The Gulf Menhaden Fishery of the Gulf of Mexico: A Regional Management Plan, 2015 Revision

Steven J. VanderKooy and Joseph W. Smith
2015

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The Gulf Menhaden Fishery of the Gulf of Mexico

A Regional Management Plan

Gulf States Marine Fisheries Commission
2015 Revision

March 2015 Number 240

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THE MENHADEN FISHERY OF THE GULF OF MEXICO, UNITED STATES:

A Regional Management Plan

2015 Revision

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Abbreviations and Symbols

ADCNR/MRD	Alabama Department of Conservation and Natural Resources/Marine Resources Division
BRD	bycatch reduction device
℃	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
MSY	Maximum Sustainable Yield
mt	metric ton
n	number
NMFS	National Marine Fisheries Service
ppm	parts per million
ppt	parts per thousand
PPI	producer price index
SD	standard deviation
SE	standard error
sec(s)	second(s)
SL	standard length
SSB	Spawning Stock Biomass
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
USDOC	United States Department of Commerce
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
YOY	young-of-the-year

Preface

The Gulf States Marine Fisheries Commission (GSMFC) was established by a 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) and profiles 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 Menhaden Advisory Committee (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.

While drafting the FMP, several data confidentiality issues came to the fore. After 1997, the reduction fishery downsized from three companies to only two (Omega Protein Corp. and Daybrook Fisheries, Inc.). With less than three entities in the fishery, the landings and catch/effort data became confidential; simply put, with landings consisting of only two companies, Company A could easily determine Company B's landings by subtraction. A similar situation has existed in the menhaden bait fishery for a number of years as well. Most federal agencies are required to protect individually identifiable data by a variety of statutes, regulations, or policies. Disclosure restrictions are applied by the agencies to limit the risk of releasing individual information when statistics are disseminated. Confidential data include detailed proprietary information provided by firms and individuals, as well as personal-identifying information and business-identifying information. Confidentiality prevents unfair competitive advantage by the disclosure of sales statistics, marketing plans, profit and loss data, overhead and operating costs, and information on financial condition. These rules apply to the Departments of Commerce, Agriculture, Education, Energy, Health and Human Services, Justice, Labor, Transportation, Treasury, the National Science Foundation, and the Social Security Administration (OMB 2005).

NOAA (Department of Commerce) utilizes the 'rule of three' in determining confidential status under the Magnuson-Stevens Fishery Conservation and Management Act (MSA). If there are less than three entities operating in any fishery at a local, state, or regional level, those data derived from those entities must be included in aggregate at a level that will not compromise individual confidentiality. In other words, if one state has confidential landings, it must be combined with the whole region to prevent disclosure.

Disclosure of confidential landings data is subject to the civil and criminal penalties. NOAA Administrative Order (NOA) 216-100 is the principal legal guidance for NMFS employees on protocols for handling confidential data including definitions, policies, operational responsibilities and procedures, penalties, and statutory authorities.

The NOAA Beaufort Laboratory (Beaufort Lab) has a special provision arranged with the menhaden reduction industry to publish combined annual and monthly menhaden purse-seine landings for reduction. In addition, the industry has granted limited permission to the GSMFC to publish summaries of the annual fish meal and fish oil production data, which would also otherwise be confidential.

Throughout this document, metric equivalents are used wherever possible. A glossary of fisheries terms pertinent to this FMP is provided in the appendix. Metric tons are widely used to characterize the landings of menhaden on both the Atlantic and Gulf coasts and are used in this document by convention. The conversion of pounds to metric tons (mt) is 1 mt = 2,204.6 lbs.

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 2015 revision of the Menhaden Fishery Management Plan.

We especially appreciate the help of Drs. Douglas Vaughan (NOAA Beaufort Lab retired), Michael Prager (NOAA Beaufort Lab retired), Amy Schueller (NOAA Beaufort Lab), Brian Langseth (NOAA Beaufort Lab), Robert Leaf (USM/GCRL), and Mr. Rob Cheshire (NOAA Beaufort Lab), who contributed and conducted the SEDAR27 and SEDAR32A assessments. Additional comments were provided by various staff from the NOAA Beaufort Lab and other outside SEDAR reviewers. We gratefully acknowledge the assistance in collection and assimilation of data provided by Dr. Alan Lowther and Ms. Melissa Yencho (NMFS), Dr. Bob McMichael (FWC), Dr. Ralf Riedel (USM/GCRL), Mr. Craig Newton (ADCNR), Mr. Mike Harden (LDWF), and Dr. Mark Fisher (TPWD).

Special thanks are owed to the menhaden reduction industry who have worked diligently throughout this process to ensure that the data needed for a complete assessment were made available to analysts, as well as to the public for review. Without the cooperation of those industry participants, the current FMP could not have been completed, nor would it have been nearly as comprehensive as it is. In addition, the MAC would like to express their appreciation to the many employees past and present of the menhaden industry in the Gulf who provided their social and demographic information through the industry survey. Several individuals took personal time to provide the oral history which was captured in the social overview (Section 8.0). Thanks goes to Mr. Ed Swindell (reduction industry, retired), Mr. Eugene Raffield (bait industry), Mr. Jack Simpson (bait industry, retired), Mr. Quinn Rossi (great-grandson of Wallace M. Quinn), Mr. Bob Jones (Southeastern Fisheries Association), and Mr. Robert Schwark (Gulf menhaden pilot, retired), as well as the current industry representatives on the MAC who all contributed to the extensive history of the Gulf's fisheries.

Finally, the MAC would like to express their appreciation to Ms. Debbie McIntyre for her support of the MAC and editorial reviews of the draft management plan and Ms. Lucia Hourihan for her extensive final review of the completed document.

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1.0 SUMMARY

The menhaden fishery in the Gulf of Mexico (Gulf) 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 north-central 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, the population is 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 were 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 was due to the decrease in effort, vessels, and plants operating in the Gulf of Mexico over the last 30 years. In 1985 the number of plants fell to seven, then increased during 1989-1990 to nine. The number of plants declined to seven in 1991, to six in 1992, then to five between 1996 and 1999. After the 1997 fishing season, the menhaden company at Morgan City, Louisiana, was acquired by one of its competitors, who closed the facility after 1999. Since 2000, only four menhaden factories have operated on the Gulf coast – one each at Moss Point, Mississippi, and Empire, Abbeville, and Cameron, Louisiana. Likewise, the fleet size in the late 1990s was about 50-55 vessels. Since 2000, the number of Gulf menhaden vessels declined slightly from 47 in 2000 to 40 in 2006, then to 37 in 2012. Reduction landings (fish converted to meal and oil) over the last decade averaged 497,500 mt annually.

The bait fishery for menhaden in the Gulf grew rapidly during the 1980s but leveled off in the 1990s and today is almost negligible, compared to reduction fishery landings. 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.

Because of the vast difference in landings by the reduction fishery versus the bait fishery, the reduction fishery is the only significant component with regard to fishing pressure on the stock. In the most recent stock assessment for Gulf menhaden, SEDAR32A (SEDAR 2013), the MAC, the GSMFC, and the states have agreed to implement an MSY proxy [fecundity (SSB)] and reference points relative to the current level of fishing effort. Estimates of biomass associated with reference target (F35%) and limit (F30%) levels were calculated at F35%, (680,765 mt) and F30% (663,583 mt). The target and threshold harvest levels will serve as accountability measures to ensure that the fishery remains viable. The assessment concluded that the Gulf menhaden stock is neither overfished nor is overfishing occurring.

2.0 INTRODUCTION

The State-Federal Fisheries Management Committee (S-FFMC) had directed the IJF staff to begin the next revision of the Gulf menhaden FMP to coincide with the completion of the next stock assessment being conducted through the Southeast Data, Assessment, and Review or SEDAR process. SEDAR is a cooperative Fishery Management Council process initiated in 2002 to improve the quality and reliability of fishery stock assessments in the South Atlantic, Gulf of Mexico, and US Caribbean and is managed by the three Regional Fishery Management Councils in coordination with NOAA Fisheries and the Atlantic and Gulf States Marine Fisheries Commissions. SEDAR seeks improvements in the scientific quality of stock assessments and greater relevance of quantities information available to address existing and emerging fishery management issues.

The SEDAR32A Gulf Menhaden Benchmark Assessment (SEDAR 2013) was coordinated in part by the Gulf States Marine Fisheries Commission (GSMFC). The Assessment Workshop (AW) was held at the NOAA/National Marine Fisheries Service (NMFS) Beaufort Laboratory in June 2013. Two models were included in the AW, the Beaufort Assessment Model (BAM) and a stock production model incorporating covariates (ASPIC). The Review Workshop (RW) was held in August 2013 to present the assessment to six independent reviewers: three from the Center for Independent Experts (CIE), two from the Scientific and Statistical Committee (SSC) of the South Atlantic Fishery Management Council, and one representing the GSMFC.

The Gulf's five marine resource agencies provided experts through the GSMFC's Menhaden Advisory Committee (MAC), which served as the technical committee throughout the assessment process. At the October 2013 meeting of the GSMFC, the MAC and the Commissioners approved the adoption of reference points included in Section 09.

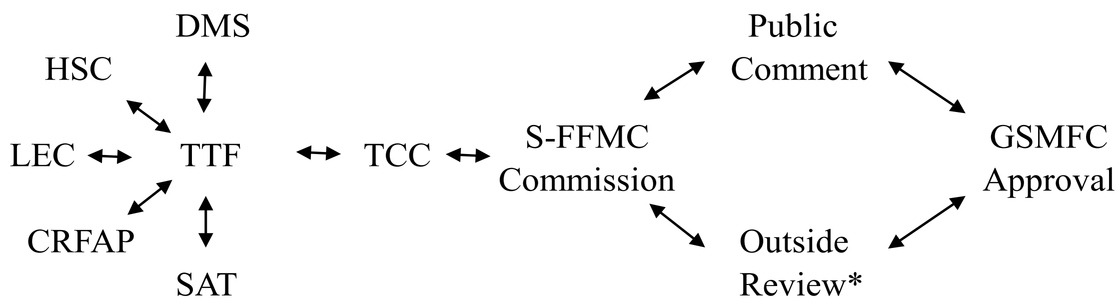
2.1 IJF Program and Management Process

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 GSMFC 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 GSMFC 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.

With respect to the Menhaden FMP revisions (1983, 1988, 1995, and 2002), the S-FFMC and the GSMFC had previously utilized the MAC which has been in place since the mid-1970s, to develop future revisions rather than form a TTF. Therefore, the revision was drafted by IJF staff and the NMFS representative on the MAC with input from the rest of the MAC. As a result, the development and approval process for the Gulf menhaden FMP evolved to its current form outlined below:



DMS = Data Management Subcommittee
SAT = Stock Assessment Team
HSC = Habitat Subcommittee
LEC = Law Enforcement Committee
CRFAP = Comm/Rec Fishery Advisory Committee
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

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Section 10.0	All
Section 11.0	All
Section 12.0	Staff
Section 13.0	All

2.5 Goal

The goal of the Menhaden FMP is to provide a management strategy for Gulf menhaden that estimates an annual maximum harvest while allowing protection of the stock from overfishing on a continuing basis.

2.6 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 of Mexico.
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/industry and to suggest management strategies and options required to solve problems and meet the needs of the stock.

3.0 DESCRIPTION OF THE STOCK COMPRISING THE MANAGEMENT UNIT

3.1 Biographical Description, Management Unit, 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) (Page et al. 2013). 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*), also occur. 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, 1.0-1.3 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 1.05-1.30 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 as well as 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 18.9-58.4 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."

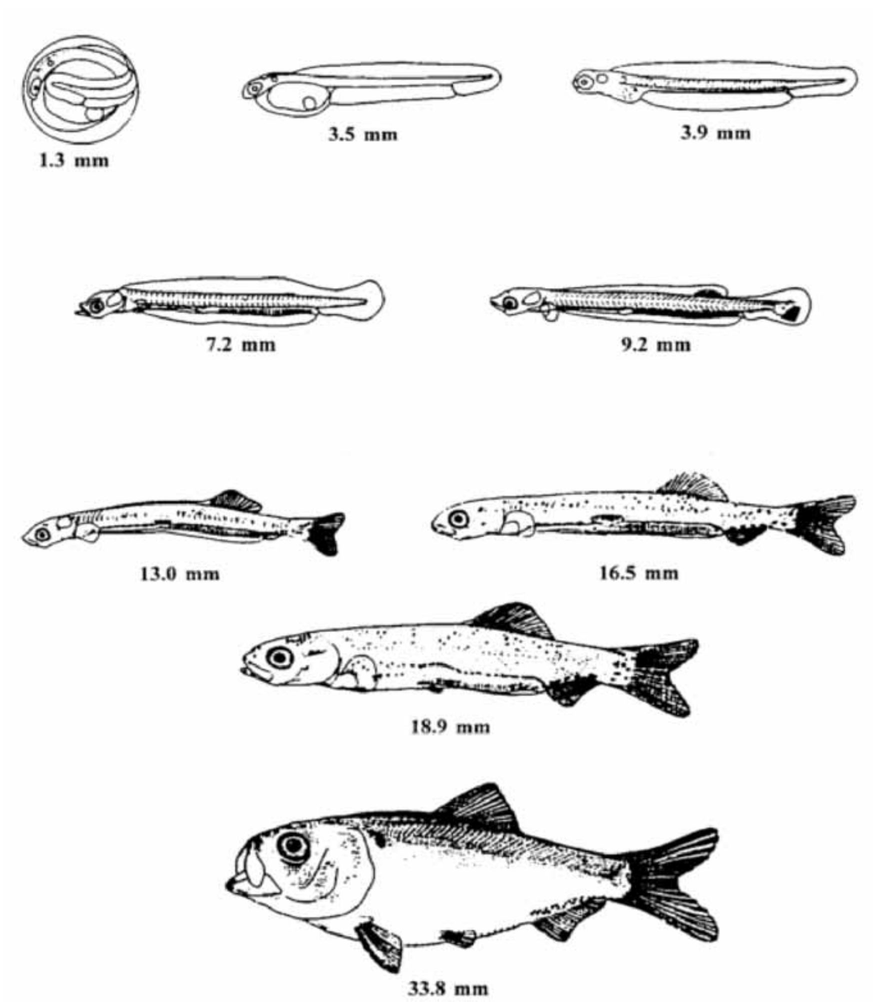


Figure 3.1. Developmental stages of Gulf menhaden at specified lengths (*from* Hettler 1984).

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 (36-50 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).

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

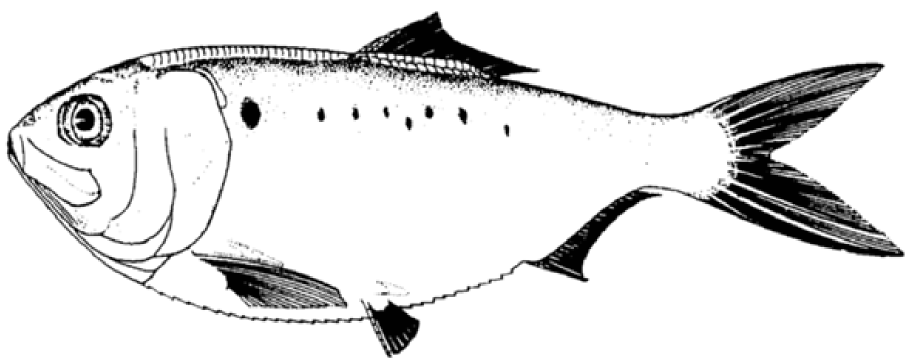


Figure 3.2 Adult Gulf mehaden (*from* Fischer 1978).

longer intestine in Gulf menhaden. These differences lead to significant dietary differences and resource partitioning between the two species.

3.1.2 Management Unit

Gulf menhaden predominate in the reduction purse-seine fishery in the Gulf of Mexico with other menhaden species representing less than 1% of the annual catch (Ahrenholz 1981). Considering that *B. patronus* is the only significant species in the fishery and is biologically considered to be a unit stock in the Gulf, the management unit in this FMP will be defined as the total population of *B. patronus* in the U.S. Gulf of Mexico.

3.1.2.1 Genetics

Genetic studies suggest a single unit stock of Gulf menhaden in the northern Gulf of Mexico. In the western Gulf (Figure 3.3), a single population of *B. patronus* has been identified using mtDNA (Anderson 2007). Anderson and McDonald (2007) noted that the Gulf menhaden and the finescale menhaden, two sympatric species, may hybridize occasionally; however, the evidence is limited to a single individual sampled from Texas waters showing introgression. In the eastern Gulf, results from Anderson and Karel (2007) indicate that unidirectional gene flow has occurred between Gulf and Atlantic menhaden, with flow coming from the southeastern Gulf

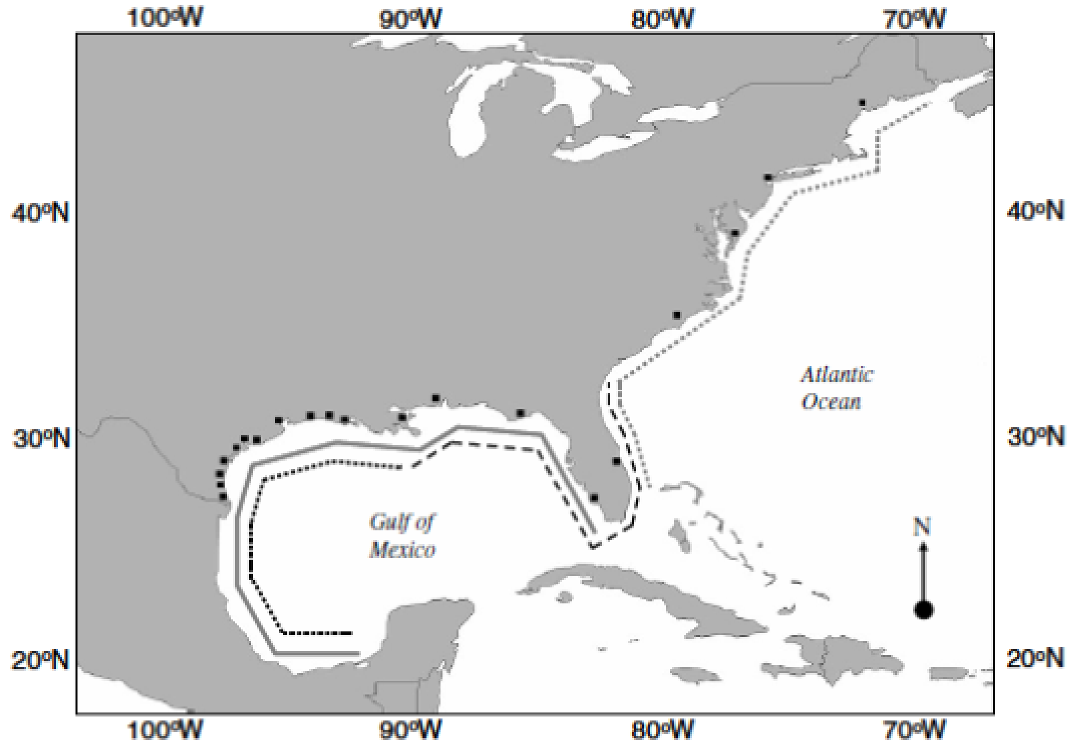


Figure 3.3 Geographic range of the four menhaden species: Gulf menhaden (*Brevoortia patronus*) - smooth gray line, Gulf; Atlantic menhaden (*B. tyrannus*) - dotted gray line, Atlantic; fine-scale menhaden (*B. gunteri*) - dotted black line, western Gulf; and yellowfin menhaden (*B. smithi*) - dashed black line, eastern Gulf. Sample sites are indicated by black boxes (*from* Anderson 2007).

into the Atlantic and reaching as far north as the Indian River Lagoon, Florida. Gene flow in the reverse direction – Atlantic to the Gulf - has not been identified.

Anderson (2006) measured genetic stock structure with extensive sampling across the range of the fishery and found little evidence of genetic structure that would indicate the presence of multiple stocks. Instead, stock structure in Gulf menhaden is more accurately described by an isolation-by-distance model, in which measurable genetic structure is shown to be largely a function of the upper limits on dispersal of individuals within a stock. In this model, genetic distance among samples is expected to increase linearly with geographic distance, which was demonstrated by Anderson (2006). While the specimen sampling was adequate, the study was limited in scope by a small genetic sample. In particular, five DNA microsatellites were assayed, with one of the five being removed due to stability/reliability issues identified prior to analysis. A mitochondrial DNA (mtDNA) locus was also assayed to test repeatability of the pattern found in the microsatellite data set, and a similar pattern (single stock) was indeed found. With new, more sensitive genetic analyses, scientists may be able to discover more detailed genetic differentiation among samples of *B. patronus* across the Gulf.

Along Florida's Panhandle, Turner (1969) found extensive hybridization and introgression between Gulf and yellowfin menhaden. Hybridization is so common that the FWC now only identifies menhaden to the genus level in their fishery-independent sampling (R. McMichael personal communication). Anderson (2006) reported that from Charlotte Harbor, Florida, 1 in 30 individuals was a Gulf and yellowfin menhaden hybrid. In summary, Anderson (2006) noted that:

> "There appears to be no organized structure of Gulf menhaden populations which would indicate distinctive genetic 'stocks' delineated by geographic boundaries… Samples of Gulf menhaden taken from southern Texas to southern Florida are not significantly different, and variation across the entire northern Gulf of Mexico exhibits only a modest degree of genetic isolation by distance. It appears that the very large and semi-migratory spawning aggregates of Gulf menhaden have resulted in high Gulf-wide genetic variation which demonstrates only a limited geographic component."

3.1.3 Geographic Distribution

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).

3.1.3.1 Biogeographical Break

The hybridization zone east of the Mobile River is further supported in additional literature. An overlapping region usually defines the geographical separation between two closely related species. The northern Gulf of Mexico is no exception, with general separation occurring at the Mississippi River, or to the east, at Mobile Bay. It is postulated, that the glacial melting within these two watersheds provided a fresh water barrier extending out into the Gulf of Mexico (Hoese and Moore 1998, McEachran and Fechhelm 1998). Increased winter and spring river flows coming out of Mobile Bay provided a boundary that determined species composition due to sediment type and nutrient load. Additionally, the Loop Current moving north and then easterly along the Florida panhandle adds to a boundary that explains species distributions (Hoese and Moore 1998). Brackish water collections of *Brevoortia* in the bays of Alabama to the Florida line have yielded only *B. patronus*, with no mention of *B. smithi* (Boschung et al. 2004, Mette 1996). The distribution of *B. patronus* is reported as rare east of Pensacola, Florida and that of *B. smithi* being limited to the west by the Chandeleur Sound (Hoese and Moore 1998, McEachran and Fechhelm 1998, Walls 1975). Providing an equidistant division of the overlapping region (Fort Morgan, AL, 88ºW) based on a biogeographical break, provides an equal probability of including and excluding each species.

3.1.3.2 Migration and Movement

Gulf menhaden are generally estuarine, shallow-water fishes, and, while some age-0 (YOY) fish may overwinter in estuaries (Turner and Johnson 1973, Deegan 1985), the overwhelming majority of juveniles and adults migrate offshore throughout summer and fall, although the extent of that 'offshore' range is uncertain. 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. Roithmayr and Waller (1963) reported catches of adult Gulf menhaden from December-February in the northern Gulf from 4-48 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. Christmas and Gunter (1960) reported capturing Gulf menhaden in mid-water trawls at depths ranging from 40-55 fathoms, although in very low numbers. Likewise, some menhaden have been reported in the SEAMAP bottom trawl sampling throughout the northern Gulf of Mexico, but in very low numbers and infrequently (SEDAR 2013).

Gulf menhaden do not exhibit extensive east/west migrations, and generally, older adults are believed to occur near the center of the population's range (the central coast of Louisiana and around the Mississippi River Delta). Ahrenholz (1981) tagged 38,445 Gulf menhaden from 1970-1972 using ferromagnetic tags from southeast Texas to the Florida Panhandle. Juveniles were tagged in estuaries during late summer or early fall just before emigration and adults were obtained, tagged, and released from the commercial fishing grounds during late spring. Those tags were subsequently recovered later in the year on magnets in the reduction factories during processing of the catch. Because reduction vessels at that time tended to fish more intensively in the area near their home ports, most tags recovered at a specific port were assumed to have been from fish caught in the waters closest to that port. Ahrenholz (1981) concluded that fish first entered the fishery primarily in the same geographic area in which they were tagged. As fish aged, there appeared to be a slow movement of fish from eastern and western fishing grounds toward the Mississippi River Delta. Fish tagged in the two most western areas (southeast Texas and Galveston) were captured in greater numbers their second year after release at the two most central ports in Louisiana (Morgan City and Dulac).

Likewise, Pristas et al. (1976) tagged about 76,000 adult Gulf menhaden from 1969-1971 using internal metallic tags, which were also recovered on magnets at the various reduction plants. Adult fish were tagged and released from commercial vessels operating on the menhaden fishing grounds. They noted very little east/west movement of adults as many of the returns were from plants near the release sites. Second-year returns showed the same pattern with little east/west mixing. Most of the adult fish that had moved offshore to over-winter returned to the areas where they had been released the previous season.

3.2 Biological Description

The following is a summary of the published information to date on the general life history of Gulf menhaden. There is very limited recent research on the biology and reproduction of this species.

3.2.1 Reproduction

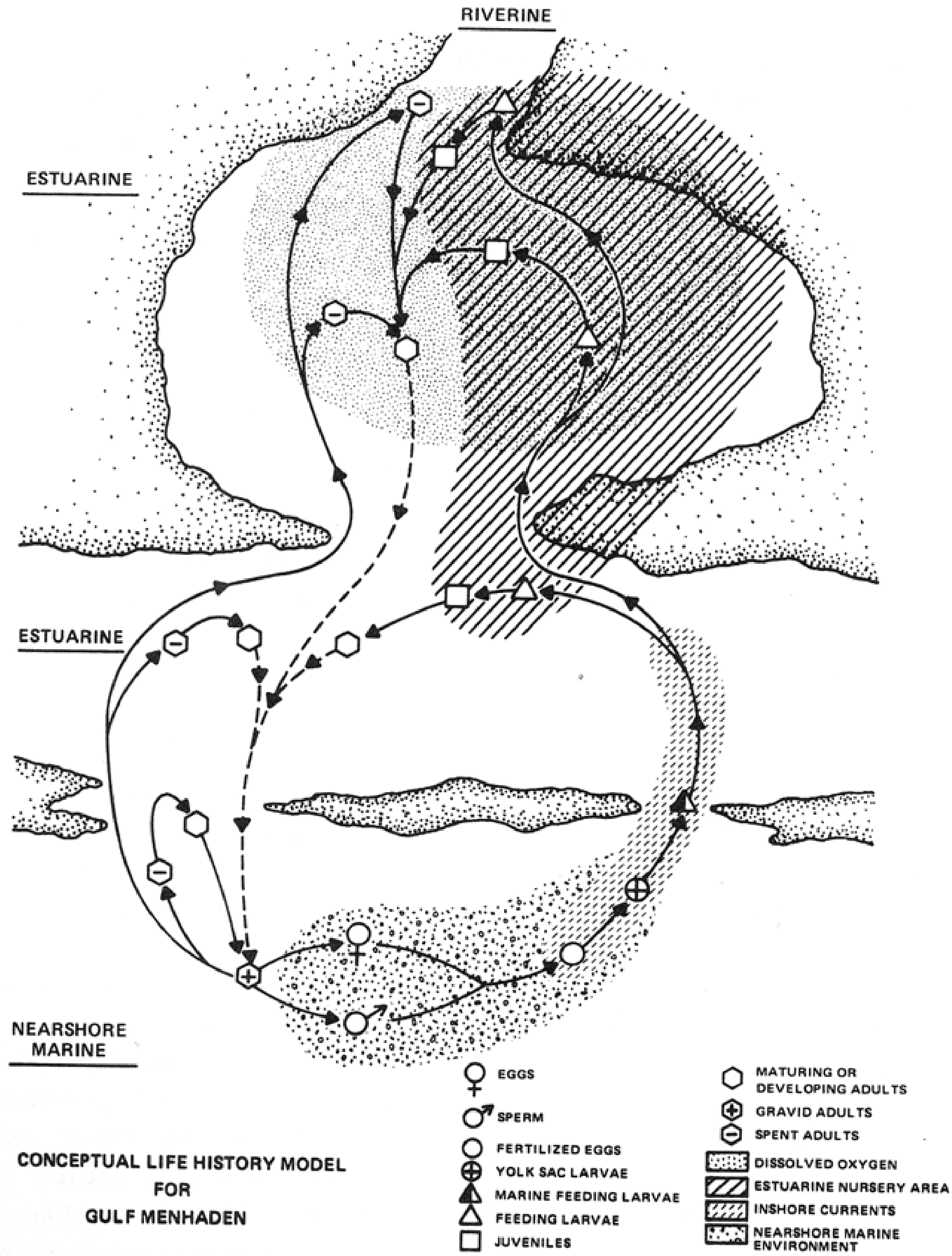


Figure 3.4 Conceptual life history model for Gulf menhaden. Dissolved oxygen indicates areas of potential depletion (from Christmas et al. 1982).

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 3.4.

3.2.1.1 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).

3.2.1.1.1 Spawning Season

Data presented by numerous researchers corroborate that Gulf menhaden spawn 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). Akin et al. (2003) examined seasonal and spatial variations in ichthyofauna in a Texas estuary and found that Gulf menhaden recruit to the upper estuary during winter and spring, which was consistent with offshore spawning during late autumn.

Hernandez et al. (2010) sampled ichthyoplankton off the coast of Alabama from 2004-2006 and reported similar occurrence of larval menhaden to those summarized by Ditty et al. (1988). However, the seasonality of spawning in the north-central Gulf of Mexico appears to be slightly shorter in duration with the majority of larvae collected from October – March.

3.2.1.1.2 Courtship and Spawning Behavior

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

3.2.1.1.3 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 in the fall and winter. The duration of individual batch spawns has not been reported.

3.2.1.1.4 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 (ca. 8-70 m) contours off Texas and Louisiana and near the Mississippi River 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 10-23 m isobaths and at temperatures and salinities of 15-18EC and 30-36 ppt, respectively. Christmas and Waller (1975) found highest egg densities at temperatures >15EC and salinities >25 ppt.

3.2.1.2 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 et al. (2007) estimated that total fecundity for the entire stock of spawners in the 1964-2004 data set varied from 7.9-164.9 trillion eggs with an average fecundity of approximately 24,450 eggs per mature female, somewhat higher than the average fecundity for age-2 Gulf menhaden (22,100). Fecundity increased with length and age, but since numbers of older fish constitute only a small fraction of the overall spawning population, age-2 fish contributed the bulk of stock fecundity. The results of SEDAR32A (SEDAR 2013) suggest that from 1977 to 2011, the highest annual fecundity occurred in 2008 and 2009 at 69.3 and 77.1 trillion ova respectively. The average for the last decade (2002-2011) was about 51.3 trillion ova produced. The average fecundity per mature female for the past decade (2002-2011) was about 23,273 eggs per mature female; however, significantly higher numbers of age-3s in 2009 and age-4s in 2010 associated with the strong 2006 year class inflated the decade's average slightly. The average number of eggs per mature female over the whole SEDAR32A dataset (1977-2011) was 21,490.

3.2.1.3 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 19-20EC (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 18.5-19.0EC (Reintjes 1962). Hettler (1968) reported a hatching time of 38-39 hours for eggs of yellowfin menhaden fertilized with sperm of Gulf menhaden and held at 19.5-21.5EC. 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.

3.2.1.4 Larval Transport

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.

Tolan (2008) examined the annual variability of ichthyoplankton in Neuces Bay, Texas. The Neuces River tends to be more saline than most Gulf estuaries, due in part to the impoundment of the river by the Lake Corpus Christi Reservoir, resulting in greatly reduced flow rates. Tolan hypothesized that the occasional flood events in the river may create a 'recruitment barrier' to most larval fishes attempting to move into the upper reaches of the estuary where lower salinity waters normally exist. However, the study found that transforming juveniles (<32mm SL) collected each spring were competent swimmers and seemed to overcome any 'barriers' at the river discharge zone to move into the upper estuary nursery areas, relying less on passive transport than active migration, even against higher flow rates.

3.2.2 Recruitment

Recruitment of Gulf menhaden, or year class strength, is influenced by numerous factors that include annual and seasonal variation in environmental conditions, prevailing currents, and adult stock densities, or combinations of these factors. Cushing (1969) concluded that clupeid stocks are particularly prone to variations in recruitment because of the importance of environmental conditions on their early life history. Since Gulf menhaden are short-lived and the fishable stock is essentially comprised of two age classes, these variations are powerful controls that can either reduce or enhance recruitment depending on the timing and magnitude of each variable. A major influence on recruitment in the Gulf of Mexico is the flow of the Mississippi River, which is at the center of the geographical range for Gulf menhaden. Several studies have examined environmental parameters, such as salinity and water temperatures, which are directly related to river flow and seemingly drive menhaden recruitment in the Gulf.

Guillory et al. (1983) examined the environmental variables associated with Mississippi River discharge in an effort to make predictions of year class strength and forecast recruitment success for management purposes. Using multiple regression models with catch-per-unit effort of age-1 Gulf menhaden, Guillory (1993) found that the discharge of the Mississippi River ranked behind water temperature in January, southeast wind speed in January, salinity in March, and tidal amplitude in January as affecting recruitment. Generally, Guillory et al. (1983) noted that relatively 'cold, dry' winters were associated with good recruitment, whereas 'warm, wet' winters were associated with poor recruitment. He also reported that many of the variables measured were highly inter-correlated and therefore, using only temperature and discharge may be an oversimplification of the recruitment process. He stated,

> "The 'cold, dry' winter is characterized not only by low temperatures and low rainfall but also by low tide levels, low Mississippi River discharge, high salinity, low wind speeds, and a low incidence of southeast winds. Besides high temperatures and high rainfall, the 'warm, wet' winter is characterized by high tide levels, high Mississippi River discharge, low salinity, high wind speeds, and a high incidence of southeast winds" (Guillory et al. 1983).

Similarly, Govoni (1997) examined Mississippi River flow and menhaden recruitment. He found an inverse association when the combined average monthly discharge rate of the river during the period of shoreward transport was compared against the numbers of half-year old (age-0) Gulf menhaden recruits. More often than not, when river discharge increased from year to year, recruitment declined. He suggested that the increased river discharge results in a more expansive plume or frontal zone that serves as a barrier to shoreward transport of larvae; this may increase their vulnerability to predation and, therefore, reduce recruitment, growth, and survival. Deegan (1990) found similar results west of the Mississippi River.

Vaughan et al. (2000) updated Govoni's (1997) recruitment/discharge relationship with a regression analysis, while Vaughan et al. (2007) revisited this relationship with additional years of data through 2004. They found the inverse relationship still valid. In addition, they reframed this relationship to produce a one-year-ahead predictive model for forecasting recruitment to age-1 from Mississippi and Atchafalaya river flows for consideration in fishery management. The authors tested the usefulness of river flow in the previous Gulf menhaden stock assessment model (Vaughan et al. 2007); they found that the model was improved significantly by inclusion of river flow data. The authors speculate that one-year-ahead forecasts may be possible, especially during years with large changes in river flows. Other untested environmental factors may also improve the model, including air/water temperatures or prevailing seasonal winds, factors also noted by Guillory et al. (1983) as highly correlated variables.

The relationships between recruitment of Gulf menhaden and river discharge found by Guillory et al. (1983), Govoni (1997) and Vaughan et al. (2011) focus on portions of the year when young menhaden, after hatching, are moving from offshore to inshore shelf waters. Generally, these studies found an inverse relationship between river discharge and recruitment on an annual scale. And, Govoni (1997) noted a shift to increasing numbers of menhaden after 1975 in years of high river flows, which suggested that other factors (e.g., nutrients leading to increased food availability) in addition to discharge may be important for recruitment in this species over decadal scales.

Sanchez-Rubio and Perry (2013), in a more comprehensive review of climate data (precipitation and Palmer Drought Severity Index along the Gulf coast), found three distinct climate regions in the Gulf of Mexico. In their study, the eastern region consisted of peninsular Florida, the central region included the Florida Panhandle and extended through Louisiana, and the western region included Texas. Earlier, Sanchez-Rubio et al. (2011) examined decadal [Atlantic Multidecadal Oscillation (AMO), Pacific Decadal Oscillation (PDO), North Atlantic Oscillation (NAO)] and annual (ENSO) climate regimes affecting hydrology in the northern Gulf of Mexico and related juvenile blue crab abundances, in Louisiana and Mississippi, to global climate factors and their effect on regional hydrology. Sanchez-Rubio and Perry (2013) found the same response by early juvenile Gulf menhaden to the two dominant climate-related hydrological regimes they identified in the earlier study: a wet regime from 1973-1994 (AMO cold, NAO positive) and a dry regime from 1997 - present (AMO warm, NAO negative). Years of high juvenile Gulf menhaden abundance occurred during the wet years when AMO and NOA were coupled (cold and positive). Years of decreasing abundance occurred during the dry period when AMO and NAO were inverted (warm and negative).

3.2.3 Growth

Hettler (1984) reported a hatching size of 2.6-3.0 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 after 11 days and 11.9 mm TL after 27 days post-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 water 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 26EC. In the laboratory at 18-22EC, 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 12.9E-21.2EC. Based on larval samples, ranging from 3.4-28.0 mm SL at 5-62 days old, 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 (16EC) and 0.042 mm/day (24EC).

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.

Gulf menhaden larvae were reported to be six-ten weeks of age 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-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 88-103 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 0.8-1.0 mm/day for large juveniles in warmer waters.

Gulf menhaden spawn between October and April, with peak activity from December through March (Turner 1969, Fore and Baxter 1972) with scale annuli forming in the first winter. Therefore, January 1 is used as the 'arbitrary' birth date for each 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, YOY 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 125-150 mm FL.

Growth of adult Gulf menhaden has been described by Nelson and Ahrenholz (1986). Initial growth is rapid and continues through age-3. Adult menhaden reach approximately 170 mm FL at age-2 and 200 mm FL at age-3, but then growth slows with individuals reaching approximately 225 mm FL at age-4 and about 235 mm FL by age-5. Gulf menhaden may reach a maximum age of 5-6 years (Ahrenholz 1991); however, fish older than age-4 are rare in commercial catches (J. Smith personal communication).

3.2.4 Age Determination

In 1964, the National Marine Fisheries Service (NMFS) at the Beaufort Lab (formerly the U.S. Bureau of Commercial Fisheries) began monitoring the Gulf menhaden purse-seine fishery for size and age composition of the catch (Nicholson 1978). From the outset, program managers realized that using otoliths to age Gulf menhaden was impractical because 1) sagittal otoliths were so small and fragile, and 2) large amounts of time and effort would be required to extract, process, and read whole or sectioned sagittae. Moreover, large numbers of ageing parts (> ca. 10,000) would be required to adequately characterize the fishery with annual landings of several hundred thousand metric tons. Thus, scales were selected for Gulf menhaden ageing.

Chapoton (1967) determined that scale development on Gulf menhaden began on larval specimens at ca. 21 mm FL and was complete in specimens > ca. 27 mm FL. Gulf menhaden scales are generally thin and translucent (Figure 3.5). Unlike most herrings, the posterior margin of Gulf menhaden scales is pectinate or serrated. The anterior field is embedded in the integument. The entire scale is sculptured with fine circuli, which are roughly semi-circular and parallel the anterior and lateral margins. The largest and most symmetrical (nearly rectangular) scales occur in a median lateral band above the lateral line and below the dorsal fin. Scale samples for ageing are removed from this area, mounted between microscope slides, and are viewed on an Eberbach macro-projector at 48x magnification. Annuli are defined as compressions or interruptions of uniformly spaced circuli in the anterior field of the scale, which are continuous through the lateral fields. Under transmitted light, age rings form narrow, continuous, dark bands roughly paralleling

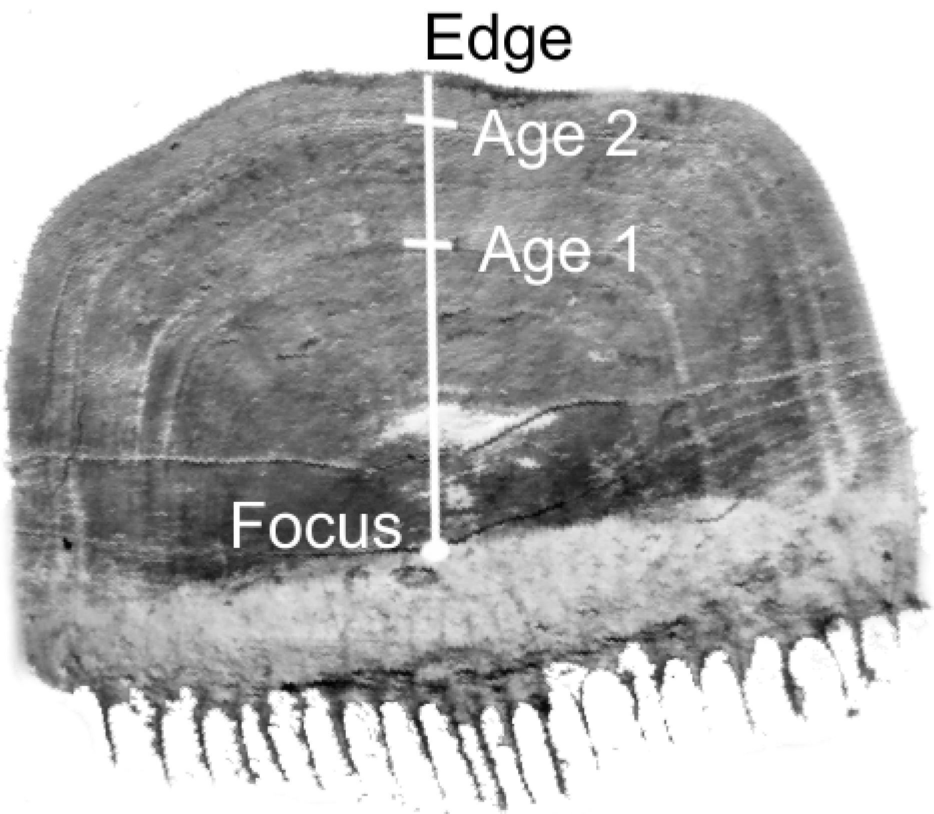


Figure 3.5 Scale sample from age-2 Gulf menhaden (NOAA Beaufort Lab).

the lateral and anterior margins of the scale. A focus is arbitrarily chosen near the center of the posterior field at the base of the circuli. Straight-line measurements are made from the focus to successive scale rings and the scale edge.

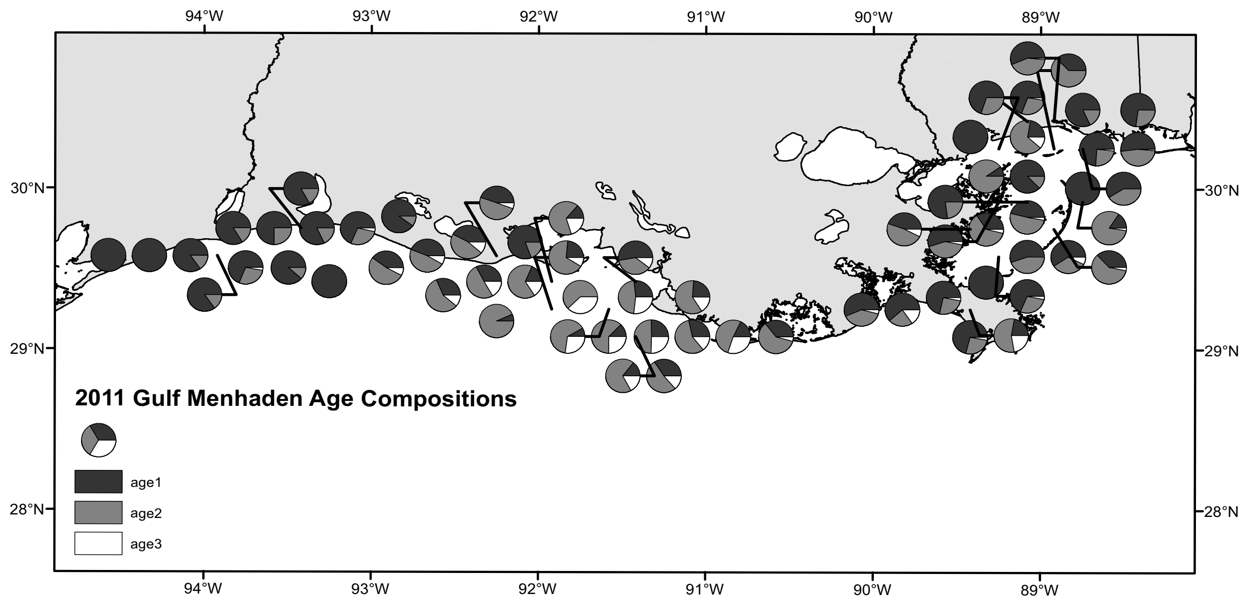
Nicholson and Schaaf (1978) found that ageing Gulf menhaden with scales was problematic; citing that only about 50% of the fish examined during 1971-1973 could be aged by scale annuli. They determined that many fish had well-defined scale rings, but others had no rings or rings that were oddly spaced. Their criteria for scale ageing were based on appearance of the scales, number and spacing of the rings, and fish fork length at time of capture. Although admitting some subjectivity, they determined that fish with one or two scale rings displayed true annuli. For fish with oddly-spaced rings, it was possible to separate out age classes by ring location. Finally, for fish with no discernible rings, they believed age could be estimated by length frequency distributions.

In an attempt to increase the probability of encountering legible scales with true annular rings, Menhaden Program personnel at the Beaufort Lab, in the early 1990s, instructed port agents to mount ten scales for ageing per specimen versus the previous directions to mount six scales. Percent legibility increased; for example in fishing year (2003), 86% (6,780 of 7,839) of Gulf menhaden scale samples had legible annular rings (compared to ca. 50% by Nicholson and Schaaf [1978]; see above). Age assignments based on ring spacing and/or length frequencies were only required for 14% of the samples.

Tagging studies in the 1970s suggest older and larger Gulf menhaden tend to move closer to the center of their range, that is, toward the central coast of Louisiana (Ahrenholz 1981).

Nevertheless, age proportions by specific area may vary because of many factors including incoming year class strength. Raw (unweighted) age proportions of port samples in 10'X10' cells of latitude and longitude are shown in Figure 3.6 for 2011 and 2012.

Confirmatory literature citations of maximum size of Gulf menhaden are lacking. Chapoton (1972) summarized information on the Gulf menhaden fishery and reported the largest specimen sampled through the early 1970s was 247 mm FL (296 g). Hoese and Moore (1998) report the maximum size of Gulf menhaden at about 10 inches (250 mm). Maximum fork length (FL) of Gulf menhaden as recorded in the NMFS biostatistical data bases through 2012 is 308 mm FL (n = 520,583); maximum weight of Gulf menhaden from the same data bases is 571 grams (n = 520,583) (SEDAR 2013). More realistic values for maximum size might be based on 99th



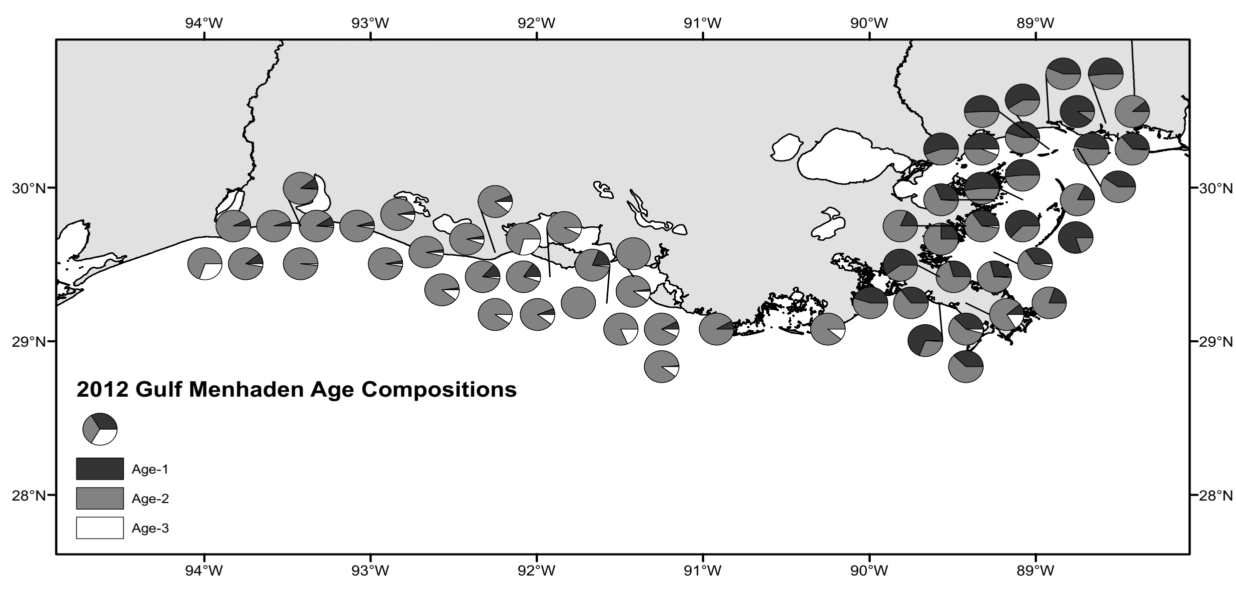


Figure 3.6 Pie diagrams of "raw" (unweighted) age compositions of 2011 and 2012 Gulf menhaden port samples by 10' x 10' cells of latitude and longitude; age-1 = black, age-2 = dark gray, age-3 = white (NOAA Beaufort Lab unpublished data).

percentiles of those values, e.g., 213 mm for fork length and 203 grams for weight (SEDAR 2013). Documentation on maximum size of Gulf menhaden may be confounded by the presence of its larger congeners in the eastern (*B. smithi*) and western (*B. gunteri*) Gulf of Mexico (Ahrenholz 1991).

3.2.5 Parasites and Disease

Pasteurella spp. is a nonmotile, gram negative bacterium 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.

3.2.6 Foraging

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). Peck (1893) concluded that adult menhaden are indiscriminate feeders and take in materials in the same proportions as they occur in ambient water. However, some studies suggest that adult menhaden can be relatively selective in their feeding.

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 narrower-meshed filter allowing them to retain uni-cellular algae; whereas, the finescale consumes mainly larger zooplankters.

Durbin and Durbin (1975) examined the feeding behaviors of Atlantic menhaden in the laboratory, offering varying sizes and densities of both phytoplankton and zooplankton to test fishes. They reported that, initially, menhaden 'gulped' their mouths and flared their opercula, which the authors attributed to 'tasting' the water. If the fish determined that food was in inadequate concentrations, then they would cease the activity. However, at some threshold level of food, the menhaden fed almost immediately, depending on the food and quantity provided test fish began a feeding frenzy, swimming very rapidly in tight formation with their mouths open wide and their opercula flaring. As the abundance of food particles were reduced, the fish decreased their swimming speed, although they continued to feed. The authors described these behaviors for both phytoplankton and zooplankton. They did note that when copepods and newly hatched *Artemia salina* were offered, the fish showed a prolonged period of frenzied feeding and quickly reduced zooplankton concentrations to very low levels.

Kemmerer (1980) described large-scale schooling behaviors in Gulf menhaden using aerial photography and catch location data from the commercial fleet. He also examined concurrent satellite imagery to measure turbidity and chlorophyll-a concentrations in the areas near the menhaden schools. Kemmerer (1980) noted that menhaden were distributed throughout the sampling area with no discernable pattern based on temperature, salinity, or chlorophyll-a. Working with the assumption that adult Gulf menhaden are strict filter feeders, he was surprised to find no relationship to phytoplankton abundance:

> "The lack of a consistent relationship between menhaden catch and chlorophyll concentrations was perplexing… the distribution of these fish and their food supply (phytoplankton or the planktonic organisms that feed on phytoplankton) was expected" Kemmerer (1980).

Kemmerer (1980) suggested that as filter feeders, Gulf menhaden have potential to lessen the effects of eutrophication locally, but this is dependent on feeding selectivity.

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). In addition, menhaden have yeast in their gut, *Pichia spartinea*, which aids in the breakdown of zooplankton exoskeletons and other crustaceans. The exoskeletons could provide menhaden with a source of carbohydrate energy and nitrogen (Deegan et al. 1990).

Deegan et al. (1990) examined the use of *Spartina* detritus by Gulf menhaden as a food source during their estuarine residence. Utilizing stable isotopes and cellulase activity, they estimated the amount of *Spartina* in the diet by comparing the difference in larvae and juvenile weights to determine growth. They suggested that 30-40% of the juvenile diet may be derived either directly or indirectly from marsh plants. *Spartina* detritus could be utilized by Gulf menhaden as another carbohydrate energy source. They suggested that "one role of detritus in the diet of menhaden may be as a caloric supplement to increase the efficiency of digesting other richer food types, such as zooplankton."

Olsen et al. (2014) examined stable carbon (^{13}C) and nitrogen (^{15}N) isotope ratios traced through coastal food webs to determine the trophic level of Gulf menhaden and their role in the northern Gulf of Mexico ecosystem. The study examined incorporation of ^{13}C and ^{15}N isotopes into the menhaden diet. Previous studies (Fry 1988, Vander Zanden et al. 1999) have shown that ^{13}C enrichment can be used to determine the carbon source in the food web and nitrogen (^{15}N) enrichment can be used to identify the foraging trophic level. The 'source' of the isotopes, therefore, provides insight into temporal, spatial, and ontogenetic variation of the consumer in the local environment. Olsen et al. (2014) determined that juvenile menhaden in the upper estuaries have a larger component of terrestrial-based detritus as the source carbon than older sub-adult fish farther from the lower parts of the estuary and offshore. The authors suggest that juvenile menhaden are 'trophically balanced' between a phytoplanktivore and zooplanktivore with an opportunistic feeding strategy based on the available food sources but did proportionally consume two to three times more phytoplankton than larger menhaden. Sub-adults and adults were also omnivorous but consumed phytoplankton and zooplankton based on the availability of larger sized prey in the ecosystem, resulting in post-juvenile menhaden moving further out of the estuary to where more appropriate sized prey were found.

Durbin and Durbin (1998) showed that when large schools of Atlantic menhaden migrate into Narragansett Bay, Rhode Island, in summer, their numbers may be sufficient to significantly reduce the abundance of larger phytoplankton and zooplankton locally. They also noted that excretion of nitrogen by these large schools of menhaden may increase the abundance and growth of smaller phytoplankton in the system. Jeffries (1975) examined the fatty acid composition of the stomachs of juvenile Atlantic menhaden in Narragansett Bay and found that very little detritus was consumed and approximately 70% of the diet was zooplankton.

Recent work by Lynch et al. (2010) examined consumption by Atlantic menhaden and removal rates of nitrogen from Chesapeake Bay. Their laboratory experiments examined the foraging capacity and removal of plankton by YOY and age-1+ menhaden. Juveniles consumed a large number of small phytoplankton (<7µm), while the age-1+ fish did not. The authors conducted a second experiment, introducing zooplankton to the tanks in order to evaluate ingestion rates among the age-1+ fish. They noted that the age-1+ menhaden may have had normal feeding had larger phytoplankton been introduced into the original experiment instead of just small phytoplankton. Similar distinction regarding prey size by size class of menhaden was noted by Durbin and Durbin (1975).

Further support for the dependence of adult Atlantic menhaden on zooplankton is provided by Friedland et al. (2011). Their work in the York River, Virginia, indicates that, while some phytoplankton are consumed by adult menhaden, zooplankton such as nauplier copepods, are critical in the diet to meet the energetic requirements of the adults. Menhaden movements into the York River and Chesapeake Bay were correlated with their foraging behavior in areas of high densities of zooplankton. The timing of the migration into and out of the Bay also correlated well with the abundance of zooplankton and not phytoplankton. Additionally, the authors found menhaden absent in the York River during periods when harmful algal blooms (HABs) dominated that system.

3.2.7 Predator/Prey Relationships

Because of their great abundance and schooling behavior (Section 3.2.8), 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 documented in the Gulf.

Menhaden eggs and larvae are potential food for various filter-feeding and larval fishes and invertebrates including but not limited to other clupeids, chaetognaths, coelenterates, mollusks, and ctenophores (Clements 1990, Ahrenholz 1991). While Nelson et al. (1977) suggested that menhaden are 'known' to cannibalize their own eggs and larvae, there is little empirical evidence for this.

Fishes that have been shown to consume 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).

In addition to fish, marine mammals have been reported as predators of menhaden (Hildebrand 1963). Leatherwood (1975) observed dolphins feeding on schools of 'baitfish'; although the prey were not actually identified, they were believed to be Gulf menhaden. Leatherwood (1975) also documented several learned behaviors by dolphins opportunistically using fishing-related activities for potential food sources. Common bottlenose dolphins (*Tursiops truncatus*) in the northern Gulf were documented using coordinated behaviors to capture and feed on Gulf menhaden (Fertl and Wursig 1995). de Silva (1998) reported that dolphins may take advantage of commercial purse-seining operations by the reduction fishery. On several occasions, dolphins were observed inside the purse nets while they were being set, but had successfully escaped the net before the purse crew had completed closing the wings of the nets (de Silva 1998).

Piscivorous birds that consume menhaden include brown pelicans, *Pelecanus occidentalis* (Gunter and Christmas 1960, Palmer 1962), osprey, *Pandion haliaetus* (Spitzer 1989), common loons, *Gavia immer* (P. Spitzer unpublished manuscript), and terns (Culliney 1976). Brown pelicans are frequently found in the Gulf circling and diving on schools of menhaden. The commercial reduction fleet often relies on observations of feeding pelicans to locate schools. In turn, pelicans will opportunistically aggregate near commercial purse nets as they are retrieved and are often found perched on the float line waiting for fish to be consolidated in the net (de Silva 1998).

Recent observations by Spitzer (unpublished manuscript) indicate that large aggregations of common loons overwinter in the northern Gulf of Mexico coastal waters. The loons appear to focus feeding activities on schools of Gulf menhaden as they migrate back into near-shore waters in early spring. He describes the event as 'flock-feeding', where loons feed in large aggregations (100+ individuals) in the passes between the Mississippi barrier islands for about a month beginning in mid-February. He has witnessed similar behavior on the Atlantic Coast, where flocks of loons dive from the surface and feed on age-0 menhaden schools, pursuing them from below to trap them at the surface.

3.2.8 Behavior

A 'shoal' of fish is defined as a social group of individual fish choosing to stay with individuals of the same species. 'Schooling' behavior in fishes is a type of shoaling which is characterized by highly synchronized and polarized behavior (Pitcher and Parrish 1993). There are many hypotheses for shoaling and schooling behaviors in fish: improved hydrodynamics, increased foraging efficiency, predator avoidance, predator confusion, and structural refuge. Pitcher and Parrish (1993) provided a literature review on shoaling and schooling in fishes and discussed the advantages of these social behaviors in foraging and 'anti-predation'. They noted that shoaling fish tend to have thin, deep body shapes, and are typically silver in color. They suggest that the synchronous movements of a school may cause fish being pursued by predators to temporarily disappear as they turn away, which serves to confuse the predator.

In terms of the definitions above provided by Pitcher and Parrish (1993), Gulf menhaden are shoaling fish that tend to remain in relatively large, tight schools when foraging and migrating. The reason for this behavior in Gulf menhaden is uncertain. Perhaps, as an open-water species where no spatial refuge exists (Pitcher and Parrish 1993), schooling behavior creates refuge. Other factors such as hydrodynamics, predator avoidance/confusion, and foraging efficiency, no doubt also play roles in menhaden schooling behavior.

Simple arithmetic, using readily available fisheries statistics, allows for a crude estimate of number of individuals per average school of Gulf menhaden. For instance, in 2009 the median catch of Gulf menhaden in successful purse-seine sets was 18.3 mt. Also for 2009, the mean weight of Gulf menhaden in the port samples was 124.5 g. Thus, about 150,000 individual Gulf menhaden were harvested from a purse-seine set of median size in 2009 (NOAA Beaufort Laboratory unpublished data).

Schooling in Gulf menhaden 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). These schools can become extremely large and may include as little as 10,000 and up to 150,000 or more individuals. 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 (Guthrie and Kroger 1974, Overstreet 1978).

Higgs and Fuiman (1996) investigated the effect of changing light intensity as a cue for 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 menhaden's eyes to capture light determined the threshold light intensities to initiate and maintain the school.

4.0 DESCRIPTION OF THE HABITAT OF THE STOCK COMPRISING THE MANAGEMENT UNIT

4.1 Description of Essential Fish Habitat

The Gulf States Marine Fisheries Commission (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 (Gulf). Later summaries include those of Jones et al. (1973), Becker and Brashier (1981), Holt et al. (1982), GMFMC (1998), and Felder and Camp (2009). 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 (Figure 4.1). 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.

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). Four of the ten largest commercial fishing ports in the United States are located in the Gulf and accounted for an estimated 1.35 billion lbs of harvested fish and shellfish in 2011 or 14% of the nation's total commercial landings (USDOC 2012).

Gulf Coast wetlands, estuaries, and barrier islands also provide important feeding, breeding, and cover habitat to wildlife species (such as waterfowl, shorebirds, and wading birds), improve water quality, and play a significant role in lessening flood and storm surge damage and minimizing erosion.

4.2.1 Circulation Patterns and Tides

Planktonic larvae of Gulf menhaden, as well as larvae of other estuarine-dependent species, 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 (Figure 4.1). The Loop Current transports massive quantities of water (700,000 840,000 m^3/sec; Cochrane 1965) upon entering the Gulf through the Yucatan Channel.

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 Current 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, large anticyclonic eddies about 300 km in diameter often separate from the main Loop Current. These warm core eddies originate as pinched-off northward penetrations of Loop Current meanders. In the following months, the eddies migrate westward at about four km/day until they reach the western Gulf shelf where they slowly disintegrate 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 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 hours) existing from St. Andrew 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. Normal tidal ranges in the Gulf are 0.3-0.6 m. Despite the small tidal range, tidal current velocities are occasionally high, especially near the constricted outlets that characterize many bays and lagoons.

4.2.2 Sediments

Two major sediment provinces exist in the Gulf of Mexico: 1) carbonate sediments found predominantly east of the Desoto Canyon and along the Florida west coast and 2) terrigenous (“derived from land sources”) sediments commonly found west of the Desoto Canyon and into Texas coastal waters (GMFMC 1998). Bottom sediments are coarse in nearshore waters extending northward from the Rio Grande River to central Louisiana and are the dominant bottom type in

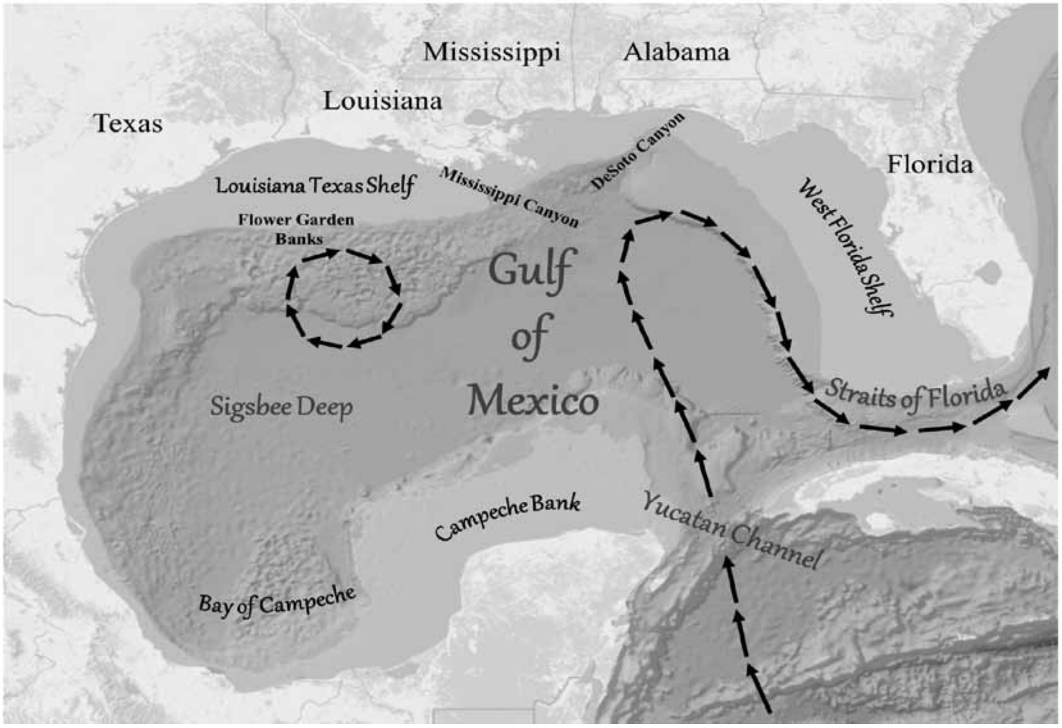


Figure 4.1 Generalized circulation pattern in the Gulf of Mexico. Also included are some geologic features of the Gulf of Mexico including shallower continental shelf regions and geologic breaks such as DeSoto Canyon off the panhandle of Florida and Mississippi Canyon on the Mississippi River Delta.

deeper waters of the central Gulf. Fine sediments are common in the northern and eastern Gulf and south of the Rio Grande because of riverine influence, particularly the Mississippi and Rio Grande rivers. Fine sediments are also found in deeper shelf waters (>80 m).

4.2.3 Submerged Vegetation

Submerged vegetation comprises 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). The distribution of seagrasses in the Gulf is asymmetrical with an estimated 98.5% along the Florida and Texas coasts; 910,000 ha of seagrasses are 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 Duke and Kruczynski 1992 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 unevenly distributed along the Gulf Coast. Marshes in the Gulf of Mexico consist of several species of marsh grasses, succulents, mangroves, and other assorted marsh complements. The Texas coastline is home to an estimated 247,670 ha of fresh, brackish, and salt marshes. Emergent plants 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 southernmost reaches of Texas also have a few isolated stands of black mangrove (*Avicennia germinans*).

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 complement 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 home to 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 among 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%) (GMFMC 1998).

4.3.1 Eastern Gulf

Gulf menhaden range throughout the eastern Gulf of Mexico to Tampa Bay, although they tend to be replaced in abundance by yellowfin menhaden, *B. smithi*, in the eastern part of their range (Section 3.1.3). The eastern Gulf 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, sandy beaches situated either on barrier islands or on the mainland. 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 Tampa Bay and vicinity, 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 turbid, nutrient-rich plume water (where photosynthesis is light-limited) with clear, nutrient-poor, Gulf of Mexico water (where photosynthesis is nutrient-limited), creating good conditions for phytoplankton growth (GMFMC 1998).

4.3.2 North-Central Gulf

The north-central 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. Annual wetlands loss along the Louisiana Coastal Zone for the period of 1978-2000 was estimated to be 7,744 ha/yr (Barras et al. 2004) and accounted for 90% of the total coastal marsh loss in the US (USACOE 2004). The shoreline of the western 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, beaches, seawalls, and brackish-freshwater marshes in the coastal rivers. Approximately 26,000 ha of mainland marsh existed in southern Mississippi in 1968 and salt marsh on the barrier islands covered 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 of low salinity, nutrient-rich, and turbid due to the high rainfall and subsequent discharges of the Mississippi, Atchafalaya, and other coastal rivers. The Mississippi River deposits approximately 150 million metric tons of sediment annually near its mouth, while the lower Atchafalaya River deposits about half this amount annually (Walker 1994). As a consequence of the large fluvial nutrient input, the Louisiana nearshore shelf is considered one of the most productive areas in the Gulf of Mexico. Average discharges (2002-2006) for the Mississippi and Atchafalaya rivers were 13,610 m^3/sec and 5,830 m^3/sec, respectively (Battaglin et al. 2010).

4.3.3 Western Gulf

Lesser quantities of Gulf menhaden are harvested along the shores of the western Gulf. The shoreline of the western Gulf includes approximately 612 km of open shoreline and contains 3,528 km of bay-estuary-lagoon shoreline along the Texas coast. 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 seagrasses cover 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).

Climate along the Texas coast ranges from humid on the upper coast, where average rainfall is 55 inches, to semi-arid on the lower coast, where rainfall averages about 25 inches. This wide range of annual rainfall results in a salinity gradient along the coast. For instance, in Sabine Lake, salinity ranges from 4-14ppt, but in the Laguna Madre, salinity ranges from 26ppt to well over 50ppt.

Upper coast bay systems are heavily influenced by the rivers that empty into them. They are typified by turbid water; silt, mud, and clay bottoms; abundant oyster reefs; and are bordered by extensive intermediate marshes with large stands of emergent vegetation. South of Corpus Christi, the hypersaline Laguna Madre with its clear water, sandy bottom, and extensive seagrass beds, represents the other end of the spectrum. Along the central Texas coast lie the San Antonio, Aransas, and Corpus Christi bay systems that represent a transition between the extremes of the upper and lower Texas coasts.

4.4 General Conditions

Upon entering estuaries, Gulf menhaden 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 (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.

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.

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 spring and were associated primarily with open water, non-vegetated bottom and, to a lesser degree, with the marsh edge at salinities of 9.3-9.8ppt. They occurred in the same habitat in 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. Likewise, Akin et al. (2003) conducted seasonal and spatial surveys of fish and macro-crustaceans around Mud Island Marsh in Matagorda Bay, Texas, and determined that Gulf menhaden were the most abundant in the upper reaches of the bay where there were higher abundances of detritus from widgeon grass (*Ruppia maritima*) which dominated the marsh.

4.5 Environmental Preferences

Fish 'habitat', in the simplest terms, is the combination of the environmental conditions required for survival of a species or a life history stage (Baltz 1990). Gulf menhaden have varying environmental requirements based on their particular life history stage being addressed. While any one condition may be less than optimal, the combination of these parameters and the availability of food or shelter in close proximity to those environmental conditions, determines where a larval or juvenile menhaden will survive and grow.

4.5.1 Salinity

Offshore spawning necessitates that Gulf menhaden eggs and larvae be euryhaline. Gulf menhaden eggs and larvae have been collected in waters with salinities ranging from 6-36ppt (Fore 1970, Christmas and Waller 1975); 88% of the eggs were collected from waters over 25ppt.

Collections of eggs and larvae were made throughout the Gulf of Mexico at the peak of spawning, from waters ranging in salinity from 20.7-36.6 ppt (Table 4.1; Christmas et al. 1982). As the larvae move inshore, they require low salinity waters to complete metamorphosis from the larval body form to the deeper–bodied juvenile/adult form. 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 availability and lower salinities. Combs (1969) found that gonadogenesis occurred only in menhaden larvae that arrived in euryhaline, littoral habitats.

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 that young menhaden enter upper marshes with salinities around 0.9ppt 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 that juvenile Gulf menhaden were most frequently collected in primary rivers and secondary streams at salinities ranging from 0-15 ppt. 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 among young Gulf menhaden and both freshwater and low salinity, brackish areas in the upper Barataria Basin of Louisiana.

Akins et al. (2003) examined fish and macro-crustacean assemblages in Matagorda Bay, Texas, and noted that Gulf menhaden were found in highest abundance during winter and spring in the upper marshes where salinities and temperatures were reduced and dissolved oxygen (DO) was elevated. Tolan and Nelson (2009) determined that, after examining a number of abiotic factors in three tidal streams in the Matagorda Bay estuary, salinity was the driving factor in determining fish assemblages. Juvenile and sub-adult Gulf menhaden were the most abundant species in all three tidal creeks over the course of their study and community responses were based on the prevailing salinity regime more than dissolved oxygen.

Turner (1969) collected eggs and larvae from stations off northern Florida at surface water temperatures ranging from 11.0°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).

Recent observations by Haley et al. (2010) found larval and juvenile menhaden 79 river miles upstream on the Alabama River, near the Claiborne Lock and Dam. Although the authors did not record station salinities, the drought situation that occurred during their sampling season may have pushed the salt wedge upstream, and consequently associated ichthyoplankton, farther upriver than during ‘normal’ years.

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

Life History Stage	Salinity (ppt)	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

4.5.2 Temperature

Gulf menhaden occupy a wide range of habitats; therefore, temperature may be more critical to egg development than to juveniles and adults, although Gulf menhaden are occasionally victims of large fish kills related to freeze events (Hildebrand and Gunter 1951, McEachron et al. 1994).

Larval and juvenile menhaden have been collected in Gulf estuaries at temperatures ranging from 5-35°C (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. Likewise, juvenile and adult menhaden suffer cold-kills during periods of freezing winter conditions, especially in narrow or shallow tidal areas.

McEachron et al. (1994) documented one such cold-kill in Texas. In December 1983, the entire Texas coast suffered a freeze that was one of the most severe in recorded history. Water temperatures dropped about 15°C in about 10 days to near 0.0°C and remained between 0.0-5.0°C for about seven days. Two more cold-kill events occurred in February of 1989 and December of 1989 which resulted in additional widespread fish kills. Coast-wide, about 980,000 Gulf menhaden died in 1983 and around 600,000 died in the two freezes of 1989. Gulf menhaden that succumbed to the cold ranged in size from 80-130 mm TL.

Cold-kills of Gulf menhaden are less common in the central northern Gulf. Overstreet (1974) suggests that:

> "Lack of proper acclimation probably determines why mass mortalities occur more frequently in Texas and Florida than in Mississippi. Fishes in Mississippi, living in water normally cooler than in Texas, are necessarily acclimated to lower temperatures. Consequently, a sudden drop to near-freezing levels would affect those fishes less."

Tolan (2008) surveyed ichthyoplankton in Nueces Bay, Texas, which tends to be more saline than most Gulf estuaries due in part to the impoundment of the river by the Lake Corpus Christi Reservoir, resulting in greatly reduced flow rates. He hypothesized that large freshwater inflow events early in the year may prevent larvae from entering the uppermost reaches of the Bay's lower salinity waters. His results indicate that the transforming juvenile menhaden were able to navigate the higher flows and enter the nursery areas up-bay. This was likely a response to increased food availability as primary production increased in the low salinity upper reaches.

4.5.3 Dissolved Oxygen (DO)

Dissolved oxygen (DO) is a critical factor in determining fish survival, and quite possibly recruitment success. Periods of low DO (hypoxia) or no DO (anoxia) can kill young fish that are unable to migrate from affected areas, especially summer when high water temperature combined with plankton blooms contribute to hypoxic conditions (see Section 4.7.1). Mass fish mortalities, which include Gulf menhaden, attributed to low DO concentrations have occurred in most Gulf estuaries (Crance 1971, Christmas 1973, Etzold and Christmas 1979). Recent fish kills of juvenile Gulf menhaden in Gulf Coast estuaries that have been noted in the popular press include mortalities at Choupique Bayou, Louisiana (August 2011), Bay Chaland, Bay Joe Wise, and Bayou Robinson in Plaquemines Parish, Louisiana (September 2010), and Weeks Bay, Alabama (July 2010).

Post-larvae and juveniles are frequently killed by anoxic conditions in backwaters (e.g., dead-end canals) during summer. 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 nearshore Gulf waters may serve to concentrate schools of Gulf menhaden closer to shore as they avoid hypoxic areas known as the 'dead zone'. The 'dead zone' results from increased levels of nutrient influx from freshwater sources coupled with high summer water temperatures, strong salinity-based stratification, and periods of reduced mixing (Justic et al. 1993).

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 midsummer (Smith 2001). The close association that Gulf menhaden have with estuaries during summer tends to decrease the effects these offshore hypoxic areas have on the population.

4.6 Habitat Elasticity

O'Connell et al. (2004) examined the fish assemblages that occurred in the Lake Pontchartrain estuary from 1950-2000 using museum specimens and collections. Over the 50 years of records, they found that, although the estuary had deteriorated substantially in environmental quality, Gulf menhaden were unchanged in their frequency and position within the estuary while other species had changed substantially. Overall, the assemblage shifted from a croaker-dominated complex to an anchovy-dominated complex, suggesting that Gulf menhaden are very elastic in their ability to handle short and long-term environmental changes (O'Connell et al. 2004).

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

Environmental factors that affect recruitment and survival are generally viewed as density-independent. These factors include physical processes, for example transport mechanisms, water temperature, dissolved oxygen, freshwater inflow, and nutrient loadings. Biological factors, such as amount of food and competition for food, or predation by higher trophic levels, which control survival and growth of young-of-the-year menhaden prior to recruitment to the fishery, can be either density-independent or density-dependent. Environmental factors can also affect the fishing process itself.

In general, maximum survival of Gulf menhaden 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 directly impact recruitment and the overall fishery significantly. 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 the northern Gulf. 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) yet support 28% of the national fisheries harvest, the largest fur harvest in the U.S., the largest concentration of overwintering waterfowl in the U.S., and provide the majority of the recreational fisheries landings (Turner 1990).

4.7.1 Eutrophication

Eutrophication, stimulated by inadequately controlled nutrient inputs, supports excessive phytoplankton blooms, which contribute to the development of hypoxic/anoxic conditions. Excessive algae and plankton growth may have a negative effect in some estuaries, while light to moderate inputs of nutrients may enhance primary productivity where biological potential is limited (Kirby and Miller 2005). Eutrophication can contribute to increased incidences of toxic or harmful algal blooms (HABs), especially dinoflagellates.

4.7.1.1 Hypoxia and Anoxia

Anoxic bottom conditions are unreported 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). Postlarvae and juveniles are frequently killed by anoxic conditions in backwaters (e.g., dead-end canals) during summer. 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 nearshore Gulf waters may serve to concentrate schools of Gulf menhaden closer to shore as they avoid hypoxic areas known as the 'dead zone' (Figure 4.2). The 'dead zone' results from increased levels of nutrient influx from freshwater sources coupled with high summer water temperatures, strong salinity-based stratification, and periods of reduced mixing (Justic et al. 1993). Most life history stages of Gulf menhaden, from eggs to adults, occur inshore (i.e., inshore of the 18m depth contour) of areas where historically the hypoxic zone 'sets up' by midsummer. Gulf menhaden appear to be only moderately susceptible to low DOs in the Gulf proper 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 midsummer (Smith 2001). The close association that Gulf menhaden have with estuaries during summer tends to decrease the effects these offshore hypoxic areas have on the population. Most notably, the age compositions of commercial port samples, in recent decades, have shown trends toward older fish (age-2s) in the landings. While this could be a signal for relatively weak incoming year classes, it is believed that this may be the result of a redistribution over time of age-1 fish toward most 'inside' waters (due to marsh habitat loss) where they become unavailable to the fishery, and possibly a 'corralling effect' that hypoxic waters in the Gulf might have on the distribution of Gulf menhaden (Smith 2001). Cowan et al. (2008) points out that in Louisiana, the largest commercial fisheries are species spawned in winter or early spring and are, therefore, less affected by periods of hypoxia and the 'dead zone'.

4.7.1.2 Algal Blooms

Algal blooms occur when algal species reproduce rapidly and overwhelm a water body. This can be caused by several factors or combinations of factors including increased nutrient input, increasing water and air temperatures, longer and more direct sunlight, or even a reduction in other planktonic competitors or predators. Algal blooms are a frequent occurrence throughout most estuarine systems including those in the Gulf of Mexico and include hundreds of species of phytoplankton and cyanobacteria. One example in the Gulf is the *Aureoumbra lagunensis* bloom

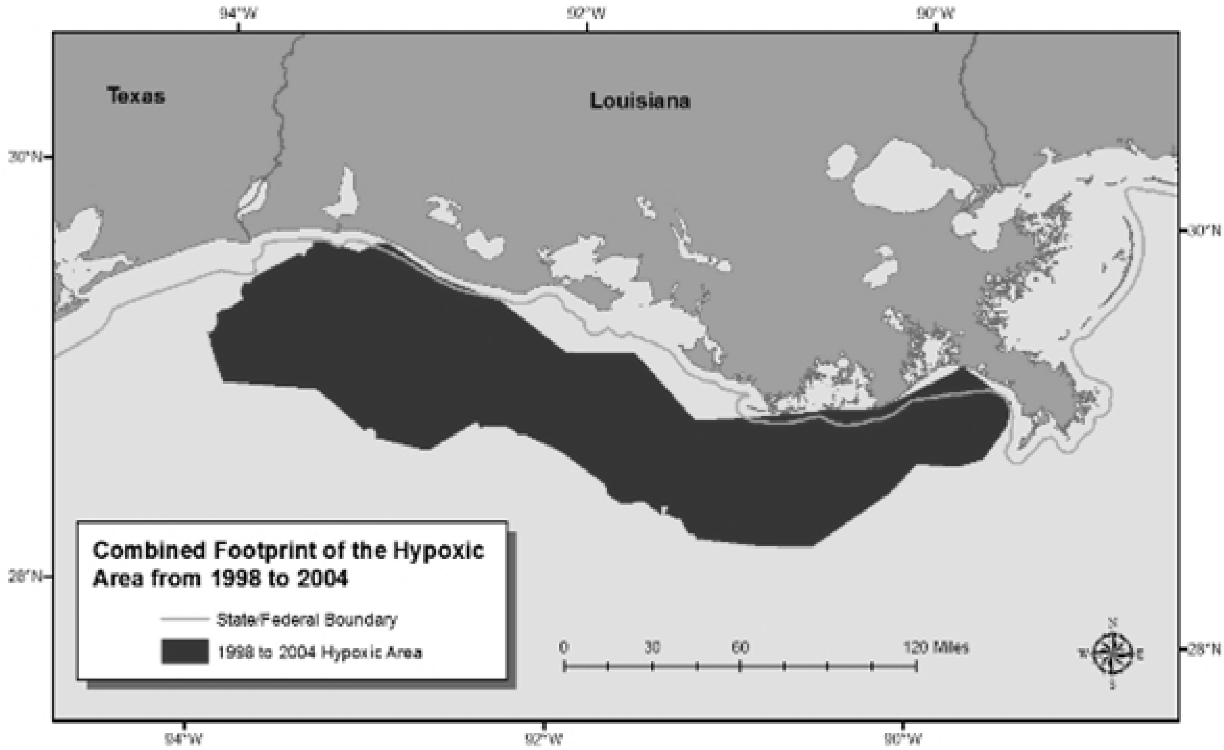


Figure 4.2 Map of the Gulf of Mexico showing the combined footprint of the Hypoxic Area or 'Dead Zone' for the period 1998-2004 (NOAA Beaufort Lab unpublished data).

commonly referred to as 'brown tide,' which occurred in Texas from late 1989 through 1997 (Buskey 2008). This species is unique to the Gulf of Mexico and was first noted in the Laguna Madre, a hypersaline bay that stretches 120 miles from Corpus Christi to Port Isabel. The brown tide can withstand a wide range of salinities and temperatures and is named, in part, by the fact that during a bloom, the water appears brown, taking on the color of the algae. While brown tide is not necessarily toxic to fish, it may affect larval growth and menhaden distribution due to its low nutritional value and its ability to increase turbidity and reduce penetration of sunlight (Boesch et al. 1997).

4.7.1.2.1 Harmful Algal Blooms (HABs)

Most algal blooms are typically non-toxic to marine organisms, but as noted above, large blooms can change the environment in such a way as to negatively impact certain organisms. Noteworthy are a few blooms which are toxic to nektonic species that come into contact with them. As in other blooms, harmful algal blooms (HABs) occur naturally throughout the Gulf of Mexico, especially during summer. Typically, excessive nutrient run-off carried from locations upstream in adjacent watersheds can result in large, widespread occurrences of HABs in the northern Gulf. The most common of these events is frequently referred to as 'red tide.'

Red tide events in the Gulf are common, 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 was recorded in 1844 (Ingersoll 1882); subsequently, they were recorded at least 24 times from 1854 to 1971 (Steidinger et al. 1973).

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

In fall and winter of 1996, unprecedented toxic algal blooms occurred in the northern Gulf of Mexico resulting in significant finfish mortalities from Texas to Florida. Best estimates indicate that three to four million finfish were killed in 1996 and 22 million in 1997 in Texas waters by the ‘red tide’; Gulf menhaden ranked high among fish species killed (McEachron et al. 1998). Additional fish kills were documented in other Gulf States as well. This particular bloom was caused by a naturally occurring alga named *Karenia brevis,* which occurs in low concentrations in the Gulf. Brevetoxin is the toxic compound produced and released by red tide cells and affects finfish and other organisms at different thresholds.

There are other hazardous algal blooms in the northern Gulf including blue-green algae, flagellates, and other dinoflagellates (Steidinger 1998). Some of these produce breve-like toxins, domoic acids, and other compounds which affect fish and other marine 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.

Regarding localized menhaden distributions and HABs, Friedland et al. (2011) observed that Atlantic menhaden abundance in the York River in lower Chesapeake Bay declined, despite a high abundance of suitable prey, because of a bloom of an ichthyotoxic dinoflagellate, *Cochlodinium polykrikoides*, which maintained densities known to be lethal to fish for one month.

4.7.2 Tropical Weather Impacts

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 (Figure 4.3). El Niño is characterized by a lessening 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 (NAS 2000). These conditions may have an impact on freshwater inflow patterns into the Gulf of Mexico and could ultimately affect menhaden distribution, recruitment success, and can influence oil yield from the reduction fishery. In many parts of the world, fish migration has been attributed to El Niño (Arntz and Tarazona 1990, Bakun and Broad 2003).

The effects of La Niña are nearly opposite that of El Niño and are characterized by a warmer than normal winter in the southeast United States. This provides favorable conditions for a strong hurricane season. Likewise, these abnormal conditions may influence fish migration and occurrence in the Gulf of Mexico (Lewis et al. 2011).

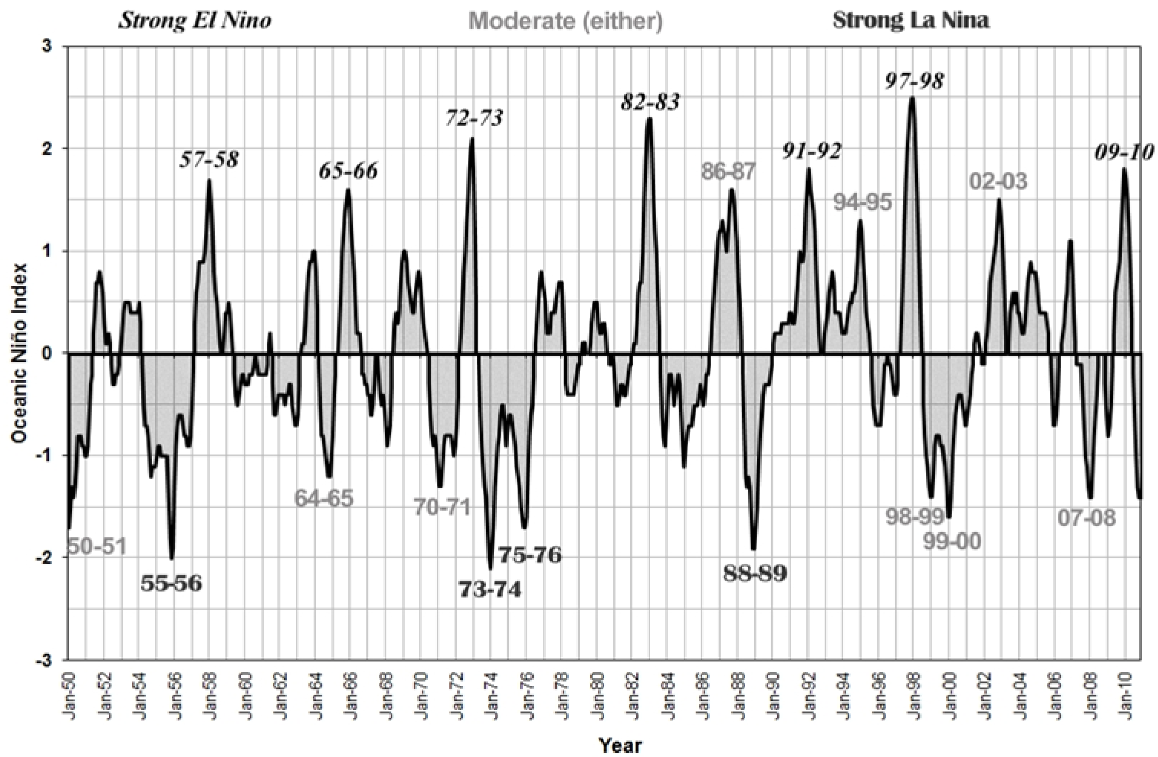


Figure 4.3 Warm (positive) and cold (negative) episodes based on a threshold of +/- 0.5°C for the Oceanic Niño Index (ONI) based on the 1971-2000 base period. For historical purposes, cold and warm episodes are defined when the threshold is met for a minimum of five consecutive over-lapping seasons (NOAA/NWS 2012).

Tropical storm and hurricane damage to coastal property is a recognized physical and monetary threat to the states located along the Gulf Coast. For the first time since records have been kept, over $100 billion in economic loss was estimated in 2005 when Hurricanes Cindy, Dennis, Katrina, Wilma, Rita, and Tropical Storm Arlene made landfall in the Gulf of Mexico. These increasing economic losses over time can be correlated to the loss of protective coastal wetlands. Costanza et al. (2008) estimated that the coastal wetlands of the United States provide $23.2 billion per year in storm protection services. Each hectare of coastal wetland lost corresponds to an average of $33,000 of increased damage from specific storms. Louisiana alone lost $816 million per year of wetland services prior to Hurricane Katrina and an additional $34 million were lost due to Hurricane Katrina. These values emphasize the need to protect and restore coastal wetlands. Due to the importance of low salinity habitat found in emergent marsh systems, the continued loss of this habitat could also have negative consequences for Gulf menhaden populations that require these areas as nursery habitat.

In addition, the Gulf menhaden fishing season frequently reflects the tropical activities during a particular year (Figure 4.4). 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. In 2005, the high frequency of storms and the direct impacts to the fleet and fishery from hurricanes Katrina and Rita virtually eliminated fishing after August. Other factors tied to tropical systems, such as water visibility for spotter planes, can affect the ability of the fleet to fish. It should be noted that many of these environmental parameters and events described in this section are probably related with each other, possibly mediated through such processes as El Niño and La Niña events.

4.7.3 Climate Change

Climate change could have many consequences for most U.S. coastal and marine ecosystems, and some of the consequences may substantially alter human dependencies and interactions with these complex and linked systems. The climatic effects will be superimposed upon and interact with, a wide array of current stresses, including excess nutrient loads, overfishing, invasive species, habitat destruction, and toxic chemical contamination. While the ability of these ecosystems to cope with or adapt to climate change or variability is compromised by extant stresses, the inverse is also likely to be true. Ecosystems will be better suited to deal with climate variability and change if other stresses are significantly reduced.

Climate change may result in higher water temperatures, stronger stratification, and increased inflows of freshwater and nutrients to coastal waters in many areas. Both past experience and model forecasts suggest that these changes will result in enhanced primary production, higher phytoplankton and macroalgal standing stocks, and more frequent or severe hypoxia.

Natural biological and geological processes should allow responses to gradual changes, such as transitions from marsh to mangrove swamp as temperatures warm, as long as environmental thresholds for plant survival are not crossed. Accelerated sea level rise also threatens these habitats with inundation, erosion, and saltwater intrusion. Over the last 6,000 years, coastal wetlands

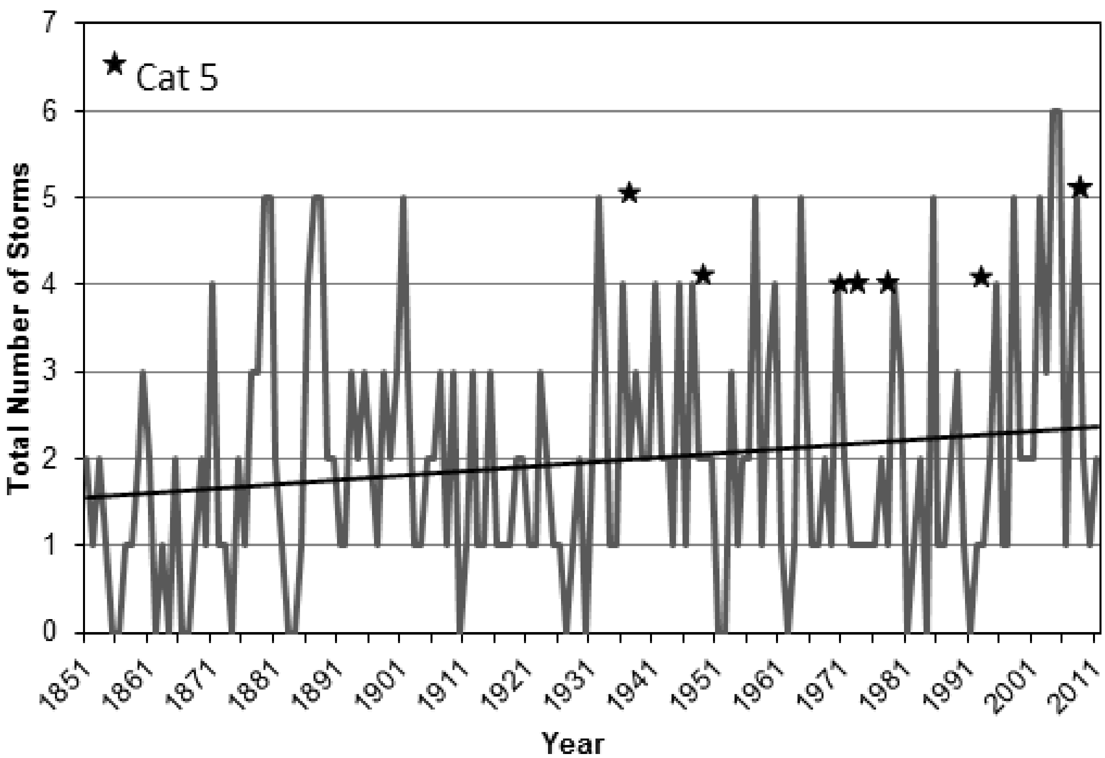


Figure 4.4 Number of tropical storms and hurricanes in the northern Gulf of Mexico, 1851-2011. Star indicates Saffir-Simpson Hurricane Wind Scale category 5 storm.

expanded inland as low-lying areas were submerged, but often did not retreat at the seaward boundary because sediment and peat formation enabled them to keep pace with the slow rate of sea level rise. If landward margins are armored, effectively preventing inland migration, then wetlands could be lost if they are unable to accumulate substrate at a rate adequate to keep pace with future increased rates of sea level rise.

Increased air, soil, and water temperature may also increase growth and distribution of coastal salt marshes and forested wetlands. For many species, including mangroves, the limiting factor for the geographic distribution is not mean temperature, but rather low temperature or freezing events that exceed tolerance limits (McMillan and Sherrod 1986, Snedaker 1995). The Gulf of Mexico is a prime candidate for mangrove expansion to occur because it is located at the northward limit of black mangrove habitat (Comeaux et al. 2012). This may come at the expense of *Spartina* spp. dominated marshes. Historically, small populations of black mangroves have been present in Louisiana in the extreme southern portion of the state. Black mangrove distribution was limited by cold winter temperatures. Black mangrove populations are now expanding in southern Louisiana's *Spartina* dominated marshes (Perry and Mendelssohn 2009). Caudill (2005) found that blue crabs were collected in higher abundances in mangrove areas in south Louisiana sites than at adjacent *Spartina* sites.

Fodrie et al. (2010) sampled seagrass areas previously sampled in the 1970s in Mississippi, Alabama, and northern Florida to compare the ichthyofauna between the two time periods. The comparison showed several new species including lane snapper, red grouper, and yellowtail snapper (*Ocyurus chrysurus*). Several other species showed large increases in abundance between 1979 and 2006, including gag grouper and mangrove snapper. The researchers also observed increased air and sea surface temperatures, which they theorize have led to northern shifts in the distribution of these warm water fish. Fodrie et al. (2010) found that nearly 20% of the fish species collected in northern Gulf of Mexico seagrass meadows during 2006–2007 were tropical or subtropical and had been nearly absent in the 1970s data. Fodrie et al. (2010) conclude that the presence of these fish may be an early indicator for the extension of tropical conditions in the northern Gulf of Mexico.

Changes in the timing and volume of freshwater delivery to coastal wetlands will also be critical, yet perhaps the most difficult to assess. In contrast to uncertainties associated with regional impacts of climate change on hydrology, it is clear that increased human population and coastal development will create higher demands for freshwater resources. While increased freshwater is likely to decrease osmotic stress and increase productivity, less freshwater may increase salinity stress. Wetlands may accommodate gradual increases in salinity as salt and brackish marshes replace freshwater marshes and swamps, although sustained or pulsed changes in salinity can have dramatic negative effects. *Panicum hemitomon,* a typical freshwater marsh species, grew at a reduced rate in water of 9ppt salinity in one study (McKee and Mendelssohn 1989) and had reduced carbon assimilation at 5ppt in another (Pezeshki et al. 1987).

Climate change will likely influence the vulnerability of estuaries to eutrophication in several ways, including changes in mixing characteristics caused by alterations in freshwater runoff, and changes in temperature, sea level, and exchange with the coastal ocean (Kennedy 1990, Peterson et al. 1995, Najjar et al. 2000). A direct effect of changes in temperature and salinity may be seen through changes in suspension feeders such as mussels, clams, and oysters. The abundance and distribution of these consumers may change in response to new temperature or salinity regimes and they can significantly alter both phytoplankton abundance and water clarity (Alpine and Cloern 1992, Meeuwig et al. 1998, NRC 2000).

Increased anthropogenic nutrient loading and a changing climate will make coastal ecosystems more susceptible to the development of hypoxia through enhanced stratification, decreased oxygen solubility, increased metabolism and remineralization rates, and increased production of organic matter. All these factors related to global change may progressively result in an onset of hypoxia earlier in the season and possibly an extended duration of hypoxia.

4.7.4 Anthropogenic Habitat Impacts

Many of the factors that 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 was approximately 12% of the total estuarine and marine wetland losses from 1986-1997 (Dahl 2000). Louisiana marshes are disappearing at a rate of about 7,744 ha/yr (Barras et al. 2004) and account for 90% of the total coastal marsh loss occurring in the nation (USACOE 2004). 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, marinas, and maintenance dredging for navigation; 2) discharges from wastewater plants and industries; 3) dredge and fill for land development; 4) agricultural runoff; 5) ditching, draining, or impounding wetlands; 6) oil spills; 7) thermal discharges; 8) mining, particularly for phosphates and petroleum; 9) entrainment and impingement from cooling operations associated with industrial activities; 10) dams; 11) alteration of freshwater inflows to estuaries; 12) saltwater intrusion; and, 13) nonpoint source discharges of contaminants (Lindall et al. 1979). In addition, erosion and subsidence also contribute to loss of coastal wetland habitats, though these processes are exacerbated by some of the above human activities.

4.7.4.1 Wetland Impoundment and Water Management

More than 50% of the population of the U.S. lives within 50 miles of a coast and development to support this population (dams, levees, and navigation projects) is a major factor in the loss of coastal wetlands along the Mississippi River and its major tributaries. These activities have resulted in a 67% decrease in the amount of sediment delivered to these Gulf coastlines (USEPA 2005). Other factors contribute as well, including sea level rise, coastal subsidence, and erosion. Most of the coastal wetland loss occurred in the Gulf of Mexico from 1998-2004 (25,010 ha/year). 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 (Dahl 1990, Turner 1990). These wetlands support 28% of the national fisheries harvest, the largest fur harvest in the United States, the largest concentration of overwintering waterfowl in the United States, and provide the majority of the recreational fishing landings (Turner 1990). Coastal wetlands encompass many habitats that provide areas for spawning, nursery, shelter, and food for finfish, shellfish, birds, and other wildlife (NRC 1997, Stedman and Dahl 2008).

Marsh loss, wetland impoundments, and saltwater intrusion are critical topics in regard to management of estuarine-dependent species such as Gulf menhaden. Subsidence, eustatic sealevel rise, and erosion due to storms and wave/wind action are naturally occurring factors, but these can be exacerbated by human activities. Such activities include levee construction along the lower Mississippi River (which eliminated the major source of sediment introduction to marshes), canal construction, dredge and fill activities, and land reclamation. In addition, damming tributaries to the Mississippi River led to a decrease in sediment load, further reducing accretion. Salinity levels may have increased in portions of coastal Louisiana in association with marsh loss and canal construction (Ning and Reyes 2001).

Changes in the amount and timing of freshwater inflow may have a major effect on the early life history of menhaden that use the estuary. These habitats rely on freshwater inflow to transport nutrients critical for increased production.

4.7.4.1.1 Hydrologic Modifications

The dredging, damming, and channelization of rivers in the United States has greatly altered the sedimentation patterns and the timing and volume of freshwater inflows into bays and estuaries. The results of dam construction, channelization, and deforestation are declines in base flows to estuaries during critical dry seasons and increases in extreme freshwater pulses during wet seasons (Browder 1991). In arid areas like southwest Texas, dams are of particular concern due to their relation to significant declines in dry season flows and to ecologically stressed hypersaline coastal lagoons (Browder and Moore 1981). For coastal systems in Texas and Florida, small changes in inflow volumes during the dry season can significantly alter salinity gradients (McPherson and Hammett 1991). In addition to the dredging, damming, and channelization affecting sedimentation and timing and volume of flows, the Mississippi (and other rivers) were de-snagged in the 1900s to aid navigation and commerce. This removal of woody debris had a large effect on the ecology of the river and seasonal inundation of the floodplain.

Levee and canal construction can significantly impact coastal wetlands by causing ponding, impoundments, low sedimentation rates, high subsidence, and increased saltwater intrusion. In Louisiana's highly organic soils, these conditions tend to stress plants and cause mortality due to high levels of hydrogen sulfide (Mendelssohn and McKee 1988, Burdick et al. 1989) and salinity (Pezeshki et al. 1987). The loss of plants causes increased erosion and land loss (Scaife et al. 1983). In Florida's oligotrophic marl soils, the network of canals and levees has a different effect. By delivering relatively high nutrient loads and increasing the flooding duration in some areas and decreasing flooding duration in others, these alterations have stimulated primary productivity and the invasion of opportunistic native plants, such as cattail (*Typha domingensis*), and invasive exotic species such as Melaleuca (*Melaleuca quinquenervia*) and Brazilian pepper (*Schinus terebinthifolius*) (Jensen et al. 1995, Wu et al. 1995).

Conversely, river reintroductions such as siphons, diversions, and delta creations all serve to increase inflows to certain areas. Many of these increases have been beneficial to primary production in the long-term; however, short-term effects have led to direct mortality (prolonged freshets), increased turbidity, and shifts in suitable habitats. It is important that any freshwater increase to the system mimic natural conditions and provide a suitable salinity and temperature range that co-occurs over a suitable physical habitat (Volety et al. 2009). These habitats rely on freshwater inflow to deliver nutrients critical for productivity and significant changes in the amount and timing of freshwater inflow may affect all life history stages of Gulf menhaden and other species that use estuaries.

4.7.4.1.2 Water Rights

Water rights are among the biggest issues concerning development on the Gulf coast. Many states in the Gulf region are embattled in 'ownership rights' of water. Freshwater sources support inland cities and populations. Freshwater removals affect communities and fisheries downstream. For example, Texas faces significant losses of freshwater inflows into bays and estuaries as water demand for increasing upstream human population growth. Water withdrawal rights in Texas are permitted in perpetuity. Return flows (water returned to the river after having been used by the permitee) have helped maintain consistent inflows into bays and estuaries; however, as demands for water increase, more of permitted water is being resold to other users, both within and outside the watershed basin, further reducing the quantity of water reaching bays and estuaries. Long-term alterations in circulation patterns and freshwater inflow into the Gulf's bays and estuaries will likely impact salinity and water qualities in these areas that are critical to Gulf menhaden.

4.7.4.1.3 Water Management Projects

A number of major freshwater control projects are underway in the Gulf states, and others are planned. A thorough knowledge of the biological and engineering feasibility of such projects is needed prior to planning, designing, and developing freshwater control projects since water control projects that disrupt the flow of fresh water for prolonged periods may result in serious adverse impacts to estuarine ecology. For example, the Bonnet Carre Spillway, located on the Mississippi River above New Orleans, serves to control river stages and flow rates. The spillway has been an important feature in controlling flood waters, and can effectively divert fresh water into Lake Pontchartrain and around New Orleans. Fresh water diversion, when the spillway is opened, can have short-term and long-term effects on estuarine ecology and estuarine-dependent species. Opening the spillway may simulate the natural flooding cycle of the river but the results may not be favorable to all species.

4.7.4.2 Point and Nonpoint Source Pollution

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

4.7.4.3 Methylmercury

Mercury is found naturally in the environment, being released into the atmosphere from rocky soils through volcanic activity. Mercury is also introduced to the environment through human activities, including incineration of solid waste, combustion of fossil fuels, and other industrial activities. Bacteria in the water convert elemental mercury into methylmercury (CH_3Hg^+) that is then absorbed by fish as a result of feeding activities. Older fish and those higher on the food chain are more susceptible to bioaccumulating high levels of mercury contamination.

In the late 1970s, the FDA established an action level of 1.0 ppm for methylmercury contamination. This level was based on data, partly contributed by the NMFS, that indicated that exposure would not increase significantly by consumption of seafood at the 1.0 ppm level. The FDA issued a fish consumption advisory for mercury in 1995, which was revised in 2004. The revised advisory states that pregnant women and women who may become pregnant should not eat shark, swordfish, king mackerel, or tilefish. Also, the advisory states that the consumption of all other fish should average no more than about 340 g (12oz.) per week as high, prolonged exposure can cause neurological damage (USEPA 2004). The technical memorandum (USEPA 2004) suggested that human consumption in fish with 0.31-0.47 ppm methylmercury should not exceed more than 2 meals per month for the average (70 kg) adult. Only for concentrations of methylmercury in fish tissues lower than 0.029 ppm were meals (8 oz. of fish) considered unrestricted (>16 meals per month per average adult). Based on these recommendations, many marine fish would fall into the 'no more than 4 meals per month' range.

Conversely, recent scientific studies have demonstrated the importance of selenium (Se) in human health and the dietary role of selenium in ameliorating the potentially toxic effects of mercury in the body (H. Perry personal communication). Selenium has a high molecular binding affinity for mercury and thus helps to prevent possible mercury toxicity when found in combination. Although selenium has been known to counteract mercury toxicity since the 1960s (Pařízek and Ošťádalová 1967), consumption advisories for mercury in fishes generally do not consider selenium and, thus, may not accurately predict risks. Ralston et al. (2008) noted that exposure to methylmercury was not sufficient to provide accurate information regarding potential risks unless selenium intakes were part of the evaluation process.

We are unaware of recent studies on concentrations of methylmercury in Gulf menhaden. In a dated study on the Atlantic coast, Cocoros et al. (1973) reported "no dangerously high mercury levels were found" in Atlantic menhaden sampled in North Carolina, Maryland, and New York. With regard to consuming seafood products in general, the Harvard School of Public Health (Nesheim and Yaktine 2007) weighed concerns of chemicals, e.g., mercury, PCBs, and dioxins, found in fish to the benefits or healthy effects of fish consumption, e.g., omega-3 fatty acids. They concluded that "Overall…the benefits of eating fish greatly outweigh the risks". Similarly, Mozaffarian and Rimm (2006) evaluated the risks and benefits of fish consumption and concluded that the benefits of fish intake exceed the potential risks from possible contaminants.

4.7.4.4 Introductions of Nonnative Flora and Fauna

According to USEPA (2000), the terms 'nonnative' and 'introduced' are synonyms for 'nonindigenous'. That reference defines nonindigenous species to include:

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

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

Introduced species in marine and estuarine systems arrive in new regions by a variety of vectors including ships (attachment to hull, ballast water, and cargo), public aquaria, aquarium pet industry, floating marine debris, fisheries, and marine aquaculture. Introduced species that occur in Gulf of Mexico freshwater, estuarine, and marine environments include 483 aquatic microbes, invertebrates, and aquatic vertebrates, and 221 aquatic plants (Battelle 2000). These introduced species have the potential to affect native populations and their habitat. The Pacific spotted jellyfish (*Phyllorhiza puncata*) were reported covering 150 km^2 in the northern Gulf of Mexico in the summer 2000. An estimated six million of these jellyfish consumed vast amounts of plankton, potentially affecting species such as Gulf menhaden. Nutria (*Myocastor coypus*) is a well-known introduced species that has had a significant adverse impact on Louisiana marshes, which could affect the nursery habitat for many species including Gulf menhaden as they undermine and convert tidal emergent marsh habitat to open water.

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

The following is a partial list of some of the most 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 most 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. States manage resources in their coastal waters out to three nautical miles (nm), with the exception of Texas and western Florida (and Puerto Rico) which claim nine nm limits. The EEZ extends from the seaward boundary of state waters to no more than 200 nm from the baseline of the territorial sea (e.g., shoreline). 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.

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

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. The NPS has regulations preventing commercial fishing within one mile of the barrier islands in the Gulf Islands National Seashore from Mississippi to the Florida Panhandle.

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.

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

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 United States 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; Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006.

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.

The 2006 reauthorization builds on the country's progress to implement the 2004 Ocean Action Plan which established a date to end over-fishing in America by 2011, use market-based incentives to replenish America's fish stocks, strengthen enforcement of America's fishing laws, and improve information and decisions about the state of ocean ecosystems.

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 (P.L. 98-369)

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 m.

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 (P.L. 93-205)

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 (P.L. 81-681)

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.

5.2.1 Florida

5.2.1.1 Florida Fish and Wildlife Conservation Commission

Florida Fish and Wildlife Conservation Commission (FWC)
620 South Meridian Street
Tallahassee, FL 32399
Telephone: (850) 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 Fish and Wildlife Research Institute (FWRI) 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 and recommends management policies and administers various saltwater fisheries programs.

The FWC, a seven-member board 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.

Table 5.1 State management institutions for the Gulf of Mexico.

State	Administrative Body and Responsibilities	Administrative Policy-making Body and Decision Rule	Legislative Involvement in Management Regulations
FL	*Florida Fish and Wildlife Conservation Commission* • administers management programs • enforcement • conducts research	• creates rules in conjunction with management plans • seven-member commission	• responsible for setting fees, licensing, and penalties
AL	*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–13-member board which advises the Commissioner • has authority to amend and promulgate regulations • authority for detailed management regulations delegated to Commissioner • statutes concerned primarily with licensing	
MS	*Mississippi Department of Marine Resources* • administers management programs • enforcement • conducts research	*Mississippi Commission on Marine Resources* • five-member board • establishes ordinances on recommendation of the MDMR Executive Director	• authority for detailed management regulations delegated to Commission • statutes concern licenses, taxes, and specific fisheries laws
LA	*Louisiana Department of Wildlife and Fisheries* • administers management programs • enforcement • conducts research makes recommendations to legislature	*Louisiana 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
TX	*Texas Parks and Wildlife Department* • administers management programs • enforcement • conducts research • makes recommendations to the Texas Parks and Wildlife Commission	*Texas 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 & penalties are set by legislation

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 Fisheries 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. Florida recently merged the old 370 (marine fisheries) and 372 (game related) statutes into the new 379 statute.

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 FWC could establish provisions but cannot set fees or penalties.

5.2.1.4 Commercial Landings Data Reporting Requirements

Florida requires wholesale dealers to maintain records of each purchase of saltwater products by filling out a Marine Fisheries Trip Ticket (Chapter 379.2521, Florida Statutes, grants rule making authority and Chapter 68E-5.002 of the Administrative Code specifies the requirements). Information to be supplied for each trip includes Saltwater Products License number; vessel identification; wholesale dealer number; date; time fished; area fished; county landed; depth fished; gear fished; number of sets; whether a head boat, guide, or charter boat; number of traps; whether aquaculture or lease number; species code; species size; amount of catch; unit price; and total dollar value which is optional. The wholesale dealer is required to submit trip tickets weekly if the tickets contain quota-managed species such as Spanish mackerel; otherwise, trip tickets must be submitted every month.

5.2.1.5 Penalties for Violations

Penalties for violations of Florida marine laws and regulations are established in Florida Statutes, Chapter 379. 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 or her 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	$400.00
• state	$550.00
Nonresident wholesale seafood dealer	
• county	$600.00
• state	$1,100.00
Alien wholesale seafood dealer	
• county	$1,100.00
• state	$1,600.00
Resident retail seafood dealer	$75.00
• Nonresident retail seafood dealer	$250.00
• Alien retail seafood dealer	$300.00
Saltwater products license	
• resident-individual	$50.00
• resident-vessel	$100.00
• resident-individual/vessel	$150.00
• nonresident-individual	$200.00
• nonresident-vessel	$400.00
• nonresident-individual/vessel	$600.00
• alien-individual	$300.00
• alien-vessel	$600.00
• alien-individual/vessel	$900.00
Recreational saltwater fishing license	
resident	
• annual	$15.50
• annual shoreline resident	$0.00
nonresident	
• three day	$15.50
• seven day	$28.50
• annual	$45.50
Annual commercial vessel saltwater fishing license (recreational for hire)	
• 11 or more customers	$800.00
• ten or fewer customers	$400.00
• four or fewer customers	$200.00
Optional pier saltwater fishing license (recreational users exempt from other licenses)	$500.00
Optional recreational vessel license (recreational users exempt from other licenses)	$2,000.00

5.2.1.7 Laws and Regulations

The following discussions are general summaries of laws and regulations, and the FWC should be contacted for more specific information. *The restrictions discussed in this section are current to the date of this publication and are subject to change at any time thereafter.*

5.2.1.7.1 Size Limits

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 three 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 - the line that divides inland waterways and coastal waterways; Florida Statutes Title 33, §80.01), 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 Quotas

In the state waters off Escambia and Santa Rosa counties along the Florida Panhandle (inside the COLREGS), there is a quota of 1.0 million pounds for commercial harvest of menhaden by all gears combined. The quota applies to closing the inside waters of Escambia and Santa Rosa counties only, not any offshore fishery. Purse seines are not allowed for harvesting menhaden anywhere else in the state within the COLREGS other than off these two counties. The purse seines within the COLREGS must be less than 500 sq foot. The closing date for the inside waters is based upon:

> “[t]he total commercial harvest of menhaden in Escambia and Santa Rosa Counties during a particular commercial fishing season shall consist of those menhaden commercially harvested by all forms of gear from all waters of these counties and waters of the federal Exclusive Economic Zone (EEZ) contiguous to such waters, based on projections from official statistics collected and maintained by the Florida Fish and Wildlife Conservation Commission pursuant to Florida’s Marine Fisheries Information System.”

Purse seine gear used by the reduction fishery precludes reduction vessels from operating in Florida state waters; however they would be free to operate offshore of the COLREGS. The Florida quota is designed to control landings by a Gulf menhaden bait fishery inside the COLREGS in those two counties of the Panhandle.

5.2.1.7.6 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 2% by weight of all fish in possession, except that any fish having an established bag limit shall not be retained.

Florida is the only state with a regulation restricting fishing to only weekdays during the 28-week season; although it is generally accepted and practiced that the industry will not make net sets on weekends or on holidays Gulf-wide.

5.2.1.7.7 Historical Changes to Regulations

July 1, 1993 B 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 B 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 three 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 B 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: (251) 861-2882

The Commissioner of the Alabama Department of Conservation and Natural Resources (ADCNR) holds management authority of fishery resources in Alabama. 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.

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 public 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 and regulations of the ADCNR. The board consists of the Governor, the ADCNR commissioner, the Director of the Auburn University Agriculture and Extension Service, and ten board members.

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

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

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 A, Class B, or Class C misdemeanors and are punishable by fines up to $2,000 and up to one year in jail.

5.2.2.6 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/AMRD 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 and Quota

Menhaden purse seine 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 2.5" 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 South and west of a line extending from the eastern tip of the South Rigolets (30°21'.120N,088°23'.490W) Westward to the charted position of Bayou LaBatre Channel marker "19", then running due south to its intersection with Dauphin Island, except those waters lying within one (1) mile of the shoreline of Dauphin Island shall be closed. The Gulf of Mexico for a distance of three (3) miles, except those waters lying within one (1) mile of the Gulf Beaches shall be closed.

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 five 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 the legislative regulations related to harvest of marine species in Mississippi. Chapter 15 also describes regulatory duties of the MCMR and the MDMR regarding the management of marine fisheries. Title 49, Chapter 27 involves the utilization of wetlands through the Wetlands Protection Act and is also administered by the MDMR.

Title 49, Chapter 15 of the Mississippi Code of 1972 §49-15-2 "Standards for fishery conservation and management; fishery management plans," was implemented by the Mississippi Legislature on July 1, 1997 and sets standards for fishery management as related to the Magnuson-Stevens Act (1996).

5.2.3.3 Reciprocal Agreements and Limited Entry Provisions

5.2.3.3.1 Reciprocal Agreements

Section §49-15-15(h) provides statutory authority to the MDMR to enter into or continue any existing interstate and intrastate agreements, in order to protect, propagate, and conserve seafood in the state of Mississippi.

Section §49-15-30(1) gives the MCMR the statutory authority to regulate nonresident licenses in order to promote reciprocal agreements with other states.

5.2.3.3.2 Limited Entry

Section §49-15-16 gives the MCMR authority to develop a limited entry fisheries management program for all resource groups.

Section §49-15-29(3) states that, when applying for a license of any kind, the MCMR will determine whether the vessel or its owner is in compliance with all applicable federal and/or state regulations. If it is determined that a vessel or its owner is not in compliance with applicable federal and/or state regulations, no license will be issued for a period of one year.

Section §49-15-80(1B) states that no nonresident will be issued a commercial fishing license for the taking of fish using any type of net, if the nonresident state of domicile prohibits the sale of the same commercial net license to a Mississippi resident.

5.2.3.4 Commercial Landings Data Reporting Requirements

Title 22 Part 9 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. All license fees listed below are subject to change at any time. *The MDMR should be contacted for current license fees.*

Menhaden boat/net	$150.00
Menhaden processor	500.00
Captain's license	10.00
Interstate commerce	20.00
Rec. Saltwater Fishing License	10.00

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.

5.2.3.7.3 Gear Restrictions

Menhaden purse seines are restricted to a total length of 1500 ft (Title 22 Part 5). There are restrictions on other gear types (gill nets, trammel nets, or other seine types) licensed to catch menhaden which include mesh size and degradability requirements for gill and trammel nets. Menhaden may be caught in a cast or brail net as long as you possess a recreational fishing license.

5.2.3.7.4 Closed Areas

All commercial saltwater fishing is prohibited north of the CSX railroad track in coastal Mississippi. Gill nets, trammel nets, purse seines, and other commercial nets may not be used within 1,200 ft of any public pier or hotel/motel pier, and they are prohibited within 300 ft of any private piers that are at least 75 ft in length. These nets are also prohibited within 1,200 ft of the shoreline of Deer Island and within 1,500 ft of the shoreline between the U.S. Highway 90 bridge and the north shore of Bayou Caddy in Hancock County. These aforementioned nets are prohibited within 100 ft of the mouth of rivers, bays, bayous, streams, lakes, and other tributaries to Mississippi marine waters, i.e., Point Aux Chenes Bay, Middle Bay, Jose Bay, L'Isle Chaude, Heron Bay, Pascagoula Bay (south of the CSX railroad bridge), and Biloxi Bay (south of a line between Marsh point and Grand Bayou). The nets must not be used in a manner to block any of these bays, bayous, rivers, streams, or other tributaries.

It shall be unlawful for any person, firm, or corporation to take or catch menhaden from the waters under the jurisdiction of the MCMR within one mile of the shoreline of Hancock and Harrison Counties, Mississippi (Title 22 Part 3).

No gill or trammel nets, seines, or like contrivance may be used within an area formed by a line running one mile from the shoreline of the national park islands of Ship, Horn, and Petit Bois. In addition, no gill or trammel nets, seines, or like contrivance may be used within one mile of Cat and Round islands, or from the shoals of Telegraph Keys and Telegraph Reef (Merrill Coquille) from May 15-September 15 of each year.

5.2.3.7.5 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 5% by weight in any single set of the net or to possess in excess of 10% 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
Marine Fisheries: (225) 765-2384
Law Enforcement: (225) 765-2989

The Louisiana Department of Wildlife and Fisheries (LDWF) is one of 21 major administrative units of the Louisiana government. The Governor appoints a seven-member board, the Louisiana Wildlife and Fisheries Commission (LWFC). Six of the members serve overlapping terms of six years, and one serves a term concurrent with the Governor. The commission is a policy-making and budgetary-control board with no administrative functions. The legislature has authority to establish management programs and policies; however, the legislature has delegated certain authority and responsibility to the LWFC and the LDWF. The LWFC may set possession limits, quotas, places, seasons, size limits, and daily take limits based on biological and technical data. The Secretary of the LDWF is the executive head and chief administrative officer of the department and is responsible for the administration, control, and operation of the functions, programs, and affairs of the department. The Governor, with consent of the Senate, appoints the Secretary.

Within the administrative system, an Assistant Secretary is in charge of the Office of Fisheries. This office performs:

> "the functions of the state relating to the administration and operation of programs, including research relating to oysters, water bottoms and seafood including, but not limited to, the regulation of oyster, shrimp, and marine fishing industries."

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 Department of Natural Resources is the state agency that monitors compliance of the state Coastal Zone Management Plan and reviews federal regulations for consistency with that plan.

5.2.4.2 Legislative Authorization

The LDWF is the state agency responsible for management of the state's renewable natural resources including all wildlife and all aquatic life. The control and supervision of these resources are assigned to the department in the Constitution of the State of Louisiana of 1974, Article IX, Section 7 and in revised statutes under Title 36 and Title 56.

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

Section 320 of Title 56 (L.R.S.) establishes methods of taking freshwater and saltwater fish. Additionally, Sections 325.1 and 326.3 of Title 56 (L.R.S.) give the LWFC the legislative authority to set possession limits, quotas, places, season, size limits, and daily take limits for all freshwater and saltwater finfish based upon biological and technical data.

5.2.4.3 Reciprocal Agreements and Limited Entry Provisions

5.2.4.3.1 Reciprocal Agreements

The LWFC is authorized to enter into reciprocal management agreements with the states of Arkansas, Mississippi, and Texas on matters pertaining to aquatic life in bodies of water that form a common boundary. The LWFC is also authorized to enter into reciprocal licensing agreements.

On and after March 1, 1951, resident and nonresident persons of Louisiana and foreign corporations are prohibited from seining for and catching menhaden or other species of fish not ordinarily used for human consumption in the inside and outside waters over which Louisiana has jurisdiction, to be transported to another state for the purpose of rendering and processing same, unless the state, to which the menhaden or other such species of fish are transported for the purpose of rendering and processing, permits citizens of Louisiana and Louisiana corporations the like privilege to seine for and catch and transport into Louisiana for the purpose of rendering and processing same, under the same conditions as provided by Louisiana law, menhaden and other like species of fish in the waters over which that state has jurisdiction.

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.

Louisiana seniors, 65 years of age and older, are not required to purchase a nonresident license to fish in all public waters in Texas. These anglers will be allowed to fish Texas water bodies with a Louisiana Senior fishing license but shall comply with Texas law. Senior anglers are advised that anglers turning 60 before June 1, 2000 are also required to possess a Louisiana Senior fishing license when fishing in Texas, except in border waters. Louisiana residents from 17-64 years of age will still be required to purchase a nonresident fishing license when fishing in Texas, except when fishing in border waters.

In all border waters, except the Gulf of Mexico, Texas and Louisiana anglers possessing the necessary resident licenses, or those exempted from resident licenses for their state, are allowed to fish the border waters of Louisiana and Texas without purchasing nonresident licenses. Border waters include Caddo Lake, Toledo Bend Reservoir, the Sabine River, and Sabine Lake.

Louisiana is also allowing Texas senior residents 65 years of age and older, to fish throughout Louisiana's public waters if they possess any type valid Special Texas Resident licenses for seniors as issued by Texas Parks and Wildlife, any type of water, saltwater or freshwater. Even Texas residents born before September 1, 1930 must possess the Texas Special Resident Fishing license when fishing in Louisiana, except in border waters.

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

Violations of Louisiana laws or regulations concerning the commercial or recreational taking of fish or shellfish by legal commercial gear shall constitute a Class 3 violation which is punishable by a fine from $250 to $500 or imprisonment for not more than 90 days, or both. Second offenses carry fines of not less than $500 or more than $800 and imprisonment of not less than 60 days or more than 90 days and forfeiture to the LWFC of any equipment seized in connection with the violation. Third and subsequent offenses have fines of not less than $750 or more than $1,000 and imprisonment for not less than 90 days or more than 120 days and forfeiture of all equipment involved with the violation. Civil penalties may also be imposed.

In addition to any other penalty, for a second or subsequent violation of the same provision of law, the penalty imposed may include revocation of the permit or license under which the violation occurred for the period for which it was issued, and barring the issuance of another permit or license for that same period.

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
Vessel license	
• resident	15.00
• nonresident	60.00
Wholesale/retail Dealer	
• resident	250.00
• nonresident	1,105.00
Purse/Menhaden Seine Gear license	
• resident (per net)	505.00
• nonresident (per net)	2,020.00

Nonresidents may not purchase any gear license for Louisiana if their resident state prohibits the use of that particular gear.

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 this publication and are subject to change at any time thereafter. The LDWF should be contacted for specific and up-to-date information.

5.2.4.7.1 Minimum Size

There are no minimum size restrictions on menhaden.

5.2.4.7.2 Seasons and Quotas

The reduction season for landing and processing menhaden is from the third Monday in April through November 1 each year. There is no quota during the reduction season.

Louisiana has an extended bait season which is intended solely for harvest of menhaden for bait after the reduction fishing season ends on November 1. The extended bait season runs from November through December 1 or until the 3,000 mt quota is reached. If the quota was not reached by December 1, then, beginning on April 1 (about three weeks before the reduction season opens) of the following year, bait Gulf menhaden may be taken until the department determines that the quota has been met.

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. 29E40'40"N, Long. 89°23'10"W; thence northerly to Deadman Point, Lat. 29E44'06"N, Long. 89°21'05"W; thence easterly to Point Lydia, Lat. 29E45'27"N, Long. 89°16'12"W; thence northerly to Point Comfort, Lat. 29E49'32"N, Long. 89°14'18"W; thence northerly to the most easterly point on Mitchell Island, Lat. 29E53'42"N, Long. 89°11'50"W; thence northerly to the most easterly point on Martin Island, Lat. 29E57'30"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 S82E53'53"E (grid) continuing along the Louisiana-Mississippi Lateral Boundary a distance of 72649.38 feet, Lat. 30°08'14.1260"N, Long. 89E52'10.3224"W; thence South (grid) a distance of 32521.58 feet to the Chandeleur Light, Lat. 30°02'52"N, Long. 88E52'18"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 5%, 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.
17. Each individual or company receiving a bait menhaden permit shall reimburse the department for all expenses incurred in the placement of an observer on each boat participating in the special bait season.

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

The following represents those actions that were taken in relation to harvest of menhaden in Louisiana waters. The Administrative Code and the specific citations to the Louisiana Register (LR) are included to indicate when and where the rule was published within the Code.

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 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 Texas Parks and Wildlife Department (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 (TPWC). The commission consists of nine members appointed by the Governor for six-year terms. The commission selects an Executive Director who serves as the administrative officer of the department. Directors of Coastal Fisheries, Inland Fisheries, Wildlife, and Law Enforcement are named by the Executive Director. The Coastal Fisheries Division, headed by a Division Director, is under the supervision of the Deputy Executive Director of Natural Resources.

Texas has habitat protection and permitting programs and a federally-approved CZM program. The Texas General Land Office (TGLO) is the lead agency for the Texas Coastal Zone Management Program (TCZMP). The Coastal Coordination Council monitors compliance of the TCZMP and reviews federal regulations for consistency with that plan. The Coastal Coordination Council is an 11-member group whose members consist of a chairman (the head of TGLO) and representatives from Texas Commission on Environmental Quality, TPWC, the Railroad Commission, Texas Water Development Board, Texas Transportation Commission, and the Texas Soil and Water Conservation Board. The remaining four places on the council are appointed by the governor and are comprised of an elected city or county official, a business owner, someone involved in agriculture, and a citizen. All must live in the coastal zone.

5.2.5.2 Legislative Authorization

Chapter 11, Texas Parks and Wildlife Code, establishes the TPWC and provides for its make-up and appointment. Chapter 12, Texas Parks and Wildlife Code, establishes the powers and duties of the TPWC concerning wildlife, and Chapter 61, Texas Parks and Wildlife Code, provides the TPWC with responsibility for marine fishery management and authority to promulgate regulations. Chapter 47, Texas Parks and Wildlife Code, provides for the authority to create commercial licenses required to catch, sell, and transport finfish commercially, and Chapter 66, Texas Parks and Wildlife Code, provides for the sale, purchase, and transportation of protected fish in Texas. All regulations pertaining to size limits, bag and possession limits, and means and methods pertaining to finfish are adopted by the TPWC and included in the annual Texas Statewide Hunting and Fishing Proclamations. Additionally, the Texas Department of State Health Services (TDSHS), under Chapter 436 of the Texas Health and Safety Code, has the authority to regulate the fish processing industry and to close areas to fishing based upon contaminant sampling to protect human health.

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. TPWD has statutory authority to enter into reciprocal management agreements under Chapter 11 of the Texas Parks and Wildlife Code Section 11.0171.

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

Chapter 66, Section 66.019, Texas Parks and Wildlife Code, provides:

a) The department shall gather statistical information on the harvest of aquatic products of this state.

b) The department shall prescribe the method or methods used to gather information and shall produce and distribute any applicable report forms.

c) Unless otherwise required by the department, no dealer who purchases or receives aquatic products directly from any person other than a licensed dealer may fail to file the report with the department each month on or before the tenth day of the month following the month in which the reportable activity occurred. The report must be filed even if no reportable activity occurs in the month covered by the report. No dealer required to report may file an incorrect or false report. A culpable mental state is not required to establish an offense under this section.

d) Unless otherwise required by the department, no dealer who purchases, receives, or handles aquatic products (other than oysters) from any person except another dealer may fail to:

1) maintain cash sale tickets in the form required by this section as records of cash sale transactions; or
2) make the cash sale tickets available for examination by authorized employees of the department for statistical purposes or as a part of an ongoing investigation of a criminal violation during reasonable business hours of the dealer.

e) All cash sale tickets must be maintained at the place of business for at least one year from the date of the sale.

f) A cash sale ticket must include:

1) name of the seller;
2) general commercial fisherman's license number, the commercial finfish fisherman's license number, the commercial shrimp boat captain's license number, the commercial shrimp boat license number, or the commercial fishing boat license number of the seller or of the vessel used to take the aquatic product, as applicable;
3) pounds sold by species;
4) date of sale;
5) water body or bay system from which the aquatic products were taken; and
6) price paid per pound per species.

5.2.5.5 Penalties for Violations

Penalties for violations of Texas' proclamations regarding fish and shellfish are provided in Chapter 66 and 47 of Texas Parks and Wildlife Code. Most are Class C misdemeanors punishable by fines ranging from $25 to $500. Under certain circumstances, a violation can be enhanced to a Class B misdemeanor ($200 to $2000 fine), Class A misdemeanor ($500 to $4,000 fine), or a State Jail Felony ($1,500-$10,000 fine). Punishment may also include jail time (Class B or higher), suspension or revocation of license for up to five years, and forfeiture of gear used to commit a violation. Under Chapter 47, Section 47.080, flagrant violations by holders of a commercial finfish license may result in revocation of the license. In addition to criminal penalties, Texas is authorized by Statute (Parks and Wildlife Code 12.301 – 12.308) from the legislature to assess a civil restitution value for the resource, based on the current values and is administered in conjunction with the Texas Attorney General's Office (see Section 7.3).

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.

5.2.5.6.1 Commercial

Menhaden fish plant	$ 180.00
Menhaden fish boat Class A	4,200.00
Menhaden fish boat Class B	50.00
General Commercial Fisherman's License	
Resident	26.00
Nonresident	189.00
Bait Dealers License	38.00

5.2.5.6.2 Recreational

Resident Saltwater Fishing Package	$ 35.00
Resident All Water Fishing Package	40.00
Senior Resident Saltwater Fishing Package	17.00
Senior Resident All Water Fishing Package	22.00
Special Resident All Water License (for legally blind)	7.00
Resident Year-From-Purchase All Water Package	47.00
Resident One Day All Water License	11.00
Nonresident Saltwater Fishing Package	63.00
Nonresident All Water Fishing Package	68.00
Nonresident One Day All Water License	16.00
Resident Fishing Guide License	210.00
Nonresident Fishing Guide License	1,050.00
Resident Super Combo Package	68.00
Senior Resident Super Combo Package	32.00
Resident Combination Hunting/Saltwater Fishing Package	55.00
Resident Combination Hunting/All Water Fishing Package	60.00
Senior Resident Combination Hunting/Saltwater	

Fishing Package	21.00
Senior Resident Combination Hunting/All Water Fishing Package	26.00
Lifetime Resident Fishing License	1,000.00
Lifetime Resident Combination Hunting and Fishing License	1,800.00
Resident Disabled Veteran Super Combo Package	Free

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 or until the annual landings limit for the season has been reached.

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. For menhaden purse seines the purse seine, not including the bag, shall not be less than three-fourths inch square mesh. 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. The menhaden industry has had a "gentleman's" agreement with TPWD not to fish within one mile of Gulf beaches, and has agreed to leave Texas waters if significant quantities of game fish are documented by TPWD to be in the vicinity.

5.2.5.7.3.2 Quotas

Currently, Texas is the only state with a quota or 'cap' on the removals of Gulf menhaden for reduction purposes from state waters. In March 2008, the Texas Parks and Wildlife Commission approved changes to the statewide hunting and fishing regulations that included establishing a Total Allowable Catch (TAC) on menhaden catches in the Texas Territorial Sea (TTS), the waters off Texas out to nine nautical miles. The TAC was set at 31.5 million pounds per year, which was set at the approximate five-year average of Texas catches during 2002-2006 (with penalties for overages). The regulations provide for maintaining an annual harvest of 31.5 million pounds by allowing upward and downward adjustments based on previous years' harvests. This regulation was heralded as precautionary management, capping removals at recent levels with an eye toward minimizing bycatch.

5.2.5.7.3.3 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.

5.2.5.7.3.4 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 Gulf-ward 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 one-half mile offshore.
- Menhaden were required to be tagged and net size could not exceed 1½" 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 Gulf-ward 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.

2008

- TPWC established a TAC on menhaden catches in the Texas Territorial Sea, the waters off Texas out to nine nautical miles.

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 Menhaden Advisory Committee (MAC)

The GSMFC formed the Gulf Menhaden Subcommittee in March 1973, which existed under various names and currently is the Menhaden Advisory Committee (MAC). The Committee completed development of the first Gulf Menhaden Fishery Management Plan in 1977.

The Menhaden Advisory Committee (MAC) is comprised of one member from each state's fishery agency and one member from each active menhaden company in the Gulf - all of whom are voting members - and one non-voting member from the NMFS. The MAC hears and addresses all management and resource issues related to Gulf menhaden and Gulf menhaden fishing (reduction and bait). Recommendations of the MAC are approved by a two-thirds majority vote of those present and voting, and then presented to their parent committee, the State-Federal Fisheries Management Committee (SFFMC). The MAC also serves as the Technical Task Force (TTF) during the revision to the Gulf menhaden FMP. The MAC meets in conjunction with the Commission's annual spring and fall meetings although there is no programmatic support for their travel or routine activities.

5.3.3 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).

5.3.3.1 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

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 (J. Smith personal communication).

For those interested in the history and evolution of the Gulf menhaden fishery, unfortunately, a volume equivalent to that which G.B. Goode (1878) compiled for the Atlantic menhaden fishery is unavailable. Goode (1878) surveyed fishermen, fish factory owners, and various seaside observers for insights about the seasonality, movements, and habits of Atlantic menhaden, as well as information on fishing operations and disposition of the catch along the U.S. Eastern Seaboard. Goode (1878) was able to cobble together a history of the Atlantic menhaden fishery back to the mid-1800s. No such author or tome has chronicled the history of the early days of the menhaden fishery in the northern Gulf of Mexico. Several sources however provide us with glimpses of the Gulf menhaden fishery beginning in the mid-twentieth century.

Frye (1978) delved into the genealogy of menhaden factory ownership for the Gulf fishery. He recounts that numerous corporate families active in the Atlantic menhaden fishery moved some or all of their operations to the northern Gulf of Mexico just before and after World War II. Simmons and Breuer (1964) make brief reference to the establishment of menhaden fishing operations in Texas in 1951. Kutkuhn (1965) was among the first to recognize that the surging landings in the Gulf menhaden fishery during 1958-1961 were primarily due to the

> "vastly improved efficiency of the fishing fleet rather than to greater abundance or availability of the resource."

Fishing fleet innovations which he cited included spotter aircraft, nylon seines, fish pumps, power blocks, refrigerated fish holds, and larger carrier vessels. Henry (1969) noted that the Gulf menhaden fishery "started much later than that for the Atlantic species." He reported that the annual catch of Gulf menhaden in the early 1940s was less than about 40,000 mt, but that the fishery had grown steadily and in 1963, for the first time in history, the Gulf menhaden catch of about 445,000 mt exceeded that of the Atlantic fishery. Henry (1969) also pointed out that although the Atlantic menhaden fleet tended to make one-day trips to the fishing grounds, the Gulf menhaden fleet generally made multiple-day trips, thus the need for refrigerated fish holds. Additionally, he categorized Gulf menhaden landings by state, noting that in 1966

> "70% of the menhaden catch from the Gulf of Mexico was landed in Louisiana, 24% in Mississippi, 5% in Texas, and 1% in Florida".

Perhaps, Nicholson (1978) best summarized the evolution of the Gulf menhaden fishery. He canvassed confidential company records and statistical digests for landings in the Gulf menhaden fishery from the first half of the 1900s. Nicholson (1978) reported that although a menhaden fishery had existed along the U.S. Gulf coast since the late 1800s, records of catches, the location and years of operation of plants, and the number of vessels prior to 1946 were fragmentary at best. Historically, up to 13 menhaden processing plants existed in the northern Gulf of Mexico, ranging from Apalachicola, Florida, to Sabine Pass, Texas. 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 1918-1961; and another near Pascagoula, Mississippi, from the 1930s until 1959.

Nicholson (1978) claimed that the modern Gulf menhaden fishery began after World War II as the worldwide demand for fish meal and fish oil increased. The first plant in Louisiana opened around 1946; shortly thereafter, additional plants opened in Mississippi, Louisiana, and Texas. As older plants were closed, larger and more efficient plants replaced them. During the 1950s to the early 1970s, the number of menhaden plants fluctuated from 9-13 (Nicholson 1978) (Figure 6.1). Between the mid-1970s to the early 1980s, the number of processing plants in the Gulf was stable at 11 (Smith 1991). Two periods of corporate consolidation followed. In 1985 the number of plants fell to seven, then increased during 1989-1990 to nine. The number of plants declined to seven in 1991, to six in 1992, then to five between 1996 and 1999. After the 1997 fishing season, the menhaden company at Morgan City, Louisiana, was acquired by one of its competitors, who closed the facility after 1999. Since 2000, only four menhaden factories have operated on the Gulf coast – one each at Moss Point, Mississippi, and Empire, Abbeville, and Cameron, Louisiana. The factory at Empire is owned by Daybrook Fisheries, Inc.; the other three factories are owned by Omega Protein, Inc.

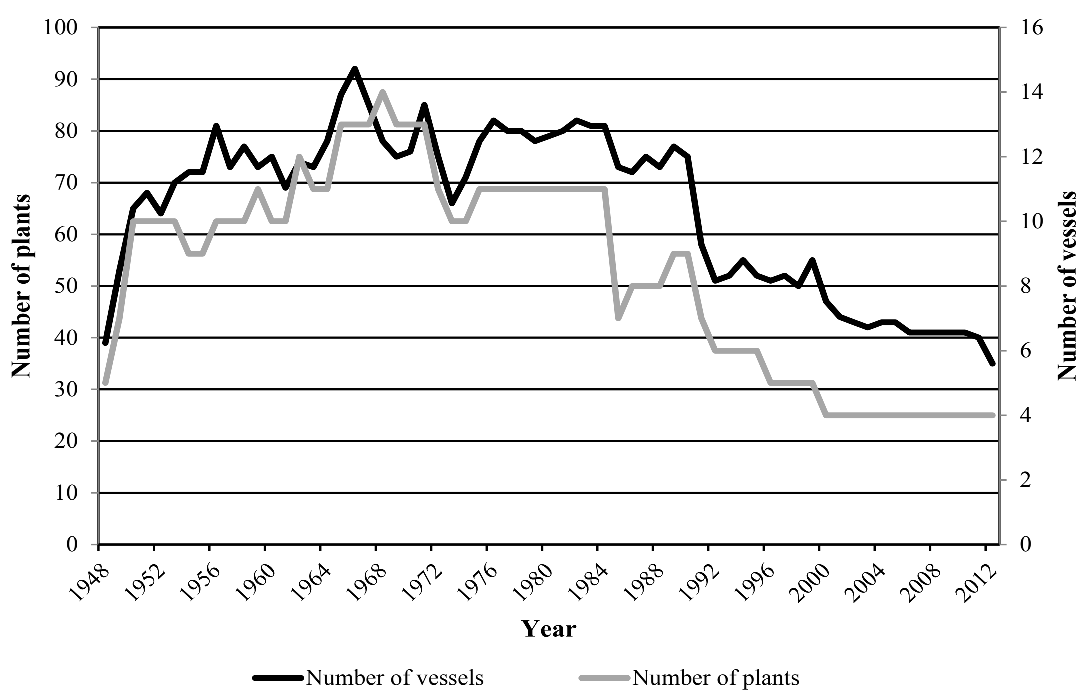


Figure 6.1 Total number of Gulf menhaden reduction plants and purse-seine vessels, 1948-2012.

In 1945, only about ten menhaden vessels were reported operating in the Gulf of Mexico (Nicholson 1978). 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). Fleet size peaked at 82 vessels in 1982, followed by two major downsizings. 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). Between 1995 and 1999, fleet size was about 50-55 vessels. Since 2000, number of Gulf menhaden vessels declined slightly from 47 in 2000 to 40 in 2006, then to 37 in 2012. (Figure 6.1)

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.

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 western Mobile Bay area, Alabama, to the east and Freeport, Texas, to the west. Gulf menhaden vessels have not fished off the Florida Panhandle for reduction since the early 1990s.

6.1.2 Fishing Methods, Gear, Vessels, and Fishing Season

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 may serve several carrier vessels.

In 2012, about nine spotter aircraft were assigned to Moss Point, Mississippi, 10 at Empire, Louisiana, 11 at Abbeville, Louisiana, and nine to the fleet at Cameron, Louisiana.

6.1.2.2 Purse Boats

Purse boats are used to set the net on schools of menhaden (Figure 6.2). They are aluminum with an open-construction design, approximately 40 feet long and 11-12 feet wide. Purse boats are capable of speeds from 5-8 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. Some vessels have used pivoting davits that rest purse boats inboard on cradles. A recent trend in fleet renovation has been to support and carry purse boats on inclined ramps on the stern of the carrier vessels. Stern ramps expedite boarding and disembarking the purse boats, as well as make the tasks safer for the crew. Purse boats on stern ramps sit adjacent one another, eliminating additional net-handling time if the boats were hung on stern davits and the net required to be draped around the stern of the steamer. Preliminary information suggests that stern ramps improved fishing efficiency, decreasing the time required to launch and retrieve purse boats, thereby increasing fishing time and the number of sets per fishing day. By 2012, all vessels in the Gulf menhaden fleet had been retrofitted with stern ramps.

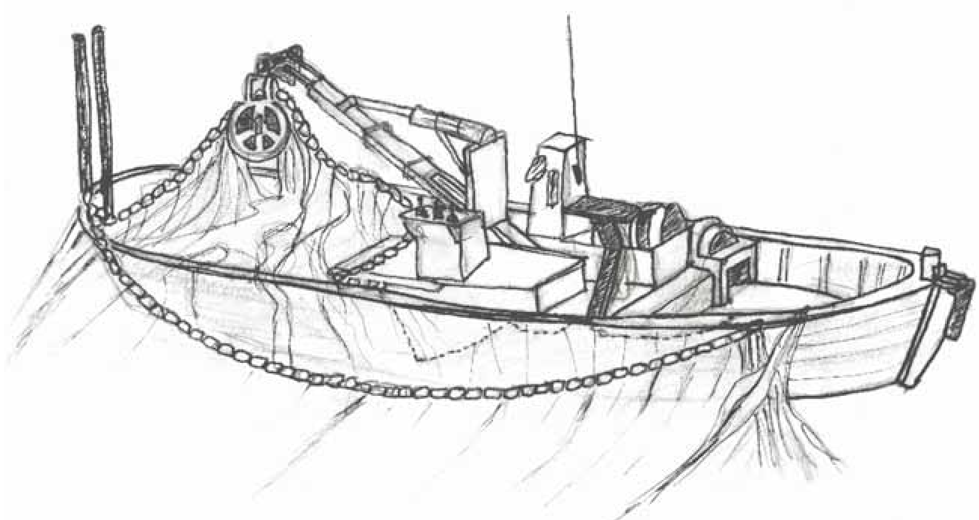


Figure 6.2 Illustration of a typical purse boat used in the Gulf menhaden reduction fishery.

6.1.2.3 Carrier Vessels

Menhaden carrier vessels, or steamers, 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 of a menhaden steamer (Figure 6.3). The fish are stored below deck in central holds that are refrigerated with chilled, re-circulated seawater. 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 up to 550 mt of menhaden.

Average age of the 35 menhaden steamers in the 2012 fleet was approximately 37 years of age. Construction/retrofit dates range from 1965-1990. The “newest” entrants to the fleet, about five vessels, were oil rig supply ships which were converted to menhaden steamers from 1988-1990.

A recent addition to Gulf menhaden fishing operations has been the addition of “run boats”, primarily to the Moss Point fleet (2-3 run boats per fishing year since about 2000). Run boats, with a crew of about four, are former menhaden steamers that no longer participate in the fishing process, but rather transfer catches from the fish holds of regular steamers on the fishing grounds, then transport accumulated catches back to the fish factory for processing. Run boats allow the steamers to remain on the fishing grounds longer, lighten the holds of the steamers permitting them access to shallower fishing grounds for longer periods of time, and conserve on fleet fuel

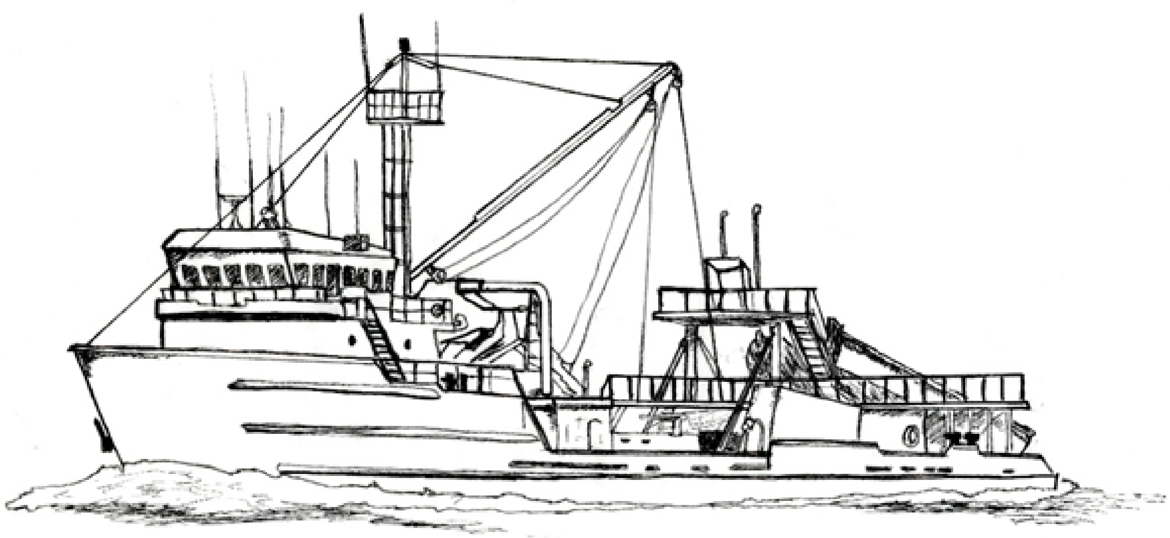


Figure 6.3 Illustration of a typical steamer used in the Gulf menhaden reduction fishery.

consumption. Run boats were used briefly at Cameron in 2000, however, since 2001 run boats used employed exclusively at Moss Point. Approximately 30-35% of the catch by the Moss Point fleet in recent years has been landed by run boats.

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-inch 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 purse 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 or pursed. The wings of the net are retrieved via power blocks suspended on a boom in each purse boat. The catch is “hardened” into the center section of net or the “bunt”. Thereafter, about a 10-inch diameter hose is lowered from the steamer into the bunt and the fish are pumped into the hold of the steamer after being diverted across a de-watering screen where pumped seawater is shunted overboard.

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 fish hose and pump system. Additionally, a large fish excluder adjacent the fish hold also serves to prevent the passage of larger, non-target species from entering the fish hold (Rester and Condrey 1999).

6.1.2.6 Fishing Operation

The Gulf menhaden reduction fishery operates during weekdays and daylight hours. Carrying a crew of about 14-15 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. On average, steamers make about 4-5 purse-seine sets per fishing day (Smith et al. 2002), although 15-16 sets may be made on exceptionally active fishing days. 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 slid from stern ramps into the water.

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 (Smith et al. 2002). Schools may contain from 3-100 mt of menhaden (NOAA Beaufort Laboratory unpublished data).

6.1.2.7 Fishing Season

Prior to 1993, the reduction fishery season for Gulf menhaden was 26 weeks in duration and extended from the third Monday in April through the Friday following the second Tuesday in October. In 1993, approximately two additional fishing weeks were added in late October. Since 1993, the Gulf menhaden season for reduction has been about 28 weeks long, beginning on the third Monday of April and ending on November 1 (although in certain years the season may extend into a 29^{th} week).

Effective in 1995, Florida banned the use of purse seines in its state territorial waters; this was a provision of a state-wide prohibition on commercial fishing nets in Florida marine waters.

For the 2009 fishing season, the Texas Parks and Wildlife Commission established a 'Cap' on removals of Gulf menhaden from Texas waters for reduction purposes, ostensibly for the menhaden fleet fishing from the port Cameron, Louisiana. The 'Cap' was calculated as the average removals from Texas waters during the previous five years, 2003-2007, or 31.5 million lbs (approx. 14,300 metric tons). A penalty on the following year is assessed for overages; a 10% allowance on the next year's 'Cap' is granted for underages. 'Cap' removals are tracked in-year via Captains Daily Fishing Reports, or CDFRs (daily logbooks) compiled by the NOAA Beaufort Lab in Beaufort, North Carolina. In 2009 and 2010, the Texas quota was not exceeded. In 2011, removals approached the Texas quota, and fishing in Texas waters was discontinued after about mid-September. In 2012 removals from Texas waters were substantially below the Cap.

6.1.3 Fishery Statistics for the Menhaden Reduction Fishery

Major fishery-dependent statistics and data-gathering programs for the Gulf menhaden purse-seine fishery have been collected and sponsored by the NOAA Beaufort Lab in Beaufort, North Carolina. The NOAA Beaufort Lab began monitoring the Atlantic menhaden fishery for catch/fishing effort and size and age composition of the catch in 1955. As the Gulf menhaden fishery grew in size and importance, the Lab expanded its biological monitoring programs to include the Gulf menhaden fishery in 1964.

6.1.3.1 Data Reporting

Fishery-dependent data for the Gulf menhaden reduction fishery are maintained by the NOAA Beaufort Lab in three large data sets. Commercial catch and nominal fishing effort data for the reduction fishery are available from 1948-2012. Contemporary landings data are supplied to the NOAA Beaufort Lab by the menhaden industry on a daily or weekly basis; catches are enumerated as daily vessel unloads. The biostatistical data, or port samples, for fork length and weight at-age are available from 1964 through 2012, and represent one of the longest and most complete time series of fishery data sets in the nation. The CDFRs itemize purse-seine set locations and estimated at-sea catches; vessel compliance is 100% in recent years. Annual CDFR data sets for the Gulf menhaden fleet are available from 1983-2012.

With only two companies in the Gulf menhaden reduction fishery since 1999 (Omega Protein Corp, and Daybrook Fisheries, Inc.), technically, catch/effort and logbook data for the fishery are confidential. The NOAA Beaufort Lab has obtained agreements with each company to publish total annual and monthly Gulf menhaden landings. In addition, the industry has granted limited permission to the GSMFC to publish a summary of the annual fish meal and fish oil production which are also legally defined by the USDOC to be confidential.

Individual company catch records (i.e., actual tallies of daily vessel unloadings of Gulf menhaden) are reported directly to the NOAA Beaufort Lab on a daily or weekly basis. Catch records are computerized and converted into metric units of weight. Cumulative Gulf menhaden landings are reported monthly by the NOAA Beaufort Lab throughout the fishing season. Catch records are also the source data base for calculating nominal fishing effort for the Gulf menhaden fishery (see Section 6.1.3.3). 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.

Port sampling efforts in the Gulf menhaden fishery are supervised by the NOAA Beaufort Lab. 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 fishery stock assessments.

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 steamer completes a form with information regarding the day's activities and catch.

The information obtained from each vessel's CDFRs include the home plant of the vessel and the date the sets were made. Check-off boxes are provided to indicate if a vessel did not leave port or if a vessel left port, but did not make a net set. Each completed purse-seine set is numbered and specific information about each set is recorded: set start and finish times, 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.

The CDFR program was initiated in the late 1970s. Despite near 100% fleet coverage, CDFR data from the late 1970s to 1980s were mostly available only as paper files. Several attempts were made to digitize data from selected years, but were unsuccessful.

In 1994 the NOAA Beaufort Lab began computerizing annual CDFR data sets. In 2000, the GSMFC and NOAA Beaufort Lab began a joint venture to key-enter CDFR data sets back to 1983. This task has been completed. Annual CDFR data sets are now available electronically 1983-2012. CDFR information has been most helpful in answering management-related questions about menhaden catches, fishing effort, and removals by area.

6.1.3.2 Landings

Presently, the menhaden reduction fishery is the largest fishery in the Gulf by volume. Monthly landings usually peak between May and August, although the peak month varies depending on the weather and other factors that affect the availability and catchability of fish. 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.

Prior to about 1948, landings of Gulf menhaden for reduction were limited and occurred intermittently, as documented in a series of historical publications to be described below. Since 1964 official commercial landings of Gulf menhaden from the reduction purse-seine fleet have been maintained by the NOAA Beaufort Lab. When the Menhaden Program began at the NOAA

Beaufort Lab in the early 1950s, staff visited menhaden plants along the Gulf coast, obtaining detailed fishery landings for the reduction fishery consistently back to 1948. Subsequently, detailed dockside landings from the reduction fishery have been maintained on computer files by calendar year (January 1 through December 31). These landings are considered the best available data in terms of conducting stock assessments.

6.1.3.2.1 Historical Commercial Landings

During the recent Atlantic menhaden assessment (ASMFC 2010), a report titled *Menhaden Fishery, 1873-1964* was examined. This report, which can be found in USFWS (1966), contains summary statistics for the menhaden fisheries (Gulf and Atlantic coasts combined) from 1873-1964. Atlantic menhaden landings were extended back to 1873 during SEDAR 20 (ASMFC 2010). These data were also used to extend Gulf menhaden landings back as well. The average proportion of Gulf to total menhaden for 1918-1940 was calculated at 2.46% (the data were more robust 1918 onward). This proportion was applied to the total menhaden landings from 1873-1917 to separate landings between the two coasts (ASMFC 2010). These Gulf menhaden landings are shown in Figure 6.4. The important point taken from these reconstructed data is that overall commercial Gulf menhaden landings were generally small prior to World War II (averaging about 5 mt for 1873-1939). Landings increased slightly during WWII and reached about 133 mt for 1947. More detailed landings from the reduction fishery became available in 1948.

6.1.3.2.2 Commercial Landings 1948-2000

As the Gulf menhaden fishery expanded after World War II, landings ranged between 100,000-200,000 mt levels during most of the 1950s (Nicholson 1978) (Table 6.1). By 1959

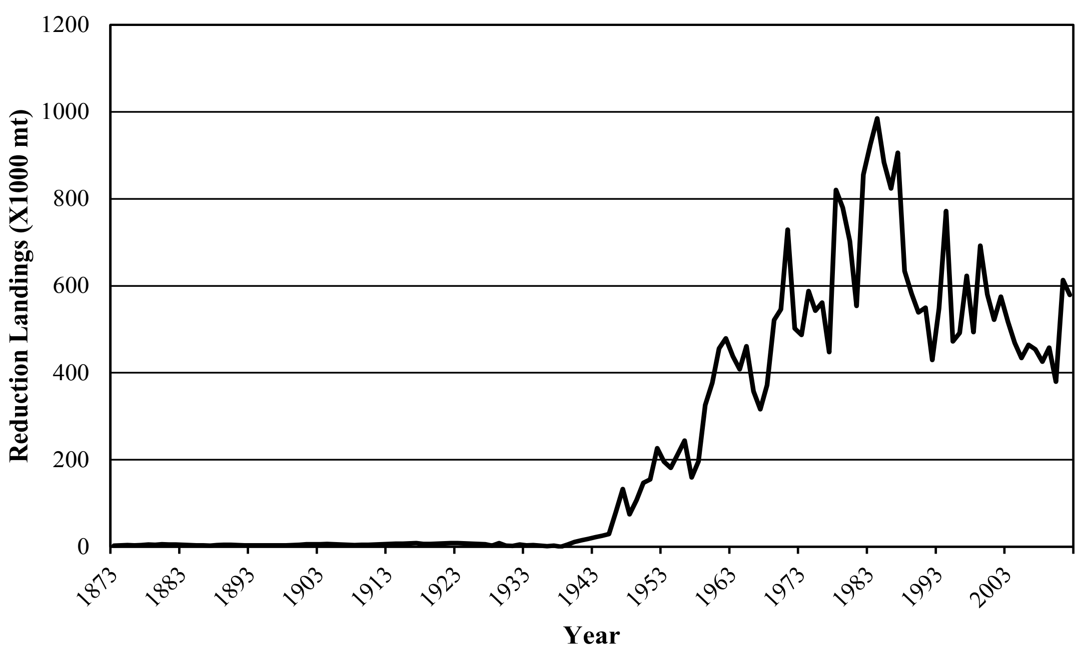


Figure 6.4 Total Gulf menhaden landings along the Gulf of Mexico coast of the U.S., 1873-2012. Reconstructed landings were developed from historical reports for 1873-1947. Reduction landings maintained at NMFS Beaufort Lab are combined with bait and recreational landings for 1948-2012 (NOAA Beaufort Lab unpublished data).

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 1982-1987, 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). Consolidation within the menhaden industry (plant closures and fewer vessels), weak product prices, and tropical systems/hurricanes were the major contributing factors to declining landings during the 1990s; annual landings during the decade averaged 552,000 mt per year and ranged from 421,400 mt in 1992 (Hurricane Andrew) to 761,600 mt in 1994.

Table 6.1 Gulf menhaden landings, effort (vessel-ton-weeks, vtw), and CPUE from the reduction purse-seine fishery 1973-2012 (NOAA Beaufort Lab unpublished data), landings from the bait fisheries 1950-2012 (NOAA/SEFSC unpublished data), landings estimated from the recreational fishery 1981-2012 (NOAA personal communication), and combined landings for all fisheries. Recreational landings represent removals of A+B1+B2 by weight. Recreational and bait landings include ALL Brevoortia species, not just B. patronus, from the region.

Year	Reduction Landings (1000 mt)	Reduction Effort (vtw)	CPUE	Bait Landings (1000 mt)	Recreational Catches (1000 mt)	Combined Total Landings (1000 mt)
1948	74.6	40.7	1.833			74.6
1949	107.4	66.2	1.622			107.4
1950	147.2	82.2	1.791	0.000		147.2
1951	154.8	94.2	1.643	0.003		154.8
1952	227.1	113.3	2.004	0.004		227.1
1953	195.7	104.7	1.869	0.001		195.7
1954	181.2	113.0	1.604	0.001		181.2
1955	213.3	122.9	1.736	0.011		213.3
1956	244.0	155.1	1.573	0.014		244.0
1957	159.3	155.2	1.026	0.003		159.3
1958	196.2	202.8	0.967	0.040		196.2
1959	325.9	205.8	1.584	0.009		325.9
1960	376.8	211.7	1.780	0.005		376.8
1961	455.9	241.6	1.887	0.011		455.9
1962	479.0	289.0	1.657	0.009		479.0
1963	437.5	277.3	1.578	0.020		437.5
1964	407.8	272.9	1.494	0.038		407.8
1965	461.2	335.6	1.374	0.196		461.4
1966	357.6	381.3	0.938	0.254		357.9
1967	316.1	404.7	0.781	0.058		316.2
1968	371.9	382.8	0.972	0.207		372.1
1969	521.5	411.0	1.269	0.137		521.6
1970	545.9	400.0	1.365	0.280		546.2
1971	728.5	472.9	1.540	0.366		728.9
1972	501.9	447.5	1.122	0.292		502.2
1973	486.4	426.2	1.141	0.446		486.8
1974	587.4	485.5	1.210	0.319		587.7

Year	Reduction Landings (1000 mt)	Reduction Effort (vtw)	CPUE	Bait Landings (1000 mt)	Recreational Catches (1000 mt)	Combined Total Landings (1000 mt)
1975	542.6	538.0	1.009	0.212		542.8
1976	561.2	575.8	0.975	0.328		561.5
1977	447.1	532.7	0.839	0.298		447.4
1978	820.0	574.3	1.428	0.404		820.4
1979	777.9	533.9	1.457	1.727		779.6
1980	701.3	627.6	1.117	0.999		702.3
1981	552.6	623.0	0.887	1.073	0.000	553.7
1982	853.9	653.8	1.306	1.577	0.045	855.5
1983	923.5	655.8	1.408	1.739	0.000	925.3
1984	982.8	645.9	1.522	2.317	0.000	985.1
1985	881.1	560.6	1.572	2.865	0.000	884.4
1986	822.1	606.5	1.355	1.675	0.000	824.0
1987	894.2	604.2	1.480	11.660	0.000	906.1
1988	623.7	594.1	1.050	10.287	0.001	634.5
1989	569.6	555.3	1.026	12.201	0.052	582.2
1990	528.3	563.1	0.938	10.210	0.054	538.6
1991	544.3	472.3	1.152	5.471	0.053	549.8
1992	421.4	408.0	1.033	8.108	0.016	429.6
1993	539.2	455.2	1.185	9.567	0.000	548.9
1994	761.6	472.0	1.614	9.988	0.052	771.8
1995	463.9	417.0	1.112	8.068	0.008	472.0
1996	479.4	451.7	1.061	12.270	0.000	491.8
1997	611.2	430.2	1.421	11.927	0.026	623.1
1998	486.2	409.3	1.188	7.444	0.008	493.7
1999	684.3	414.5	1.651	8.137	0.015	692.5
2000	579.3	417.6	1.387	0.793	0.007	580.3
2001	521.3	400.6	1.301	0.760	0.000	522.1
2002	574.5	386.7	1.486	0.472	0.004	575.1
2003	517.1	363.2	1.424	0.486	0.000	517.7
2004	468.7	390.5	1.200	0.421	0.000	469.2
2005	433.8	326.0	1.331	0.281	0.000	434.1
2006	464.4	367.2	1.265	0.177	0.000	464.6
2007	453.8	369.2	1.229	0.264	0.000	454.1
2008	425.4	355.8	1.196	0.139	0.000	425.6
2009	457.5	377.8	1.211	0.134	0.000	457.7
2010	379.7	320.3	1.185	0.069	0.092	379.8
2011	613.3	367.2	1.670	0.260	0.154	613.7
2012	578.4	332.7	1.739	0.319	0.326	579.0

6.1.3.2.3 Contemporary Commercial Landings 2001-2012

During 2000-2012, landings averaged 497,500 mt annually, a decline of 10% from the average of the previous decade (Table 6.1). Landings since 2000 have ranged from 379,700 mt in 2010 [BP's Deepwater Horizon (DWH) Disaster - see Section 6.6] to 613,300 mt in 2011.

6.1.3.3 Nominal or Observed Fishing Effort

Often, menhaden vessels unload their catches daily, although trips of 2-3 days are not uncommon. The menhaden plant records, while showing the date and amount of fish unloaded per vessel, do not list number of days fished, nor days when the catch was zero. Logbooks were placed on Atlantic menhaden vessels during the late 1950s and early 1960s to obtain better information on 'fishing' and 'non-fishing' days at sea (Roithmayr and Waller 1963), but compliance was incomplete (Nicholson 1971). Similar attempts to maintain logbooks on Gulf menhaden vessels (1964-1969) also met with mixed results (Nicholson 1978). Thus, through the late 1970s there was no satisfactory way to acquire a complete at-sea history of each menhaden vessel.

Considering that menhaden vessels generally operate continuously over the course of a fishing season and fish every day that weather permits, Nicholson (1971) argued that the vessel-week (one vessel fishing at least one day of a given week) was a satisfactory unit of nominal fishing effort for the Atlantic menhaden purse-seine fishery. Thus, a vessel unloading a catch at least one time during a given week was assigned one vessel-week of effort. Vessel-weeks for all vessels in the Atlantic fleet were calculated across all months of operation, and then summed for an estimate of annual nominal or observed fishing effort for the fishery. For the Gulf menhaden fishery, Chapoton (1971) noted that fish catching ability is more directly related to size of the vessel and its fish hold capacity. Thus, the vessel-ton-week (vtw, one vessel fishing at least one day of a given week times its net tonnage) is used as a measure of nominal fishing effort for the Gulf menhaden fishery, as it better accounts for efficiencies among different sized vessels. Similar to Atlantic menhaden, the correlation between Gulf menhaden landings and nominal fishing effort (vtw) is significantly ($r^2 = 0.82$ for 1955-2012). The regression of landings on nominal effort is presented with observed values in Figure 6.5.

Heretofore, as a general rule, estimates of nominal fishing effort have only been used by the Menhaden Program at the NOAA Beaufort Lab for forecasting annual catches for the Gulf and Atlantic menhaden fisheries. In a broad, predictive sense, the amount of nominal fishing effort expended is a good indicator of the amount of fish that will be removed from the stock in a given year.

6.1.3.3.1 Vessel-Ton-Week (vtw)

Nominal fishing effort is measured on the basis of vessel-ton-week (vtw). For an individual, nominal fishing effort 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 Gulf menhaden fleet is summed across all vessels. Nominal fishing effort statistics for 1948-2012 are shown in Table 6.1.

As the Gulf menhaden fishery expanded, so to nominal fishing effort increased for three consecutive decades. During the 1960s nominal fishing effort averaged 320,800 vtw with a peak of 411,000 vtw in 1969 (Figure 6.6). In the 1970s, it averaged 498,700 vtw, peaking at 575,800 vtw in 1976. Landings for the fishery peaked during the mid-1980s; commensurately, nominal

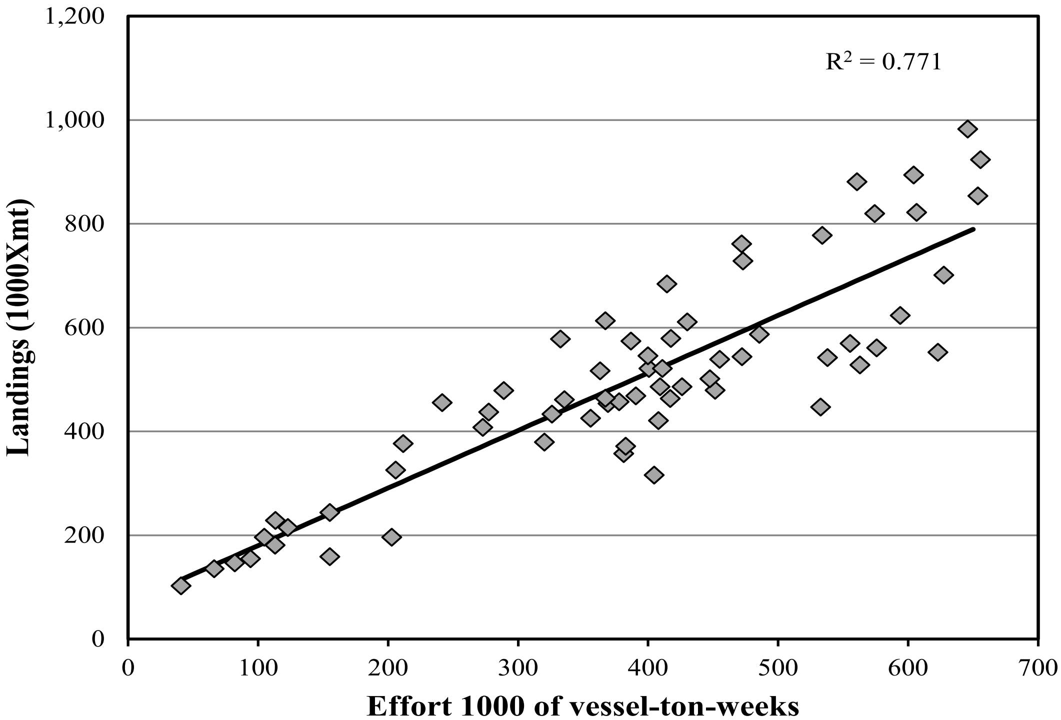


Figure 6.5 Relationship between Gulf menhaden reduction landings (1000 mt) and nominal fishing effort (vessel-ton-week), 1948-2012 (NOAA Beaufort Lab unpublished data).

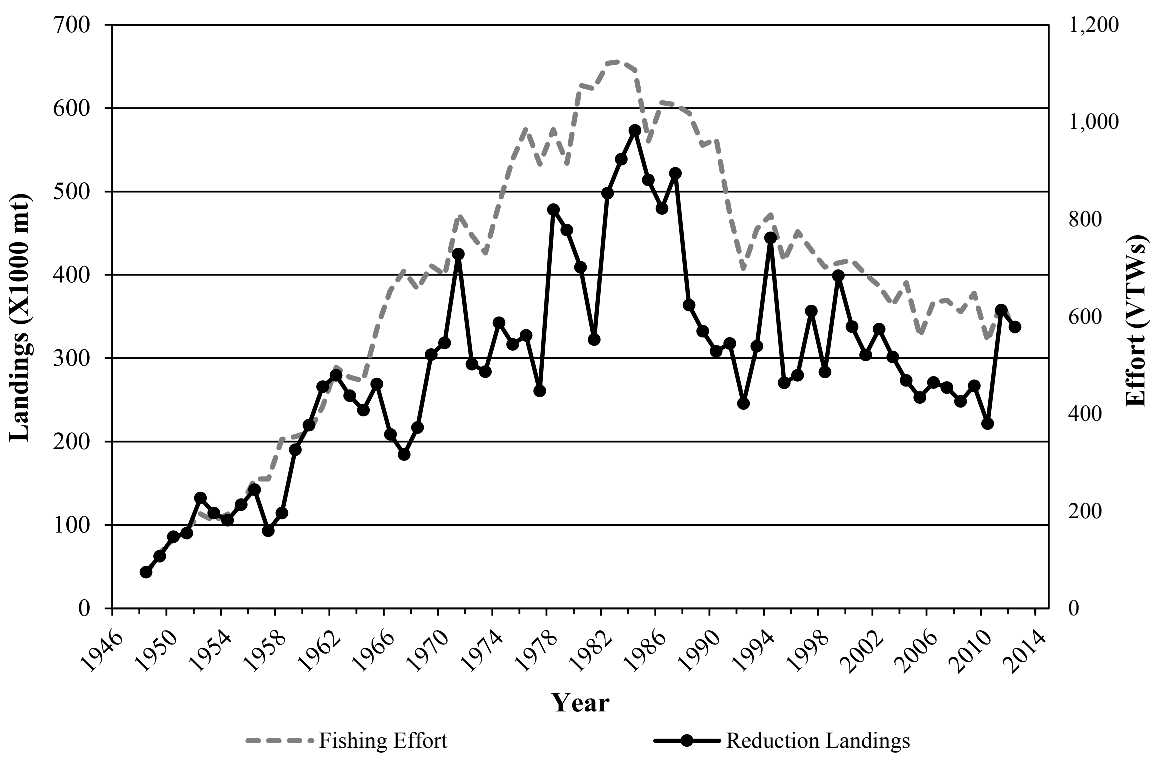


Figure 6.6 Annual values of Gulf menhaden reduction landings (1000 mt) and nominal effort (vessel-ton-week), 1948-2010.

fishing effort rose to its highest level and averaged 612,700 vtw, with peak effort for the fishery in 1983 of 655,800 vtw, presaging by one year peak landings for the fishery of 982,800 mt in 1984. In recent decades average nominal fishing effort declined to 449,300 vtw during the 1990s (with a decadal peak of 563,100 vtw in 1990), with an additional decay to 375,500 vtw during 2000-2009 (with a peak of 417,600 vtw in 2000). Nominal fishing effort in 2010 (DWH Disaster - see Section 6.6) was the lowest value on record (320,300 vtw) for the fishery since 1964. Nominal effort rose again in 2011 to 367,200 vtw, but then fell in 2012 to 332,700 vtw.

6.1.3.3.2 Alternate Measures of Nominal Fishing Effort

In fall 2007, the MAC requested that the NOAA Beaufort Lab explore alternate units of nominal fishing effort for the Gulf menhaden fishery that might replace the traditional effort unit, the vtw, for predicting annual menhaden forecasts. Since annual CDFR data sets are available electronically for most years, with nearly 100% compliance beginning in 1983 (except 1992, 1993, and 2005 when some records were lost), we explored two potential alternate units of nominal fishing effort: 1) total number of purse-seine sets, and 2) total number of fishing days when at least one purse-seine set was made (Figure 6.7). Some conclusions of this exercise were that:

1) total number of sets and number of days with >=1 purse-seine set were closely correlated with the traditional unit of observed effort, vtw, and
2) vtw were adequate for current use in NMFS landings forecast models.

During the SEDAR32A Data Workshop portion of the benchmark stock assessment (SEDAR 2013), the use of catch per fishing trip as a unit of CPUE for the Gulf fishery was explored (Figure 6.8). Catch per trip was calculated simply as the total annual landings of Gulf menhaden

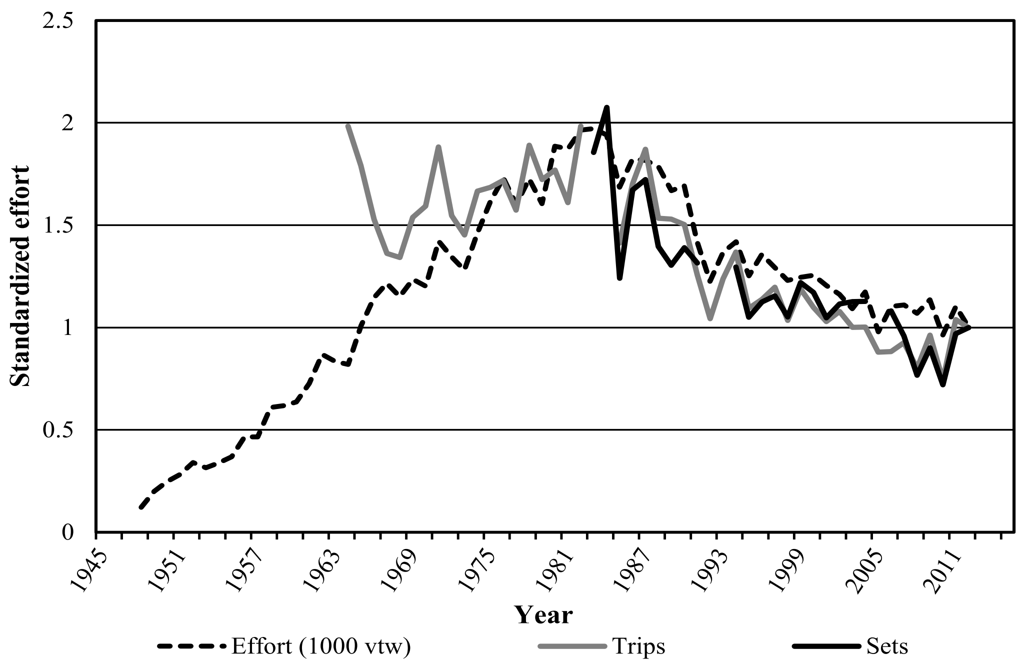


Figure 6.7 Comparison of nominal fishing effort for Gulf menhaden reduction fleet. Effort compared includes: (1) vessel-ton-week, 1948-2012, (2) trips, 1964-2012, and (3) purse-seine sets, 1983-2012. All effort estimates are standardized by dividing by the respective value in 2010 to put them on a common scale. Years with incomplete data (sets in 1992, 1993, and 2005) are left blank (NOAA Beaufort Lab unpublished data).

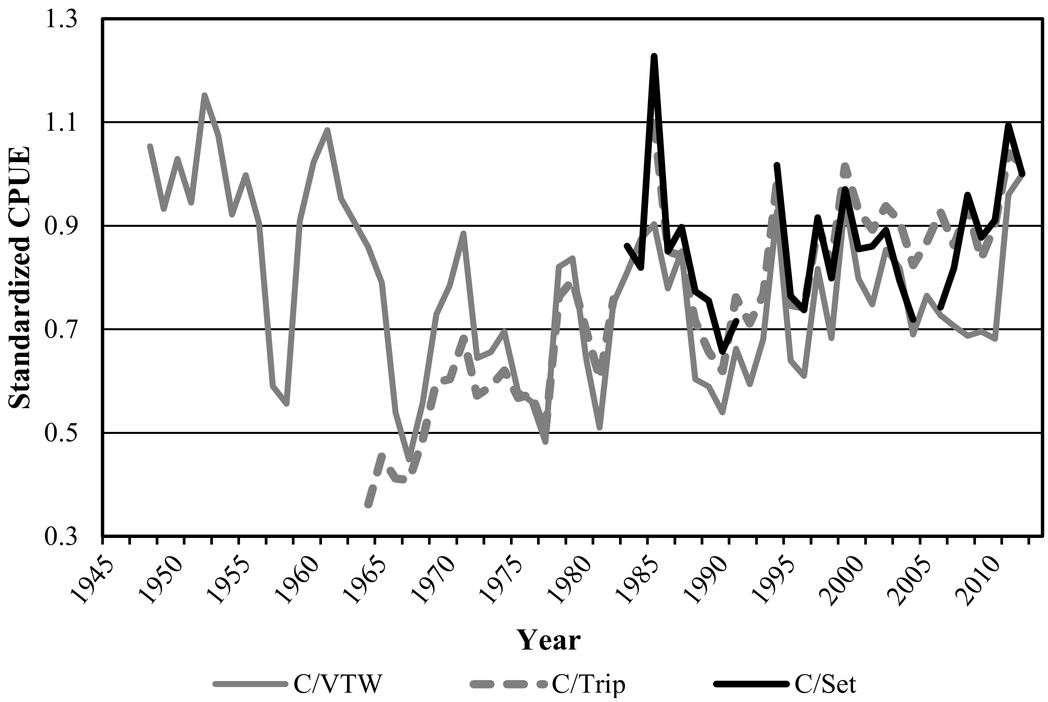


Figure 6.8 Comparison of calculated CPUE across different measures of fishing effort, including landings per vessel-ton-week (C/vtw), landings per trip (C/Trip) and catch per set (NOAA Beaufort Lab unpublished data)

for reduction divided by the number of times Gulf menhaden vessels unloaded during the fishing season (unload events for 1983 and 1984 are incomplete). Notably, catch per trip for the Gulf fleet has risen steadily from the mid-1980s to present (Figure 6.8). Reasons for this increase are probably:

1) longer trip duration, hence greater volumes of fish at each unloading,
2) as older vessels are retired, newer vessels in the fleet have larger fish holds, and
3) improved efficiencies within the fleet, notably use of stern ramps or similar devices by most vessels to launch and retrieve the purse boats, permitting greater number of sets per fishing day (NOAA Beaufort Lab, unpublished data).

These three measures of nominal fishing effort were scaled to 2012 for comparison purposes in Figure 6.8. Similarly, catch per unit effort based on these three measures of nominal fishing effort are compared in Figure 6.8. From about 1980 onwards, similar trends were found for all three measures. However for the period from 1964 to about 1980, there were differences found between vtw and trips as measures of fishing effort. Changes in fleet characteristics since about the 1980s may explain this divergence. As older and smaller vessels were phased out of the Gulf menhaden fleet during the 1970s and early 1980s, newer vessels with larger fish holds and greater net tonnages joined the fleet (net tonnage is a calculation of the volume of cargo space within a ship). Vessels with larger fish hold capacities presumably can stay on the fishing grounds longer and necessarily make fewer trips in a given fishing year. Table 6.2 illustrates this trend toward greater mean vessel net tonnage in the Gulf menhaden fleet over the past forty years. Indeed, mean net tonnage of the fleet has increased over 100 net tons since 1970.

Table 6.2 Mean net tonnage (metric) of the Gulf menhaden purse-seine fleet by selected fishing years since 1970.

Fishing Year	Mean net tonnage	No. of vessels in calculation	Range of net tonnages
1970	248	72	80-386
1980	315	79	139-453
1990	317	75	147-447
2000	338	43	197-453
2010	354	40	187-453

6.1.3.4 Contemporary Landings/Catch Statistics

Landings of Gulf menhaden by the reduction purse-seine fishery - landings referring to the port where menhaden are unloaded - are readily available from the catch records reported to the NOAA Beaufort Lab by the menhaden companies. However, the CDFR data bases give a better understanding of the spatial distribution of catch - in the northern Gulf of Mexico - catch referring to the actual site of the menhaden removals. The sections below discuss both landings and catches.

6.1.3.4.1 Landings by Month

Landings of Gulf menhaden by month can be parsed out from catch records collected by the NOAA Beaufort Lab. Table 6.3 shows landings by year and month since 1991 with the month of peak landings shaded. On average, July (19.4%) ranked first as month of peak landings over the period, followed closely by June (18.4%) and August (18.6%). Average landings for May (15.0%) and September (14.5%) were nearly equivalent, while landings in October (9.2%) and May (4.9%) lagged behind. Annual peak monthly landings occurred almost exclusively between June and August (except in 1996 and 2012) and most frequently in July (n = 9) (Figure 6.9).

6.1.3.4.2 Landings by State

Historically, the majority of Gulf menhaden landings occurred in Louisiana, with Mississippi ranking a distant second (VanderKooy and Smith 2002). 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% were landed in Louisiana, 22% in Mississippi, 7% in Texas, and 0.4% in Florida, although fishing still occurred in those states waters. From 1975 to 1987, 18% of total Gulf landings were landed in Mississippi and 82% in Louisiana.

The apportionment of landings of Gulf menhaden by state since 1991 remains skewed towards Louisiana (Table 6.4). During 1991-2012, landings in Louisiana averaged 437,122 mt, representing on average 84% of the total landings for reduction. Since 1991, landings in Mississippi averaged 83,730 mt, representing on average 16% of the total landings for reduction.

6.1.3.4.3 Catch by State

Information from the CDFR data bases provides a better understanding of the spatial distribution of at-sea catches of Gulf menhaden. Accordingly, removals for reduction purposes

Table 6.3 Total monthly purse-seine landings of Gulf menhaden for reduction in metric tons (mt), 1991-2012, with means and percent of total reduction landings; shaded cells show month of peak landings.

Year	April	May	June	July	August	September	October	Total
1991	21,783	27,941	100,183	147,794	122,097	96,224	28,230	544,252
1992	20,834	73,727	85,404	76,589	69,108	60,829	34,944	421,436
1993	18,184	83,250	86,505	119,885	79,753	83,432	68,192	539,202
1994	31,979	121,231	123,560	132,419	157,042	134,785	60,569	761,584
1995	22,565	61,243	93,734	85,703	85,392	82,617	32,681	463,936
1996	26,513	87,374	98,618	50,169	76,445	103,847	36,409	479,376
1997	13,562	77,991	119,874	109,523	112,078	113,895	64,295	611,217
1998	24,934	98,062	77,460	114,118	89,311	35,392	46,927	486,205
1999	41,198	97,832	137,950	129,181	112,225	123,951	41,934	684,271
2000	51,766	73,405	99,270	128,790	107,726	62,686	55,671	579,315
2001	29,053	63,374	70,317	126,017	96,541	80,453	55,605	521,361
2002	38,456	72,977	101,681	144,085	111,043	58,990	47,298	574,530
2003	20,304	101,008	101,061	68,532	99,403	72,113	54,657	517,079
2004	13,466	63,046	71,444	104,196	95,885	72,253	48,446	468,736
2005	24,844	90,286	120,202	64,539	95,315	16,790	21,809*	433,784
2006	32,629	67,293	80,954	81,371	91,323	89,430	21,394	464,393
2007	13,660	51,110	89,678	110,809	90,730	66,720	31,126*	453,832
2008	29,084	54,587	95,659	98,668	74,586	24,072	48,786	425,442
2009	9,775	76,779	92,597	85,608	82,736	83,566	26,397	457,457
2010	20,790	61,579	71,873	8,340	73,883	54,415	88,847	379,727
2011	20,825	88,056	103,784	125,198	127,963	72,990	74,445*	613,261
2012	39,723	131,306	89,947	111,598	75,067	66,512	64,209*	578,362
means	25,724	78,339	95,989	101,052	96,620	75,271	47,858	520,853
%	4.9	15.0	18.4	19.4	18.6	14.5	9.2	

*includes landings on November 1

by state waters were reported for a limited number of years during the mid-1990s in Smith et al. (2002). Complete annual CDFR data sets between 1983-2012 are currently available electronically at the NOAA Beaufort Lab (except for 1992, 1993, and 2005 when data sets are incomplete), and provide the best estimates of catch by state (Table 6.5).

Since 1983, catches in Louisiana state waters have dominated the fishery (Table 6.5) and have averaged 88.5% of the catch by area, although removals have generally declined since the 1980s, the period of peak coast-wide landings. Estimated catches from Louisiana averaged 702,900 mt in the 1980s (1983-1989), 494,500 mt in the 1990s, and 448,200 mt since 2000. On the other hand, as fishing on the extremes of the species range has declined, that is, Alabama and Florida to the east and Texas to the west, removals from Louisiana have comprised an increasing percentage of the coast-wide catch - 75.4% in the 1980s, 87.8% in the 1990s, and 90.7% since 2000.

Average estimated catch in Mississippi waters has declined from a peak in the 1980s of 43,900 mt to 23,200 mt in the 1990s, but has risen slightly to 28,900 mt since 2000. Annual

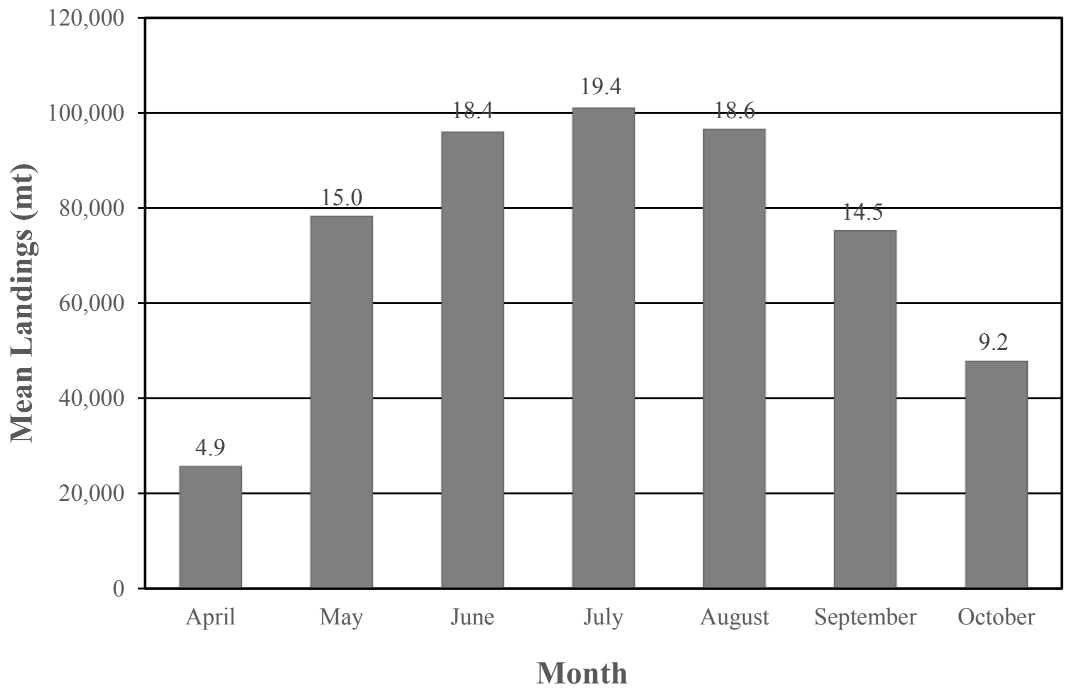


Figure 6.9 Average monthly reduction landings (mt) from 1991-2012. Each month includes the percent contribution to the total average landings over the time period (NOAA Beaufort Lab unpublished data).

removals from Mississippi as a percentage of coast-wide catch has remained fairly level at 5.5% in the 1980s, 4.2% in the 1990s, and 5.9% since 2000.

Estimated removals from Texas waters show almost a three-fold decline over the time series; annual catches peaked in the 1980s when they averaged 47,500 mt, declined to an average of 37,800 mt in the 1990s, and fell again to 15,700 mt since 2000. Annual removals from Texas as a percentage of coast-wide catch was 5.9% in the 1980s, rose to 6.9% in the 1990s, and fell to 3.2% since 2000.

Estimated removals from Alabama and Florida waters, respectively, have averaged less than 2% of the coast-wide catch since 1983.

6.1.3.4.4 Catch by Distance from Shore

As noted in the previous sections, annual Gulf menhaden CDFR data sets provide the best estimates of the spatial distribution of the Gulf menhaden catch. The CDFR data sets for 2011-2012 were deemed typical of recent fishing trends and chosen to tabularize the two-year average of Gulf menhaden catches by degrees longitude and distance from shore (Table 6.6). In recent years catches have been relatively light on the fringes of the extant fishery, that is, in the 88°W interval on the eastern bound of the fishery (7% of the coast-wide catch during 2011-2012) and in the 94°W interval on the western bound of the fishery (1% of the coast-wide catch) - roughly, eastern Mississippi Sound and Texas waters, respectively.

The greatest proportion of coast-wide catch (46%) came from the 89°W stratum - essentially western Mississippi, Chandeleur, and Breton sounds and west of the Mississippi River to Grand Isle (Table 6.6). Catches here were closely tied to nearshore waters with 66% of the catch harvested within three miles of the shoreline. This area is fished almost exclusively by vessels from the

Table 6.4 Purse-seine landings of Gulf menhaden for reduction in metric tons (mt) by state, 1990-2012, with means and percent of total reduction landings (NOAA Beaufort Lab unpublished data).

Year	Mississippi		Louisiana		Total
	mt	%	mt	%	mt
1991	90,809	16.7	453,443	83.3	544,252
1992	70,944	16.8	350,492	83.2	421,436
1993	67,502	12.5	471,700	87.5	539,202
1994	88,684	11.6	672,901	88.4	761,584
1995	52,629	11.3	411,306	88.7	463,936
1996	61,119	12.7	418,256	87.3	479,376
1997	68,207	11.2	543,011	88.8	611,217
1998	82,108	16.9	404,097	83.1	486,205
1999	108,539	15.9	575,731	84.1	684,271
2000	86,257	14.9	493,058	85.1	579,315
2001	87,298	16.7	434,062	83.3	521,361
2002	88,616	15.4	485,913	84.6	574,530
2003	85,254	16.5	431,825	83.5	517,079
2004	72,994	15.6	395,742	84.4	468,736
2005	71,544	16.5	362,240	83.5	433,784
2006	96,504	20.8	367,889	79.2	464,393
2007	97,603	21.5	356,229	78.5	453,832
2008	85,780	20.2	339,662	79.8	425,442
2009	98,298	21.5	359,159	78.5	457,457
2010	47,509	12.5	332,218	87.5	379,727
2011	121,005	19.7	492,255	80.3	613,261
2012	112,862	19.5	465,499	80.5	578,362
means	83,730	16.1	437,122	83.9	520,850

ports of Moss Point and Empire. In the 90°W interval - Grand Isle to Isle Dernieres, Louisiana - catches were a minor proportion of the coast-wide catch (3%), and closely tied to the shoreline with 80% of the catch taken within 3 miles of shore. Lack of Gulf menhaden catch in the 90°W interval - despite being near the geographic center of the species' range - reflects its distance from nearest-neighbor menhaden factories; the interval is on the western extreme range of the fleet from Empire and on the eastern extreme range of the fleet from Abbeville. Adjacent fish factories at Dulac (1995) and Morgan City (1999) were closed in the previous decade.

The areas off western Louisiana, strata 91°W (10%), 92°W (18%), and 93°W (16%), combined comprised 44% of the coast-wide catch of Gulf menhaden. The fleet from Abbeville operates primarily in the 91°W stratum, the fleet from Cameron operates primarily in the 93°W stratum, with overlap by both fleets in the 92° stratum. Catches in all three areas are less closely aligned with the shoreline than on fishing grounds farther east. For example, 84% of the catch in the 91°W interval occurred 3.1-10 miles from shore, 46% of the catch in the 92°W interval occurred 3.1-10 miles from shore, while 48% of the catch in the 93°W interval occurred 3.1-10 miles from shore.

Table 6.5 At-sea estimates of removals of Gulf menhaden [in thousands of metric tons (1000 mt)] by state and percent of total annual catch, 1983-2012 from CDFR data bases; 1992, 1995, 2005 data sets are incomplete (NOAA Beaufort Lab unpublished data). Shading indicates no purse-seine harvest after implementation of the Florida Net Limitation Amendment of 1995.

Year	FL		AL		MS		LA		TX	
	1000 mt	%	1000 mt	%	1000 mt	%	1000 mt	%	1000 mt	%
1983	1.6	0.2	11.2	1.2	53.8	5.8	774.8	83.9	82.1	8.9
1984	5.3	0.5	17.1	1.7	52.6	5.4	843.5	85.8	64.3	6.5
1985	0.0	0.0	6.6	0.7	23.9	2.7	833.2	94.6	17.4	2.0
1986	15.4	1.9	15.2	1.8	41.2	5.0	699.9	85.1	50.4	6.1
1987	16.1	1.8	14.8	1.7	53.1	5.9	771.1	86.2	39.1	4.4
1988	6.1	1.0	10.4	1.7	52.2	8.4	504.2	80.8	50.8	8.1
1989	6.5	1.1	10.5	1.8	30.4	5.3	493.7	86.7	28.4	5.0
1990	2.2	0.4	8.6	1.6	35.9	6.8	450.2	85.2	31.3	5.9
1991	8.8	1.6	2.7	0.5	13.2	2.4	467.5	85.9	52.1	9.6
1992	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1993	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1994	0.2	>0.1	5.8	0.8	17.4	2.3	684.7	91.5	39.9	5.3
1995			6.0	1.3	17.0	3.7	401.0	87.6	34.0	7.4
1996			6.0	1.3	21.0	4.5	409.0	87.0	34.0	7.2
1997			1.0	0.2	16.0	2.7	516.0	87.5	57.0	9.7
1998			2.0	0.4	28.0	6.0	402.0	85.9	36.0	7.7
1999			4.2	0.6	36.8	5.4	625.6	91.4	17.7	2.6
2000			0.5	0.1	17.2	3.0	530.2	91.5	31.4	5.4
2001			2.3	0.4	40.4	7.7	444.5	85.3	34.1	6.5
2002			4.7	0.8	22.6	3.9	517.8	90.1	29.5	5.1
2003			0.0	0.0	36.4	7.0	476.5	92.1	4.2	0.8
2004			0.3	0.1	24.3	5.2	433.3	92.4	10.8	2.3
2005			NA	NA	NA	NA	NA	NA	NA	NA
2006			0.2	0.0	29.0	6.3	420.6	91.2	11.6	2.5
2007			0.9	0.2	18.0	4.0	419.2	92.3	16.1	3.5
2008			0.1	0.0	21.9	5.1	391.9	92.1	11.6	2.7
2009			0.0	0.0	33.4	7.3	417.5	91.3	6.4	1.4
2010			0.3	0.1	33.0	8.7	337.0	88.8	9.4	2.5
2011			0.2	0.1	58.0	9.5	538.1	87.8	15.2	2.5
2012			0.2	0.1	26.5	4.6	544.5	94.2	6.6	1.2

6.2 Bait Fishery

6.2.1 History

The bait fishery for menhaden in the northern Gulf of Mexico has historically accounted for only a minute portion (1-2%) of the total landings of Gulf menhaden (VanderKooy and Smith 2002). Although little published information exists on menhaden bait fisheries (Smith and O'Bier

Table 6.6 Estimate catch of Gulf menhaden in metric tons (mt) by degree of longitude and distance from shore averaged over the 2011-2012 fishing seasons (NOAA Beaufort Lab unpublished data).

Distance from shore (miles)	Latitude						
	94°	93°	92°	91°	90°	89°	88°
	mt (%)	mt (%)	mt (%)	mt (%)	mt (%)	mt (%)	mt (%)
≤1.0	441 (10)	11,487 (12)	15,563 (15)	2,116 (4)	9,823 (53)	62,884 (23)	4,146 (10)
1.1 - 2.0	757 (17)	17,129 (19)	23,136 (22)	3,383 (6)	2,847 (15)	66,183 (24)	9,737 (24)
2.1 - 3.0	692 (15)	19,278 (21)	17,399 (16)	3,688 (6)	2,151 (12)	50,732 (19)	13,107 (32)
3.1 - 5.0	1,117 (24)	26,600 (29)	24,693 (23)	8,495 (14)	960 (5)	60,625 (22)	12,163 (30)
5.1 - 10.0	1,559 (34)	16,965 (18)	20,599 (19)	28,441 (47)	285 (2)	31,211 (11)	1,478 (4)
>10		879 (1)	4,365 (4)	14,127 (23)		1,407 (1)	259 (1)
Totals	**4,564**	**92,336**	**105,753**	**60,248**	**18,543**	**273,039**	**40,888**
% of catch	**1**	**16**	**18**	**10**	**3**	**46**	**7**

2011), the majority of Gulf menhaden harvested for bait in the northern Gulf of Mexico probably are used as bait in the blue crab trap fishery and the crawfish fishery. Some bait is sold fresh at dockside; however, most is probably frozen and trucked throughout the Gulf region. Menhaden are also used commercially by long-line and hook and line fishermen as bait and chum for red snapper, grouper, and other reef fishes. In the recreational fishery, menhaden are used fresh and frozen as bait and chum by sport fishermen and the charter boat industry.

Historically, Florida and Louisiana have been the main participants in the Gulf menhaden bait fisheries. Purse-seine landings of Gulf menhaden for bait in Florida increased substantially during the mid-1980s, peaked in about 1990, declined to lower levels in the 1990s, and have shown a steady downward trend since 2000 (Table 6.7). During the peak years, Florida bait landings were concentrated in Tampa Bay and off the Panhandle region. Closure of Tampa Bay to purse-seine fishing by about 1991-1992 and the Net Limitation Amendment to the Florida Constitution in 1995 (prohibiting purse-seine gear in state waters) no doubt contributed to the decline in landings.

Purse-seine landings of Gulf menhaden for bait in Louisiana increased significantly in the late 1980s when two companies began using previously moth-balled reduction fishery steamers

Table 6.7 Summary statistics for Gulf menhaden bait samples from Morgan City and Cameron, Louisiana, 1996-1998 (NOAA Beaufort Lab 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

to harvest Gulf menhaden in the northern Gulf near Morgan City and Cameron (Table 6.7). The operation in Cameron was closed in 2000. The company in Morgan City closed in 2007; consequently, Gulf menhaden landings for bait in Louisiana declined sharply.

6.2.2 Fishing Methods and Markets

Historically, the bait fishery for Gulf menhaden was primarily conducted in Tampa Bay and along the coasts of the Florida Panhandle and Louisiana. In Florida menhaden were primarily caught using purse seines 1,950-2,400 ft in length fished from relatively small boats (35-65 ft). The Florida Limitation Amendment in 1995, eliminated all entangling nets, including purse seines in state waters (Section 8.2).

In Louisiana, menhaden were caught for bait generally using the same type gear, vessels, and methods as previously described for the reduction fishery. Two older menhaden steamers, formerly employed in the reduction fishery, F/V Surprise and F/V Sea Raider II, fished for bait from the ports of Morgan City and Cameron, respectively. If the bait markets were weak, or the size of the fish was too small for the bait markets, their catch was often unloaded for reduction at the fish factories in Morgan City, Abbeville, or Cameron. In the Gulf, small amounts of menhaden are also caught with other commercial gear, for example, gill nets, trawls, and cast nets (Section 6.2.3 and 8.2) but those landings are minor compared to the reduction landings and are included with the historic purse landings for bait (Table 6.1).

Although some bait was sold fresh at dockside, most was frozen and trucked throughout the Gulf region. There is little published information about the markets for Gulf menhaden bait. Smith and O'Bier (2011) recently described the Atlantic menhaden bait fishery in Chesapeake Bay. Their interviews suggest that substantial amounts of frozen Atlantic menhaden are shipped to the Gulf coast as bait for blue crabs and crawfish. Smaller quantities are probably used as chum or bait by sport fishermen. In recent years the demand for bait in the northern Gulf has been so acute that the state of Louisiana offered 'start-up' grant funds to entrepreneurs willing to establish a commercial bait fishery for Gulf menhaden (LDWF 2011) (Section 8.2).

Gulf menhaden harvested by recreational anglers as bait are poorly represented in the recreational surveys despite a large number of anglers opportunistically targeting them with cast nets. The amount reported in the four states participating in the MRFSS/MRIP survey from 2000 to 2012 for ALL species of menhaden (Gulf, finescale, and yellowfin) ranged from a high of just over 718,000 lbs in 2012 to a low in 2002 of 12 lbs (NOAA personal communication). However, there were four years during that period in which there were no (zero) recreational landings of menhaden recorded, although it should be assumed there were some menhaden landed recreationally for live bait even if they were not intercepted or reported.

6.2.3 Bait Landings, Seasonality, and Age and Size Composition

Table 6.1 shows commercial bait landings of all species of menhaden in the Gulf of Mexico from 1948-2012 (NOAA/SEFSC unpublished data). Further breakdown of landings by state is not possible because of the proprietary nature of some landings; regardless, Florida and Louisiana were the major producers.

Bait landings of Gulf menhaden occur from March through December, usually within 2-3 miles of shore. Similar to the reduction fishery, greatest landings are from April through August. In 1989, Louisiana extended the bait purse-seine fishery beyond the traditional season for the reduction fishery, that is, about mid-April through mid-October. Louisiana bait operations were permitted to begin fishing on April 1, with their season extended to December 1; a quota of 3,000 mt was established for the additional weeks. The biostatistical data on the catch in the Louisiana bait fishery is limited; however, age and size composition of the catch from the mid-1990s is provided in Table 6.7.

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, Roithmayr (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 (personal communication) 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 wing nets. 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 (*Ariopsis*), 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. (2001) 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 Environmental and Meteorological Events Affecting the Gulf Menhaden Stock

Govoni (1997) demonstrated an association between the discharge of the Mississippi and Atchafalaya rivers and Gulf menhaden recruitment. In particular, he found an inverse association between Mississippi River discharge and estimates of half-year old recruits, using recruitment data from Vaughan et al. (1996). Vaughan et al. (2000) updated this relationship with regression analysis. Vaughan et al. (2007) revisited this relationship with additional years of data through 2004. They found that the inverse relationship continued to hold. In addition, they reframed this relationship to produce a 1-year ahead prediction model for forecasting recruitment to age-1 from Mississippi River flow for consideration in fishery management. Finally, they revisited the stock assessment model of Vaughan et al. (2007), and they demonstrated improved model performance when information on annual river flow was incorporated (Vaughan et al. 2011).

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 (Section 4.7.2). El Niño is characterized in the southeastern United States by winter droughts which are often followed by summer floods. 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 (NAS 2000).

Historically, the menhaden fishing season frequently reflects the tropical activities during a particular year (Table 6.8). 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

Table 6.8. Recent meteorological, corporate, and managerial events affecting landings and nominal effort in the Gulf menhaden purse-seine fishery (landings and effort are reported as 1000 mt and 1000 vtw) (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.	
1999	684.3	414.5		Omega Protein closes Morgan City plant after 1999 fishing season reducing vessels in fleet to about 43.
2000	579.3	417.6	Little tropical cyclone activity, but drought conditions persist throughout summer; bloom of large, invasive jellyfish hamper fishing activities in Mississippi Sound; persistent red tide event in Texas waters all summer.	
2001	521.3	400.6	TS Allison in June and TS Barry in August disrupt fishing in the Gulf	Spotter airplane grounded for several weeks following tragic events of September 11th.

Year	Landings	Effort	Meteorological Events	Corporate and Managerial Events
2002	574.5	386.7	Fleet loses considerable fishing time in September due to TS Edouard, Faye, and Hanna, then Hurricane Lili in early October	
2003	517.1	363.2	Drought conditions in western Gulf in early summer; TS Bill makes landfall near Morgan City in July; Hurricane Claudette strikes Corpus Christi in mid-July.	
2004	468.7	390.5	Hurricane Ivan swept through northern Gulf making landfall in Gulfshores reducing number of days fishing.	
2005	433.8	326.0	Hurricanes Katrina, Rita, and Wilma decimated the plants, docks, and ports in Mississippi and Louisiana in August and September.	
2006	464.4	367.2	Plants recovering from 2005 hurricanes; all four Gulf plants not back on-line until mid-June.	
2007	453.8	369.2	TS Erin and Hurricanes Dean and Humberto in August and September disrupt fishing activities; very windy conditions in October hampers fleet activities.	
2008	425.4	355.8	Hurricane Ike makes landfall in eastern Texas; damage to plants at Abbeville and Cameron, Louisiana.	Texas establishes 'Cap' (31.5 million lb) on removals of menhaden by purse seine.
2009	457.5	377.8	Noteworthy for lack of tropical cyclone activity.	First year Texas Cap enforced.
2010	379.7	320.3	Weather was irrelevant after the BP DWH Disaster.	BP DWH Disaster – major closures to traditional menhaden fishing grounds May through August.
2011	613.3	367.2	High rainfall in the Midwest led to the opening of the Louisiana spillways in May and moved fishing away from the River. Two minor tropical storms in September reduced effort slightly.	
2012	578.4	332.7	Limited tropical activity and a mild dry winter led to the best season start in a decade.	

of fishable days. In 2005, the high frequency of storms and the direct impacts to the fleet and fishery from hurricanes Katrina and Rita virtually eliminated fishing after August. Effort remained low as the reduction plants were put back on-line and the vessels, in some cases, were returned to the water. Other factors such as visibility for spotter planes can affect the ability of the fleet to fish and the 'dead zone' can move fish into areas inaccessible to the fleet. It should be noted that many of these environmental parameters and events described in this section are probably related with each other, possibly mediated through such processes as El Nino/La Nino events.

6.6 BP's Deepwater Horizon (DWH) Disaster and the Gulf Menhaden Fishery

The 2010 Gulf menhaden fishing season opened on Monday, April 19th. The BP Deepwater Horizon (DWH) oil rig exploded and sank on Tuesday, April 20th. Beginning about two weeks after the DWH event, the Gulf menhaden fishery experienced unprecedented closures of long-established fishing grounds because of the subsequent oil spill. Over the course of the next three months, the fishery was gradually restricted to fish in a narrow corridor of state territorial sea (0-3 miles from the shore line), west of about Morgan City, Louisiana (Figure 6.10; NOAA Federal Fisheries closure map July 2010). In mid-summer, landings were down 30-40% from landings in recent years. By August many of the restricted areas had re-opened to commercial fishing, and the Gulf menhaden fleet returned to fish traditional areas.

During the last week of April (second week of the DWH Disaster), the winds in the Gulf of Mexico shifted to the south and oil from the spill began moving shoreward. With the potential for the Port of Pascagoula to close due to the threatening oil, menhaden vessels from the fish factory at Moss Point left Mississippi about April 28th for Abbeville, Louisiana. In early May, the NMFS closed the EEZ east of the Mississippi River and the LDWF closed Breton and Chandeleur sounds east of the River, although Mississippi Sound remained open to commercial fishing. In mid-May LDWF closed state waters west of the Mississippi River to about Point Au Fer (in the vicinity of Morgan City); thus, most of the menhaden fleet fished west of Morgan City during the latter half of May, although a few of the vessels from Empire fished in Mississippi Sound. Catches in May were best adjacent the factory at Abbeville, Louisiana (NOAA Beaufort Lab unpublished data).

In early June, vessels from Mississippi began moving back to the factory at Moss Point. For about two weeks in mid-June, LDWF re-opened Breton and Chandeleur sounds, and vessels from Empire and Moss Point made good catches there. Through June, Gulf menhaden landings were down 14% from 2009, and down 17% from the previous five-year average, for equivalent time.

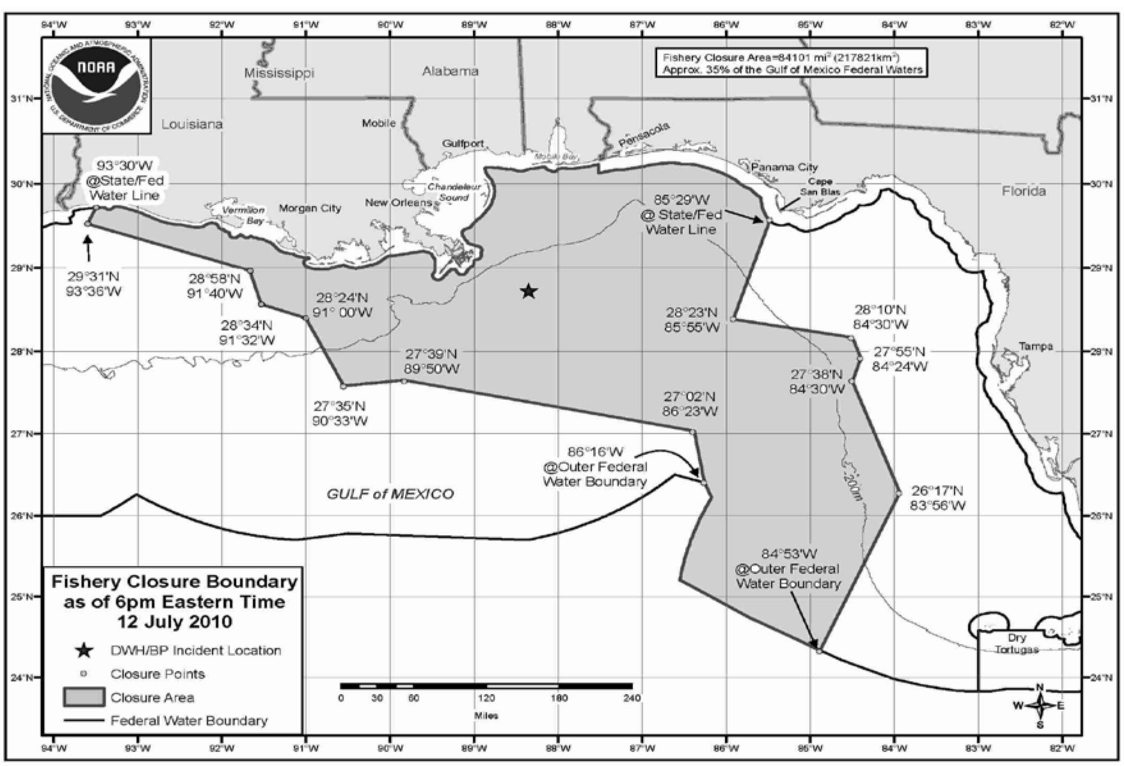


Figure 6.10 Map of the Gulf of Mexico showing the site (★) of BP's Deepwater Horizon (DWH) and fishery closure boundary (dark gray shaded) on 12 July 2010 resulting from the disaster (Source: NOAA Fisheries SERO 2010)

By early July, the MDMR closed Mississippi Sound to commercial fishing and LDWF re-closed waters east of the Mississippi River. Moreover, NOAA Fisheries extended the EEZ closure for commercial fishing to almost the Texas border. Hence, during July 2010, menhaden fishing was restricted to state waters west of about Morgan City. Total landings of 8,340 metric tons in July were the lowest monthly total on record in the NOAA Beaufort Laboratory data base. The few catches that were made in July came from the Cameron area. Through July, Gulf menhaden landings were down 39% from 2009, and down 41% from the previous five-year average, for equivalent time.

Restricted fishing areas were gradually re-opened in early August, as MDMR re-opened Mississippi Sound and LDWF re-opened east of the Mississippi River. By mid-August, LDWF re-opened most areas west of the River. Fair landings occurred at the ports of Cameron, Abbeville, and Empire. Notwithstanding, cumulative landings for the 2010 fishing season still lagged recent years. Through August, Gulf menhaden landings were down 32% from 2009, and down 35% from the previous five-year average, for equivalent time.

In September, the NMFS re-opened the EEZ west of the Mississippi River to about the Morgan City area, but poor weather hampered fishing operations through mid-month. Fair weather prevailed throughout October, and landings were exceptionally good at all four fish factories. Much of the cumulative landings deficit from mid-summer was narrowed in October as final landings for the 2010 Gulf menhaden fishery amounted to 379,727 metric tons; this was down 17% from 2009, and down 15% from the previous five-year average.

7.0 THE ECONOMIC CHARACTERISTICS, PROCESSING, MARKETING, AND ORGANIZATIONS OF THE MENHADEN INDUSTRY

7.1 Reduction Fishery

The market structure, product exploitation levels, processing capacities, and other economic factors of the Gulf menhaden reduction fishery have been stable compared to those of other Gulf fisheries. There has been minor variation in the number of processing plants since the early 1990s with about four to six plants participating in the fishery. Reasons for the relative stability of the industry are varied and complex, but likely include the high capital cost required of a new firm to enter the industry and costs to existing firms to expand fleet size and processing capabilities. At current prices, a modern menhaden vessel would cost in excess of $8.0M. Gulf menhaden fishing vessels are specialized in nature and not easily adapted to other fisheries, or even other waters, because they have a shallower draft and a flatter bottom than other vessels commonly used in the Atlantic menhaden fishery and in other purse-seine fisheries in the world.

Processing plant infrastructure and development are expensive. Depending upon plant size, the cost of a well-located land site and equipment choices, a processing plant built today would probably cost $50-75M. Additionally there exist regulatory hurdles for coastal development and environmental discharge permits that may be difficult to obtain. It would take at least six vessels to supply one processing plant, and eight or more vessels would be optimum. Six 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 management staff and sales force. Because of the extremely high initial capital costs and the time required to obtain and train personnel, a new-entry firm would have to be prepared for heavy losses, perhaps for a substantial period. The overall cost of new entrant would probably be about $100-120M. 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, Inc., and later Omega Protein Corp.) has resulted in two reduction companies operating in the Gulf of Mexico: Omega Protein Corp. and Daybrook Fisheries, Incorporated. As a result of the mergers, several reduction plants were closed as the companies consolidated their assets. Since 2000, active processing plants have been located at Moss Point, Mississippi, and Empire, Abbeville, and Cameron, Louisiana (Figure 6.1). The Omega Protein Corp. became a publicly-traded company on the New York Stock Exchange (OME) in April 1998 raising $68M in capital (Chaillot 1999).

In summary, the economic structure of the Gulf menhaden reduction industry is unlike most commercial 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). Because there are only two companies currently fishing for reduction, confidentiality issues arise with publishing these type of economic data so the total landings and values are combined with Gulf menhaden bait production (Table 7.1).

7.1.1 Value and Price

7.1.1.1 Dockside

Table 7.1 Landings and ex-vessel value of the Gulf menhaden reduction and bait fishery, 1980-2012 (NOAA/SEFSC personal communication). Adjusted (real) values were derived using the 1982-1984 CPI (BLS 2013) with a base year of 2012.

Year	Landings (1000 mt)	Value (x$1,000)	
		Nominal	Real ($2012)
1980	702.3	69,238	192,919
1981	553.7	47,825	120,795
1982	855.5	72,495	172,482
1983	925.2	82,665	190,557
1984	985.1	88,203	194,907
1985	884.0	67,503	144,035
1986	823.8	67,140	140,648
1987	905.9	70,814	143,121
1988	634.0	72,485	140,678
1989	581.8	53,098	98,315
1990	538.5	48,861	85,831
1991	549.6	58,858	99,218
1992	429.3	50,515	82,666
1993	548.5	58,804	93,432
1994	771.6	82,774	128,235
1995	472.0	52,273	78,750
1996	491.7	54,489	79,735
1997	623.1	72,146	103,204
1998	493.6	56,424	79,475
1999	692.4	78,312	107,923
2000	580.1	79,126	105,498
2001	522.1	71,478	92,664
2002	575.0	51,194	65,335
2003	517.6	45,795	57,143
2004	469.1	45,402	55,183
2005	434.1	38,650	45,437
2006	464.6	51,069	58,161
2007	454.1	61,842	68,479
2008	425.5	65,114	69,436
2009	457.6	60,988	65,268
2010	379.8	57,505	60,548
2011	613.5	89,786	91,644
2012	578.7	93,908	93,908

In the Gulf menhaden industry, processors own their vessels and employ crews to catch fish. Each company markets their products, and as such, the menhaden industry is vertically integrated. Since each company uses raw production landed by its own vessels, no true market price or ex-vessel price can be established. Consequently, NOAA Fisheries calculates an ex-vessel price for menhaden by factoring extant pricing for the fishery's chief products, i.e., fish meal, fish oil, and fish solubles. 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 later causing variation in price and value.

7.1.1.2 Products

Landings of Gulf menhaden, along with its congener Atlantic menhaden on the Atlantic coast, account for the majority of the fish meal and fish oil production in the U.S. Moreover, in 2011 and 2012 Gulf menhaden accounted for 74% and 65% respectively of the total domestic fisheries landings for reduction purposes (USDOC 2013). An additional product marketed by the menhaden industry are fish solubles, which are the aqueous fraction of reduction process. Approval by the USFDA in June 1997, the general use of refined menhaden fish oil in foods in the U.S. opened 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, immune disorders, inflammation, and macular degeneration (Georgiou et al. 2013, Hunt and McManus 2014). Fish meal prices are influenced by the availability of globally-produced fish meal and other competing proteins including soybean meal and animal byproduct meals. Similarly, the price for menhaden oil is influenced by the supply and demand for competing products, which include vegetable oils and other animal fats. Years with excess supplies and thus lower values of soybean products typically have a negative impact on the price of menhaden products. About 55% of the total exvessel, or raw weight of menhaden is water and is removed during the cooking and evaporation processes (Table 7.2).

In recent years, the consumer awareness of the primary sources for Omega-3 fatty acids – henceforth Omega-3s has resulted in the isolation of fish meal and fish oil specifically from other competing animal proteins and plant-based fat/oils. Increasing aquaculture production worldwide consumes the majority of globally produced fish meal and fish oil. While efforts have been made to include more terrestrial-based fats and proteins in aquaculture diets, it is clear that fish meal and fish oil are required and command premium prices from this growing market segment. Additionally, the awareness of Omega-3 benefits in humans and pets has greatly boosted prices and further separated fish-based products from competing plant and animal-based fats and proteins.

The reported annual production of fish solubles can vary widely because most producers add solubles back to fish meal and sell it as 'whole meal,' to increase yield and value. Consequently, the volume reported may be significantly different from the actual production. Nevertheless, some solubles are intentionally reserved to sell as a high value product to the organic fertilizer and bait industries.

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 7.3). The United States exported 73% of its total production of fish oil in 2012 with five countries receiving 76% of the total exports: Denmark, Canada, Chile, Japan, and Norway (USDOC 2013).

7.1.2 Processing and Wholesaling

7.1.2.1 Costs

Table 7.2 Fish meal, oil, solubles, and total production from the Gulf of Mexico menhaden reduction fishery, 1980-2012 (NOAA/OST personal communication).

Year	Meal Production (mt)	Oil Production (mt)	Soluble Production (mt)	Total Production (mt)
1980	157,852	114,494	36,288	308,633
1981	127,007	60,513	32,659	220,179
1982	188,696	135,670	58,968	383,334
1983	199,583	151,761	56,246	407,590
1984	215,912	145,545	29,547	391,004
1985	204,119	109,511	88,905	402,534
1986	204,119	137,111	80,740	421,970
1987	181,229	113,737	82,636	377,602
1988	157,303	81,672	46,837	285,811
1989	140,254	84,165	45,925	270,344
1990	121,093	93,212	38,241	252,547
1991	132,863	100,982	49,052	282,897
1992	104,424	62,089	33,923	200,437
1993	133,606	99,395	46,441	279,442
1994	192,156	109,579	60,235	361,970
1995	117,868	79,452	25,995	223,315
1996	118,521	75,587	28,548	222,656
1997	152,010	94,934	45,766	292,711
1998	119,123	75,511	14,177	208,811
1999	170,394	115,753	39,128	325,274
2000	151,879	64,270	39,981	256,130
2001	130,451	103,794	27,048	261,292
2002	147,092	78,630	43,775	269,497
2003	131,502	70,693	35,122	237,317
2004	119,698	66,789	23,436	209,922
2005	110,590	59,118	23,556	193,264
2006	117,535	51,111	31,253	199,899
2007	114,837	58,903	27,370	201,110
2008	104,957	72,834	29,146	206,937
2009	112,037	63,955	32,375	208,367
2010	109,220	49,135	7,600	165,955
2011	150,918	52,876	17,805	221,599
2012	182,440	46,579	34,014	263,034

Vertical integration of the industry complicates the determination 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 overhead at various levels: vessel, plant, and corporate office. Acquisition of raw materials (catching menhaden), other labor, and energy costs comprise the bulk of operating costs. Individual plant costs for raw materials vary depending

Table 7.3 Total U.S. production, exports, and imports of all fish oil (x1000lbs) for 1985-2012 (NOAA/OST personal communication).

Year	Domestic Production (x1,000lbs)	Exports (x1,000lbs)	Imports (x1,000lbs)
1985	285,077	279,079	20,570
1986	336,706	192,213	23,746
1987	298,495	249,119	30,509
1988	224,733	149,279	27,668
1989	225,478	194,796	25,450
1990	301,123	222,343	36,703
1991	273,277	254,065	21,830
1992	183,357	176,950	23,772
1993	300,585	179,617	26,051
1994	291,882	234,362	40,642
1995	241,942	259,260	23,913
1996	248,399	182,498	35,625
1997	283,379	213,635	25,622
1998	222,697	194,078	24,214
1999	286,182	232,270	25,674
2000	192,348	141,751	27,223
2001	279,416	247,793	23,530
2002	210,867	210,724	33,416
2003	195,699	143,504	39,008
2004	179,400	107,538	48,036
2005	157,680	117,161	66,924
2006	142,747	138,596	44,364
2007	152,205	121,269	55,145
2008	190,023	124,510	53,781
2009	168,157	107,862	34,342
2010	136,362	167,206	45,061
2011	143,171	143,883	48,882
2012	115,090	84,441	52,055

on vessel and aircraft costs. These in turn vary because of their age and number, location and availability of fish, distance from the plant to fishing grounds, and rising insurance costs. It is estimated that the cost of landing menhaden as raw material to the plant is approximately 55-65 percent of the total cost of the processed products. Of the remaining one-third, labor, energy, and insurance 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 and vessels 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 daily catches often cause plants to operate below full capacity. The combination of these factors causes a high fixed cost per unit of product.

The industry has been relatively stable since the late 1990s with four factories and about 40 vessels operating in the Gulf of Mexico. However, during the 1980s and 1990s, there was considerable consolidation of infrastructure due to rising costs of operation and product price volatility. This forced the industry to become more efficient, both in fishing and production, in order to remain competitive and profitable. Efficiency gains have occurred through improvements onboard vessels as well as in plant technology (improved cookers, dryers, and evaporators).

7.1.2.2 Reduction Operations

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 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 semi-clarified 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 fish oil by centrifugation is called stickwater. The stickwater is partially concentrated in a multi-effect evaporator, and most is returned to the press cake. When these solids are added to the press cake, the resultant meal is then termed whole meal. Sometimes stickwater is concentrated to a 30% protein (45-50% solids) content and brought to a pH of 4.5 to preserve nutritional qualities and is called condensed fish solubles.

Figure 7.1 illustrates the general reduction process of raw menhaden to its product components. Variations in the quantity of final menhaden components are primarily related to the menhaden’s condition (amount of oil or fat content), 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. Fish meal also contains desirable levels of important minerals such as calcium phosphate, natural selenium, as well as Omega-3s.

The animal feed industry is the main customer for menhaden fish meal. In the past two decades, menhaden meal has become a more important ingredient in aquaculture feed than its more traditional use in poultry and swine feeds. Aquaculture producers place a higher value on the

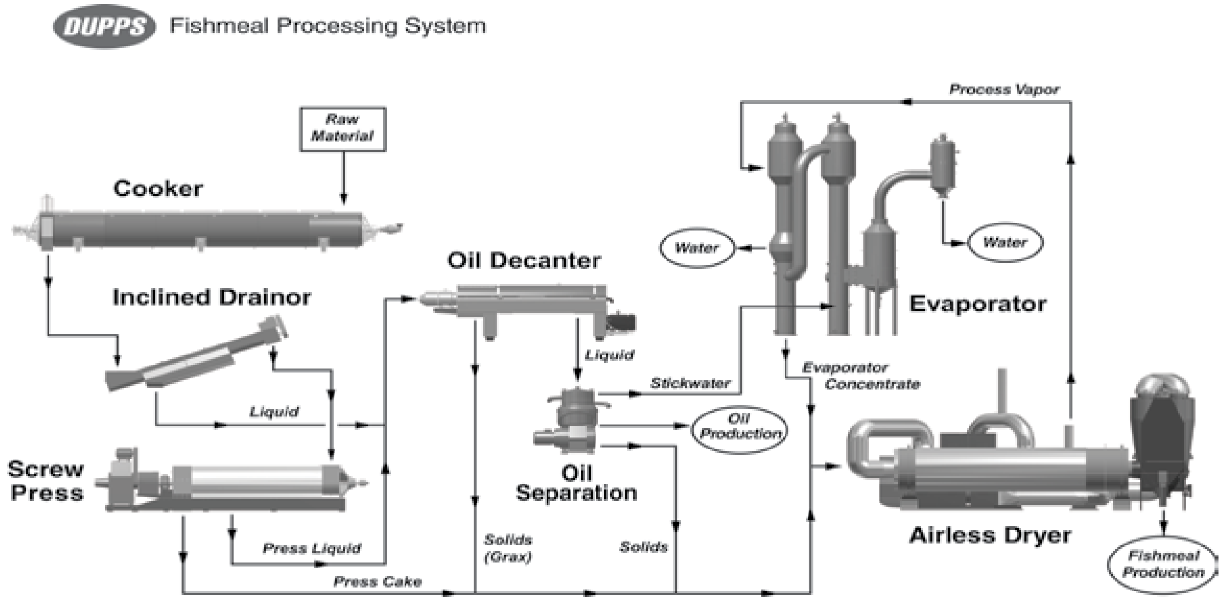


Figure 7.1 The processing of raw menhaden through a modern reduction plant (diagram courtesy Dupps 2014).

Omega-3 content of the meal. Likewise, most menhaden oil is utilized by the salmon aquaculture industry; the high quality and quantity of Omega-3s in menhaden oil have made it a staple in salmon diets in Norway, Canada, UK, and Chile. Additionally, the U.S pet food and cattle industries have realized the benefits of the Omega-3s and have become significant consumers of both crude and refined menhaden oil.

A growing market for refined menhaden oil is Omega-3s for human-consumption. The use of global fish oils in Omega-3 related supplements, food ingredients, and pharmaceuticals has grown by 2% to 20% of global production over the last decade. Although menhaden oil is currently a small percentage of the overall fish oil market, it is growing and may soon influence global pricing for this commodity.

In more traditional industrial uses, refined menhaden oil has unique chemical properties beneficial to the production of alkyds, resins, and plasticizers found in some marine lubricants and greases, rubber, and the paint industry.

Menhaden solubles are a feed ingredient that has the consistency of motor oil and contains about 30% protein, 10% fat, and 10% minerals. Solubles are primarily sold into the fertilizer market, although there is a significant demand from the feed and bait industries. Solubles are listed as organic by the Organic Materials Review Institute (OMRI) and as the organic produce market grows, the demand for solubles should continue to increase.

Until the end of World War II, most fish products were sold through brokers; customers for fish meal included a few major companies that purchased large quantities each year. The feed industry, particularly the poultry feed industry, expanded rapidly in the decades 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 who in turn sell to the feed industry.

Few feed mills carry more than several days or week supply of fish meal (or other bulk ingredients). They are dependent on the supplier and railroads or trucking companies to deliver the material to their plants as needed. Most fish meal inventory is held in menhaden company warehouses, and sales departments direct the sale and shipment of the product. The shipments are in units of truckloads (25 tons), rail carloads (75-85 tons), or barges (1,600 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. 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 car, or vessel load 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.

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.

In 2011, nearly half of the total menhaden production was exported because foreign international markets placed a higher value on it than the domestic market. Asia, primarily China, is the biggest buyer, where it is primarily used in aquaculture and swine feeds. Exports of fish meal from Peru, Chile, and Scandinavia (Norway, Denmark, and Iceland) dominate world markets.

7.2 Bait Industry

In the Gulf of Mexico, the majority of the menhaden for bait that is used in the local crab and crawfish fisheries originates from the U.S. East Coast, primarily from Virginia, Maryland, and New Jersey. Historically – through about 2000 - most Gulf menhaden for bait were landed in Florida along the Panhandle and in Louisiana (Table 6.1). In 1995, Florida's Net Limitation Amendment to the Florida Constitution virtually eliminated most of the Florida's landings of menhaden for bait, although one company continued to land menhaden for bait until the mid-2000s. Current landings of Gulf menhaden for bait in Florida are made by cast net. Total Gulf menhaden harvest for bait throughout the Gulf are presently minimal when compared to landings in the reduction fishery (see Section 8.2 for a history of the bait fishery in the Gulf of Mexico).

Traditionally, Gulf menhaden sold for bait were processed in two forms: 1) the Louisiana market demanded individually quick frozen (IQF) fish for commercial crab and crawfish traps, while 2) the Florida market preferred a whole box blast-frozen product which required thawing before use. The product was sold in a single 100-lb box for around $12 in 1985 and $24 in 2007. This was less than the bait imported from the East coast at a cost of $0.35/lb, which included about $0.10/lb for shipping. The imported product was blast frozen and came in a solid block compared to the IQF fish offered by some Gulf bait producers. The bait producers in the eastern Gulf utilized the blast freezer product as well and provided a 'block' product. When the East Coast prices were lower than the Gulf bait prices, imported products outcompeted the local bait. The annual bait prices for the Gulf of Mexico are presented in Table 7.4.

Table 7.4 Average price per pound for bait menhaden from 1987-2012 (NOAA/SEFSC personal communication). Adjusted (real) values were derived using the 1982-1984 CPI (BLS 2013) with a base year of 2012.

Year	Florida ($/lb)		Alabama ($/lb)		Louisiana ($/lb)	
	Nominal	Real ($2012)	Nominal	Real ($2012)	Nominal	Real ($2012)
1987	NA	NA	NA	NA	0.04	0.07
1988	NA	NA	NA	NA	0.04	0.08
1990	NA	NA	NA	NA	0.06	0.11
1991	NA	NA	NA	NA	0.05	0.09
1992	NA	NA	0.08	0.13	0.07	0.12
1993	NA	NA	0.08	0.13	0.07	0.12
1994	NA	NA	0.10	0.15	0.15	0.24
1995	NA	NA	0.10	0.14	0.25	0.38
1996	NA	NA	0.09	0.13	0.17	0.26
1997	0.14	0.20	0.09	0.13	NA	NA
1998	0.23	0.32	0.09	0.12	0.16	0.23
1999	0.10	0.14	0.08	0.11	0.15	0.21
2000	0.17	0.23	0.09	0.12	0.05	0.07
2001	0.27	0.35	0.08	0.11	0.06	0.08
2002	0.19	0.24	0.10	0.13	NA	NA
2003	0.31	0.38	0.10	0.13	NA	NA
2004	0.22	0.26	0.11	0.13	0.06	0.07
2005	0.32	0.37	0.12	0.14	0.06	0.07
2006	0.34	0.38	0.14	0.16	NA	NA
2007	0.26	0.29	0.15	0.17	NA	NA
2008	0.39	0.41	0.22	0.24	NA	NA
2009	0.20	0.22	0.22	0.24	NA	NA
2010	0.37	0.39	0.18	0.19	NA	NA
2011	0.20	0.20	0.16	0.16	NA	NA
2012	0.21	0.21	0.16	0.16	NA	NA

In addition to commercial demand for bait, recreational fishermen utilize menhaden for bait for several species including cobia, *Rachycentron canadum*, and snappers, *Lutjanus* spp. Recreational anglers rely heavily on 'chumming' to bring the game fish near the boat. Chum primarily consists of ground fish meal mixed with fish oil. Processed chum is frozen and sold in 3lb and 5lb blocks or in five gallon buckets. In addition, saltwater tournament anglers often purchase refined menhaden oil, then slowly drip the oil from hospital IV bags to lure game-fish near their boats. The fish oil is used to establish a 'slick' which, when combined with chum, mimics predatory fish feeding on schools of prey and can stimulate feeding responses on the target game fish (J. Franks personal communication).

Recent actions by management agencies on the U.S. East coast have diminished the bait supplies to both the Atlantic and Gulf coasts. The New England Fishery Management Council recently moved to reduce Atlantic herring quotas by up to 40%; herring are a favored bait for the

New England lobster fishery. In 2013 the Atlantic States Marine Fisheries Commission levied a coast wide quota on Atlantic menhaden harvest which in effect reduced landings by 20%. These actions have effectively reduced the supply of bait available on the Atlantic and Gulf coasts, resulting in higher costs to the end users. With bait prices on the rise, there is no doubt a ripe situation for bait harvest and market development in the northern Gulf.

7.3 Civil Restitution Values and Replacement Costs

Some states have assigned monetary values wherein they assess damage for the loss of finfish resulting from negligence or illegal activities, namely fish kills. These values are determined in a variety of ways for both recreationally and commercially important species. Cost of replacement may be assessed based on the costs associated with hatchery production, willingness to pay by users and non-users, or travel cost expenditures by recreational users. The individual states may utilize additional methods for estimating the value associated with an individual fish for the purpose of damage assessment, such as utilizing existing market prices for commercially important species and estimated hourly valuation of fishing for recreationally-important species (LDWF 1989, TPWD 1996). The American Fisheries Society (Southwick and Loftus 2003) has estimated replacement values for certain species (primarily freshwater) and provides the methods for determining these values. State civil restitution values may be linked directly with these published estimates and methods.

Restitution values vary considerably by state, and if there is not an explicit value associated with a species in a state's administrative codes, the AFS estimates for clupeids in aggregate (Atlantic, finescale, and Gulf menhaden, gizzard and threadfin shad, and skipjack herring) are often applied (Southwick and Loftus 2003). The AFS combines these clupied species at a value of $0.41/lb or $0.12/fish. Florida has used this estimate for menhaden in the past to assess damages in state waters (O'Hop personal communication). Alabama has never applied a damage assessment related to menhaden but uses the AFS estimates for most of their other fish related cases (Mareska personal communication).

Under the Louisiana Administrative code, the restitution or replacement value for Gulf menhaden is $0.11/lb. Mississippi's Department of Environmental Quality (MDEQ) has used the same value as Louisiana for menhaden damages in Mississippi waters. Texas provides restitution values for menhaden based on the size of the impacted fish (Table 7.5).

7.4 Organizations

7.4.1 International

International Fishmeal and Fish Oil Organization (IFFO)
Unit C, Printworks
22 Amelia Street
London
SE17 3BZ
United Kingdom

7.4.2 Regional

Menhaden Advisory Committee
Gulf States Marine Fisheries Commission
2404 Government Street
Ocean Springs, Mississippi 39564

Menhaden Advisory Council for the Gulf of Mexico
Rick Schillaci
Omega Protein, Inc.
5735 Elder Ferry Rd
Moss Point, MS 39563

Menhaden Fisheries Coalition
% Saving Seafood
1025 Thomas Jefferson Street, NW
Suite 420 East
Washington, DC 20007

Table 7.5 Values based on inches and value of menhaden for civil restitution in Texas (TPWD 1996).

Length (inches)	Value per Fish
1	$0.15
2	$0.15
3	$0.15
4	$0.15
5	$0.15
6	$0.15
7	$0.15
8	$0.15
9	$0.15
10	$0.21
11	$0.29
12	$0.38
13	$0.48
14	$0.60
15	$0.75
16	$0.91
17	$1.10
18	$1.31
19	$1.55
20	$1.81
21	$2.11
22	$2.43
23	$2.79
24	$3.18

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

The social and cultural aspect of the Gulf menhaden fishery in the Gulf of Mexico has not been investigated to the extent that other fisheries have (e.g., black drum, blue crab, and mullet). This is primarily due to the fact that this fishery is vertically integrated; i.e., the menhaden companies own the vessels, nets, and processing equipment, as well as hiring the captains and crew, owning the dockside catch, and processing the product. The community description is essentially the company demographics. While there were a few small independent bait processors in the northern Gulf of Mexico, most have gone out of business. This section is intended to provide the reader with an understanding of the demographic and social composition of the purse-seine reduction fishery for Gulf menhaden fishery.

8.1 Reduction Fishery

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 – Omega Protein Inc. and Daybrook Fisheries Inc. Unlike other traditional finfish fisheries in which harvesters sell their catch to processors or dealers who in turn sell to third parties or directly to the public, the menhaden fishery is vertically-integrated, and as a result, the social makeup of the menhaden fishery has not been well-studied or documented with the exception of Chapoton (1970) and Frye (1999) who gave a history of the menhaden fishery. Frye's book, *The Men All Singing* (1999), provides a narrative of how the industry developed and of the individuals and families who established and expanded the reduction fishery; nevertheless, he provided little information on the men and women employed in the industry.

8.1.1 Reduction Fishery Pre-2000

Save for Frye's (1999) narrative, there is little information regarding the participants in the Gulf menhaden fishery prior to WWII. Several small plants operated across the Gulf beginning in the late 1940s. As older plants were closed, larger and more efficient plants replaced them. As noted in Section 6.1.1, by the 1960s and 1970s up to 13 menhaden processing plants existed in the northern Gulf of Mexico, ranging from Apalachicola, Florida, to Sabine Pass, Texas. According to landings records, menhaden have not been landed for reduction in Alabama since 1931, in Texas since 1971 when the last Sabine factory closed, and in Florida (the Apalachicola River area) since 1972. By the late 1970s and early 1980s, the number of reduction facilities had declined to about 11 total plants. Then, in a series of buyouts and mergers starting in the mid-1980s, plants closed as the various companies consolidated. During the mid-1990s, five factories (at Moss Point, MS and Empire, Morgan City, Abbeville, and Cameron, LA) existed to process menhaden. In 1999, the plant at Morgan City, Louisiana, closed. Through the mergers and plant closures, two companies survived into the 21st century. Omega Protein Inc. operates three plants at Moss Point, Mississippi, Abbeville, Louisiana, and Cameron, Louisiana. Daybrook Fisheries owns one plant at Empire, Louisiana.

Similarly, as the fishery expanded, the number of vessels grew to over 80 in the 1970s and 1980s. With consolidation, the number of vessels fell to about 75 in the late 1980s, to about 50 by the late 1990s, and to about 35-40 since 2000. Unfortunately, there is little information on the demographics of the crews and factory workers during the peak of the Gulf fishery – in terms of landings – during the mid-1980s. However, interviews with managerial personnel who have been with the companies over several decades give informative views into the evolution of the fishery.

8.1.1.1 Vessel Operations

As the fishing fleet modernized and technology allowed the purse boats to become more efficient, the size of the traditional fishing crew declined. At the height of the fishery, a typical crew aboard a reduction vessel was about 20 men - not including the captain, mate, or pilot. Fishing operations then were much more labor intensive; the back-breaking tasks of retrieving and raising the purse net were done by shear strength of the crewmen. The crew deployed the purse boats, set the net, retrieved the purse boats, hardened the net, and eventually brailed the catch into the steamer vessel. Until the end of World War II, prior to the introduction of nylon nets, the vessels returned to port nightly because the fish would deteriorate without refrigeration and the cotton nets needed to be brined or pickled to keep them from rotting. Bags of salt were spread over the nets in the purse boats every night, then nets were hosed down to saturate them in the salt all night. Boats were drained the next day as crews prepared to get underway. When nylon nets were introduced into the fishery in the 1950s, the salting process was no longer required with synthetic nets. Later power blocks aboard purse boats made retrieval and movement of nets much easier.

By the mid-1990s, most of the vessels had upgraded to hidrostal pumps which did much less damage to the fish catch than their predecessors, the impeller pumps. By the 1980s, crew size declined to about 18 men. In the mid-1980s, crew size dropped to 16, and by the 1990s through 2000, a single vessel could be handled by a crew of 14. This was the minimum crew that could leave the dock safely and still fish efficiently. In the event that a crewman was injured, ill, or simply did not report for work, the boat operated much less efficiently, and at times, did not leave the dock at all.

Initially, crewman were paid as piece-work with their pay scale determined by the vessel's catch and their position in the crew hierarchy. For most of the vessels, each crew member received a check every two weeks based solely on the fish that were caught in that pay period. By late 1980s crewmen received a minimum pay guarantee regardless of activity. If weather prevented the vessel from fishing, then the crew could look forward to their "guarantee" for the pay period. In addition, bonuses were paid based on total vessel landings which fostered competition among the vessels for top boat. Post-season bonuses served as incentives to keep the crew throughout the entire fishing season, lest they move on to other employment. After season's end, crew members competed to be hired onto the high-liner vessels run by the most productive captains the following season. Guarantees are still used in the industry today.

Historically, the vessel crews and mates were dominated by African-American workers, although there was a mix of African-Americans and Caucasians among the vessel officers (captain, pilot, and engineer); as early as the 1950s there were minority captains at most ports. There were few Hispanic crewmen prior to 2000. Despite the introduction of many refugees from Southeast Asia in the 1970s, few entered into the menhaden fishery; nevertheless, large numbers entered other Gulf of Mexico fisheries including the shrimp and crab fisheries.

Vessel crews and officers typically lived in the local community, especially when fish factories were adjacent to a large community like Moss Point/Pascagoula, Mississippi, and Abbeville and Morgan City, Louisiana. At more rural fish factories the crew members might live as far as 20-50 miles away. Regardless, most crews arrived at the port on Sunday afternoon to load and prepare the vessel for the week, then returned to their homes and families the following Friday, for the weekend. When the menhaden fishing season was over, many of the crew members took other work until fishing commenced again in spring. The vessel mate typically located and hired the crew, so often most of the crew members originated from the same community as the mate.

Plant workers and vessel crew typically enlisted sons, close relatives and friends to work in the fishery. Despite menhaden employment being seasonal, it is estimated that prior to 2000, most of the crew (as much as 95%) returned annually, often to the same vessel they had worked on in the previous season. Crews that worked well together after six months of living together at sea, tended to prefer to stay with the same captain and crew mates, even if the vessel was not necessarily the highest producer. The comfort and familiarity of the crew was critical to a vessel's success.

As the fishery was first developing in the Gulf, the vessel captains spent time in the crow's nest spotting fish themselves and directing the fleet and the crew from above. When the captain was spotting fish, the pilot controlled the vessels and the mate totally controlled the actions of the purse boats. Later, when planes were enlisted to spot for the vessel, the captain was able to direct the crew actions himself. As a general rule of thumb, the two engineers and cook stayed on the vessel when the crew was in the purse boats setting the nets. Occasionally, the 2nd engineer would go aboard the purse boat as an extra crewman when needed. The two engineers worked in watches since their job was 24hrs while at sea. Prior to the late 1950s (before refrigeration was maintained), their duties included checking the generators while the rest of the crew slept. Early in the fishery (in the 1950s) the engineers were typically white with only a few African-American second engineers in the fleet.

8.1.1.2 Spotter Planes and Operations

At some point in the early 1950s, the industry experimented with aircraft to look for fish and guide the fleets to schools. The dozen plants began to contract pilots with float planes to improve their catch. Initially, there were only about 10 pilots along both coasts but the industry found that the use of aerial help leveled the field a bit for the fleet, not relying only the captains to locate fish. However, even with the use of planes, the captain continued to stay in the crow's nest and assisted spotting fish. Captains had a tough time allowing themselves to come down out of the crow's nest either due to a lack of trust of the spotter pilots or a limited availability of planes to assist. Some pilots reported that the captains were so unwilling to follow the planes that they threw their walkie-talkies overboard. The result was that a number of captain continued to stay aloft for many years even with aircraft spotters. The younger captains seemed to embrace the new spotting technique and began to harvest increasingly more fish as a result.

The pilots came from all over the southeast and were full employees of the industry but only worked during the regular season with the exception of a few of the chief spotters who stayed all year to get the planes maintained and certified as needed during the offseason. At first, many of the companies contracted a pilot and plane. Very few of the plants owned their own aircraft. Eventually, the plants purchased planes which they would maintain and simply hire a pilot to fly. The FAA license requirements set the standards for the potential pilots first, but not all qualified pilots were able to successfully see fish as well as fly; many washed out when they couldn't produce fish. Eventually, the fleet became much more reliant on the planes to locate fish and many of the spotter pilots logged more hours flying than commercial pilots. The planes were based at the plant and with floats, they would ramp into the water to take off and return to shore when necessary for refueling or at night. Turntables were built to turn the planes around to be able to quickly return the float planes back down the ramp. By the early 1960s, the industry was switching to land-based planes but a few float planes stayed in service providing supplies to the vessels at sea, retrieve injured or ill crewman, or any other service that was required quickly on the water. Even today, parts are occasionally dropped to the vessels in float bags by the spotter planes. The switch from float planes to land-based planes opened up a larger opportunity to pilots that didn't have prior water experience and increased the number of pilots available to the fishery for spotting.

During the float plane period, there may have been only four planes in use at a plant due to the maintenance costs and general expense of the planes themselves with a rotation of only two flying at a time. Today, there are up to ten land-based planes supporting an individual plant with up to five flying at any time spotting, greatly improving the coverage and efficiency of fishing.

The company owned planes were kept at local municipal airfields. Each company would typically contract an on-site mechanic to service their aircraft. Often, other planes would be moved down the list of priorities if a 'pogy' plane came in needing immediate service. Prior to stricter FAA safety regulations, there was no shift work and a spotter pilot might fly 12-14 hours per day, but newer guidelines prevented too many hours and reduced fatigue considerably.

Prior to the consolidation of the industry, the spotter pilots flew for one company and only provided support for that company's fleet. The result was more competition between planes to locate fish and not tip off the other spotters and vessels from the competing fleet. The pilots typically flew a scouting trip on Sunday in order to put their boats on fish the next morning. In addition, each day before shutting down, the pilots would break off from the fleet and fly some additional sorties getting a plan ready for the next day. The pilots tried to remain quiet and not let the rest of the companies know where fish were being seen. The spotter pilots were paid a salary but also a bonus on fish caught which started at a penny per thousand fish but eventually became more and was significant by the end of the season. The pilots today still get some bonuses at the end of the season but have a guarantee today, just like the crews.

Spotter pilots were hired by the plant but tested by the fleet. Once a pilot was vetted by the captains, they tended to stay on long-term despite it only being a six-month job. The pilots participated in a variety of other jobs during the off-season with some working construction, or guiding for hunting and fishing. A few spotter pilots were kept active by the companies and would fly people and company personnel to meetings and other functions as needed. Some of the spotters moved to the east coast during winter and flew planes for the roe menhaden season along the North Carolina coast. This kept their flight logs up-to-date and was a good source of additional income each year.

Pilots starting with the companies were often retired military flyers and were commercial pilots. In the early years, there were mostly military pilots who just wanted to continue to fly and they knew how to take and give orders and worked well with the fleet. In their down-time, many instructed or flew for other companies as co-pilots or by flying small, lighter commercial freight flights. The demographic makeup of the pilots hasn't changed much over the years. Most of the pilots were Caucasian and early to middle aged but came from all over the US.

Prior to the advancements in radio communication, the pilots often dove at the water to indicate the location of a school or used some sort of physical signal like circling or wagging the wings to indicate locations to the vessels. Later, loudspeakers were added to hail the vessels directly by flying close to the vessel and broadcasting location information. The advantage of the loudspeaker system was that a spotter could direct a vessel much farther distances by telling them to head north so many miles, knowing that the transit time would allow them to refuel or resupply before they were needed again at the school's location. A major improvement was the introduction of Citizens Band (CB) radio sets in the 1960s and eventually standard marine VHF and ship-to-ship radios with the current technology available today.

Eventually, the sky over the Gulf coast became very crowded with fish spotting airplanes and oil and gas support helicopters resulting in a few collisions and casualties. A committee was formed by the pilots in the late 1960s to coordinate the flights and adopted flight ceilings/altitudes for safety. The spotter pilots would hail each other with their altitudes and general locations to avoid contact with other planes. The pilots began to standardize the communications, purchasing dedicated VHF frequencies on the radios to better coordinate in real-time. At the same time, there were a huge number of helicopters flying for the oil and gas industry who agreed to fly at 1000ft or below when departing or approaching the coast which was below the spotter pilot's altitude when they were in and around the fishing grounds. Further complicating flights along the coast was the inclusion of illegal transportation of contraband in the US. Drug runners flying across the Gulf would attempt to 'hide' among the many small aircraft spotting fish for the fleet. The FAA coordinated with the spotter pilots to generate a pre-arranged 'squawk' that would identify the flight as legitimate. If the plane in question did not respond accordingly, a law enforcement or military plane would intercept the illegal flight. The spotter pilots reported frequent crashes of the illegal flights in nearshore waters or coastal marshes during this time.

8.1.1.3 Plant and Dock Operations

Plant workers were not as seasonal as vessel crews. Those who worked in the factory cooking and processing fish often continued through the off-season as product was marketed, prepped, and shipped year-round. Some skilled workers remained on-site to continue maintenance of equipment after the fishing grounds shut down. The shore-based workforce tended to include a more even mix of African-American and Caucasian workers as well as both men and women. Throughout the early part of the fishery until the expansion of the oil and gas industry in the 1980s in Louisiana, many of the plant employees to the east of the state were more Creole in origin (French, Black, Native American, and Hispanic), while those to the Central coast and west were Cajun (French Acadian). During the 1980s, many of these employees moved into the petroleum support industry and vacancies in the reduction industry were left to be filled.

In the early years of the fishery through the mid-1980s throughout Louisiana, the net sheds were traditionally populated with Portuguese net menders who were very experienced working with nets. Some of the other plants such as Moss Point, Mississippi may have been less reliant on Portuguese and had other local groups involved in net mending. By the late 1980s, the ageing net menders eventually retired causing a great void within the industry. In Louisiana, a push was made at that time to locate additional workforce from the surrounding communities. A grant program was provided by the state to assist industry to train unskilled workers in return for partial reimbursement of the trainees' wages. The menhaden industry took advantage of the program in a few plants and hired a number of Asian-descent workers and a higher proportion of women and trained them in the plants. After six months, many of the trainees remained and became skilled workers in the production areas as well as areas like the net sheds where they made and repaired the fleet's purse seines.

The reduction plants traditionally provided much of what the employees needed during the regular fishing season. In exploring a number of old aerial photos of the former factories from around the Gulf, a number of buildings and structures existed, especially in more remote areas where there is less of a local community as noted above. As one industry representative noted, "the plant was almost like a small military base where employees shopped at the company store, received their meals, and worked until there were no more fish to process". Prior to the 1970s, several of the plants traditionally provided bunkhouses for plant workers, bailers, and in some cases, the vessel crews who might not live aboard the vessel when in port. At that time, the plants all operated on a single working shift which meant that the same workers ran the plant 24/7 in season. The bunks were made available when employees had down time to sleep. Often there were multiple employees doing the same job so that they could rotate on-shift when production slowed. The bailers, the dock workers whose responsibility it was to offload the incoming vessels, were on standby around the clock during the season so they were frequently provided a special "bailers' quarters". The bailers tended to remain on the plant grounds to be ready whenever a vessel returned to port. They were paid by the offload which provided them an incentive for a speedy turnaround of the vessels back to the fishing grounds and like the vessel crew, was provided a guarantee for times of inactivity. Unlike the other plant/dock workers, they continue to be paid and housed in this manner today.

Up until the 1970s, all employees were provided four hot meals a day in a plant cafeteria. Breakfast, lunch, dinner, and a midnight meal were available due to the single shift and the vessel crews that returned at all hours of the day or night. Many of the crews ate onboard their vessels and in many cases, provided their own 'grub'. The industry did not pay for the stocking of the galley on board the vessels.

After 1970, most of the companies went to a two-shift schedule, eliminating the need for housing and multiple meals. This was driven by new federally mandated employment regulations on overtime primarily. These regulations eliminated the 24hr shift. After, the plants generally provided a hot lunch and a midnight meal since most of the employees could provide their own meals before and after their shifts. The plants did open what was basically a canteen for the employees (often run by the employees), providing snacks, cold drinks, and some necessity items. Eventually, by the 1990s, the canteen evolved into vending machine areas. Prior to 2000, another comfort provided by the factories prior to the widespread use of cell phones was the payphone. The plants struggled to provide enough payphones on-site for employees to call home and handle personal matters during the regular fishing season and still afford to keep them during the off season when demand was much lower. The phone company charged the plants for the use of each payphone and it was difficult to balance the expense yet maintain adequate service for the employees.

In the off season, (late October through mid-April) an entirely different group of seasonal workers would come to the port to man the vessels as repairs and modifications were made to the fleet. These were highly skilled workers (welders, fabricators, pipe-fitters, etc.) who would maintain and upgrade the fleet in preparation for the next fishing season. Again, depending on the location of the plant to a nearby community, workers may have been brought in from beyond the 'local' area and may include skilled workers from the Atlantic coast. Captains often hailed from areas outside the region as well and might stay on through part of the off-season or return frequently to oversee work on their specific vessels.

Welders were needed year-round for plant repairs as well as vessel repairs. In winter, the most welders were needed to change out vessel components or machinery components. The vessels were taken to shipyards every year for routine maintenance. The bottoms had to be maintained very well. Excessive barnacles on the hull would tear up nets when hardening the bunt so a lot of time was spent cleaning the bottoms and repainting after every season. The vessel's bottom was key to successful fishing. In the plant, contract welders might have been used to do major jobs but most of the plant crews were able to weld and did the routine maintenance year-round on the existing equipment.

8.1.2 Reduction Fishery Post-2000

Since 2000, a number of global circumstances have changed the face of the reduction fishery significantly. Again, this is not a well-documented change, but through interviews with current fishery managers, the changes are summarized here.

The number of plants operating in the Gulf fishery has stabilized since 1999 at four. The number of vessels since 2000 has been relatively constant at about 35-40. A few run boats have been added to the fleet since 2000, primarily at Moss Point; run boats do not fish but rather transfer catch from one or more of the steamers on the fishing grounds then back to the fish factory. In 2012, 35 steamers and one run boat participated in the Gulf menhaden fishery.

Roughly from 2000 through 2007, the menhaden industry found it difficult to crew vessels with local workers. At one point, nearly 50% of the vessel crew members were Hispanic foreign workers hired with H2B visas. Moreover, after Hurricane Katrina in 2005, many coastal communities were significantly damaged and local citizens were displaced or found disaster recovery jobs which paid better than the fishing industry, further complicating the hiring process. In an effort to increase the willingness of the people within adjacent communities to return to the industry, wages and benefits were increased. The result has been lower turnover and a more skilled labor force in the plants and on the vessels since about 2008. Currently, about 25% of the vessel crews are Hispanic, while the remainder are African-Americans. In recent years more African-Americans are filling officer positions, including vessel captains and mates, which prior to 2000, tended to be filled by Caucasians.

Since about 2005, the vessel crew size was increased from 14 to 15 men. Previously, the industry had difficulties going to sea if the minimum of 14 crew members did not show up for work. By adding another man to the crew, vessels could proceed to sea and commence fishing even if one crew member failed to meet the boat at the dock. In addition, a minor at-sea injury did not cripple a vessel and force it to return to port due to safety issues with less than minimal complement of crew. While the additional crewman increased company costs, it also enabled vessels to remain on the fishing grounds longer. Vessel crews continue to be paid with a minimum weekly salary guarantee and with year-end bonuses upon completion of the fishing season. Captains have reported improved discipline onboard the vessels because crew members realize that the vessels can operate without an individual. A crewman left at the dock or put ashore does not get paid while the boat continues to fish and the guarantee does not apply in that situation. Turnover among contemporary crews is fairly low.

Schedules of plant workers have not changed much since 2000. The factories operate on two 12-hour shifts, providing limited meal service and housing (trailers) for their shore-based employees. A number of factory employees remain on-site throughout the fishing week and return to their homes on the weekends. Vessel crews live aboard the boats when in port and go home on the weekends as well. After Hurricane Katrina in 2005, Daybrook Fisheries Inc. at Empire provided temporary housing on the factory grounds for employees and their families. The company also provided full meal service as well after Hurricane Katrina until a few local restaurants were able to rebuild and reopen in 2006. Even today, communities in and around Empire – about 50 miles south of New Orleans – are still fragmented in the aftermath of the storm. The fish factory at Empire is still one of the major employers in the area.

With the rise in cellular phone technology, the need to provide communication for employees has virtually disappeared with the exception of the at-sea vessels. While the plants have done away with payphones, the vessels have company-owned cell phones for the crew and officers to use when offshore.

The ethnic makeup of the dockside and plant workers has not changed much since 2000 with the exception of a more recent influx of Hispanic workers. Foreign workers must meet the minimum H2B requirements and have Social Security cards, while companies must pay payroll taxes along with their domestic employees. The net sheds where the purse seines are repaired are still dominated by highly skilled and well-trained Asian-American workers, while the dockside fish bailers and plant workers are split 60:40 between African-American and Caucasian employees.

8.1.3 Sociocultural Survey of the Present Day Fishery

In the last revision to the Gulf menhaden FMP (VanderKooy and Smith 2002), we pointed out that

> "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."

In an effort to address this lack of social and demographic information, the GSMFC conducted a sociocultural survey of the reduction industry in the Gulf of Mexico in the summer of 2011. We developed a survey instrument similar to the one used in the commercial blue crab fishery in 1998-1999 and reported in the GSMFC's Blue Crab FMP (Guillory et al. 2001). The survey instrument (Appendix 13.2) was designed as a single page with a series of questions related to some personal information such as age, family, race and ethnicity, and education. Additional questions identified where the respondent worked in the industry (i.e., their role in fishing), job satisfaction, and income contribution from fishing (i.e., full time vs part time fishermen/employees).

As the industry is vertically integrated with the companies owning the vessels, the catch, the processing, the products, and the market, not all the respondents were necessarily 'fishermen' but all were employed by a commercial fishing enterprise. Since only two companies operate in the Gulf region, only the total responses will be reported by company. All other survey responses will be combined into an overall response to avoid reporting proprietary company hiring practices, strategies, and to protect employee identities and anonymity in responding.

Of the 1,022 total individuals employed at the four reduction plants in the summer of 2011, 691 (67.6%) participated in the survey. Response rate of total employees at each plant is as follows: Cameron (Omega Protein) 57.8%, Abbeville (Omega Protein) 79.7%, Empire (Daybrook Fisheries) 43.0%, and Moss Point (Omega Protein) 98.3% (Table 8.1). Again, this does not represent all the employees in the reduction fishery but includes those who were active during the regular fishing season, not the seasonal, winter employees and contractors.

Table 8.1 Menhaden industry sociocultural survey returns and participation for 2011. Total employees does not represent all the employees hired in a single year, just those during the active fishing season when the survey was conducted.

Plant	State	Total Employees	Total Surveys Returned	Return Rates
Cameron	LA	211	122	57.8%
Abbeville	LA	241	192	79.7%
Empire	LA	330	142	43.0%
Moss Point	MS	240	236	98.3%
Total		**1,022**	**691**	**67.6%**

8.1.3.1 Jobs in the Industry

In general, vessel labor is almost entirely seasonal employment. Because of increased efficiency of fishing operations over time, typical crew size has declined over time from an average of 25 in 1960 to about 17 in 1973. Since the mid-1980s, the average crew has been around 14-15 on most of the vessels. While there is some turnover of 'green' crew members early in the fishing season, by mid-summer, most of the crews have committed to the vessel and remain for the remainder of the season. Captain/crew pay scales depends upon catch levels with a built-in incentive to work the entire season.

Non-vessel employment in the processing plants, corporate offices, and sales is generally year-round, but only includes around 25% of the total employees. Those who are seasonal participate in a number of other occupations during the off-season which may include retail, construction, trades, or the oil industry. As a result, off-season employees may not return to the fishery the following year. Historically, there were many more family ties to the companies and individual reduction plants which encouraged the return of seasonal labor or secured more full-time positions within the plant for family members shifting from vessel to dock or plant labor.

Those who were relatively new to the industry, five years or less, were dominated by vessel crew members, making up about 56% of all the 'new' respondents and includes both 'Crew' (42%) and 'Deck Hand' (14%) (Figure 8.1). This supports the idea of relatively green crews in the industry with most of the more recent hires. This may also be, in part, due to a lack of long-term crewmen returning to fishing following the hurricanes of 2005 (Katrina and Rita) and 2008 (Gustav). When fishing was slow and vessels and plants were damaged, a number of crew may have moved away and not returned. In addition, the DWH disaster in 2010 may have contributed. The industry members reported having difficulty crewing vessels at the beginning of the season (Section 8.1.2).

Interestingly, the number of responses indicating they were 'Captain' was very high, a total of 67. This is nearly double the number of vessels operating at that time. A total of 19 individual returns listed 'Captain' as their job which was 6% of the new (1-5 year) respondents. It is unclear if there has been turnover in the fleet in recent years or if the category was ambiguous and might include First Mates and other 'officers' not listed on the survey form as job options. The deck hand category may have contributed to the confusion for officers. Current Coast Guard regulations

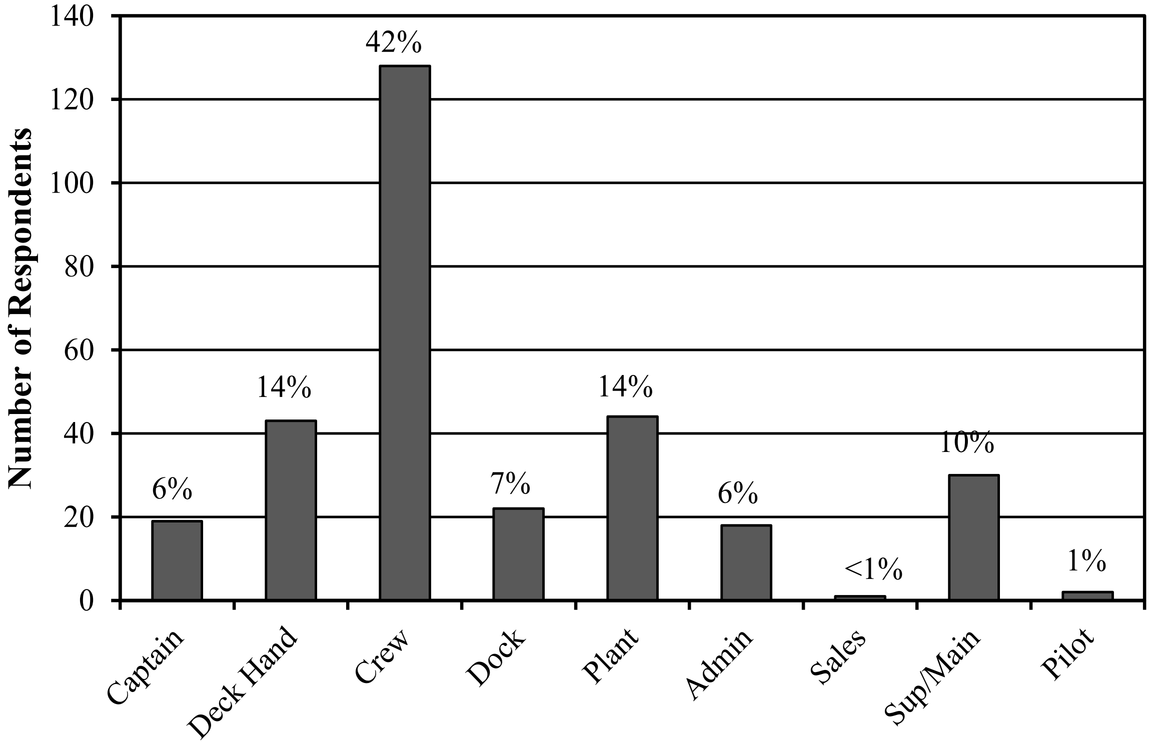


Figure 8.1 Survey results for the reported jobs of relatively new (1-5 year) employees within the Gulf's reduction fishery. New employees make up about 42% of all the industry respondents.

require two licensed captains aboard menhaden vessels which may explain crew reporting the category if they hold a valid captains license. Clearly more work will be needed in the future to improve the survey instrument in the future.

Looking at the more labor intensive jobs, the majority of respondents were older, even though many were not necessarily long-term employees. Of all the positions in the industry, the vessel crews, dock workers, and plant operations are probably the most physically demanding jobs. This seems to hold true just looking at the overall ages for those positions. The respondents identifying vessel crew as their job were dominated by individuals in the 31-35 age bracket (96%). Those identifying dock as their job were in the 41-45 year old bracket (94%) while the plant workers were dominated by 46-50 year olds (92%). This seems to bear true when you compare to the age breakdown related to longevity in the industry (Section 8.1.3.3). While not asked in the survey, there may be a migration through time of workers moving from the vessels to the docks as they age.

8.1.3.2 Familial Ties to Fishing

Commercial fishing in general tends to have strong family ties which can benefit the group by providing support when needed whether financial, labor, gear, etc. However, when these family/friend networks of fishermen are impacted by regulations or fishery disasters, it can become difficult to get help as their closest social networks would also be experiencing the same stresses.

The menhaden fishery is not like more traditional fisheries in that the 'corporation' experiences the stress, not a community of individuals. However, the employees do form a sort of family unit or community, without which, the corporation wouldn't be able to operate. This was true following the hurricanes of 2004, 2005, and 2008. Storm surge associated with the hurricanes impacted much of the industry infrastructure on multiple occasions. When possible, the companies took care of their workers by providing temporary housing and hired a number of them to help with the cleanup and retooling, getting the plants back on-line and getting the boats back to fishing. Family was an important element in this case, pulling the employees (the menhaden community) together.

Family is a strong bond within the menhaden industry in the Gulf. Approximately 53% of the survey respondents had at least one family member active in the fishery. Two respondents who had been in the fishery 40 years and 25 years indicated that they had 12 and 15 family members respectively in the fishery. However, overall, of those reporting having any family in the fishery, the average was 2.9 family members. Overall, about 15% of the respondents have parents employed by the fishery, 26% have siblings, and 28% have in-laws in the fishery. In addition, approximately 7% of the respondents also had children active in some part of the fishery as well.

Of those surveyed, the majority (62%) were married and 31% were single. An additional 6% reported being divorced while the remaining 1% indicated they were widowed. Of those married respondents, 56% had family involved in reduction industry with 103 reporting a father or mother active and 31 reporting a spouse. Of those respondents indicating they were divorced, 106 had a parent in the fishery and 28 indicated that their spouse (assuming ex-spouse) was employed by the industry as well.

Considering that the majority of respondents (about 62%) were employed in the fishery for less than 10 years, it's not surprising that nearly half of those (47%) also had family in the fishery. Of those in that group that were still fairly new to the fishery, 68 had parents in the industry, 85 had one or more siblings, and 18 had a husband or wife active in the fishery.

When asked who introduced them to the industry, 40% of respondents indicated a family member had gotten them into the reduction fishery (Table 8.2). Of those, 18% (126) reported a

Table 8.2 Total responses to survey question about who introduced you to fishing. Total excludes 25 non-responses (5%).

Introduction to Fishing	Responses	Percent
Parent	126	18%
Wife	7	1%
Husband	1	0%
Brother	43	6%
Sister	3	0%
Child	3	0%
Cousin	40	6%
In-Law	56	8%
Friend	237	34%
Other	150	22%
Total Respondents	666	95%

parent had brought them into the fishery. About 34% (237) of respondents indicated a friend had introduced them to menhaden fishing, while an additional 22% reported 'other'.

When comparing family networks within the industry by race and ethnicity, 'African-American' and 'Caucasian' make up the largest percentage of the respondents (73%; Section 8.1.3.4) in the industry. Within those two groups, 62% of the 'African-American' respondents reported having family in the industry, while 'Caucasians' reported 52% of respondents having family involved in menhaden fishing. 'Hispanic' respondents had the same family percentage as 'Caucasian' at 52% although the overall number was less than half (51 respondents compared to 121 'Caucasian'). 'African-American' respondents with family averaged 2.8 family members with a maximum reported of 12. 'Caucasian' respondents averaged 2.7 family members with a maximum of 15. 'Hispanic' and 'Asian-American' participants had lower overall employees with family (52% and 27% respondents with family respectively) but had higher averages indicating 3.3 and 3.5 family members respectively. Interestingly, one 'Hispanic' employee reported having 17 family members involved in the industry.

8.1.3.3 Longevity

Almost half the respondents (42%) reported only having been in the fishery for 1-5 years and 18% were employed for 6-10 years. While the majority of respondents were relatively new to the fishery (Table 8.3), the median age of respondents was between 41-50 years of age (26%). Those respondents up to the age of 40 made up about 48% of all the respondents. Those 50 to 70+ comprised about 30% of the work force. Interestingly, those who were newest to the fishery, weren't necessarily the youngest (Figure 8.2). The expected trend occurred with the majority of middle aged workers (35-45 year olds) who were approaching 20 years in the industry, while some of the older individuals (age-55+; 21%) joined the industry later in life. For example, two respondents in their late 60s reported that they had only been involved with the menhaden fishery between 15 and 20 years; one indicated having been on a vessel crew while the other worked support and maintenance for a plant.

When examining the longer-term employees, those with 20+ years in the industry, the majority were still involved with the fishing fleet primarily. Of those 160 experienced employees that participated in the survey, 72% were directly involved with the fishing operations onboard the vessels. A total of 52 respondents indicated that they were a 'Captain' or 'Deck Hand'. The next

Table 8.3 Summary of responses for years in the Gulf's menhaden industry from the survey.

Years Fishing	Responses (%)
1-5	292 (42%)
6-10	126 (18%)
11-15	56 (8%)
16-20	43 (6%)
21-25	35 (5%)
16-30	41 (6%)
31-35	40 (6%)
36-40	20 (3%)
40+	24 (3%)

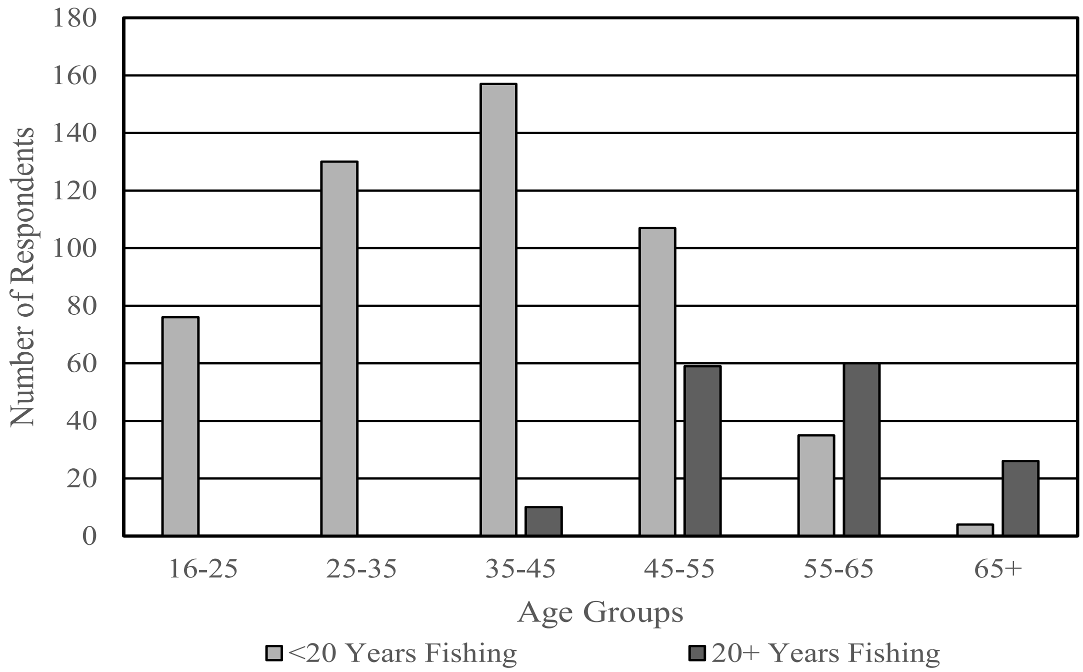


Figure 8.2 Responses from survey participants regarding age and years in the industry. Two groups were isolated, those in the industry less than 20 years and those over 20 years.

largest categories which included long-term employees was 'Plant' and 'Support and Maintenance' at 17 and 16 respondents respectively. The long-term employees made up about 23% of all the survey respondents in the industry.

8.1.3.4 Race/Ethnicity and Citizenship

There is a fundamental difference between a person's 'race' and their 'ethnicity'. Race and ethnic group labels in America are not clearly based on criteria that everyone understands, agrees with, and can easily use. Race generally relates to a person's appearance - chiefly the color of their skin. It is determined biologically, with genetic traits that are passed on from parents. Ethnicity, on the other hand, relates to cultural factors such as nationality, culture, ancestry, language, and beliefs. These points must be taken into consideration when a socio-demographic survey is designed. The surveyor's concept of race and ethnicity does not always match the respondent's concept. For the purposes of this survey, eight of the most common races and ethnic groups were provided although a respondent could select multiple categories such as Caucasian and African American or Caucasian and Hispanic.

The overall racial/ethnic composition of the respondents was 39% African-American, 34% Caucasian, 14% Hispanic, and Asian-American, Native-American, and 'Other' comprised around 13% combined. When examining the racial makeup of the various jobs within the fishery, vessel labor/deck hands were predominantly African-American (46%) with an almost equal split between Caucasians and Hispanics at about 21% each. Dock and plant workers were again dominated by African-Americans at almost 45%, 28% Caucasian, and 15% Asian-American with the remainder being Hispanic, Native-American, and 'Other'. Caucasian was the major racial group represented in administration/sales (88%), vessel captains (53%), and support/maintenance (63%) with African-

American representing 27% and 19% of the respondents under captain and support/maintenance. Asian-Americans made up almost 11% of support/maintenance.

Some (127 respondents, 18%) were not US citizens with 106 (15%) having been in the fishery less than ten years and were predominately vessel workers (70%). Interestingly, about 20 respondents that were not US citizens were employed in the Gulf reduction fishery for over 10 years with about 6 respondents involved in menhaden fishing for 20-40 years, and were hired in their early 20s. The majority (54%) of the non-US workers were from Mexico or South America, and 5 (<4%) were from Vietnam. Of the 52 who did not report their country of origin, 28 reported their race/ethnicity as Hispanic, 7 as African, 9 as Caucasian, and 1 Native-American.

8.1.3.5 Education

In general, about 75% of the respondents had, at most, a high school education or equivalent; these were predominantly vessel workers and deck hands (83%) (Table 8.4). An additional 12% of vessel workers reported having at least some college background, while 6% completed college or advanced graduate work. For those respondents with less than 20 years in the industry, the overall education level was 62% with a high school education or equivalent with an additional 25% having at least some college or upwards of graduate education. However, looking at only those just entering the industry in the last five years, the level of education shifts substantially.

Of the new respondents (1-5 years), 60% have a high school education, 19% report attended some college, another 10% completed college, and 2% indicated some graduate level coursework for a total of 31%. When we examine those respondents who have been in the industry over 20 years, who represent the older, long-term employees, 84% report having a high school education or equivalent with fewer attending any college or more advanced education (16%).

Table 8.4 Breakdown of responses regarding education level completed in specific jobs.

Total reporting	Education Level	Vessel/Deck	Dock/plant	Admin/Sales
18 (3%)	Elementary education	14 (2%)	2 (<1%)	0
91 (13%)	Middle school	60 (9%)	19 (3%)	0
419 (61%)	High school	262 (38%)	67 (10%)	9 (1%)
94 (14%)	Some college	49 (7%)	22 (3%)	8 (1%)
46 (7%)	College degree	13 (2%)	9 (1%)	13 (2%)
14 (2%)	Graduate degree	11 (2%)	0	1 (<1%)

This would suggest that not only are people entering the fishery at an older age (Section 8.1.3.3), but they are also staying in school longer today than previous generations of respondents. Of those 127 non-US workers (Section 8.1.3.4), 109 (86%) have a high school education or less, with the remaining 14% indicating some college or graduate school. About 50% of those with higher levels of education have been in the industry less than 10 years.

When we examine the level of job satisfaction respondents report based on their education level, in every category from 'Elementary' to "Graduate School Degree', the majority of employees are ‘Satisfied’ to ‘Highly Satisfied’ ranging from 72% to 98%. The lowest satisfaction appears to be in the ‘Graduate School Degree’ grouping however, with 21% reporting relative dissatisfaction with menhaden fishing in general. The survey did not provide any questions to allow respondents to indicate where dissatisfaction might lay.

8.1.3.6 Income

Switching fisheries is a common occurrence as commercial fishermen tend to hold multiple endorsements and move between species according to season, value, or availability. The menhaden reduction fishery is unique in that the fishermen work for the company, not themselves so there is no requirement to hold an individual harvester license. However, the definite seasonality of reduction fishing can allow workers who are tied to harvesting the opportunity to participate in other fisheries during the ‘off season’ which runs from November 1 to mid-April.

Of the 691 people surveyed, 339 (49%) of respondents claimed all their income comes from menhaden fishing only. A total of 177 respondents reported participating in other fisheries than menhaden with 19% having income from crabs, 41% from shrimp, 33% from oysters, and 52% generating income from ‘other fin-fish’. A number of respondents participated in multiple other fisheries besides menhaden with six respondents indicating that they fished all four additional categories provided.

Looking at the income by job, of 388 who indicated they were deck hands or crew, 238 or 62% reported that they made 100% of their income from commercial fishing. An additional 89 (38%) of the vessel labor/deck hands indicated that they participated in non-fishing activities. Considering that most of the positions in the fishing fleet are seasonal, this is not surprising. This includes 38 participating at least part-time in construction, eight in retail, seven in oil and gas, and two in the hospitality industry. Respondents were allowed to write in specific jobs in the ‘other’ category and 37 reported additional side occupations which included cooking, tree trimming, working tug boats, and driving a taxi.

8.1.3.7 Job Satisfaction

When the respondents were asked about their job satisfaction in the reduction fishery, the overall mean was slightly better than satisfied, approaching ‘Mostly Satisfied’. By race and ethnicity, the Asian-American workers were generally the most satisfied; they tended to be dock and plant workers and tend to have year-round work, but are fewer in number than other ethnicities in the fishery. Caucasian, Hispanic, and the ‘Other’ categories are reasonably ‘Satisfied’, as well with Caucasian and Hispanic, making up the majority of employees in the reduction fishery. Interestingly, the Hispanic group tends to be the more seasonal workers on vessels and Caucasians tend toward dock/plant and administration positions. The respondents who were the most satisfied were in the combined 36-45 year old age bracket while the least satisfied respondents were in the combined 16-35 age group. However, the overall response was still in the middle at ‘Satisfied’ for the younger age employees.

African-Americans, who make up the majority of the fishery workers, have the lowest job satisfaction overall with about half as seasonal employees working as deck hands and vessel crews, and the other half as plant and dock workers with more long-term positions. In addition, US citizens overall were less satisfied with their jobs in the menhaden fishery than non-US citizens, albeit only a difference of 3.7 to 4.1 on average, yet this was statistically significant ($p=0.027$).

Comparing respondents overall, there was no pattern to the degree of satisfaction by age or time in the industry. Those who were 'Unsatisfied' included ages from the youngest to a few of the oldest; likewise were the 'Highly Satisfied' responses covering a wide range of age and experience. Across all jobs within the industry, the overall average response was better than satisfied suggesting that most of the employees in the fishery are content with their choice of profession. The majority of those surveyed were relatively happy with their profession working in the menhaden reduction fishery.

8.2 Historic Bait Fishery

As noted in Section 6.2.1, traditionally some Gulf menhaden have been landed as bait for the blue crab trap fishery and the crawfish industry, but these landings (1-2% of the coast-wide Gulf of Mexico menhaden landings) pale when compared to the Gulf menhaden reduction landings. The majority of the menhaden for bait originated from the East coast and was shipped boxed and frozen to support the local crab and crawfish fisheries. Even today, most of the bait menhaden in the Gulf originates from three major areas on the East coast: Virginia and New Jersey, and Maryland.

Recreational and commercial hook-and-line fishermen use dead and live menhaden for baits, while some sport-fishermen relied on menhaden meal and especially menhaden oil as chum or an attractant.

Through about 2000 Florida and Louisiana dominated the Gulf menhaden bait industry. Florida's landings of Gulf menhaden for bait fell dramatically after the 1995 Net Limitation Amendment which prohibited purse seining in state waters. Louisiana has been the primary source for bait until the early to mid-2000s. While there are likely significant recreational cast net landings of 'bait' fish in the Gulf today by recreational fishermen (cigar minnows, scaled sardines, threadfin herring, Spanish sardines, and Gulf menhaden), there are virtually no commercial landings for bait in the Gulf since 2007 when the last company that purse seined Gulf menhaden specifically for bait in Morgan City, Louisiana, closed. Commercial harvest of menhaden for bait in the Gulf of Mexico at present is probably limited to catches by cast nets, gill nets and some trawls.

The Gulf's bait industry does not have a long history like the reduction fishery. Other than minor sales dockside from the reduction plants prior to the early 1970s, there were few entities landing menhaden exclusively for bait. Beginning in the early 1980s, one Florida dealer caught and shipped menhaden to dealers in Louisiana for the crab and crawfish industry. Menhaden were harvested from a 50 ft stern-rig vessel, similar to menhaden bait vessels used on the East coast. The vessel set the purse seine and the catch was pumped onto a second vessel which returned the fish to port for processing. This was a relatively small harvesting operation compared to the reduction fishery. The menhaden caught for bait was processed along with several other species, e.g., thread herring and cigar minnows. The Net Limitation Amendment to the Florida Constitution implemented in 1995 banned entangling nets in state waters and limited all nets in nearshore waters to no more than 500 square feet and prohibited commercial net fishing inside three miles from shore. The Amendment made the bait business unprofitable for the processors; they virtually stopped fishing for menhaden. Since the Net Limitation Amendment, the company has sold less than a few hundred thousand pounds of menhaden as a specialty bait by request. Local cast net fishermen are employed to fill a few bait orders each year; the volume is minor compared to bait landings pre-1995. Considering the location of the dealer on the Florida Panhandle, these menhaden were likely a mix of both Gulf and finescale menhaden. Two other companies attempted to get into the bait business in the late 1980s, setting up operations in Cameron, Louisiana and near the Rigolets which connects Lake Pontchartrain with Lake Borgne in eastern Louisiana. Both failed after only a year or so.

Several companies harvested Gulf menhaden for bait in Louisiana beginning in the 1980s. A firm near the Rigolets in eastern Louisiana failed after about one year. In 1985, a bait facility was built in Morgan City, Louisiana, near the site of the old Seacoast reduction plant. The owners began their fishing careers decades earlier in the reduction fishery. A small menhaden vessel (140 ft) from the reduction fishery was purchased and targeted fishing for menhaden for bait. Onshore, a small processing plant was built which utilized a brine freezing procedure. The individual quick freeze, or IQF process, froze freshly offloaded menhaden in large tanks of brine which were super-cooled to below freezing. Paddles in the tanks kept the individual fish moving through the solution until they were frozen seven hours later. The product was conveyed from the tanks into 100-lb boxes and were either held in storage or put directly onto refrigerated trucks and shipped throughout the Gulf coast. Menhaden bait buyers west of the Mississippi River preferred brined, IQF fish which held up better in bait wells in crab pots. Bait buyers east of the Mississippi River tended to prefer block frozen menhaden for bait which would thaw on the dock and be easier to put in bait wells; they wanted to see the oil running out of the fish when they baited up.

Purse-seining for bait and processing the product was similar to the reduction fishery except for how the final product was marketed and the overall scale of the operation. The bait carrier vessel however could only hold 300 tons of fish compared to the reduction boats which held almost twice as many fish. Unlike the reduction fishery, when the bait boat returned to port, the vessel crew was paid extra to offload the vessel using the same onboard pump system so no shore-based machinery was required. The catch went directly to the IQF tanks. The vessels fished on Monday-Friday but the plant ran seven days per week to handle the frozen product storage, sales, and shipping.

The crew was local to the area and almost entirely African-American. The captain and mate hired the crew and most crewmen returned the following year. Louisiana passed a regulation in 1989 allowing a longer bait fishing season which began on April 1 (about two weeks earlier than the start of the reduction fishery) and ended on December 1 (about a month after the close of the reduction season). Sometimes when the bait plant was overloaded with catch, the bait vessel would unload its catch for reduction purposes at a fish plant in Morgan City or later in Abbeville. Often this was done to keep the vessel and crew fishing rather than stay idle at the dock. The profits from landing for reduction purposes was minimal, but it covered the operational costs of the vessel and crew to continue making wages.

Initially, the bait plant hired a spotter pilot and plane to assist with fishing, however, the plane could only fly for five hours and then had to return to refuel. Alternately, the bait boat could follow the reduction boats from the Morgan City plant to find fish. The company ended up eliminating their own plane and contracted with the reduction fishery to use one of their spotter pilots.

When fishing ceased in November, the number of bait plant personnel fell from eight or nine down to about four to load and ship the frozen product during winter. The bait plant was reasonably automated with conveyers moving fish to the IQF tanks and out to individual boxes for packaging, but plant crew men still stacked boxes, moved them into storage, and made up orders for shipping which had to be loaded onto the trucks.

The company was vertically integrated similar to the reduction industry. The bait plant owned the vessel, paid the crew, processed the fish, marketed, sold, and distributed the product. The company even owned the refrigerated trucks and hired the drivers. The Louisiana-based company supplied over 100 dealers in three states with bait. About 90% of those dealers were in Louisiana, but many still purchased bait product from the US East coast to meet the demand. In a single season, 300-500 tractor trailer loads of frozen Gulf menhaden bait was distributed from Aransas Pass, Texas, to Pascagoula, Mississippi. A single 100-lb box sold for around $12 in 1985 and $24 in 2007. This was comparable to the bait imported from the East coast at a cost of $0.35/lb which included about $0.10/lb for shipping. The imported product was blast frozen and came in a solid block compared to the IQF fish offered in the Gulf. The blast freezing process required additional time for freezing, usually around 36 hrs, and was generally considered inferior to the Gulf's IQF product.

The bait plant in Morgan City closed in 2007; since then, there has been no bait industry in the Gulf that utilizes Gulf menhaden. In an effort to stimulate a bait fishery, Louisiana in 2010 offered start-up funds for entrepreneurs interested in developing localized bait fishing operations. Two grants were awarded in 2011 to investors to enter the bait fishery. One group of investors, located near the Abbeville reduction plant, purchased a small purse-seine vessel and made numerous attempts to land fish. The second group of investors, also near Abbeville, began working on the shore-based infrastructure to land and process menhaden for bait using the IQF process.

8.3 Industry Related Stressors

For industries associated with near-shore environments, there are many natural or manmade issues which can affect operations. These stressors can be acute or chronic. Acute stressors are those which develop over a relatively short period of time and may include environmental stressors such as flooding, oil spills, hurricanes, harmful algal blooms, and drought. Although these may develop over weeks or even hours, acute stressors can have long-term impacts. Chronic stressors are those that occur over a long period of time. They tend to occur slowly, but over time, have lasting consequences which may be punctuated with more serious consequences.

8.3.1 Gulf Hurricanes

During 1950-2011, the NOAA's National Hurricane Center reports that there were 58 hurricane strikes in the Gulf of Mexico, seven of which were Category 5 (see Section 4.7.2). The major impacts of hurricanes to fisheries include coastal gentrification, rising fuel costs, labor shortages, a shift from commercial to recreational fisheries, and rising insurance costs (IAI 2007). Hurricanes may accelerate coastal gentrification as fishing infrastructure is altered, devalued, or in some cases, destroyed. Docks and processing facilities typically compete with casinos, recreational fishing facilities, and condominiums for space. While less of an issue for the reduction fishery, the decline of 'working waterfronts' elsewhere signals a cultural shift away from traditional fishing lifestyles to tourism and other uses.

When a tropical system forms in the Atlantic or Gulf basins, the menhaden industry is concerned about how the system will affect at-sea fishing operations and whether its track will bring it close to one or several of the fish plants. Two major hurricanes occurred in 2005 which significantly impacted the reduction fishery.

Hurricane Katrina struck the Gulf coast in August 2005, heavily impacting fishing ports in Mississippi, Louisiana, and Alabama. The economic loss to marine infrastructure Gulf-wide was estimated at $330 million (NMFS 2005). Boats, docks, processing establishments, icehouses, and restaurants were damaged or destroyed. Extensive damage occurred at the menhaden factories at Moss Point and Empire. In addition to infrastructure damage, labor for repairs was in short supply. Daybrook Fisheries Inc. at Empire had to provide temporary housing for its displaced employees who also lost homes in the area. The Omega Protein plant in Moss Point fared better, but had significant flooding throughout its facility in Mississippi. In addition, a number of vessels were damaged or pushed by storm surge into surrounding marshes, structures, and even onto a major highway.

In late September 2005, only weeks after Katrina made landfall, Hurricane Rita made landfall along the central Louisiana coast, pushing storm surge into the plants at Abbeville and Cameron. While Moss Point, and Abbeville were able come back on-line after these two hurricanes, Empire and Cameron closed and did not process fish until spring 2006. Most of the shore-side infrastructure was severely damaged at Cameron and Empire; many losses were uninsured. There was considerable concern that employees who were displaced following the storms might not return to the fishery since construction and hurricane-recovery jobs paid higher wages following the disasters.

8.3.2 Oil Spills and Pollution

The Gulf of Mexico is an important region for the production, shipping, and refining of petroleum. Petroleum spills come from both industry and shipping. When spilled, the lighter components enter the air while the heavier ones either become floating balls of tar or sink to the bottom where they can damage benthic organisms. Some compounds can last many years in the sediments. The type of damage incurred by the fisheries, therefore, depends not only on the quantity of petroleum spilled, but also on the type of product spilled and the time it takes to respond to the spill. The long-term effects on the environment and marine organisms are yet to be determined.

Menhaden are filter-feeders and as such, the menhaden industry is concerned about the bioaccumulation of toxins, especially from petroleum pollution. The menhaden fishery is concerned with the quality and purity of the fish meal and fish oil that they produce. Considerable effort and costs have been incurred to set up quality assurance laboratories at each menhaden plant. In addition, the companies outsource to highly sophisticated testing laboratories to ensure that their products meet international food and feed safety requirements.

In the aftermath of the Deepwater Horizon (DWH) disaster in April 2010, the closure of almost 90,000 square miles of the Gulf of Mexico caused significant stress to the menhaden industry as much of the traditional fishing grounds were closed. Even in 2014, there were still areas in the nearshore Louisiana marshes that remained closed to fishing due to oiling from the BP disaster. Industry concerns are still great regarding the long-term effects of petroleum and dispersants on the Gulf of Mexico and its marine life. The potential for impacts to menhaden recruitment success, adult mortality, susceptibility to disease, and other life history parameters are a constant concern to the industry.

8.3.3 Increased Costs to Industry

8.3.3.1 Insurance

The menhaden companies in the Gulf have always self-insured to a point, but since the 2005 hurricanes, flood and wind insurance costs have soared along with coastal property rates.

In 2012, Congress passed Biggert-Waters Flood Insurance Reform Act of 2012 (BW-12) which has contributed to great uncertainty as to how much these insurance costs will eventually rise. As a result, people are leaving the coastal areas because they are no longer able to afford the flood insurance on their personal dwellings and are unable to secure home loans without insurance. This is dramatically impacting the 'local workforce' and the ability to find laborers by the industry.

8.3.3.2 Inability to Secure a Qualified and Willing Labor Force

Increased transiency of workers and the increased availability of higher paying, less laborious jobs have reduced the quality and quantity of the local labor force. The necessity to find qualified workforce requires more use of legal, alien workers onboard vessels and dockside however, many of these personnel do not have the expertise to work with the more elaborate process controls in the plants. As the local economies have declined and the cost of living along coastal areas has increased (see Section 8.3.3.1), the industry has continued to have trouble locating and keeping skilled workers.

8.3.3.3 Improvements to Processing for Quality Control

Quality demands by global markets and consumers of fishery products have resulted in increased production costs as the industry experiments with new equipment and methods to assure higher quality standards of their products. These include mechanical improvements as well as expensive and elaborate quality control procedures and testing facilities (see Section 8.3.2). In order to staff these facilities, the industry must find qualified plant workers to operate the sophisticated equipment utilized in contemporary processing techniques.

8.3.3.4 Fuel and Energy Costs

Increasing fuel costs have always been a concern for the industry. Most of the companies buy bulk quantities of fuel and store it on site. Since about 2002, the cost of No. 2 diesel fuel has risen by approximately 300% (USEIA 2013). The industry does benefit by using less-expensive, off-road diesel fuel, versus DOT approved highway diesel fuel. Also, no roadway taxes are levied on the off-road fuel. High fuel costs in the U.S. are related to additional refining that is now required under more stringent EPA regulations to reduce sulfur emissions.

High U.S. fuel prices have given a competitive advantage to foreign fish meal and fish oil producing countries. Foreign countries often subsidize fuel in an effort to increase profitability of their fishing fleets (Sumaila et al. 2013; see Section 8.3.5).

Energy costs have also been a chronic source of stress for day-to-day plant operations as the average cost of electricity in Louisiana and Mississippi has increased 120% over the last decade.

8.3.4 Ageing Fleet

Menhaden vessels are highly-specialized and expensive. Modernization of the menhaden fleet is a continuous process; significant modifications and retrofits are made annually in winter to improve functionality and safety at sea. Constant maintenance has extended the life of many vessels. Indeed, Omega Protein at Moss Point purchased a neighboring shipyard to maintain its fleet. Also, any 'new' vessels entering the menhaden fleet in the past several decades tend to be surplus oil rig supply vessels which are refurbished into menhaden purse-seiners.

8.3.5 Unfair Competition Practices

Foreign fish meal and fish oil competitors often receive government subsidies that are unavailable in the U.S. menhaden industry. Cheaper labor forces also allow 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 price supports for farmers, while menhaden meal is produced with no assistance and there is still no analog to 'crop insurance' for fisheries failures.

Government subsidies for fisheries world-wide are substantial. Sumaila et al. (2013) reviewed subsidy programs globally and found that fisheries subsidies were estimated at about $35B annually in US dollars. Fuel subsidies were the greatest proportion (22%) of the total. World-wide, Asian countries were the most heavily subsidized (43% of total global value was Japan and China) followed by Europe and North America (25% and 16% respectively. However, it should be noted that when examining those subsidies that were deemed 'beneficial', those that "enhance the growth of fish stocks through conservation, and the monitoring of catch rates through control and surveillance measures to achieve a biological and economic optimal use" were highest in the U.S. despite Asia and Europe providing the most subsidies in total. Yet, when one examines the regional distribution of the subsidies within the U.S., only about 4% of the total $6.4B distributed from 1996-2004 ($713M/year) could be traced to the Gulf of Mexico region with half going to Alaska and the Western Pacific (Sharp and Sumaila 2009).

9.0 MANAGEMENT OF GULF MENHADEN: ISSUES, MEASURES, CONSIDERATIONS, AND RECOMMENDATIONS

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*

The primary fishery is the reduction purse-seine fishery. Relatively minor amounts of menhaden are harvested by other commercial and recreational fisheries as bait.

9.2 Management Unit

The reduction purse-seine fishery in the northern Gulf of Mexico harvests almost exclusively Gulf menhaden, *B. patronus*; other menhaden species and Atlantic thread herring (*Opisthonema oglinum*), represent less than 1% of the catch (Ahrenholz 1981). Considering that *B. patronus* is the only significant species in the fishery and is biologically considered to be a unit stock in the Gulf (Texas to Florida Panhandle), the management unit in this FMP is defined as the total population of *B. patronus* in its range within the U.S. Gulf of Mexico.

9.3 Management Goals

In summary of the following considerations and recommendations, the plan is to provide management with a set of easily understandable strategies to evaluate the actions, encourage compatibility and standardize among resource agencies, facilitate enforcement's role, incorporate ecosystem services as that information becomes available, and reduce management conflicts to provide optimum benefits. Menhaden management should continue to develop collaboration among all stakeholder agencies and entities that directly or indirectly affect Gulf menhaden resources in the estuarine and marine environment. In addition, Gulf menhaden are a critical species in healthy estuarine systems, and any management strategy must incorporate Gulf menhaden both as an ecosystem resource, as that information becomes available, and a fishery resource. Given the following considerations and recommendations, management goals for future evaluation are:

- Maintain the Gulf menhaden population at a level to sustain their ecosystem role; and, to the extent practicable, maintain economically viable fisheries, with continued support for important social and cultural aspects of the associated fishing communities.
- Improve the states' role in monitoring the resource through improved data collection methods, reporting, and knowledge of menhaden's role in the ecosystem.
- Evaluate the effects of changes in the environment (e.g., sea level rise, marsh loss, fresh water diversions) in order to help estimate trends in future stock carrying capacity.
- Develop methods to identify environmental factors that affect menhaden stocks, and more fully integrate those factors into stock assessments.

9.3.1 Specific Objectives

The following sections contain specific objectives to achieve the management goals. These objectives are priority items that require action to meet management goals and improve data for the next benchmark assessment. Objectives are divided into three categories: management, population dynamics, and environment. Each objective may address one or more of the management goals as they are inter-related.

9.3.1.1 Management Objectives

- Determine the status of Gulf menhaden resources through SEDAR or a similar comprehensive process with a benchmark stock assessment conducted every five years:
- Establish standardized ageing programs for Gulf menhaden in the region by 2015.

9.3.1.2 Population Dynamics Objectives

- Within two years of the completion of each assessment, evaluate potential for additional research or monitoring programs to help measure stock and recruitment variation, based on the analyses conducted and recommendations of the most recent benchmark stock assessment.
- Select key predatory finfish species, then process and identify their stomach contents to species (across several life history stages) for two years across five Gulf states using standardized protocols.
- On annual and standardized bases, collect and process sub-samples of Gulf menhaden from state fishery-independent surveys, focusing on size and age composition, maturity schedules, and genetic component of the samples.
- Sample seasonally using a Gulf-wide standardized gear for pelagic baitfish species in estuarine habitats to quantify abundance and importance of menhaden as a prey item in relation to co-occurring prey species; develop a time series of indices of abundance.

9.3.1.3 Environment Objectives

- Compare analysis of habitat changes (e.g., marsh loss and freshwater diversions) to indices of abundance of juvenile and adult Gulf menhaden to determine net effects.

9.4 Management Measures and Considerations to Attain Management Goals

The following is a discussion of relevant issues related to the effective management of menhaden through the setting of goals and objectives. The process begins with consideration of those items of careful reflection that have a direct bearing on Gulf menhaden. Items to consider were compiled from outputs and data gaps identified through the assessment process, comments from resource managers, and public comment. Next, based upon considered items, recommendations are proposed actions to bring about resolution of those items. The final steps are the setting of goals and objectives. Goals are the ambitious end to which objectives are directed, and objectives are the measurable action(s) to which effort/resources are directed. The final goals and objectives in no way restrict any agency from addressing any of the considerations or recommendations.

9.4.1 Management

9.4.1.1 Stock Status

Limit reference points (limits) are the basis for determining stock status, i.e., whether overfishing is occurring or a stock is overfished. When the fishing mortality rate (*F*) exceeds the fishing mortality limit (F_{limit}), then overfishing is occurring; the rate of removal of fish by the fishery exceeds the ability of the stock to replenish itself. When the reproductive output measured as spawning stock biomass (*SSB*) or population fecundity (*FEC*) falls below the spawning stock biomass (SSB_{limit}), then the stock is overfished, meaning there is insufficient mature female biomass (*SSB*) or egg production (population fecundity, or *FEC*) to replenish the stock.

The Magnuson-Stevens Fishery Conservation and Management Act of 2007 states that management measures define an overfished condition and a target level for the stock. The biomass limit for an overfished menhaden stock was previously proposed as $0.5*SSB_{MSY}$ (Vaughan et al. 2007). The suggested target for spawning biomass, or population fecundity (*FEC*), should be near B_{MSY} (or its proxy). The target level chosen for fishing mortality is less clear, other than the stipulation that F_{target} be sufficiently below the F_{limit}.

9.4.1.2 Reference Points and Control Measures for Management

Reference points are typically defined only for fishery removals that allow for 'natural' removals through a separate mortality term. The natural mortality term (*M*) is often constant, but is sometimes allowed to vary with age and time when data are sufficient. Reference points based on *MSY* treat this natural mortality term as 'lost yield' in that fishing mortality is typically increased in populations with a high *M* and decreased in population with a low *M*. The difficulty with this approach is that it does not consider the value of natural mortality to the ecosystem in the form of prey biomass for other stocks (e.g., large predators). Awareness of the issue of accounting for the role of Gulf menhaden as a prey resource has increased in recent years due in part to changes in the status of Atlantic menhaden (ASMFC 2010) and a general increase in both public and regulatory awareness of the importance of ecosystem issues. During the completion of SEDAR32A, there was considerable discussion relative to these factors of ecosystem value (SEDAR 2013). In addition, those factors were also discussed for defining potential fishery reference points. However, it was concluded that the data were simply insufficient for inclusion in the current benchmark assessment.

In SEDAR32A, the BAM model did not produce a reliable estimate of maximum sustainable yield, MSY was infinite (SEDAR 2013). Given the constraints of the assessment results, levels of effort in reference to the MSY proxy (fecundity (SSB)) were selected as reference points by the MAC and approved by the GSMFC. Estimates of biomass associated with a reference target ($F_{35\%}$) and limit ($F_{30\%}$) levels were calculated at $F_{35\%}$, (663,583 mt) and $F_{30\%}$ (680,765 mt). These harvest levels will serve as accountability measures to ensure the fishery remains viable. Based on the reference points approved by the GSMFC, the Gulf menhaden stock is neither overfished nor is overfishing occurring.

If two consecutive fishing years produce harvests exceeding the target $F_{35\%}$, a stock assessment update will be requested. If harvest surpasses the limit $F_{30\%}$ in a single year, a stock assessment update will be requested.

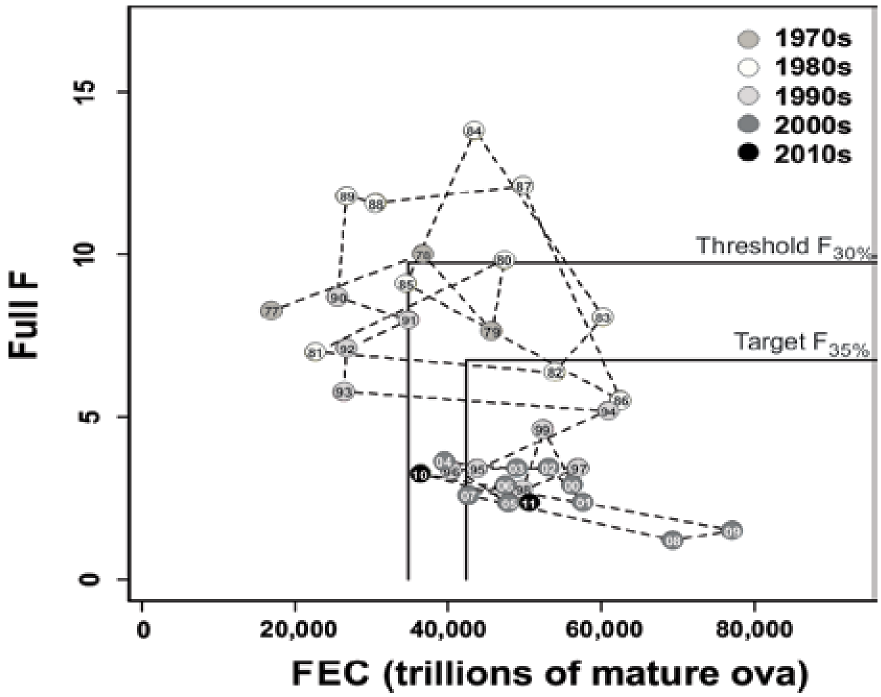


Figure 9.1 Phase plot for fishing years 1977 to 2011 from the base run of the Gulf menhaden assessment with fishing mortality benchmarks of $F_{30\%}$ and $F_{35\%}$ and with the associated spawning stock biomass (fecundity in billions of eggs) benchmarks of $SSB_{30\%}$ and $SSB_{35\%}$ (SEDAR 2013).

A phase plot for fishing years 1977 to 2011 the base run of the Gulf menhaden assessment with fishing mortality benchmarks of $F_{30\%}$ and $F_{35\%}$ was generated (Figure 9.1). The plot includes the associated spawning stock biomass (fecundity) benchmarks of $SSB_{30\%\ limit}$ and $SSB_{35\%\ target}$.

Considerations

- In the SEDAR32A benchmark assessment of Gulf menhaden (SEDAR 2013), the primary model did not successfully find a stock-recruitment relationship and could not produce reliable estimates of *MSY* and F_{MSY}. Under these circumstances, proxy values for *MSY* are typically based on yield-per-recruit calculations and used to estimate reference points for harvest targets and limits in fisheries such as *F* as some percent SPR. Because Gulf menhaden spawn offshore during winter prior to the start of the fishing season, almost all fish reach maturity and spawn before being targeted by the fishery. Subsequently, a large proportion of age-1 individuals survive to become age-2s and are therefore able to spawn before being harvested by the fishery. If this selectivity in the fishery continues, F_{MSY} would be expected to continue as infinite.

- A number of alternative management reference points were offered in SEDAR32A, and the assessment panel agreed to make a general statement that given commonly applied benchmarks in the region, the Gulf menhaden stock is likely not undergoing overfishing and is likely not overfished (SEDAR 2013).

- Considerable discussion occurred before and after the completion of the SEDAR32A benchmark assessment for Gulf menhaden regarding the alternative reference points for management (SEDAR 2013). The most critical concern of managers was that there was too much uncertainty regarding estimates of biomass for Gulf menhaden. The bio-statistical data from the commercial reduction fishery does not include many younger or older fish. Therefore, the only appropriate action that could be taken by the state agencies would be to manage for effort or harvest levels.

Recommendations

1. The states agencies should adopt Gulf-wide management reference points for the Gulf menhaden fishery of a target of 663,583 mt ($F_{35\%}$ fecundity *SSB*) and a limit of 680,765 mt ($F_{30\%}$ fecundity *SSB*).
2. A benchmark stock assessment should be conducted every five years in conjunction with an FMP revision.
3. If two consecutive years of fishing produce harvests exceeding the target $F_{35\%}$, a stock assessment update will be requested.
4. If harvest surpasses the limit $F_{30\%}$ in a single year, a stock assessment update will be requested.
5. Forecasts of year class strength utilizing the state agencies' fishery-independent data should be provided to the MAC prior to the fishing season to help track fluctuations in population abundance and year class strength.

9.4.1.3 Measures to Support Management

A number of research needs which are listed in Section 10.0 were enumerated as a result of the SEDAR32A stock assessment (SEDAR 2013). Many of these items include data gaps which have been acknowledged in previous FMP revisions and continue to hinder the ability of the Gulf states to develop many of the necessary data elements required in today's data-hungry assessment models. While the reduction fishery for Gulf menhaden enjoys comprehensive, detailed, and accurate fishery-dependent data streams, fishery-independent data collection for Gulf menhaden by the Gulf states has often suffered due to limited funds, resources, and personnel.

9.4.2 Population Dynamics

9.4.2.1 Fishery-Independent Monitoring

The NOAA Beaufort Lab has maintained a fishery-dependent sampling program for Gulf menhaden since 1964; it provides detailed information on daily vessel landings, nominal or observed fishing effort, and port samples (on a port/week basis) for size and age composition of the catch. These data are used to annually estimate the numbers-at-age of fish landed (the catch-at-age matrices); they form the foundation of the statistical catch-at-age model used to assess the status of the Gulf menhaden stock in the Gulf of Mexico (SEDAR 2013). The Gulf states have been monitoring juvenile to adult menhaden population in the estuarine to near shore waters for decades. With the exception of Louisiana, this information has been seldom used to predict year class strength or age composition due to the robust nature of the population. It is important that the states begin enhancing their programs by incorporating additional components such as ageing samples from the fishery-independent surveys in the estuarine and near shore waters for comparison to the offshore fishery-dependent samples to help predict production, regulate harvest, and direct management practices.

Fishery-independent monitoring, based on applied scientific and statistical protocols, provides an essential component for making science-based management decisions regarding Gulf menhaden in state waters. Fishery-independent monitoring is standardized and replicated over relevant spatial and temporal scales and therefore gives a better picture of the source population, unbiased by size-selective harvest. This typically includes sampling larvae, juveniles and/or adults to develop data to determine recruitment, growth and survival, natural mortality, and standing stock biomass.

Most fishery-independent monitoring programs involve various gears deployed in a random statistical design by scientists to collect larvae, juveniles, and adults. This information is used to develop abundance indices (state seine and gill net surveys) and ultimately involved in assessing the status of present and future stocks.

Additional data includes genetic information which may better define the management unit and the potential for multiple stocks or genetic populations.

Considerations

- The current benchmark stock assessment for Gulf menhaden (SEDAR32A) utilizes data from several fishery-independent monitoring programs conducted by the Gulf states (see Section 9.4.1.1). State seine surveys, as well as trawl surveys, are used to develop independent indices of juvenile abundance. State gill net surveys are used to develop independent indices of adult abundance.
- Not all the state monitoring programs provide length, weight, and age data associated with Gulf menhaden. Basic population characteristics are collected that could be useful in future assessments across the entire range of the population, not just where the fishery occurs.
- Validation of age composition from the fishery-independent sampling programs could address some of the data gaps identified in SEDAR32A.
- The existing Southeast Area Monitoring and Assessment Program (SEAMAP) surveys and gear are not designed to sample juvenile menhaden, thus a recruitment index from these data is unavailable. Sampling protocols should be developed to this end, with sampling efforts directed to coastal bays and river systems where juvenile menhaden spend up to their first year of life.
- The GSMFC's MAC has discussed and designed a fishery-independent surface-trawl survey for juvenile Gulf menhaden from Florida to Texas based on original survey work of Ahrenholz et al. (1989). However, funding for a pilot survey has been unavailable; nevertheless, extant juvenile surveys conducted by the Gulf states appear adequate for assessment purposes.
- Although there are inshore state surveys for juvenile Gulf menhaden, there is no analogous survey in the northern Gulf of Mexico proper that targets adults. In SEDAR32A, the lack of an index of adult abundance on the fishing grounds was identified as a major impediment for accurate assessment menhaden populations (SEDAR 2013). The extant

fishery-independent sampling program in the northern Gulf of Mexico SEAMAP utilizes trawl gear which is inappropriate for menhaden.

- Species overlap of Gulf and yellowfin menhaden occurs east of the Mississippi River and Gulf and finescale menhaden overlap west of the Mississippi River. Separation of adult specimens can usually be determined in the field by characteristic and meristic differences. However, these differences are not as pronounced in sub-adults. Identification issues led to the exclusion of some data from the species' range extremes in the SEDAR32A data analysis (SEDAR 2013).

Recommendations

1. The Gulf states and NOAA Fisheries need to evaluate the available fishery-independent data and explore ways to combine the data from each state or develop state only indices in order to provide a coast-wide index which would benefit the stock assessment by providing information on trends in abundance over time.

2. The states should implement fishery-independent surveys that include capture of juvenile menhaden in a consistent manner in order to provide information to determine menhaden recruitment in the rivers and upper bays of the northern Gulf of Mexico and provide an index of juvenile abundance for future stock assessments.

3. The states should generate updated estimates of fecundity, maturity schedules, and sex ratios, preferably from both fishery-dependent and fishery-independent samples.

4. The states should implement additional independent sampling of offshore pelagic stocks that include menhaden; gear should be designed to provide data on adult indices beyond the nearshore waters and to provide information on other pelagic ecosystem components.

5. The states should consider re-establishing a Gulf menhaden tag/recovery study. Many more tools exist today to simplify tag/recapture of fishes, and an updated tag/recapture study would allow for a contemporary estimate of natural mortality.

6. The states should design and implement studies including genetic identification (mtDNA fingerprinting) for all menhaden species in independent samples to ensure positive identification of young specimens, improve estimates of juvenile abundance for the species, monitor potential range expansions, and determine of extent of hybridization in the three menhaden species, especially in the sympatric zones to the east and west.

9.4.2.2 Fishery-Dependent Monitoring

Fishery-dependent monitoring involves collecting and analyzing landings data and is intended to sample both the resource and the fishery. Typically, fishery-dependent sampling generates larger sample sizes than fishery-independent monitoring at lower cost. Landings data are often used by fisheries managers to monitor population changes by analyzing trends in catch and effort and are critical in evaluating management practices. Monitoring data can include size-at-age and biomass of landings, the number of fishermen, amount of observed fishing effort, fishing locations, and other parameters that represent actual fisheries activities.

Long-term, fishery-dependent monitoring provides an essential component in making science-based management decisions, and analyses and results are critical elements in all adaptive management strategies. Fishery-dependent monitoring reports generally have a longer and more consistent history than fishery-independent data sets; however, there are some considerations when utilizing this type of data. Deficiencies in reporting requirements, regulatory changes, and enforcement may affect the utility of commercial landings.

The primary purpose of fishery-dependent monitoring is to gather data on catch and effort, size-at-age, and various somatic growth parameters. These data are critical for accurate stock assessments. The NOAA Beaufort Laboratory, in cooperation with the menhaden reduction industry, monitors landings of Gulf menhaden. Clerical staff at the menhaden factories supply landings data to the Beaufort Lab on a daily or weekly basis – timely intervals unavailable in most fishery monitoring systems. Several Gulf states also collect similar catch data from the menhaden fishery via trip ticket programs.

Crews of menhaden vessels also complete daily logbooks, or CDFRs, enumerating each purse-seine set with data on estimated catch, fishing time and location, and several weather variables. CDFR data sets are maintained at the Beaufort Lab and vessel compliance has been nearly 100%. CDFRs are a rich source of spatial and temporal information for the Gulf menhaden fishery.

Considerations

- Port sampling efforts for Gulf menhaden have an unfortunate history of tenuous funding. Annual funding for this activity often requires "eleventh-hour" decisions by federal, state, and/or Commission managers to ensure continued data collection.
- NOAA Fisheries has other data priorities that do not necessarily include Gulf menhaden. There has always been a struggle to continue federal support for the data collection program when the fishery is prosecuted primarily in state waters.
- NOAA Fisheries, the Gulf states, and the industry all collect or report landings. The individual state data programs are not reviewed with the NMFS data programs regularly to evaluate effectiveness and duplication of effort.
- The current unit of nominal fishing effort used in the Gulf menhaden fishery is the vessel-ton-week (VTW). The NOAA Beaufort Lab has evaluated other units of nominal fishing effort, such as number of trips, number of days with at least one set, and number of sets, but found the vessel-ton-week to be a satisfactory unit of nominal fishing effort, given existing data. Evaluation of other potential measures of fishing effort should continue.
- There are inherent biases using observed effort data derived from purse-seine fisheries that rely on spotter planes to locate concentrations of fish schools.

Recommendations

1. NOAA Fisheries should continue to support their Menhaden Program and personnel at their NOAA Beaufort Lab; NOAA Fisheries should also maintain sufficient funding for Gulf menhaden port sampling programs and maintenance of long-term Gulf menhaden data sets.

2. NOAA Fisheries should continue to re-evaluate use of CDFRs as an alternate measure of nominal fishing effort for the Gulf menhaden fishery.
3. NOAA Fisheries 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.
4. The NMFS should evaluate the feasibility of using spotter plane logs to estimate spatial and temporal changes in abundance of Gulf menhaden.

9.4.2.3 Predator/Prey Relations

Most inferences concerning feeding behavior of Gulf menhaden are based on studies of Atlantic menhaden. One key research need is information on Gulf menhaden food habits, which would improve this facet of specificity in ecosystem models. This includes direct analysis of diet, as well as examinations of feeding behavior, in response to key prey items. Direct diet enumeration is difficult due to the planktonic nature of the prey, but biochemical techniques such as analysis of stable isotope ratios (Litvin and Weinstein 2004, Rooker et al. 2006) and fatty acid profiles (Rooker et al. 1998), provide valuable tools for diet analysis of filter feeders. These techniques can also be used to examine the role of Gulf menhaden as a prey item for higher trophic level piscivores (see Section 3.2.7), which will allow for a more precise inclusion of menhaden in food web models of the Gulf of Mexico.

Population dynamics objectives need to quantify menhaden role in the ecosystem by determining their abundance in the environment and stomach contents of predators relative to other pelagic species that serve as the forage base in the food web.

Considerations

- An emphasis on quantifying the trophic role of menhaden in the Gulf of Mexico is an important step in the shift towards ecosystem-based management.

Recommendations

1. Establish methods to determine the trophic role of Gulf menhaden in the Gulf of Mexico.

9.4.3 Environment

9.4.3.1 Habitat Monitoring

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. Hurricanes, erosion, sea level rises, subsidence, and accretion are natural sources of wetland loss. Some human activities have accelerated or exacerbated the effects of some of these factors as described in Section 4.7.

Considerations

- Since menhaden are estuarine-dependent during their early life stages, states could increase efforts to identify critical habitats and monitor potentially negative changes.
- The effects that environmental factors have on catchability of different fishery-independent and fishery-dependent gears may inform the model concerning changes in catchability over time.
- The GSMFC's TCC Habitat Subcommittee has been made inactive due to budgetary issues related to the dissolution of the joint relationship with the Gulf of Mexico Fisheries Management Council. The Subcommittee traditionally reviewed and provided monitoring of habitat-related projects and reported to the Commission on issues of concern within the region.

Recommendations

1. The Gulf states need to explore environmental factors that play a crucial role in Gulf menhaden recruitment dynamics and catchability (both fishery-dependent and fishery-independent).
2. Reassess the status of the GSMFC's Habitat Subcommittee and prioritize funding to support its activation for issues related to habitat and habitat loss in the Gulf of Mexico.

9.4.3.2 Sustaining and Protecting Freshwater Sources

The importance of freshwater to Gulf menhaden recruitment, growth, and survival is well-known (see Section 4.7.4.1.1). Growing reliance on freshwater diversion projects to control flooding, create reservoirs, enhance coastal development opportunities, and ensure drinking and irrigation water supplies threaten the ecological stability of estuarine systems that depend upon short-term and long-term variations in river stages and flow rates. This is especially problematic for managers in estuaries that receive fresh water from a single drainage basin.

Typically, short-term changes in river stages, volumes, and flow rates are part of the ecology of coastal estuaries, and estuarine organisms can cope or even thrive under the changing conditions. However, when freshwater input is disrupted for prolonged periods, serious adverse impacts to estuarine ecology may result.

Water control projects that disrupt the flow of fresh water for prolonged periods may result in serious adverse impacts to juvenile Gulf menhaden ecology. Some major freshwater control projects are underway in the Gulf states, and others are planned (see Section 4.7.4.1.3). For example, Alabama, Florida, and Georgia are currently involved in negotiations and litigation over activities which affect the amount of fresh water reaching Apalachicola Bay from the Apalachicola, Choctawhatchee, and Flint rivers. Interstate agreements which affect water usage in large river drainage basins should consider the positive and adverse effects of water use practices on estuarine ecology.

Management Considerations

- Properly planned and implemented freshwater control projects may have long-term positive ecological and economic impacts. In many instances, fisheries resource managers have little influence on the processes that shape coastal development, but it remains important that fisheries resource issues are included in regional and local comprehensive planning.
- Water management for alternative objectives can be contrary to biological management objectives in estuarine systems.
- Freshwater diversion may biologically change both the area from which water is diverted and the area receiving diverted fresh water. Production of some species (e.g., oysters) may be enhanced at the expense of other species (e.g., shrimp). Thus, biological, social and economic value disputes are possible, while the cumulative environmental impacts and benefits are difficult to determine.
- Depending on the freshwater source and the drainage basin, diversion projects may decrease water quality and increase sedimentation in an area which may enhance some species at the expense of others (e.g., oysters).
- Diversion projects and reservoirs can impact the nature of high flow events and result in declines in important nutrient and sediment loads critical for habitat maintenance and primary production.

Management Recommendations

1. Resource managers should review and evaluate all available information relating to freshwater control projects, habitat restoration, water use policies and practices during the planning process. Such review includes an assessment of the biological, hydrological, ecological, geomorphological, social, and economic impacts that are likely to result from a project or practice in order to provide accurate projections of a project's impacts on estuarine resources. The project design, objectives and implementation should include collaborative efforts to involve all stakeholders who, through their actions, could directly or indirectly impact Gulf menhaden resources in the estuarine and marine environment.

9.4.3.3 Water Quality

Pollution represents a serious threat to estuarine communities at the local level, but the cumulative impacts of all types of pollution threaten estuarine species on a regional level (Section 4.7.4.2). Pollutants include a wide variety of substances that are introduced into the environment, including solid wastes, nutrients, chemicals (petrochemicals), toxic substances (pesticides, herbicides), and other harmful and deleterious substances. Pollutants degrade water quality and habitat, and expose estuarine populations to serious threats. Pollutants and contaminants can stress and ultimately kill estuarine-dependent organisms directly or in combination with other factors, impair reproduction, and adversely affect survival of all life stages. In some instances, pollutants may act indirectly to degrade the environment; for example eutrophication, reduced water quality, food web disruption, altered species diversity, and increased occurrence of HABs. The discharge of nutrients by river systems, such as the Mississippi River, has produced the largest, most persistent zone of hypoxia in the U.S. (Section 4.7.1.1). The direct effect of this area on menhaden populations is unknown, but it may concentrate schools of Gulf menhaden closer to shore as they avoid areas of low DO.

Management Considerations

- Since hypoxic conditions generally occur in the bottom-half of the water column, surface-dwelling menhaden may be less affected than demersal finfish and invertebrates.
- Increased nutrient discharge may provide increased forage for menhaden initially in the form of small phytoplankton and increased zooplankton.

Management Recommendations

1. The Gulf states water quality agencies should encourage improved multi-jurisdictional coordination to identify, permit, and monitor pollution and river nutrient loads including those sources contributing to the persistence and expansion of the ‘dead zone’.
2. Resource managers must continue to work toward a more comprehensive approach to managing estuaries amidst a growing threat from pollution, including engagement in comprehensive planning for coastal development activities.

10.0 RESEARCH AND DATA NEEDS

Throughout the course of the SEDAR32A benchmark assessment for Gulf menhaden (SEDAR 2013) and the drafting of this management plan revision, a number of items were identified by the assessment panel and the Menhaden Advisory Committee as important research topics for future stock assessments. The consensus priority list is based upon available or future funding opportunities and the 'immediate' need to improve current knowledge or assessment. A lower priority does not suggest that the recommendation or data element is not important; it simply does not rank as high as the other items as an 'immediate' need.

DATA ELEMENT	RECOMMENDATION	PRIORITY
FISHERY-INDEPENDENT ADULT INDEX	Collect Gulf menhaden ageing structures (scales and otoliths) from fishery-independent gears (e.g., gill nets and trawls) to determine selectivity. Expand efforts to age menhaden by state agencies. Determine readability of whole versus sectioned otoliths.	**Very High**
FISHERY-INDEPENDENT ADULT INDEX	Improve species identifications at the periphery of the Gulf menhaden's range in Texas and Alabama/Florida waters.	**Very High**
FECUNDITY/MATURITY	Reinvestigate whether Gulf menhaden are determinant or indeterminant spawners and update fecundity estimates, maturity schedules (GSI), and sex ratios. Studies need to include spawning from winter collections.	**High**
FISHERY-INDEPENDENT JUVENILE INDEX	Improve species identifications at the periphery of the Gulf menhaden's range in Texas and Alabama/Florida waters.	**High**
FISHERY-INDEPENDENT JUVENILE INDEX	Design and implement a survey dedicated to determining menhaden recruitment in the coastal rivers and upper bays of the northern Gulf of Mexico.	**Med/High**
FISHERY-INDEPENDENT ADULT INDEX	Develop/expand menhaden sampling protocols for gill nets and trawls in inshore waters. Standardize protocols and gears across states.	**Med/High**
MODELING	Benchmarks – Develop procedures to establish assessment benchmarks (e.g., F_{msy} or proxies) that account for the multiple priorities of ecosystem management; such as an alteration of the calculation of F_{msy} that includes predation mortality as a component of ecological yield separate from other forms of natural mortality.	**Med/High**
FISHERY-DEPENDENT SURVEYS	Develop fish spotter plane survey to estimate relative abundance of adult Gulf menhaden; incorporate search time/flight path into survey as potential survey effort value.	**Med**
TAGGING STUDY	Conduct Gulf menhaden tag/recovery study for better estimates of natural mortality, migration, growth, etc. which are inputs for the stock assessment.	**Med**
GENETICS AND STOCK STRUCTURE	Identify menhaden-specific nuclear DNA markers (preferably microsatellites or SNPs) using lab-based DNA library screening techniques. Evaluate these markers for use in genetic studies of Gulf menhaden.	**Med**
FISHERY-INDEPENDENT JUVENILE INDEX	Expand state-independent sampling to include more sites in under-represented areas (Perdido Bay, Florida Panhandle, and Mississippi Sound) on a monthly schedule.	**Med**
FISHERY-INDEPENDENT ADULT INDEX	Develop side-by-side gear comparisons among the states for standardization (trawls and gillnet/strike nets).	**Low/Med**
PREDATOR/PREY	Expand the diet and stable isotope database to determine the trophic role of Gulf menhaden in the Gulf of Mexico. Investigate fatty acids profiles as an additional more specific indicator of important prey items of Gulf menhaden.	**Low/Med**

DATA ELEMENT	RECOMMENDATION	PRIORITY
PREDATOR/PREY	Initiate food habit studies of major predator species in the northern Gulf of Mexico to determine the importance of menhaden in the diets of fish, seabirds, and marine mammals. Sampling protocols and data collection should be compatible among the state agencies to ensure compatibility in future ecosystem approaches.	**Low/Med**
FISHERY-DEPENDENT SURVEYS	Conduct additional sampling to address the homogeneity of the catch in the hold of the reduction fishery vessels. Supplemental samples must periodically be pulled from throughout the fish hold during the fishing trip.	**Low/Med**
FISHERY-INDEPENDENT JUVENILE INDEX	Develop side-by-side gear comparisons between the states for standardization (seines and trawls).	**Low**
FISHERY-DEPENDENT SURVEYS	Develop a Gulf-wide aerial survey as a useful tool to measure adult Gulf menhaden abundance; 'ground-truthing' for fish size and age and school size would be a necessary adjunct to the survey.	**Low**
MODELING	Develop a habitat index to examine the potential shift in the Gulf menhaden population to more inshore waters as marsh converts to open water from coastal land loss.	**Low**
MODELING	Conduct additional research into simulation models such as MSVPAs, ECO-SIM, EcoPath, etc.; results could produce better estimates of natural mortality as well as other fishery parameters.	**Low**

11.0 REVIEW AND MONITORING OF THE PLAN

11.1 Review

As needed, the State-Federal Fisheries Management Committee's (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.

11.2 Monitoring

The GSMFC, NOAA Fisheries, state agencies, 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 9.0 on a regular basis.

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13.0 APPENDICES

13.1 GLOSSARY

(Modified from Roberts et al. 1991 *and amended in* Wallace et al. 1994).

A

A - See annual mortality.

ABC - See allowable biological catch.

Absolute Abundance - The total number of kind of fish in 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.

Allele – One member of a pair (or any of the series) of genes occupying a specific spot on a chromosome (called locus) that controls the same trait.

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

Allowable Biological Catch (ABC) - A term used by a management agency which refers to the range of allowable catch for a species or species group. It is set each year by a scientific group created by the management agency. The agency then takes the ABC estimate and sets the annual total allowable catch (TAC).

Allozyme – Variant of an enzyme coded by a different allele.

Anadromous - Fish that migrate from saltwater to fresh water to spawn.

Angler - A person catching fish or shellfish with no intent to sell who typically represents the recreational fishermen. This includes people releasing the catch.

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

Aquaculture - The raising of fish or shellfish under some controls. Ponds, pens, tanks, or other containers may be used. Feed is often used. A hatchery is also aquaculture, but the fish are released before harvest size is reached.

Artisanal Fishery - Commercial fishing using traditional or small scale gear and boats.

Availability - Describes whether a certain kind of fish of a certain size can be caught by a type of gear in an area.

B

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

Benthic - Refers to animals and fish that live on or in the water bottom.

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

Bycatch – All species caught other than the targeted species which are classified into two groups 1) incidental catch and 2) discarded catch.

C

CPUE - See catch per unit of effort.

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

Catch Curve - A breakdown of different age groups of fish, showing the decrease in numbers of fish caught as the fish become older and less numerous or less available. Catch curves are often used to estimate total mortality.

Catch Per Unit of Effort (CPUE) - The number of fish 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 fish.

Charter Boat - A boat available for hire, normally by a group of people for a short period of time. A charter boat is usually hired by anglers.

Cohort - A group of fish spawned during a given period, usually within a year.

Cohort Analysis - See virtual population analysis.

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. It can be fish in public waters, trees on public land, and the air. The government regulates the use of a common property resource to ensure its future benefits.

Compensatory Growth - An increase in growth rate shown by fish when their populations fall below certain levels. This may be caused by less competition for food and living space.

Compensatory Survival - A decrease in the rate of natural mortality (natural deaths) that some fish show when their populations fall below a certain level. This may be caused by less competition for food and living space.

Condition - A mathematical measurement of the degree of plumpness or general health of a fish or group of fish.

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

Controlled Access - See limited entry.

Cumulative Frequency Distribution - A chart showing the number of animals that fall into certain categories; for example, the number of fish caught that are less than one pound, less that three pounds, and more than three pounds. A cumulative frequency distribution shows the number in a category, plus the number in previous categories.

D

Demersal - Describes fish and animals that live near water bottoms. Examples are flounder and croaker.

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

Disappearance (Z') - Measures the rate of decline in numbers of fish caught as fish become less numerous or less available. Disappearance is most often calculated from catch curves.

Discarded Catch – The portion of the catch returned to the sea because of regulatory, economic, or personal considerations.

E

EEZ - See exclusive economic zone.

EIS - See environmental impact statement.

ESO - See economics and statistics office.

Economic Efficiency - In commercial fishing, the point at which the added cost of producing a unit of fish is equal to what buyers pay. Producing fewer fish bring the cost lower than what buyers are paying. Producing more fish would raise the cost higher than what buyers are paying. Harvesting at the point of economic efficiency produces the maximum economic yield. See maximum economic rent.

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

Economic Rent - The total amount of profit that could be earned from a fishery owned by an individual. Individual ownership maximizes profit, but an open entry policy usually results in so many fishermen that profit higher than opportunity cost is zero. See maximum economic yield.

Economics and Statistics Office (ESO) - A unit of the National Marine Fisheries Service (NMFS) found in the regional director's office. This unit does some of the analysis required for developing fishery policy and management plans.

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

Electrophoresis - A method of determining the genetic differences or similarities between individual fish or groups of fish by using tissue samples.

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

Escapement - The percentage of fish in a particular fishery that escape from an inshore habitat and move offshore, where they eventually spawn.

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

Evolutionary Significant Unit (ESU) – A population or group of populations that is substantially reproductively isolated from other conspecific populations and that represents an important component of the evolutionary legacy of the species.

Exvessel - Refers to activities that occur when a commercial fishing boat lands or unloads a catch. For example, the price received by a captain for the catch is an exvessel price.

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.

F

F - See fishing mortality

Fmax - The level of fishing mortality (rate of removal by fishing) that produces the greatest yield from the fishery.

FMP - See fishery management plan.

Fecundity - A measurement of the egg-producing ability of a fish. Fecundity may change with the age and size of the fish.

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

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

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

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

Fishing Effort - See effort.

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

Fork Length (FL) - The length of a fish as measured from the tip of its snout to the fork in the tail.

G

GSI - See gonosomatic index.

Gonosomatic Index (GSI) - The ratio of the weight of a fish's eggs or sperm to its body weight. This is used to determine the spawning time of species of fish.

Groundfish - A species or group of fish that lives most of its life on or near the sea bottom.

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

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

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

H

Harvest - The total number or poundage of fish caught and kept from an area over a period of time. Note that landings, catch, and harvest are different.

Head Boat - A fishing boat that takes recreational fishermen out for a fee per person. Different from a charter boat in that people on a head boat pay individual fees as opposed to renting the boat.

I

ITQ - See individual transferable quota.

Incidental Catch - Retained catch of non-targeted species.

Individual Transferable Quota (ITQ) - A form of limited entry that gives private property rights to fishermen by assigning a fixed share of the catch to each fisherman.

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

Intrinsic Rate of Increase (z) - The change in the amount of harvestable stock. It is estimated by recruitment increases plus growth minus natural mortality.

Isopleth - A method of showing data on a graph which is commonly used in determining yield-per-recruit.

J

Juvenile - A young fish or animal that has not reached sexual maturity.

L

Landings - The number or poundage of fish unloaded at a dock by commercial fishermen or brought to shore by recreational fishermen for personal use. Landings are reported at the points at which fish are brought to shore. Note that landings, catch, and harvest define different things.

Latent Species - A species of fish that has the potential to support a directed fishery.

Length Frequency - A breakdown of the different lengths of a kind of fish in a population or sample.

Length-Weight Relationship - Mathematical formula for the weight of a fish in terms of its length. When only one is known, the scientist can use this formula to determine the other.

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

M

M - See natural mortality.

MSY - See maximum sustainable yield.

Mariculture - The raising of marine finfish or shellfish under some controls. Ponds, pens, tanks, or other containers may be used, and feed is often used. A hatchery is also mariculture but the fish are released before harvest size is reached.

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

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.

Meristics - A series of measurements on a fish, such as scale counts, spine counts, or fin ray counts which are used to separate different populations or races of fish.

Microsatellite – A section of DNA consisting of very short nucleotide sequences repeated many times, the number of repeats varying between members of the species: used as a marker in determining genetic diversity, identifying important genetic traits, and in forensics, population studies, and paternity studies.

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 fish; for example, coloration. Morphometric differences are sometimes used to identify separate fish populations.

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.

N

National Standards - The Fishery Conservation and Management Act requires that a fishery management plan and its regulations meet seven standards. The seven standards were developed to identify the nation's interest in fish management.

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

O

Open Access Fishery - A fishery in which any person can participate at any time. Almost all fisheries in federal waters are open to anyone with a fishing boat.

Opportunity Cost - An amount a fisherman could earn for his time and investment in another business or occupation.

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. This term includes both commercial and sport yields.

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

P

Pelagic - Refers to fish and animals that live in the open sea, away from the sea bottom.

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

Population Dynamics - The study of fish 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). The stage of each species' life cycle and the degree of interaction are important factors.

Prey - A species being fed upon by other 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 primary productivity in marine or aquatic systems is made up of phytoplankton which are tiny one-celled algae that float freely in the water.

Pulse Fishing - Harvesting a stock of fish, then moving on to other stocks or waiting until the original stock recovers.

Q

Quota - The maximum number of fish that can be legally landed in a time period. It can apply to the total fishery or an individual fisherman's share under an ITQ system. Could also include reference to size of fish.

R

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

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

Recruitment - A measure of the number of fish that enter a class during some time period, such as the spawning class or fishing-size class.

Recruitment Overfishing - When fishing pressure is too heavy to allow a fish 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 fish population abundance used to compare fish population from year to year. This does not measure the actual numbers of fish but shows changes in the population over time.

Rent - See economic rent.

S

s - See survival rate.

SPR - See spawning potential ratio.

SSBR - See spawning stock biomass per recruit.

Selectivity - The ability of a type of gear to catch a certain size or kind of fish, compared with its ability to catch other sizes or kinds.

Simulation - An analysis that shows the production and harvest of fish 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 fish of various sizes in a sample or catch. The sizes can be in length or weight. This is most often shown on a chart.

Slot Limit - A limit on the size of fish that may be kept. Allows a harvester to keep fish under a minimum size and over a maximum size but not those in between the minimum and maximum. Can also refer to size limits that allow a harvester to keep only fish that fall between a minimum and maximum size.

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 fish (recruits) entering a population is related to the number of parent fish (spawners).

Spawning Potential Ratio (SPR) - The number of eggs that could be produced by an average recruit in a fished stock divided by the number of eggs that could be produced by an average recruit in an unfished stock. SPR can also be expressed as the spawning stock biomass per recruit (SSBR) of a fished stock divided by the SSBR of the stock before it was fished.

Spawning Stock Biomass - The total weight of the fish in a stock that are old enough to spawn.

Spawning Stock Biomass Per Recruit (SSBR) - The spawning stock biomass divided by the number of recruits to the stock or how much spawning biomass an average recruit would be expected to produce.

Species - A group of similar fish that can freely interbreed.

Sport Fishery - See recreational fishery.

Standing Stock - See biomass.

Stock - A grouping of fish usually based on genetic relationship, geographic distribution, and movement patterns. Also a managed unit of fish.

Stock-Recruit Relationship - See spawner-recruit relationship.

Stressed Area - An area in which there is special concern regarding harvest, perhaps because the fish are small or because harvesters are in conflict.

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 fish weight or the sustainable yield.

Survival Rate(s) - The number of fish alive after a specified time, divided by the number alive at the beginning of the period.

T

TAC - See total allowable catch.

TIP - See trip interview program.

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 Allowable Catch (TAC) - The annual recommended catch for a species for species group. The regional council sets the TAC from the range of the allowable biological catch.

Total Mortality (Z) - A measurement of the rate of removal of fish 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 fish dying in one year. Instantaneous mortality is that percentage of fish 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.

U

Underutilized Species - A species of fish that has potential for large additional harvest.

Unit Stock - A population of fish grouped together for assessment purposes which may or may not include all the fish in a stock.

V

VPA - See virtual population analysis.

Virgin Stock - A stock of fish with no commercial or recreational harvest. A virgin stock changes only in relation to environmental factors and its own growth, recruitment, and natural mortality.

Virtual Population Analysis (VPA) - A type of analysis that uses the number of fish 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 fish in a cohort at various ages.

Y

Year-Class - The fish spawned and hatched in a given year, a "generation" of fish.

Yield - The production from a fishery in terms of numbers or weight.

Yield Per Recruit - A model that estimates yield in terms of weight (but more often as a percentage of the maximum yield) for various combinations of natural mortality, fishing mortality, and time exposed to the fishery.

Z

z - See intrinsic rate of increase.

Z - See total mortality.

Z' - See disappearance.

13.2 MENHADEN INDUSTRY SURVEY

GULF STATES MARINE FISHERIES COMMISSION

2404 Government Street, Ocean Springs, MS 39564

(228) 875-5912 • (228) 875-6604 Fax

www.gsmfc.org

Larry B. Simpson

Executive Director

September 15, 2011

The Gulf States Marine Fisheries Commission is revising the fishery management plan (FMP) for the Gulf of Mexico gulf menhaden fishery. There is very little information available regarding the participants in this fishery and in an effort to document how the fishery may be changing over time; you have been selected to receive this sociologic survey. For this survey to be accurate and representative, your participation in this process is critical. It is important that each questionnaire be completed and returned for processing.

You may be assured of complete confidentiality – your name will not be recorded and specific information will not be used on an individual basis. We will be combining all the surveys to give an overview of the industry in the Gulf.

Thank you for your assistance in helping us describe your fishery and improve our management of this species by understanding the fishermen.

Sincerely,

Steve VanderKooy
Interjurisdictional Fisheries
Program Coordinator

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DAYBROOK

MENHADEN INDUSTRY SURVEY

With pencil or pen, please darken all boxes that apply: [1-5] (For computer scoring)

1. How many years have you been in the menhaden fishery?
[1-5] [6-10] [11-15] [16-20] [21-25] [26-30] [31-35] [36-40] [40+]

2. Which other members of your immediate family/friends are in the fishery? Please mark total number of each that apply: Father/Mother [1] [2] Wife [1] Husband [1] Brothers [1] [2] [3] [4]
Sisters [1] [2] [3] [4] Son/Daughters [1] [2] [3] [4] [5] Cousins/uncles/in-laws [1] [2] [3] [4] [5]
Friends [1] [2] [3] [4] [5]

3. Who first introduced you to the menhaden industry? Father/Mother [1] Wife [2] Husband [3]
Brother [4] Sister [5] Son/Daughter [6] Cousin [7] Friend [8] In-laws [9] Other [10]

4. What is your race or ethnic background? Caucasian [1] Asian-American [VIET] [LAO] [CAM] [THAI]
Hispanic-American [3] African-American [4] Native American [5] Other [6]

5. Are you a US citizen? No [1] Yes [2] If no, what is your country of origin? _______________

6. What is your age? [16-20] [21-25] [26-30] [31-35] [36-40] [41-45] [46-50] [51-55] [56-60] [61-65] [66-70] [71+]

7. Are you? Single [1] Married [2] Divorced [3] Widowed [4]

8. Indicate highest level education completed: Elementary [6] Middle School [9]
High School/GED [12] Some College [14] College Degree [16] Graduate School Degree [20]

9. How satisfied are you with the menhaden fishery as an occupation? Highly satisfied [5]
Mostly satisfied [4] Satisfied [3] Not very satisfied [2] Unsatisfied [1]

10. Indicate where you work in the fishery: Boat Captain [1] Deck Hand [2] Boat Crew [3]
Dock [4] Plant [5] Administration [6] Sales [7] Support and Maintenance [8]

11. Do you participate in other commercial fishing activities outside the regular menhaden season?
No [1] Yes [2]
If yes, indicate your alternative: Crabs [1] Shrimp [2] Oysters [3] Finfish [4]
If you participate in non-fishing activities, please indicate: Construction [5] Retail [6]
Oil and Gas [7] Hospitality [8] Other [9] ______________________

12. Please estimate what percentage of your annual *total income* comes from *commercial fishing*:
[10%] [20%] [30%] [40%] [50%] [60%] [70%] [80%] [90%] [100%]

Thank you for your participation

13.3 STOCK ASSESSMENT

Southeast Data, Assessment, and Review

SEDAR 32A

Stock Assessment Report

Gulf of Mexico Menhaden

September 2013

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

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Preface

This regional assessment was completed through the SouthEast Data, Assessment, and Review (SEDAR) process and the Gulf States Marine Fisheries Commission (GSMFC). The GSMFC coordinated the Data and Assessment Workshops, while SEDAR coordinated the Review Workshop. This report is the culmination of a two-year effort to gather and analyze available data for Gulf menhaden from the commercial purse-seine fishery, fishery-independent sampling programs of the Gulf States, and the recreational sector. The Gulf's five marine resource agencies provided experts through the GSMFC's Menhaden Advisory Committee (MAC), which served as the technical committee throughout the assessment process. The GSMFC provided travel and facilitated several conference calls and webinars in preparation for the workshops. Participants in the conference calls and webinars included the MAC members and a number of individuals representing Non-Governmental Organizations with interest in Gulf menhaden. All meetings and workshops were held at NOAA's Beaufort Laboratory in North Carolina.

The SEDAR32A draft report was generated and provided to three reviewers from the Center for Independent Experts (CIE), two members from the Statistics and Science Committee of the South Atlantic, and an expert representing the GSMFC. The Review Workshop was held in Morehead City, NC on August 27-30, 2013 in conjunction with the SEDAR 32 South Atlantic blueline tilefish review. At the Workshop, the reviewers had opportunities to address concerns they had with the data and models and query the analysts and agency representatives regarding any additional questions that arose during their reviews. Finally, a Review Workshop Report (Section II) was generated with comments and overall opinions about the data sources, models, and assessment results. Following the receipt of the Review Workshop Report by the SEDAR office, the MAC continued to discuss and develop potential management goals and reference points for the Gulf menhaden stock and the fishery. The results will be included in the revision to the Gulf Menhaden Fishery Management Plan.

The GSMFC and the MAC wishes to thank the reviewers for their expertise and time that supported the completion of the regional stock assessment for Gulf menhaden.

SEDAR
Southeast Data, Assessment, and Review

SEDAR 32A
Gulf of Mexico Menhaden

Assessment Report

August 2013

A. Schueller, J. Smith, and S. VanderKooy (eds)

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

GSMFC
2404 Government St.
Ocean Springs, MS 39564

Executive Summary

Gulf menhaden, *Brevoortia patronus*, range from the Yucatan Peninsula in Mexico, across the western and northern Gulf of Mexico to Tampa Bay, Florida, but they are most abundant in the central portion of their range from eastern Texas to western Alabama. Gulf menhaden are estuarine-dependent: adult Gulf menhaden generally occur in the near-shore waters of the Gulf of Mexico proper, while juveniles spend most of their first year of life in estuarine waters, including brackish and near-freshwater habitats. Spawning peaks in winter and larvae enter the estuaries in the early spring after riding the prevailing currents from the offshore spawning grounds. Genetic evidence suggests a single unit stock of Gulf menhaden in the northern Gulf of Mexico and tagging studies indicate that the species does not exhibit extensive east-west migrations; generally, older adults tend to occur near the Mississippi River delta and the central Louisiana coast.

The modern Gulf menhaden fishery began after World War II as the worldwide demand for fish meal and fish oil increased. Annual landings of Gulf menhaden in the early 1940s were less than about 40,000 mt, but by the early 1960s landings in the Gulf fishery – 437,500 mt in 1963 – exceeded those in the Atlantic menhaden fishery. During the 1960s and 1970s, the Gulf menhaden fishery continued to expand and fleet size ranged about 70 to 80 vessels. Landings peaked in 1984 at 982,800 mt. Thereafter through the 1990s, landings, fleet size, and participants in the fishery declined because of corporate consolidation, weak product prices, and weather conditions. Since 2000, the fishery has been reasonably stable with four fish factories – at Abbeville, Cameron and Empire, Louisiana and Moss Point, Mississippi – and about forty vessels.

The commercial purse-seine reduction fishery for Gulf menhaden has been extensively sampled by the National Marine Fisheries Service. Fishery-dependent data sources from 1977-2011 that inform this Gulf menhaden stock assessment include: 1) detailed catch records that enumerate daily vessel landings, 2) port samples that include comprehensive dockside sampling of vessels throughout the fishing season at all menhaden factories for size and age composition of the catch, and 3) daily logbooks that itemize catch and fishing locations for individual purse-seine sets. Landings of gulf menhaden for bait are generally less than 2% of total landings for the species. Bait landings and recreational landings of Gulf menhaden, which are minimal, were combined with landings from the reduction fishery to provide a complete time series (1977-2011) of removals.

The five Gulf States collect a significant amount of fishery-independent data on finfish from their inshore surveys. Although Gulf menhaden are generally not the target species of these surveys, total Gulf menhaden numbers and lengths are recorded. Gulf menhaden data from state surveys form the basis for two indices of relative abundance: 1) a recruitment index from 1996 to 2010 based on the seine survey data from Louisiana, Mississippi, and western Alabama, and 2) an adult abundance index from 1988 to 2011 based on Louisiana gill net survey data. The recruitment index showed large year classes of juveniles in 1996, 2003, 2009, and 2010; when compared against a CPUE index based on the catches by the commercial fishery at age-1, the correlation with a one-year lag was quite high. The adult index showed an increasing trend from

the late 1980s to the mid-1990s, then a stable trend through the mid-2000s, and high adult abundances in the most recent years. Likewise, the adult index was highly correlated with a CPUE index based on age-2 catch from the commercial reduction fishery. For the adult index, length composition data were available 1996-2011 and were used to estimate selectivity of the index given that age data from the survey were unavailable.

In this assessment, we employed two separate modeling approaches: the Beaufort Assessment Model (BAM, a forward-projecting age-structured model) and a surplus production model (A Stock Production Model Incorporating Covariates or ASPIC). The base configuration of the BAM incorporated: fishing seasons 1977-2011, ages 0 to 4+, spawning occurring on January 1, age-varying natural mortality scaled to an estimated based on a tagging study, a single time series of landings, commercial age compositions, a recruitment index based on seine data, an adult abundance index based on Louisiana gill net data, length compositions from the gill net survey, a Beverton-Holt stock recruitment curve with a fixed value for steepness, logistic selectivity for the gill net index, and dome-shaped selectivity for the reduction fishery. Uncertainty was explored with BAM using sensitivity runs and Monte Carlo bootstrapping (MCB), with additional exploration in ASPIC using bootstrapping. Sensitivity runs for BAM investigated differences in the start year of the model, selectivity for the fishery, values of natural mortality, the stock-recruitment curve, weighting, and growth. MCB runs (N = 5,000) included uncertainty in all of the data streams, maturity, selectivity, the stock recruitment curve, and growth.

The base run fit all of the data streams reasonably well. Highly variable fishing mortalities were noted throughout the time series; highest fishing mortalities occurred in the 1980s, with declining fishing mortalities into the 2000s. Nevertheless, Gulf menhaden are not fully selected until age- 2, thus the fishing mortality rate on other ages is much lower. Throughout the time series, the age-2 fish produced most of the total estimated number of eggs spawned annually, although age- 3 and -4 fish have contributed more significantly in recent years. Sensitivity analyses revealed differences from the base run configuration depending upon the assumption tested, and the MCB runs demonstrated the amount of uncertainty around the base run values. None of the results were unexpected.

At this time, the Gulf's agency managers are working to define the goals for the fishery and to specify objectives for the fishery. Once that has been completed, appropriate benchmarks can be discussed and formally adopted. In the meantime, general stock status declarations have been made based on a suite of benchmark options. Based on those benchmarks presented, the results suggest that generally the current stock status is not overfished and overfishing is not occurring. Moreover, most of the sensitivity runs and the MCB uncertainty analysis runs resulted in a current stock status of not overfished and overfishing not occurring. The assessment panel discussed factors necessary to adequately account for the ecosystem value of Gulf menhaden in defining fishery reference points and concluded that data and techniques are insufficient at present to incorporate them into the assessment; data specifically addressing the value of menhaden in the ecosystem as prey biomass for other stocks (e.g., piscivorous, avian, and mammalian predators) are lacking.

Cover art used by permission. The Gulf States Marine Fisheries Commission has a general policy to recruit artists from the Gulf States. Cover art for the Gulf Menhaden Fishery Management Plan was graciously provided by Joe Jewell, a native of the Mississippi Gulf Coast, currently residing in Ocean Springs. The Gulf of Mexico shoreline and its creatures were intrinsic elements of his childhood. Joe combines a scientific eye and artistic background to create detailed representations of marine life primarily in color pencils and pen and ink.

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