if social, economic, and biological conditions of the fishery dictate the need. Finally, states could restrict the use of certain gear in specific areas or seasons for various reasons, including but not limited to those discussed in Section 10.4.

10.4 Area and Seasonal/Time Closures

Areas have been closed by various states to protect juvenile stocks from premature harvest and for other reasons. In most cases, areas are closed primarily to commercial operations and may be linked to the gear because of confined spaces where there is insufficient room for net operations (rivers, bayous, and bays), sensitive habitat that might be negatively impacted by commercial gear and potential conflicts with other water-related uses, *e.g.*, recreational boating, shipping, and commercial crabbing. States could use area closures to protect stocks, reduce conflicts among water-related users, promote water safety, protect habitat, and for other reasons.

Closed seasons could also be used to protect spawners when deemed necessary and/or to manage quotas if they are reached. Closed seasons could also be used either alone or in combination with closed areas to protect juveniles and nonspawning adults outside the roe season.

Time closures (*e.g.*, closures within a particular season) have been used in Florida to reduce effort during the roe season. These measures could be effective in reducing fishing pressure, and other states could evaluate their potential for use.

10.5 Limited Access Considerations

Limited access systems are increasingly being employed in various fisheries throughout the United States and the world. Townsend (1990) stated that a program can be defined as "limited entry" or "limited access" when "some institution establishes administrative preconditions that determine who may or may not fish." He also noted that most restrictive access programs involve some form of license limitation. In addition to license limitation, many restrictive access programs have included area and/or seasonal restrictions or quotas.

Potential benefits from limited access systems are twofold. They can be used to help achieve biological goals, and they can be used to enhance the profitability (rent) within the targeted fishery. The ability for restricted access programs to achieve the biological and/or economic goals set forth by the management agency is a function of how the program is instituted. In general, the more restrictive the program, the greater the probability of achieving some stated biological goal and enhancing profitability within the fishery. In general, limited access programs are relatively inflexible to change; consequently, they should be structured carefully before implementation. A critique of limited entry programs throughout the world has recently been presented by Townsend (1990). States could consider limited access programs for mullet in the Gulf, and in the process, they should examine whether the structure of the proposed program will bring about the desired impacts.

10.6 Monitoring Programs

10.6.1 Fishery-Independent Monitoring

Fishery-independent monitoring programs involve the use of various gear by scientists to collect larvae, juveniles, and adults. This information is used to assess the status of present and future stocks. States could evaluate existing studies regarding mullet to determine whether they are adequate.

10.6.2 Fishery-Dependent Monitoring

The primary purpose of fishery-dependent monitoring is to gather reliable data on catch and effort. This information along with other biological and economic information (age, size-at-age, fecundity, fishing costs and revenues, etc.) can be used to assess the biological and economic "health" of a fishery and associated changes in a fishery through time. The data can also be used to model the fishery and investigate the biological and economic impacts associated with proposed management measures. Fishery-dependent data from trip tickets, as currently employed in the state of Florida, appears to be a very cost-effective method of obtaining detailed information which can be used in devising and evaluating alternative management measures. States could evaluate existing programs to determine if they are producing the desired data.

10.6.2.1 Catch Data

The Cooperative Statistics Program (CSP) and the Marine Recreational Fisheries Statistics Survey (MRFSS) are the main programs used by the Gulf States to monitor catches of mullet. Various individual programs are also utilized by the states to collect additional catch data. States could review their individual efforts and those under the CSP and MRFSS to determine if they are adequately obtaining the necessary information for management decisions. Data from fishermen, dealers, and processors would be included in the evaluation and if they are determined to be insufficient, appropriate changes to laws, regulations, and policies could be sought.

10.6.2.2 Effort Data

With the exception of the state of Florida, effort information pertaining to the Gulf of Mexico mullet fishery is inadequate. The trip ticket system, as adopted by the state of Florida, provides a cost effective vehicle to enhance collection of effort data. Effort data is used in conjunction with catch data to examine changes in catch per trip by season and over time, concentration within the fishery, other species harvested by mullet fishermen, and other trends. Recreational effort statistics could be enhanced by an expanded MRFSS or individual state's creel surveys.

10.6.2.3 Social and Economic Data

Socio-economic information on the Gulf of Mexico fishery is inadequate to establish the potential impacts associated with management measures. More detailed information on prices, the structure of the fleet, export markets, wholesaling and processing channels, the structure and dependencies within fishing communities, and other data could help the decision-making process. States could pursue ways to gather additional social and economic data.

10.6.3 Habitat Monitoring

Since mullet are dependent on quality estuarine habitat, states could increase efforts to identify critical habitat and monitor potentially negative changes. States could consider the full impact of habitat altering activities that have the potential to damage or destroy mullet critical habitat and identify and support activities that could develop or enhance it. These actions could be taken through more focused habitat management programs that review proposals for dredging, filling, channelization, and various other construction in or near critical habitat. The habitat management programs could also include monitoring of effluent discharges, marine debris, and other contamination.

10.7 Measures to Support Management

States could review the current level of support being received by management and determine if it is adequate to provide for and maintain optimum benefits from mullet stocks. If support is lacking, states could prioritize their needs and pursue sources of revenue to meet them including but not limited to increased user fees, special funds, general funds, and federal funds.

10.8 Cooperative Management Programs

States could review the possibilities for development of cooperative management programs as outlined by Berrigan *et al.* (1991) and Leard *et al.* (1993) for their respective mullet fisheries.

11.0 MANAGEMENT RECOMMENDATIONS

When considering management recommendations, the first step is to determine the biological status of the stock using a stock assessment. Based on a unit stock assumption, the stock assessment for striped mullet in the Gulf of Mexico does not show evidence of overfishing, either growth or recruitment. If mullet are managed holistically as a unit stock in the Gulf, there is little concern for potential recruitment overfishing in local areas (*e.g.*, in Florida) because populations in other areas of the Gulf can supply the recruits needed to maintain the stock. Under this approach, annual fluctuations in landings as a result of weather and other environmental conditions are also of little regard unless they are observed throughout the Gulf. Unit stock management can, however, allow regional reductions in commercially fishable populations to levels which reduce their economic viability in the fishery. Since striped mullet populations do not move significant longitudinal distances after initial recruitment, they may be managed on a state-by-state or regional basis. This management strategy is recommended because it addresses regional and state-specific factors that affect populations, particularly their annual abundance and catchability. Consequently, each part of the stock is perpetuated in a commercially viable condition. Individual state analyses are, however, variable or lacking, and additional data are needed.

On average, fishing pressure should not reduce egg production or the SPR below a threshold level for replacement for any stock of fish (Mace and Sissenwine 1993). This "threshold" SPR is uncertain for mullet in the Gulf. Fishing pressure varies greatly both within and among the Gulf States, and these variations have resulted in regional differences in SPR estimates. Estimates of the SPR for Florida in 1988-1989 were relatively low (15% to 22%), and landings had declined gradually over the past 30 years. These factors and others were the impetus for the establishment of an increased "target" SPR and the adoption of additional regulations from 1990 through 1992. Subsequently, Florida's SPR estimate increased to between 18% and 25%. More stringent regulations were adopted in 1993, and recovery to a "target" SPR of 35% was expected by the year 2000. Landings in Alabama and Mississippi have fluctuated. Recent estimates of SPR in Alabama were 34%, while Mississippi lacks sufficient data to conduct this analysis. Louisiana's landings have steadily increased in recent years, and SPR has been estimated at 31%. Texas has never developed a significant commercial fishery, and populations exist in virtually an unfished condition with no estimate of SPR.

Based on analyses of biological data, fishing effort, the effects of existing state regulations, and other parameters; mullet populations were determined to be either meeting established management goals and/or SPR standards (Texas, Louisiana, Mississippi, and Alabama) or recovering (Florida). These determinations were made based on the best available scientific data on the mullet fishery. States should continue their management efforts by establishing conservation standards (*e.g.*, "target" SPRs) as needed to maintain a "threshold" SPR of 30% until such time as a more appropriate standard is determined.

The GSMFC supports scientific management of fisheries with the goal of achieving optimum yield from these resources. Prior actions by various states to prohibit or severely restrict the use of certain commercial gear to catch mullet are inconsistent with this philosophy. As a general recommendation of this plan, the GSMFC recommends that the Gulf States reexamine their philosophies and positions with regard to management of common-property,

marine fishery resources in an effort to ascertain whether or not they are in the best interest of all citizens. The following additional management recommendations are made:

11.1 Fishing Year

Individual states should establish fishing years as necessary to effectuate data collection, quota management, and for other purposes. Fishing years should be consistent among states to the greatest extent possible.

11.2 Quotas and Trip Limits

Although none of the Gulf States has established an annual, commercial quota for mullet (*i.e.*, allowable biological catch [ABC] or total allowable catch [TAC]), Florida, Alabama, and Louisiana previously adopted trip limits for varying periods immediately preceding the roe season. Each of these states should review its regulations and evaluate their effectiveness at achieving management goals or solving management problems. Mississippi and Texas should review the need for such regulations, and all states should determine if such regulations can be more consistent.

11.3 Minimum Size Restrictions

The preferred and most widely used commercial gears (gill nets) are selective for larger, older fish, and current regulations on minimum mesh size preclude the need for size restrictions when these gears are used. Florida and Mississippi have established minimum size limits for mullet taken in the commercial fishery of 11" FL and 10 " TL, respectively, to accommodate the use of other gears. None of the Gulf States has established size restrictions for the recreational fishery.

Minimum size restrictions can be effective in increasing SSB and yield per recruit by allowing more fish to spawn and to reach a larger size before harvest. It is recommended that each state consider adoption of consistent minimum size regulations for the food component of both the commercial and recreational fisheries. If a state allows the harvest of undersized mullet for bait, it should be regulated by daily possession limits, reporting requirements and/or quotas for commercial operations, or other regulations to control harvest as necessary.

11.4 Bag and Possession Limits

Florida has established a daily bag/possession limit for the recreational fishery of 50 fish per person or vessel. Alabama limits cast net fishermen to 25 fish from October 25 through December 31 of each year. Each state should evaluate the need for bag/possession limits for recreational fishermen when harvesting fish for either food or bait and commercial fishermen when harvesting for bait (see 11.3 above). Such regulations should be consistent among states to the greatest extent possible.

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11.5 Sale and Landing

It is recommended that only licensed commercial fishermen be allowed to sell mullet. Both commercially and recreationally caught mullet should be landed whole with heads, tails, and flesh naturally attached.

11.6 Gear Restrictions

It is recommended that each state evaluate the biological, social, and economic impacts of laws that prohibit or severely restrict the use of certain gear. They should also review and evaluate the impacts of all allowable gear on spawning stocks and other factors in the fishery. Each state should take necessary steps to modify laws and restrictions that are determined to be inconsistent with these evaluations.

States should also study the effects of various gear on bycatch species and if necessary adopt appropriate regulations to control mortality. Finally, states should ascertain whether mullet fishing gear conflicts with other fishing and near-shore, water-related activities. Solutions should be developed to minimize conflicts with public safety and public interest being key elements.

11.7 Area and Seasonal Closures

States should maintain closed areas and seasons as necessary to manage stocks, promote water safety, protect sensitive habitat, and for other purposes.

11.8 Limited Access Considerations

States should evaluate the use of limited access strategies to control harvest and for social and economic purposes.

11.9 Monitoring and Management Programs

States should review current fishery-independent and fishery-dependent monitoring programs and expand these programs as needed to evaluate the effects of recently enacted legislation on SSB. These monitoring programs should be consistent among states to the extent practicable.

States should develop habitat monitoring programs to qualify and quantify vital habitat for mullet during all life stages. States should also take aggressive action to protect key habitat and to ameliorate or restore damaged habitat.

States should determine if current management programs are sufficient to meet goals and solve problems. Management programs and strategies should be modified as necessary and practicable with the least adverse impacts to users.

12. 0 REGIONAL RESEARCH AND DATA NEEDS

Until the relatively recent expansions in the roe mullet fishery, mullet in all Gulf States except Florida were basically considered as an underutilized species. Consequently, research and data collection programs did not focus on these stocks. Since the mid 1970s and particularly in the 1980s, the increasing concern expressed by fishermen, managers, politicians, environmentalists, and others in regard to the status of mullet stocks prompted increased research and data collection efforts by the Gulf States. Although these programs have increased our knowledge of mullet from previous years, there are still many unknowns in the biological, social, economic, and environmental areas. The following is a partial list of some of the more important research and data needs.

12.1 Biological/Ecological

- Identify key spawning areas particularly off Florida and Louisiana.
- Develop a long-term assessment program to monitor the age structure and develop age/length keys for the spawning stocks including Texas where there is no established commercial fishery.
- Increase mark-recapture studies to evaluate inter- and intrastate movement as well as mixing among schools.
- Determine natural and fishing mortality estimates of mullet throughout their range in the Gulf.
- Determine schooling aggregation and climatological characteristics for developing predictive models.
- Identify key habitat areas for larvae and juveniles in the five Gulf States.
- Identify estuarine areas that are likely to incur fish kills as a result of severe cold or hypoxia and develop plans to ameliorate these effects if possible.
- Determine the importance of mullet as a forage species.
- Identify mechanisms that regulate year-class strengths.

12.2 Industrial/Technological

- Identify value added handling and processing activities that may increase overall demand for flesh products.
- Assess potential for aquaculture.

12.3 Economic and Social

- Develop appropriate databases from which economic and social impacts of various management measures can be determined.
- Assess the potential for comanagement in the mullet fisheries of the five Gulf States.

12.4 Resource Management

- Increase collection of data on catch and effort of commercial and recreational mullet fishermen and develop a long-term program to continue these efforts.

- Develop long-term programs (monthly biosampling of commercial catch for size/age) to assess the size and age structure of spawning populations in the Gulf that are consistent to the greatest extent possible among the five Gulf States.
- Revise data collection programs as necessary to account for transient fishing.
- Develop programs to prevent future losses of key habitat and to enhance and restore areas where losses have occurred.

13.0 REVIEW AND MONITORING OF THE PLAN

13.1 Review

As needed, status of the stock, condition of the fishery and habitat, the effectiveness of management regulations, and research efforts will be reviewed. Results of this review will be presented to the S-FFMC for approval and recommendation to the GSMFC and the appropriate management authorities in the Gulf States.

13.2 Monitoring

The GSMFC, the NMFS, states, and universities should document their efforts at plan implementation and review these with the S-FFMC. The S-FFMC will also monitor each state's progress with regard to implementing recommendations in Section 11.0 on an annual basis.

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15.0 APPENDICES

IRC

15.1 ORGANIZATIONS

15.1.1 National

National Coalition for Marine Conservation
Ken Hinman
5105 Paulsen Street, Suite 243
Savannah, CA 31403

National Fisheries Institute
Lee J. Weddig
1525 Wilson Boulevard, Suite 500
Arlington, VA 22209

American Sportfishing Association
Norville Prosser
1033 North Fairfax Street
Suite 200
Alexandria, VA 22314

15.1.2 Regional

Coastal Conservation Association (GCCA)
Walter Fondren, Chairman
4801 Woodway, Suite 220W
Houston, TX 77056

Gulf and South Atlantic Fishery Development Foundation
Judy L. Jamison
Lincoln Center, Suite 997
5401 West Kennedy Boulevard
Tampa, FL 33609

Southeastern Fisheries Association
Robert Jones
312 East Georgia Street
Tallahassee, FL 32301

15.1.3 Local (State)

The following organizations are concerned with finfish-related legislation and regulations, and they are consequently interested in their affects on mullet.

15.1.3.1 Florida

Florida Conservation Association
Dave Lear
905 East Park Avenue
Tallahassee, FL 32301-2646

Florida Department of Agriculture and Consumer Services
Bureau of Seafood and Aquaculture
Charles Thomas
2051 East Dirac
Tallahassee, FL 32310

Florida League of Anglers
M.T. Stoppelbein
534 North Yachtsman
Sanibel, FL 33957

Organized Fishermen of Florida
Jerry Sansom
P.O. Box 740
Melbourne, FL 32901

Seafood Consumers and Producers Association, Inc.
Tom Murray
P.O. Box 25954
Tampa, FL 33622-5954

15.1.3.2 Alabama

Alabama Coastal Conservation Association
Dr. Bob Shipp
P.O. Box 16987
Mobile, AL 36616
(334) 478-3474

Southeast Alabama Seafood Association
Lawrence Johnson
Route 1, Box 648
Coden, AL 36523

15.1.3.3 Mississippi

Mississippi Coastal Conservation Association
Ray Lenaz
P.O. Box 4434
Biloxi, MS 39535-4434

Gulf Coast Seafood Producers and Consumers Association
Tommy Bordage
11 Chantilly Terrace
Bay St. Louis, MS 39520

Mississippi Charterboat 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

Pass Christian Commercial Fishermen's Association
P.O. Box 324
Pass Christian, MS 39571-0324

Save America's Seafood Industry
Jean Williams
P.O. Box 2275
Pascagoula, MS 39569-2275

United Fisheries Cooperative
Earl Fayard
400 Front Beach Drive
Ocean Springs, MS 39564

15.1.3.4 Louisiana

Louisiana Seafood Management Council
Benny Miller, President
P.O. Box 874
Metairie, LA 70004
(504) 834-9393

Concerned Citizens and Fishermen's Association
Mr. Tyrone Edwards
P.O. Box 63
Davant, LA 70046

Concerned Finfishermen of Louisiana and Louisiana Fishermen for Fair Laws
Henry Truelove
P.O. Box 292
Charenton, LA 70523

Gulf Coast Conservation Association
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 League of Anglers
Will Scheffler, President
P.O. Box 1848
Marrero, LA 70073

Louisiana Seafood Processors Council
Mike Voisin
P.O. Box 3916
Houma, LA 70361-3916

Louisiana Seafood Promotion and Marketing Board
Karl Turner
P.O. Box 70648
New Orleans, LA 70172

Louisiana Wildlife Federation
Randy Lanctot, Executive Director
P.O. Box 65239
Baton Rouge, LA 70896-5239

Organization of Louisiana Fishermen
L.J. Brunet
P.O. Box 220
Galliano, LA 70354

15.1.3.5 Texas

Finfish Producers of Texas
Carroll and Ruth West
P.O. Box 60-B
Riviera, TX 78379

Tournament Directors Foundation of Texas (TDF of TX)
Pam Basco
P.O. Box 75231
Houston, TX 77034

Women in the Seafood Industry (WISI)
Jonell Wright
c/o Anchor Seafood
Rockport, TX 78382

15.2 MULLET WHOLESALERS AND PROCESSORS SURVEY

15.2.1 Mullet Wholesaler's Survey

I am an anthropologist working with the Gulf States Marine Fisheries Commission (GSMFC) to develop a Gulf-wide management plan for mullet. Most management plans previously developed by state and federal authorities have not adequately addressed the importance of understanding the roles and perceptions of those who catch and process fish. This information is needed to determine the effects of proposed regulations on the people most directly benefitting from the fishery. To address potential impacts and to characterize the mullet industry, I am doing a brief survey on the mullet fishery. This survey will help detail the social organization of the fishery, including wholesaling and processing operations. By doing this survey, I hope to provide the GSMFC with current information on the involvement, needs, and potential impacts to human users of mullet. This survey is completely voluntary. If you find any of the questions objectionable, you need not answer. Please take a few minutes to complete the questionnaire and return it to me. Your individual responses will be kept confidential, and the results of this survey will be made available to you in a report form upon request. Please return the completed questionnaire by **August 31, 1994** to:

Dr. Christopher L. Dyer
Gulf States Marine Fisheries Commission
P.O. Box 726
Ocean Springs, MS 39566-0726
Phone: (601) 875-5912
Fax: (601) 875-6604

Thank you for your cooperation in this survey.

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MULLET WHOLESALER'S SURVEY

Name of Business:
Name:
Address:
City, State, Zip:

Part I

First of all, I would like to begin by asking a few things about yourself and your family. This will help us understand the social background of people involved in fish wholesaling.

1. a. What is your age? _____
   b. Sex: M ____ F_____

2. What are the ages of the people you live with, and how are they related to you?

Age	Relationship

3. a. Were you born in this state? Yes _____ No _____
   b. Where do you consider your home town? _____

4. What is your ethnic background?
   White _____ Asian _____ African American_____ Other _____

5. How long have you been involved in fish wholesaling? _____

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6. a. Why did you choose this occupation? _____

   b. Is this a family occupation? Yes _____ No _____

7. Are any of your relatives involved in this business? Yes _____ No _____

8. If yes, what jobs do your relatives hold in fish wholesaling?

   _____

9. Was your father a fish wholesaler? Yes _____ No _____

10. Who taught you how to do your present job? _____

11. a. Did you go to school here? Yes _____ No _____

    b. What was your highest level of schooling completed? _____

Part II

This section deals with aspects of the fish wholesaling business.

12. What kinds of finfish products do you regularly sell?

    _____

13. If you had to rank the finfish you sell from the previous question, how would they rank in economic importance (top to bottom)?

    1. _____ 4. _____

    2. _____ 5. _____

    3. _____ 6. _____

14. How would you respond to these statements?

	Strongly Disagree SD - 1	Disagree D -2	Neutral N - 3	Agree A - 4	Strongly Agree SA - 5
Mullet are doing well in the Gulf.	1	2	3	4	5
Mullet are overfished in the Gulf.	1	2	3	4	5
I cannot get enough mullet to meet the demand.	1	2	3	4	5
There should be stricter regulations on the mullet fishery.	1	2	3	4	5
If mullet were not available to market, I would not be affected.	1	2	3	4	5
I cannot find buyers for mullet products.	1	2	3	4	5
More fishermen should catch mullet.	1	2	3	4	5
Mullet are an important food fish.	1	2	3	4	5
Mullet are being affected by loss of habitat.	1	2	3	4	5
Mullet are being affected by pollution in the Gulf.	1	2	3	4	5

15. How is mullet sold?

	Percentage (%) of Total Pounds Sold
_____ whole fish	_____
_____ gutted & headed fresh	_____
_____ whole frozen	_____
_____ gutted & headed frozen	_____
_____ fresh filleted	_____
_____ frozen filleted	_____
_____ smoked	_____
_____ stripped for roe	_____
_____ other (specify)	_____

16. How many suppliers (fishermen and other wholesale dealers) do you have for all species? _____

17. How many fishermen and wholesale dealers supply you with mullet? _____

18. Where do your mullet fishermen live?

	Percentage (%)
Locally (same city or county)	_____
Same state	_____
Out-of-state	_____

19. To whom do you sell your mullet product?

	Percentage (%) of Total Pounds Sold
_____ brokers	_____
_____ retailers	_____
_____ private individuals	_____
_____ restaurants/institutions	_____
_____ wholesalers	_____
_____ other (specify)	_____

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20. In what locations do you sell mullet products?

	Percentage (%)
Locally (same city or county)	_____
Same state	_____
Out-of-state	_____
Other countries	_____

21. How long do you estimate it takes to receive mullet after it is caught?

_____ 1-2 hours
_____ 4 hours
_____ 6 hours
_____ 8 hours
_____ 10 hours
_____ 12 hours
_____ more than 12 hours

22. In what condition are the mullet you receive?

	Flesh	Roe
_____	Poor	_____
_____	Fair	_____
_____	Good	_____
_____	Very Good	_____
_____	Excellent	_____

23. What is the average price per pound you can get for mullet today?

_____ flesh _____ roe

Part III

This last section concerns your personal opinion of your livelihood and problems you see in the wholesaling industry.

24. What are the problems facing the commercial finfish industry? (Rank them - 1 being most significant)

_____ insufficient product
_____ too much product

_____ little demand

_____ lack of market outside region

_____ too few fishermen (suppliers)

_____ poor prices

_____ poor condition of product (fish)

List other problems not included above _____

25. Is there anything that might cause you to give up fish wholesaling as an occupation?

_____

26. If commercial fishermen can no longer use nets to catch mullet or other inshore species, what do you think would happen to the habitat of inshore waters (*e.g.*, would it improve, would it be destroyed by development, would it become polluted, etc.)?

_____

_____

27. Should fishermen be given the opportunity to manage their own fisheries resources without state interference, or do you think it is impossible to conserve fish without government's help?

_____

28. If fishermen could no longer fish in your local state waters inshore, would they go to other areas/states to fish? _____ yes _____ no _____ don't know

If yes, where would they go? _____

29. Do you think your needs and expectations for your fishing occupation are being met or addressed by fishery agencies (*e.g.*, the National Marine Fisheries Service or your states department of natural resources)? _____ yes _____ no

Please explain why your needs and expectations have or have not been met.

_____

30. Does commercial fishing, marketing and/or processing represent a way of life to you and your family, or is it just a "job"? _____ way of life _____ just a job

If you answered "way of life," what do you expect would happen to you if commercial fishing was outlawed?

_____

31. Do you want your children to have the choice to be involved with commercial fishing for mullet and/or other species? _____ yes _____ no _____ don't care

Why, or why not? _____

32. How well are you doing in your life? Below is a scale that represents a ladder. Think of the ladder as a scale that represents how well you are doing in your life in general. The bottom of the ladder is zero (0) and means that "my life is extremely bad." The top of the ladder is ten (10) and means that "my life is very good." Circle the number from 0 to 10 that best indicates how *you* felt about your position in life at that point in time.

Ten Years Ago	Five Years Ago	Two Years Ago	Today	In Two Years	In Five Years
10	10	10	10	10	10
9	9	9	9	9	9
8	8	8	8	8	8
7	7	7	7	7	7
6	6	6	6	6	6
5	5	5	5	5	5
4	4	4	4	4	4
3	3	3	3	3	3
2	2	2	2	2	2
1	1	1	1	1	1
0	0	0	0	0	0

Part IV

33. In this last section, I would like to find out what would make you consider leaving the fish wholesaling industry. I'd like you to rank the 11 items listed below in order from the most important factor being number 1 to the least important being number 11

_____ Government health regulations

_____ Operating costs

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_____ Permit costs

_____ Lack of product

_____ Scarce or inexperienced labor

_____ Family pressures

_____ Uncertainty caused by market prices

_____ Excessive work and absence from home

_____ Too much competition with other processors

_____ Health or age

_____ Pollution of fish and fishing grounds

34. What other factors might cause you to leave fishing?

_____

15.2.2 Mullet Processor's Survey

I am an anthropologist working with the Gulf States Marine Fisheries Commission (GSMFC) to develop a Gulf-wide management plan for mullet. Most management plans previously developed by state and federal authorities have not adequately addressed the importance of understanding the roles and perceptions of those who catch and process fish. This information is needed to determine the effects of proposed regulations on the people most directly benefitting from the fishery. To address potential impacts and to characterize the mullet industry, I am doing a brief survey on the mullet fishery. This survey will help detail the social organization of the fishery, including wholesaling and processing operations. By doing this survey, I hope to provide the GSMFC with current information on the involvement, needs, and potential impacts to human users of mullet. This survey is completely voluntary. If you find any of the questions objectionable, you need not answer. Please take a few minutes to complete the questionnaire and return it to me. Your individual responses will be kept confidential, and the results of this survey will be made available to you in a report form upon request. Please return the completed questionnaire by **August 31, 1994** to:

Dr. Christopher L. Dyer
Gulf States Marine Fisheries Commission
P.O. Box 726
Ocean Springs, MS 39566-0726
Phone: (601) 875-5912
Fax: (601) 875-6604

Thank you for your cooperation in this survey.

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MULLET PROCESSOR'S SURVEY

Name of Business:
Name:
Address:
City, State, Zip:

Part I

First of all, I would like to begin by asking a few things about yourself and your family. This will help us understand the social background of people involved in fish processing.

1. a. What is your age? _____
   b. Sex: M____ F_____

2. What are the ages of the people you live with, and how are they related to you?

Age	Relationship

3. a. Were you born in this state? Yes _____ No _____
   b. Where do you consider your home town?

   _____

4. What is your ethnic background?
   White _____ Asian _____ African American_____ Other _____

5. How long have you been involved in fish processing? _____

1 ~ 1

6. a. Why did you choose this occupation?

_____

b. Is this a family occupation? Yes _____ No _____

7. Are any of your relatives involved in this business? Yes _____ No _____

8. If yes, what jobs do your relatives hold in fish processing?

_____

9. Was your father a fish processor? Yes _____ No _____

10. Who taught you how to do your present job?

_____

11. a. Did you go to school here? Yes _____ No _____

b. What was your highest level of schooling completed? _____

Part II

This section deals with aspects of the fish processing business.

12. What kinds of finfish products do you regularly process?

_____

13. If you had to rank the finfish you sell from the previous question, how would they rank in economic importance (top to bottom)?

1. _____ 4. _____

2. _____ 5. _____

3. _____ 6. _____

14. How would you respond to these statements?

	Strongly Disagree SD - 1	Disagree D -2	Neutral N - 3	Agree A - 4	Strongly Agree SA - 5
Mullet are doing well in the Gulf.	1	2	3	4	5
Mullet are overfished in the Gulf.	1	2	3	4	5
I cannot get enough mullet to meet the demand.	1	2	3	4	5
There should be stricter regulations on the mullet fishery.	1	2	3	4	5
If mullet were not available to market, I would not be affected.	1	2	3	4	5
I cannot find buyers for mullet products.	1	2	3	4	5
More fishermen should catch mullet.	1	2	3	4	5
Mullet are an important food fish.	1	2	3	4	5
Mullet are being affected by loss of habitat.	1	2	3	4	5
Mullet are being affected by pollution in the Gulf.	1	2	3	4	5

1 ~ 2

15. How is mullet prepared for sale?

	Percentage (%) of Total Pounds Sold
_____ whole fish	_____
_____ gutted & headed fresh	_____
_____ whole frozen	_____
_____ gutted & headed frozen	_____
_____ fresh filleted	_____
_____ frozen filleted	_____
_____ smoked	_____
_____ stripped for roe	_____
_____ other (specify)	_____

16. How many suppliers (fishermen and wholesale dealers) do you have for all species? _____

17. How many fishermen and wholesale dealers supply you with mullet? _____

18. Where do your mullet fishermen live?

	Percentage (%)
Locally (same city or county)	_____
Same state	_____
Out-of-state	_____

19. To whom do you sell your mullet product?

	Percentage (%) of Total Pounds Sold
_____ brokers	_____
_____ retailers	_____
_____ private individuals	_____
_____ restaurants/institutions	_____
_____ wholesalers	_____
_____ other (specify)	_____

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20. In what locations do you sell mullet products?

	Percentage (%)
Locally (same city or county)	_____
Same state	_____
Out-of-state	_____
Other countries	_____

21. How long do you estimate it takes to receive mullet after it is caught?

_____ 1-2 hours
_____ 4 hours
_____ 6 hours
_____ 8 hours
_____ 10 hours
_____ 12 hours
_____ more than 12 hours

22. In what condition are the mullet you receive?

Flesh		Roe
_____	Poor	_____
_____	Fair	_____
_____	Good	_____
_____	Very Good	_____
_____	Excellent	_____

23. What is the average price per pound you can get for mullet today?

_____ flesh _____ roe

Part III

This last section concerns your personal opinion of your livelihood and problems you see in the processing industry.

24. What are the problems facing the commercial finfish industry? (Rank them - 1 being most significant)

_____ insufficient product
_____ too much product
_____ little demand

_____ lack of market outside region

_____ too few fishermen (suppliers)

_____ poor prices

_____ poor condition of product (fish)

List other problems not included above _____

25. Is there anything that might cause you to give up fish processing as an occupation?

_____

26. If commercial fishermen can no longer use nets to catch mullet or other inshore species, what do you think would happen to the habitat of inshore waters (*e.g.*, would it improve, would it be destroyed by development, would it become polluted, etc.)?

_____

_____

27. Should fishermen be given the opportunity to manage their own fisheries resources without state interference, or do you think it is impossible to conserve fish without government's help?

_____

28. If fishermen could no longer fish in your local state waters inshore, would they go to other areas/states to fish? _____ yes _____ no _____ don't know

If yes, where would they go? _____

29. Do you think your needs and expectations for your fishing occupation are being met or addressed by fishery agencies (*e.g.*, the National Marine Fisheries Service or your states department of natural resources)? _____ yes _____ no

Please explain why your needs and expectations have or have not been met.

_____

30. Does commercial fishing, marketing and/or processing represent a way of life to you and your family, or is it just a "job"? _____ way of life _____ just a job

If you answered "way of life," what do you expect would happen to you if commercial fishing was outlawed? _____

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Why, or why not? _____

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Part IV

33 In this last section, I would like to find out what would make you consider leaving the fish processing industry. I'd like you to rank the 11 items listed below in order from the most important factor being number 1 to the least important being number 11

_____ Government health regulations

_____ Operating costs

_____ Permit costs

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_____ Lack of product

_____ Scarce or inexperienced labor

_____ Family pressures

_____ Uncertainty caused by market prices

_____ Excessive work and absence from home

_____ Too much competition with other processors

_____ Health or age

_____ Pollution of fish and fishing grounds

34 What other factors that might cause you to leave fishing?

_____

1 of 9

15.3 STOCK ASSESSMENT

15.3.1 Introduction

Striped mullet, *Mugil cephalus*, are distributed throughout the northern Gulf of Mexico. Although there is little east/west movement by adults, egg and larval drift and other factors appear to sufficiently mix populations that most researchers (Campton and Mahmoudi 1991, Thompson *et al.* 1991) consider the stock to be genetically homogeneous (panmictic) in the United States Gulf of Mexico. Based on these data, striped mullet are considered a unit stock in the Gulf.

Fishing mortality on the stock is highly variable among the five Gulf States. Florida, for example, has an extensive commercial fishery for both flesh and roe that dates to the early 1900s. Texas has only harvested mullet for an extremely small bait fishery. Louisiana, Alabama, and Mississippi have never harvested significant amounts of mullet for their flesh. In the last 10 to 15 years, however, fishing for roe (October-January) has substantially increased landings in most of these states.

The purpose of this document was to prepare a current stock assessment for mullet stocks in the Gulf. Existing fisheries databases and biological data were analyzed using an age-based population simulation model. The simulation model was then used to diagnose past and present conditions and trends of the stock and also to examine future conditions by simulating the response of the spawning stock to various management scenarios.

15.3.2 Landings and Fishing Effort

During 1989-1994, annual commercial landings in the Gulf averaged 27.3 million pounds of mullet, and the state of Florida contributed 70% of the total landings followed by Louisiana (23%) and Alabama (5%) (Figure 1). The commercial fishery for mullet is characterized by highly variable landings (Figure 2). Landings from Florida seem to show a cyclic pattern with an overall long-term downward trend. In Louisiana, commercial landings were low prior to 1976. Landings increased substantially between 1977 and 1994 following the development of the roe market in the mid 1970s. Data from Alabama indicate high landings in the mid 1960s, a significant decline in the mid-1970s to early 1980s, and then a slight increase in the late 1980s. Mullet landings from Mississippi peaked in 1980, declined sharply for two years, and remained relatively stable thereafter. Commercial landings of mullet in Texas are small and relatively stable over the past ten years. Despite a sharp increase in market demand and price for mullet roe over recent years, mullet landings in Florida, Alabama, and Mississippi have not reached historic high levels of production reported in the 1950s, 1960s, and 1970s. The estimated recreational catch of mullet in the Gulf averaged about 1.3 million pounds between 1989-1993.

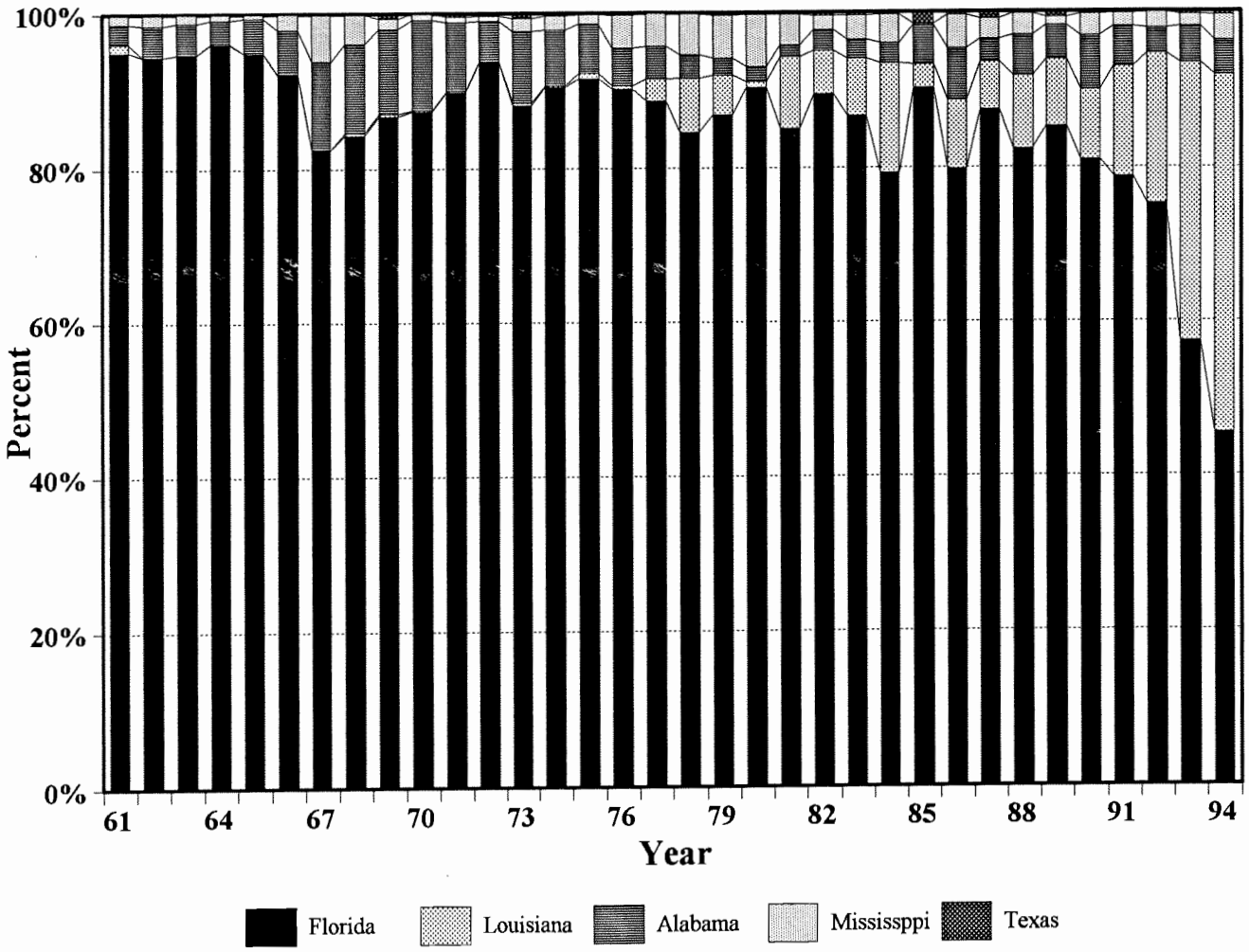

Figure 1. Striped mullet commercial landings by state, percent of total Gulf.

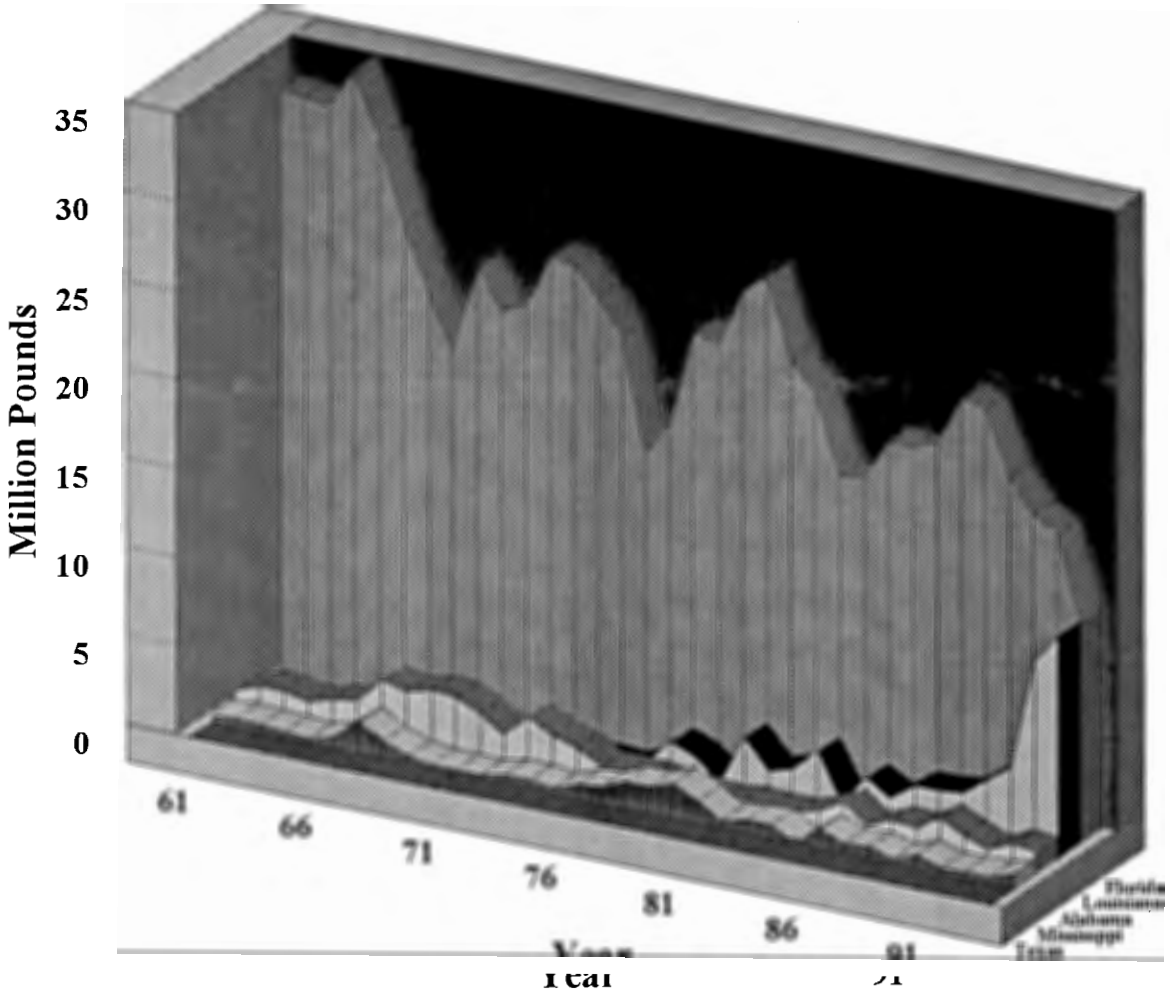

Figure 2. Trends in commercial landings of mullet by state, 1961-1994.

The observed fluctuations in mullet landings may be related to one or more factors including market fluctuations, changes in habitat conditions, fishing pressure, climatological variability, changes in fishing practices, and management regulations. The mullet fishery has been and will continue to be of prime importance to the finfish industry in the Gulf. Prior to the 1970s, mullet were often classified as an underutilized species, primarily because of the lack of consumer acceptance of mullet as a food product in northern Gulf regions. During this period, market demand determined the fishing production, price, and thus fishing effort (Cato *et al.* 1976). Since the development of export markets for mullet roe in the mid-1970s, market demand and price for female mullet has sharply increased. The market demand for mullet as a food fishery has also increased in recent years but at a slower rate.

The cyclic pattern in Florida's landings (Figure 3) may be caused by effects of fishing and environmental variabilities on the spawning stock and recruitment. The effect of cold fronts on mullet schooling activity and their spawning emigration (spawning run) has been examined in Florida (Mahmoudi 1992). Mullet aggregate inshore at the onset of their spawning season, and aggregations intensify during the passage of cold fronts. These large schools then emigrate from inshore waters (mainly through deep channels) to offshore spawning grounds. Mullet are caught (mainly by the commercial fishery) at the mouths of rivers, bayous, passes, and along shorelines and beaches during these spawning runs. The rate of aggregation and spawning emigration depends upon the intensity and duration of cold fronts and reproductive condition of mullet. Seasonal catches depend largely on the number and intensity of cold fronts. Seasons with a higher number of severe cold fronts generally have higher catches. This subject is discussed in more detail in the previous sections.

The commercial mullet fishery is primarily a gill-net fishery in the Gulf of Mexico. Historically, mullet were also caught with a variety of other gears including purse seines, haul seines, and trammel nets. The transition from a seine fishery to a gill- and trammel-net fishery occurred because of changes in market conditions (*e.g.*, demand for large females during the roe season); regulations (*e.g.*, prohibition of purse-seine gear in food-fish fisheries in Florida, Louisiana, and Alabama); and reduction in habitat available for haul seine operations due to water-front development and habitat degradation. Pre-juvenile and juvenile survival and growth of striped mullet may also be influenced by changes in habitat conditions. For example, the degradation of habitat in recent years could have been a factor in the long-term (gradual) decline in recruitment as reflected in Florida's landings.

In the past five years, several regulations have been adopted by the various Gulf States for management of mullet fisheries. These include minimum mesh sizes, a maximum size limit, net length restrictions, closed areas and times, and trip limits. The impact of these restrictions on fishery production and spawning stock biomass (SSB) has not been fully examined.

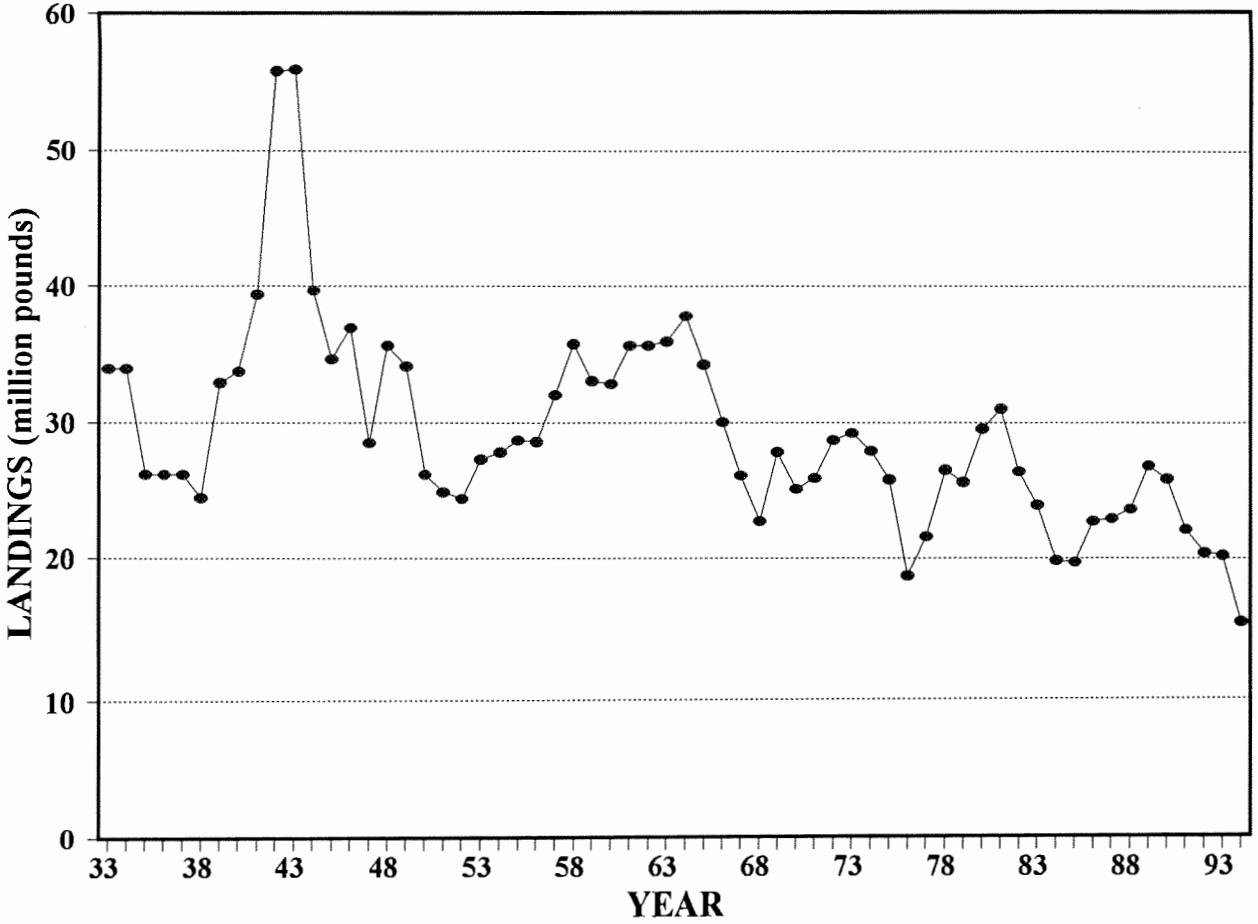

Figure 3. Commercial landings of mullet, Gulf coast of Florida, 1933-1994.

Statistics on fishing effort in the mullet fishery are limited. In Florida, data on fishing effort (number of successful one-day trips) have been collected by the Marine Fisheries Information System (trip ticket) since 1986. These statistics show that the annual number of one day trips gradually increased during 1986-1990 and declined during 1991-1994 (Figure 4). Statistics on fishing effort for other Gulf States are limited to the Trip Information Program (TIP) statistics that were not collected consistently over the past ten years.

15.3.3 Population Dynamics Parameters

15.3.3.1 Stock Structure

Mullet spawn in offshore oceanic waters. Fry are transported by currents into estuaries and remain in inshore (fresh and estuarine) waters until they mature. Little movement occurs during the adult phase except for an inshore-offshore spawning migration during the October-January spawning season (Broadhead and Mefford 1956). Tagging experiments during the spawning season in Tampa Bay and Charlotte Harbor, Florida, showed that the majority of adults return to the same system in which they were tagged (Mahmoudi 1990, 1991).

The lack of long-range movement of mullet suggests that several sub-groups may exist. Based on tagging, morphometric, and meristic data, de Sylva *et al.* (1956) hypothesized that distinct northern and southern stocks of mullet exist along the east and west costs of Florida; however, Tatum *et al.* (1993), Campton and Mahmoudi (1991), and Thompson *et al.* (1991) found no genetic basis for the separation of stocks based on their independent electrophoretic studies of mullet collected from Texas to northeast Florida. These data suggest that differences found by other investigators may be based on ecophenotypic characters, and the gene flow within and between the Gulf of Mexico and Atlantic coasts of Florida is sufficient to maintain a genetically homogenous mullet population. Such a conclusion would be consistent with the semi-catadromous life history of striped mullet (*i.e.*, a long-range offshore spawning migration and a wide-range dispersal of mullet eggs and larvae).

Despite the genetic homogeneity, there are regional morphological differences influenced by environmental factors and habitat conditions. Mullet remain in the same region all their juvenile and adult life and rarely move long distances. Thus, there is support for regional or state-specific assessments and management with the goal of maintaining the overall spawning stock at a level where the probability of recruitment failure is low.

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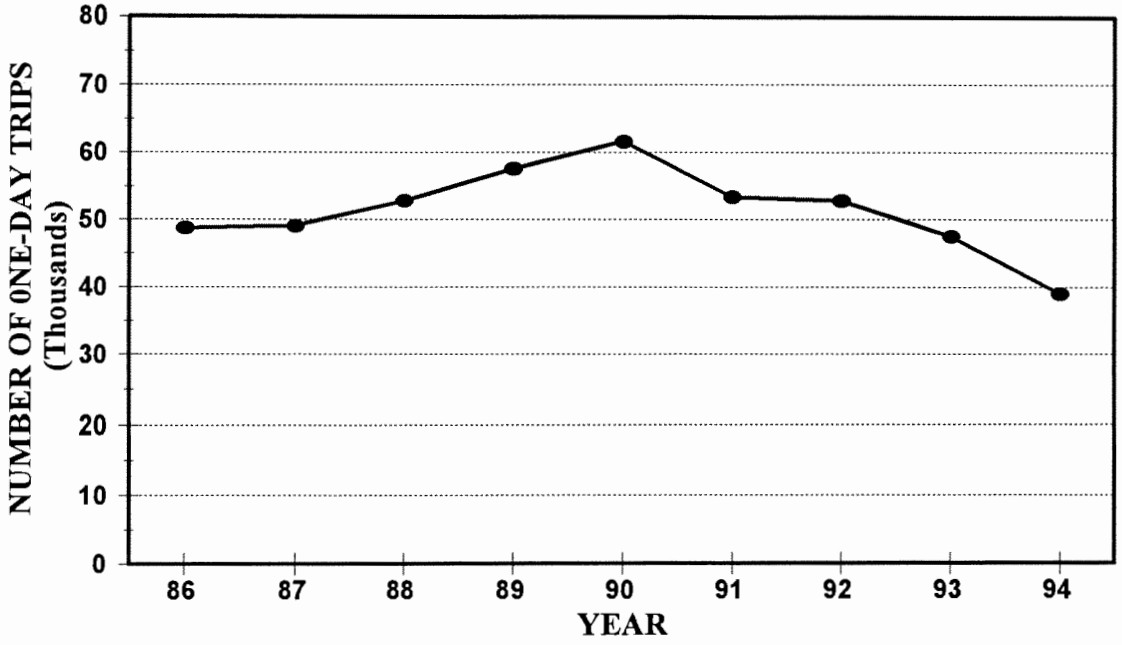


Figure 4. Annual number of one day fishing trips, Gulf coast of Florida.

15.3.3.2 Age, Growth, and Reproduction

Estimates of von Bertalanfy growth parameters K, L_{inf}, and t_0 by region and sex are available for Gulf of Mexico mullet (Table 1). Growth data from Florida (Mahmoudi 1992), Louisiana (Thompson *et al.* 1991), and Alabama (Lazauski 1995) represent the most complete data sets on mullet because they are sex-specific. The K values range from 0.36 to 0.51 for males and 0.22 to 0.36 for female; L_{inf} values range from 367 mm FL to 395 mm FL for males and from 451 mm FL to 500 mm FL for females; and t_0 values range from -0.15 yr to 0.042 yr for males and -0.05 yr to -1.94 yr for females. Data from both Florida and Louisiana showed significant differences in growth rates between sexes. Length-weight regression equations by region and sex are also provided in Table 1. The slopes of the equations did not differ between males and females based on data from Florida and Louisiana.

The spawning season of striped mullet varies between regions and is generally October-December in the northern Gulf region and November-January for the central-southeast regions of the Gulf of Mexico. Fecundity estimates are available from studies conducted in Florida (Greely *et al.* 1987, Mahmoudi 1992) and Louisiana (Thompson *et al.* 1991). Fecundity ranged from 1.0 million to 3.7 million eggs per female. The equations to predict fecundity based on standard length (SL) and fork length (FL) are given in Table 2. Data on size and age at maturity are available for Florida (Mahmoudi 1992) and Louisiana (Thompson *et al.* 1991) by sex and region (Table 2). Along the central, west coast of Florida, size/age of recruitment into estuaries is estimated at 22 mm TL (age 30-50 days) and occurs from January through April (K. Peters, unpublished data).

15.3.3.3 Gear Selectivity and Size/Age Composition

Size and age of recruitment to the fishery vary by region depending on gear type used (*e.g.*, gill net, haul seine, purse seine, and trammel net) and regulations. In Florida, Alabama, and Mississippi mesh size is modified seasonally to maximize the catchability of fish sought by fishermen (Figure 5). The size composition of mullet in purse-seine, haul-seine, and trammel-net fisheries is shown in Figure 6.

15.3.3.4 Mortality Estimates

Estimates of instantaneous total mortality rates (Z) for mullet have been based on analyses of annual catch curves and mark/recapture data. The Z is partitioned into M (instantaneous mortality due to natural causes) and F (instantaneous mortality due to fishing) and expressed as $Z = M + F$. Natural mortality can be estimated from Pauly's equation for schooling fish:

$$M = 0.8 * \exp[-0.0152 - 0.279] * \ln L_{inf} + 0.6543 * \ln K + 0.463 * \ln T$$

Table 1. Estimates of von Bertalanffy growth parameters and length-weight equations for striped mullet by region and sex.

Regions	K	L_{inf}	t_0	t	L-W Equations	Sources
Louisiana						
Female	0.33	453.9	-0.05	8	$W=0.000021\ (FL)^{2.93}$	Thompson *et al.* (1992)
Alabama						
Male						
Female	0.22	500	-1.94			Lazauski (unpublished data)
Combined	0.45	450	0.03	7		FIMAS 1988
Florida-Panhandle						
Male	0.49	380	-.030	5		Mahmoudi (1990)
Female	0.35	451	-.045	7		
Combined	0.37	440	-.039	7		
Florida-Central Southwest						
Male	0.51	395	.042	6		Mahmoudi (1990)
Female	0.36	472	-.114	8	$W=0.000008794\ FL^{3.086}$	
Combined	0.35	468	.162	8		
Others						
Australia	0.34	604	-.140			Grant and Spain (1975)
Taiwan	0.39	498	-.100			Tung (1970)
Georgia						
Male					$W=0.000082\ FL^{2.694}$	
Female					$W=0.000065\ FL^{2.737}$	

Table 2. Size/age at maturity, fecundity, and length-fecundity equations for striped mullet by region.

Region	Size/Age at Maturity	Fecundity	Equation	Source
Louisiana	280-290 (2-3)	2-3 x 10^6		Thompson *et al.* 1992
Florida West Coast	290-300 (2-3)	1-3 x 1^6	f=0.039923 $FL^{2.94398}$	Mahmoudi (unpublished data)
Florida East Coast	270-310		f=25.84 $SL^{2.97}$	Greely (1987)
Others				
Australia	310-350 (3)	1.6 x 10^6	f=0.009 $FL^{3.16}$	Granr (1975)
India		1.3 x 10^6	f=0.000594$^{L2.903}$	Sarojini (1951)
Cubia		0.4 x 10^6	f=3.2187W + 4.9405	Alvarez (1982)

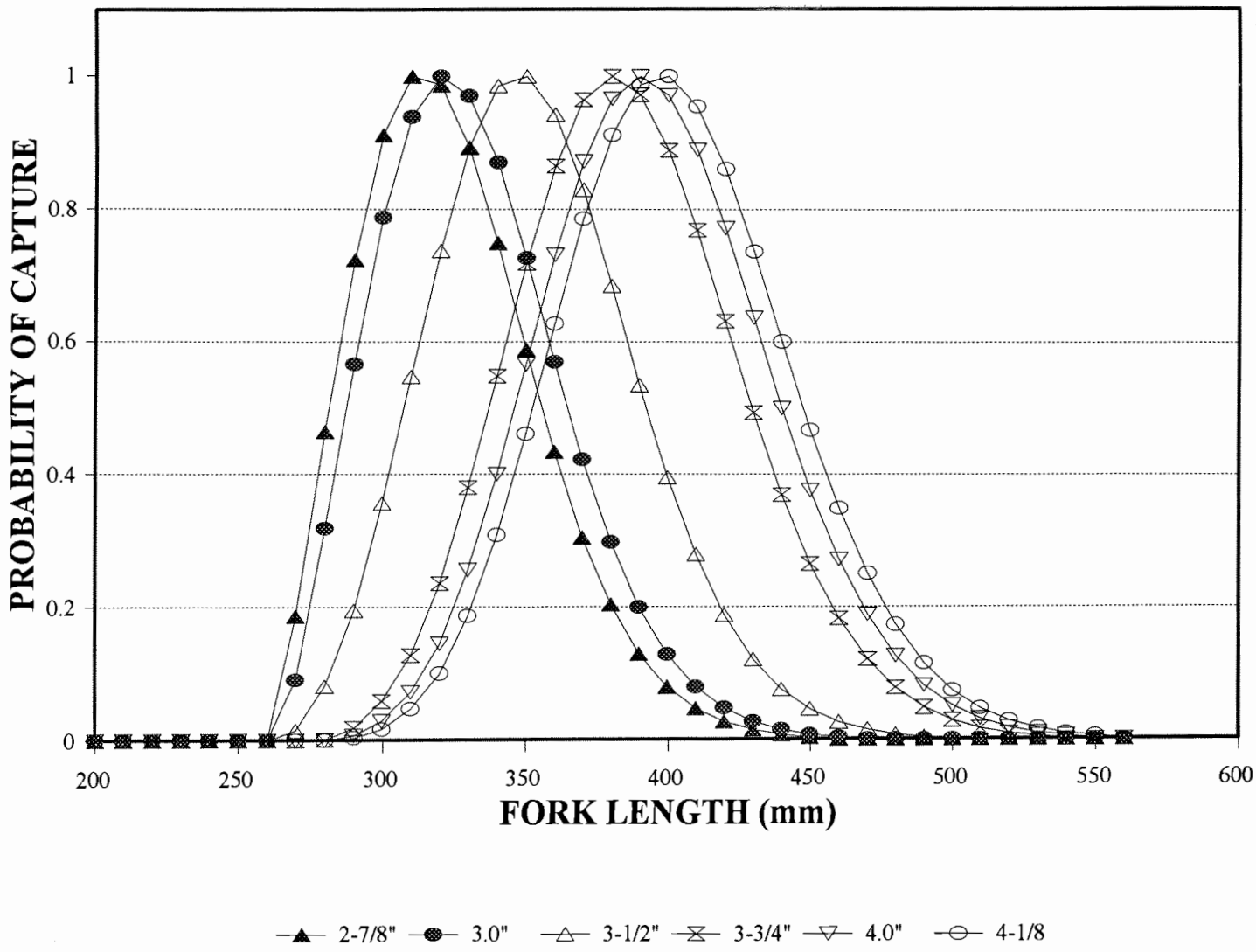


Figure 5. Gill net selection curves for various mesh sizes used in Florida's mullet fishery.

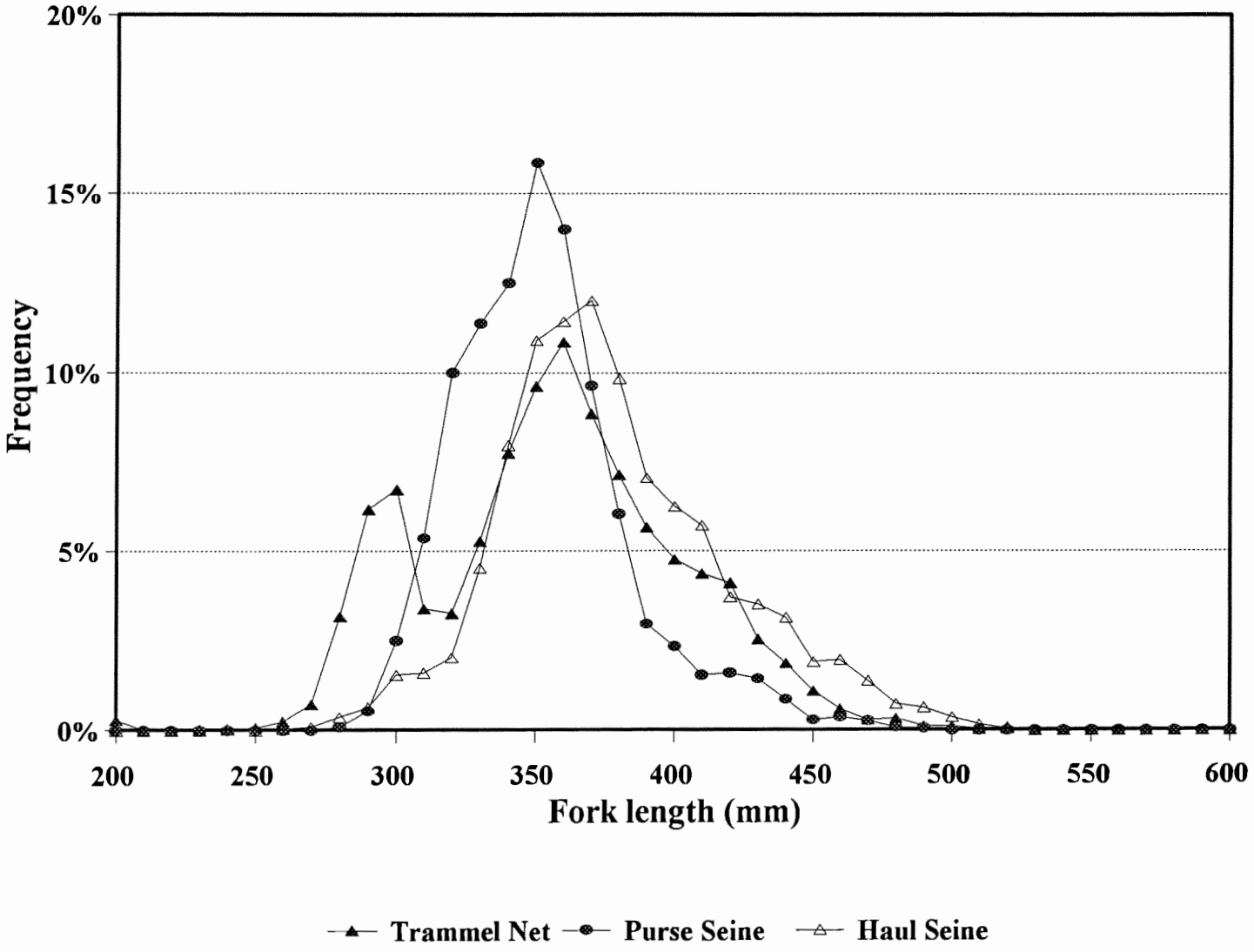


Figure 6. Size composition of mullet caught in trammel-net, purse seine, and haul seine gears.

as presented in Sparre (1989). This equation estimates M using the von Bertalanffy growth parameters K and L_{inf} and average water temperature (T). Using Pauly's equation, natural mortality rates of 0.42-0.65 have been calculated for striped mullet in the Gulf (Mahmoudi 1992, Shepard *et al.* 1992, Lazauski 1993). Sparre (1989) suggested that estimates of M based on Pauly's method are only rough estimates, and in some cases, they are twice or half of what they should be. Pauly (1980) provided an estimate of M=0.31 for male mullet in Taiwan. In previous stock assessments for mullet in the Gulf, a range of M=0.3-0.4 has been used in Florida (Mahmoudi 1993) and M=0.3 in Louisiana (Shepard *et al.* 1992) and Alabama (Lazauski 1993). The use of M=0.3 is a more conservative approach because it results in higher estimates of F and lower estimates of SPR.

Fishing mortality rates (F) were calculated based on a catch-curve method (developed from age-frequency data) and/or mark/recapture studies. The most recent estimates of F were 0.5 for Louisiana (Shepard *et al.* 1992) based on a catch-curve method, 0.60 for Alabama (Lazauski 1995) based on a catch-curve method, and 1.0 for Florida (Mahmoudi 1993) based on a catch-curve and mark/recapture methods. There were no estimates of F for Mississippi or Texas.

15.3.4 Population Models and Assessment

Several population models (*i.e.*, yield per recruit, surplus production, virtual population analysis [VPA], and spawning stock biomass per recruit [SSB/R]) were reviewed for the assessment of the mullet stock in the Gulf. The VPA analysis requires long-term and continuous data on gear-specific age frequencies of the catch and total catch and effort. The surplus production model requires long-term data on annual catch and effort. Long-term data on catch and effort and size/age frequency were not available for these analyses. Given available data bases (*i.e.*, age and growth, mortality rates, reproduction, and maturity schedules), the SSB/R model was selected as the most appropriate method for evaluating the mullet stock. Gabriel *et al.* (1989) noted that the maximum SSB/R is obtained under conditions of no fishing mortality. Fishing reduces SSB/R, which can be expressed as percentages of the maximum SSB/R (Goodyear 1989). This ratio (SSB/R when F>0 divided by SSB/R when F=0) is termed spawning potential ratio (SPR). The SSB/R model accumulates female SSB/R across all ages. In a generalized model, female SSB is calculated by summing over female biomass at age t(B_t) as follows:

$$SSB = \sum B_t = N_t * S_t * W_t * P_t$$

where N_t is the cohort abundance at age t; S_t is the proportion of females; W_t is the mean weight of females at age t; P_t is the proportion of mature females at age t; and $\sum$ is the summation over all ages. The abundance of youngest age (recruits) is the same when calculating female biomass with and without fishing mortality.

The SSB/R model requires estimation of a number of input parameters (*i.e.*, growth, age-specific weight, maturity schedule, maximum age, fecundity, and M). The SSB/R and SPR were calculated for stocks of mullet in Louisiana (Shepard *et al.* 1992), Florida (Mahmoudi 1993), and Alabama (Lazauski 1995) using parameter estimates presented in Tables 1 and 2. The SSB/R model was run with appropriate age at first harvest for each region for a range of fishing

mortality rates. The current values of SPR were estimated for the most recent estimates of fishing mortality rates.

For the assessment of the mullet stock in Florida, estimates of SSB/R were calculated using the generalized exploitation population simulator (GXPOPS) (a computer program developed by Fox [1973] and later modified by Ault and Fox [1989] to include the effects of stochastic processes). Population processes programmed into the model were month-specific fishing effort, catchability/availability rates, and natural and fishing mortality rates on the recruited population; density-independent growth; sex- and age-specific maturation; reproductive success as related to random mating; and density-dependent or density-independent stock-recruitment models. Biological and fishery data collected during 1988-1989 were used to calculate SSB/R and SPR for the pre-regulation period. The SPR was estimated in the range of 15% to 22% based on a fishing mortality rate of 1.13 (Mahmoudi 1992). During 1990-1992, management measures including a minimum mesh size for nets of 3" and weekend closures of 36 and 54 hours (October to January) were adopted by the FMFC. A fishing mortality rate of 1.0 was estimated for 1992, and SPR was calculated at 18% to 25% (Figure 7).

The SSB/R and SPR for mullet stocks in Louisiana and Alabama were estimated using similar SSB/R models (Shepard *et al.* 1992 and Lazauski 1995). The age at entry to the fishery was adjusted based on the mesh size regulations in each state. A natural mortality rate of M=0.3 was used in the modeling. Based on estimates of fishing mortality rates of F=0.5 for Louisiana in 1991 and F=0.6 for Alabama in 1994, current SPRs were calculated as 31% for Louisiana (Figure 8) and 34% for Alabama (Figure 9). There are no analyses of SSB/R and SPR available for Mississippi and Texas due to the lack of fishing mortality estimates.

Biological reference points are used as indicators of overfishing. The most widely used biological reference points are those derived from yield-per-recruit analyses (F_{max} and $F_{0.1}$) and spawner-per-recruit analyses (various percentages of maximum SPR which occurs at F=0 and associated fishing mortality rates such as $F_{20\%}$ and $F_{35\%}$). The F_{max} represents the level of fishing mortality which maximizes yield per recruit, while $F_{0.1}$ represents the level of fishing mortality where the slope of the increasing yield per recruit is 10% of the slope at the origin (Sissenwine and Shepard 1987). The $F_{20\%}$ and $F_{35\%}$ represent fishing mortality rates that produce equilibrium SPRs of 20% and 35%, respectively.

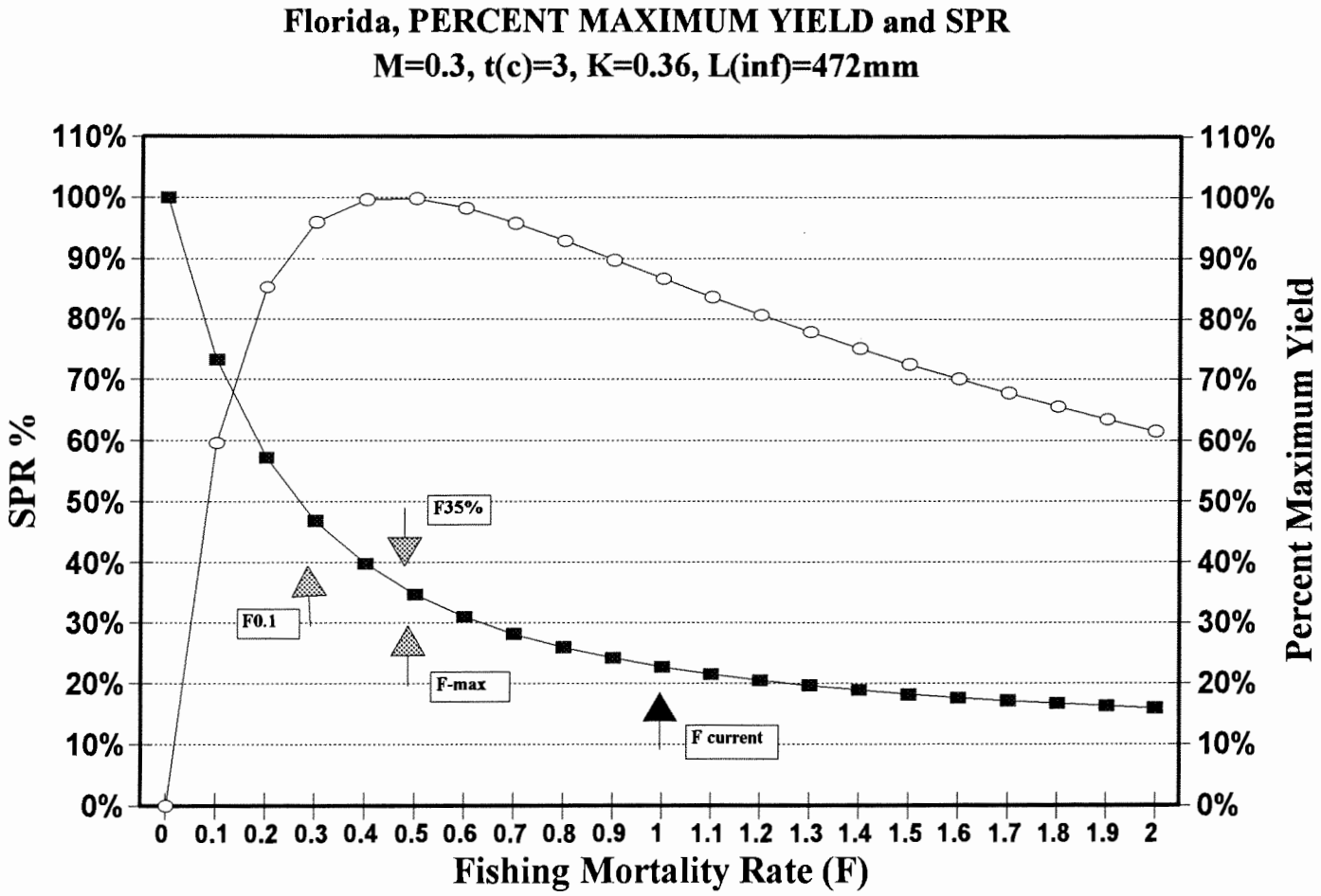


Figure 7. Estimated percent maximum yield and SPR for mullet, 1990-92, west coast of Florida.

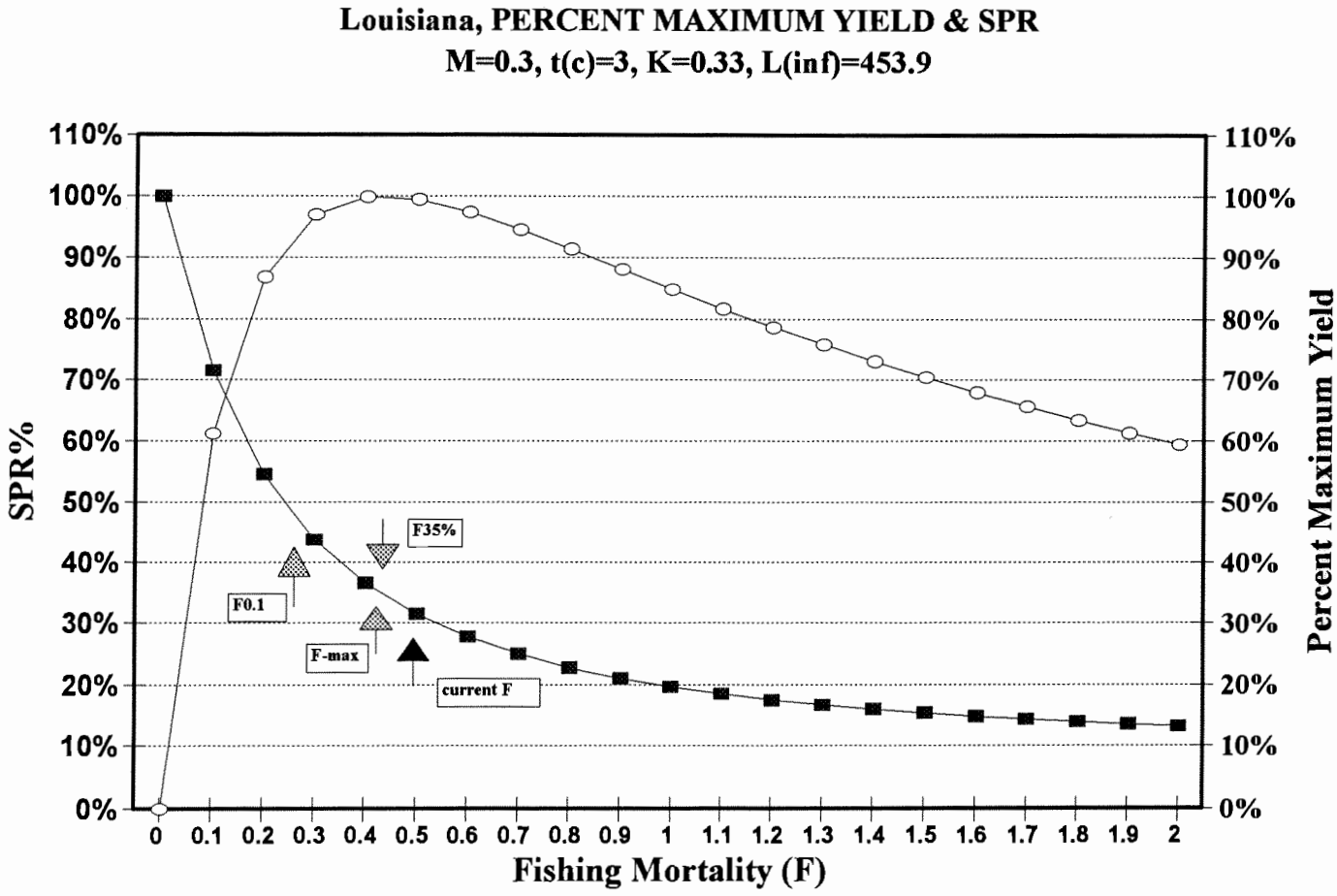


Figure 8. Estimated percent maximum yield and SPR for mullet, 1992, Louisiana.

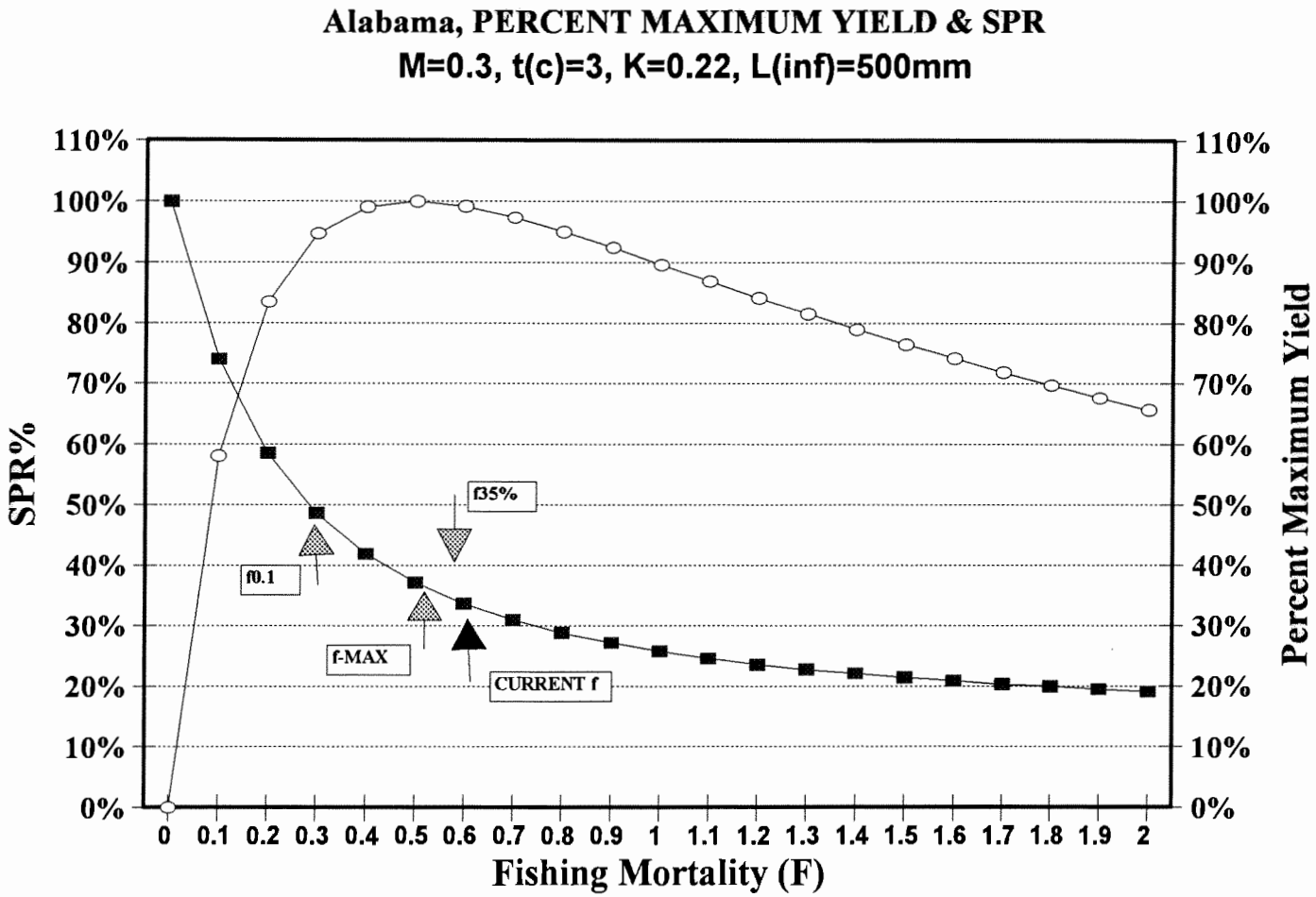


Figure 9. Estimated percent maximum yield and SPR for mullet, 1995, Alabama.

Mace and Sissenwine (1993) conducted yield-per-recruit and spawner-per-recruit analyses to obtain estimates of $F_{0.1}$ and F_{max} for 91 European and North American fish stocks. The average SPR corresponding to $F_{0.1}$ was 38%, and the average SPR corresponding to F_{max} was 21%. For fish stocks on which stock-recruitment relationships were lacking, Mace and Sissenwine (1993) suggested that a conservative strategy would be to maintain at least a 30% SPR (approximately the 80th percentile result) as a default "threshold"; whereas, Clark (1991) recommended a SPR of 35% (to achieve at least 75% of the MSY) as a management "target." Mullet assessments in the Gulf show that for M=0.3, the estimates of F_{max} range from 0.43 to 0.49 (producing SPRs in the range of 35% to 37%); while estimates of $F_{0.1}$ range from 0.26 to 0.28 (producing SPRs in the range of 48% to 50%) (Table 3). The $F_{30\%}$ ranges from 0.54 to 0.74, and $F_{35\%}$ ranges from 0.43 to 0.56. Recent estimates of F for Louisiana and Alabama are approximately at the $F_{30\%}$ "threshold" level while the estimate of F for Florida exceeds the $F_{30\%}$ level.

Table 3. Biological reference points, F_{max}, $F_{0.1}$, $F_{20\%}$, $F_{30\%}$, and $F_{35\%}$ and associated SPR for mullet stocks in Florida, Louisiana, and Alabama.

Reference Points	Louisiana		Alabama		Florida	
	F-level	SPR %	F-level	SPR %	F-level	SPR %
F_{max}	0.43	34.8	0.49	37.4	0.45	36.8
$F_{0.1}$	0.26	47.9	0.28	50.5	0.27	49.8
$F_{20\%}$	0.97	20.0	1.77	20.0	1.25	20.0
$F_{30\%}$	0.54	30.0	0.74	30.0	0.63	30.0
$F_{35\%}$	0.43	35.0	0.56	35.0	0.49	35.0
Current F	0.50	31.5	0.60	33.6	1.00	22.7

15.3.5 Management Implications-Florida

In 1993, the FMFC adopted additional management measures (extension of the 54-hour week-end closures to 72-hours from July through January, a pre-roe season trip limit of 500 pounds [July through September], and reduction of the maximum gill net length to 600 yards) aimed at increasing the SPR to 35%. These measures were intended to reduce catch and increase escapement of spawners during the roe season. Weekend closures should reduce optimum fishing time and catchability rates especially during the passage of cold fronts when large schools emigrate from the inshore waters to offshore spawning grounds. To determine the effects of weekend closures, reductions in catchability rates were measured under randomized cold front events using a Monte Carlo simulation model. Base-line data necessary for modeling were statistical relationships between cold front events and catch rates, a probability distribution function for cold front events, seasonal trends in population availability, seasonal trends in fishing effort, and effort shifting.

A time-series model, superposed epoch (Prager and Hoenig 1989) was used to test for an association between cold front passages and catch rates. The superposed epoch is a

nonparametric technique that does not rely on the usual assumptions (random sampling, normality, homogeneity of variance, and independence of observations) of parametric testing. In this analysis, catch during key-event days (days in which cold fronts occurred) are compared with catch in background days (the days immediately preceding the key-event days). Two sets of data were used: (1) daily landings from three spawning seasons (November-January 1986/1987, 1987/1988, and 1988/1989) in Tampa Bay collected by the Florida Marine Fisheries Information System-trip ticket and (2) a time series of cold front events for the period of November through January of each year from 1985 through 1992 collected by Ruskin Climatological Data Center, NOAA. In order to use catch data for the epoch analysis, the daily catch was adjusted for the weekly and week-day effects. To adjust for week-day effects, daily catches were first divided by weekly means to normalize the seasonal (weekly) effects. Then a linear model in the form of:

$$Y = \text{constant} + \text{day}$$

(where Y is daily catch, and day is a categorical variable) was fitted to the daily catch. The results indicated highly significant (PR>F=0.0001 for 1986/1987, 0.0166 for 1987/1988, and 0.0002 for 1988/1989) week-day effects on daily distributions of catch. Secondly, the least squared means (LSM) values (Table 4) generated from the linear model were used to remove the week-day effects from the catch time series. The epoch model was then run on the adjusted daily catch and the time series of cold fronts each year from 1986/1987 through 1988/1989 spawning seasons. The results indicated a strong association (PR>F=0.01 for 1986/1987, 0.006 for 1987/1988, and 0.001 for 1988/1989) between cold front events and variabilities in catch (Table 5).

The results from epoch analyses were used to develop a Monte Carlo simulation model that included the effects of cold frontal variability, seasonal changes in population availability, seasonal trends in fishing effort, and effort shifting. The model was then used to calculate reduction in yield under various week-end closures. The model calculates fishing yield for week-end closures based on the following equation:

$$C' = [\, q * q' \,] * [\, f * f' \,] * N'$$

where C' is the predicted catch, q is the catchability coefficient, q' is the q multiplier, f is the fishing effort, f' is the effort shifting rate or multiplier, and N' is the population availability index derived from catch.

Table 4. A multivariate (ANOVA) model to test the effect of regulation (54-hour week-end closure) on the weekday's fishing effort.

Analysis of Variance					
Source	Sum-of-Squares	DP	Mean-Square	F-Ratio	P
Wkday	62.113	6	10.352	95.396	0.000
Wkday Closure	9.375	6	1.562	14.398	0.000
Error	47.963	442	0.109		

Least Squares Means		LS Mean	SE	N
Wkday	3.000	1.190	0.042	65
Wkday	4.000	1.189	0.042	65
Wkday	5.000	1.222	0.043	65
Wkday	6.000	1.282	0.042	65
Wkday	7.000	0.508	0.042	65
Wkday	8.000	0.317	0.042	65
Wkday	9.000	1.293	0.042	65
Wkday Closure	3.000 0.000	1.162	0.051	39
Wkday Closure	3.000 1.000	1.217	0.062	26
Wkday Closure	4.000 0.000	1.147	0.051	39
Wkday Closure	4.000 1.000	1.231	0.062	26
Wkday Closure	5.000 0.000	1.092	0.051	39
Wkday Closure	5.000 1.000	1.351	0.062	26
Wkday Closure	6.000 0.000	1.175	0.051	39
Wkday Closure	6.000 1.000	1.390	0.062	26
Wkday Closure	7.000 0.000	0.806	0.051	39
Wkday Closure	7.000 1.000	0.210	0.062	26
Wkday Closure	8.000 0.000	0.415	0.051	39
Wkday Closure	8.000 1.000	0.188	0.062	26
Wkday Closure	9.000 0.000	1.173	0.051	39
Wkday Closure	9.000 1.000	1.413	0.062	26

Table 5. Results of superimposed epoch analysis to test for associations between cold front passages and catch rates based on daily catch and effort and cold front events (November-January) during 1986-1989.

Results of Superposed Epoch Analysis

Width of epoch:	3
Background Years:	The 2 years on the left. The 0 years on the right.
Random number seed:	-1800

Number of rows in input data	91
ID of first row	1
ID of law row	91
Range of ID values	91
Number of rows with missing data	0

Number of key periods: 18

Key period #1:	1	Sign: +1
Key period #2:	5	Sign: +1
Key period #3:	10	Sign: +1
Key period #4:	14	Sign: +1
Key period #5:	22	Sign: +1
Key period #6:	28	Sign: +1
Key period #7:	31	Sign: +1
Key period #8:	35	Sign: +1
Key period #9:	41	Sign: +1
Key period #10:	46	Sign: +1
Key period #11:	55	Sign: +1
Key period #12:	58	Sign: +1
Key period #13:	64	Sign: +1
Key period #14:	70	Sign: +1
Key period #15:	73	Sign: +1
Key period #16:	77	Sign: +1
Key period #17:	83	Sign: +1
Key period #18:	88	Sign: +1

Test statistic used was W

Test statistic for real key events 5.3404

Number of Monte Carlo trials	1000
Minimum spacing between Monte Carlo key events	1
Number of trials with larger W	1

Estimated probability of a larger W .0010

170

Table 5. (continued)

Results of Superposed Epoch Analysis

Width of epoch:	3
Background Years:	The 2 years on the left. The 0 years on the right.
Random number seed:	-911

Number of rows in input data	91
ID of first row	1
ID of law row	91
Range of ID values	91
Number of rows with missing data	0

Number of key periods: 15

Key period #1:	3	Sign: +1
Key period #2:	5	Sign: +1
Key period #3:	11	Sign: +1
Key period #4:	19	Sign: +1
Key period #5:	29	Sign: +1
Key period #6:	34	Sign: +1
Key period #7:	40	Sign: +1
Key period #8:	45	Sign: +1
Key period #9:	52	Sign: +1
Key period #10:	59	Sign: +1
Key period #11:	64	Sign: +1
Key period #12:	69	Sign: +1
Key period #13:	74	Sign: +1
Key period #14:	81	Sign: +1
Key period #15:	86	Sign: +1

Test statistic used was W

Test statistic for real key events 3.4200

Number of Monte Carlo trials	1000
Minimum spacing between Monte Carlo key events	1
Number of trials with larger W	6

Estimated probability of a larger W .0060

Table 5. (continued)

Results of Superposed Epoch Analysis

Width of epoch:	3
Background Years:	The 2 years on the left. The 0 years on the right.
Random number seed:	-1800

Number of rows in input data	90
ID of first row	1
ID of law row	90
Range of ID values	90
Number of rows with missing data	0

Number of key periods: 15

Key period #1:	3	Sign: +1
Key period #2:	13	Sign: +1
Key period #3:	20	Sign: +1
Key period #4:	28	Sign: +1
Key period #5:	31	Sign: +1
Key period #6:	41	Sign: +1
Key period #7:	50	Sign: +1
Key period #8:	54	Sign: +1
Key period #9:	57	Sign: +1
Key period #10:	61	Sign: +1
Key period #11:	65	Sign: +1
Key period #12:	68	Sign: +1
Key period #13:	79	Sign: +1
Key period #14:	82	Sign: +1
Key period #15:	87	Sign: +1

Test statistic used was W

Test statistic for real key events 3.2444

Number of Monte Carlo trials	1000
Minimum spacing between Monte Carlo key events	1
Number of trials with larger W	10

Estimated probability of a larger W .0100

The base line data used in the model included a probability distribution of the number of days between cold front events, a daily distribution of catch and effort, a effort shifting rate, and a catchability-coefficient multiplier. The observed probability distribution of days elapsed between cold fronts (Figure 10) was based on long-term (1978-1992) hourly data on wind speed, wind direction, minimum temperature, and barometric pressure. To determine the seasonal distribution of effort, the daily number of trips during the period 1986/1987 through 1988/1989 (pre-regulation) were corrected for the week-day effects using the linear model previously discussed. The adjusted daily effort (Figure 11) was then used as the base-line fishing effort (f) in the model. The effort shifting rate was calculated using a multivariate model as follows:

$$\text{Trips} = \text{Constant} + \text{Weekdays} + \text{Regulation Effect} + \text{Weekdays*Regulation}$$

Daily trip data from the pre-regulation period (1986/1987 through 1988/1989) and from the regulation period (54-hour week-end closures in 1990-1991 and 1991-1992) were used as input data. The results of this analysis indicated that the 54-hour week-end closure had significant effects on the daily distribution of effort (Table 4). Effort shifting was more significant on Thursdays and Fridays (days prior to the closure) and on Mondays (day after the closure) than other days of the week (Figure 12a). The LSM values from pre-regulation and regulation periods were used to calculate the effort shifting rate. The average increase in the number of trips (f') for Thursday, Friday, and Monday was estimated at about 20% (Figure 12b).

To estimate the rate of change in catchability (q') as the result of the cold fronts, the roe-season daily catch data for the pre-regulation periods (1986/1987-1988/1989) and time series of cold-front events for the same period were used. Daily catch was corrected for the week-day and weekly effects using the method previously discussed. The adjusted catches were plotted against the days with cold-front events (plus one day after the cold fronts to account for the potential lag in reporting) and days with no cold fronts. The results indicated that on the average, catches increased by about 44% as the result of cold front passages. Thus, $q' = 1.44$ was used as the catchability multiplier in the model. To determine the seasonal distribution of population availability (N'), daily catch data were used. The daily catch from 1986/1987 through 1988/1989 (pre-regulation) were adjusted for the effects of cold fronts by dividing the observed daily catch by the catchability multiplier (q') (Figure 13).

Once the base-line data were generated, the Monte Carlo model was run for 1,000 trials to calculate yield and population size for 92 days (November through January) of fishing with no week-end closure. Then, the percent reduction in catch was calculated for various week-end closure scenarios. Table 6 shows the Monte Carlo estimates of percent reduction in yield for various 72-hour week-end closures and an alternate-week closure.

Selection curves were developed using Sechin's Model (Sechin 1969) for various mesh sizes in the gill net fishery and used to determine the probability of capture with a 3" mesh size. The age equivalent to the size of entry was determined using the von Bertalanffy growth equation to express age as a function of length.

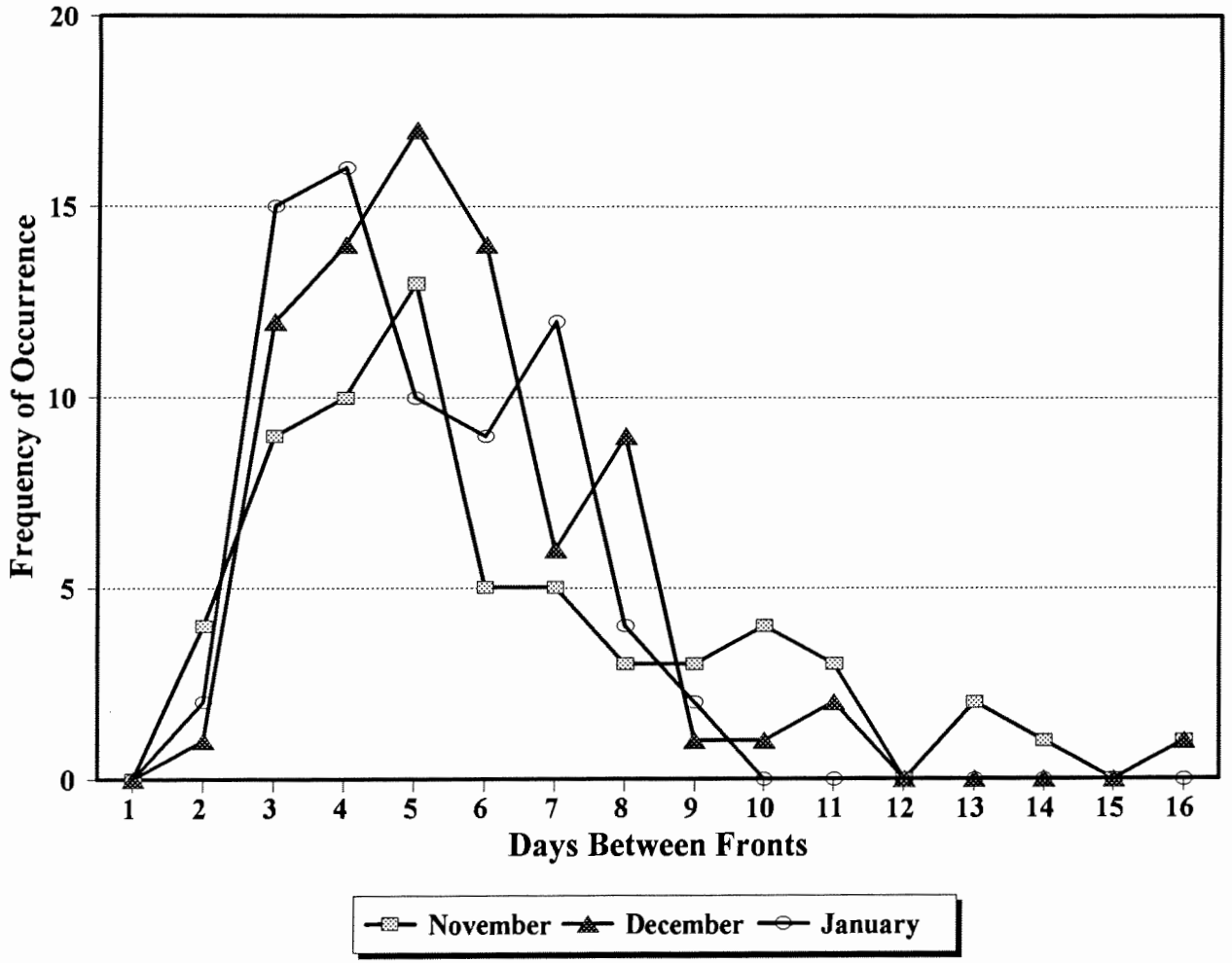


Figure 10. Frequency of cold front occurrence during mullet roe season along west coast of Florida.

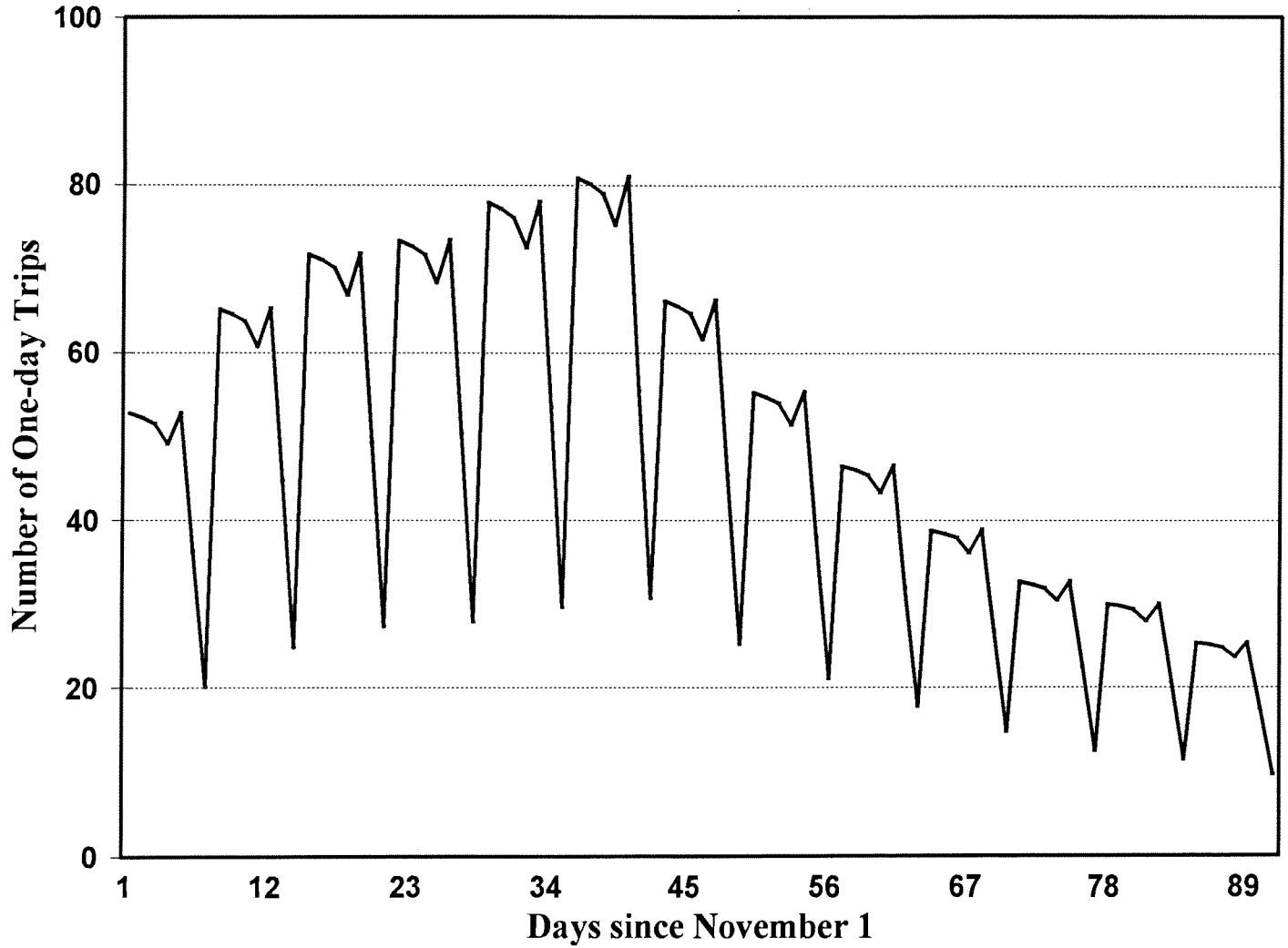
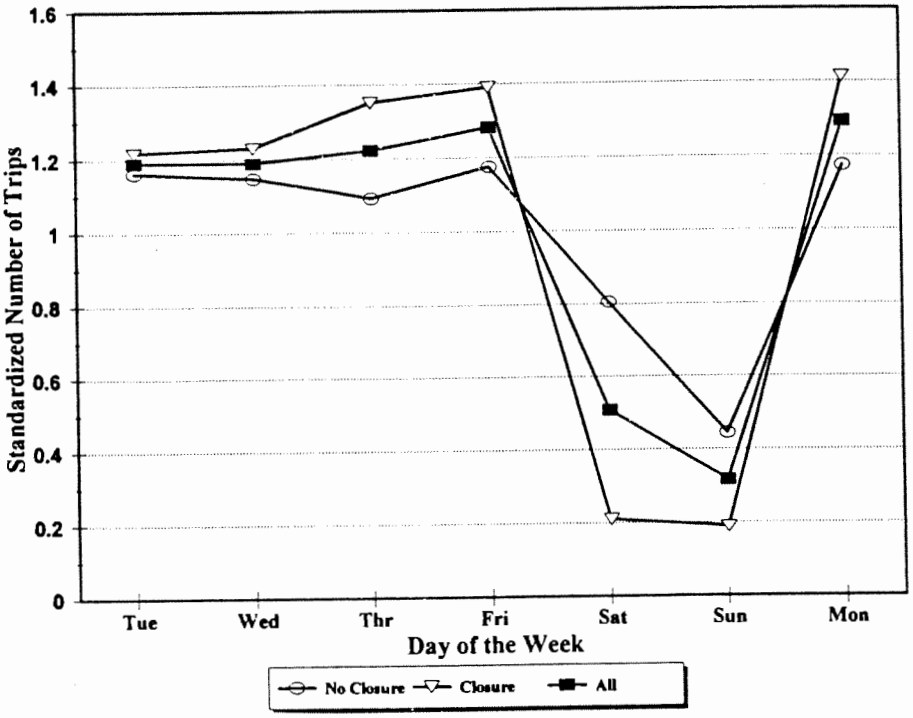


Figure 11. Seasonal (daily) distribution of effort in mullet fishery during roe season adjusted for week-day effects.

a



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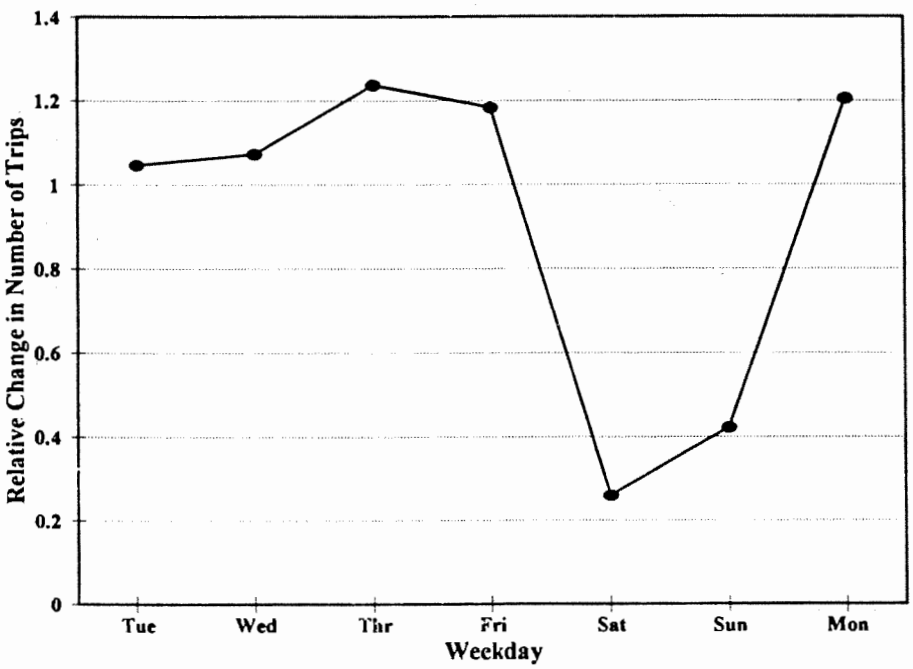


Figure 12. The effort shifting rate in mullet fishery as the result of 54-hour week-end closure during 1990-92 roe seasons.

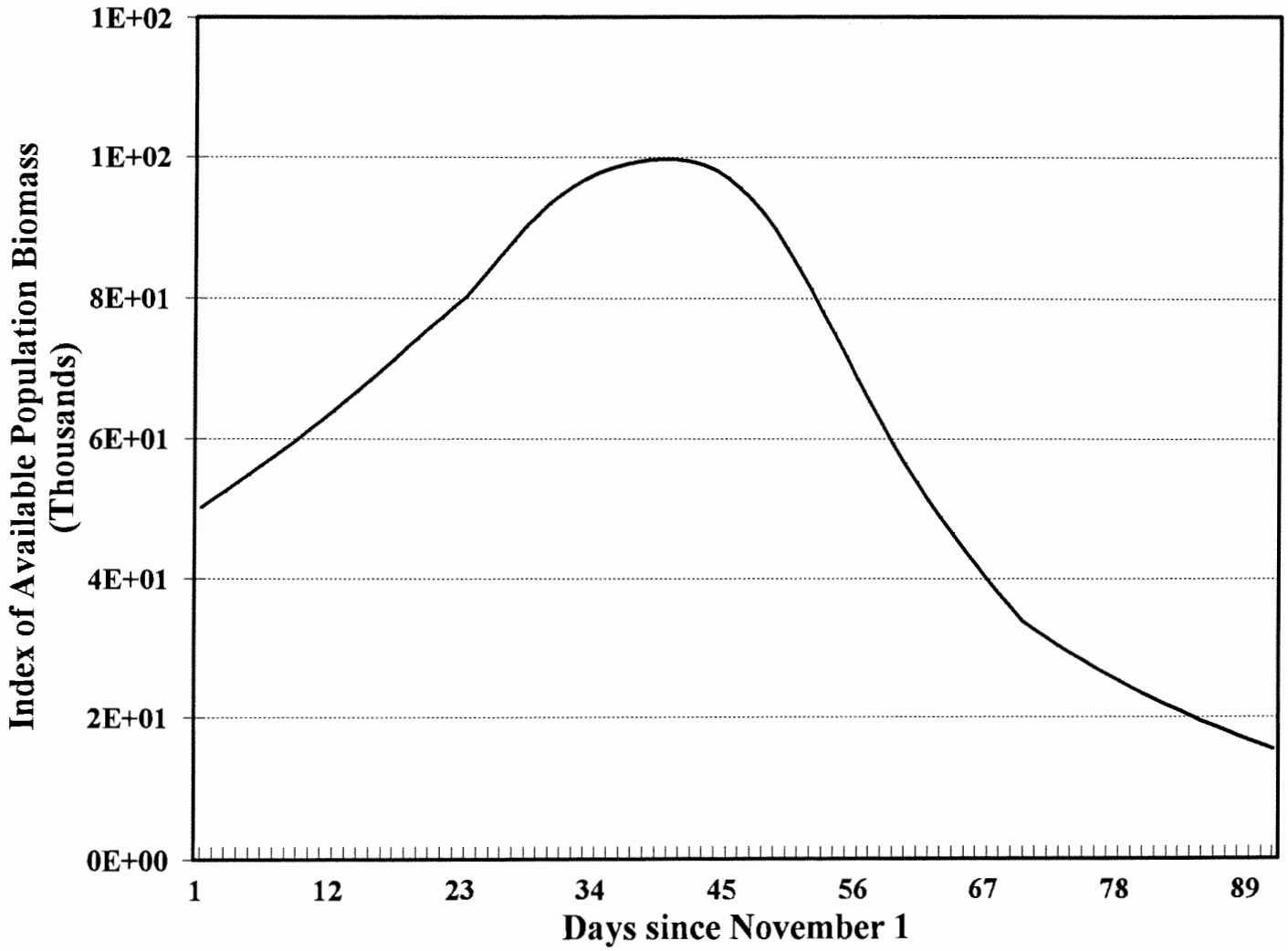


Figure 13. Mullet population availability index during roe season, based on daily catch and effort data, 1986-1989.

Table 6. Percent reduction in yield (escapement) during roe season calculated using the Monte Carlo Simulation Analysis for various 72-hour management options.

	Effort Reduced During Time Closure		
	80%	90%	100%
Option 1 (72 hours per week with one 10-day roe season closure)	0.28	0.33	0.37
Option 2 (72 hours per week with two 10-day roe season closures)	0.34	0.39	0.44
Options 3 and 4 (72 hours per week with 96-hour alternate week closures)	0.31	0.37	0.42
Option 5 (72 hours per week with no 10-day closure)	0.26	0.30	0.34
Option week alternate	0.37	0.42	0.47

To calculate SSB/R and SPR based on regulations adopted in 1993 in Florida, the catchability matrix in the SSB/R model was adjusted for the effects of the 72-hour week-end closure and 3" minimum mesh size. The results of these analyses showed that under these management measures, SPR was expected to reach the "targeted" 35% in 5 to 7 years as the SSB increased by 90% (Figure 14).

15.3.6 Trends in Fishery-dependent and Fishery-independent Data

15.3.6.1 Fishery-dependent Data

As previously discussed, statistics on fishing effort in the mullet fishery are limited. In Florida, roe- and post-roe season catch rates were estimated for the period 1986-1994 based on trip-ticket data collected by the Florida Marine Fisheries Information System. These data indicated a general downward trend in catch rates despite a slight increase in catch rates in the past three years for both seasons (Figure 15a, 15b).

Trends in catch rates should be interpreted with caution because: (1) bias is associated with the analyses using only successful trip data; (2) potential changes in trip ticket reporting may have occurred as the result of the restricted-species endorsement program in Florida; (3) schooling aggregation of mullet during the roe season is affected by the frequency of cold front passages (during roe season, mullet fishermen fish on schools that are tightly aggregated and catch rates can be high even at low levels of population abundance); and (4) weekend closures probably impact catchability and catch rates.

15.3.6.2 Fishery-independent Data

Data on juvenile abundance are available for Florida, Mississippi, Alabama, Louisiana, and Texas. The number of juveniles collected in seine gear were standardized to determine trends in abundance. Results show that juvenile indices from each of the Gulf States (Figure 16a through e) were highly variable with no particular trend.

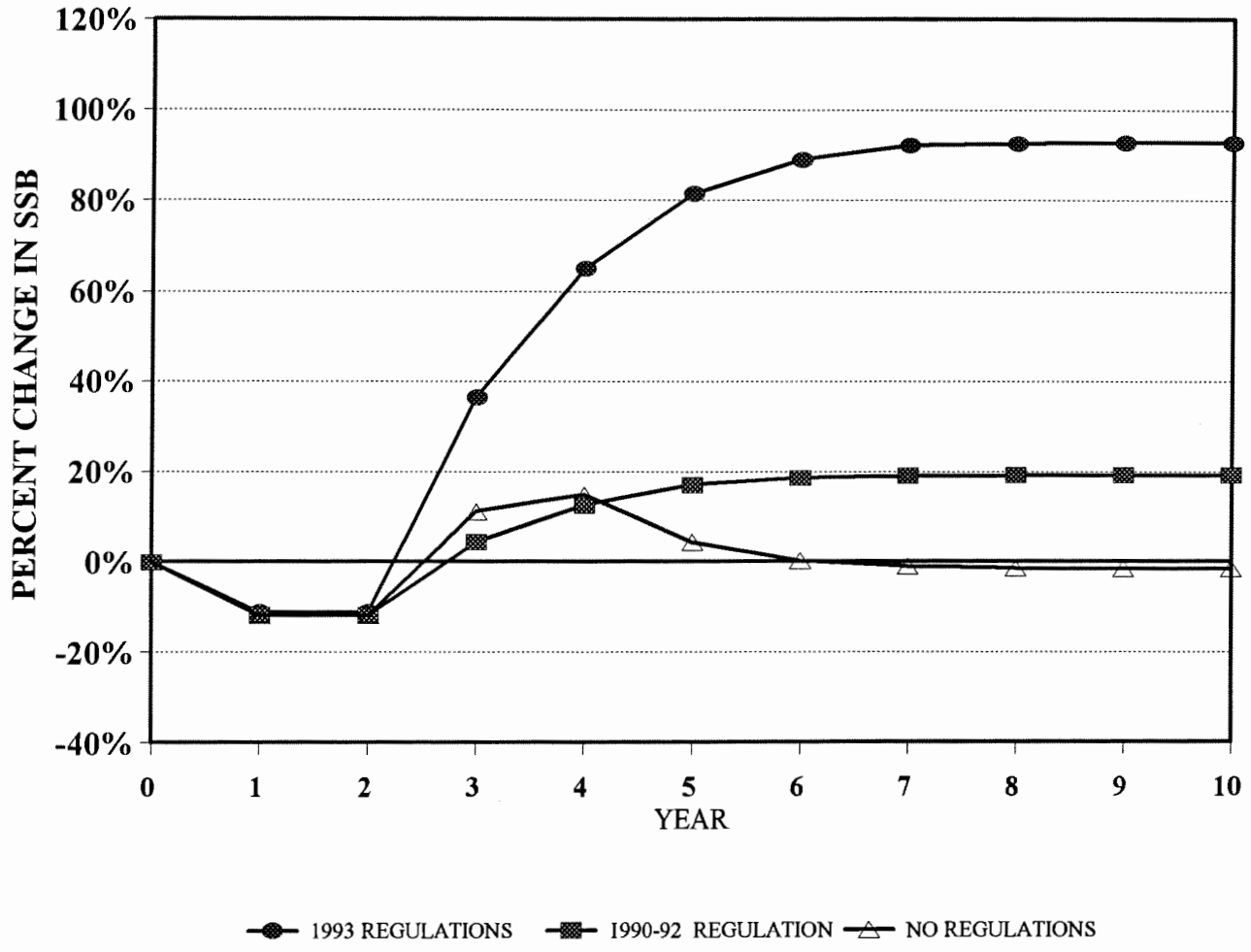
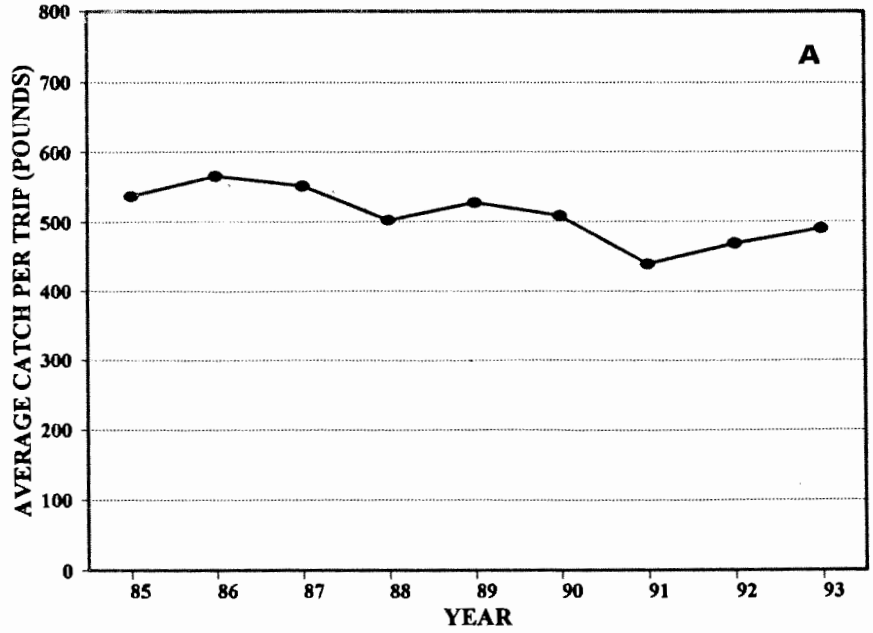


Figure 14. Estimated changes in stock biomass of mullet for various management regulations adopted in Florida.



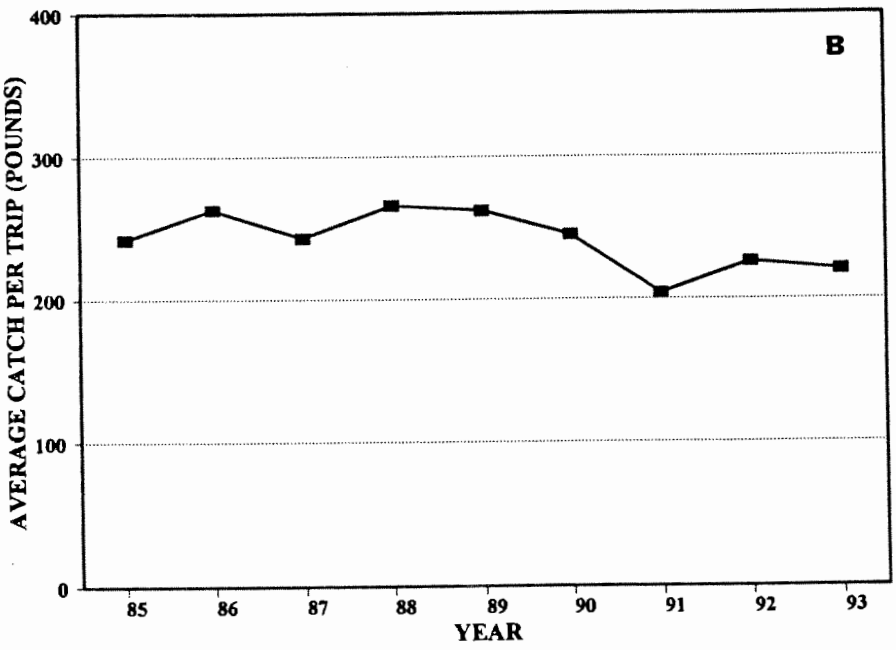


Figure 15. Trends in roe season (Nov-Jan) (a) and non-roe season (Feb-Jun)(b) catch rates, west coast of Florida.

10A

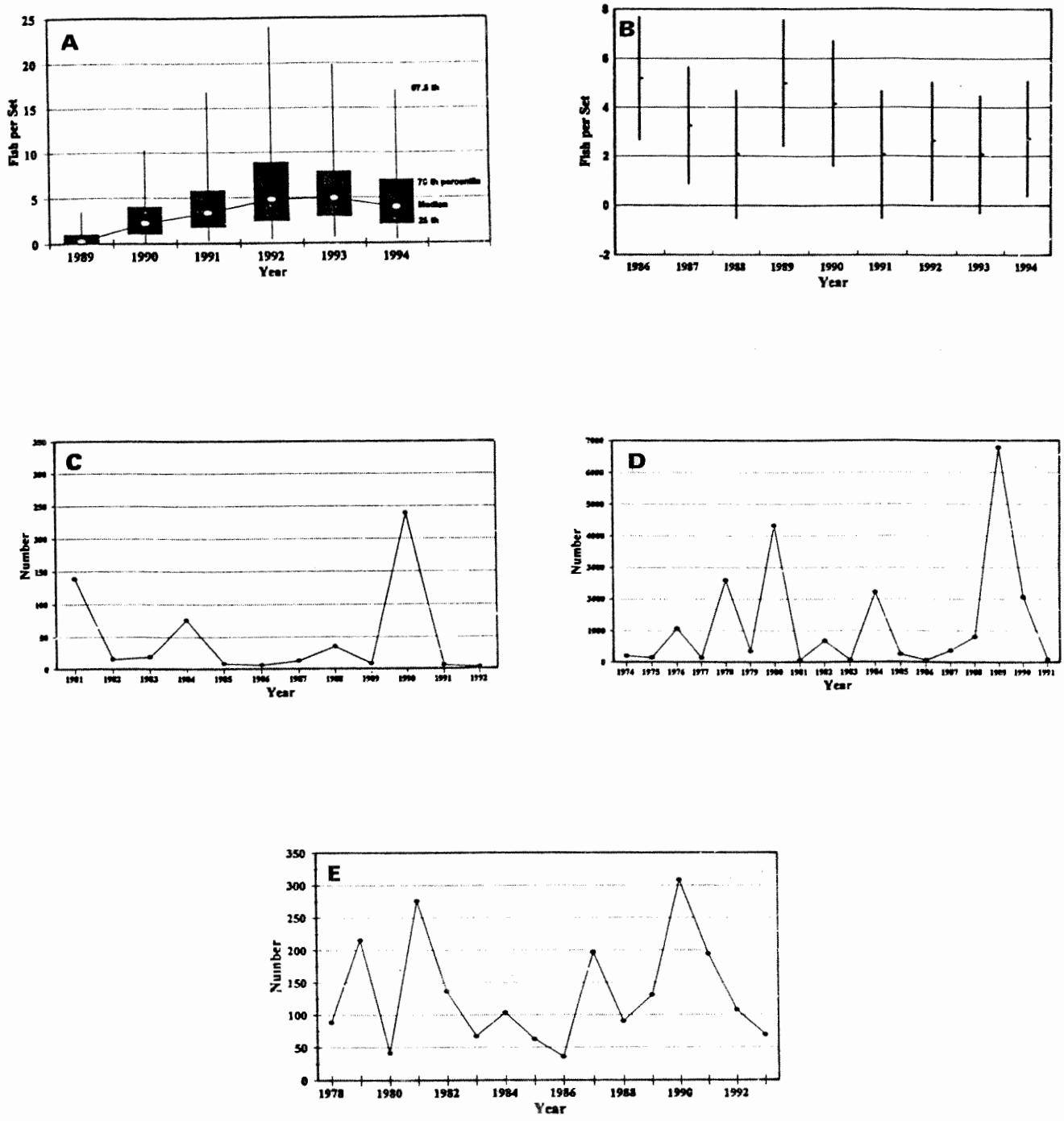


Figure 16. Trends in juvenile abundance indices for Florida (A), Louisiana (B), Alabama (C), Mississippi (D), and Texas (E).

15.3.7 Conclusions

Based on the analyses of all biological reference points (F0.1, Fmax, F20%, F30%, and F35%) using M=0.3, mullet populations in Alabama and Louisiana were meeting or exceeding the conservation criteria suggested by Mace and Sissenwine (1993). Estimates of F in Florida, however, exceeded both the F30% and F35% criteria. Mullet stocks in Florida may be more heavily fished than in the other Gulf States because of the historical, year-round food fishery, earlier development of the roe market, and previous utilization of smaller mesh sizes in the gill net fishery. Additionally, recruitment (as reflected in long-term catch statistics) has probably gradually declined as the result of loss of habitat (pollution and coastal development) and/or fishing pressure. The assessment of mullet populations in Florida indicates that the SPR level (35%) selected by the FMFC is considered to be an appropriate "target" for improving the condition of the spawning stock in Florida. Current estimates of SPRs in other Gulf States that have sufficient data (Louisiana and Alabama) are above 30%, and this level is considered to be conservative for maintenance of the spawning stock.

15.3.8 References

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