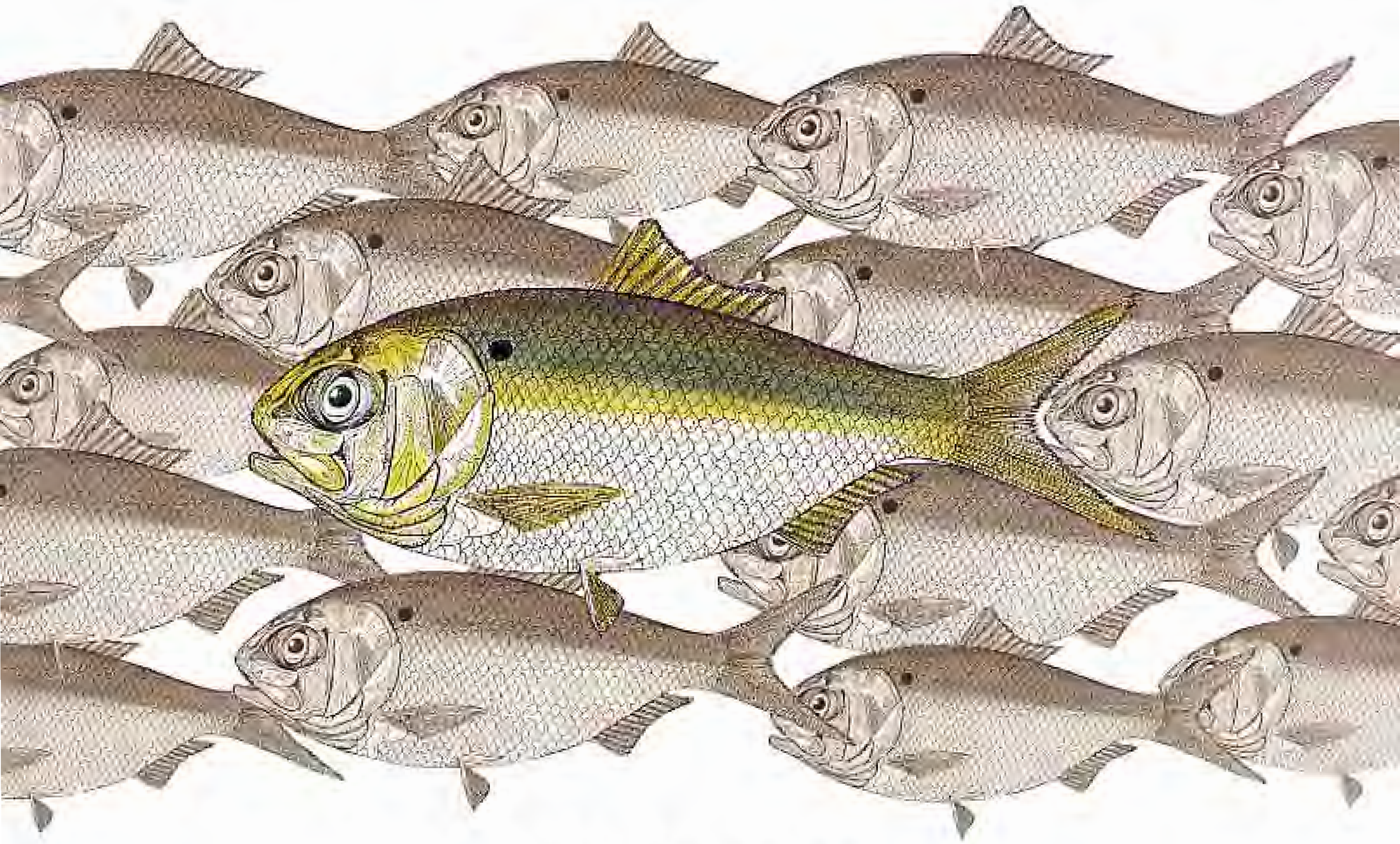
THE MENHADEN FISHERY OF THE GULF OF MEXICO, UNITED STATES: A Regional Management Plan



2002 Revision

Gulf States Marine Fisheries Commission

March 2002 **Number 99**

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2002 Revision

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

March 2002 **Number 99**

A publication of the Gulf States Marine Fisheries Commission pursuant to National Oceanic and Atmospheric Administration Award Number 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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Abbreviations and Symbols

ADCNR/MRD	Alabama Department of Conservation and Natural Resources/Marine Resources Division
BRD	bycatch reduction device
°C	degrees Celsius
DO	dissolved oxygen
EEZ	exclusive economic zone
FFWCC/FMRI	Florida Fish and Wildlife Conservation Commission/Florida Marine Research Institute
FMP	fishery management plan
ft	feet
g	gram
GMFMC	Gulf of Mexico Fishery Management Council
GSMFC	Gulf States Marine Fisheries Commission
hr(s)	hour(s)
ha	hectare
IJF	interjurisdictional fisheries
kg	kilogram
km	kilometer
lbs	pounds
LDWF	Louisiana Department of Wildlife and Fisheries
m	meter
mm	millimeters
min(s)	minute(s)
MDMR	Mississippi Department of Marine Resources
MRFSS	Marine Recreational Fisheries Statistical Survey
mt	metric ton
n	number
NMFS	National Marine Fisheries Service
ppm	parts per million
‰	parts per thousand
PPI	producer price index
SD	standard deviation
SE	standard error
sec(s)	second(s)
SL	standard length
S-FFMC	State-Federal Fisheries Management Committee
TCC	Technical Coordinating Committee
TED	turtle exclusion device
TL	total length
TPWD	Texas Parks and Wildlife Department
TTF	technical task force
TTS	Texas Territorial Sea
TW	total weight
USDEPA	United States Department of Environmental Protection Agency
USDOC	United States Department of Commerce
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
YOY	young-of-the-year

Preface

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

The GSMFC 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 GSMFC is empowered to recommend to the governor and legislature of the respective states action on programs helpful to the management of marine fisheries; however, the states do not relinquish any of their rights or responsibilities in regulating their own fisheries by 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 GSMFC's activities to develop and maintain regional fishery management plans (FMPs) for important Gulf species.

The menhaden fishery management plan is a cooperative planning effort of the five Gulf States under the IJF Act. Various members of the MAC contributed to this effort by drafting and/or reviewing assigned sections. In addition, all members contributed their expertise to discussions that resulted in revisions and led to the final draft of the revised plan.

The GSMFC made all necessary arrangements for meetings and workshops to develop the plan. Under contract with the NMFS, the GSMFC funded travel for state agency representatives and consultants other than federal employees.

The existence of only two reduction companies in the Gulf of Mexico since 1997 has led to a confidentiality issue. A similar situation has existed in the bait fishery since 1994; therefore, only the total gulf menhaden landings and ex-vessel values through 1998 will be reported in this document.

Throughout this document, metric equivalents are used wherever possible. A glossary of fisheries terms pertinent to this FMP is provided in the appendix.

Acknowledgements

The Gulf States Marine Fisheries Commission (GSMFC) would like to thank the State-Federal Fisheries Management Committee (S-FFMC) Menhaden Advisory Committee (MAC) for their assistance in developing the 2002 revision of the Menhaden Fishery Management Plan.

We especially appreciate the help of the Dr. Douglas Vaughan, Joseph Smith, and Dr. Michael Prager who drafted the stock assessment. We gratefully acknowledge the assistance in collection and assimilation of data provided by Mr. Steve Koplin with the National Marine Fisheries Service (NMFS). The MAC also thanks the GSMFC Stock Assessment Team for their review of the stock assessment.

Finally, the MAC extends its most heartfelt appreciation to Lucia Hourihan and Cynthia Yocom for their skills to ensure the quality of this document.

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1.0 SUMMARY

The menhaden fishery in the Gulf of Mexico is primarily a single-species fishery for the gulf menhaden, *Brevoortia patronus*; however, small amounts of finescale menhaden, *B. gunteri*; yellowfin menhaden, *B. smithi*; and Atlantic thread herring, *Opisthonema oglinum*, are sometimes taken.

The biology and geographic distribution of gulf menhaden has been described by numerous authors and is typical of most estuarine-dependent species. The life cycle includes offshore spawning with recruitment to and maturation in nearshore rivers, bays, bayous, and other nearshore habitats and return to offshore waters to complete the cycle. Menhaden grow rapidly as they filter feed on an abundant supply of plankton in estuaries, and most reach maturity at age-1. Menhaden are very prolific and are abundant throughout nearshore waters where they form schools, usually of the same size and age class.

Gulf menhaden are distributed throughout the Gulf of Mexico from the Yucatan Peninsula to Tampa Bay, Florida; however, they are most abundant in the northcentral Gulf. Gulf menhaden are widely distributed, but migration is primarily inshore/offshore to spawn. Larvae are, however, passively transported alongshore.

Because gulf menhaden are distributed throughout most of the Gulf, populations are affected by the jurisdictions and authorities of a large number of federal and state agencies. They are predominantly found in the territorial waters of the five Gulf States; consequently, the individual states, and not the Gulf of Mexico Fishery Management Council (GMFMC), exercise the most direct management authority. Other federal agencies including the National Park Service (NPS), the U.S. Army Corps of Engineers (USACOE), the U.S. Fish and Wildlife Service (USFWS), the National Oceanic and Atmospheric Administration (NOAA), and the Environmental Protection Agency (EPA) are also involved directly or indirectly with the management of menhaden. These agencies along with various state agencies administer programs to regulate land and water use, pollution control, wetlands protection, and other activities that could affect menhaden populations.

The menhaden fishery is one of the United States' oldest and most valuable fisheries with landings dating to the late 1800s. Data for the fishery are incomplete prior to World War II; thereafter, however, landings generally increased through the mid 1980s as the industry grew. Although there are considerable annual fluctuations, gulf menhaden landings increased to a record of 982,000 metric tons (mt) in 1984 and then declined to a 20-year low of 421,400 mt in 1992. This reduction is due to the decrease in effort, vessels, and plants operating in the Gulf of Mexico over the last 20 years. Landings currently range between 500,000 to 600,000 mt. The 1998 gulf menhaden landings of 486,200 mt comprised 62% of the U.S. menhaden landings and 11.6% of total U.S. landings of fish and shellfish.

The menhaden fishery in the Gulf can be separated into two components: the reduction fishery and the bait fishery. Landings for the reduction fishery greatly overshadow bait landings with highest totals of 982,000 mt (1984) for reduction compared to 17.3 mt for bait (1987).

Wet reduction of menhaden yields three products: fish meal, fish oil, and condensed fish solubles. Menhaden meal is a valuable ingredient for animal feeds. It contains a minimum of 60% protein with a well-balanced amino acid profile. The poultry industry is heavily dependent on fish meal to improve feed efficiency and produce maximum growth rates. Other valuable markets for fish meal as feed include swine and aquaculture operations.

Menhaden oil has been used in edible products for many years in Europe and has recently been approved for use in the United States as well. The oil is refined, deodorized, and hydrogenated to blend with other fats for cooking oils, shortening, margarine, and other products. Menhaden oil is used as an additional additive in feed for aquaculture. It is also used in nonconsumptive products such as paints, plastics, resins, and others. In June 1997, the U.S. Food and Drug Administration (USFDA) approved refined menhaden fish oil for general use in foods for human consumption. This decision by the USFDA should open significant new markets in the U.S. for refined menhaden oil as an edible oil for human consumption.

Solubles are used to fortify fish meal in feed formulas to increase nutrition for poultry and swine. It is also used in liquid feed where it is combined with molasses and other ingredients to develop a liquid feed supplement for cattle.

The value and price of reduction fishery products may vary greatly from year to year, primarily due to competition with other products. Additionally, menhaden products often compete in volatile markets.

The bait fishery for menhaden grew rapidly during the 1980s but leveled off in the 1990s. Menhaden are most often used for bait in the blue crab and crawfish fisheries; however, they are also used in the fisheries for stone crab, spiny lobster, and various commercial and recreational finfish.

Although there is some evidence that the management unit for gulf menhaden in the U.S. Gulf of Mexico could be split, it is considered to be a single, unit stock in this plan. Because of the wide discrepancy in landings for the reduction fishery versus the bait fishery, the reduction fishery is the only significant component with regard to fishing pressure on the stock. Stock analysis based on available fish and fishing pressure shows that the current stock is healthy and catches are generally below long-term maximum sustainable yield (MSY) estimates of 717,000 to 753,000 mt. Comparisons of recent estimates of fishing mortality to biological reference points do not suggest overfishing.

Although past destruction of menhaden habitat has likely reduced overall yields to some degree, present problems in the fishery are primarily economic and social in nature. Increased costs (operation, insurance, etc.); a variable labor market; foreign competition; and other factors have combined to reduce profitability.

Existing regulations that have been adopted by states to manage harvests appear to be adequate to sustain yields and prevent overfishing. The maintenance of a consistent, Gulf-wide season for the reduction fishery is needed and recommended. Other needs of the fishery include identification and assessments of ways to increase profitability and stability of the fishery and predictions of potential future harvests. Efforts should also be undertaken to better understand the relationships between coastal habitat and the dynamics of the menhaden population and fishery. If current habitat loss trends continue in the northern Gulf, habitat may become an important limit to sustaining current or expanding future harvests.

2.0 INTRODUCTION

The S-FFMC of the GSMFC addressed the need to revise and update the Menhaden Fishery Management Plan at their March 17, 1998, meeting. The committee noted the biggest change in the fishery involved the merger of Zapata Protein, Gulf Protein, and AMPRO in 1997 forming Omega Protein, Inc. This merger has resulted in only three companies operating in the U.S. reduction fishery since 1998; Omega Protein, Inc. and Daybrook Fisheries, Inc. operate in the Gulf, while Omega Protein, Inc. and Beaufort Fisheries, Inc. operate on the Atlantic coast. Approval of refined fish oil for human consumption in the U.S. has also been a significant market change for the menhaden fishery. An updated stock assessment from the NMFS coupled with the organizational changes in the Gulf led to the need for a revision of the FMP. The existence of only two reduction companies in the Gulf of Mexico has led to a confidentiality issue. A similar situation has existed in the bait fishery since 1994; therefore, bait landings for gulf menhaden will not be reported by state.

2.1 IJF Program and Management Process

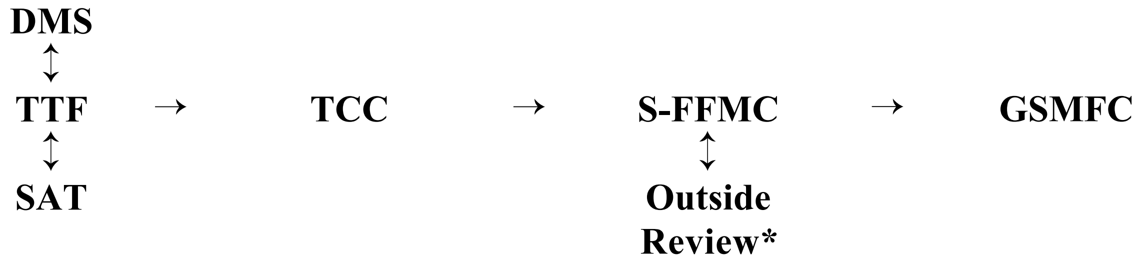
The Interjurisdictional Fisheries Act of 1986 (Title III, Public Law 99-659) was established by Congress to: (1) promote and encourage state activities in support of the management of interjurisdictional fishery resources and (2) promote and encourage management of interjurisdictional fishery resources 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 and revision of interstate FMPs by the GSMFC and the other marine fishery commissions.

After passage of the act, the GSMFC initiated the development of a FMP planning and approval process. The Commission decided to pattern its plans after those of the GMFMC under the Magnuson Fishery Conservation and Management Act of 1976. This decision ensured compatibility in format and approach to management among states, federal agencies, and the council.

The Commission also established the requirements that each plan be developed by a technical task force (TTF) comprised of experts from each state. These members were to be appointed by each state's representative on the S-FFMC. Each of the following subcommittees or committees of the GSMFC (Commercial/Recreational Fisheries Advisory Panel, Law Enforcement Committee, and TCC Habitat Subcommittee) also appointed one member or delegate to the TTF.

In reviewing the Menhaden FMP revision, the S-FFMC and the GSMFC noted the uniqueness of this fishery and the presence of the S-FFMC Menhaden Advisory Committee, an advisory committee which has been in place since the mid 1970s. They also observed that the original plan and the 1983 and 1988 revisions were developed by the advisory committee without the need to form a separate TTF. They consequently agreed to modify the approval process to substitute the S-FFMC MAC for the TTF.

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



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

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

2.2 Goal

The goal of the Menhaden FMP is a management strategy for gulf menhaden that allows an annual maximum harvest while protecting the stock from overfishing on a continuing basis.

2.3 FMP Management Objectives

The objectives of the Menhaden FMP are:

1) To summarize, reference, and discuss relevant scientific information and studies regarding the past, present, and future management of menhaden in the Gulf.
2) To describe the biological, social, and economic aspects of the menhaden fishery.
3) To review state and federal management authorities and their jurisdiction, laws, regulations, and policies affecting menhaden.
4) To ascertain optimum benefits of the menhaden 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 menhaden fishery and to suggest management strategies and options needed to solve problems and meet the needs of the stock.

3.0 DESCRIPTION OF THE STOCK(S) COMPRISING THE MANAGEMENT UNIT

3.1 Biographical Description and Geographic Distribution

Various authors have summarized the biology, geographic distribution, and movements of gulf menhaden. Gunter and Christmas (1960) published a review of the literature on menhaden with special reference to the Gulf of Mexico. Annotated bibliographies on biological aspects of American menhadens have been compiled by Christmas and Collins (1958), Reintjes et al. (1960), Reintjes (1964a), Reintjes and Keney (1975), and Dudley (1988). A computerized menhaden bibliography developed by Fontenot et al. (1980) includes over 1,200 references. Lassuy (1983) developed a species profile for gulf menhaden, and Ahrenholz (1991) reviewed the population biology and life history.

The NMFS has collected biostatistical data on gulf menhaden including data on age and size since 1964, landings data from the menhaden purse seine fishery since 1946 (Smith et al. 1987), and captain's daily fishing reports since 1979 (Smith 1991). Additional special data files include information on juvenile abundance (Turner et al. 1974, Ahrenholz et al. 1989) and tagging studies (Ahrenholz et al. 1991).

3.1.1 Classification and Morphology

3.1.1.1 Classification

The following classification of gulf menhaden was developed from Pennak (1988):

Phylum - Chordata
  Subphylum - Vertebrata
    Class - Osteichthyes
      Order - Isospondyli
        Family - Clupeidae
          Genus - *Brevoortia*
            Species - *patronus*

The valid scientific name for gulf menhaden is *Brevoortia patronus* (Goode) (Robins et al. 1991). The following synonymy has been developed from the literature: *Brevoortia patronus* (Goode 1878), *Brevoortia tyrannus patronus* (Jordan and Evermann 1896), and *Brevoortia tyrannus* (Gunter 1945).

Although the gulf menhaden is the most abundant species of menhaden in the Gulf of Mexico, finescale menhaden, *B. gunteri*, and yellowfin menhaden, *B. smithi*, are also found. Other common names for menhaden include pogy, sardine, large-scale menhaden, shad, fatback, bunker, and moss bunker.

3.1.1.2 Morphology

The life history stages of gulf menhaden have been described by various authors. Houde and Fore (1973) reported that fertilized gulf menhaden eggs are spherical, 1.0 to 1.3 mm in diameter, non-adhesive, buoyant in sea water, and float in loose aggregations near the surface. Powell (1993) reported the mean diameter of gulf menhaden eggs at 1.22 ± 0.04 mm. Eggs of yellowfin, gulf, and hybrid menhaden ranged from about 1.05 to 1.30 mm in diameter (Hettler 1968, Reintjes 1962). Hettler (1984) described and compared the eggs and larvae of gulf and yellowfin menhaden reared in the laboratory. Powell and Phonlor (1986) suggested that *B. tyrannus* eggs and larvae are larger than *B. patronus*; however, Ahrenholz (1991) noted that menhaden eggs are morphologically indistinguishable. Descriptions of finescale menhaden eggs and larvae are lacking.

At hatching, larvae are poorly developed with undeveloped mouths and fin rays and nonfunctional, unpigmented eyes (Reintjes 1962, Houde and Fore 1973). Powell (1993) measured larval gulf menhaden at the time of hatching from 2.8-3.1 mm standard length (SL) and reported first feeding at 2.9-5.7 days at 4.3 mm (SL). Suttkus (1956) described larval and juvenile menhaden in Louisiana from 18.9 to 58.4 mm (SL). As larvae transform into juveniles, body depth and weight increase substantially with only a minimal increase in length (Ahrenholz 1991). Significant changes in internal morphology also occur and are described by June and Carlson (1971). Figure 3.1 shows various developmental stages of gulf menhaden at specified lengths.

Adult menhaden were perhaps first described by Goode (1878) as follows: "D. 17-21; A. 20-23; P. 14-17; Sc. 36-50; Gr. 40-150; body silvery, greenish on back, with dark humeral spot and usually with series of smaller spots behind humeral one." Adult gulf menhaden have also been described by Walls (1975) and Hoese and Moore (1977). Figure 3.2 shows a typical adult gulf menhaden.

Menhaden are distinguished from other clupeids by a large head, absence of teeth in juveniles and adults, pectinated scales, the dorsal fin located over the interval between the pelvic and anal fins, and a compressed body with bony scutes (Reintjes 1969). Other features include numerous, long gill rakers; a unique muscular pyloric stomach or gizzard; and a dark, conspicuous scapular spot.

Gulf menhaden are characterized by large scales (36 to 50 oblique rows crossing the midline of the body); a series of smaller spots on the body behind the scapular spot; and prominent, radiating striations on the upper part of the opercle. Yellowfin and finescale menhaden have smaller scales (58-76 rows) and lack the smaller spots and strong opercular striations (Hildebrand 1948).

Recent work by Castillo-Rivera et al. (1996) compared the morphology of the branchial apparatus in the gulf and finescale menhaden. They determined that the branchiospinule numbers were higher in the gulf menhaden and therefore were closer together when compared to the finescale menhaden. The epibranchial organs were longer and had thinner walls in the gulf menhaden than the finescale menhaden. Other differences include longer intermediate gill rakers and a significantly longer intestine in gulf menhaden. These differences lead to significant dietary differences and resource partitioning between the two species.

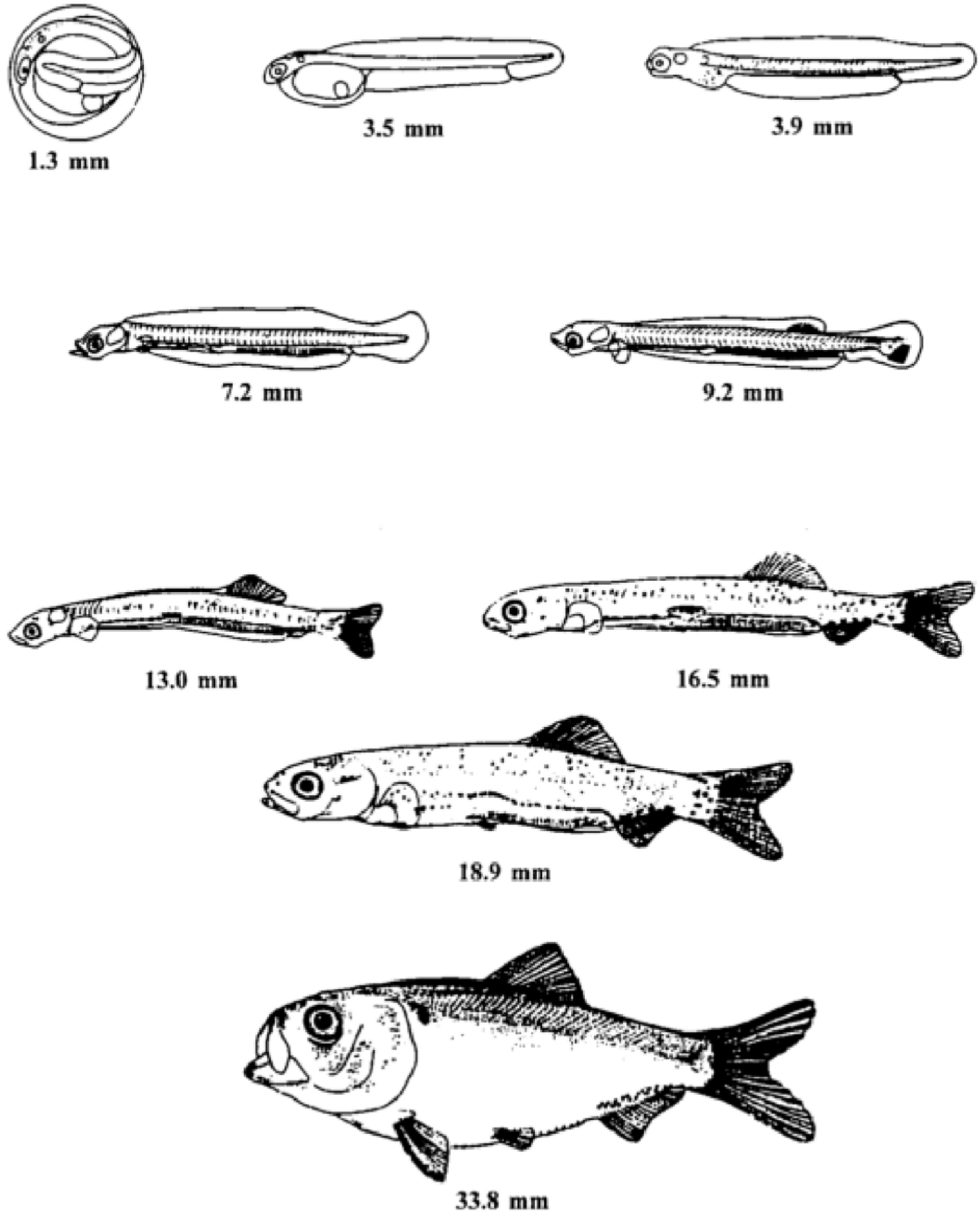
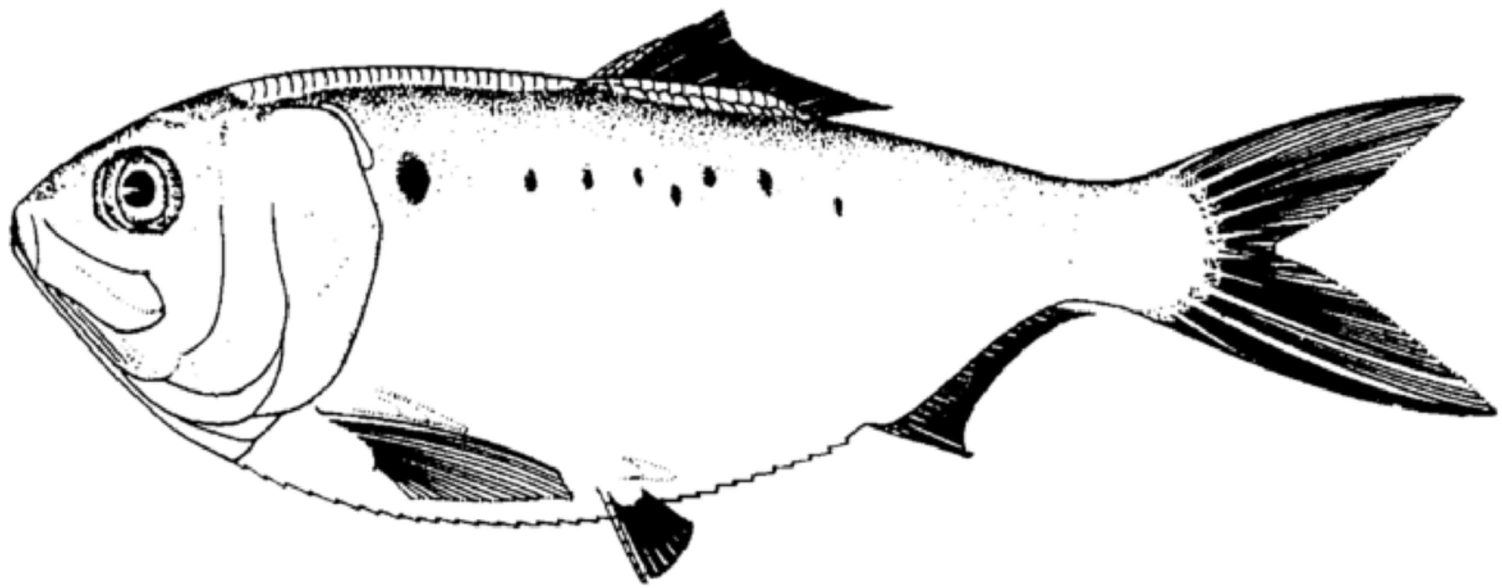


Figure 3.1. Developmental stages of gulf menhaden at specified lengths (from Hettler 1984).



. Adult gulf mehaden (from Fischer 1978).

3.1.2 Biological Description

3.1.2.1 Growth, Maturation, and Age

Hettler (1984) reported a hatching size of 2.6 to 3.0 mm SL for laboratory-reared gulf menhaden, and Warlen (1988) used the Gompertz growth model to back-calculate a hatching size of 2.4 mm SL for wild-caught gulf menhaden.

Hettler (1968) reported that larvae from yellowfin menhaden (female) x gulf menhaden (male) reached a length of 3.6 mm total length (TL), 3.9 mm TL, 4.2 mm TL, 4.5 mm TL, and 4.3 mm TL in 6, 26, 58, 82, and 130 hours, respectively. The yolk sac was completely absorbed after 80 hours, but most of the larvae did not start feeding and shrunk. Larvae of yellowfin menhaden artificially fertilized and reared in the laboratory were 7.6 mm TL 11 days and 11.9 mm TL 27 days after hatching (Hettler 1970). Powell (1993) determined gulf menhaden began feeding between 2.9 and 5.7 days after hatching at 4.3 mm (SL).

Larval growth rates are dependent on temperature and the availability of food (Ahrenholz 1991). Houde and Swanson (1975) observed an average growth rate for yellowfin menhaden of 0.45 mm/day at 26°C. In the laboratory at 18°-22°C, Hettler (1984) found that gulf menhaden grew at a rate of 0.27-0.33 mm/day for the first 90 days. Warlen (1988) observed a similar rate (0.30 mm/day) for wild-caught larvae at temperatures ranging from 12.9°-21.2°C. Based on larval samples ranging from 3.4 to 28.0 mm SL and ages 5 to 62 days, Warlen (1988) calculated age-specific growth rates from approximately 7% per day at 10 days of age to <0.4% per day at age 60 days. He also noted that larval gulf menhaden grew rapidly, and maximum absolute growth rate occurred at 7.9 mm SL and 13 days of age. Powell (1993) reported growth rates of gulf menhaden after 10 days from hatching ranged from 0.038 mm/day (16°C) and 0.042 mm/day (24°C).

Warlen (1988) observed that larvae from spawns early in the season (November and December) grew more rapidly than those spawned later (February). Although warmer waters may have been a causative factor, other growth interactions (i.e., food availability) preclude definitive determination. These early-spawned larvae did not appear to significantly affect recruitment because of their relatively low numbers and the positive effects of later-season currents on transport to estuaries (Christmas and Waller 1975, Shaw et al. 1985a).

Warlen (1988) compared growth rates of larvae in 1981 from waters off Cape San Blas, Florida; Southwest Pass, Louisiana; and Galveston, Texas. Although larvae from Louisiana grew slightly faster than larvae from Texas, water temperature was higher in Louisiana, and he could not determine if Louisiana fish were faster growing or if environmental conditions caused the effect. Other comparisons by area showed no significant differences in larval growth rates.

Larvae of gulf menhaden were reported to be ages three to five weeks when they enter estuaries (Fore 1970, Reintjes 1970, Shaw et al. 1988, Warlen 1988) and 10-32 mm TL (Fore 1970, Tagatz and Wilkens 1973). Deegan (1985) and Deegan and Thompson (1987) estimated a considerably longer oceanic larval period of six to ten weeks. Tagatz and Wilkens (1973) noted that menhaden larvae may enter estuaries along the northeastern Gulf at an earlier age and/or smaller size than in other areas of the Gulf. Differences among these studies may be related to distance between estuaries and spawning areas; however, the actual cause is unknown.

Springer and Woodburn (1960) found that gulf menhaden less than 33 mm SL were most abundant in March and April in Tampa Bay, Florida. They also found that small yellowfin menhaden (average 23.3 mm TL) were most abundant during May and concluded that this species probably spawns during spring, later than gulf menhaden. Greatest abundance of larval menhaden in the neritic waters of the Gulf of Mexico off Louisiana occurred in January and February (Ditty 1986) and from January to March with a peak in February (Shaw et al. 1985a). In estuaries, largest numbers of larval menhaden also occurred in January and February (Guillory and Kasprazak unpublished data, Dunham 1975, Shaw et al. 1988).

The transformation of gulf menhaden larvae to juveniles has been postulated at 28-30 mm SL (Suttkus 1956), 30-33 mm TL (Tagatz and Wilkens 1973), and 30-35 mm SL (Deegan 1986) and at a reported age range of 88 to 103 days (Deegan and Thompson 1987). Juvenile growth and development occurs primarily in estuaries. The duration of this stage and the ultimate size reached varies based on estuarine conditions and the absolute age of individual fish (relative to when they were spawned during the season) (Lassuy 1983, Ahrenholz 1991). Loesch (1976) and Deegan (1985) reported average daily growth rates as approximately 0.2 mm/day for small juveniles in cool waters and 0.8 to 1.0 mm/day for large juveniles in warmer waters.

Since January 1 of a given season is used as the "arbitrary" birth date of that season's year class (Ahrenholz 1991) and most of that year's "crop" are still immature at the end of the year, Lewis and Roithmayr (1981) concluded that spawning occurs for the first time at age 1 as the fish approach their "arbitrary" second birthday. Lassuy (1983) suggested, however, that some large, young-of-the-year fish may become sexually mature at age 0. Lewis and Roithmayr (1981) found that in January and February all fish over 150 mm fork length (FL) contained maturing ova. Nelson and Ahrenholz (1986) estimated average size at age-1 at approximately 125 mm FL. Although the actual size at maturity is unknown for gulf menhaden, these studies suggest that it probably falls between 125 and 150 mm FL.

Growth of adult gulf menhaden has been described by Nelson and Ahrenholz (1986). Initial growth is rapid, and adults reach a size of approximately 125 mm FL by age-1. Significant growth continues through age-3 with individuals reaching approximately 170 mm FL at age-2 and 200 mm FL at age-3. After age-3, growth is minimal with individuals reaching approximately 225 mm FL at age-4 and about 235 mm FL at age-5. Gulf menhaden may reach a maximum age of five to six years (Ahrenholz 1991); however, fish older than age-4 are rare in commercial catches (J. Smith personal communication).

3.1.2.2 Reproduction

In general, gulf menhaden life history is typical of the cycle followed by most estuarine-dependent species in the Gulf. Spawning occurs offshore, and young move into estuarine nursery areas where they spend the early part of their lives (Reid 1955). Maturing adults return to offshore waters to spawn completing the cycle. A conceptual life history model is shown in Figure 3.3.

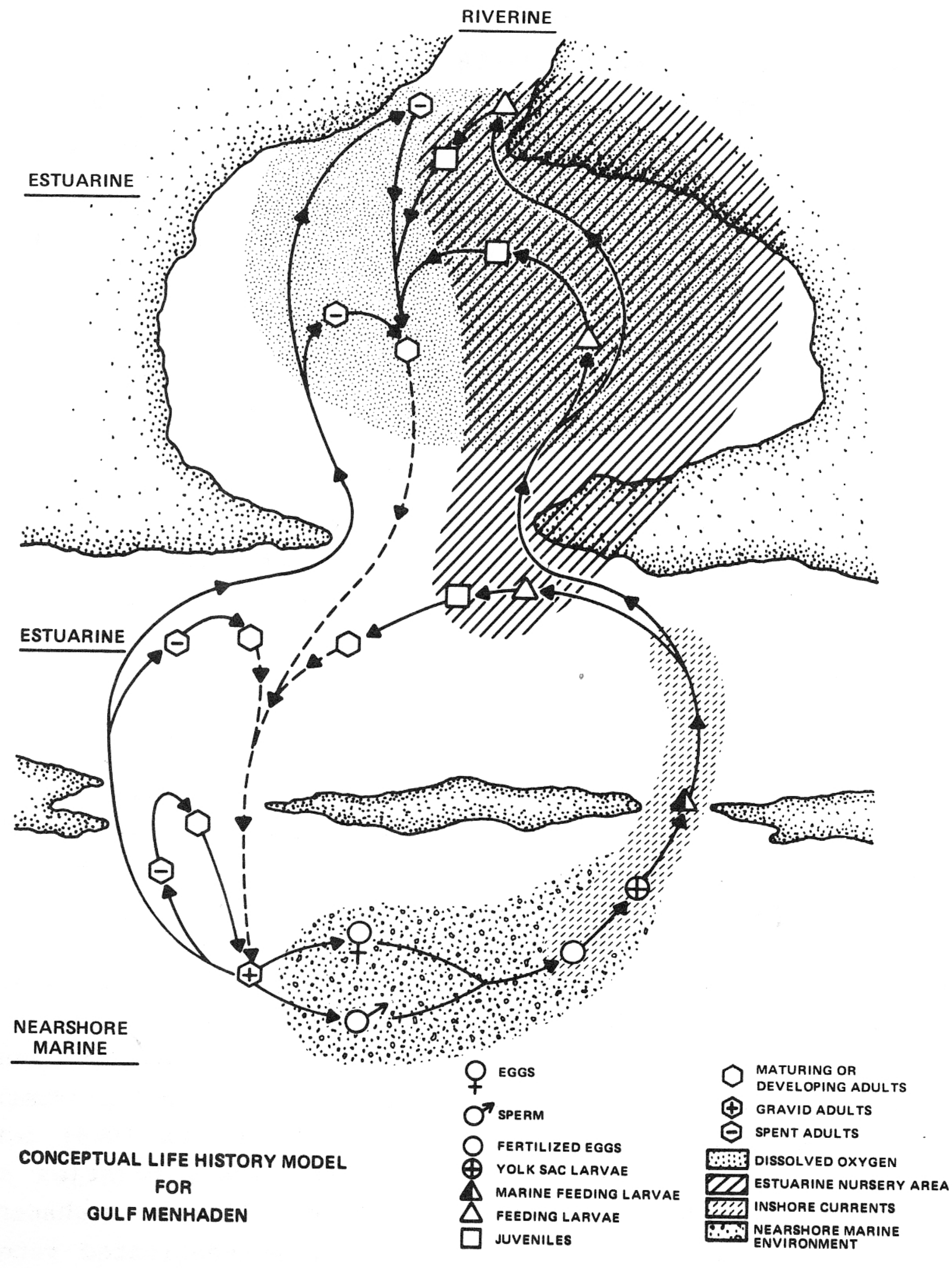


Figure 3.3. Conceptual life history model for gulf menhaden. Dissolved oxygen indicates areas of potential depletion (Christmas et al. 1982).

3.1.2.2.1 Spawning

Peak spawning periods fluctuate from year to year probably in response to varying environmental conditions (Suttkus 1956). Spawning periods and areas have been substantiated by collections of eggs, larvae, juveniles, and adults with ripe gonads and by the examination of ovarian components (Combs 1969, Turner 1969, Fore 1970, Christmas and Waller 1975).

3.1.2.2.1.1 Season

Data presented by numerous researchers corroborate a gulf menhaden spawning season extending from about September to April with a peak generally between December and February (Gunter 1945, Baldauf 1954, Suttkus 1956, Simmons 1957, Arnold et al. 1960, Hoese 1965, Combs 1969, Turner 1969, Fore 1970, Perret et al. 1971, Swingle 1971, Christmas and Waller 1973, Tagatz and Wilkens 1973, Etzold and Christmas 1979, Guillory and Roussel 1981, Shaw et al. 1985a, Warlen 1988).

3.1.2.2.1.2 Courtship and Spawning Behavior

Courtship and spawning behavior have not been observed (Shaw et al. 1985a, Ahrenholz 1991).

3.1.2.2.1.3 Duration

Combs (1969) and Lewis and Roithmayr (1981) reported that gulf menhaden were multiple, intermittent spawners with ova being released in batches or fractions over a protracted spawning season. The duration of individual, batch spawns has not been reported.

3.1.2.2.1.4 Location and Effects of Temperature and Salinity

Actual spawning sites have not been delineated, but data indicate that gulf menhaden spawn offshore. Turner (1969) presented indirect evidence of spawning areas in the eastern Gulf from collections of menhaden eggs and larvae off Florida. He observed that eggs were collected within the five fathom curve and suggested that spawning takes place nearshore in Florida waters. Combs (1969) did not delineate the geographical areas of gulf menhaden spawning, but he provided evidence that spawning occurs only in high-salinity waters.

Based on the distribution of eggs, Fore (1970) indicated that spawning of gulf menhaden occurs mainly over the continental shelf between Sabine Pass, Texas, and Alabama. Greatest concentrations were found in waters between the 4 - 40 fathom (≈7 - 70 m) contours off Texas and Louisiana and near the Mississippi Delta. Sogard et al. (1987) found high densities of larvae near the Mississippi River supporting the conclusions of Fore (1970) and Christmas and Waller (1975) that spawning is concentrated near the mouth of the Mississippi River.

Shaw et al. (1985a) found highest egg densities between the ten and 23 m isobaths and at temperatures and salinities of 15° to 18°C and 30‰ to 36 ‰, respectively. Christmas and Waller (1975) found highest egg densities at temperatures >15°C and salinities >25‰.

3.1.2.2.2 Fecundity

Batch fecundity estimates have not been calculated, and estimates of egg production have been based on the total number of ova produced by individual fish over an entire season. The number of eggs spawned by a mature female usually increases with the size of the fish. Suttkus and Sundararaj (1961) examined ovaries of female gulf menhaden at age 1, 2, and 3 and reported that the mean numbers of eggs per fish per age group were 21,960; 68,655; and 122,062, respectively. Lewis and Roithmayr (1981) examined spawning age and egg number per cohort to determine the reproductive potential of gulf menhaden.

Vaughan (1987) estimated that total fecundity for the entire stock of spawners in the 1964-1984 data set varied from 10.3 to 143.3 trillion eggs with an average fecundity of approximately 23,000 eggs per mature female. Fecundity increased with length and age, but since numbers of older fish constitute only a small fraction of the overall spawning population, late age 1 or early age 2 fish contributed the bulk of stock fecundity.

3.1.2.2.3 Incubation

It is presumed that gulf menhaden eggs remain near the surface until hatching, and the larvae are planktonic. Gulf menhaden eggs have been recorded to hatch in 40-42 hours at 19°-20°C (Hettler 1984). Hatching time has been shown to vary with increasing or decreasing temperatures (Reintjes 1962, Hettler 1968, Ahrenholz 1991).

Kuntz and Radcliffe (1917) gave an account of hatching and early larval development of Atlantic menhaden. They reported that fertilized eggs hatched within 48 hours. Hatching time for yellowfin menhaden was 46 hours from fertilization at 18.5° to 19.0°C (Reintjes 1962). Hettler (1968) reported a hatching time of 38 to 39 hours for eggs of yellowfin menhaden fertilized with sperm of gulf menhaden and held at 19.5° to 21.5°C. Hettler (1970) observed that yellowfin menhaden eggs began hatching 48 hours after artificial fertilization with yellowfin menhaden sperm. He also noted that dead or unfertilized eggs sink, while fertilized menhaden eggs float in sea water.

3.1.2.3 Parasites and Disease

Pasteurella spp. is a nonmotile, gram negative bacteria that infects gulf menhaden and causes skin ulcers, pale gills, and small hemorrhages (Lewis et al. 1970). Plumb et al. (1974) observed heavy mortality of gulf menhaden caused by *Streptococcus* spp. bacteria.

A small hematozoan flagellate has been reported from the blood of *B. patronus*; however, its pathogenicity is unknown (Becker and Overstreet 1979).

Various monogenetic and digenetic trematodes parasitize menhaden in the Gulf of Mexico. Monogenetic flukes, *Diclidophora lintoni* (also called *Clupeocotyle lintoni*), have been found on the gills of *B. gunteri* in Texas and Mississippi (Koratha 1955, Hargis 1959, R. Overstreet personal communication). Hargis (1959) also reported *C. brevoortia* from the gills of gulf menhaden in Florida; however, this name is probably a synonym of *C. lintoni* (R. Overstreet personal communication). *Kuhnia brevoortia, C. megaconfibula*, and *Mazocraeoides georgei* are other monogenes reported from the gills of *B. patronus* of Florida (Hargis 1955a, 1955b), and *M. georgei* was also observed in gulf menhaden from Mississippi (R. Overstreet personal communication). Digenetic flukes, *Lepocreadium brevoortiae*, *Lecithaster confusus*, and *Parahemiurus merus* have been found in the intestines and stomachs of gulf menhaden (Nahhas and Short 1965). Metacercariae of *Aphanurus* sp. were observed by Govoni (1983) in larval gulf menhaden, and he also found plerocercoids of the tapeworm *Scolex pleuronectis*.

The parasitic copepod, *Lernanthropus brevoortiae*, has been found on the gills of menhaden by Bere (1936) and Overstreet (personal communication) from Florida and Mississippi, respectively. *Lernaeenicus radiatus* was discovered embedded in flesh of gulf menhaden (Causey 1955, Dahlberg 1969, R. Overstreet personal communication). Pearse (1952) found *Caligus ventrosetosus* on the gills of *B. gunteri* from Texas.

Bere (1936) and Overstreet (personal communication) found *Nothobomolochus teres* on the inner surface of the operculum of *B. patronus* from Mississippi. Bere (1936) also reported finding *Bomolochus teres* on *B. tyrannus* in Florida, but Overstreet (personal communication) noted that the copepod was probably *N. teres* and the menhaden *B. patronus*.

The isopod, *Olencira praegustator*, has been reported to parasitize gulf menhaden, yellowfin menhaden, and their hybrids (Richardson 1905, Turner and Roe 1967, Dahlberg 1969). Overstreet (1978) found *O. praegustator* in the mouth and on the gills of gulf menhaden.

3.1.2.4 Feeding, Prey, and Predators

Menhaden are selective feeders throughout most of the larval stage (June and Carlson 1971, Ahrenholz 1991). Juveniles and adults are omnivorous filter feeders (June and Carlson 1971, Ahrenholz 1991), and Peck (1893) concluded that adult menhaden are indiscriminate feeders and take in materials in the same proportions as they occur in ambient water.

Larvae appeared to prefer large phytoplankton initially (Govoni et al. 1983); however, as they approached the juvenile stage, zooplankton became more important. Govoni et al. (1983) and Stoecker and Govoni (1984) provided data on food habits with respect to larval size. Darnell (1958) found that phytoplankton and organic detritus/silt made up the bulk of the stomach contents of juveniles and adults, respectively. Based on minimum size threshold studies by Durbin and Durbin (1975) and Friedland et al. (1984), food size varied with the size of the fish.

As young menhaden develop, the maxillary and dentary teeth become nonfunctional and disappear. Gill rakers increase in length, number, and complexity, and pharyngeal pockets appear. The alimentary tract folds forward, and a muscular stomach (gizzard) and many pyloric cecae develop while the intestine forms several coils (June and Carlson 1971).

Darnell (1958) suggested that food is captured primarily by mechanical sieving. Friedland (1985) studied structures of the branchial basket associated with filter feeding in Atlantic menhaden and proposed a mechanism for moving food particles from the point of capture to the point of ingestion. Friedland et al. (1984) studied filtration rates and found that maximum filtration efficiency for 138 mm FL juveniles was achieved for particles about 100 µm. They also noted that filtering efficiency changed when detritus was present. Castillo-Rivera et al. (1996) compared the food resource partitioning of gulf and finescale menhaden based on ecomorphological characteristics. They found that the two co-occuring menhaden were morphologically adapted to select different food items. The structure of the branchial apparatus in gulf menhaden forms a finer-meshed filter than the finescaled menhaden allowing them to retain uni-cellular algae whereas the finescale consumes mainly larger zooplankters.

The importance of detritus in the diet of menhaden has been addressed (Darnell 1958, Jeffries 1975, Peters and Kjelson 1975, Peters and Schaaf 1981, Friedland et al. 1984, Lewis and Peters 1984, Castillo-Rivera et al. 1996). Deegan (1985) demonstrated that gulf menhaden have two mechanisms (microbial cellulase activity and a gizzard-like stomach) that allow digestion of detritus. Digestion of phytoplankton, particularly diatoms, is probably also aided by these mechanisms. The length of the intestine in gulf menhaden was found to be correlated to an increased amount of detritus in the gut (Castillo-Rivera et al. 1996).

Because of their great abundance and schooling behavior (Section 3.1.3), menhaden are prey for a large number of piscivorous fish and birds (Reid 1955, Simmons and Breuer 1950, Reintjes 1970, Kroger and Guthrie 1972, Dunham 1975, Overstreet and Heard 1978, Overstreet and Heard 1982, Medved et al. 1985). The effects of predation in estuarine and marine communities have not been quantified, and the role of adult gulf menhaden as a forage species is not well known in the Gulf. Recent studies by de Silva and Condrey (1998) have suggested that sharks encountered in menhaden nets forage on the schools either prior to or during fishing operations.

Menhaden eggs and larvae are potential food for various filter-feeding and larval fishes and invertebrates including but not limited to themselves, other clupeids, chaetognaths, coelenterates, mollusks, and ctenophores (Clements 1990, Ahrenholz 1991). Fishes known to eat menhaden include: the mackerels (*Scombridae*), bluefish (*Pomatomus saltatrix*), sharks, white and spotted seatrout (*Cynoscion* spp.), blue runner (*Caranx crysos*), ladyfish (*Elops saurus*), longnose and alligator gars (*Lepisosteus osseus* and *L. spatula*), and red drum (*Sciaenops ocellatus*) (Simmons and Breuer 1950, Reintjes 1970, Kroger and Guthrie 1972, Overstreet and Heard 1978, Etzold and Christmas 1979, Overstreet and Heard 1982).

Piscivorous birds that have been found to consume menhaden include: brown pelicans, *Pelecanus occidentalis* (Gunter and Christmas 1960, Palmer 1962); osprey, *Pandion haliaetus* (Spitzer 1989); and common loons, *Gavia immer* [P.R. Spitzer cited by Ahrenholz (1991)]; and terns (Culliney 1976). Marine mammals have also been reported as predators of menhaden (Hildebrand 1963).

3.1.3 Behavior

Schooling is apparently an innate behavioral characteristic beginning at the late larval stage and continuing throughout the remainder of life. Menhaden occur in dense schools, generally by species of fairly uniform size (Reintjes and June 1961). There is some evidence that larger, diseased, or injured menhaden may school with smaller ones to recuperate or to become more equally matched in terms of mobility (Overstreet 1978).

Although schooling behavior by juvenile and adult gulf menhaden has been well documented by many authors (3.1.2.4), the mechanism for schooling in larval menhaden has not been well studied. Higgs and Fuiman (1996) investigated the affect of changing light intensity on the schooling behavior of larval gulf menhaden. The authors found that at high light intensities the angle and distance between larvae were relatively constant but as intensity decreased the group became more dispersed. They determined that schooling initiation and cessation are linked to the amount of available light and that the ability of the larval menhadens eyes to capture light determined the threshold light intensities to initiate and maintain the school.

3.1.4 Geographic Distribution and Migration

Gulf menhaden range from the Yucatan Peninsula in Mexico across the western and northern Gulf to Tampa Bay, Florida. Finescale menhaden occur from Mississippi Sound southwestward to the Gulf of Campeche in Mexico. Yellowfin menhaden range from Chandeleur Sound, Louisiana, southeastward to the Caloosahatchee River, Florida (and presumably around the Florida peninsula), to Cape Lookout, North Carolina (Hildebrand 1948, Suttkus 1956 and 1958, Christmas and Gunter 1960, Gunter and Christmas 1960, Reintjes and June 1961, Reintjes 1964b, Turner 1969 and 1970). The yellowfin menhaden was reported from Grand Bahama Island and became the first authenticated record of a North American species from beyond the Continental Shelf (Levi 1973).

Planktonic larvae require favorable currents to make their way into estuaries. Whether the movement of larvae from their hatching area to estuaries represents passive drifting, active swimming, or a combination of the two is, however, unknown. Ekman transport studies in the northern Gulf of Mexico have shown net northerly movement of surface waters during winter (Cushing 1977). Shaw et al. (1985b) developed a qualitative transport model for western Louisiana that indicated a west-northwest, alongshore direction of movement within the coastal boundary layer was the major mechanism transporting larvae to the estuaries as opposed to south-to-north, cross-shelf transport. Once menhaden larvae reach the estuary, they move from the higher-salinity waters of the lower estuary to the lower-salinity waters in the upper estuary and tributaries. As they grow to juveniles in late spring and summer, they move downstream to higher-salinity waters.

Although some young-of-the-year menhaden may overwinter in estuaries (Turner and Johnson 1973, Deegan 1985), the overwhelming majority of juveniles and adults migrate offshore. Migration apparently occurs throughout summer and fall. Springer and Woodburn (1960) reported that migration from the estuaries in the Tampa Bay, Florida, area took place during June and July, and Tagatz and Wilkens (1973) found that most juveniles had moved out of estuaries in the Pensacola Bay, Florida, area by September. Suttkus (1956) reported that migration of age-0 menhaden from Lake Pontchartrain, Louisiana, appeared to occur in August or September. Copeland (1965) found that the greatest migration of advanced juveniles from estuaries at Port Aransas, Texas, occurred from November through May.

Extensive coast-wide migrations by Gulf of Mexico menhaden are not known to occur. Ahrenholz (1981) concluded that fish first entered the fishery primarily in the same geographic area in which they were tagged. Pristas et al. (1976) noted very little east-west movement of adults; however, there is some evidence that older adults move toward the Mississippi River delta.

Gulf menhaden are shallow-water fishes, and information on their offshore range is limited. Roithmayr and Waller (1963) reported catches of gulf menhaden from December through February in the northern Gulf between four and 48 fathoms both east and west of the Mississippi River Delta. They concluded that at least some fish do not move far offshore but winter on the inner and middle continental shelf area just off the Mississippi River delta. Turner (1969) collected adult menhaden within the ten-fathom contour off the Florida coast but did not collect any in gill nets fished in ten to 32 fathoms of water, thus indicating that menhaden in that area do not move far offshore. Adults were, however, collected 20 to 25 miles offshore by bottom trawls and surface nets in waters 20 fathoms in depth. Mid-water trawls caught *B. patronus* at depths ranging from 40 to 55 fathoms (Christmas and Gunter 1960).

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

4.1 Description of Essential Fish Habitat

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

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

For the purposes of describing those habitats that are critical to gulf menhaden in this FMP, we will utilize this definition but refer to such areas as "essential habitat" to avoid confusion with the EFH mandates in the Magnuson-Stevens Act. These mandates include the identification and designation of EFH for all federally-managed species, development of conservation and enhancement measures including those which address fishing gear impacts, and require federal agency consultation regarding proposed adverse impacts to those habitats.

4.2 Gulf of Mexico

Galstoff (1954) summarized the geology, marine meteorology, oceanography, and biotic community structure of the Gulf of Mexico. Later summaries include those of Jones et al. (1973), Becker and Brashier (1981), Holt et al. (1982), and the GMFMC (1998). In general, the Gulf is a semi-enclosed basin connected to the Atlantic Ocean and Caribbean Sea by the Straits of Florida and the Yucatan Channel, respectively. The Gulf has a surface water area of approximately 1,600,000 km^2 (GMFMC 1998), a coastline measuring 2,609 km, one of the most extensive barrier island systems in the United States, and is the outlet for 33 rivers and 207 estuaries (Buff and Turner 1987). Oceanographic conditions throughout the Gulf are influenced by the Loop Current and major episodic freshwater discharge events from the Mississippi/Atchafalaya rivers. The Loop Current directly affects species dispersal throughout the Gulf while discharge from the Mississippi/Atchafalaya rivers creates areas of high productivity that are occupied by gulf menhaden and many other commercially and recreationally important marine species.

The Gulf coast wetlands and estuaries provide habitat for an estimated 95% of the finfish and shellfish species landed commercially and 85% of the recreational catch of finfish (Thayer and Ustach 1981). Five of the top-ten commercial fishery ports in the United States are located in the Gulf and account for an estimated 559.7 million kg of fish and shellfish harvested annually from the Gulf (USDOC 1998). The Gulf fishery accounts for 18% of the nation's total commercial landings and supports the most valuable shrimp fishery in the United States (USDOC 1998). Additionally, the Gulf of Mexico's wetlands, coastal estuaries, and barrier islands also support large populations of wildlife (e.g., waterfowl, shorebirds); play a significant role in flood control and water purification; and buffer the coastal mainland from hurricanes and lesser storm events.

4.2.1 Circulation Patterns and Tides

Planktonic larvae, such as the gulf menhaden, require favorable currents to make their way into estuaries from open water spawning grounds. Hydrographic studies depicting general circulation patterns of the Gulf of Mexico include those of Parr (1935), Drummond and Austin (1958), Ichiye (1962), Nowlin (1971), and Jones et al. (1973). Circulation patterns in the Gulf are dominated by the influence of the upper-layer transport system of the western North Atlantic. Driven by the northeast trade winds, the Caribbean Current flows westward from the junction of the Equatorial and Guiana current, crosses the Caribbean Sea, and continues into the Gulf through the Yucatan Channel eventually becoming the eastern Gulf Loop Current. Upon entering the Gulf through the Yucatan Channel, the Loop Current transports massive quantities of water (700,000 - 840,000 m^3/sec; Cochrane 1965).

Moving clockwise, the Loop Current dominates surface circulation in the eastern Gulf and generates permanent eddies over the western Gulf. During late summer and fall, the progressive expansion and intrusion of the loop reaches as far north as the continental shelf off the Mississippi River Delta. High productivity associated with the discharge from the Mississippi/Atchafalaya river systems benefits gulf menhaden and numerous other finfish and invertebrate species that use the northern Gulf as a nursery ground. Additionally, dispersal of tropical species from the Caribbean into the Gulf is accomplished via Loop Current transport. Nearshore currents are driven by the impingement of regional Gulf currents across the shelf, passage of tides, and local and regional wind systems. The orientation of the shoreline and bottom topography may also place constraints on speed and direction of shelf currents.

When the Loop Current is north of 27°N latitude, a large anticyclonic eddy about 300 km in diameter usually separates. These warm core eddies originate as pinched off northward penetrations of Loop Current meanders. In the following months, the eddy migrates westward at about 4 km/day until it reaches the western Gulf shelf where it slowly disintegrates over a span of months. The boundary of the Loop Current and its associated eddies is a dynamic zone with meanders and strong convergences and divergences which can concentrate planktonic organisms including the gulf menhaden and other pelagic fish eggs and larvae.

Tide type varies widely throughout the Gulf with diurnal tides (one high tide and one low tide each lunar day of 24.8 h) existing from St. Andrew's Bay, Florida, to western Louisiana. The tide is semi-diurnal in the Apalachicola Bay area of Florida, and mixed (diurnal, semi-diurnal, and combinations of both) in west Louisiana and Texas. Gulf tides are small and noticeably less developed than along the Atlantic or Pacific coasts. The normal tidal range at most places is not more than 0.6 m. Despite the small tidal range, tidal current velocities are occasionally high especially near the constricted outlets that characterize many of the bays and lagoons.

4.2.2 Sediments

Two major sediment provinces exist in the Gulf of Mexico: carbonate sediments found predominantly east of DeSoto Canyon and along the Florida west coast and terrigenous sediments commonly found west of DeSoto Canyon and into Texas coastal waters (GSMFC 1998). Quartz sand sediments are found relatively nearshore from Mississippi eastward across Alabama and the Panhandle and west coast of Florida. Due to the influence of the Mississippi and Rio Grande rivers, fine sediments (i.e., silt and mud) are common in the western Gulf and south of the Rio Grande, respectively and are also found in deeper shelf waters (>80 m) (Darnell et al. 1983).

West of Mobile Bay, fine-grained organic-rich silts and clays of terrestrial origin are brought to the shelf by distributaries of the Mississippi, Pearl, and other rivers (Darnell and Kleypas 1987). These fine sediments spread eastward from the Louisiana marshes to Mobile Bay, but off the Mississippi barrier islands, they are interrupted by a band of coarser quartz sand. Fine sediments are also found southwestward of the Everglades extending the full length of the Florida Keys. Another area of fine sediments lies along the eastern flank of DeSoto Canyon.

Quartz sand predominates in the nearshore environment from the Everglades northward along the coast of Florida. However, from below Apalachicola Bay to Mobile Bay it covers the entire shelf, except the immediate flank of DeSoto Canyon. The outer half to two-thirds of the Florida shelf is covered with a veneer of carbonate sand of detrital origin. Between the offshore carbonate and nearshore quartz, there lies a band of mixed quartz/carbonate sand.

4.2.3 Submerged Vegetation

Submerged vegetation comprise an estimated 1,475,000 ha of seagrasses and associated macroalgae in the estuarine and shallow coastal waters of the Gulf (MMS 1983). Turtle grass (*Thalassia testudinum*), shoal grass (*Halodule wrightii*), manatee grass (*Syringodium filiforme*), star grass (*Halophila engelmanni*), and widgeon grass (*Ruppia maritima*) are the dominant seagrass species (GMFMC 1998). Distribution of seagrasses in the Gulf is predominantly (98.5%) along the Florida and Texas coasts with 910,000 ha of seagrass being located on the west Florida continental shelf, in contiguous estuaries, and in embayments (MMS 1983). Macroalgae species including *Caulerpa* sp., *Udotea* sp., *Sargassum* sp., and *Penicillus* sp. are found throughout the Gulf, but are most common on the west Florida shelf and in Florida Bay.

Duke and Kruczynski (1992) provide a status and trends assessment of emergent and submerged vegetated habitats of Gulf of Mexico coastal waters. Coastal wetlands of the Gulf of Mexico are of special interest because of their recognized importance in maintaining productive fishery resources. The USFWS National Wetland Inventory data (aerial photographs) from 1972-1984 provide the current status of five wetland categories for the Gulf coast states (seagrass habitat was not included in the NOAA survey). The five coastal wetland types included: 66% salt marsh, 17% forested scrub-shrub, 13% tidal flats, 3% tidal fresh marsh, and 1% forested. Louisiana contains most of the Gulf's salt marshes with 69%, followed by Texas (17%), Florida (10%), Mississippi (2%), and Alabama (1%). Texas contains 54% of the tidal flats, and Florida has 97% of the estuarine forested scrub-shrub (mostly mangrove) (Duke and Kruczynski 1992).

4.2.4 Emergent Vegetation

Emergent vegetation is not evenly distributed along the Gulf coast. Marshes in the Gulf of Mexico consist of several species of marsh grasses, succulents, mangroves, and other assorted marsh compliments. In Texas, emergents include shore grass (*Monanthochloe littoralis*), saltwort (*Batis maritima*), smooth cordgrass (*Spartina alterniflora*), saltmeadow cordgrass (*Spartina patens*), saltgrass (*Distichlis spicata*), black needlerush (*Juncus roemerianus*), coastal dropseed (*Sporobolus virginicus*), saltmarsh bulrush (*Scirpus robustus*), annual glasswort (*Salicornia bigelovii*), seacoast bluestem (*Schizachyrium scoparium*), sea blite (*Suaeda linearis*), sea oat *(Uniola paniculata*), and gulfdune paspalum (*Paspalum monostachyum*) (Diener 1975, GMFMC 1998). The southern most reaches of Texas also have a few isolated stands of black mangrove (*Avicennia germinans*). Over 247,670 ha of fresh, brackish, and salt marshes occur along the Texas coastline.

Louisiana marshes comprise more than 1.5 million ha or over 60% of all the marsh habitat in the Gulf (GMFMC 1998). They include a diverse number of species including smooth cordgrass, glasswort, black needlerush, black mangrove, saltgrass, saltwort, saltmeadow cordgrass, threecorner grass (*Scirpus olneyi*), saltmarsh bulrush, deer pea (*Vigna luteola*), arrowhead (*Sagittaria* sp.), wild millet (*Echinochloa walteri*), bullwhip (*Scirpus californicus*), sawgrass (*Cladium jamaicense*), maiden cane *(Panicum hemitomon*), pennywort (*Hydrocotyl*e sp.), pickerelweed (*Pontederia cordata*), alligator-weed (*Alternanthera philoxeroides*), and water hyacinth (*Eichhornia crassipes*) (Perret et al. 1971).

Mississippi and Alabama have a combined 40,246 ha of mainland marsh habitat (26,237 and 14,009 ha, respectively). Mississippi marshes are dominated by black needlerush, smooth cordgrass, saltmeadow cordgrass, and threecorner grass (Eleuterius 1973, Wieland 1994). Other common species of saltmarsh vegetation include saltgrass, torpedo grass (*Panicum repens*), sawgrass, saltmarsh bulrush, sea myrtle (*Baccharis halimifolia*), sea ox-eye (*Borrichia frutescens*), marsh elder (*Iva frutescens*), wax myrtle (*Myrica cerifera*), poison bean (*Sesbania drummondii*), pennywort, and marsh pink (*Sabatia stellaris*) (C. Moncreiff personal communication). Alabama marshes contain the same compliment of species as Mississippi with the addition of big cordgrass (*Spartina cynosuroides*), common reed (*Phragmites communis*), and hardstem bullrush (*Scirpus californicus*). In addition, the Mississippi Sound barrier islands contain about 860 ha of saltmarsh habitat (GMFMC 1998).

Florida's west coast and Panhandle include 213,895 ha of tidal marsh (GMFMC 1998). Emergent vegetation is dominated by black needlerush but also includes saltmarsh cordgrass, saltmeadow cordgrass, saltgrass, perennial glasswort (*Salicornia perennis*), sea ox-eye, saltwort, and sea lavender (*Limonium carolinianum*). An additional 159,112 ha of Florida's west coast is covered in red mangrove (*Rhizophora mangle*), black mangrove, and buttonwood (*Conocarpus erectus*). A fourth species, white mangrove (*Laguncularia racemosa*), occurs on the west coast but is much less abundant.

4.3 Estuaries

Gulf estuaries provide essential habitat for gulf menhaden as well as a variety of forage, commercial, and recreationally important species. Estuaries serve primarily as nursery grounds for juveniles but also as habitat for adults during certain seasons. The Gulf of Mexico is bordered by 207 estuaries (Buff and Turner 1987) that extend from Florida Bay to the Lower Laguna Madre. Perret et al. (1971) reported 5.62 million ha of estuarine habitat in the five Gulf states including 3.2 million ha of open water and 2.43 million ha of emergent tidal vegetation (Lindall and Saloman 1977). Emergent tidal vegetation includes 174,000 ha of mangrove and 1 million ha of salt marsh (USDOC 1991); submerged vegetation covers 324,000 ha of estuarine bottom throughout the Gulf (GMFMC 1998). The majority of the Gulf's salt marshes are located in Louisiana (63%), while the largest expanses of mangroves (162,000 ha) are located along the southern Florida coast (GMFMC 1998).

4.3.1 Eastern Gulf

Although less abundant than *Brevoortia smithi*, the gulf menhaden ranges throughout the eastern Gulf to Tampa Bay (Section 3.1.4). The eastern Gulf of Mexico extends from Florida Bay northward to Mobile Bay on the Florida/Alabama boundary and includes 40 estuarine systems covering 1.2 million ha of open water, tidal marsh, and mangroves (McNulty et al. 1972). Considerable changes occur in the type and acreage of submergent and emergent vegetation from south to north. Mangrove tidal flats are found from the Florida Keys to Naples. Sandy beaches and barrier islands occur from Naples to Anclote Key and from Apalachicola Bay to Perdido Bay (McNulty et al. 1972). Tidal marshes are found from Escambia Bay to Florida Bay and cover 213,895 ha with greatest acreage occurring in the Suwanee Sound and Waccasassa Bay. The coast from Apalachee Bay to the Alabama border is characterized by wide, sand beaches situated either on barrier islands or on the mainland itself. Beds of mixed seagrasses and/or algae occur throughout the eastern Gulf with the largest areas of submerged vegetation found from Apalachee Bay south to the tip of the Florida peninsula. Approximately 9,150 ha of estuarine area, principally in the Tampa Bay area, have been filled for commercial or residential development.

Coastal waters in the eastern Gulf may be characterized as clear, nutrient-poor, and highly saline. Rivers which empty into the eastern Gulf carry little sediment load. Primary production is generally low except in the immediate vicinity of estuaries or on the outer shelf when the nutrient-rich Loop Current penetrates into the area. Presumably, high primary production in frontal waters is due to the mixing of nutrient rich, but turbid, plume water (where photosynthesis is light limited) with clear, but nutrient poor, Gulf of Mexico water (where photosynthesis is nutrient limited), creating good phytoplankton growth conditions (GMFMC 1998).

4.3.2 Northcentral Gulf

The northcentral Gulf, which is the primary fishing grounds for gulf menhaden, includes Alabama, Mississippi, and Louisiana. Total estuarine area for Louisiana includes 29 major water bodies covering 2.9 million ha of which 1.3 million ha is surface water and 1.5 million ha is marsh (Perret et al. 1971). The eastern and central Louisiana coasts are dominated by sand barrier islands and associated bays and marshes. The most extensive marshes in the United States are associated with the Mississippi/Atchafalaya river deltas. The loss of wetlands along the Louisiana Coastal Zone is estimated to be 6,600 ha/yr (USEPA 1994). The shoreline of the western one-third of Louisiana is made up of sand beaches with extensive inland marshes. A complex geography of sounds and bays protected by barrier islands and tidal marshes acts to delay mixing resulting in extensive areas of brackish conditions. The Alabama and Mississippi coasts are bounded offshore by a series of barrier islands which are characterized by high energy sand beaches grading to saltwater marshes with interior freshwater marshes. The mainland shoreline is made up of saltwater marsh, beach, seawall, and brackish-freshwater marsh in the coastal rivers. Approximately 26,000 ha of mainland marsh existed in southern Mississippi in 1968, and salt marsh on the barrier islands covers 860 ha (GMFMC 1981).

Approximately 2,928 ha of submerged vegetation, including attached algae, have been identified in Mississippi Sound and in the ponds and lagoons on Horn and Petit Bois islands (C. Moncreiff personal communication). Approximately 4,000 ha of mainland marsh along the Mississippi Coastal Zone have been filled for industrial and residential use since the 1930s (Eleuterius 1973). Seagrasses in Mississippi Sound declined 40%-50% since 1969 (Moncreiff et al. 1998). The Alabama Coastal Zone contains five estuarine systems covering 160,809 ha of surface water and 14,008 ha of tidal marsh (GMFMC 1998). An estimated 4,047 ha of submerged vegetation exists in the Alabama Coastal Zone.

In general, estuaries and nearshore Gulf waters of Louisiana and Mississippi are low saline, nutrient-rich, and turbid due to the high rainfall and subsequent discharges of the Mississippi, Atchafalaya, and other coastal rivers. The Mississippi River deposits 684 million mt of sediment annually near its mouth (Holt et al. 1982). Average (1980-1988) discharge for the Mississippi and Atchafalaya rivers was 1,400m^3/sec and 6.02m^3/sec, respectively. As a probable consequence of the large fluvial nutrient input, the Louisiana nearshore shelf is considered one of the most productive areas in the Gulf of Mexico.

4.3.3 Western Gulf

A minor component of the gulf menhaden fishery occurs along the western Gulf. The shoreline consists of salt marshes and barrier islands. The estuaries are characterized by extremely variable salinities and reduced tidal action. Eight major estuarine systems are located in the western Gulf and include the entire Texas coast. These systems contain 620,634 ha of open water and 462,267 ha of tidal flats and marshlands (GMFMC 1998). Submerged seagrass coverage is approximately 92,000 ha. Riverine influence is highest in Sabine Lake and Galveston Bay. Estuarine wetlands along the western Gulf decreased 10% between the mid 1950s and early 1960s with an estimated loss of 24,840 ha (Moulton et al. 1997).

4.4 General Conditions

Upon entering estuaries, postlarvae occupy quiet, low salinity waters from bottom depths to 6.6 feet (Fore and Baxter 1972). After transformation, most juvenile menhaden remain in nearshore estuaries until they are approximately 100 mm FL and approaching maturity (Lassuy 1983). Lewis and Roithmayr (1981) reported that some maturing juveniles emigrate with adults to offshore waters during the spawning season.

The dependency of menhaden on estuaries is apparent, although the relationship is somewhat obscure. Reintjes and Pacheco (1966) discussed the relationship and reported that the association of menhaden with estuaries for the greater part of the first year of life appears to be a consistent, if not necessary, aspect of the life cycle. Reintjes (1970) noted that the suitability of estuaries was linked to growth, survival, and abundance of menhaden, and suitability varied among estuaries and within the same estuary by year. June and Chamberlin (1959) observed that arrival in estuaries may be essential to the survival of larvae and their metamorphosis to juveniles based on food and lower salinities. Combs (1969) found that gonadogenesis occurs only in menhaden larvae that arrived in a euryhaline, littoral habitat.

Recent work by Minello and Webb (1997) demonstrated the importance of *Spartina alterniflora* saltmarsh to several species including the gulf menhaden. The authors compared the use of natural and created marsh by various estuarine organisms. Their results indicate that gulf menhaden dominated the fish samples in the spring and were associated primarily with open water, non-vegetated bottom and to a less degree with the marsh edge at salinities of 9.3 to 9.8 ‰. They were found in the same habitat in the fall but in much smaller numbers. A stepwise multiple regression indicated that depth and salinity are the critical environmental variables in predicting gulf menhaden density.

Christmas et al. (1982) used numerous variables (temperature, salinity, dissolved oxygen, marsh habitat, substrate, and water color) to evaluate certain Gulf Coast estuaries as nursery habitat for larval and juvenile gulf menhaden. They found that these factors directly influenced the availability of food and the survival of all stages, and that optimum habitat included estuaries with extensive marsh (>1,000 acres), mud substrate, and brown or green water color.

4.5 Salinity, Temperature, and Other Requirements

The value of low-salinity marsh to juvenile gulf menhaden is well known but not well documented. Only a few studies have looked at the dependence of nektonic menhaden on low salinity marshes as nursery habitat. Gunter and Shell (1958) reported young menhaden entering upper marshes with salinities around 0.9‰ at Grand Lake, part of the Mermentau River Basin, Louisiana. Copeland and Bechtel (1974) investigated the environmental parameters associated with several commercial and recreational species and reported juvenile gulf menhaden were most frequently collected in primary rivers and secondary streams at salinities ranging from 0‰-15‰. The authors point out that these low-salinity waters supported the greatest numbers of juvenile menhaden (Copeland and Bechtel 1974). Likewise, Chambers (1980) found a similar relationship between young gulf menhaden and both freshwater and low salinity, brackish areas in the upper Barataria Basin of Louisiana.

Turner (1969) collected eggs and larvae from stations off northern Florida at surface-water temperatures ranging from 11°C (February) to 18°C (March). In southern Florida, samples were taken from 16°C (January) to 23°C (March), and in Mississippi Sound temperatures ranged from 10°C (January) to 15°C (December). Eggs and larvae were collected at salinities ranging from 25‰ to 32‰ in Mississippi Sound (December) and 33‰ to 35‰ off southern Florida (January).

Larval and juvenile menhaden have been collected in Gulf estuaries at temperatures ranging from 5° to 35°C and in salinities from 0‰ to 67‰ (Table 4.1) (Christmas and Waller 1973, Perret et al. 1971, Swingle 1971). Reintjes and Pacheco (1966) cited references indicating that larval menhaden may suffer mass mortalities when water temperatures are below 3°C for several days or fall rapidly to 4.5°C.

Table 4.1. Optimum temperature and salinity conditions for the egg and larval stages based on the habitat suitability indices (HSI) for gulf menhaden (Christmas et al. 1982).

	Salinity (‰)	Temperature (°C)
eggs/yolk-sac larvae (marine)	25-36*	14-22*
feeding larvae (marine)	15-30*	15-25*
feeding larvae/juveniles (estuarine)	5-13*	5-20*

*lowest mean monthly winter value

4.6 Dissolved Oxygen (DO)

Mass mortalities that are attributed to low concentrations of DO have occurred in estuaries (Crance 1971, Christmas 1973, Etzold and Christmas 1979). Postlarvae and juveniles are frequently killed by anoxic conditions in backwaters (e.g., dead-end canals) during summer months. Hypoxic and anoxic conditions may also occur in more open estuarine areas as a result of phytoplankton blooms. In Louisiana, west of the Mississippi River delta, low DOs in near shore Gulf waters may serve to concentrate schools of gulf menhaden closer to shore as they avoid hypoxic areas known as the "dead zone" (see Section 4.7.1).

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

The general knowledge of the importance of habitat and nursery areas to the survival of many nearshore fish species is well known, although the specific interactions of various biotic and abiotic factors is less understood. A better understanding of estuarine dependent species is necessary to assess the relative importance of abiotic factors, food resources, predation, and habitat quality (Allen and Baltz 1997).

Gulf menhaden possess pelagic eggs which are buoyant. The larvae move from offshore to inshore where they spend the early part of their lives (Reid 1955). Maximum survival of larvae depends, in part, upon the availability of adequate food sources, minimal predation, and a quality habitat within the nearshore coastal waters, hence drastic changes to the estuary could significantly impact this fishery. Christmas (1973) thought that human population growth and industrial pollution exceeded the assimilative capacity of some Mississippi estuaries and was partly responsible for fish kills along its coasts. Hoss and Thayer (1993) pointed out that physical alterations to vegetated and non-vegetated estuarine habitats that either remove or modify such a habitat would have a negative impact on most life stages of the animals that utilize those habitats for feeding, growth, predator avoidance, and/or reproduction.

According to Dahl and Johnson (1991) estuarine vegetated wetlands decreased by 28,734 ha from the mid 1970s through the mid 1980s with the majority of these losses occurring in Gulf coast states. Most of this loss was due to the shifting of emergent wetlands to open saltwater bays. The most dramatic coastal wetland losses in the United States are in the northern Gulf of Mexico. This area contains 41% of the national inventory of coastal wetlands and has suffered 80% of the nation's total wetlands loss (Turner 1990, Dahl 1990). These wetlands support 28% of the national fisheries harvest, the largest fur harvest in the U.S., and the largest concentration of overwintering waterfowl in the U.S., and provide the majority of the recreational fishing landings (Turner 1990).

4.7.1 Hypoxia

Anoxic bottom conditions have not been reported for most of the eastern Gulf with the exceptions of local hypoxic events in Mobile Bay and several bay systems in Florida (Tampa, Sarasota, and Florida bays). However, extensive areas (averaging up to 1,820,000 ha between 1993 and 1997) of low DO (<2 ppm) occur in offshore Louisiana and Texas waters during the summer (Rabalais et al. 1999). Increased levels of nutrient influx from freshwater sources coupled with high summer water temperatures, strong salinity-based stratification, and periods of reduced mixing appear to contribute to what is now referred to in the popular press as "the dead zone" (Justić et al. 1993). Most life history stages of gulf menhaden, from eggs to adults, occur inshore (i.e., inshore of the 10 fathom curve) of areas where historically the hypoxic zone "sets up" by mid summer. Gulf menhaden appear to be only moderately susceptible to low DOs and probably move out of hypoxic areas, resulting in displacement rather than mortality. Preliminary analyses of menhaden logbook data suggest that during some years, exceptionally low catches of gulf menhaden off the central Louisiana coast may have been a result of hypoxic waters impinging upon nearshore waters in mid summer (Smith in press). The close association that gulf menhaden have with estuaries during the summer tends to decrease the effects these offshore hypoxic areas have on the population. Minor inshore hypoxic events have been documented in several estuaries in the Gulf of Mexico (Gunter and Lyles 1979).

4.7.2 Algal Blooms

Algal blooms are a frequent occurrence throughout most estuarine systems including those in the Gulf of Mexico. Hundreds of species of phytoplankton and cyanobacteria affect our waters every year. For example, perturbations affecting the Florida Bay, the shallow lagoon separating mainland Florida and the Florida Keys, include extensive cyanobacteria and phytoplankton (Butler et al. 1994) and the loss of sponge communities over hundreds of square kilometers (Butler et al. 1995). The causes of these environmental disturbances are not clear. A number of researchers have shown evidence that phosphorus-rich water being transported through advective processes from the Gulf of Mexico into the Florida Bay are at least partially responsible (Fourqurean et al. 1992, 1993; Lapointe et al. 1994). Alternatively, the cyanobacteria blooms may have been initiated by nutrients liberated from the decomposition of dead seagrass that have coincided with the algal blooms (Butler et al. 1995). Although the causes of the disturbances are unclear, the results of these changes to the environment have profound effects on the organisms that live there. Sponge and seagrass habitats in the Florida Bay are documented nursery and foraging grounds for shrimp, lobster, fish, sea turtles, and wading birds.

Most algal blooms are not typically toxic to marine organisms but, as illustrated above, large blooms can change the environment in such a way as to negatively impact particular organisms. There are, however, a few blooms which are very toxic to many of the organisms that come into contact with them. These events are often referred to as "red tides."

Red tide events in the Gulf of Mexico are not uncommon, particularly along Florida's west coast. Outbreaks along the western Gulf of Mexico waters off southern Texas and northern Mexico have been reported by Wilson and Ray (1956). The earliest record of a red tide event (i.e., streaks of discolored water and associated marine mortalities) in Florida go back as far as 1844 (Ingersoll 1882) and have been recorded at least 24 times from 1854 to 1971 (Steidinger et al.1973). The areas of greatest severity and frequency in Florida are from Apalachee Bay to the Florida Keys (Steidinger et al.1973).

There are 85 species of toxic algae in the world; 70% of those are dinoflagellates. Of that 70%, half occur in the Gulf of Mexico (Steidinger 1998, Steidinger et al. 1998). Algae bloom when particular chemical-physical conditions occur precisely, thus great variability exists in the frequency of occurrence, distribution, and potential impact that these blooms may have on a fishery in any given year. This additional contribution to natural mortality is difficult to quantify and perhaps impossible to predict.

In the fall and winter of 1996, an unprecedented occurrence of toxic algal blooms occurred in the northern Gulf of Mexico resulting in a significant number of finfish deaths from Texas to Florida. The best estimates indicate that three to four million finfish were killed in 1996 and 22 million in 1997 in Texas waters alone by the "red tide" and although they included several commercial species, the schooling and filter-feeding species like gulf menhaden predominated the estimates (McEachron et al. 1998). Additional fish kills were documented in other Gulf states as well. This particular algal bloom was a naturally occurring organism named *Gymnodinium breve* which is found annually in very low amounts in the Gulf. Brevetoxin is the toxic compound produced and released by red tide cells and affects finfish and other organisms at different thresholds.

Another longstanding non-toxic algal bloom, *Aureumbra lagunensis*, has occurred in Texas since 1990 and may affect larval growth and menhaden distribution due to low nutritional value and increased turbidity (Boesch et al. 1997).

There are other hazardous algal blooms including blue-green algaes, flagellates, and other dinoflagellates (Steidinger 1998). Some of these produce breve-like toxins, domoic acids, and other compounds which affect fish or organisms. Algal blooms may also affect finfish with their propensity to shade out ambient light and greatly reduce DO, thus contributing to hypoxic conditions often leading to death in fishes that are already under neurotoxic stress.

4.7.2.1 *Pfiesteria*

Although *Pfiesteria* and *Pfiesteria*-like organisms are algal blooms and belong in the previous section (Section 4.7.2), the propensity of these organisms to affect menhaden throughout the Atlantic has increased public concern and will be addressed separately here. *Pfiesteria*-like organisms have probably always occurred throughout coastal waters along the Atlantic and the Gulf of Mexico; however, the frequency, duration, and extent of the blooms depends greatly on the prevailing conditions (C. Moncreiff personal communication). These organisms occurred in very low numbers and were only detectable after extreme manipulations under laboratory conditions. Under normal environmental conditions, these *Pfiesteria*-like organisms remain undetectable and relatively benign. Although several *Pfiesteria*-like species have been isolated along the Atlantic coast of Florida and in the Gulf around Pensacola and Mobile bays (Burkholder et al. 1995), *Pfiesteria piscicida* has never been found in the Gulf.

4.7.3 El Niño and La Niña

El Niño [also referred to as El Niño Southern Oscillation (ENSO)] is a change in the eastern Pacific's atmospheric system which contributes to major changes in global weather. El Niño is characterized by a dwindling or sometimes reversal of equatorial trade winds causing unusually warm ocean temperatures along and on both sides of the equator in the central and eastern Pacific. The change in ocean temperature affects global atmosphere and causes unusual weather patterns around the world. In the southeastern United States, winter droughts are sometimes followed by summer floods. These conditions may have an impact on freshwater inflow patterns into the Gulf of Mexico and could ultimately affect menhaden distribution. In many parts of the world, fish migration has been attributed to El Niño.

The effects of La Niña are nearly opposite that of El Niño and is characterized by a warmer than normal winter in the southeast. This provides favorable conditions for a strong hurricane season. Likewise, these abnormal conditions may influence fish migration and occurrence in the Gulf of Mexico.

4.7.4 Anthropogenic Habitat Impacts

Many of the factors which impact gulf menhaden populations in the Gulf of Mexico overlap and, at times, are almost impossible to separate. In an effort to provide a broad description of the sources of present, potential, and perceived threats to habitat, this section attempts to offer a general overview of these impacts which include negative, positive, and benign habitat issues.

Estuarine-dependent species are susceptible to negative impacts on their populations because of the dynamic nature of the estuary and its close proximity to human activities. The conversion of wetland to open saltwater systems resulting from both natural and man-induced activities approximated 12% of the total estuarine and marine wetland losses from 1986 to 1997 (Dahl 2000). Louisiana marshes are disappearing at a rate of about 6,500 ha/ year (USEPA 1994). Except in terms of lost habitat, the effects of perturbations on overall estuarine productivity in the Gulf are largely undocumented. Human activities in inshore and offshore habitats of menhaden that may affect recruitment and survival of stocks include:

1) Ports and maintenance dredging for navigation projects;
2) Discharges from wastewater plants and industries;
3) Dredge and fill for land use conversion including commercial and residential development;

4) Agricultural runoff;
5) Ditching, draining, or impounding wetlands;
6) Oil spills;
7) Thermal discharges;
8) Petroleum and mineral extraction;
9) Entrainment and impingement from electrical power plants and other water-dependent industries;
10) Dams;
11) Marinas;
12) Alteration of freshwater inflows to estuaries;
13) Saltwater intrusion; and,
14) Point and nonpoint source discharges of contaminants (Lindall et al. 1979).

Erosion and subsidence also contribute to loss of coastal wetland habitats, though these processes are exacerbated by some of the above human activities.

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

The following is a partial list of some of the more important agencies and a brief description of the laws and regulations that could potentially affect gulf menhaden and their habitat. Individual Gulf States and federal agencies should be contacted for specific and up-to-date state laws and regulations, which are subject to change on a state-by-state basis.

5.1 Management Institutions

Menhaden are estuarine-dependent species that spawn in Gulf waters and move to nearshore and inshore areas in the spring. Larval and juvenile stages are completed in territorial and inland waters, and adults are found in inland waters, the territorial sea, and Gulf waters. Because of this variance in geographic range, menhaden 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 menhaden and their habitat. These may change at any time, and the individual agencies, particularly the marine fishery management agency in the individual states, should be contacted for specific, current laws and regulations.

5.1.1 Federal

Although menhaden occur in the exclusive economic zone (EEZ) of the Gulf of Mexico, they are most abundant in state waters. The commercial fishery operates primarily in state management jurisdictions. Consequently, laws and regulations of federal agencies primarily influence menhaden abundance by maintaining and enhancing habitat, preserving water quality and food supplies, and abating pollution. Federal laws may also affect regulations regarding product quality and salability of certain products.

5.1.1.1 Regional Fishery Management Councils

With the passage of the Magnuson Fishery Conservation and Management Act (MFCMA), the federal government assumed responsibility for fishery management within the 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 FMPs developed by regional fishery management councils. Each council prepares plans for each fishery requiring management within its geographical area of authority and amends such plans as necessary. Plans are implemented as federal regulation through the U.S. Department of Commerce (USDOC).

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 a).

The GMFMC has not developed nor is it considering a management plan for menhaden. Furthermore, no significant fishery for menhaden is known to exist in the EEZ of the U.S. Gulf of Mexico.

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

The Secretary of Commerce, acting through the NMFS, has the ultimate authority to approve or disapprove all FMPs prepared by regional fishery management councils. Where a council fails to develop a plan, or to correct an unacceptable plan, the Secretary may do so. The NMFS also collects data and statistics on fisheries and fishermen. It performs research and conducts management authorized by international treaties. The NMFS has the authority to enforce the Magnuson Act and the 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 menhaden in the Gulf of Mexico. It conducts some research and data collection programs and comments on all projects that affect marine fishery habitat.

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

The OCRM asserts management authority over marine fisheries through the National Marine Sanctuaries Program. Under this program, marine sanctuaries are established with specific management plans that may include restrictions on harvest and use of various marine and estuarine species. Harvest of menhaden could be directly affected by such plans.

The OCRM may influence fishery management for menhaden 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 menhaden depend.

5.1.1.4 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 menhaden harvest if implemented within a given park area.

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

The USFWS has little direct management authority over menhaden. The ability of the USFWS to affect the management of menhaden is based primarily on the Fish and Wildlife Coordination Act, under which the USFWS, 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 menhaden habitat.

Much of the coastal marsh in the Gulf of Mexico is within national wildlife refuges, and management of these areas has the potential to affect menhaden populations. In certain refuge areas, the USFWS may directly regulate fishery harvest through the National Wildlife Refuge Administration Act (Section 5.1.3.17). Special use permits may be required if commercial harvest is to be allowed in refuges.

5.1.1.6 United States Department of 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 menhaden habitat. Applications for permits to discharge pollutants into estuarine waters may be disapproved or conditioned to protect resources on which menhaden and other species rely.

5.1.1.7 United States Army Corps of Engineers (USACOE), Department of the Army

The abundance of menhaden may be influenced by the USACOE's responsibilities pursuant to Section 404 of the Clean Water Act, Section 10 of the Rivers and Harbors Act, and others. Under these laws, the USACOE issues or denies permits to individuals and other organizations for proposals to dredge, fill, and construct in wetland areas and navigable waters. The USACOE is also responsible for planning, construction, and maintenance of navigation channels and other projects in aquatic areas. Such projects could affect menhaden habitat and subsequent populations.

5.1.1.8 United States Coast Guard

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

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

5.1.1.9 The U.S. Food and Drug Administration (USFDA)

The USFDA may directly regulate the harvest and processing of menhaden by its administration of the Food, Drug, and Cosmetic Act. Also, the USFDA influences the sanitary quality of menhaden by assisting states and other entities through the Public Health Services Act.

5.1.2 Treaties and Other International Agreements

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

5.1.3 Federal Laws, Regulations, and Policies

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

5.1.3.1 Magnuson Fishery Conservation and Management Act of 1976 (MFCMA); Magnuson-Stevens Conservation and Management Act of 1996 (Mag-Stevens) and Sustainable Fisheries Act

The MFCMA mandates the preparation of FMPs for important fishery resources within the EEZ. It sets national standards to be met by such plans. Each plan attempts to define, establish, and maintain the optimum yield for a given fishery. The 1996 reauthorization of the MFCMA included three additional national standards to the original seven for fishery conservation and management, included a rewording of standard number five, and added a requirement for the description of essential fish habitat and definitions of overfishing.

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

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

5.1.3.3 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.

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

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.

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

The FDCA prohibits the sale, transfer or 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.

5.1.3.6 Clean Water Act of 1981 (CWA)

The CWA requires that an EPA approved National Pollution Discharge Elimination System (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 affect marine populations. The NMFS and USFWS are the federal trustees for living natural resources in coastal and marine areas under United States jurisdiction pursuant to the CWA.

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

Discharge of oil and oily mixtures in the navigable waters of the U.S. is governed by the FWPCA and 40 Code of Federal Regulations (CFR), Part 110. 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.

5.1.3.8 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.

5.1.3.9 Endangered Species Act of 1973 (ESA), as amended

The ESA 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 secretaries of the DOI or DOC to be critical.

5.1.3.10 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.

5.1.3.11 Fish and Wildlife Coordination Act of 1958

Under the Fish and Wildlife Coordination Act, the USFWS 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 serves to provide some 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 USFWS and NMFS, and must provide the same level of consideration to fish and wildlife resources as are afforded other factors in reaching their decisions.

5.1.3.12 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.

5.1.3.13 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.

5.1.3.14 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.

5.1.3.15 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 decomposable 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 Annex V in the United States.

5.1.3.16 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.

5.1.3.17 National Wildlife Refuge Administration Act of 1966 (16USC668dd)

This Act serves as the "organic act" for the National Wildlife Refuge System. The National Wildlife Refuge System Administration Act, as amended, consolidated the various categories of lands administered by the Secretary of the Interior through the Service into a single National Wildlife Refuge System. The act creates a refuge system for the purpose of protection and conservation of fish and wildlife, including species that are threatened with extinction, wildlife ranges, game ranges, wildlife management areas, or waterfowl production areas and ensures opportunities for compatible wildlife-dependent uses.

5.2 State Authority, Laws, Regulations, and Policies

Table 5.1 outlines the various state management institutions and authorities.

5.2.2.1 Florida Fish and Wildlife Conservation Commission

Florida Fish and Wildlife Conservation Commission (FWC)
620 South Meridian Street
Tallahassee, FL 32399
Telephone: (904) 487-0554

The agency charged with the administration, supervision, development, and conservation of fish and wildlife resources is the FWC. This commission is not subordinate to any other agency or authority of the executive branch. The administrative head of the FWC is the executive director. Within the FWC, the Florida Marine Research Institute (FMRI) 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, and Division of Marine Fisheries recommends management policies and administers various saltwater fisheries programs.

Table 5.1. State management institutions - Gulf of Mexico.

	Administrative body and its responsibilities	Administrative policy-making body and decision rule	Legislative involvement in management regulations
FLORIDA	FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION · administers management programs · enforcement · conducts research	· creates rules in conjunction with management plans · ten member commission	· responsible for setting fees, licensing, and penalties.
ALABAMA	DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES · administers management programs · enforcement · conducts research	· Commissioner of department has authority to establish management regulation · Conservation Advisory Board is a thirteen- member board and advises the commissioner · has authority to amend and promulgate regulations · authority for detailed management regulations delegated to commissioner · statutes concerned primarily with licensing	
MISSISSIPPI	MISSISSIPPI DEPARTMENT OF MARINE RESOURCES · administers management programs · conducts research · enforcement	COMMISSION ON MARINE RESOURCES · seven-member board · establishes ordinances on recommendation of executive director (MDMR)	· authority for detailed management regulations delegated to commission statutes concern licenses, taxes, and some specific fisheries laws
LOUISIANA	DEPARTMENT OF WILDLIFE AND FISHERIES · administers management programs · enforcement · conducts research · makes recommendations to legislature	WILDLIFE AND FISHERIES COMMISSION ·seven-member board establishes policies and regulations based on majority vote of a quorum (four members constitute a quorum) consistent with statutes	· detailed regulations contained in statutes · authority for detailed management regulations delegated to commission
TEXAS	PARKS AND WILDLIFE DEPARTMENT · administers management programs · enforcement · conducts research · makes recommendations to Texas Parks & Wildlife Commission (TPWC)	PARKS AND WILDLIFE COMMISSION · nine-member body · establishes regulations based on majority vote of quorum (five members constitute a quorum) · granted authority to regulate means and methods for taking, seasons, bag limits, size limits and possession	· licensing requirements and penalties are set by legislation

The FWC, a ten-member board (that will be reduced to seven as terms expire) appointed by the governor and confirmed by the senate, was created by an amendment to the state constitution, which became effective July 1, 1999. This commission was delegated rule-making authority over marine life, game, and freshwater fish in the following areas of concern: gear specification; prohibited gear; bag limits; size limits; quotas and trip limits; designation of species that may not be sold; protected species; closed areas; seasons; and quality control code enforcement.

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

5.2.1.2 Legislative Authorization

Prior to 1983, the Florida Legislature was the primary body that enacted laws regarding management of menhaden in state waters. Chapter 370 of the Florida Statutes, annotated, contains 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 Fish Commission (FMFC) and provided the commission with various duties, powers, and authorities to promulgate regulations affecting marine fisheries including menhaden. Rules of the FMFC were codified under Chapter 46, Florida Administrative Code. On July 1, 1999 the FMFC (as well as the marine resource functions in the Department of Environmental Protection) and the Game and Freshwater Fish Commission (GFC) were merged into one commission. Marine fisheries rules of the new FWC are now codified under Chapters 68B, 68C, and 68E, of the Florida Administrative Code.

5.2.1.3 Reciprocal Agreements and Limited Entry Provisions

5.2.1.3.1 Reciprocal Agreements

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

5.2.1.3.2 Limited Entry

Florida has no statutory provisions for limited entry in the menhaden fishery. The FMFC could establish provisions but cannot set fees or penalties.

5.2.1.4 Commercial Landings Data Reporting Requirements

On at least 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 FWC, FMRI, Marine Fisheries Information System.

5.2.1.5 Penalties for Violations

Penalties for violations of Florida marine laws and regulations are established in Florida Statutes, Chapter 370. Additionally, upon the arrest and conviction for violation of specified laws or regulations, a license holder is required to show just cause as to why his saltwater products license or, in some cases, the specific endorsement, should not be suspended or revoked. Major violations trigger a suspension or monetary penalty and the license holder has administrative recourse.

5.2.1.6 Annual License Fees

The following is a list of annual license fees that are current to the date of publication; however, they are subject to change at any time.

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	
· central location	25.00
· other locations	10.00
Nonresident retail seafood dealer	
· central location	200.00
· other locations	25.00
Alien retail seafood dealer	
· central location	250.00
· other locations	50.00
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

5.2.1.7 Laws and Regulations

The following is a general summary of Florida laws and regulations regarding the harvest of menhaden. They are current to the date of this publication and are subject to change at any time. The FMFC should be contacted for specific and up-to-date information.

5.2.1.7.1 Size Limits

No size limits have been promulgated for menhaden in Florida.

5.2.1.7.2 Seasons

There is no closed season for menhaden in Florida.

5.2.1.7.3 Gear Restrictions

Nonspecific gear may be regulated by mesh size and length both seasonally and in specific areas; however, these regulations are not specifically directed at the taking of menhaden for bait. Purse seines that are used in the directed menhaden fishery are regulated by region; however, in all areas within 3 miles of shore, the maximum mesh size is two inches, stretched mesh and limited to 500 ft^2. Use of gill nets or entangling nets in all marine waters is prohibited.

5.2.1.7.4 Closed Areas

In Region 1 (waters of Escambia and Santa Rosa counties landward of the Colregs Demarcation Line), if the total commercial harvest of menhaden by all gears during the period beginning on June 1 and ending on October 31 of each year is not projected to reach 1,000,000 pounds, then these waters shall be closed on November 1. If the total commercial harvest of menhaden from this area is projected to reach 3,000,000 pounds before May 31, the menhaden purse seine fishery in these waters shall be closed on the date such harvest is projected to reach that amount. Other area restrictions include: (1) no person shall fish with, set, or place any purse seine in the waters of Big Lagoon, Santa Rosa Sound, Escambia Bay north of the railroad trestle across the bay just north of the Interstate 10 bridge, Blackwater Bay north of the respective Interstate 10 bridge across the bay, or in any bayou in the inside waters of these counties, except Bayou Texan and Bayou Chico; (2) no person shall fish with, set, or place any purse seine during any weekend (between official sunset on Friday through official sunrise on the following Monday) or on any state holiday as specified in Section 110.117(1), Florida Statutes.

In Region 2 (Hernando and Pasco counties), purse seines are prohibited in inshore waters (rivers, canals, bayous, etc.) landward of the Colregs Demarcation Line. In Pinellas, Hillsborough, and Manatee counties (Region 3), purse seines are prohibited within three miles of shore (Colregs Line). In Region 4 (from the Manatee/Sarasota County line to the Collier/Monroe County line, purse seines are prohibited in all state waters (to nine nautical miles). Purse seines are also prohibited within the Everglades National Park.

5.2.1.7.5 Other Regulations

Purse seines may not be used to catch food fish other than tuna. Also, food fish may not be used for making oil, fertilizer, or compost.

In Escambia and Santa Rosa counties, purse seine boats fishing landward of the Colregs Demarcation Line must be less than 40 feet in documented length. In this area, purse seine harvest of species other than menhaden shall not exceed two percent by weight of all fish in possession, except that any fish having an established bag limit shall not be retained.

5.2.1.7.6 Historical Changes to Regulations

July 1, 1993 Florida rules to prohibit the use of purse seines in the Tampa Bay area (Pinellas, Hillsborough, and Manatee counties) inside the three mile COLREGS line. This rule repealed local purse seine gear restrictions in this area and established a maximum purse seine length of 600 yards with a maximum depth of 1,500 meshes outside the COLREGS line for this area only.

July 1, 1995 A Constitutional Amendment to limit size and type of nets used in state waters became effective. Purse seines with an area in excess of 500 ft^2 can be used outside one mile on the Atlantic coast and outside 3 miles on the Gulf coast. Additionally it prohibited the use of all gill and entangling nets in marine waters of the state of Florida.

November 12, 1997 Florida Legislature to establish a "tarp seine" pilot program and directs the MFC to set an annual (July 1 through June 30) total allowable harvest for 9 targeted baitfish species, including menhaden (2,415,000 lbs) during the three-year program. This pilot program ceased July 1, 2000.

5.2.2 Alabama

5.2.2.1 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 of 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: (a) the advertisement of the intent of the regulation, (b) a public hearing for the regulation, (c) a 35-day waiting period following the pubic hearing to address comments from the hearing, and (d) a final review of the regulation by a joint house and senate review committee.

Alabama also has the Alabama Conservation Advisory Board (ACAB) that is endowed with the responsibility to provide advice on policies 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, conducting marine biological research, and serving as the administrative arm of the commissioner with respect to marine resources. The AMRD recommends regulations to the commissioner.

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

5.2.2.2 Legislative Authorization

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

5.2.2.3 Reciprocal Agreements and Limited Entry Provisions

5.2.2.3.1 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.

5.2.2.3.2 Limited Entry

Alabama has no statutory provisions for limited entry in the menhaden fishery.

5.2.2.4 Commercial Landings Data Reporting Requirements

Alabama law requires that wholesale seafood dealers file monthly reports to the ADCNR; however, thorough records were not collected prior to 1982. Under a cooperative agreement, monthly records of sales of seafood products are now collected jointly by the NMFS and ADCNR port agents. A trip ticket program was initiated in August 2000 that will increase the detail of data collected from dealers.

5.2.2.5 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.

5.2.2.6 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 may vary based on the charge for similar fishing activities in the applicant's resident state.

Gill nets, trammel nets, seines*
0-2400 ft in length

· resident	$300.00
· nonresident	1,500.00

Purse seine	
· resident	1,500.00
· nonresident	3,000.00
Seafood dealer license**	200.00

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

5.2.2.7 Laws and Regulations

Alabama laws and regulations regarding the harvest of menhaden 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.

5.2.2.7.1 Size Limits

No size limits have been promulgated for menhaden in Alabama.

5.2.2.7.2 Seasons

Menhaden season opens the third Monday in April and extends through November 1 of each year. The Commissioner of Conservation and Natural Resources may set an additional season, after the closing date of November 1, for the taking of menhaden for bait purposes only. The additional season will remain open until a quota, set by the regulation, is reached.

5.2.2.7.3 Gear Restrictions

Menhaden are primarily caught with purse seines that are required to have a minimum mesh size of ¾" bar. The maximum length for any seine, trammel net, or gill net is 2,400 ft, except the Commissioner of Conservation and Natural Resources may set additional length for purse seines by regulation.

Gill nets and other entangling nets are sometimes used to catch menhaden for bait. Gill nets, trammel nets, and other entangling nets used in Alabama coastal waters for the taking of menhaden must have a minimum mesh size of 2½" stretched mesh.

The use of nets is prohibited in coastal rivers, bayous, creeks, and streams south of Interstate Highway 10 (with the exception of those portions of the Blakely and Apalachee Rivers south of the I-10 Causeway). The minimum mesh for nets used for the taking of menhaden in the Blakely and Apalachee Rivers south of I-10 shall be the same as previously described.

5.2.2.7.4 Closed Areas

The taking of menhaden by purse seine shall be permitted only in those waters of Mississippi Sound and the Gulf of Mexico as described below:

Mississippi Sound and the Gulf of Mexico west of a line extending from the southernmost tip of Point aux Pines to the southernmost Bayou La Batre channel marker, then to the southernmost point of the Isle aux Herbes (Coffee Island), thence eastward to the easternmost point of Marsh Island, then southward to Gulf Intracoastal Waterway Range Beacon "C," thence southward into the Gulf of Mexico for a distance of three (3) miles, except those waters lying within a radius of one (1) mile from the western point of Dauphin Island.

5.2.2.7.5 Other Restrictions

Menhaden purse seine boats may not possess more than 5% by number of species (excluding game fish) other than menhaden, herrings, and anchovies.

5.2.3 Mississippi

5.2.3.1 Mississippi Department of Marine Resources

Mississippi Department of Marine Resources (MDMR)
1141 Bayview Avenue, Suite 101
Biloxi, Mississippi 39530
Telephone: (228) 374-5000

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 MCMR consists of seven members appointed by the governor. 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 Coastal Zone Management Plan. The MCMR is charged with administration of the Mississippi Coastal Program (MCP) which requires authorization for all activities that impact coastal wetlands. The CZMP reviews activities which would potentially and cumulatively impact coastal wetlands located above tidal areas. The Executive Director of the MDMR is charged with administration of the CZMP.

5.2.3.2 Legislative Authorization

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

5.2.3.3 Reciprocal Agreements and Limited Entry Provisions

5.2.3.3.1 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.

5.2.3.3.2 Limited Entry

State Statute 49-15-16, Mississippi Code of 1972, annotated, provides that the MCMR may develop a limited entry program for all user groups.

5.2.3.4 Commercial Landings Data Reporting Requirements

Ordinance Number 9.002 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.

5.2.3.5 Penalties for Violations

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

5.2.3.6 Annual License Fees

The following is a list of license fees for activities related to the capture and processing of menhaden. They are current 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.

Menhaden boat/net	$150.00
Menhaden processor	500.00
Captain's license	10.00
Interstate commerce	20.00

5.2.3.7 Laws and Regulations

The following is a general summary of laws and regulations that affect the harvest of menhaden. 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.

5.2.3.7.1 Size Limits

There are no minimum or maximum size limits on menhaden.

5.2.3.7.2 Seasons

Menhaden season opens on the third Monday of April and closes on November 1 each year.

5.2.3.7.4 Gear Restrictions

There are no specific restrictions on gear as applied to purse seines licensed to catch menhaden. There are restrictions on other gear types (gillnets, trammel nets or other seine types) licensed to catch menhaden which include mesh size and degradability requirements for gill and trammel nets.

5.2.3.7.5 Closed Areas

Menhaden fishing is prohibited within one mile of the shoreline of Harrison and Hancock counties. Commercial fishing is prohibited in all waters north of the CSX railroad bridge. It is unlawful to catch, take or carry away any saltwater fish within 100 feet of the mouth of any river, bayou, creek, canal, stream, tributary, lake, bay, inlet, or other water source entering into areas defined as salt waters under the jurisdiction of the MCMR.

5.2.3.7.6 Other Restrictions

It is unlawful for any boat or vessel carrying or using a purse seine to have any quantity of red drum on board in Mississippi territorial waters. It is unlawful for any person, firm, or corporation using a purse seine or having a purse seine aboard a boat or vessel within Mississippi territorial waters to catch in excess of five percent by weight in any single set of the net or to possess in excess of ten percent by weight of the total catch of any of the following species: spotted seatrout, bluefish, Spanish mackerel, king mackerel, dolphin, pompano, cobia, or jack crevalle.

5.2.3.7.6 Historical Changes to Regulations

1960 - Adopted one mile restriction from shoreline in Harrison and Hancock counties.
1975 - Adopted menhaden fishing season, third Monday of April until the second Tuesday of October each year.
1993 - Adopted new menhaden fishing season, third Monday of April through November 1st of each year.
2000 - Defined shoreline as that area where water contacts the land including the mainland and all offshore and barrier islands.

5.2.4 Louisiana

5.2.4.1 Louisiana Department of Wildlife and Fisheries

Louisiana Department of Wildlife and Fisheries (LDWF)
P.O. Box 98000
Baton Rouge, Louisiana 70898-9000
Telephone: (225) 765-2623

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 LWFC is a policy-making and budgetary-control board with no administrative functions. The legislature has sole authority to establish management programs and policies; however, the legislature has delegated certain authority and responsibility to the LDWF. 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 LDWF Secretary is appointed by the governor with consent of the senate.

Within the administrative system, the LDWF 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. The Coastal Management Division of the Louisiana Department of Natural Resources is the lead agency for Louisiana coastal zone management. The Federal Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) was passed in 1990. It funds wetland enhancement projects nationwide, including substantial work in Louisiana. The CWPPRA Task Force recommends projects to be funded under this initiative. The Task Force is made up of five federal agencies (Department of Agriculture, Department of Commerce, Department of Army, Department of Interior, and Environmental Protection Agency) and the State of Louisiana, represented by the Executive Assistant for Coastal Activities in the Governor's Office. Each project has a federal sponsor.

5.2.4.2 Legislative Authorization

Title 56, Louisiana Revised Statutes, contains rules and regulations that govern marine fisheries in the state.

5.2.4.3 Reciprocal Agreements and Limited Entry Provisions

5.2.4.3.1 Reciprocal Agreements

5.2.4.3.1.1 Licenses

The LWFC is authorized to enter into reciprocal fishing license agreements with the proper authorities of any other states.

5.2.4.3.1.2 Management

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.

5.2.4.3.2 Limited Entry

Louisiana law presently does not provide for limited entry.

5.2.4.4 Commercial Landings Data Reporting Requirements

R.S. 56:303.7 and 56:345 provides for mandatory reporting requirements for all fish taken or landed in Louisiana. This is the legislation for the "Trip Ticket" program. A special trip ticket has been designed and implemented for the menhaden industry and monthly reporting of landings.

5.2.4.5 Penalties for Violations

Penalties depend upon the class of violation and previous offenses. Civil penalties may be applied in certain situations.

5.2.4.6 Annual License Fees

The following is a list of annual license fees that are current to the date of publication; however, they are subject to change at any time.

Commercial fisherman license	
· resident	$ 55.00
· nonresident	460.00
· alien	920.00
Vessel license	
· resident	15.00
· nonresident	60.00
· alien	120.00
Wholesale/retail Dealer	
· resident	250.00
· nonresident	1,105.00
· alien	2,210.00
Gear license	
· resident (per net)	500.00
· nonresident (per net)	2,000.00
· alien	4,000.00

5.2.4.7 Laws and Regulations

The following is a general summary of Louisiana laws and regulations regarding the harvest of menhaden. They are current to the date of the publication and are subject to change at any time. The LDWF should be contacted for specific and up-to-date information.

5.2.4.7.1 Minimum Size

There are no minimum size restrictions on menhaden.

5.2.4.7.2 Seasons

The reduction season for landing and processing menhaden is from the third Monday in April through November 1 each year. A special season for harvest of menhaden used for bait purposes runs from the close of the regular season until December 1 and from April 1 through the beginning of the regular season or until the 3,000 mt quota is reached.

5.2.4.7.3 Gear Restrictions

Menhaden may be harvested during the regular reduction season or the special bait season with any gear specifically approved in legislative statutes. Purse seines shall have a mesh size and design such that they are not primarily used to entangle commercial-size fish by the gills or bony projections.

5.2.4.7.4 Area Restrictions

The harvest of menhaden shall be restricted to waters seaward of the inside-outside line described in R.S. 56:495 including waters in the federal EEZ and in Chandeleur and Breton Sounds as described below. All other inside waters and passes are permanently closed to menhaden fishing.

> Beginning at the most northerly point on the south side of Taylor Pass, Lat. 29°23'00"N, Long. 89°20'06"W which is on the inside-outside shrimp line as described in R.S. 56:495; thence westerly to Deep Water Point, Lat. 29°23'36"N, Long. 89°22'54"W; thence westerly to Coquille Point, Lat. 29°23'36"N, Long. 89°24'12"W; thence westerly to Raccoon Point, Lat. 29°24'06"N, Long. 89°28'10"W; thence northerly to the most northerly point of Sable Island, Lat. 29°24'54"N, Long 89°28'27"W; thence northwesterly to California Point, Lat. 29°27'33"N, Long. 89°31'18"W; thence northerly to Telegraph Point, Lat. 29°30'57"N, Long. 89°30'57"W; thence northerly to Mozambique Point, Lat. 29°37'20"N, Long. 89°29'11"W; thence northeasterly to Grace Point (red light no. 62 on the M.R.G.O.), Lat. 29°40'40"N, Long. 89°23'10"W; thence northerly to Deadman Point, Lat. 29°44'06"N, Long. 89°21'05"W; thence easterly to Point Lydia, Lat. 29°45'27"N, Long. 89°16'12"W; thence northerly to Point Comfort, Lat. 29°49'32"N, Long. 89°14'18"W;

thence northerly to the most easterly point on Mitchell Island, Lat. 29°53'42"N, Long. 89°11'50"W; thence northerly to the most easterly point on Martin Island, Lat. 29°57'30"N, Long. 89°11'05"W; thence northerly to the most easterly point on Brush Island, Lat. 30°02'42"N, Long. 89°10'06"W; thence northerly to Door Point, Lat. 30°03'45"N, Long. 89°10'08"W; thence northerly to the most easterly point on Isle Au Pitre, Lat. 30°09'27"N, Long. 89°11'02"W; thence north (grid) a distance of 19214.60 feet to a point on the Louisiana-Mississippi Lateral Boundary, Lat. 30°12'37.1781"N, Long. 89°10'57.8925"W; thence S60°20'06"E (grid) along the Louisiana-Mississippi Lateral Boundary a distance of 31555.38 feet, Lat. 30°09'57.4068"N, Long. 89°05'48.9240"W; thence S82°53'53"E (grid) continuing along the Louisiana-Mississippi Lateral Boundary a distance of 72649.38 feet, Lat. 30°08'14.1260"N, Long. 89°52'10.3224"W; thence South (grid) a distance of 32521.58 feet to the Chandeleur Light, Lat. 30°02'52"N, Long. 88°52'18"W, which is on the inside-outside shrimp line as described in R.S. 56:495; thence southeasterly along the inside-outside shrimp line as described in R.S. 56:495 to the point of beginning.

Waters on the south side of Grand Isle from Caminada Pass to Barataria Pass, in Jefferson Parish, from the southeast side of Caminada Bridge to the northwest side of Barataria Pass at Fort Livingston, extending from the beach side of Grand Isle to 500 ft beyond the shoreline into the Gulf of Mexico, are designated closed zones, and these waters are closed to the taking of fish with saltwater netting, trawls, and seines from May 1 to September 15, inclusive.

5.2.4.7.5 Other Restrictions

Anyone legally taking menhaden shall not have in their possession more than five percent, by weight, of any species of fish other than menhaden and herring-like species. Menhaden and herring-like species include those species contained within the family Clupeidae. The possession of red drum at any time is prohibited.

Special rules and regulations for menhaden bait season permit holders are:

1. Permits will not be issued for gear types which are specifically prohibited by law.
2. Possession of a permit does not exempt the bearer from laws or regulations except for those which may be specifically exempted by the permit.
3. All permits shall be applied for and/or granted from January 1 to July 31 of each year. All permits expire December 31 following the date of issuance.
4. Each applicant will be assessed an administrative fee of $50 at the time of appointment. Each applicant will be required to post a performance fee deposit - $1,000 for Louisiana residents, $4,000 for nonresidents.
5. Permit requests shall include boat name and registration, gear type(s) to be used, dealer(s) to whom the permittee will be selling the catch, and other information.

6. Information gained by the LDWF through the issuance of a permit is not privileged and will be disseminated to the public.
7. The holder of a permit shall be onboard and have the permit in possession at all times when using permitted gear.
8. No gear other than permitted gear may be onboard or in possession of permittee.
9. The permitted boat used in the program shall have a visible, distinguishing sign with the word "EXPERIMENTAL."
10. If citation(s) are issued to any permittee regarding fisheries laws or conditions regulated by the permit, all permittee's permits will be suspended. The LDWF Secretary, after review, may reinstate or revoke the permit. If found guilty by legal or civil process, the deposit is also forfeited.
11. Permits may not be issued to any applicant found guilty of a fisheries Class II violation or greater, as defined in the Laws Pertaining to Wildlife and Fisheries.
12. The LDWF reserves the right to observe the operations taking place under the permit at any time.
13. All permittees shall notify the LDWF prior to leaving port to fish under permitted conditions and immediately upon returning from a permitted trip.
14. The bearer of a permit shall report the catch and other required information within 72 hours after returning.
15. When the annual quota of 3,000 mt has been reached, or is projected to be reached, the LDWF shall close the bait menhaden season at least 72 hours after public notice. Commercial landing of bait menhaden in Louisiana regardless of where caught, is prohibited after the closure. Bait menhaden legally taken prior to the closure may be legally possessed.
16. Menhaden landed for bait during the regular season will not be considered as part of the special bait quota.

Menhaden caught in Louisiana waters cannot be transported to and processed in another state, unless that state permits menhaden caught within its waters to be transported to and processed in Louisiana. Only licensed wholesale/retail seafood dealers may transport seafood (fish) out of state.

5.2.4.7.6 Historical Changes to Regulations

Title 76

Oct 1979

LR 5:329 original 76:VII.307

- The menhaden season shall be from the third Monday in April through the Friday following the second Tuesday in October.
- It shall apply to all areas in the territorial sea outside of the inside waters line as described in 56:495 LRS 1950.
- During the open season, menhaden fishing is also permitted in Chandeleur and Breton Sounds. All other inside waters and passes are permanently closed to menhaden fishing.

Mar 1987
LR13:189
- Definition of menhaden and herring-like species as those species within the family Clupeidae, 76:VII.311.

Aug 1988
14:547 amended 76:VII.307.
- No menhaden may be landed in Louisiana ports except during the menhaden season.
- Description of Breton and Chandeleur Sounds

Jan 1993
19:58 amended 76:VII.307.C&D
- Redescribed that portion of Chandeleur and Breton Sounds open to menhaden fishing.

Sep 1993
19:1179 amended 76:VII.307.A
- Extended the closure of season through November 1.

March 1999
25:543 76:VII.357
- Shark rules do not apply to menhaden fishery.

Title 56

Act 1979 No. 593 bycatch
- Anyone fishing with a menhaden license shall not have in their possession more than five percent, by volume, of any species of fish other than menhaden, herring-like species, and mullet. The taking of mullet shall require, in addition to a menhaden license, a special permit which shall be obtained from the LDWF.

Act 1981 No. 838
- Amended Act 1979 No. 593 of bycatch, Anyone fishing with a menhaden license shall not have in their possession more than five percent, by weight, of any species of fish other than menhaden and herring like species.

Act 1981 No. 737
- Defined a purse seine.

Act 1982 No. 320 & Act 1985 No. 541
- Amended definition.

Act 1986 No. 387
- Prohibited the possession of red drum or spotted seatrout, except as provided for in 56:324.

Act 1986 No. 904

Section 1 - Purse seines/ menhaden seines: $505 for each purse seine in use.

Section 3 - Amended bycatch - Anyone legally taking menhaden shall not have in their possession more than five percent, by weight, of any species of fish other than menhaden and herring-like species.

Section 5 - Commercial provisions of Act 1986 No. 904 shall become effective for the 1987 license year.

Act 1989 No. 414, 1
- Established a special bait season for menhaden, 56:325.6.

Act 1997 No. 684
- 303.2 established License possession; menhaden.

5.2.5 Texas

5.2.5.1 Texas Parks and Wildlife Department

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

The TPWD 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 the TPWD Executive Director who serves as the chief administrative officer of the department. A Director of the Coastal Fisheries Division and a Director of the Law Enforcement Division are named by the TPWD Executive Director.

5.2.5.2 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.

5.2.5.3 Reciprocal Agreements and Limited Entry Provisions

5.2.5.3.1 Reciprocal Agreements

Texas statutory authority allows the TPWC to enter into reciprocal licensing agreements in waters that form a common boundary, i.e., the Sabine River area between Texas and Louisiana. Texas has no statutory authority to enter into reciprocal management agreements.

5.2.5.3.2 Limited Entry

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

5.2.5.4 Commercial Landings Data Reporting Requirements

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

5.2.5.5 Penalties for Violations

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

5.2.5.6 Annual License Fees

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

Menhaden fish plant	$ 150.00
Menhaden fish boat Class A	3,500.00
Menhaden fish boat Class B	50.00

5.2.5.7 Laws and Regulations

The following is a general summary of Texas laws and regulations regarding the harvest of menhaden. They are current to the date of this publication and are subject to change at any time. The TPWD should be contacted for specific and up-to-date information.

5.2.5.7.1 Size Limits

No size limits have been promulgated for menhaden in Texas.

5.2.5.7.2 Seasons

Menhaden season opens the third monday in April and extends through November 1 each year.

5.2.5.7.3 Gear Restrictions

Gill nets, trammel nets, seines, except purse seines for menhaden, and any other type of net or fish trap are prohibited in the coastal waters of Texas. Cast nets that do not exceed 14' in diameter and small mesh beach seines not exceeding 20' in length may be used for taking bait. The minimum mesh size for menhaden purse seines is 1.5" stretched mesh, excluding the bag. There are no restrictions on the length of menhaden purse seines.

5.2.5.7.3.1 Closed Areas

Menhaden may not be fished in any bay, river, or pass within 0.5 mile from shore in Gulf waters or within one mile of any jetty or pass.

5.2.5.7.3.2 Other Restrictions

Purse seines used in taking menhaden may not be used to harvest any other edible products for sale, barter, or exchange. Purse seine catches may not contain more than 5% by volume of other edible products.

5.2.5.7.3.3 Historical Changes to Regulations

Prior to 1950 (specific date unavailable)
- Commission given authority to regulate the taking of menhaden from the public water of Texas.
- A Commercial Fisherman's License and Commercial Fishing Boat License were required to take menhaden.
- The taking of menhaden was restricted to waters within the gulfward boundary lines of Jackson, Calhoun, Refugio, Aransas, San Patricio, Kleberg, Kennedy, Wallace, Jefferson and Cameron counties.
- Seines and nets could not be used in any bay, river, pass or tributary or within ½ mile offshore.
- Menhaden were required to be tagged and net size could not exceed 1-1/2 inch stretched mesh.

1951
- Authority to require permit application prior to construction and operation of menhaden plants.

1975
- Area restrictions to the taking of menhaden concerning gulfward boundary lines of counties removed.
- Boats used in taking menhaden from the public water required to have a Menhaden Boat License.

1993
- Menhaden season extended until November 1.

1997
- Menhaden Boat License changed to Class A Menhaden Boat license. Requirement for Commercial Fishing License and Commercial Boat License removed.

- Boats used in assisting licensed menhaden boats required to have a Class B Menhaden License.

5.3 Regional/Interstate

5.3.1 Gulf States Marine Fisheries Compact (P.L. 81-66)

The Gulf States Marine Fisheries Commission (GSMFC) was established by an act of Congress (P.L. 81-66) in 1949 as a compact of the five Gulf States. Its charge is

> "to promote better utilization of the fisheries, marine, shell and anadromous, of the seaboard of the Gulf of Mexico, by the development of a joint program for the promotion and protection of such fisheries and the prevention of the physical waste of the fisheries from any cause."

The GSMFC is composed of three members from each of the five Gulf States. The head of the marine resource agency of each state is an ex-officio member, the second is a member of the legislature, and the third, a citizen who shall have knowledge of and interest in marine fisheries, is appointed by the governor. The chairman, vice chairman, and second vice chairman of the GSMFC are rotated annually among the states.

The GSMFC is empowered to make recommendations to the governors and legislatures of the five Gulf States on action regarding programs helpful to the management of the fisheries. The states do not relinquish any of their rights or responsibilities in regulating their own fisheries by being members of the GSMFC.

Recommendations to the states are based on scientific studies made by experts employed by state and federal resource agencies and advice from law enforcement officials and the commercial and recreational fishing industries. The GSMFC is also authorized to consult with and advise the proper administrative agencies of the member states regarding fishery conservation problems. In addition, the GSMFC advises the U.S. Congress and may testify on legislation and marine policies that affect the Gulf States. One of the most important functions of the GSMFC is to serve as a forum for the discussion of various problems, issues and programs concerning marine management.

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

The IJF Act of 1986 established a program to promote and encourage state activities in the support of management plans and to promote and encourage management of IJF resources throughout their range. The enactment of this legislation repealed the Commercial Fisheries Research and Development Act (P.L. 88-309).

5.3.2.1 Development of Management Plans [Title III, Section 308(c)]

Through P.L. 99-659, Congress authorized the Department of Commerce to appropriate funding in support of state research and management projects that were consistent with the intent of the IJF Act. Additional funds were authorized to support the development of interstate fishery management plans by the Gulf, Atlantic, and Pacific States Marine Fisheries Commissions.

6.0 DESCRIPTION OF FISHING ACTIVITIES AFFECTING THE STOCK(S)

6.1 Reduction Fishery

6.1.1 History

The menhaden fishery of the U.S. Gulf of Mexico is almost exclusively a single species fishery for gulf menhaden, *B. patronus*. Small and relatively insignificant amounts of other menhaden species, i.e., yellowfin menhaden, *B. smithi*, or finescale menhaden, *B. gunteri*, may be incidentally harvested as these species may overlap with *B. patronus* at the extreme east and west ranges of the gulf menhaden fishery (Ahrenholz 1991). Occasionally, vessels in the menhaden fishery make directed purse-seine sets on schools of Atlantic thread herring, *Opisthonema oglinum*. This occurs primarily in the central portion of the northern Gulf of Mexico by vessels fishing from the port of Empire, Louisiana.

Although a fishery for menhaden has existed in the northern Gulf of Mexico since the late 1800s (Nicholson 1978), records of catches, the location and number of plants, and the number and types of vessels prior to World War II are fragmentary at best. Nicholson (1978) canvassed confidential company records and statistical digests on the fishery for the first half of the 1900s. He reported that one plant was known to have operated in Texas from around the turn of the century until at least 1923; another near Port St. Joe and Apalachicola, Florida, from about 1918 to 1961; and another near Pascagoula, Mississippi, from the 1930s until 1959. He suggested that annual landings between 1918-1944 ranged from about 2,000 to 12,000 mt, all from the above three states. Additionally, Frye (1999) provided some interesting accounts of plants, vessels, and company entrepreneurship in the gulf menhaden industry before World War II.

Although landings records of gulf menhaden were incomplete for a few years immediately following World War II, Nicholson (1978) documented that 103,000 mt of gulf menhaden were landed in 1948 at ports in Florida, Mississippi, Louisiana, and Texas. Chapoton (1970, 1971) reviewed the history and status of the fishery from 1946 to 1970. He cited a general trend toward greater landings over the 25-year period. This upward trend in landings continued during the 1980s culminating with six consecutive years of landings over 800,000 mt (1982 through 1987) and record landings of 982,800 mt in 1984 (Smith et al. 1987, Smith 1991).

Historically, the menhaden resource has been primarily used by the reduction industry to produce fish meal, fish oil, and fish solubles. Purse seines have been the traditional gear used for the harvest of menhaden. Fishing equipment and methods used in the menhaden purse-seine fishery have a long history and have been described by Simmons and Breuer (1950), Lee (1953), Perret (1968), Whitehurst (1973), June and Reintjes (1976), Frye (1999), and Nicholson (1978). From the mid 1800s until World War II, there were very few fundamental changes in fishing gear and techniques. After World War II, a number of important changes took place including: 1) the use of aircraft in the late 1940s to locate menhaden schools; 2) net material changed from natural to synthetic fibers making nets stronger and longer lasting; 3) hydraulic power blocks for retrieval of the net; 4) elimination of the striker boat; 5) refrigerated fish holds in the mid 1950s; 6) aluminum, diesel-powered purse (or seine) boats in the 1960s that added speed and maneuverability; 7) hydraulic davits and stern ramps to speed up launching and retrieving of purse boats; and

8) pumps to transfer the catch from the net to the carrier vessel. Some of these were pioneered in the Gulf.

After 1950, carrier vessels were constructed of steel which increased carrying capacity, speed, and operating range. Vessels generally became larger, and more comfortable living accommodations were included for the crew members. Since the mid 1980s, the menhaden industry has acquired surplus supply vessels from the petroleum industry for conversion to menhaden carrier vessels. About a dozen such vessels have been retrofitted to fish in the gulf and Atlantic menhaden fisheries.

Historically, vessels were generally owned and operated by menhaden companies, and some vessels were shifted from one state to another depending on the availability of fish during a season. Consequently, numbers of vessels landing fish in each state were not additive.

In 1940, only six menhaden vessels were reported operating in the Gulf of Mexico (Table 6.1). After World War II, the fleet grew rapidly and reached 81 vessels by 1956. During the 1960s and 1970s, fleet size fluctuated and ranged from 65 vessels in 1973 to 92 vessels in 1966 (Nicholson 1978, Smith 1991). In recent decades, fleet size peaked at 82 vessels in 1982, followed by two major "downsizings" of the carrier vessel fleet. The first occurred in 1985 when the fleet was reduced from 81 to 73 vessels (Smith 1991); the second occurred in 1991 when the fleet was reduced from 75 to 58 vessels (Vaughan et al. 1996). Since 1995, fleet size has been about 50-52 vessels. Figure 6.1 indicates the location and number of plants and vessels operating in the northern Gulf of Mexico from the late 1980s to present.

While the number of vessels in the fishery has fluctuated since the 1950s, their efficiency or ability to catch fish has steadily increased. Increased catch per vessel primarily resulted as the fleet evolved from small wooden boats (under 75 net tons) to large steel boats (over 200 net tons).

Other innovations that increased catch per vessel included the use of fish pumps in 1951 (all vessels were using fish pumps in 1962), power blocks in 1956, and refrigeration. These and other changes reduced search and loading time, decreased the amount of manual labor, and allowed vessels to range farther, stay out longer, and land more fish of a better quality.

Historically, up to 13 menhaden processing plants existed in the northern Gulf of Mexico, ranging from Apalachicola, Florida, to Sabine Pass, Texas. During the mid 1970s to the early 1980s, the number of processing plants in the Gulf was stable at eleven (Smith 1991). Two periods of corporate consolidation followed. In 1985 the number of plants fell to seven, then increased in 1989/1990 to nine. In 1991 the number of plants declined to seven, then six in 1992, then to the present number of five in 1996. Since 1996, active processing plants have been located at Moss Point, Mississippi, and Empire, Morgan City, Abbeville, and Cameron, Louisiana.

Table 6.1. Total number of purse-seine vessels and reduction plants by port, (-) indicates closure of the port (NMFS Beaufort Laboratory unpublished data).

Fishing Year	Number Reduction Vessels	Number Reduction Plants	Ports							
			A	MP	E	D	MC	IC	C	SP
1964	78	11	0	3	2	2	1	0	2	1
1965	87	13	0	3	2	3	1	1	2	1
1966	92	13	1	3	2	2	1	1	3	1
1967	85	13	0	3	2	2	1	1	3	1
1968	78	14	1	3	2	2	1	1	3	1
1969	75	13	1	3	2	1	1	1	3	1
1970	76	13	-	3	2	2	1	1	3	1
1971	85	13	-	3	2	2	1	1	3	1
1972	75	11	-	3	2	1	1	1	3	-
1973	66	10	-	2	2	1	1	1	3	-
1974	71	10	-	2	2	1	1	1	3	-
1975	78	11	-	3	2	1	1	1	3	-
1976	82	11	-	3	2	1	1	1	3	-
1977	80	11	-	3	2	1	1	1	3	-
1978	80	11	-	3	2	1	1	1	3	-
1979	78	11	-	3	2	1	1	1	3	-
1980	79	11	-	3	2	1	1	1	3	-
1981	80	11	-	3	2	1	1	1	3	-
1982	82	11	-	3	2	1	1	1	3	-
1983	81	11	-	3	2	1	1	1	3	-
1984	81	11	-	3	2	1	1	1	3	-
1985	73	7	-	2	1	1	0	1	2	-
1986	72	8	-	2	2	1	0	1	2	-
1987	75	8	-	2	2	1	0	1	2	-
1988	73	8	-	2	2	1	0	1	2	-
1989	77	9	-	2	2	1	1	1	2	-
1990	75	9	-	2	2	1	1	1	2	-
1991	58	7	-	1	2	1	1	1	1	-
1992	51	6	-	1	1	1	1	1	1	-
1993	52	6	-	1	1	1	1	1	1	-
1994	55	6	-	1	1	1	1	1	1	-
1995	52	6	-	1	1	1	1	1	1	-
1996	51	5	-	1	1	-	1	1	1	-
1997	52	5	-	1	1	-	1	1	1	-
1998	50	5	-	1	1	-	1	1	1	-

A = Apalachicola, FL: Fish Meal Co. (1966, 1968-1969)
MP = Moss Point, MS: Seacoast Products Co. (1964-1972, 1975-1984), AMPRO Fisheries, Inc. (formerly Standard Products) (1964-1990), Zapata Haynie, Inc. (1964-1993), Omega Protein (1997-)
E = Empire, LA: Empire Menhaden Company (1964-1991), Daybrook Fisheries (formerly Petrou Fisheries, Inc.) (1964-)
D = Dulac, LA: Dulac Menhaden Fisheries (1964-1968, 1970-1971), Fish Meal and Oil Co. (1964-1965), Zapata Haynie, Inc. (1965-1996)
MC = Morgan City, LA: Seacoast Products Co. (1965-1984), Gulf Protein (1989-1996), Omega Protein (1997-)
IC = Intracoastal City, LA: Seacoast Products Co. (1965-1984), Zapata Haynie, Inc. (1985-1996), Omega Protein (1997-)
C = Cameron, LA: Louisiana Menhaden Co (1964-1990), Seacoast Products Co. (1964-1984), Zapata Haynie, Inc. (1967-1996), Omega Protein (1997-)
SP = Sabine Pass, TX: Texas Menhaden Co. (1964-1971)

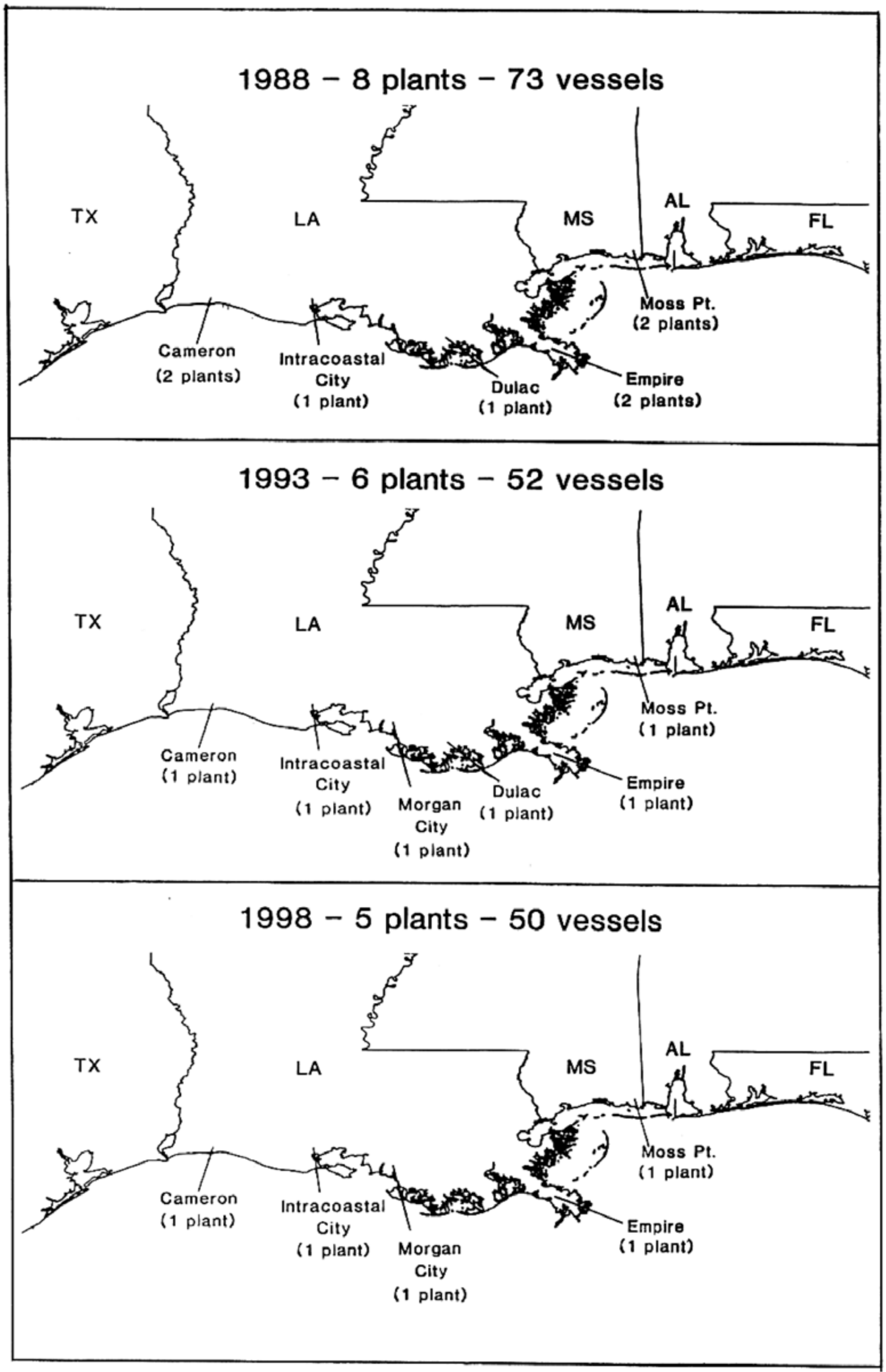


Figure 6.1. Map of northern Gulf of Mexico indicating changes in the location and number of menhaden reduction plants and number of vessels for 1988, 1993, and 1998 (NMFS, Beaufort Laboratory).

6.1.2 Fishing Methods, Gear, and Vessels

6.1.2.1 Fish Spotting Aircraft

Spotter planes are used to locate concentrations of menhaden schools. These aircraft are usually single-engine, land-based with a single, overhead wing. They are fully equipped with electronic navigation and communication systems and are capable of flying for extended periods of time without refueling. The pilots are highly skilled and experienced in identification and general behavior of menhaden schools as well as fishing procedures and can closely estimate the quantity and size of the fish in a school (based on comparisons of pilots' estimates with actual landings data). Planes are either owned or under contract by the fishing company and are based near the plants. The pilots are usually employed by the fishing company and are compensated by a salary plus bonuses based on the amount of fish landed.

During the fishing season, actual fishing operations are conducted in daylight hours during weekdays. In general, spotter pilots make reconnaissance flights on Sunday to determine the general location, movement, and size of menhaden schools. Spotter planes communicate this information to fleet captains and rendezvous at dawn with the fishing vessels for which they are spotting. The spotter pilot makes radio contact with the carrier vessels and maintains visual contact with the school or schools of menhaden. When the carrier vessel arrives in the fishing area, the spotter pilot directs it to the best available school and directs the purse boats in the setting of the purse seine. One spotter aircraft usually serves several carrier vessels.

6.1.2.2 Purse Boats

Purse boats are used to set the net on schools of menhaden. They are aluminum with an open-construction design, approximately 40 feet long and 11-12 feet wide. Purse boats are capable of speeds from five to eight knots. Two purse boats are deployed to set a net with each boat carrying half the net.

Traditionally, purse boats have been carried (supported) on davits on either side of the stern of the carrier vessel. Embarkation and disembarkation by purse boat crews can be time-consuming, especially in rough weather. A recent trend in fleet construction and renovation has been to support and carry purse boats on inclined ramps on the stern of the carrier vessels. Alternately, some vessels use pivoting davits that rest purse boats inboard on cradles. Both innovations probably expedite boarding and disembarking the purse boats, along with making the task safer for the crew. Although quantitative information is not yet available, stern ramps have probably improved fishing efficiency, that is, shortened time required to launch and retrieve purse boats, thereby increasing the number of sets in a fishing day, or being better suited to capture a school before a competing vessel.

6.1.2.3 Carrier Vessels

Menhaden carrier vessels are specialized craft that transport the catch from the fishing grounds to the reduction plants. They carry the purse seine and the two purse boats. The vessels also serve as crew quarters. A high bow, a low stern, fish holds amidships, and a tall mast with a crow's nest are common characteristics. The fish are stored below deck in central holds that are refrigerated with chilled, re-circulated seawater (RSW). The wheel house, crew quarters, and galley are usually located forward and the engine room aft. The vessels range from 140 to nearly 200 feet in length and may carry approximately 550 mt of menhaden.

6.1.2.4 Purse Seines

Purse seines used by gulf menhaden fishermen are conventional in design. The size and material may vary, but usually a seine is about 1,200 feet long, ten or more fathoms deep and made of ¾" or ⅞" bar-mesh synthetic twine. The curtain-type net is hung between lines containing surface floats, ring line, and noncorrosive purse rings. The bottom of the net is closed by drawing a line through the rings along the bottom line. This is accomplished by dropping the ends of the net overboard adjacent to a heavy lead weight or “tom” to which pulleys or blocks are attached and through which the purse line passes thereby allowing the net to be closed.

6.1.2.5 Bycatch Reduction Devices

While bycatch reduction is a major issue in many U.S. fisheries, the U.S. Gulf of Mexico menhaden industry has used bycatch reduction devices since the 1950s. Large non-target species which are netted during the menhaden fishing operation can slow the pumping and damage pumping gear; therefore, attempts are made to remove large bycatch organisms from the net prior to this process. Currently the industry employs a hose cage designed to prevent the larger fish from being drawn up into the pump system and a large fish excluder which serves to prevent the passage of larger, non-target species from entering the hold.

6.1.2.6 Fishing Operation

Carrying a crew of about 14 men (captain, mate, pilot, chief engineer, second engineer, cook, and eight fishermen), carrier vessels depart from various plants and arrive on the fishing grounds near daybreak. Up to 16 purse-seine sets may be made during a fishing day. Depending on their catch, the weather, and other factors, a vessel may make several trips during the week.

The search for menhaden is conducted by three persons, the spotter pilot, the vessel captain, and the vessel pilot. Once a "color" or "whip" is sighted indicating that a school of appropriate size is within range, the carrier vessel crew goes into action. On orders from the captain, the purse-boat crews (fishermen) rush to stations at the purse boats near the stern. The purse boats are lowered into the water and join at the stern of the carrier.

Each purse boat carries half of the purse seine as they race together toward the school of fish. Once they get close to the school, the purse boats separate and begin to "play out" or "set" the net as they proceed in a half circle around the school and meet with the school surrounded by the net. The purse line, running through the bottom rings, closes the bottom of the seine to confine the menhaden. The seine is then retrieved mechanically by the power block aboard each boat forcing the fish into a relatively small section of the net known as the "bunt."

The carrier vessel moves to the purse boats where they are secured to the port side. The fish are raised closer to the surface as the net is lifted by a large boom. The catch is then pumped across dewatering screens into the refrigerated hold through a large, flexible hose that is attached to a suction pump. The excess transport water is returned to the sea. If it appears that there will be more fish in the immediate area, the purse boats are secured to the stern of the carrier vessel and towed to an adjacent location.

Once the hold is full or the trip is otherwise completed, the carrier vessel returns to the plant where the fish are unloaded by pumps. The number of "sets" made by the vessel per day depends on the availability and size of the schools. Usually schools contain from 3 to 100 mt of menhaden.

6.1.2.7 Data Reporting

Two major fishery-dependent data sets, i.e., catch records and the Captain's Daily Fishing Reports (CDFRs), are reported by the menhaden fishing companies directly to the NMFS, while the port sampling efforts are supervised through the NMFS at dockside.

Individual company catch records (i.e., actual tallies of daily vessel unloadings of gulf menhaden) are reported directly to the NMFS on a monthly basis. Catch records are computerized and converted into metric units of weight. Monthly status reports of total gulf menhaden landings are reported by the NMFS throughout the fishing season. Catch records are also the source data base for calculating nominal fishing effort for the gulf menhaden fishery (see below). Additionally, unloadings by plant-week are used to calculate estimated numbers of fish at-age caught by the fishery, which is a key input data set for stock assessments using virtual population analyses.

The CDFR project is a joint industry, state, and federal undertaking. Data obtained from these reports provide critical information about the fishing process and the gulf menhaden resource. Through the course of each fishing day, the captain or vessel pilot of the carrier vessel completes a form with information regarding the day's set activities and catch.

The information obtained from each vessel's CDFRs include the home plant of the vessel, the date the sets were made, and the amount of time the vessel was at sea. Even for days when a vessel does not leave the dock or leaves and makes no sets, the reasons for no fishing activity are recorded on a CDFR, e.g., weather-related, mechanical problems, lack of crew, etc. Each completed set is numbered and specific information about each set is recorded: set start and finish, the estimated number of standard fish in each set, the spotter planes which assisted in the set, the location of the set, and the prevailing weather conditions during the set.

Data from the CDFRs are entered into a computerized database by the NMFS, and the season is closely monitored. These data are then used for biological analyses and assessment of the gulf menhaden stock and allow for time-dependent analyses of fishing effort in the fishery.

Port sampling efforts in the gulf menhaden fishery are supervised by the NMFS. However, in recent years due to cutbacks in the federal workforce, most gulf menhaden port agents are now contract employees through the GSMFC. Port agents acquire gulf menhaden samples at dockside, consisting of ten fish per sample. Sample fish are measured for fork length (mm), weighed (grams), and a scale patch is used to age each fish. Generally during peak fishing weeks, 10-20 samples are processed from each plant. Average lengths and weights and age proportions are calculated by the

NMFS. Along with catch records, these data form the foundation data sets for estimating number of fish at-age caught by the fishery. In turn, these data are the building blocks of virtual population analyses used in stock assessments.

6.1.3 State Reduction Fisheries

Presently, the menhaden reduction fishery is the largest fishery in the Gulf by volume (Table 6.2). Monthly catches usually peak between May and August, but the peak month varies depending on the weather and other factors that affect the availability and catchability of fish (Figure 6.2). In addition, year class strength, seasonal abundance and quality of menhaden food supply, coupled with environmental factors, further confound the spatial and temporal fluctuations in landings.

Nominal fishing effort is measured on the basis of vessel-ton-weeks. Nominal fishing effort for an individual vessel is calculated by multiplying a vessel's net tonnage by the number of weeks throughout the fishing season in which at least one landing occurred. Nominal fishing effort for the fleet is summed across all vessels. Effort statistics for 1961-1998 are shown in Table 6.2. Unfortunately, this unit of fishing effort is not useful in directly assessing fishing pressure because single and multiple landings during a given week have equal weighting. For stock assessment purposes, units of nominal effort must be converted to units of effective effort.

Historically, processing plants for the reduction fishery have been located throughout the northern Gulf from Apalachicola, Florida, to Sabine Pass, Texas. Prior to the development of refrigerated fish holds, fishing generally was limited to areas near fish plants. Modern menhaden vessels have greater range than their predecessors, yet current vessels tend to favor fishing areas adjacent or nearby their home port (cf. Smith 1999 relative to the Chesapeake Bay fleet). The present broad, geographical spacing of gulf menhaden plants tends to minimize fleet overlap on most fishing grounds, except in Breton and Chandeleur sounds of eastern Louisiana where the Empire and Moss Point fleets compete for fish.

There are five extant menhaden plants in the northern Gulf of Mexico, namely, at Moss Point, Mississippi, and Empire, Morgan City, Abbeville, and Cameron, Louisiana. As might be expected, a majority of the gulf menhaden catch occurs off the Louisiana coast, with smaller amounts harvested off Mississippi, Texas, and Alabama. Extremes of the range of the current gulf menhaden fleet are Orange Beach, Alabama, to the east and Freeport, Texas, to the west. Gulf menhaden vessels for reduction have not fished off the Florida panhandle since the early 1990s.

Table 6.2. Total Gulf of Mexico menhaden landings (all fisheries) and reduction fishery effort, 1963-1998 (NMFS unpublished data).

Year	Total Gulf Landings	Fishing Effort (1000 vessel-ton-weeks)
1963	438,939	277.3
1964	410,093	272.9
1965	463,952	335.6
1966	359,654	381.3
1967	317,555	404.7
1968	373,337	382.8
1969	523,991	411.0
1970	548,605	400.0
1971	728,868	472.9
1972	502,184	447.5
1973	486,655	426.2
1974	587,801	485.5
1975	542,940	538.0
1976	561,448	575.8
1977	447,458	532.7
1978	820,344	574.3
1979	779,383	533.9
1980	702,067	627.6
1981	552,562	623.0
1982	854,328	653.8
1983	923,571	655.8
1984	982,874	645.9
1985	883,520	560.6
1986	828,509	606.5
1987	907,109	604.2
1988	638,722	594.1
1989	519,587	555.3
1990	519,590	563.1
1991	550,718	472.3
1992	432,718	408.0
1993	551,822	455.2
1994	767,448	472.0
1995	472,039	417.0
1996	491,612	451.7
1997	621,943	430.2
1998	497,461	409.3

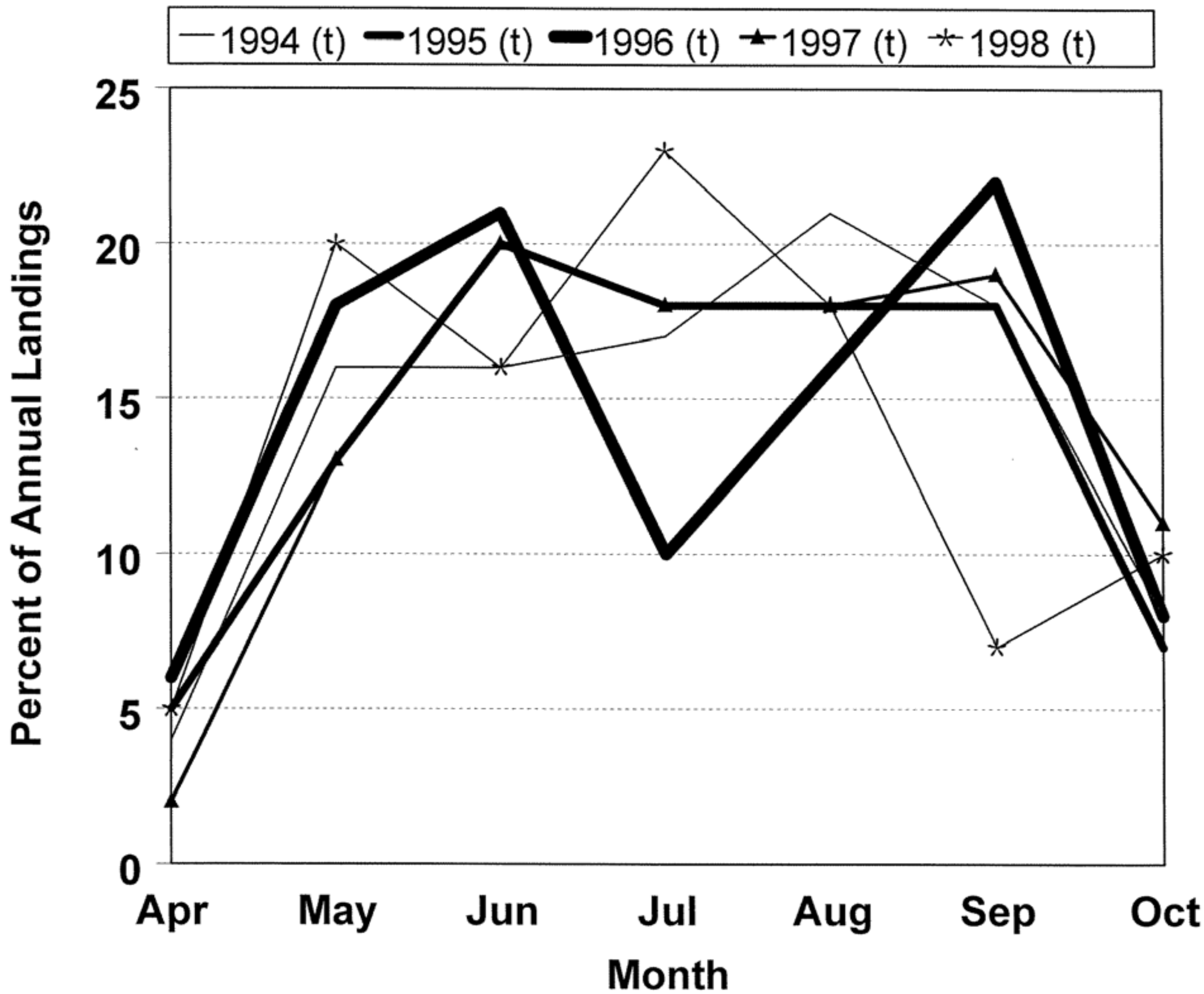


Figure 6.2. Percent of gulf menhaden reduction landings by month, 1994-1998 (NMFS, Beaufort Laboratory).

During the early 1960s when the NMFS commenced monitoring the gulf menhaden fishery, landings data for gulf menhaden (i.e., tonnage by port of landing) were readily available from menhaden company unloading records. To better understand the spatial distribution of at-sea gulf menhaden catches, the NMFS initiated a vessel logbook program. From this early logbook program, Nicholson (1978) estimated that from 1964 to 1969, 45% of the fishing sets occurred west of the Mississippi River delta, and 44% to 93% of those were made less than ten miles from shore. East of the delta, 100% of the sets were made less than ten miles from shore. He also noted that fishing west of the delta was probably "restricted to a narrower band adjacent to shore than is indicated by the data." This original logbook program was discontinued after 1969. The CDFR program was initiated in the late 1970s. Despite near 100% fleet coverage, CDFR data from the late 1970s through 1992 are available only as paper files. Several attempts were made to digitize data from certain years, but were unsuccessful.

In recent years with the advent of personal computers, the NMFS has computerized CDFR records from the 1994-1998 fishing seasons. Limited analyses of these data sets has been performed. The data sets have been most helpful in answering management-related questions about menhaden catches and fishing effort by distance from shore. Table 6.3 provides some summary statistics for the five annual CDFR data sets that have been computerized to date. Table 6.4 summarizes CDFR estimated catch of gulf menhaden (in metric tons) and effort (in number of purse-seine sets) by state by distance from shore for the 1994-1998 fishing seasons. Table 6.5 breaks down the annual menhaden catch by water body.

Table 6.3 Summary statistics for gulf menhaden CDFR data bases, 1994-1998 (NMFS unpublished data).

Year	CDFRs Processed	Vessels	Total Sets	Modal Sets/Day	Median Set Size (mt)	Mean Set Time (min)
1994	6,975	53	26,234	5	22	48
1995	6,823	50	21,264	4	17	44
1996	6,719	49	22,777	4	17	43
1997	6,712	48	23,512	5	19	44
1998	6,551	47	21,317	5	18	41
Totals	33,780		115,104			
Mean	6,756		23,021			

Although contemporary catches of gulf menhaden range from Alabama through eastern Texas, landings are restricted to Louisiana and Mississippi. Historically, the majority of menhaden landings in the Gulf occurred in Louisiana followed by Mississippi. Menhaden have not been landed for reduction in Alabama since 1931, in Texas since 1971, and in Florida since 1972. Of the total menhaden landed in the Gulf States from 1948 through 1975, 70.1% were landed in Louisiana, 22.3% in Mississippi, 7.2% in Texas, and 0.4% in Florida. From 1975 to 1987, 18% of total Gulf landings were landed in Mississippi, 37% in east Louisiana (Empire, Dulac and Morgan City), and 45% in west Louisiana (Abbeville and Cameron). Similarly, between 1988 and 1998, 16% of total annual gulf menhaden landings were made in Mississippi, 41% in east Louisiana, and 43% in west Louisiana (J. Smith personal communication).

Table 6.4. Average annual catch of gulf menhaden in metric tons (mt) by distance from shore (miles) and state, and average number of purse-seine sets by distance from nearest shore, 1994-1998, from CDFR data bases (n.b. Catch values are unadjusted captains' at-sea estimates, but are close approximations of actual catch, i.e., +/-10%; see Smith 1999).

Distance from Shore	Texas	Louisiana	Mississippi	Alabama	mt Totals	Set Totals
≤1 mi.	5,978	92,944	2,056	1,008	101,986	4,470
1.1-2 mi.	11,569	88,143	7,064	1,393	108,169	4,485
2.1-3 mi.	8,428	65,975	4,471	838	79,712	3,314
3.1-5 mi.	8,817	85,166	4,111	520	98,614	4,131
5.1-10 mi.	4,792	99,932	795	177	105,696	4,487
>10 mi.	215	41,011	23	0	41,250	1,708
mt Totals	39,799	473,171	18,520	3,936	535,426	22,595

Table 6.5 Estimates of annual catch of gulf menhaden in metric tons by water body, 1994-98, from CDFR data bases (n.b. Catch values are unadjusted captains' at-sea estimates, but are close approximations of actual catch, i.e., +/-10%; see Smith 1999).

Year	Breton Sound	Chandeleur Sound	Mississippi Sound
1994	74,287	16,214	14,115
1995	65,235	11,485	17,300
1996	74,845	13,188	20,474
1997	92,645	9,478	15,017
1998	72,358	38,129	26,311

As the gulf menhaden fishery expanded after World War II, landings ranged between 100,000 to 200,000 mt levels during most of the 1950s (Nicholson 1978). By 1959 landings reached 335,300 mt and continued to climb to 523,700 mt by 1969 (Nicholson 1978). Landings in the 1970s peaked at 820,000 mt in 1978 but fell to 552,600 mt by 1981 (Smith 1991). From 1982 through 1987, annual gulf menhaden landings were unprecedented, above the 800,000 mt level, and culminated in 1984 with record landings for the fishery of 982,800 mt (Smith 1991). Landings declined substantially through the early 1990s, falling to 421,400 mt in 1992, the least total annual landings in the fishery since 1968. Through the remainder of the 1990s, landings have fluctuated widely from 463,900 mt in 1995 to 761,600 mt in 1994.

Aside from changes in effort, variations in annual landings are primarily caused by yearly changes in environmental conditions that affect recruitment of gulf menhaden (Section 3.1.2). Favorable estuarine conditions for larval and juvenile survival and growth usually result in successful catches in the following year. Unprecedented landings above 800,000 mt for six consecutive years in the mid 1980s were in part due to exceptionally good recruitment to the fishery during the 1980s (Vaughan et al. 1996). Nevertheless, adverse meteorological events in the Gulf of Mexico do affect the amount of fishing effort expended by the gulf menhaden fleet, and hence landings (Section 6.5). The decreased landings in 1992 (421,400 mt) can be primarily attributed to poor weather early in the fishing season coupled with Hurricane Andrew late in the fishing season. These events drastically reduced fishing time and subsequent landings. Likewise in 1998, landings (486,200 mt) and fishing effort fell due to windy weather in June and five successive tropical disturbances during August and September. Additionally during the mid to late 1990s, landings were heavily influenced by both the El Niño and the La Niña weather patterns (Section 4.7.1), increasing the tropical activity (Section 6.5) in the Carribean and Gulf of Mexico and decreasing the fishing effort (Table 6.2). Other significant factors affecting landings are variations in economic conditions, markets for processed products, and the manner in which the fishery is conducted.

Prior to 1993, the reduction fishery season for gulf menhaden was 26 weeks in duration and extended from mid April through mid October. In 1993, two additional fishing weeks were added in late October; since 1993, the gulf menhaden season for reduction has been 28 weeks long. Regardless of duration, the fishing season has been consistent among Gulf States, except Florida, since about 1980. In 1994, Florida banned the use of purse seines in its state territorial waters.

The states' reduction fisheries primarily catch age-1 and age-2 gulf menhaden. Between 1980 and 1992, age-1 fish averaged 60% of the landings; age-2, 36%; and age-3 and older, approximately 4%. Age-1 fish are not heavily exploited in the eastern and western limits of the fishing grounds, but they are fully exploited in the more traditional areas of the north-central Gulf. Age-2 and older fish tend to move to the center of the traditional fishing areas (Mississippi and Louisiana) and are fully exploited (Ahrenholz 1981). Figure 6.3 also shows a somewhat cyclic variation in landings of age-1 and age-2 fish and a long-term downward trend in the catch of age-1 fish (Vaughan et al. 2000). The reasons for this cyclic trend and the long-term reduction in the percentage of age-1 fish are unknown. The cyclic trend could be related to weather patterns (Section 6.5), and Guillory et al. (1983) determined that more successful recruitment occurs following cold and dry winters. The slight downward trend in percentage of age-1 landings could be the result of long-term habitat loss (see Section 9.4).

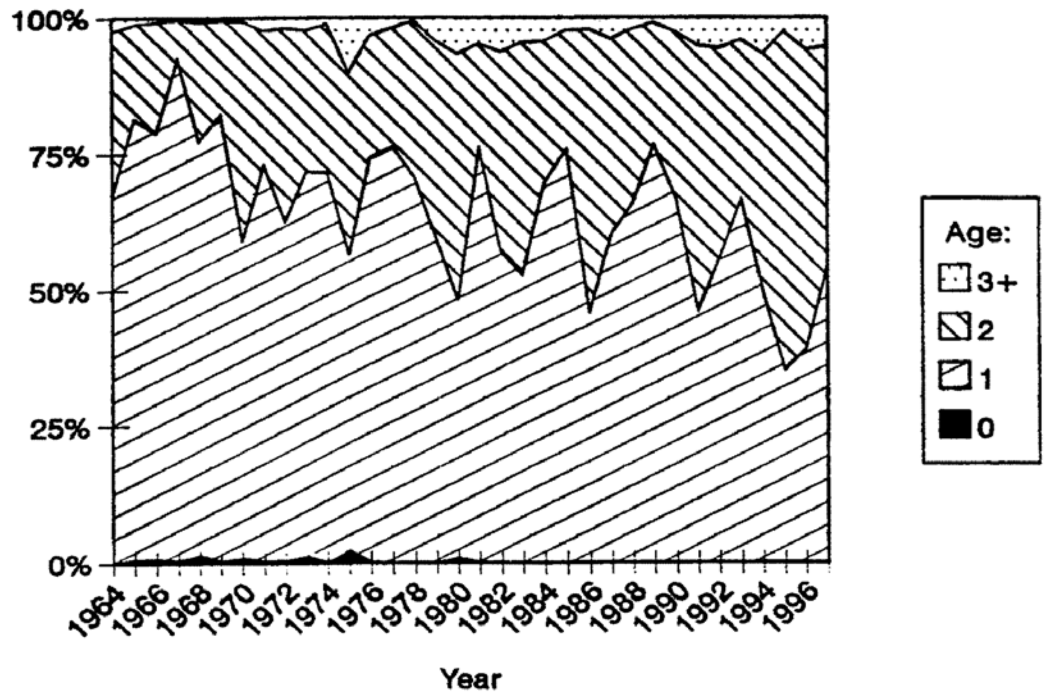


Figure 6.3. Percent of numbers for ages 1-4+ estimated from landings by the gulf menhaden (*Brevoortia patronus*) reduction fishery, 1964-1997 (Vaughan et al. 2000).

6.2 Bait Fishery

6.2.1 History

The bait fishery for menhaden has historically accounted for only a minute portion of the total landings of gulf menhaden. Until the mid 1980s, the bait fishery for menhaden occurred almost exclusively in Florida. Louisiana and Alabama began landing menhaden for bait in 1984, and Louisiana's landings increased substantially through the mid to late 1980s. Neither Mississippi nor Texas has recorded commercial bait production in recent years. Through the 1990s, two bait companies in Morgan City and Cameron, Louisiana, have been responsible for a majority of the gulf menhaden landings for bait in the central northern Gulf.

6.2.2 Fishing Methods, Gear, and Vessels

The current menhaden bait fishery is primarily conducted along the Florida Panhandle and Louisiana, although the gear used in these two areas is quite different. Historically in Florida, menhaden were primarily caught using ¾" to 1" bar purse seines 1,950 to 2,400 feet in length fished from relatively small boats (35 to 65 feet). Currently, there are approximately ten purse-seine boats operating on the west coast of Florida. After the Florida net-ban in July 1995, banning all entangling nets including purse seine in state waters, a new gear (tarp net) has been developed and used in state waters since 1997.

In Louisiana, menhaden are caught for bait generally using the same type gear, vessels, and methods as previously described for the reduction fishery. Although some bait is sold fresh at dockside, most is probably frozen and trucked throughout the Gulf region. There is little published information about the markets for gulf menhaden bait. No doubt a majority is used in the blue crab and crawfish fisheries. Smaller quantities are probably used as chum or bait by sport fishermen. In the Gulf, small amounts of menhaden are also caught with other gear, e.g., gill nets and trawls.

6.2.3 State Bait Fisheries

Table 6.6 shows menhaden commercial bait landings from 1980 through 1999 for the entire U.S. Gulf of Mexico. Further breakdown of landings by state is not possible due to the confidentiality problems in Louisiana; however, Florida and Louisiana are the major producers. Table 6.7 shows the percentage of menhaden landings for bait by region in Florida from 1986 through 1999. Menhaden bait landings declined 82% in Florida following the 1995 net ban. In 1998, menhaden landings were made by tarp net (40%), purse seine (36%), cast nets (22%), and trawls (<1%).

Table 6.6. Gulf menhaden landings for bait, 1980 to 1999 (NMFS unpublished data, ADNCR unpublished data, FWC unpublished data).

Year	**Total Gulf Landings** (mt)
1980	998.7
1981	1,074.5
1982	1,576.7
1983	1,739.2
1984	2,317.4
1985	2,997.8
1986	8,521.1
1987	17,260.7
1988	16,023.4
1989	13,503.5
1990	11,085.0
1991	8,634.9
1992	10,912.0

Year	Total Gulf Landings (mt)
1993	12,038.7
1994	9,880.1
1995	8,063.9
1996	8,963.6
1997	8,832.2
1998	9,965.3
1999	9,777.5

Table 6.7. Percentage of menhaden bait fishery landings by region, Florida west coast, 1986 through 1999 (FWC unpublished data).

Year	Sarasota-Collier	Tampa Bay	Pasco-Franklin	Gulf-Escambia	Total
1986	0.1	35.1	0.4	64.4	100
1987	0.1	38.3	0.3	61.3	100
1988	0.1	19.0	6.6	74.3	100
1989	0.3	12.7	7.1	79.9	100
1990	0.4	1.5	4.1	94.0	100
1991	2.5	14.6	6.7	76.2	100
1992	2.5	6.8	7.8	82.9	100
1993	3.0	8.0	0.2	88.9	100
1994	0.1	2.3	0.0	97.6	100
1995	0.2	23.5	10.8	65.5	100
1996	1.2	6.0	14.8	78.0	100
1997	1.1	0.1	6.6	92.2	100
1998	2.0	0.1	0.7	97.2	100
1999	0.2	0.1	4.2	95.5	100

Menhaden are caught for bait from March through December, usually within two to three miles of shore, and largest catches usually occur from April through August, similar to the reduction fishery. In 1989, however, Louisiana established a special winter season for bait production that is described in Section 5.2.4.7.2. The data on the catch in the Louisiana bait fishery is limited; however, a breakdown of the age composition of the catch is provided in Table 6.8.

Table 6.8. Summary statistics for gulf menhaden bait samples from Morgan City and Cameron, Louisiana, 1996-1998 (NMFS unpublished data).

Year	N	% Age-1	% Age-2	% Age-3	Average FL (mm)	Average weight (g)
1996	283	29	63	8	173	112
1997	43	28	67	5	174	113
1998	126	12	81	7	177	116

In 1993, Florida had four bait processors/dealers operating in the Panhandle Region. Throughout the 1990s, Louisiana only had only one or two major bait processor/dealers, although small amounts of bait have been handled by some reduction plants and a few other small companies. The number of bait operators in Alabama has ranged from six to 12 companies over the last ten years (ADCNR unpublished data).

Prior to 1986, Florida did not operate its trip ticket program, and reported landings are probably under reported (Table 6.6). Also, the strong increase in reported landings in 1986 and 1987 could be caused in part by the increased market for bait in Louisiana. When the fishery in Tampa Bay severely declined in 1988-1989, Louisiana subsequently adopted its special winter season to compensate for the loss of imported bait from Florida. Florida's contribution to the total Gulf landings of menhaden for bait has generally decreased since 1986, primarily because of the decline of this fishery in Tampa Bay.

6.3 Incidental Catch

The shrimp and industrial groundfish fisheries have been shown to have incidental catches of menhaden. Haskell (1961) noted that menhaden made up an average of 2.2% by weight of the industrial bottomfish catch in 1959; however, Roithmayer (1965) noted that few menhaden are taken by this fishery. Juhl and Drummond (1976) estimated that in the inshore shrimp fishery of Louisiana, 2,958,041 lbs or 23.7% of the total finfish discards of the shrimp fishery is menhaden. Eymard (unpublished data) estimated that, by weight, menhaden made up 16.5% of the inshore and 8.0% of the offshore finfish discards of the shrimp fleet in Louisiana in 1976. Guillory et al. (1985) examined gulf menhaden/shrimp ratios in trawls and wingnets. They found that substantial numbers of menhaden may be taken as bycatch in the inshore shrimp fishery; however, no detrimental effect on the population was postulated.

Bycatch in the gulf menhaden fishery has been documented in numerous surveys (Knapp 1950, Miles and Simmons 1950, Christmas et al. 1960, Dunham 1972, Guillory and Hutton 1982, Condrey 1994). Bycatch percentages were as follows: 0.06% to 0.14% by number (Knapp 1950, Miles and Simmons 1950); 3.90% by number and 2.80% by weight (Christmas et al. 1960); 0.05% by number in 1971 and 1.59% by weight in 1972 (Dunham 1972); 2.68% by number and 2.35% by weight (Guillory and Hutton 1982); and 1.2% by number and 1.0% by weight (Condrey 1994).

Christmas et al. (1960) collected 62 incidental fish species in the gulf menhaden fishery of Mississippi/eastern Louisiana with the following ten species in order of abundance comprising over 90% of the total bycatch: striped mullet (*Mugil cephalus*), Atlantic croaker (*Micropogonias undulatus*), spot (*Leiostomus xanthurus*), threadfin shad (*Dorosoma petenense*), gafftopsail catfish (*Bagre marinus*), hardhead catfish (*Arius felis*), sand seatrout (*Cynoscion arenarius*), harvestfish (*Peprilus alepidotus*), *Cynoscion* spp. (not *C. nebulosus*), and pinfish (*Lagodon rhomboides*). Guillory and Hutton (1982) found 35 fish species with the most abundant species of fish by number being Atlantic croaker (25.2%), sand and silver seatrout (*Cynoscion* spp.) (19.7%), threadfin shad (13.2%), Atlantic bumper (*Chloroscombrus chrysurus*) (12.6%), hardhead catfish (8.3%), and spot (5.8%). These six species comprised approximately 85% of the total weight of bycatch. Condrey (1994) found that the most important component of the bycatch was Atlantic croaker. Atlantic croaker was the most frequently encountered (30% of the sets), the most abundant (47% of the total number), and the heaviest (25% of the total weight). Atlantic croaker was followed in frequency of occurrence by Atlantic bumper (10%), silver seatrout (*Cynoscion nothus*) (9%), gafftopsail catfish (7%), sand seatrout (6%), penaeid shrimp (5%), striped mullet (4%), hardhead catfish (5%), and butterfish (*Peprilus* sp.) (3%). These nine species accounted for 78% of the cumulative frequency of occurrences. No sea turtles have been reported in Gulf bycatch studies.

In reviewing previous studies in light of their own, Guillory and Hutton (1982) proposed an east-west classification of the bycatch. They noted that the bycatch in Mississippi/eastern Louisiana is characterized by higher numbers of species and by the predominance of striped mullet and sciaenids. In western Louisiana/Texas, the bycatch is characterized by lower numbers of species and by the predominance of clupeids and Atlantic bumper. Of the top ten most numerous species encountered by Christmas et al. (1960), Guillory and Hutton (1982), and Condrey (1994), Atlantic croaker, sand and silver seatrout, and hardhead catfish were common to all three studies. Striped mullet, threadfin shad, spot, Atlantic bumper, and gafftopsail catfish were among the top ten in two of the three studies.

Ninety-three percent of the total weight of the retained bycatch was accounted for by eight species in Condrey's (1994) study. These were Atlantic croaker (25%), striped mullet (17%), gafftopsail catfish (12%), silver seatrout (10%), Spanish mackerel (*Scomberomorus maculatus*) (9%), Atlantic bumper (8%), hardhead catfish (6%), and sand seatrout (6%).

De Silva and Condrey (1998) examined the temporal and spatial patterns of bycatch species in the menhaden fishery and proposed potential bycatch "hot spots," areas in which one could predictably encounter certain bycatch organisms during certain seasons such as Atlantic croaker, sand seatrout, hardhead catfish, spotted seatrout, and bull sharks . Additional work by de Silva et al. (in press) suggests that the higher encounter rate with sharks by the menhaden fishery during certain periods is related to strong predator/prey relationship between the two. Based on the digestive state of the menhaden sampled from the sharks encountered in the study, the authors suggest that feeding on the school by sharks occurred prior to and during netting activities.

6.4 Foreign Activity

Currently, there is no foreign involvement in the menhaden fishery of the U.S. Gulf of Mexico. Additionally, no total allowable level of foreign fishing (TALFF) has been established. In the vertically integrated gulf menhaden industry, there is no proposal to deliver fish to foreign vessels.

6.5 Significant Meteorological Events Affecting the Gulf and Caribbean

Historically, the menhaden fishing season frequently reflects the tropical activities during a particular year. For example, in years of minimal tropical activity, fishing effort and landings generally increased. The opposite was true in years of high tropical activity. Landings were low in 1998 due to the high number of storms that entered the Gulf and reduced the number of fishable days. The 1998 landings in no way reflect a biological problem in the gulf menhaden population. Table 6.9 highlights the recent fishing seasons with major storms and corporate/managerial events which may have significantly affected the reported landings.

Table 6.9. Recent meteorological, corporate, and managerial events affecting landings and effort in the gulf menhaden purse-seine fishery (landings and effort are reported as X1000 mt and X1000 vessel-ton-weeks) (J. Smith personal communication).

Year	Landings	Effort	Meteorological Events	Corporate and Managerial Events
1990	528.3	563.1	Inclement weather April and May; landings in May lowest for month since 1968.	
1991	544.3	472.3	Inclement weather in April and May; combined landings through May lowest for respective months since 1968.	Industry consolidates from 75 vessels and 9 plants in 1990 to 58 vessels and 7 plants in 1991.
1992	421.4	408.0	High winds hamper fishing in April. Hurricane Andrew strikes Gulf in August.	Industry continues to consolidate; fleet reduced to 51 vessels. Plant at Dulac experiments with "West Coast" seine boats. Dulac plant closes for the season after hurricane.
1993	539.2	455.2	High winds in late April and May curtail fishing operations.	Fishing season extended two additional weeks from traditional 26-week season (ending in mid-October) to approx. 28-week season ending by November 1st.
1994	761.6	472.0	Periodic poor weather conditions regionally in the eastern Gulf in May, western Gulf in June, and throughout the Gulf in mid-October, but summer 1991 notable for lack of tropical storm activity.	
1995	463.9	417.0	Active tropical storm season in Gulf with Hurricane Allison in June, T.S. Dean and Hurricane Erin in July, and Hurricane Opal in early October.	Dulac plant closes permanently after season.
1996	479.4	451.7	Fishing season notable for lack of tropical storm activity in the Gulf, except for Hurricane Josephine in early October.	Industry operates with five factories beginning in 1996, and fleet of about 51 vessels.
1997	611.2	430.2	Weather generally favorable for fishing, except for rough seas during Hurricane Danny in July and windy conditions in late June and September.	
1998	486.2	409.3	Smoke and haze from forest fires in Mexico hamper fish-spotting efforts in western Gulf mid- to late May. Windy and wet conditions during June in western Gulf; run-off turns nearshore waters turbid making fish-spotting difficulty. Smoke from local marsh fires hamper fish-spotting activity in western Gulf during early August. Beginning in mid-August, Gulf is subjected to series of tropical storms, T.S. Earl, T.S. Frances, and T.S. Hermine, culminating with Hurricane Georges in late September.	

7.0 DESCRIPTION OF THE ECONOMIC CHARACTERISTICS, PROCESSING, MARKETING, AND ORGANIZATIONS

7.1 Reduction Fishery

Historically, the gulf menhaden reduction fishery has been very stable compared to other Gulf fisheries as measured by market structure, product exploitation levels, processing capacities, and other economic factors. There was little variation in the number of processing plants from the early 1960s until the mid 1980s, and the number of participating vessels was relatively constant through 1990. Reasons for this historical, relative stability of the industry are undoubtedly varied and complex but certainly include the high capital cost required of a new firm to enter the industry. At current prices, a modern menhaden vessel would cost in excess of two million dollars, and these vessels are specialized in nature and not easily adapted to other fisheries or even other waters because they have a somewhat shallower draft and a flatter bottom than other vessels commonly used in the Atlantic and in many other purse-seine fisheries in the world.

Processing plants are also expensive. Depending upon plant size, cost of a well-located land site and equipment choices, a processing plant built today would probably cost in the range of 10 to 15 million dollars. Additionally, environmental discharge permits may be difficult to obtain. It would take at least three vessels to supply one processing plant, and five or more vessels would be optimum. Two or more spotter aircraft would also be needed on a purchase or contract basis.

In addition to capital investments, there would be additional start-up costs related to obtaining qualified captains and crews and developing a qualified management staff and sales force. Because of the extremely high, initial capital costs and the time required to obtain and train personnel, a newly entered firm would have to be prepared for heavy losses, perhaps for a substantial period. The overall cost of new entry would probably be in the vicinity of 25 million dollars. In addition to start-up costs, a large amount of working capital would be required due to the seasonal nature of the fishery.

In recent years, a series of mergers (Zapata Protein, Gulf Protein, and AMPRO forming Omega Protein, Incorporated and later Omega Protein Corporation) has resulted in two reduction companies operating in the Gulf of Mexico; Omega Protein Corporation and Daybrook Fisheries, Incorporated. As a result of the mergers, several reduction plants were closed as the companies consolidated their assets. Since 1996, active processing plants have been located at Moss Point, Mississippi, and Empire, Morgan City, Abbeville, and Cameron, Louisiana (Figure 6.1). The Omega Protein Corporation became a publicly traded company on the New York Stock Exchange in April 1998 raising $68 million in capital (Chaillot 1999).

In summary, the economic structure of the gulf menhaden reduction industry is unlike most fisheries in the United States. There are only two firms presently in the fishery, the capital costs are larger than commonly found in other fisheries, and the industry uses advanced technology (Section 6.1.2).

7.1.1 Value and Price

7.1.1.1 Dockside

In the gulf menhaden industry, processors own their vessels and contract crews to catch fish based on agreed shared costs. Each company markets their products, and as such, the menhaden industry is vertically integrated. Since each company is using raw production landed by its own vessels, no true market price or ex-vessel price can be established. Consequently, reports of the ex-vessel value calculated by the USDOC had been used in the past to examine trends or compare relative values from year to year. Since the ex-vessel value for the reduction fishery has continued to diminish in its usefulness, only the values through 1993 are presented in Table 7.1. In addition, statistics concerning volume, value, and price of menhaden products may be misleading because production figures may be actual or in some cases estimated, and production from a given year may be stored and sold at a later time causing variation in price and value.

Table 7.1. Landings and ex-vessel value of the gulf menhaden reduction fishery, 1980-1993 (NMFS unpublished data). Ex-vessel values are not estimated for 1994-1998 due to diminished usefulness as an economic indicator in the vertically integrated reduction fishery.

Year	Landings (1000 mt)	Value (x1000)
1980	701.3	69,100
1981	552.6	47,700
1982	853.9	72,300
1983	923.5	82,500
1984	982.8	88,000
1985	881.1	67,300
1986	822.1	67,000
1987	894.2	69,900
1988	623.7	71,300
1989	569.6	52,000
1990	528.3	55,600
1991	544.3	57,700
1992	421.4	50,200
1993	539.2	57,800
1994	761.6	—

Year	Landings (1000 mt)	Value (x1000)
1995	463.9	—
1996	479.4	—
1997	611.2	—
1998	486.2	—

7.1.1.2 Products

Gulf menhaden are one of the several species of fish used to produce fish meal and oil making up 61% and 65% of the total domestic landings for reduction in 1997 and 1998, respectively (USDOC 1999). Approval by the USFDA in June 1997 of refined menhaden fish oil for general use in foods in the U.S. should open significant new markets for refined menhaden oil as an edible oil for human consumption. Refined menhaden oil is rich in Omega-3 fatty acids that research has shown to significantly reduce the incidence of heart disease, diabetes, cancer, and immune disorders. The prices for menhaden oil are significantly influenced by the supply and demand for competing products which include vegetable oils and fats. Table 7.2 lists the volume, value, and price of menhaden oil from the Gulf for the period 1962-1998. Similarly, fish meal prices are driven by the availability of soybean meal. Years with excess supplies of soybean products result in a decline in the price of menhaden products. Table 7.3 shows the production, value, and price of menhaden meal from the Gulf of Mexico for the period 1962-1998. In recent years, total domestic utilization has exceeded domestic production by the menhaden industry.

Table 7.2. Production, value, and price of menhaden oil from the Gulf of Mexico, 1962-1998. Consumer Price Index base years 1982-1984 (USDOC 1999, NMFS unpublished data).

Year	Production (lbs x1000)	Value ($ x1000)	Deflated Value ($ x1000)	Dockside Price ($/lb)	Deflated Dockside Price ($/lb)
1962	112,265	4,968	16,450	.04	.15
1963	90,747	5,331	17,422	.06	.19
1964	99,174	7,535	24,306	.08	.25
1965	116,365	9,095	28,873	.08	.25
1966	100,622	8,229	25,398	.08	.25
1967	61,612	2,996	8,970	.05	.15

Year	Production (lbs x1000)	Value ($ x1000)	Deflated Value ($ x1000)	Dockside Price ($/lb)	Deflated Dockside Price ($/lb)
1968	94,877	4,129	11,865	.04	.13
1969	120,105	6,638	18,087	.06	.15
1970	140,034	12,756	32,876	.09	.23
1971	190,688	15,024	37,096	.08	.19
1972	119,617	7,840	18,756	.07	.16
1973	158,790	17,430	39,257	.11	.25
1974	175,599	38,517	78,128	.22	.44
1975	186,000	25,816	47,985	.14	.26
1976	151,641	23,670	41,599	.16	.27
1977	82,857	18,689	30,840	.23	.37
1978	244,330	51,400	78,834	.21	.32
1979	214,334	44,781	61,682	.21	.29
1980	252,413	46,646	56,609	.18	.22
1981	133,407	24,218	26,642	.18	.20
1982	299,099	46,749	48,445	.16	.16
1983	334,572	55,345	55,567	.17	.17
1984	320,868	54,394	52,352	.17	.16
1985	241,427	35,723	33,200	.15	.14
1986	302,276	40,263	36,736	.13	.12
1987	250,745	29,321	25,811	.12	.10
1988	180,053	27,905	23,588	.15	.13
1989	185,550	19,614	15,818	.11	.09
1990	205,496	19,478	14,903	.09	.07
1991	222,624	24,763	18,181	.11	.08
1992	136,882	21,044	14,999	.15	.11

Year	Production (lbs x1000)	Value ($ x1000)	Deflated Value ($ x1000)	Dockside Price ($/lb)	Deflated Dockside Price ($/lb)
1993	219,126	30,696	21,243	.14	.10
1994	214,577	30,908	20,856	.14	.10
1995	175,159	31,496	20,667	.18	.12
1996	166,638	28,662	18,268	.17	.11
1997	209,292	39,094	24,358	.19	.12
1998	166,472	43,243	26,529	.26	.16

Table 7.3 Production, value, and price of menhaden meal from the Gulf of Mexico, 1962-1998. Consumer Price Index base years 1982-1984 (USDOC 1999, NMFS unpublished data).

Year	Production (lbs x1000)	Value ($ x1000)	Deflated Value ($ x1000)	Dockside Price ($/lb)	Deflated Dockside Price ($/lb)
1962	194,296	11,493	38,056	.06	.20
1963	182,614	11,020	36,013	.06	.20
1964	175,164	10,737	34,635	.06	.20
1965	203,940	14,952	47,467	.07	.23
1966	163,816	12,724	39,272	.08	.24
1967	144,470	9,468	28,347	.07	.20
1968	171,382	11,655	33,491	.07	.20
1969	240,882	19,888	54,191	.08	.22
1970	252,322	23,181	59,745	.09	.24
1971	330,498	26,126	64,509	.08	.20
1972	226,536	20,492	49,024	.09	.22
1973	215,340	52,025	117,173	.24	.54
1974	273,944	42,459	86,124	.15	.31

Year	Production (lbs x1000)	Value ($ x1000)	Deflated Value ($ x1000)	Dockside Price ($/lb)	Deflated Dockside Price ($/lb)
1975	256,000	30,634	56,941	.12	.22
1976	264,000	45,250	79,525	.17	.30
1977	220,000	41,827	69,021	.19	.31
1978	396,000	68,684	105,344	.17	.27
1979	376,000	70,115	96,577	.19	.26
1980	348,000	65,161	79,079	.19	.23
1981	280,000	55,268	60,801	.20	.22
1982	416,000	67,880	70,342	.16	.17
1983	440,000	76,677	76,985	.17	.17
1984	476,000	75,990	73,138	.16	.15
1985	450,000	54,048	50,230	.12	.11
1986	450,000	56,718	51,750	.13	.12
1987	399,538	85,571	75,327	.21	.19
1988	346,790	79,454	67,163	.23	.19
1989	309,204	59,903	48,309	.19	.16
1990	266,962	43,355	33,171	.16	.12
1991	292,910	54,464	39,988	.19	.14
1992	230,214	44,955	32,042	.20	.14
1993	294,548	50,807	35,161	.17	.12
1994	423,628	69,418	46,841	.16	.11
1995	259,852	48,228	31,646	.19	.13
1996	261,292	56,535	36,033	.22	.14
1997	335,122	83,671	52,131	.25	.16
1998	262,618	68,075	41,764	.26	.16

Table 7.4 lists the volume, value, and price of menhaden solubles from the Gulf for 1962-1998. These figures can be misleading because most producers add solubles back to fish meal and sell it as "whole meal," rather than liquid solubles. Consequently, the volume reported may be significantly different from the actual production. Stringent water quality regulations and discharge requirements are the main reasons for production and marketing of solubles because of their low value.

Table 7.4. Production, value, and price of menhaden solubles from the U.S. Gulf of Mexico, 1962-1998. Consumer Price Index base years 1982-1984 (USDOC 1999, NMFS unpublished data).

Year	Production (lbs x1000)	Value ($ x1000)	Deflated Value ($ x1000)	Dockside Price ($/lb)	Deflated Dockside Price ($/lb)
1962	69,832	1,751	5,798	.03	.08
1963	74,890	2,213	7,232	.03	.10
1964	68,094	2,041	6,584	.03	.10
1965	77,428	2,224	7,060	.03	.09
1966	69,894	2,043	6,306	.03	.09
1967	58,764	1,776	5,317	.03	.09
1968	60,140	1,620	4,655	.03	.08
1969	92,598	2,308	6,289	.02	.07
1970	88,546	2,163	5,575	.02	.06
1971	60,002	2,444	6,035	.04	.10
1972	96,070	1,707	4,084	.02	.04
1973	109,054	7,011	15,791	.06	.14
1974	120,184	4,807	9,751	.04	,08
1975	84,000	2,717	5,050	.03	.06
1976	88,000	4,969	8,733	.06	.10
1977	70,000	4,986	8,228	.07	.12
1978	138,000	9,814	15,052	.07	.11
1979	114,000	6,603	9,095	.06	.08

Year	Production (lbs x1000)	Value ($ x1000)	Deflated Value ($ x1000)	Dockside Price ($/lb)	Deflated Dockside Price ($/lb)
1980	80,000	3,905	4,739	.05	.06
1981	72,000	4,293	4,723	.06	.07
1982	130,000	6,760	7,005	.05	.05
1983	124,000	6,395	6,421	.05	.05
1984	65,140	7,958	7,659	.12	.12
1985	196,000	11,478	10,667	.06	.05
1986	178,000	10,687	9,751	.06	.05
1987	182,179	11,248	9,901	.06	.05
1988	103,256	8,555	7,232	.08	.07
1989	101,247	7,435	5,996	.07	.06
1990	84,307	7,079	5,416	.08	.06
1991	108,140	7,867	5,776	.07	.05
1992	74,787	6,987	4,980	.09	.07
1993	102,384	8,396	5,810	.08	.06
1994	132,793	13,352	9,009	.11	.07
1995	57,309	5,387	3,535	.09	.06
1996	62,937	4,594	2,928	.07	.05
1997	100,896	8,200	5,109	.08	.05
1998	31,255	3,245	1,991	.10	.06

The market factors influencing price are particularly complex in the menhaden reduction fishery primarily because almost all menhaden oil is exported and competes in the international marketplace (Table 7.5). The United States exported 88% of its total production of fish oil in 1998 with four countries receiving 91% of the total exports — Netherlands, Canada, Japan, and Norway (USDOC 1999).

Table 7.5 U.S. production, exports, and imports of fish oil in lbs (x1000) for 1987-1998 (USDOC 1999).

Year	Domestic Production	Exports	Imports
1987	298,496	249,246	30,509
1988	224,733	150,002	27,667
1989	225,478	198,009	25,449
1990	281,949	236,589	36,702
1991	267,345	254,525	21,828
1992	180,899	177,446	23,772
1993	293,452	184,488	26,052
1994	291,189	242,788	40,642
1995	241,941	260,394	23,913
1996	248,399	187,294	35,622
1997	283,379	215,255	25,622
1998	223,149	196,664	24,213

7.1.2 Processing and Wholesaling

7.1.2.1 Costs

Vertical integration of the industry complicates the examination of processing costs and profitability. Processing costs are generally divided into two categories: operating costs and fixed costs. Operating costs vary while fixed costs reflect the vessels' and plants' overhead. Production of raw materials (catching menhaden), other labor, and energy costs comprise the bulk of operating costs. Individual plant costs for raw materials vary depending on vessel and aircraft costs that in turn vary because of their age and number, location and availability of fish, distance from the plant to fishing grounds, rising insurance costs, etc. It is estimated that the cost of landing menhaden as raw material to the plant is about two-thirds of the total cost of the processed products. Of the remaining one-third, labor and energy are the most significant contributors.

Fixed costs are commonly referred to as overhead and are incurred to maintain the plant irrespective of actual production levels. The seasonal nature of the fishery causes fixed processing costs to be quite high. Plants must be maintained in the off-season when no processing occurs. Also, plants must be capable of handling a large daily catch; consequently, variations in catches from day-to-day often cause plants to operate below full capacity. The combination of these factors causes a high fixed cost per unit of product. In the last ten years, the increase in processing units, mostly energy related, has been significant while the real price for the product has dropped. This has placed the gulf menhaden industry in a cost-price squeeze.

As previously discussed, the number of menhaden processing plants operating in the Gulf of Mexico has fallen dramatically with only four plants currently (FY2000) working. A major reason for the decrease is rising costs of operation that have forced the industry to become more efficient in order to remain competitive and profitable.

7.1.2.2 Operation

At the dock, whole menhaden are unloaded by pumps from the hold of the carrier vessel and conveyed to a continuous-process, steam cooker. Cooking coagulates the protein and releases bound oil and water from the flesh. The mass of solids and liquids is firm enough to withstand high pressurization as it is conveyed through a continuous press. This operation squeezes oil and water containing dissolved and suspended solids from the mass leaving a damp intermediate known as "press cake" which is conveyed to continuous-process driers. The resulting product (fish scrap) is then milled into meal and treated with an antioxidant that helps the meal maintain its protein and energy qualities during storage and shipment.

The oil and water phase, "press liquor," is pumped through screens and decanters to remove suspended solids that are later returned to the "press cake." The semiclarified liquor is then separated into the oil and water components by continuous-process centrifuges. The oil undergoes a final centrifuging to remove practically all water and impurities before shipment.

The combination of water and dissolved solids separated from the oil by centrifugation is called "stickwater." At most processing plants, the "stickwater" is partially concentrated in a multi-effect evaporator, and a percentage is returned to the "press cake." When these solids are added to the "press cake" and to the resultant meal, it is then termed "whole" or "full" meal. Some "stickwater" is concentrated to a 50% solids content and brought to a pH of 4.5 to preserve nutritional qualities. This product is called condensed fish solubles.

Figure 7.1 illustrates the processing of 100 metric tons of raw menhaden. Numbers used for this figure are based on data developed from the proximate components of gulf menhaden (Dubrow et al. 1976). The numbers represent averages since proportions of water, protein, fat, and ash in raw fish vary considerably by the area that they are caught and from year-to-year and during a season. Variations in the menhaden components are primarily related to the amount of oil which in turn is related to environmental conditions and food availability.

7.1.3 Markets and Product Distribution

The wet reduction of menhaden yields the three aforementioned products: menhaden meal, menhaden oil, and menhaden solubles. Menhaden meal is a valuable ingredient in animal feeds. It contains a minimum of 60% protein with a well-balanced amino acid profile. High levels of the essential sulfur amino acids, lysine, and methionine are present. Fish meal also contains desirable levels of important minerals such as calcium metaphosphate and natural selenium.

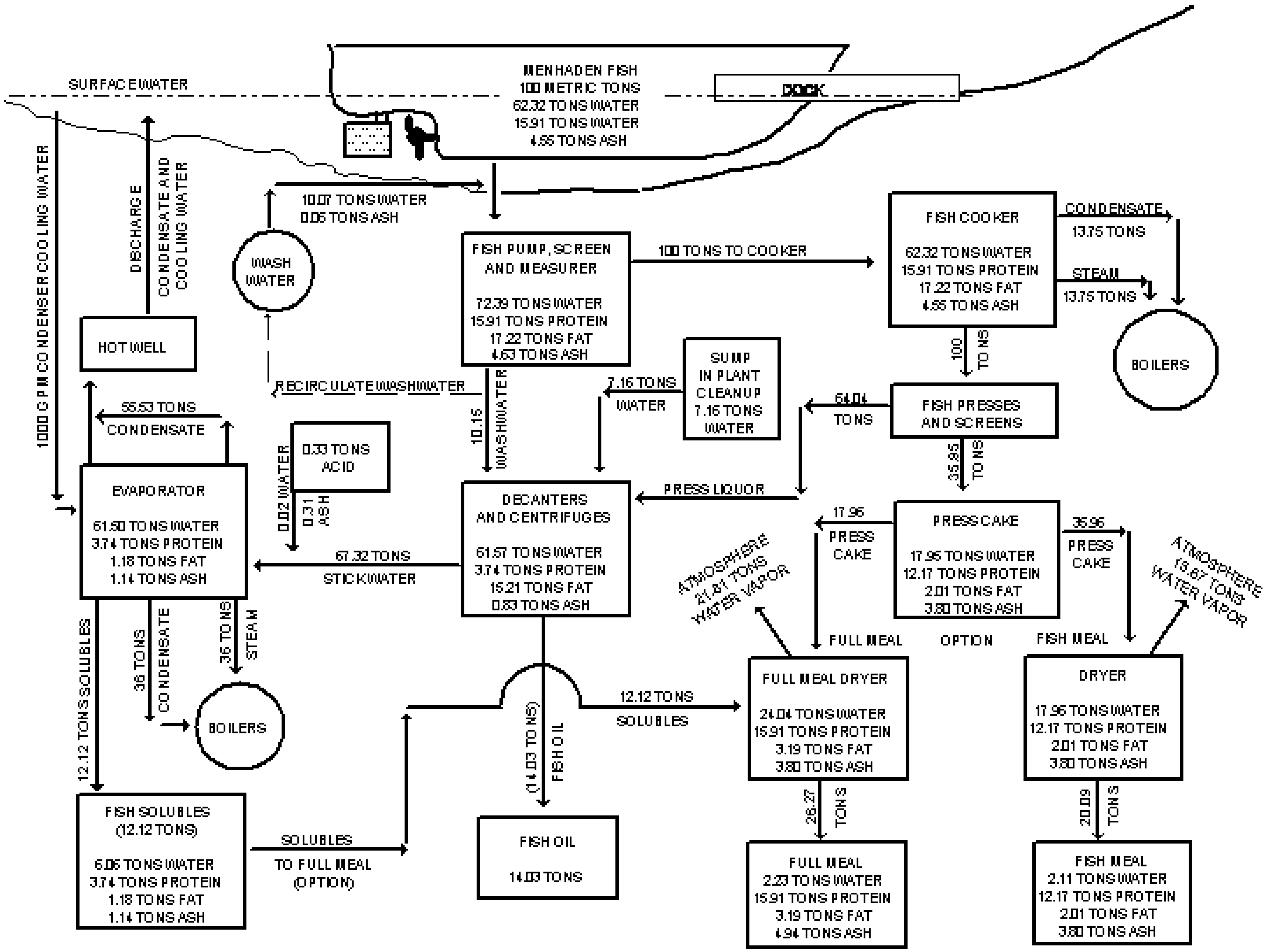


Figure 7.1. The processing of 100 metric tons of raw menhaden through a modern plant.

The poultry industry is heavily dependent on fish meal as a feed ingredient. Depending on price and availability of fish meal, poultry rations may contain up to 8% fish meal. Because of this specific use and because the large poultry producing area is located in the near-Gulf region, a large percentage of gulf menhaden meal is committed to the poultry industry.

Another valuable market for fish meal is swine feeds. Additionally, aquaculture demonstrates ever increasing demands for menhaden fish meal. Formulated feeds for catfish, trout, salmon, and shrimp may contain up to 40% fish meal.

Menhaden oil has been used for many years in edible products for human consumption in Europe and South America. The oil is refined, hydrogenated, deodorized, and then blended with other fats to make cooking oils, shortening, margarine, and other products. As mentioned previously, the approval by the USFDA in June 1997 of refined menhaden fish oil for general use in foods in the U.S. may open significant new markets for refined menhaden oil as an edible oil for human consumption.

Menhaden oil also has technical value in the U.S., and it is a component of marine lubricants and greases. Fatty acid manufacturers fractionate menhaden oil to recover the highly unsaturated fatty acids peculiar to this oil. These fatty acids are used as plasticizers for the rubber industry. Fish oil is also sold to feed manufacturers who combine it with supplemental fats for animal feeds. Menhaden oil is also used in the manufacture of alkyd resins and processed oil for the paint industry.

Menhaden solubles are a feed ingredient that has the consistency of molasses and contains about 30% protein, 10% fat, and 10% mineral. They also contain an important "unidentified growth factor." Solubles are used as a feed ingredient in the poultry and swine industries to complement or replace fish meal. A large market for menhaden solubles exists in the swine-producing midwest where solubles are dried on a carrier such as soybean meal or mill feeds. Fish solubles are combined with molasses and fortified with other soluble nutrients and used as a liquid feed supplement for cattle.

Until the end of World War II, all fish products were sold through brokers. At that time, customers for fish meal included a few, large companies that consumed large quantities each year. The feed industry, particularly the poultry feed industry, expanded rapidly in the decade following World War II. This expansion created many new but smaller feed companies throughout the Midwest as well as along the Atlantic and Gulf Coasts. Menhaden companies observed that they were using the same brokers to distribute their products to a rapidly increasing number of customers and reasoned that to fully exploit the expanding market they should have their own sales staff. Today, each menhaden company has its own sales department, and each sells to consumers or to brokers and jobbers who in turn sell to the feed industry.

Few feed mills carry more than several days supply of fish meal (or other bulk ingredients) and are dependent on the supplier and the railroads or trucking companies to deliver the material to their plant as needed. Most fish meal inventory is held in company warehouses, and sales departments direct the sale and shipment of the product. The shipments are in units of truckloads (25 tons), rail carloads (60 tons), or barges (1,400 tons). Sales contracts may be executed for a single truckload for immediate delivery, or they may call for the delivery of hundreds or thousands of tons over an extended period of time. The price may be fixed at the time of sale, or it may vary based on negotiations between the buyer and seller on the date of shipment or periodically throughout the life of the contract.

Fish oil and fish solubles are also sold in multiple units of truckload, rail carload, or bargeload quantities. A producer may sell the entire season's production of fish oil for a plant in two or three individual sales. Fish oil that is exported is transported in large quantities by ship.

Due to the past exclusion of menhaden oil from domestic edible products by the FDA, more than 90% of the total production is exported to Europe where historically fish oil has been an inexpensive source of raw material in the production of edible fats.

Traditionally, menhaden oil competed in the world markets with other fish oils; however, in recent years soybean oil and the growing use of rapeseed oil and palm oil have provided strong competition. Additionally, one major fat processor purchases 70%-75% of the total fish oil thus often controlling the prices of fish oil at that company's convenience and valuation.

Exports of fish meal from Chile, Peru, Ecuador, Denmark, Iceland, and Japan dominate world markets. Only small quantities produced by the United States are exported. The United States is generally a net importer of fish meal and demand may vary from year to year depending on price.

7.2 Bait Industry

Menhaden caught for bait have primarily been used in the blue crab, *Callinectes sapidus*, and crawfish, *Procambarus clarki*, fisheries. Smaller amounts have also been sold to recreational finfishermen (see below). Menhaden that are caught for bait in the Gulf are almost exclusively sold in the Gulf Region. In recent years, dockside prices ranged from \$0.05 to \$0.11 per pound, averaging about \$0.09 (NMFS unpublished data); while wholesale dealers received from \$0.14 to \$0.18 per pound (G. Raffield personal communication). Blue crab fishermen pay approximately \$0.25 to \$0.32 per pound for menhaden (T. Floyd personal communication). The average price/lb from 1993-1999 for each of the states landing menhaden for bait is reported in Table 7.6. The increase in price reported for Florida in 1995 and following is a direct result of the net ban which took effect mid year.

Table 7.6 Average price per pound for bait menhaden from 1993-1999 (NMFS unpublished data, ADNRC unpublished data, FWC unpublished data).

Year	Florida	Alabama	Louisiana
1993	\$0.10	\$0.09	\$0.06
1994	\$0.11	\$0.10	\$0.15
1995	\$0.12	\$0.10	\$0.25
1996	\$0.24	\$0.09	\$0.18

Year	Florida	Alabama	Louisiana
1997	$0.25	$0.09	$0.18
1998	$0.29	$0.21	$0.14
1999	$0.31	$0.08	$0.15

Whole menhaden are sold for bait in 50-100 lb boxes and packaged and frozen in five or seven pound boxes. The recreational fisheries for cobia, *Rachycentron canadum*, and snappers, *Lutjanus* spp., rely heavily on "chumming" as a technique to bring fish near the boat. Chum primarily consists of ground fish meal mixed with various grades of fish oil. The processed chum is frozen and sold in three and five pound blocks or in five gallon buckets. In addition, saltwater tournament anglers have been known to purchase high grade menhaden oil to set up slow release, drip systems likened to hospital IV bags to lure game fish near their boats (J. Franks personal communication).

7.3 Organizations

7.3.1 International

International Fish Meal and Oil Manufacturer's Association (IFOMA)
2 College Yard, Lower Dagnall Street
Saint Albans, Hertfordshire
United Kingdom AL34PE
Phone: 0727-842-844
Fax: 0727-842-866

7.3.2 National

National Fish Meal and Oil Association (NFMOA),
A Division of National Fisheries Institute
1525 Wilson Boulevard, Suite 500
Arlington, Virginia 22209
Phone: (703) 524-8884
Fax: (703) 524-4619

7.3.3 Regional

Menhaden Advisory Committee
Gulf States Marine Fisheries Commission
P.O. Box 726
Ocean Springs, Mississippi 39566-0726
Phone: (228) 875-5912
Fax: (228) 875-6604

Menhaden Advisory Council for the Gulf of Mexico
9220 W. Judge Perez Drive
Chalmette, Louisiana 70042-4519
Phone: (504) 288-8211
Fax: (504) 288-8426

8.0 SOCIAL AND CULTURAL FRAMEWORK OF FISHERMEN, PROCESSORS, AND THEIR COMMUNITIES

The menhaden fishery is unique in the Gulf of Mexico in that not only is it the largest fishery, by volume, in the Gulf, but it also has the least number of participants involved in the fishery. Unlike other traditional finfish fisheries which have harvesters who sell their catch to processors or dealers who in turn sell to third parties or directly to the public, the menhaden fishery is self contained. The companies own and man the harvesting vessels, process the catch, and distribute the product. As a result, the social makeup of the menhaden fishery has never been well studied or documented with the exception of Frye (1999) who gave a history of the menhaden fishery from the Chesapeake Bay to the Gulf of Mexico. The following text remains unchanged from the last FMP revision (Leard et al. 1995) because although brief, it does provide a good narrative of the fishery as it still exists.

The menhaden reduction fishery is one of the United States' oldest and most valuable fisheries. The industry originated about 1800 on the east coast of the United States. Later, it expanded southward along the Atlantic Coast and entered the Gulf of Mexico around 1900 in Florida moving westward thereafter. Native Indians and European immigrants along the Atlantic coast used menhaden for soil enrichment prior to the nineteenth century (Lee 1953, Whitehurst 1973); however, menhaden are no longer used for fertilizer except for special culturing.

Fishermen in the gulf menhaden reduction industry do not fit the generational natural resource community (NRC) concept proposed by Dyer et al. (1992) primarily because there are employment opportunities other than fishing in the fishing and processing communities of the Gulf. All the gulf menhaden reduction plants and home ports for vessels are in areas where competing employment alternatives exist, i.e., the offshore oil industry.

Vessel labor is almost entirely seasonal employment in the reduction industry, and numbers of crew members have been affected by increased efficiency of fishing operations over time. Crew size dropped from an average of 25 in 1960 to about 17 in 1973, 14 in 1985, and 14 in 1993. Captain/crew pay depends upon catch levels with a built-in incentive to work the entire season. Within the industry, considerable competition exists for the more highly skilled captains and crew members as this "human factor" is a large ingredient in vessel landings and corporate profitability. Employment within the processing plants is, however, fairly steady throughout the year for many workers, and approximately 50% of a processing plant's employment is year-round.

From this general description of the menhaden labor market, it is clear that the sociological and anthropological problems faced by some U.S. fisheries (McCay 1981, McCay and Acheson 1987, Acheson 1988, McGoodwin 1990) are not present in this fishery to a serious degree. Fishery management alternatives and optimum yield are not sharply limited by local labor employment traditions and/or employment of redundant fishing labor.

In 1993, the gulf menhaden reduction fishery employed 886 seasonal (April 19 through November 1) employees and 295 year-round or full-time employees for a total of 1,181 employees in the fishery.

There are no estimates of the number of jobs created by the menhaden reduction industry in service and distribution sectors; consequently, there are no current estimates of the industry's cumulative impact on local communities. Traditional and transgenerational participation in the fishery is likewise unknown, and there are no estimates of the level of entry or exit of the labor force either annually or over extended periods of time.

The menhaden bait fishery includes operations that handle bait almost exclusively and others that are primarily involved with food fish. As with the reduction fishery, there are little data on the social and anthropologic characteristics of the fishermen and processors/dealers.

9.0 MANAGEMENT CONSIDERATIONS

9.1 Definition of the Fishery

The fishery includes three species of menhaden in the U.S. Gulf of Mexico:

Gulf menhaden: *Brevoortia patronus*
Yellowfin menhaden: *Brevoortia smithi*
Finescale menhaden: *Brevoortia gunteri*

9.2 Management Unit

Because *B. patronus* is the only significant species component in the fishery and since it is biologically considered to be a unit stock in the gulf, the management unit is defined as the total population of *B. patronus* in the U.S. Gulf of Mexico.

9.3 Stock Assessment

The NMFS has maintained a sampling program from 1964 to present that provides detailed information on daily vessel landings and fish sampled for length, weight, and age (from scales). This information has been used to estimate the number of fish landed at age, 1964-1997 and to periodically assess the status of menhaden stocks in the Gulf of Mexico (Vaughan et al. 2000). The following is a summary of the current status of menhaden stocks based on various analyses by Vaughan et al. (2000).

The status of the gulf menhaden, *Brevoortia patronus*, fishery was assessed with purse-seine landings data from 1946 to 1997 and port sampling data from 1964 to 1997. These data were analyzed to determine growth rates, biological reference points for fishing mortality from yield per recruit and maximum spawning potential analyses, spawner-recruit relationships, and maximum sustainable yield (MSY). Landings and nominal effort were quite high during the 1980s, but have declined precipitously during the late 1980s and early 1990s. Landings peaked in 1984 with 982,800 mt, while nominal fishing effort peaked in 1983 with 655,800 vessel-ton-weeks. Declines in landings between 1988 and 1992 raised concerns about the status of the gulf menhaden stock, but landings have fluctuated without trend since 1992, averaging about 571,000 mt.

To calibrate the gulf menhaden virtual population analysis, we originally intended to use juvenile abundance indices obtained from Louisiana and Texas. Unfortunately, unstable results were obtained from the computer program FADAPT (Restrepo 1996), while the limited number of ages precluded use of other programs such as XSA (Darby and Flatman 1994) or ICA (Patterson and Melvin 1995). Further exploration of calibration approaches is needed. Hence, the separable virtual population approach was used for the period 1976-1997 (augmented by earlier analyses for 1964-1975) to obtain point estimates of stock size, recruits to age-1, spawning stock size, and fishing mortality rates. Exploitation rates for age-1 fish ranged between 11% and 45%, for age-2 fish between 32% and 72%, and for age-3 fish between 32% and 76%. Biological reference points from yield per recruit and spawning potential ratio were obtained for comparison with recent estimates of fishing mortality (F). Recent estimates of F (ages-1 to 4) are below $F_{0.1}$ for the range of natural mortality (M) considered in this assessment. For the preferred natural mortality value of 1.1/yr (based on tagging), mean of the estimates of F (ages-1 to 4) is 0.6/yr. This value is well below $F_{0.1}$ (2.5/yr), F_{20} (between 1.9 and 2.4/yr), and F_{30} (between 1.2 and 1.6/yr). When lower estimates of natural mortality (M) are assumed, then the estimated biological reference points decrease while estimates of fishing mortality increase. For M of 0.8/yr, recent estimates of F (mean of 0.8/yr for 1990–1997) are below estimates of $F_{0.1}$ (1.4/yr), F_{20} (1.3–1.9/yr), and F_{30} (0.8–1.2/yr). Only the biological reference point for F_{30} based on egg production is about equal to the mean F for the 1990s. The retrospective pattern observed in current-year estimates of F indicates that it takes several years of observation for estimates of F to be known with good precision, which implies that management actions based on recruitment would be made under considerable uncertainty. Recent spawning stock estimates (as biomass or eggs) are above the long-term average, while recent recruits to age-1 are comparable to the long-term average.

Parameters from Ricker-type spawner-recruit relations were estimated, although considerable variability remained unexplained. Recent survival to age-1 recruitment has generally been below that expected based on the Ricker spawner-recruit relation. Based on values of the relative survival index from the Ricker curve, recent estimates of recruits to age-1 are below what would be expected from the available spawning stock biomass. This relatively poor survival should be viewed in the context that while spawning stock biomass was generally rising from 1989 to 1997 (161,000 mt to 292,100 mt), recruits to age-1 have fluctuated without apparent trend (13 to 23 billion during the 1990s).

Estimates of long-term MSY from production models using PRODFIT and ASPIC were 717,000 mt and 753,000 mt, respectively. Landings between 1982 and 1987 were very high, exceeding estimates of long-term MSY, but were supported by generally high recruitment to age-1. More recent landings (421,400 to 761,600 mt) are comparable to, or somewhat below, recent estimates of MSY (717,000 to 753,000 mt based on the PRODFIT and ASPIC estimates). Recent estimates of relative F (F/F_{MSY}) and relative biomass (B/B_{MSY}) from the ASPIC fit to the Schaefer surplus production models suggest that recent fishing mortality is low and biomass is high relative to F_{MSY} and B_{MSY}, respectively.

In summary, gulf menhaden have higher natural mortality and are shorter lived than Atlantic menhaden, and as a result, there are rapid annual changes in the gulf menhaden fishable stock. Gulf menhaden are highly fecund. Thus, variation in recruitment to age-1, largely mediated by environmental conditions, influences fishing success over the next two years (as age-1 and 2 fish). Comparisons of recent estimates of fishing mortality to biological reference points do not suggest overfishing. The gulf menhaden stock appears reasonably stable in view of the age composition, life span, and effects of environmental factors. Annual production, fishing effort, and fleet size appear reasonably balanced and risk of overfishing low with 1997-1998 fleet size and recent mean recruitment. Given the variability in the data and model estimates, recent landings below long-term MSY (and well below high landings of the mid 1980s) suggest that the stock is reasonably stable.

9.4 Problems in the Fishery

9.4.1 Habitat Problems

Because menhaden are short-lived and occupy a low trophic level in the food web, their abundance and the subsequent fishery are highly sensitive to habitat changes. Both short-term and long-term changes can drastically affect populations. Habitat alterations over the life of the fishery have probably had an overall negative impact; however, they have not been quantified. Habitat losses have resulted from both natural and man-induced forces; however, alterations by humans have posed the greatest threat to the menhaden industry. Natural wetland losses have been caused by hurricanes, erosion, sea level rises, subsidence, and accretion, although some human activities have accelerated or exacerbated the effects of some of these factors. The major man-induced activities that have impacted environmental gradients in the estuarine zone are:

1) Construction and maintenance of navigation channels;
2) Construction of dams, marinas, and levees;
3) Dredging and filling activities;
4) Ditching, draining, or impounding wetlands;
5) Other alterations of freshwater inflows to estuaries;
6) Discharges from wastewater plants and other industries;
7) Oil and gas production;
8) Thermal discharges;
9) Agricultural operations;
10) Mining activities other than for oil and gas; and
11) Nonpoint source discharges of contaminants.

Alterations have occurred in both the offshore adult habitat and the estuarine nursery habitat. The primary threat to offshore habitat has come from oil and gas development and production, offshore dumping of dredged material, disposal of chemical wastes, and the discharge of contaminants by river systems such as the Mississippi River. On the continental shelf off Louisiana, these activities and perhaps other factors have combined to produce the largest, most persistent zone of hypoxia (dissolved oxygen levels <2 mg/l) in the U.S. (Section 4.7.1). Hypoxic conditions have been recorded from April to October, 5-60 kilometers offshore and at depths of 5-60 meters.

The effects of this area on menhaden populations are unknown. Since the hypoxia occurs along the bottom and to 20 m above it, surface-dwelling menhaden should be less affected than bottom fish and invertebrates. The area has, however, generally grown larger with time and could directly affect menhaden if it moves to shallow waters or if a storm produces a turnover. Its effect on the trophic structure in the area may also be causing indirect impacts to menhaden populations.

The estuarine nursery area, mainly vegetated wetlands, is the most critical habitat for menhaden, and it appears to be the most impacted habitat. In some areas, coastal erosion from natural or man-induced activities has severely reduced the amount of vegetated wetlands. In most areas, however, wetlands have been lost as the result of the cumulative effects of various man-induced activities. Construction of navigation channels and levees has drastically changed hydrological conditions in estuaries causing reduced freshwater inflow, saltwater intrusion, modifications to current and tidal flow patterns, and alterations of detrital movement. Dredging, filling, and impoundment have caused extensive losses of wetlands. Day et al. (1990) reported that approximately 30% of the total wetland area in the Louisiana coastal zone was impounded prior to 1985, and additional areas will probably be impounded (Herke and Rogers 1989).

The extent to which each of these activities has affected wetlands varies from state-to-state and intrastate, and they have been conducted for different purposes. In Florida, activities such as dredging and filling for residential development have perhaps been most damaging. In Mississippi, Alabama, and Texas, alterations for nearshore industrial development have probably been the most significant contributors to losses. In Louisiana, all of the aforementioned activities have affected wetlands; however, construction of navigation channels and impoundments and dredging for oil and gas production have caused the greatest impacts.

Loss of wetlands, particularly marsh areas, is approaching critical proportions in Louisiana which is the largest and most critical habitat area for menhaden. The current rate of loss is approximately 35 square miles annually (May and Britsch 1987). Losses are also continuously occurring in other areas of the Gulf despite management efforts.

How and to what degree wetland losses have affected menhaden populations in the Gulf is unknown. Several studies have examined the relationship between production of estuarine species and total vegetated habitat among Gulf States (Turner 1977 and 1979, Nixon 1980, Deegan et al. 1986, Orth and Montfrans 1990). Although these studies did not specifically address menhaden, they do show positive correlations between the abundance of various estuarine-dependent species and wetland habitat. These results would suggest that losses of vegetated wetlands have probably reduced menhaden stocks in the Gulf.

In addition to loss of wetlands, alterations to salinity and temperature regimes and degradation of water quality may also adversely impact gulf menhaden in estuarine habitats. Industrial and chemical wastes from point sources and agricultural and urban runoff from non-point sources can be laden with toxic substances or nutrients. Excessive nutrient loading can cause accelerated eutrophication and hypoxia; whereas other substances may directly cause mortality. Since the menhaden fishery is not considered to be overfished at this time, habitat factors are not of major concern with regard to limitations on sustainable harvest. However, if historic coastal wetlands loss trends continue, and particularly if fishing pressure increases in future years, the importance of adequate habitat could be substantially magnified. Better understanding of the quantitative relationships between wetland habitat availability, as well as other habitat factors, and menhaden population dynamics, would improve future ability to maintain sustainable harvest of menhaden in the Gulf of Mexico.

9.4.2 Lack of Adequate Data for Predictive Modeling

Effort data from Captain's Daily Fishing Reports have been collected for many years; however, past reductions in funding for the NMFS precluded its computerization and ultimate use by scientists and the industry for modeling menhaden populations. Since 1992, the acquisition of relatively inexpensive personal computers and new software has enhanced efforts to digitize these annual data sets. Limited analyses have been performed on the 1992-1998 data bases; however, most of the pre-1992 data remain unedited. These data could help improve predictive models of catch as well as assessments of the effects of fishing on menhaden stocks.

9.4.3 Increased Costs

9.4.3.1 Insurance

Insurance costs, particularly for vessels and crew members, have increased dramatically because of claims and lawsuits from within the menhaden fishery, other fisheries, and various marine-related operations.

9.4.3.2 Inability to Secure a Qualified and Willing Labor Force

Increased transiency and the increased availability of higher paying, less laborious jobs have reduced the quality and quantity of the labor force. Increased costs have resulted as the industry experiments with new equipment and methods to operate more efficiently with fewer people. At the same time, the industry has been forced to operate with more inexperienced personnel which reduces efficiency.

9.4.4 Inability to Secure Financing

Because the industry is extremely capital intense and complex when compared to other industries, it has become increasingly difficult to secure both long- and short-term loans.

9.4.4.1 Ageing Fleet

Vessels are extremely specialized and expensive. Without long-term financing they cannot be replaced, and the industry is currently operating with an ageing, less efficient fleet that also increases operating costs.

9.4.4.2 Inefficiency of Operation

Financing is needed to develop ways to increase efficiency of operations by vessels and plants. Such funding is currently not available.

9.4.5 Unfair Competition Practices

Foreign competitors often receive support, at least in part, from government subsidies that are not available in the U.S. menhaden industry. A cheaper labor force also allows foreign companies to produce products at a lower cost. Competition in the U.S. between the menhaden industry and the soybean industry for meal markets is also biased in favor of the soybean industry. The U.S. Department of Agriculture provides certain price supports for farmers while menhaden meal is produced with no assistance.

10.0 AVAILABLE MANAGEMENT MEASURES

The menhaden fishery is perhaps the closest example of a truly cooperatively managed fishery in the Gulf. Although the reduction industry has no legal management authority, it has successfully worked with states and the NMFS to develop consistent management measures to maintain and fully utilize the menhaden stock. States, the NMFS, and the industry should continue to review their roles to maintain and perhaps expand their cooperation in management of Gulf menhaden.

The following management measures should continue to be assessed with regard to their benefit and potential use in the Gulf of Mexico menhaden fishery.

10.1 Quotas and Trip Limits

Quotas and trip limits are two management measures that have traditionally been used to control catch over a specified period. 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 identified for the entire menhaden fishery of the Gulf, for individual states, or separately for the reduction fishery and the bait fishery. Quotas could be managed through trip limits or individual quota systems, e.g., individual transferable quotas (ITQs).

10.2 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. Current gear restrictions in the menhaden fisheries of the Gulf States do not affect harvest efficiency, but they do preclude the use of certain gear in designated areas.

States could limit the length, width, and other parameters of net gear based on areas fished, the desires of users, and other criteria. States could also further restrict the use of certain gear in specific areas or during particular seasons based on stock assessment data and needs of the industry.

10.3 Area and Seasonal 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 because: there is insufficient room for net operations (rivers, bayous, and bays); sensitive habitat might be negatively impacted by commercial gear; and potential conflicts with other water-related uses, e.g., recreational boating, shipping, and other commercial and recreational fisheries. States could reevaluate their use of closed areas, to reduce conflicts among water-related users, promote water safety, and for other reasons.

Closed seasons have also been used to protect spawners and to manage the overall harvest. Closed seasons could be reevaluated either alone or in combination with closed areas to assess their effectiveness in protecting juveniles and nonspawning adults and in managing and maintaining optimum levels of harvest.

10.4 Limited Access Considerations

Limited access strategies have been employed in various fisheries of the U.S. where effort was greater than or equal to that needed to harvest available stocks and where the availability of fish was seasonal. Since the menhaden fishery in the Gulf fits these criteria, limited access strategies could be used to manage this fishery.

The Gulf States, with reduction fisheries, could evaluate limited entry strategies including but not limited to issuance of a predetermined number of licenses, special permits, and ITQs to determine their effectiveness at meeting management goals, preventing overfishing, solving problems, and their social and economic acceptability by users. The economic benefits and potential disenfranchisements would also need careful review prior to adoption of most limited access measures.

10.5 Monitoring Programs

10.5.1 Fishery-Independent Monitoring

Most fishery-independent monitoring programs involve the random 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 and the NMFS could evaluate existing studies of menhaden to determine whether they are adequate.

10.5.2 Fishery-Dependent Monitoring

The primary purpose of fishery-dependent monitoring is to gather data on catch and effort. Other biological information such as age, size-at-age, etc. are also collected. These data are critical for accurate stock assessments, and states and the NMFS could evaluate the adequacy of current fishery-dependent monitoring programs.

10.5.2.1 Catch Data

The NMFS, in cooperation with the menhaden reduction industry, conducts the main program that monitors catches of menhaden in the Gulf. Various individual programs are also utilized by the states to collect additional catch data. The NMFS and the Gulf States could review their individual efforts to determine if they are adequately obtaining the necessary information for management decisions. If they are determined to be insufficient, appropriate changes to laws, regulations, and policies could be sought.

10.5.2.2 Effort Data

Effort data is primarily gathered by the NMFS from the reduction industry, and it is currently recorded as vessel-ton-weeks. The NMFS could evaluate the effectiveness of using this criterion versus other estimates of effort (e.g., from Captain's Daily Fishing Reports) to meet management goals. If other criteria are determined to be more effective in estimating effort, the NMFS and the Gulf States could determine the need and costs versus benefits to changing the measurement of effort.

10.5.3 Habitat Monitoring

Since menhaden depend on various estuarine habitats during their early life stages, states could increase efforts to identify critical habitats and monitor potentially negative changes. States could more vehemently oppose activities that have the potential to damage or destroy critical menhaden habitats and more actively 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 menhaden habitats. The habitat management programs could also include monitoring of effluent discharges, marine debris, and other contamination.

10.6 Measures to Support Management

States and the NMFS could review the current level of management effort in conjunction with the level of support being received for management of menhaden to determine if support is adequate to meet the needs of resource management. If support is determined to be inadequate, states and the NMFS could pursue other means of funding.

11.0 MANAGEMENT RECOMMENDATIONS

- If any state fishery management agency, the NMFS, USFWS, or other agencies determine that a proposed activity will have a deleterious effect on menhaden resources, they should advise the S-FFMC MAC and utilize any and all appropriate authorities to prevent or mitigate the adverse effects of such activities.

- The NMFS should actively seek sufficient staff and funding to continue computerizing the current-year Captain's Daily Fishing Reports and to maintain this data base in a manner consistent with other fishery data collection and utilization programs. The NMFS should seek additional funding to computerize historical Captain's Daily Fishing Reports data from the late 1970s through 1993.

- The NMFS should maintain sufficient funding for port sampling programs and maintenance of their long-term data base.

- State and federal biologists should investigate the feasibility of using available data on juvenile abundance to predict year-class strength in the fishery.

- The states should re-examine the reproduction study in the gulf menhaden fishery by Lewis and Roithmayr (1981), updating fecundity estimates, maturity schedules, and sex ratios.

- The NMFS should investigate the feasibility of using spotter plane logs for estimates of effort in the reduction fishery as well as spatial and temporal changes in abundance of gulf menhaden.

12.0 RESEARCH AND DATA NEEDS

- Evaluate the efficiency of current operations by the menhaden industry to determine ways to increase economic benefits, competitiveness, and profits using various economic analyses including but not limited to:

  1) Bio-economic models to determine the best use allocation of the resource,
  2) Appropriate supply and demand models for harvested and processed products,
  3) Relevant cost functions for the harvesting and processing sectors, and
  4) Market analyses of processed products.

- Investigate the feasibility of using weather patterns, tides, rainfall, river stages, juvenile indices, and other parameters to develop earlier predictive models for future harvests.

- Continue research efforts to determine new products from menhaden, as well as further U.S. utilization of existing products from menhaden oil.

- Continue to computerize Captain's Daily Fishing Reports and develop a new effort index.

- Develop models of the effects of coastal habitat changes (i.e., marsh loss, salinity changes, etc.) on the menhaden population and fishery.

- Determine the social and cultural aspects of the fishery.

- Investigate the effects of environmental factors on larval and juvenile menhaden growth, mortality, abundance, and distribution.

- Study techniques to reduce mortality to nontarget species, e.g., gear changes, areas fished, detection (sonar).

- State and federal biologists should seek to improve their ability to forecast year class strength of gulf menhaden and to develop a coast wide young-of-the-year index.

13.0 REVIEW AND MONITORING OF THE PLAN

13.1 Review

As needed, the S-FFMC MAC will review the status of the stock, condition of the fishery and habitat, the effectiveness of management regulations, and research efforts. Results of this review will be presented to the 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.

14.0 REFERENCES

Acheson, J.M. 1988. The lobster gang of Maine. University Press of New England, Hanover, New Hampshire.

Ahrenholz, D.W. 1981. Recruitment and exploitation of gulf menhaden, *Brevoortia patronus*. Fishery Bulletin 79(2):325-335.

Ahrenholz, D.W. 1991. Population biology and life history of the North American menhadens, *Brevoortia* spp. Marine Fisheries Review 53(4):3-19.

Ahrenholz, D.W., D.L. Dudley, and E.J. Levi. 1991. Overview of mark-recovery studies on adult and juvenile Atlantic menhaden, *Brevoortia tyrannus*, and gulf menhaden, *B. patronus*. Marine Fisheries Review 53(4):20-27.

Ahrenholz, D.W., J.F. Guthrie, and C.W. Krouse. 1989. Results of abundance surveys of juvenile Atlantic and gulf menhaden, *Brevoortia tyrannus* and *B. patronus*. U.S. Department of Commerce, NOAA, NMFS Technical Report Number 84. 14 pp.

Alabama Department of Conservation and Natural Resources (ADCNR). Unpublished data. Alabama Department of Conservation and Natural Resources, Marine Resources Division, Gulf Shores, Alabama.

Allen, R.L. and D.M. Baltz. 1997. Distribution and microhabitat use by flatfishes in a Louisiana estuary. Environmental Biology of Fishes 50:85-103.

Arnold, E.L., Jr., R.S. Wheeler, and K.N. Baxter. 1960. Observations on fishes and other biota of East Lagoon, Galveston Island, Texas. U.S. Fish and Wildlife Service, SSRF 344:30 pp.

Baldauf, R.J. 1954. Survey and study of surface and subsurface conditions in and around Beaumont, Texas. Biological survey of the Neches River in the region of Beaumont, Texas. Texas A&M Research Foundation, unreleased mimeo. 184 pp.

Becker, C.P. and R.M. Overstreet. 1979. Haematozoa of marine fishes from the northern Gulf of Mexico. Journal of Fish Diseases 2:469-479.

Becker, H. and J. Brashier. 1981. Final environmental impact statement, proposed OCS oil and gas sales 67 and 69. Department of the Interior, Bureau of Land Management, New Orleans, Louisiana, USA.

Bere, R. 1936. Parasitic copepods from Gulf of Mexico fish. The American Midland Naturalist 17(3):577-625.

Boesch, D.F., D.A. Anderson, R.A. Horner, S.E. Shumway, P.A. Tester, and T.E. Whitledge. 1997. Harmful algal blooms in coastal waters: for prevention, control and mitigation. NOAA

Coastal Oceans Program Decision Analysis Series No. 10. NOAA Coastal Ocean Office, Silver Spring, Maryland. 46p.

Buff, V. and S. Turner. 1987. The Gulf Initiative. pages 784-792 *In*: Magoon et al. (eds). Coastal Zone 1987, Proceedings of the Fifth Symposium on Coastal and Oceans Management. May 26-29, 1987. Vol. 1.

Burkholder, J.M., H.B. Glasgow Jr., and C.W. Hobbs. 1995. Fish kills linked to a toxic ambush-predator dinoflagellate: distribution and environmental conditions. Marine Ecology Progress Series 124:43-61.

Butler, M.J. IV, W.F. Herrnkind, J.H. Hunt. 1994. Sponge mass mortality and Hurricane Andrew: catastrophe for juvenile spiny lobsters in south Florida? Bulletin of Marine Science 54:1073.

Butler, M.J. IV, J.H. Hunt, W.F. Herrnkind, M.J. Childress, R. Bertelsen, W. Sharp, T. Matthews, J.M. Field, and H.G. Marshall. 1995. Cascading disturbances in Florida Bay, USA: Cyanobacteria blooms, sponge mortality, and implications for juvenile spiny lobsters *Panulirus argus*. Marine Ecology Progress Series 129:119-125.

Castillo-Rivera, M., A. Kobelkowsky, and V. Zamayoa. 1996. Food resource partitioning and trophic morphology of *Brevoortia gunteri* and *B. patronus*. Journal of Fish Biology 49:1102-1111.

Causey, D. 1955. Parasitic copepoda from Gulf of Mexico fish. Occasional Papers of the Marine Laboratory 9:1-19.

Chaillot, B. 1999. Omega reeling in 'money fish.' The Sunday Advertiser, Sept 19, 1999.

Chambers, D.G. 1980. An analysis of nekton communities in the upper Barataria Basin, Louisiana. M.S. Thesis. University of Delaware. 286 pp.

Chapoton, R.B. 1970. History and status of the Gulf of Mexico's menhaden purse seine fishery. The Journal of the Elisha Mitchell Scientific Society 86(4):183-184.

Chapoton, R.B. 1971. The future of the gulf menhaden, the United States' largest fishery. Proceedings of the Gulf and Caribbean Fisheries Institute 24:134-143.

Christmas, J.Y. 1973. Area description: Phase I. p. 1-71. *In*: J.Y. Christmas (editor). Cooperative Gulf of Mexico estuarine inventory and study, Mississippi. Gulf Coast Research Laboratory. Ocean Springs, Mississippi.

Christmas, J.Y., Jr. and R.A. Collins. 1958. An annotated bibliography of menhaden. Gulf Coast Research Laboratory, Ocean Springs, Mississippi. 61 pp.

Christmas, J.Y. and G. Gunter. 1960. Distribution of menhaden, genus *Brevoortia*, in the Gulf of Mexico. Transactions of the American Fisheries Society 89(4):338-343.

Christmas, J.Y., G. Gunter, and E.C. Whatley. 1960. Fishes taken in the menhaden fishery of Alabama, Mississippi, and eastern Louisiana. U.S. Department of Interior, Fish and Wildlife Service SSRF-339. 10 pp.

Christmas, J.Y., J.T. McBee, R.S. Waller, and F.C. Sutter, III. 1982. Habitat suitability models: gulf menhaden. U.S. Department of Interior, Fish and Wildlife Service, FWS/OBS 82/10.23. 23 pp.

Christmas, J.Y. and R.S. Waller. 1973. Estuarine vertebrates, Mississippi. Pages 320-403. *In*: J.Y. Christmas (editor), Cooperative Gulf of Mexico Estuarine Inventory and Study, Mississippi. Section 5. Gulf Coast Research Laboratory, Ocean Springs, Mississippi.

Christmas, J.Y. and R.S. Waller. 1975. Location and time of menhaden spawning in the Gulf of Mexico. Gulf Coast Research Laboratory, Ocean Springs, Mississippi. 20 pp.

Clements, L.C. 1990. Chaetognaths versus larval fish. Fourteenth Larval Fish Conference, American Fisheries Society, May 6-9, 1990, Beaufort, North Carolina (abstract).

Cochrane, J.E. 1965. The Yucatan Current. Pages 20-27 *In*: Annual Report, Project 286, Texas A&M University, Ref. 65-17T, College Station, USA.

Combs, R.M. 1969. Embryogenesis, histology and organology of the ovary of *Brevoortia patronus*. Gulf Research Reports 2(4):333-434.

Condrey, R.E. 1994. Bycatch in the U.S. Gulf of Mexico menhaden fishery. Results of onboard sampling conducted in the 1992 fishing season. Coastal Fisheries Institute, Louisiana State University, Baton Rouge, Louisiana. 42 pp.

Copeland, B.J. 1965. Fauna of the Aransas Pass inlet. Texas I. Emigrations as shown by the tide trap collections. Publications of the Institute of Marine Science 10:9-21.

Copeland, B.J. and T.J. Bechtel. 1974. Some environmental limits of six Gulf coast estuarine organisms. Contributions in Marine Sciences 18:169-203.

Crance, J.H. 1971. Description of Alabama estuarine areas-cooperative Gulf of Mexico estuarine inventory. Alabama Marine Resources Bulletin 6:85 pp.

Culliney, J.L. 1976. The forests of the sea. Sierra Club Books, San Francisco, California. p. 60.

Cushing, D.H. 1977. The problems of stock and recruitment. *In*: Fish Population Dynamics. J.A. Gulland (editor) John Wiley and Sons, Ltd. 372 pp.

Dahl, T.E. 2000. Status and trends of wetlands in the conterminous United States 1986 to 1997. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 82 pp.

Dahl, T.E. 1990. Wetlands losses in the United States 1780's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 21 pp.

Dahl, T.E. and C.E. Johnson. 1991. Status and trends of wetlands in the conterminous United States, mid-1970's to mid-1980's. United States Department of the Interior, United States Fish and Wildlife Service. Washington, D.C. 28 pp.

Dahlberg, M.D. 1969. Incidence of the isopod, *Olencira praegustator*, and copepod, *Lernaeenicus radiatus*, in three species of hybrid menhaden (*Brevoortia*) from the Florida coasts, with five new host records. Transactions of the American Fisheries Society 98:111-115.

Darby, C.D. and S. Flatman. 1994. Virtual population analysis: version 3.1 (Windows/DOS). ICCAT, Collective Volume of Scientific Papers 32:443-460.

Darnell, R.M. 1958. Food habits of fishes and larger invertebrates of Lake Pontchartrain, Louisiana, an estuarine community. Publications of the Institute of Marine Science, University of Texas, Austin, Texas. 5:353-416.

Darnell, R.M. and J.A. Kleypas. 1987. Eastern Gulf Shelf bio-atlas: A study of the distribution of demersal fishes and penaeid shrimp of soft bottoms of the continental shelf from the Mississippi River Delta to the Florida Keys. OCS Study MMS86-0041. New Orleans, Louisiana. 548 pp.

Darnell, R.M., R.E. Defenbaugh, and D. Moore. 1983. Northwestern Gulf shelf bio-atlas, a study of the distribution of demersal fishes and penaeid shrimp of soft bottoms of the continental shelf from the Rio Grande to the Mississippi River Delta. Open File Report 82-04. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office, New Orleans, Louisiana.

Day, R.H., R.K. Hol, and J.W. Day. 1990. An inventory of wetland impoundments in the coastal zone of Louisiana, USA: historical trends. Environmental Management 14(2):229-240.

Deegan, L.A. 1985. The population ecology and nutrient transport in gulf menhaden in Fourleague Bay, Louisiana. Doctoral Dissertation. Louisiana State University, Baton Rouge. 134 pp.

Deegan, L.A. 1986. Changes in body composition and morphology of young-of-the-year menhaden, *Brevoortia patronus* Goode, in Fourleague Bay, Louisiana. Journal of Fish Biology 29:403-415.

Deegan, L.A., J.W. Day, and J.G. Gosselink. 1986. Relationships among physical characteristics, vegetation distribution and fisheries yield in Gulf of Mexico estuaries. Pages 83-100. *In*: D. Wolfe (editor), Estuarine Variability. Academic Press, New York, New York. p. 83-100.

Deegan, LA. and B.A. Thompson. 1987. Growth rate and life history events of young-of-the-year gulf menhaden as determined from otoliths. Transactions of the American Fisheries Society 116:663-667.

de Silva, J.A. and R.E. Condrey. 1998. Discerning patterns in patchy data: a categorical approach using gulf menhaden, *Brevoortia patronu*s, bycatch. Fishery Bulletin 96:193-209.

de Silva, J.A., R.E. Condrey, and B.A. Thompson. In press. Profile of shark bycatch in the U.S. gulf menhaden fishery. North American Journal of Fisheries Management.

Diener, R.A. 1975. Cooperative Gulf of Mexico estuarine inventory and study — Texas: area description. NOAA Technical Report NMFS CIRC-393. 127 pp.

Ditty, J.G. 1986. Ichthyoplankton in neritic waters of the northern Gulf of Mexico off Louisiana: composition, relative abundance, and seasonality. Fishery Bulletin 84(4):935-944.

Drummond, K.H. and G.B. Austin, Jr. 1958. Some aspects of the physical oceanography of the Gulf of Mexico, in U.S. Fish and Wildlife Service, Gulf of Mexico physical and chemical data from Alaska cruises: U.S. Fish and Wildlife Service Special Scientific Report-Fisheries 249:5-13.

Dubrow, D., M. Hale, and A. Bimbo. 1976. Seasonal variations in chemical composition and protein quality of menhaden. MFR Paper 1199. From Marine Fisheries Review 38(9). 16 pp.

Dudley, D.L. 1988. Annotated bibliography on the biology of the menhaden, genus *Brevoortia*, 1981-1987. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SEFC-206. 35 pp.

Duke, T. and A. Kruczynski. 1992. Report on the status and trends of emergent and submerged vegetated habitats of Gulf of Mexico coastal waters, USA. Gulf of Mexico program. EPA 800-R-92-003. 173 pp.

Dunham, F.O. 1972. A study of commercially important estuarine-dependent commercial fishes. Louisiana Wildlife and Fisheries Commission Technical Bulletin 4. 63 pp.

Dunham, F.O. 1975. A study of gulf menhaden, *Brevoortia patronus*, in Barataria and Terrebonne Bays, Louisiana. Louisiana Wildlife and Fisheries Commission (mimeo). 57 pp.

Durbin, A.G. and E.G. Durbin. 1975. Grazing rates of the Atlantic menhaden, *Brevoortia tyrannus*, as a function of particle size and concentration. Marine Biology 33:265-277.

Dyer, C.L., D.A. Gill, and J.S. Picou. 1992. Social disruption and the Valdez oil spill: Alaskan natives in a natural resource community. Sociological Spectrum 12(2):105-126.

Eleuterius, L.N. 1973. The marshes of Mississippi. Pages 147-190. *In*: J.Y. Christmas (ed). Cooperative Gulf of Mexico estuarine inventory and study, Mississippi. Gulf Coast Research Laboratory. Ocean Springs, Mississippi.

Eymard, T. Unpublished data. Louisiana Department of Wildlife and Fisheries, P.O. Box 98000, Baton Rouge, Louisiana 70898-9000.

Etzold, D.J. and J.Y. Christmas (editors). 1979. A Mississippi marine finfish management plan. Mississippi-Alabama Sea Grant Consortium, MASGP-78-046. 36 pp.

Fischer, W. (editor). 1978. FAO species identification sheets for fishery purposes. Western-central Atlantic (fishing area 31). Rome, FAO, Volumes 1-7, various pages.

Florida Fish and Wildlife Conservation Commission (FWC), unpublished data. Florida Fish and Wildlife Conservation Commission, Tallahassee, Florida, 32399.

Floyd, T. Personal Communication. Mississippi Department of Marine Resources. 1141 Bayview, Biloxi, Mississippi.

Fontenot, D.D., R.E. Condrey, and T.B. Ford. 1980. A menhaden bibliography. Louisiana State University, Center for Wetland Resources, Baton Rouge, Louisiana. 105 pp.

Fore, P.L. 1970. Oceanic distribution of eggs and larvae of the gulf menhaden. *In*: Report of the Bureau of Commercial Fisheries Biology Laboratory, Beaufort, North Carolina, for the fiscal year ending June 30, 1968. U.S. Fish and Wildlife Service Circular 341:11-13.

Fore, P.L. and K.N. Baxter. 1972. Diel fluctuations in the catch of larval gulf menhaden, *Brevoortia patronus*, at Galveston Entrance, Texas. Transactions of the American Fisheries Society 101(4):729-732.

Fourqurean, J.W., J.C. Zieman, and G.V.N Powell. 1992. Phosphorus limitation of primary productivity in Florida Bay: evidence from C:N:P ratios of the dominant seagrasses, *Thalassia testudinum*. Limnological Oceanography 37:162-171.

Fourqurean, J.W., R.D. Jones, and J.C. Zieman. 1993. Processes influencing water column nutrient characteristics and phosphorus limitation of phytoplankton biomass in Florida Bay, FL, USA: inferences from spatial distributions. Estuaries and Coast Shelf Science 36:295-314.

Franks, J. Personal Communication. University of Southern Mississippi, Institute of Marine Sciences, Gulf Coast Research Laboratory. Ocean Springs, Mississippi.

Friedland, K.D. 1985. Functional morphology of the branchial basket structures associated with feeding in the Atlantic menhaden, *Brevoortia tyrannus* (Pisces: Clupeidae). Copeia 1985(4):1018-1027.

Friedland, K.D., L.W. Haas, and J.V. Merriner. 1984. Filtering rates of the juvenile Atlantic menhaden, *Brevoortia tyrannus* (Pisces: Clupeidae), with consideration of the effects of detritus and swimming speed. Marine Biology 84(2):109-117.

Frye, J. 1999. The men all singing, Second Edition. Donning Company, Virginia Beach, Virginia. 242 pp.

Galstoff, P. 1954. (ed). Gulf of Mexico, its origin, waters, and marine life. Fishery Bulletin 55(89):1-604.

Gulf of Mexico Fishery Management Council (GMFMC). 1998. Generic amendment for addressing essential fish habitat requirements in fishery management plans of the Gulf of Mexico. GMFMC, 507 pp.

Goode, G.B. 1878. A revision of the American species of the genus *Brevoortia*, with a description of a new species from the Gulf of Mexico. Proceedings of the U.S. National Museum 1:30-42.

Govoni, J.J. 1983. Helminth parasitism of three larval fishes in the northern Gulf of Mexico. Fishery Bulletin 81(4):895-898.

Govoni, J.J., D.E. Hoss, and A.J. Chester. 1983. Comparative feeding of three species of larval fishes in the northern Gulf of Mexico: *Brevoortia patronus, Leiostomus xanthurus* and *Micropogonius undulatus*. Marine Ecology Progress Series 13:189-199.

Guillory, V., P. Bowman, and C. White. 1985. Gulf menhaden bycatch in the Louisiana inshore shrimp fishery. Proceedings of the Louisiana Academy of Sciences 48:74-81.

Guillory, V., J. Geaghan, and J. Roussel. 1983. Influence of environmental factors on gulf menhaden recruitment, Louisiana Department of Wildlife and Fisheries. Technical Bulletin 37. 32 pp.

Guillory, V. and G. Hutton. 1982. A survey of bycatch in the Louisiana gulf menhaden fishery. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 36:213-223.

Guillory, V. and R. Kasprzak. Unpublished data. Louisiana Department of Wildlife and Fisheries, P.O. Box 98000, Baton Rouge, Louisiana 70898-9000.

Guillory, V. and J. Roussel. 1981. Seasonal and areal abundance of gulf menhaden in Louisiana estuaries. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 35:365-371.

Gulf of Mexico Fishery Management Council (GMFMC). 1998. Generic Amendment for Addressing Essential Fish Habitat Requirements. Gulf of Mexico Fishery Management Council, Tampa, Florida. October 1998.

Gulf of Mexico Fishery Management Council (GMFMC). 1981. Draft fishery management plan, environmental impact statement, and regulatory analysis for ground fish in the Gulf of Mexico. Unpublished Manuscript. GMFMC. Tampa, Florida.

Gunter, G. 1945. Studies on marine fishes of Texas. Publications of the Institute of Marine Science, University of Texas, Austin, Texas. 1(1):1-190.

Gunter, G. and C.H. Lyles. 1979. Localized plankton blooms and jubilees on the Gulf coast. Gulf Research Reports 6(3):297-299.

Gunter, G. and W.E. Shell, Jr. 1958. A study of an estuarine area with water-level control in the Louisiana Marsh. Proceedings of the Louisiana Academy of Sciences 21:5-34.

Gunter, G. and J.Y. Christmas. 1960. A review of literature on menhaden with special reference to the Gulf of Mexico menhaden, *Brevoortia patronus* Goode. U.S. Fish and Wildlife Service, Special Scientific Report 363:31 pp.

Hargis, W.J., Jr. 1955a. Monogenetic trematodes of Gulf of Mexico fishes. Part VI. Transactions of the American Microscopical Society 74(4):361-377.

Hargis, W.J., Jr. 1955b. Monogeneitc trematodes of Gulf of Mexico fishes. Part VII. Quarterly Journal of the Florida Academy of Science 18(2):114-119.

Hargis, W.J., Jr. 1959. Systematic notes on the monogenetic trematodes. Proceedings of the Helminthological Society of Washington 26(1):14-31.

Haskell, W.A. 1961. Gulf of Mexico trawl fishery for industrial species. U.S. Department of Interior, Fish and Wildlife Service, Commercial Fisheries Review 23(2):6 pp.

Herke, W.H. and B.D. Rogers. 1989. Threats to coastal fisheries. *In*: W.G. Duffy and D. Clark (editors), Marsh Management in Coastal Louisiana: Effects and Issues - Proceedings of a Symposium. U.S. Fish and Wildlife Service Biological Report 89(22):196-212.

Hettler, W.F., Jr. 1968. Artificial fertilization among yellowfin and gulf menhaden (*Brevoortia*) and their hybrid. Transactions of the American Fisheries Society 97(2):119-123.

Hettler, W.F., Jr. 1970. Rearing larvae of yellowfin menhaden, *Brevoortia smithi*. Copeia 1970:775-776.

Hettler, W.F., Jr. 1984. Description of eggs, larvae and early juveniles of gulf menhaden, *Brevoortia patronus*, and comparisons with Atlantic menhaden, *B. tyrannus*, and yellowfin menhaden, *B. smithi*. Fishery Bulletin 82(1):85-95.

Higgs, D.M. and L.A. Fuiman. 1996. Light intensity and schooling behaviour in larval gulf menhaden. Journal of Fish Biology 48:979-991.

Hildebrand, S.F. 1948. A review of the American menhaden, genus *Brevoortia*, with a description of a new species. Smithsonian Miscellaneous Collection 107(18):39 pp.

Hildebrand, S.F. 1963. Family Clupeidae. Memoir of the Sears Foundation for Marine Research. Yale University, New Haven, Connecticut. 1(3):257-451.

Hoese, H.D. 1965. Spawning of marine fishes in the Port Aransas, Texas area as determined by the distribution of young and larvae. Doctoral Dissertation. University of Texas, Austin, Texas. 144 pp.

Hoese, H.D. and R.H. Moore. 1977. Fishes of the Gulf of Mexico: Texas, Louisiana and adjacent waters. Texas A&M University Press, College Station, Texas. 327 pp.

Holt, G.J., M. Bartz and J. Lehman. 1982. Regional environmental impact statement, Gulf of Mexico. Department of the Interior, Minerals Management Service. 735 pp.

Hoss, D.E. and G.W. Thayer. 1993. The importance of habitat to early life history of estuarine dependent fishes. American Fisheries Society Symposium 14:147-158.

Houde, E.D. and P.L. Fore. 1973. Guide to the identity of eggs and larvae of some Gulf of Mexico clupeid fishes. Florida Department of Natural Resources, Marine Research Laboratory Leaflet Series 4(Part 1, No. 23):14 pp.

Houde, E.D. and L.J. Swanson, Jr. 1975. Description of the eggs and larvae of yellowfin menhaden, *Brevoortia smithi*. Fishery Bulletin 73(3):660-673.

Ichiye, T. 1962. Circulation and water mass distribution in the Gulf of Mexico. Geofisica Internac 2:47-76.

Ingersoll, E. 1882. On the fish-mortality in the Gulf of Mexico. Proceedings of the U.S. Natural History Museum 4:74-80.

Jeffries, H.P. 1975. Diets of juvenile Atlantic menhaden (*Brevoortia tyrannus*) in three estuarine habits as determined from fatty acid composition of gut contents. Journal of the Fisheries Research Board of Canada 32(5):587-592.

Jones, J.I., R.E. Ring, M.O. Rinkel, and R.E. Smith (eds). 1973. A summary of knowledge of the eastern Gulf of Mexico, State University System of Florida Institute of Oceanography, St. Petersburg, Florida.

Jordan, D.S. and B.W. Everman. 1896. A checklist of the fishes and fish-like vertebrates of Northern and Middle America. Report of the U.S. Commission on Fish and Fisheries. 283 pp.

Juhl, R. and S.B. Drummond. 1976. Shrimp bycatch investigation in the USA - a status report. U.S. Department of Commerce, NOAA, NMFS. Mimeo Southeast Fisheries Center, Pascagoula, Mississippi. 33 pp.

June, F.C. and F.T. Carlson. 1971. Food of young Atlantic menhaden, *Brevoortia tyrannus*, in relation to metamorphosis. Fishery Bulletin 68(3):493-512.

June, F.C. and J.L. Chamberlin. 1959. The role of the estuary in the life history and biology of Atlantic menhaden. Proceedings of the Gulf and Caribbean Fisheries Institute. p. 41-45.

June, F.C. and J.W. Reintjes. 1976. The menhaden fishery. Pages 136-149. *In:* M.E. Stansby (editor), Industrial fishery technology. R.E. Krieger Publishing Company. New York, New York.

Justić, D., N.N. Rabalais, R.E. Turner, and W.J. Wiseman, Jr. 1993. Seasonal coupling between riverborne nutrients, net productivity, and hypoxia. Marine Pollution Bulletin. 26(4):184-189.

Knapp, R.T. 1950. Menhaden utilization in relation to the conservation of food and game fishes of the Texas Gulf Coast. Transactions of the American Fisheries Society 79:137-144.

Koratha, K.J. 1955. Studies of the monogenetic trematodes of the Texas coast. II. Descriptions of species from marine fishes of Port Aransas. Proceedings of the Institute of Marine Science 4(1):253-278.

Kroger, K.J. and J.F. Guthrie. 1972. Effect of predators on juvenile menhaden in clear and turbid estuaries. Marine Fisheries Review 34(11-12):78-80.

Kuntz, A. and L. Radcliffe. 1917. Notes on the embryology and larval development of twelve teleostean fishes. Bulletin of the U.S. Bureau of Fisheries 35:87-134.

Lapointe, B.E., D.A. Tomasko, and W.R. Matzie. 1994. Eutrophication and trophic state classification of seagrass communities in the Florida Keys. Bulletin of Marine Science 54:696-717.

Lassuy, D.R. 1983. Gulf menhaden, species profiles: life histories and environmental requirements (Gulf of Mexico). U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/11.2, U.S. Army Corps of Engineers, TREL-82-4. 13 pp.

Leard, R.L., J. Merriner, V. Guillory, B.Wallace, and D. Berry. 1995. The menhaden fishery of the Gulf of Mexico, United States: a regional management plan. Gulf States Marine Fisheries Commission. Report No. 32.

Lee, C.F. 1953. Menhaden industry-past and present. U.S. Department of Interior, Fish and Wildlife Service. Fishery Leaflet 412. 17 pp.

Levi, E.J. 1973. Juvenile yellowfin menhaden from the Bahama Islands. Transactions of the American Fisheries Society 102(4):848-849.

Lewis, D.H., L.C. Grumbles, S. McConnel, and A.I. Flowers. 1970. *Pasteurella*-like bacteria from an epizootic in menhaden and mullet in Galveston Bay. Journal of Wildlife Diseases 6(3):160-162.

Lewis, R.M. and C.M. Roithmayr. 1981. Spawning and sexual maturity of gulf menhaden, *Brevoortia patronus*. Fishery Bulletin 78(4):947-951.

Lewis, V.P. and D.S. Peters. 1984. Menhaden - A single step from vascular plant to fishery harvest. Journal Experimental Marine Biology and Ecology 84(1):95-100.

Lindall, W. N., Jr. and C. H. Saloman. 1977. Alteration and destruction of estuaries affecting fishery resources of the Gulf of Mexico. Marine Fisheries Review 39(9):1-7.

Lindall, W.N., Jr., A. Mager, Jr., G.W. Thayer, and D.R. Ekberg. 1979. Estuarine habitat mitigation planning in the southeast. *In*: The Mitigation Symposium: a national workshop on mitigating losses of fish and wildlife habitats. Ft. Collins, Colorado. July 16-20, 1979. U.S. Department of Agriculture. Technical Report RM:65.

Loesch, H.C. 1976. Observations on menhaden (*Brevoortia*) recruitment and growth in Mobile Bay, Alabama. Proceedings of the Louisiana Academy of Sciences 39:35-42

May, J.R. and L.D. Britsch. 1987. Geological investigations of the Mississippi River deltaic plain: land loss and accretion. U.S. Army Corps of Engineers Waterways Experiment Station, Technical Report G11-87-13.

McCay, B.J. 1981. Optimal foragers or political actors? Ecological analysis of a New Jersey fishery. American Ethnologist 8:356-382.

McCay, B.J. and J.M. Acheson (editors). 1987. The question of the commons: the culture and ecology of communal resources. University of Arizona Press, Tucson, Arizona.

McEachron, L., D. Pridgen, and R. Hensley. 1998. Texas Red Tide fish kill estimates. Abstract, April 17-18, 1998 Workshop Meeting, Red Tide in Texas: From Science to Action, University of Texas Marine Science Institute, Port Aransas, Texas.

McGoodwin, J.R. 1990. Crisis in the world's fisheries: people, problems, and policies. Stanford University Press, Stanford, California.

McNulty, J.K., W.N. Lindall, Jr., and J.E. Sykes. 1972. Cooperative Gulf of Mexico estuarine inventory and study, Florida: Phase I, area description. U. S. Department of Commerce, NOAA Technical Report, NMFS CIRC-368. 126 pp.

Medved, R.J., C.E. Stillwell, and J.J. Casey. 1985. Stomach contents of young sandbar sharks, *Carcharhinus plumbeus*, in Chincoteague Bay, Virginia. Fishery Bulletin 83:395-402.

Miles, D.W. and E.G. Simmons. 1950. The menhaden fishery. Texas Game, Fish, and Oyster Commission, Marine Lab Series II. 28 pp.

Minello, T.J. and J.W. Webb, Jr. 1997. Use of natural and created *Spartina alterniflora* salt marshes by fishery species and other aquatic fauna in Galveston Bay, Texas, USA. Marine Ecology Progress Series 151:165-179.

Minerals Management Service (MMS). 1983. Final regional environmental impact statement volume 1. United States Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office, New Orleans, Louisiana.

Moncrieff, C. Personal Communication. University of Southern Mississippi, Institiute of Marine Sciences, Gulf Coast Research Laboratory. Ocean Springs, Mississippi.

Moncreiff, C.A., T.A. Randall, and J.D. Caldwell. 1998. Mapping of seagrass resources in Mississippi Sound. Gulf Coast Research Laboratory Project Number BY3-156-3238. Mississippi Department of Marine Resources, Report. 41 pp.

Moulton, D.W. , T.E. Dahl, and D.M. Dahl. 1997. Texas coastal wetlands; status and trends, mid 50s to early 1990s. U.S. Department of the Interior, Fish and Wildlife Service, Albuqerque, New Mexico, USA. 32 pp.

Nahhas, F.M. and R.B. Short. 1965. Digenetic trematodes of marine fishes from Apalachee Bay, Gulf of Mexico. Tulane Studies in Zoology 12:39-50.

National Marine Fisheries Service (NMFS). Unpublished Data. Commercial bait landing statistics. NMFS, Silver Spring, Maryland and New Iberia, Louisiana.

Nelson, W.R. and D.W. Ahrenholz. 1986. Population and fishery characteristics of gulf menhaden, *Brevoortia patronus*. Fishery Bulletin 84(2):311-325.

Nicholson, W.R. 1978. Gulf menhaden, *Brevoortia patronus*, purse seine fishery: catch, fishing activity, and age and size composition, 1964-1973. U.S. Department of Commerce, NOAA, NMFS. Technical Report SSRF-722. 8 pp.

Nixon, S. 1980. Between coastal marshes and coastal waters - a review of twenty years of speculation and research on the role of salt marshes in estuarine productivity and water chemistry. Pages 437-525. *In*: P. Hamilton and K. MacDonald (editors), Estuarine and Wetland Processes. Plenum Publishing Corp., New York, New York.

Nowlin, W.D. 1971. Water masses and general circulation of the Gulf of Mexico. Oceanographic International 6(2):28-33.

Orth, R.J. and J.V. Montfrans. 1990. Utilization of marsh and seagrass habitats by early stages of *Callinectes sapidus*: a latitudinal perspective. Bulletin of Marine Science 46(1):126-144.

Overstreet, R.M. Personal communication. Gulf Coast Research Laboratory, P.O. Box 7000, Ocean Springs, Mississippi 39566-7000.

Overstreet, R.M. 1978. Marine maladies? Worms, germs, and other symbionts from the northern Gulf of Mexico. Mississippi-Alabama Sea Grant Consortium, MASGP-78-021. 140 pp.

Overstreet, R.M. and R.W. Heard. 1978. Food of the red drum, *Sciaenops ocellata*, from Mississippi Sound. Gulf Research Reports 6(2):131-135.

Overstreet, R.M. and R.W. Heard. 1982. Food contents of six commercial fishes from Mississippi Sound. Gulf Research Reports 7(2):137-149.

Palmer, R.S. 1962. Handbook of North American birds. Volume I, Loons through Flamingos. Yale University Press, New Haven, Connecticut.

Parr, A.E. 1935. Report on hydrographic observations in the Gulf of Mexico and the adjacent straits made during the Yale Oceanographic Expedition on the MABEL TAYLOR in 1932. Bulletin of the Bingham Oceanographic Collections 5(1):1-93.

Patterson, K.R. and G.D. Melvin. 1995. Integrated catch at age analysis, Version 1.2, User's Manual. Aberdeen Marine Laboratory, Aberdeen, Scotland, 52 pp.

Pearse, A.S. 1952. Parasitic crustacea from the Texas coast. Publications of the Institute of Marine Science, University of Texas, Austin, Texas 2(2):5-42.

Peck, J.J. 1893. On the food of menhaden. Bulletin of the U.S. Fisheries Commission 13:113-126.

Pennak, R.W. 1988. Collegiate Dictionary of Zoology. Robert E. Krieger Publishing Company, Malabar, Florida. p. 576-577.

Perret, W.S 1968. Menhaden or pogies: Louisiana's most valuable commercial fish. Louisiana Conservationist 20 (1 and 2):14-15.

Perret, W.S., W.R. Latapie, J.F. Pollard, W.R. Mock, G.B. Adkins, W.J. Gaidry, and C.J. White. 1971. Fishes and invertebrates collected in trawl and seine samples in Louisiana estuaries. Section I. Pages 39-105. *In*: Cooperative Gulf of Mexico estuarine inventory and study. Phase IV, Biology. Louisiana Wildlife and Fisheries Commission, Baton Rouge, Louisiana.

Peters, D.S. and M.A. Kjelson. 1975. Consumption and utilization of food by various postlarval and juvenile North Carolina estuarine fishes. Pages 448-472. *In*: L.E. Cronin (editor), Estuarine Research, volume 1. Academic Press, New York, New York.

Peters, D.S. and W.E. Schaaf. 1981. Food requirements and sources for juvenile Atlantic menhaden. Transactions of the American Fisheries Society 110(3):317-324.

Plumb, J.A., J.H. Schachte, J.L. Gaines, W. Peltier, and B. Carroll. 1974. *Streptococcus* sp. from marine fishes along the Alabama and northwest Florida coast of the Gulf of Mexico. Transactions of the American Fisheries Society 103(2):358-361.

Powell, A.B. 1993. A comparison of early-life-history traits in Atlantic menhaden *Brevoortia tyrannus* and gulf menhaden *B. patronus*. Fishery Bulletin, U.S. 91:119-128.

Powell, A.B. and G. Phonlor. 1986. Early life history of Atlantic menhaden, *Brevoortia tyrannus*, and gulf menhaden, *B. patronus*. Fishery Bulletin 84(4):991-995.

Pristas, P.J., E.J. Levi, and R.L. Dryfoos. 1976. Analysis of returns of tagged gulf menhaden. Fishery Bulletin 74(1):112-117.

Rabalais, N.N., R.E. Turner, D. Justić, Q. Dortch and W.J. Wiseman. 1999. Characterization of hypoxia, Topic 1 report for the integrated assessment of hypoxia in the Gulf of Mexico. NOAA, National Ocean Service, Coastal Ocean Program Decision Analysis Series No. 15. 185 pp.

Raffield, G. Personal Communication. Raffield Fisheries, Inc. Port St. Joe, FL 32456

Reid, G.K., Jr. 1955. A summer study of the biology and ecology of East Bay, Texas. Part I. Texas Journal of Science 7(3):316-343.

Reintjes, J.W. 1962. Development of eggs and yolk-sac larvae of yellowfin menhaden. Fishery Bulletin 62:93-102.

Reintjes, J.W. 1964a. Annotated bibliography on biology of menhadens and menhadenlike fishes of the world. Fishery Bulletin 63(3):531-549.

Reintjes, J.W. 1964b. The importance of the occurrence of menhaden in the coastal waters and estuaries of peninsular Florida. Proceedings of the Gulf and Caribbean Fisheries Institute 16:108-113.

Reintjes, J.W. 1969. Synopsis of biological data on Atlantic menhaden, *Brevoortia tyrannus*. U.S. Department of the Interior, Fish and Wildlife Service Circular 320. 30 pp.

Reintjes, J.W. 1970. The gulf menhaden and our changing estuaries. Proceedings of the Gulf and Caribbean Fisheries Institute 22:87-90.

Reintjes, J.W., J.Y. Christmas, and R.A. Collins. 1960. Annotated bibliography on the biology on American menhaden. Fishery Bulletin 60:297-322.

Reintjes, J.W. and F.C. June. 1961. A challenge to the fish meal and oil industry in the Gulf of Mexico. Proceedings of the Gulf and Caribbean Fisheries Institute 13:62-66.

Reintjes, J.W. and P.M. Keney. 1975. Annotated bibliography on the biology of the menhadens, genus *Brevoortia*, 1963-1973. U.S. Department of Commerce, NOAA, NMFS Technical Report No. SSRF-687:92 pp.

Reintjes, J.W. and A.L. Pacheco. 1966. The relation of menhaden to estuaries. *In*: R.F. Smith, A.H. Swartz, and W.H. Massman (editors). A symposium on estuarine fisheries. American Fisheries Society Special Publication 3:50-58.

Rester, J.K. and R.E. Condrey. 1999. Characterization and evaluation of bycatch reduction devices in the gulf menhaden fishery. North American Journal of Fisheries Management 19(1):42-50.

Restrepo, V.R. 1996. FADAPT Version 3.0, A guide. University of Miami, 21p.

Richardson, H. 1905. Monograph of the isopods of North America. Bulletin of the U.S. National Museum 54. 727 pp.

Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1991. Common and scientific names of fishes from the United States and Canada. Fifth Edition, American Fisheries Society, Special Publication 20, 183 pp.

Roithmayr, C.M. 1965. Review of the industrial bottomfish fishery in the northern Gulf of Mexico, 1959-1962. U.S. Department of Interior, Fish and Wildlife Service, Commercial Fisheries Review 27(1):6 pp.

Roithmayr, C.M. and R.A. Waller. 1963. Seasonal occurrence of *Brevoortia patronus* in the northern Gulf of Mexico. Transactions of the American Fisheries Society 92(3):301-302.

Shaw, R.F., B.D. Rogers, J.H. Cowan, Jr., and W.H. Herke. 1988. Ocean-estuary coupling of ichthyoplankton and nekton in the northern Gulf of Mexico. American Fisheries Society Symposium 3:77-89.

Shaw, R.F., J.H. Cowan, Jr., and T.L. Tillman. 1985a. Distribution and density of *Brevoortia patronus* (gulf menhaden) eggs and larvae in the continental shelf waters of Western Louisiana. Bulletin of Marine Science 36(1):96-103.

Shaw, R.F., W.J. Wiseman, Jr., R.E. Turner, L.J. Rouse, Jr., R.E. Condrey, and F.J. Kelley. 1985b. Transport of larval gulf menhaden, *Brevoortia patronus*, in continental shelf waters of western Louisiana: a hypothesis. Transactions of the American Fisheries Society 114:452-460.

Simmons, E.G. 1957. An ecological survey of the upper Laguna Madre of Texas. Publications of the Institute of Marine Science, University of Texas, Austin, Texas. 4(2):156-200.

Simmons, E.G. and J.P. Breuer. 1950 (revised 1964, 1967). The Texas menhaden fishery. Texas Parks and Wildlife Department Series Number II, Bulletin 45-A:16 pp.

Smith, J.W. Personal communication. National Marine Fisheries Service, Beaufort Laboratory, 101 Pivers Island Road, Beaufort, North Carolina 28516-9722.

Smith, J.W. Iin press. Distribution of catch in the gulf menhaden, *brevoortia patronus*, purse seine fishery in the northern Gulf of Mexico from logbook information: Are there relationships to the hypoxic zone? *In:* Preceeding of Hypoxia Workshop at Baton Rouge. American Geophysical Union.

Smith, J.W. 1999. Distribution of Atlantic menhaden, *Brevoortia tyrannus*, purse-seine sets and catches from southern New England to North Carolina, 1985-96. NOAA Technical Report NMFS 114. 22 pp.

Smith, J.W. 1991. The Atlantic and gulf menhaden purse seine fisheries: origins, harvesting technologies, biostatistical monitoring, recent trends in fisheries statistics, and forecasting. Marine Fisheries Review 53(4):28-41.

Smith, J.W., E.L. Levi, D.S. Vaughan, and E.A. Hall. 1987. Gulf menhaden, *Brevoortia patronus*, purse seine fishery, 1974-1985, with a brief discussion of age and size composition of the landings. U.S. Department of Commerce, NOAA, NMFS Technical Report Number 60. 8 pp.

Sogard, S.M., D.E. Hoss, and J.J. Govoni. 1987. Density and depth distribution of larval gulf menhaden, *Brevoortia patronus*, Atlantic croaker, *Micropogonias undulatus*, and spot, *Leiostomus xanthurus*, in the northern Gulf of Mexico. Fishery Bulletin 85(3):601-609.

Spitzer, P.R. 1989. Osprey. Pages 22-29. *In*: Proceedings of the Northeast Raptor Management Symposium Workshop. National Wildlife Federation, Washington, DC.

Springer, V.G. and K.D. Woodburn. 1960. An ecological study of the fishes of the Tampa Bay area. Florida State Board of Conservation, Marine Research Laboratory, Professional Paper Series 1:104 pp.

Steidinger, K.A. 1998. Harmful algal blooms in Florida. Abstract, April 17-18, 1998 Workshop Meeting, Red Tide in Texas: From Science to Action, University of Texas Marine Science Institute, Port Aransas, Texas.

Steidinger, M.A., M.A. Burklew, and R.M. Ingle. 1973. The effects of *Gymnodinium breve* toxin on estuarine animals. Pages 179-202. *In*: Marine Pharmacognosy. Academic Press, New York.

Steidinger, K.A., G.A. Vargo, P.A. Tester and C.R. Tomas. 1998. Bloom dynamics and physiology of *Gymnodinium breve* with emphasis on the Gulf of Mexico. Pages 133-153. *In*: D.M. Anderson, A.D. Cembella and G.M. Hallegraeff (eds.) Physiological Ecology of harmful Algal Blooms. NATO ASI Series, Vol. G41. Springer-Verlag Berlin Heidelberg.

Stoecker, D.K. and J.J. Govoni. 1984. Food selection by young larval gulf menhaden (*Brevoortia patronus*). Marine Biology 80(3):299-306.

Suttkus, R.D. 1956. Early life history of the gulf menhaden, *Brevoortia patronus*, in Louisiana. Transactions of the North American Wildlife Conference 21:390-406.

Suttkus, R.D. 1958. Distribution of menhaden in the Gulf of Mexico. Transactions of the North American Wildlife Conference 23:401-410.

Suttkus, R.D. and B.I. Sundararaj. 1961. Fecundity and reproduction in the largescale menhaden, *Brevoortia patronus*, Goode. Tulane Studies in Zoology 8(6):177-182.

Swingle, H.A. 1971. Biology of Alabama's estuarine areas-cooperative Gulf of Mexico estuarine inventory. Alabama Marine Resources Bulletin 5:1-123.

Tagatz, M.E. and E.P.H. Wilkens. 1973. Seasonal occurrence of young gulf menhaden and other fishes in a northwestern Florida estuary. U.S. Department of Commerce, NOAA, NMFS Technical Report No. SSRF-672:14 pp.

Thayer, G.W. and J.F. Ustach. 1981. Gulf of Mexico Wetlands: Value, state of knowledge and research needs. Pages 1-30. *In*: D. K. Atwood (convener). Proceedings of a symposium on environmental research needs in the Gulf of Mexico (GOMEX), Vol I1B.

Turner, R.E. 1977. Intertidal vegetation and commercial yields of penaeid shrimp. Transactions of the American Fisheries Society 106(5):411-416.

Turner, R.E. 1979. Louisiana's coastal fisheries and changing environmental conditions. Pages 363-367. *In*: J.W. Day, D.D. Culley, Jr., R.E. Turner, and A.J. Mumphrey, Jr. (editors), Proceedings: Third Coastal Marsh and Estuary Management Symposium. Louisiana State University, Division of Continuing Education, Baton Rouge.

Turner, R.E. 1990. Landscape development and coastal wetland losses in the northern Gulf of Mexico. American Zoologist 30:89-105.

Turner, W.R. 1969. Life history of menhadens in the eastern Gulf of Mexico. Transactions of the American Fisheries Society 98(2):216-224.

Turner, W.R. 1970. Occurrence of *Brevoortia gunteri* in Mississippi Sound, Quarterly Journal of the Florida Academy of Sciences 33(4):273-274.

Turner, W.R. and G.N. Johnson. 1973. Distribution and relative abundance of fishes in Newport River, North Carolina. U.S. Department of Commerce, NOAA, NMFS Technical Report No. SSRF-666:23 pp.

Turner, W.R., G.N. Johnson, and H.R. Gordy. 1974. Compendium of juvenile abundance surveys in coastal streams of the northern Gulf of Mexico. U.S. Department of Commerce, NOAA, NMFS Data Report Number 89, 189 pp.

Turner, W.R. and R.B. Roe. 1967. Occurrence of the parasitic isopod *Olencira praegustator* in the yellowfin menhaden, *Brevoortia smithi*. Transactions of the American Fisheries Society 96(3):357-359.

U.S. Department of Commerce (USDOC), NOAA, NMFS. Fisheries of the U.S. Current Fisheries Statistics (various issues).

United States Environmental Protection Agency (USEPA). 1994. Habitat degradation action agenda for the Gulf of Mexico. First Generation Management Committee Report. EPA 800.

Vaughan, D.S. 1987. Stock assessment of the Gulf menhaden, *Brevoortia patronus*, fishery. NOAA Technical Report NMFS 58. 18 pp.

Vaughan, D.S., E.J. Levi, and J.W. Smith. 1996. Population characteristics of Gulf menhaden, *Brevoortia patronus*. NOAA Technical Report 125. 18 pp.

Vaughan, D.S., J.W. Smith, and M.H. Prager. 2000. Population characteristics of gulf menhaden, *Brevoortia patronus*. U.S. Department of Commerce, NOAA Technical Report NMFS 149. 19 pp.

Walls, J.G. 1975. Fishes of the northern Gulf of Mexico. T.F.H. Publications, Inc., Neptune City, New Jersey. 432 pp.

Warlen, S.M. 1988. Age and growth of larval gulf menhaden, *Brevoortia patronus*, in the northern Gulf of Mexico. Fishery Bulletin 86(1):77-90.

Whitehurst, J.W. 1973. The menhaden fishing industry in North Carolina. University of North Carolina Sea Grant Publication UNC-SG-72-12. 51 pp.

Wieland, R.G. 1994. Marine and estuarine habitat types and associated ecological communities of the Mississippi Coast. Mississippi Department of Wildlife, Fisheries, and Parks. Museum of Natural Science, Museum Technical Report 25:1-270.

Wilson, W.B. and S.M. Ray. 1956. The occurrence of *Gymnodinium brevis* in the western Gulf of Mexico. Ecology 36:388.

15.0 APPENDIX

15.1 Glossary of Terms

Modified from: Wallace, R.K., W. Hosking, and S.T. Szedlmayer. 1994. Fisheries Management for Fishermen: A manual for helping fishermen understand the federal management process. Auburn University Marine Extension & Research Center.

Absolute Abundance - The total number of kind of individuals the population. This is rarely known, but usually estimated from relative abundance, although other methods may be used.

Abundance - See relative abundance and absolute abundance.

Age frequency or Age Structure - A breakdown of the different age groups or individuals. The share a user group gets is sometimes based on historic harvest amounts.

Allocation - Distribution of the opportunity to individuals among user groups or individuals. The share a user group gets is sometimes based on historic harvest amounts.

Annual Mortality (A) - The percentage of individuals dying in one year due to both fishing and natural causes.

Aquaculture - The raising of fish or shellfish under some controls. Ponds, pens, tanks, or other containers may be used. Feed is often used.

Availability - Describes whether a certain sized individual can be caught by a type of gear in an area.

Bag Limit - The number and/or size of a species that a person can legally take in a day or trip. This may or may not be the same as a possession limit.

Benthic - Refers to organisms that live on or in the water bottom.

Biomass - The total weight or volume of a species in a given area.

Bycatch - The harvest of fish or shellfish other than the species for which the fishing gear was set. Example: blue crabs caught in shrimp trawls. Bycatch is also often called incidental catch. Some bycatch is kept for sale.

Catch - The total number or poundage of individuals captured from an area over some period of time. This includes individuals that are caught but released or discarded instead of being landed. The catch may take place in an area different from where the individuals are landed. Note: Catch, harvest, and landings are different terms with different definitions.

Catch Per Unit of Effort (CPUE) - The number of individuals or poundage caught by an amount of effort. Typically, effort is a combination of gear type, gear size, and length of time gear is used. Catch per unit of effort is often used as a measurement of relative abundance for a particular organism.

Cohort (Modal Group) - A group of individuals spawned during a given period.

Commercial Fishery - A term related to the whole process of catching and marketing fish and shellfish for sale. It refers to and includes fisheries resources, fishermen, and related businesses directly or indirectly involved in harvesting, processing or sales.

Common Property Resource - A term that indicates a resource owned by the public. The government regulates the use of a common property resource to ensure its future benefits.

Confidence Interval - The probability, based on statistics, that a number will be between an upper and lower limit.

Cumulative Frequency Distribution - A chart showing the number of animals that fall into certain categories. A cumulative frequency distribution shows the number in a category, plus the number in previous categories.

Directed Fishery - Fishing that is directed at a certain species or group of species. This applies to both sport fishing and commercial fishing.

Economic Efficiency - In commercial fishing, the point at which the added cost of producing a unit of crabs is equal to what buyers pay. Harvesting at the point of economic efficiency produces the maximum economic yield.

Economic Overfishing - A level of harvesting that is higher than that of economic efficiency; harvesting more than is necessary to have maximum profits for the fishery.

Effort - The amount of time and fishing power used to harvest a species. Fishing power includes gear size, boat size, and horsepower.

Environmental Impact Statement (EIS) - An analysis of the expected impacts of a fisheries management plan (or some other proposed action) on the environment.

Euryhaline - Organisms that live in a wide range of salinities.

Ex-vessel - Refers to activities that occur when a commercial fishing boat land or unloads a catch. For example, the price received by a captain for the catch is an ex-vessel price.

Exclusive Economic Zone (EEZ) - All waters from the seaward boundary of coastal states out to 200 natural miles. This was formerly called the Fishery Conservation Zone.

Fecundity - A measurement of the egg-producing ability of an organism. Fecundity may change with the age and size of the crab.

Fishery - All the activities involved in catching a species or group of species.

Fishery Conservation Zone (FCZ) - The area from the seaward limit of state waters out to 200 miles. The term is used less often now than the current term, exclusive economic zone.

Fishery Dependent Data - Data collected on an organism or fishery from sport fishermen, commercial fishermen, and seafood dealers.

Fishery Independent Data - Data collected on an organism by scientists who catch the organisms themselves, rather than depending on fishermen and seafood dealers.

Fishery Management Plan (FMP) - A plan to achieve specified management goals for a fishery. It includes data, analyses, and management measures for a fishery.

Fishing Effort - See effort.

Fishing Mortality (F) - A measurement of the rate of removal of organisms from a population by fishing. Fishing mortality can be reported as either annual or instantaneous. Annual mortality is the percentage of organisms dying in one year. Instantaneous is the percentage of organisms dying at any one time. The acceptable rates of fishing mortality may vary from species to species.

General Linear Model (GLM) - A mathematical formula that relates one biological factor to another. Once a mathematical relationship is established, scientists use the formula to predict one factor over another.

Growth - Usually an individual's increase in length or weight with time. Also may refer to the increase in numbers of individuals in a population with time.

Growth Model - A mathematical formula that describes the increase in length or weight of an individual with time.

Growth Overfishing - When fishing pressure on smaller individuals is too heavy to allow the fishery to produce its maximum poundage. Growth overfishing, by itself, does not affect the ability of a population to replace itself.

Harvest - The total number or poundage of individuals caught and kept from an area over a period of time. Does not include organisms caught and released. Catch includes the number or poundage caught whether kept or released.

Incidental Catch - See bycatch.

Instantaneous Mortality - See fishing mortality, natural mortality, and total mortality.

Juvenile - A young individual that has not reached sexual maturity.

Landings - The number or poundage of crabs unloaded by commercial fishermen or brought to shore by recreational fishermen for personal use within a geographic area. Landings are reported at the points at which crabs are sold or brought to shore.

Limited Entry - A program that changes a common property resource like crabs into private property for individual fishermen. License limitation and the individual transferable quota (ITQ) are two forms of limited entry.

Mariculture - The raising of marine species under some controls. Ponds, pens, tanks, or other containers may be used, and feed is often used.

Mark-Recapture - The tagging and releasing of crabs to be recaptured later in their life cycles. These studies are used to study movement, migration, mortality, and growth, and to estimate population size.

Maximum Sustainable Yield (MSY) - The largest average catch that can be taken continuously (sustained) from a stock under average environmental conditions. This is often used as a management goal.

Mean - Another word for the average of a set of numbers. Simply add up the individual numbers and then divide by the number of items.

Model - In fisheries science, a description of something that cannot be directly observed. Often a set of equations and data used to make estimates.

Morphometrics - The physical features of a species, for example, coloration.

Multiplier - A number used to multiply a dollar amount to get an estimate of economic impact. It is a way of identifying impacts beyond the original expenditure. It can also be used with respect to income and employment.

National Standards - The Fishery Conservation and Management Act requires that a fishery management plan and its regulations meet seven standards.

Natural Mortality (M) - A measurement of the rate of removal of individuals from a population from natural causes. Natural mortality can be reported as either annual or instantaneous. Annual mortality is the percentage of individuals dying in one year. Instantaneous mortality is the percentage of individuals dying at any one time. The rates of natural mortality may vary from species to species.

Open Access Fishery - A fishery in which any person can participate at any time.

Optimum Yield (OY) - The harvest level for a species that achieves the greatest overall benefits, including economic, social, and biological considerations. Optimum yield is different from maximum sustainable yield in that MSY considers only the biology of the species. The term includes both commercial and sport yields.

Overfishing - Harvesting at a rate greater than which will meet the management goal.

Pelagic - Refers to organisms that live in the water column in the open sea.

Population - Individuals of the same species inhabiting a specified area.

Population Dynamics - The study of populations and how fishing mortality, growth, recruitment, and natural mortality affect them.

Possession Limit - The number and/or size of a species that a person can legally have at any one time. Refers to commercial and recreational fishermen. A possession limit generally does not apply to the wholesale market level and beyond.

Predator - A species that feeds on another species. The species being eaten is the prey.

Predator-Prey Relationship - The interaction between a species (predator) that eats another species (prey).

Prey - A species being fed upon by another species. The species eating the other is the predator.

Primary Productivity - A measurement of plant production that is the start of the food chain. Much of the primary productivity in marine or aquatic systems is made up of phytoplankton (tiny one-celled algae that float freely in the water).

Quota - The maximum number or weight of individuals that can be legally landed in a time period. It can apply to the total fishery or an individual fisherman's share.

Recreational Fishery - Harvesting for personal use, fun, and challenge. Recreational fishing does not include sale of catch. The term refers to and includes the fishery resources, fishermen, and businesses providing needed goods and services.

Recruit - An individual that has moved into a certain class, such as the spawning class, modal group, or fishing-size class.

Recruitment - A measure of the number of individuals that enter a class during some time period, such as the spawning class or fishing-size class.

Recruitment Overfishing - When excessive mortality of the spawning stock does not allow a population to replace itself.

Regression Analysis - A statistical method to estimate any trend that might exist among important factors. An example in fisheries management is the link between catch and other factors like fishing effort and natural mortality.

Relative Abundance - An index of population abundance used to compare populations from year to year. This does not measure the actual numbers of individuals, but shows changes in the population over time.

Scattergram - A graph that shows how factors relate to each other. This is visual, not statistical, and is used when it is necessary to compare two factors, like age and size.

Selectivity - The ability of a type of gear to catch a certain size or kind of individual, compared with its ability to catch other sizes or kinds.

Simulation - An analysis that shows the production and harvest of a species using a group of equations to represent the fishery. It can be used to predict events in the fishery if certain factors changed.

Size Distribution - A breakdown of the number of individuals of various sizes in a sample or catch. The sizes can be in width, length or weight.

Social Impacts - The changes in people, families, and communities resulting from a fishery management decision.

Socioeconomics - A word used to identify the importance of factors other than biology in fishery management decisions. For example, if management results in more fishing income, it is important to know how the income is distributed between small and large boats or part-time and full-time fishermen.

Spawner-Recruit Relationship - The concept that the number of young individuals (recruits) entering a population is related to the number of parents (spawners).

Species - A group of similar organisms that can freely interbreed.

Sport Fishery - See recreational fishery.

Standing Stock - See biomass.

Stock - A grouping of individuals usually based on genetic relationship, geographic distribution, and movement patterns. Also a managed unit.

Stock-Recruit Relationship - See spawner-recruit relationship.

Surplus Production Model - A model that estimates the catch in a given year and the change in stock size. The stock size could increase or decrease depending on new recruits and natural mortality. A surplus production model estimates the natural increase in weight or the sustainable yield.

Survival Rate (s) - The number of individuals alive after a specified time, divided by the number alive at the beginning of the period.

Territorial Sea - The area from average low-water mark on the shore out to three miles for the states of Louisiana, Alabama, and Mississippi, and out to nine miles for Texas and the west coast of Florida. The shore is not always the baseline from which the three miles are measured. In such cases, the outer limit can extend further than three miles from the shore.

Total Mortality (Z) - A measurement of the rate of removal of individuals from a population by both fishing and natural causes. Total mortality can be reported as either annual or instantaneous. Annual mortality is the percentage of individuals dying in one year. Instantaneous mortality is that percentage of individuals dying at any one time. The rate of total mortality may vary from species to species.

Trip Interview Program (TIP) - A cooperative state-federal commercial fishery dependent sampling activity conducted in the Southeast region of NMFS, concentrating on size and age information for stock assessments of federal, interstate, and state managed species. TIP also provides information on the species composition, quantity, and price for market categories, and catch-per-unit effort for individual trips that are sampled.

Virtual Population Analysis (VPA) - A type of analysis that uses the number of individuals caught at various ages or lengths and an estimate of natural mortality to estimate fishing mortality in a cohort. It also provides an estimate of the number of individuals in a cohort at various ages.

Width Frequency - A breakdown of the different carapace widths of individuals in a population or sample. Size in crabs is usually given as carapace width, the distance from point to point between the long lateral spines.

Width-Weight Relationship - Mathematical formula for the weight of an individual in terms of its width. When only one is known, the scientist can use this formula to determine the other.

Year-Class - Individuals spawned and hatched in a given year.

Yield - The production from a fishery in terms of numbers or weight.

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