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

A Regional Management Plan

1995 Revision

by

The State-Federal Fisheries Management Committee
Menhaden Advisory Committee

edited by

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published by

Gulf States Marine Fisheries Commission
P.O. Box 726
Ocean Springs, Mississippi 39566-0726

April 1995

Number 32

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

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Acknowledgements

The Gulf States Marine Fisheries Commission (GSMFC) would like to thank the State-Federal Fisheries Management Committee (S-FFMC) Menhaden Advisory Committee (MAC) for their many hours of work and dedication in developing the 1995 revision of the Menhaden Fishery Management Plan.

We gratefully acknowledge the assistance in collection and assimilation of data provided by Mr. Josh Bennett, Mr. Lee Usie, Dr. Mark Holiday, Mr. Steve Koplin, and others with the National Marine Fisheries Service.

We especially appreciate the help of the Dr. Douglas Vaughan along with Mr. Eldon Levi and Mr. Joseph Smith who drafted the stock assessment, and the technical assistance from Dr. Dean Ahrenholz and other members of the National Marine Fisheries Service, Beaufort Laboratory Menhaden Team for their review of this document. The MAC also thanks the GSMFC Stock Assessment Team for their review of the stock assessment.

Finally, the MAC extends its most heartfelt appreciation to Mrs. Cynthia Yocom for her effort, skill, and patience to ensure the quality of this document.

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1.0 SUMMARY

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 sketchy prior to World War II; thereafter, however, landings generally increased through the mid 1980s as the industry grew. Although there may be considerable annual fluctuations, Gulf landings increased to a record of 2.2 billion pounds in 1984. This figure amounted to 76% of U.S. menhaden landings and 29% of total U.S. landings of fish and shellfish.

The fishery 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, populations are affected by the jurisdictions and authorities of a large number of federal and state agencies. They are predominantly found in the territorial waters of the five Gulf States; consequently, the individual states, and not the Gulf of Mexico Fishery Management Council, exercise the most direct management authority. Other federal agencies including the National Park Service, the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, the National Oceanic and Atmospheric Administration, and the Environmental Protection Agency 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 in the Gulf can be separated into two components: the reduction fishery and the bait fishery. Landings for the reduction fishery greatly overshadow bait landings with highest totals of 2.2 billion pounds (1984) compared to 38 million pounds for bait (1987).

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

Menhaden oil has been used in edible products for many years in Europe. The oil is refined, deodorized, and hydrogenated to blend with other fats for cooking oils, shortening, margarine, and other products. It is also used in nonconsumptive products such as paints, plastics, resins, and others.

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

The value and price of reduction fishery products may vary greatly from year to year, primarily due to competition with other products. Additionally, menhaden products often compete in an international market exacerbating fluctuations.

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

Although there is some evidence that the management unit for gulf menhaden in the U.S. Gulf of Mexico could be split, it is considered to be a single, unit stock in this plan. Because of the wide discrepancy in landings for the reduction fishery versus the bait fishery, the reduction fishery is the only significant component with regard to fishing pressure on the stock. Stock analysis based on available fish and fishing pressure shows that the current stock is healthy and catches are generally below maximum sustainable yield (MSY) estimates of 600,000 to 700,000 mt. The fishery is, however, fully exploited at the present level of participation.

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

Existing regulations that have been adopted by states to manage harvests appear to be adequate to sustain yields and prevent overfishing. The maintenance of a consistent, Gulf-wide season for the reduction fishery is needed and recommended. Other needs of the fishery include identification and assessments of ways to increase profitability and stability of the fishery and predictions of potential future harvests.

2.0 INTRODUCTION

The S-FFMC of the GSMFC addressed the need to revise and update the Menhaden Fishery Management Plan at their April 8, 1992, meeting. The committee noted numerous changes that have occurred in the fishery since the last revision and concluded that an update was needed to address these changes.

2.1 IJF Program and Management Process

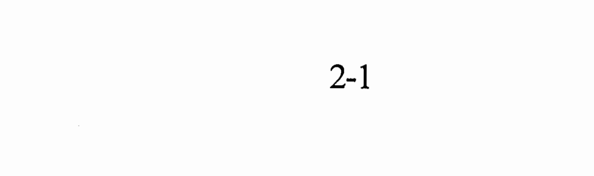
The Interjurisdictional Fisheries Act of 1986 (Title III, Public Law 99-659) was established by Congress to: (1) promote and encourage state activities in support of the management of interjurisdictional fishery resources and (2) promote and encourage management of interjurisdictional fishery resources throughout their range. Congress also authorized federal funding to support state research and management projects that were consistent with these purposes. Additional funds were authorized to support the development and revision of interstate FMPs by the GSMFC and the other marine fishery commissions.

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

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

In reviewing the Menhaden FMP update, the S-FFMC and the GSMFC noted the uniqueness of this fishery and the presence of an existing advisory committee, the S-FFMC MAC. They also observed that the original plan and the 1983 and 1988 updates were developed by the advisory committee without the need for a separate TTF. They consequently agreed to modify the approval process to substitute the S-FFMC MAC for the TTF.

The Commission's review and approval process for the Menhaden FMP is as follows:



DMS = Data Management Subcommittee
SAT = Stock Assessment Team
MAC = Menhaden Advisory Committee

TCC = Technical Coordinating Committee
S-FFMC = State-Federal Fisheries Management Committee
GSMFC = Gulf States Marine Fisheries Commission

2.2 Goal

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

2.3 FMP Management Objectives

The objectives of the Menhaden FMP are:

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

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

3.1 Biographical Description and Geographic Distribution

Various authors have summarized the biology, geographic distribution, and movements of gulf menhaden. Gunter and Christmas (1960) published a review of the literature on menhaden with special reference to the Gulf of Mexico. Annotated bibliographies on mostly the 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 1200 references. Lassuy (1983) developed a species profile for gulf menhaden, and Ahrenholz (1991) reviewed the population biology and life history.

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

3.1.1 Classification and Morphology

3.1.1.1 Classification

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

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

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

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

3.1.1.2 Morphology

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

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

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

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

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

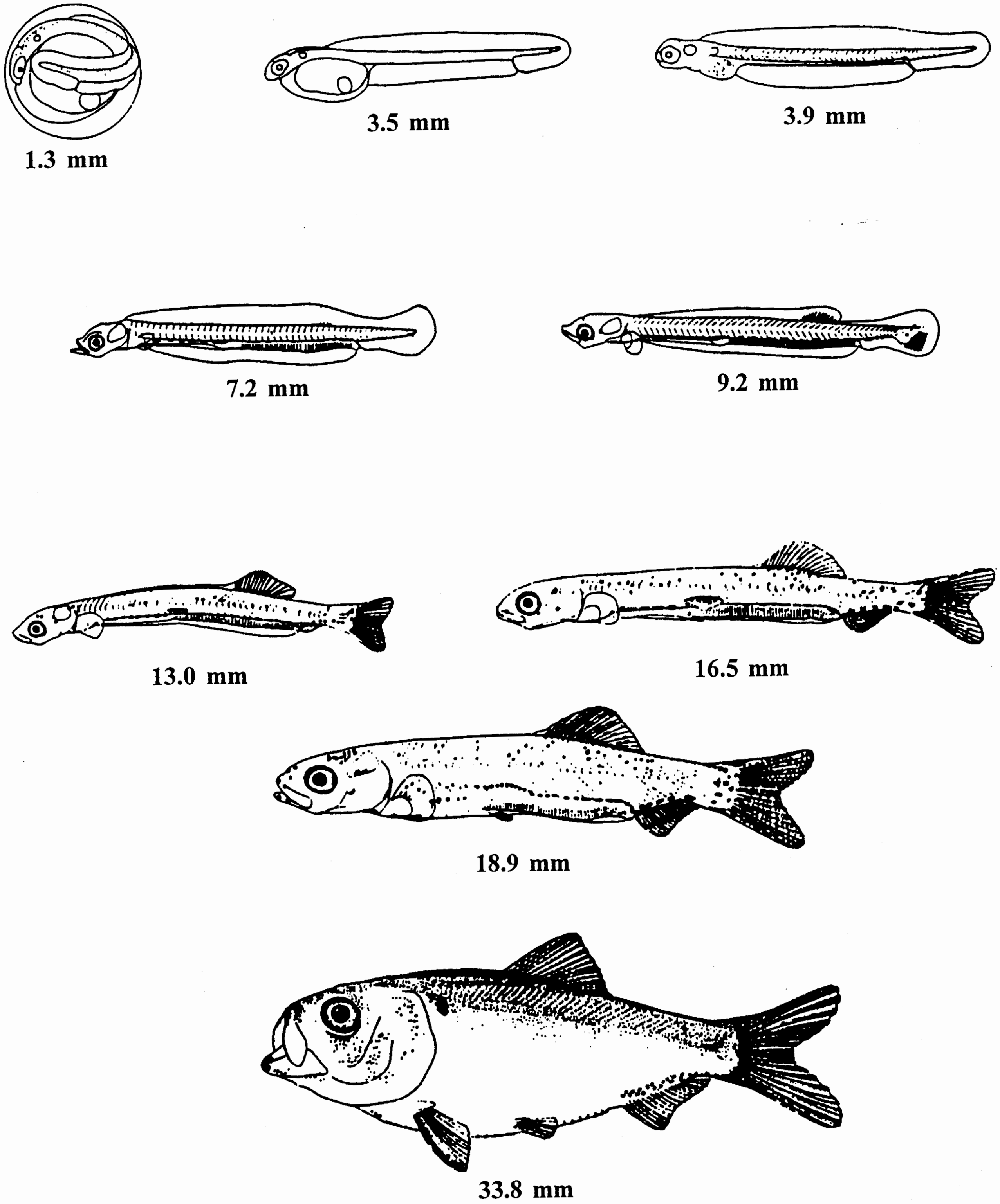


Figure 3.1. Developmental stages of gulf menhaden at specified lengths (from Hettler 1984).

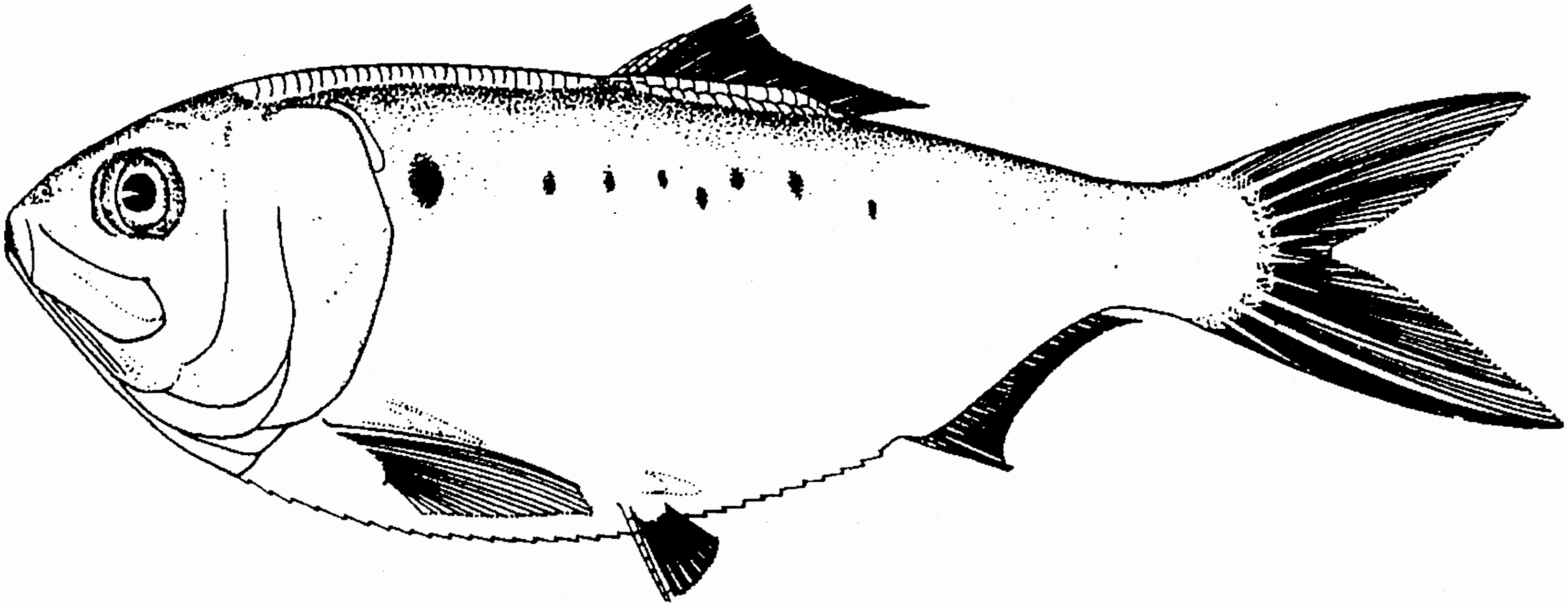


Figure 3.2. Adult gulf mehaden (from Fischer 1978).

3.1.2 Biological Description

3.1.2.1 Growth, Maturation, and Age

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

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

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

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. 1985).

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

Larvae of gulf menhaden were reported to be ages 3 to 5 weeks when they enter estuaries (Fore 1970, Reintjes 1970, Shaw et al. 1988, Warlen 1988) and 10-32 mm TL (Fore 1970, Tagatz and Wilkins 1973). Deegan 1985 and Deegan and Thompson (1987) estimated a considerably longer oceanic larval period of 6-10 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. 1985). 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 Wilkins 1973), and 30-35 mm SL (Deegan 1986) and at a reported age range of 88 to 103 days (Deegan and Thompson 1987). Juvenile growth and development occurs primarily in estuaries. The duration of this stage and the ultimate size reached varies based on estuarine conditions and the absolute age of individual fish (relative to when they were spawned during the season) (Lassuy 1983, Ahrenholz 1991). Loesch (1976) and Deegan (1985) reported average daily growth rates as approximately 0.2 mm/day for small juveniles in cool waters and 0.8 to 1.0 mm/day for large juveniles in warmer waters.

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

Growth of adult gulf menhaden has been described by Nelson and Ahrenholz (1986). Initial growth is rapid, and adults reach a size of approximately 125 mm FL by age 1. Significant growth continues through age 3 with individuals reaching approximately 170 mm FL at age 2 and 200 mm FL at age 3. After age 3, growth is minimal with individuals reaching approximately 225 mm FL at age 4 and about 235 mm FL at age 5. Gulf menhaden may reach a maximum age of 5-6 years (Ahrenholz 1991); however, fish older than age 4 are extremely uncommon in commercial catches (J. Smith, personal communication).

3.1.2.2 Reproduction

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

3.1.2.2.1 Spawning

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

3.1.2.2.1.1 Season

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

3.1.2.2.1.2 Courtship and Spawning Behavior

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

3.1.2.2.1.3 Duration

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

3.1.2.2.1.4 Location and Effects of Temperature and Salinity

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

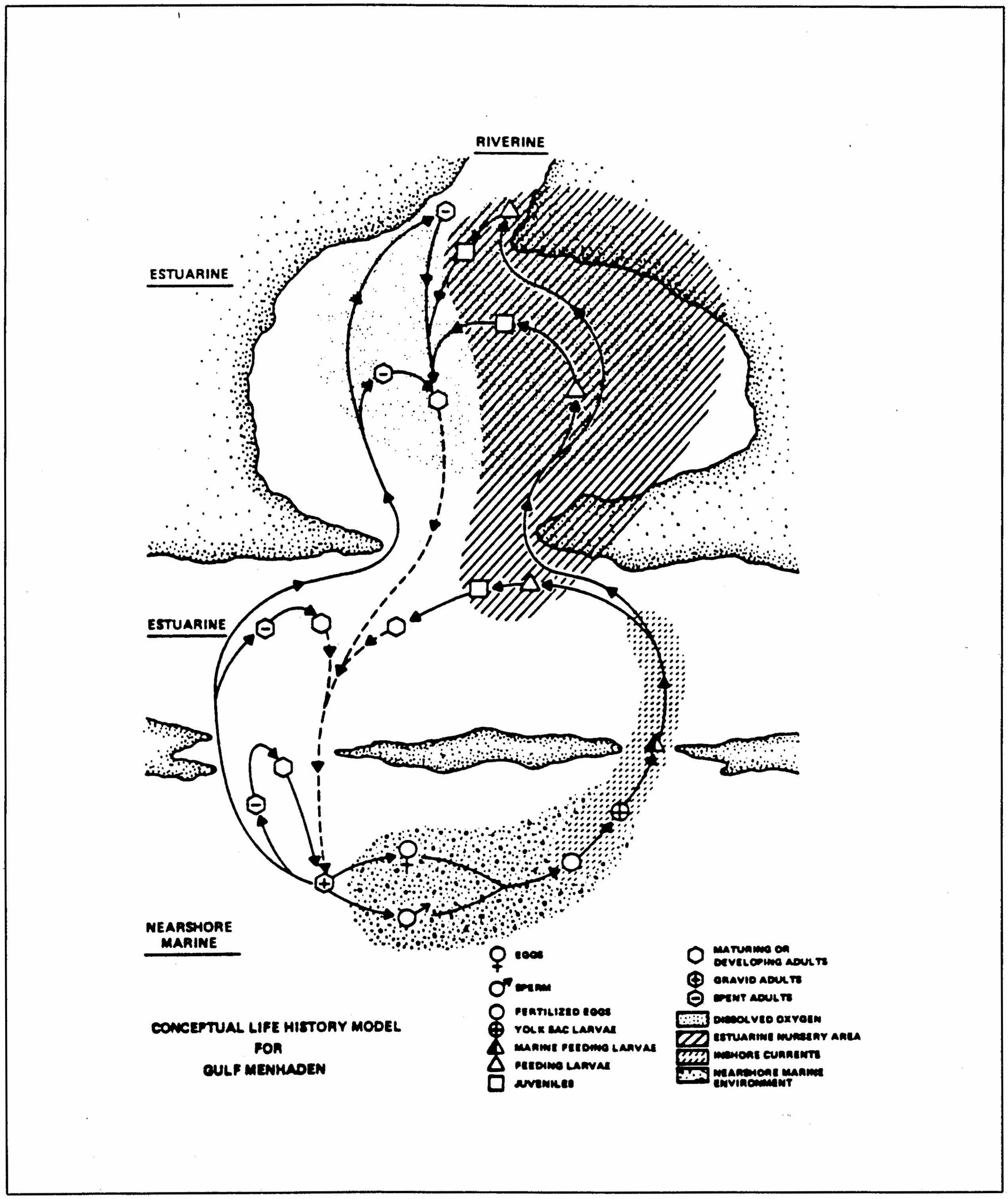


Figure 3.3. Conceptual life history model for gulf menhaden. Dissolved oxygen indicates areas of potential depletion (Christmas et al. 1983).

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 and 40 fathom contours off Texas and Louisiana and near the Mississippi Delta. Sogard et al. (1987) found high densities of larvae near the Mississippi River supporting the conclusions of Fore (1970) and Christmas and Waller (1975) that spawning is concentrated near the mouth of the Mississippi River.

Shaw et al. (1985) found highest egg densities between the 10 and 23 m isobaths and at temperatures and salinities of 15° to 18°C and 30‰ to 36 ‰, respectively. Christmas and Waller (1975) found highest egg densities at temperatures >15°C and salinities >25‰. They also concluded that menhaden spawn along the entire United States Gulf Coast from near shore to as far as 60 miles offshore.

3.1.2.2.2 Fecundity

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

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

3.1.2.2.3 Incubation

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

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

3.1.2.3 Parasites and Disease

Pasteurella spp. is a nonmotile, gram negative bacteria that infects gulf menhaden causing 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 (Korutha 1955; Hargis 1959; 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* (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 (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; Overstreet, personal communication). Pearse (1952) found *Caligus ventrosetosus* on the gills of *B. gunteri* from Texas.

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

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

3.1.2.4 Feeding, Prey, and Predators

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

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

As young menhaden develop, the maxillary and dentary teeth become nonfunctional and disappear. Gill rakers increase in length, number, and complexity, and pharyngeal pockets appear. The alimentary tract folds forward, and a muscular stomach (gizzard) and many pyloric cecae develop while the intestine forms several coils (June and Carlson 1971). Darnell (1958) suggested that food is captured primarily by mechanical sieving. Friedland (1985) studied structures of the branchial basket associated with filter feeding in Atlantic menhaden and proposed a mechanism for moving food particles from the point of capture to the point of ingestion. Friedland et al. (1984) studied filtration rates and found that maximum filtration efficiency for 138 mm FL juveniles was achieved for particles about 100 µm. They also noted that filtering efficiency changed when detritus was present.

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). 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.

Because of their great abundance and schooling behavior, menhaden are prey for a large number of piscivorous fish and birds (Reid 1955, Simmons and Breuer 1950, Reintjes 1970, Kroger and Guthrie 1972, Dunham 1975, Overstreet and Heard 1978, Overstreet and Heard 1982, Medved et al. 1985). The effects of predation in estuarine and marine communities have not been quantified, and the role of adult gulf menhaden as a forage species is not well known in the Gulf.

Menhaden eggs and larvae are potential food for various filter-feeding and larval fishes and invertebrates including but not limited to themselves, other clupeids, chaetognaths, coelenterates, mollusks, and ctenophores (Clements 1990, Ahrenholz 1991). Fishes known to eat menhaden include: mackerel (*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 Gutherie 1972, Overstreet and Heard 1978, Etzold and Christmas 1979, Overstreet and Heard 1982).

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

3.1.3 Behavior

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

3.1.4 Geographic Distribution and Migration

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

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

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

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

Gulf menhaden are shallow-water fishes, and information on their offshore range is limited. Roithmayr and Waller (1963) reported catches of gulf menhaden from December through February in the northern Gulf between 4 and 48 fathoms both east and west of the Mississippi River Delta. They concluded that at least some fish do not move far offshore but winter on the inner and middle continental shelf area just off the Mississippi River delta. Turner (1969) collected adult menhaden within the 10-fathom contour off the Florida coast but did not collect any in gill nets fished in 10 to 32 fathoms of water, thus indicating that menhaden in that area do not move far offshore. Adults were, however, collected 20 to 25 miles offshore by bottom trawls and surface nets in waters 20 fathoms in depth. Mid-water trawls caught *B. patronus* at depths ranging from 40 to 55 fathoms (Christmas and Gunter 1960).

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

4.1 General Conditions

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

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

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 (>1000 acres), mud substrate, and brown or green water color.

4.2 Salinity, Temperature, and Other Requirements

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

Larval and juvenile menhaden have been collected in Gulf estuaries at temperatures ranging from 5° to 35°C and in salinities from 0‰ to 67‰ (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. Christmas et al. (1982), in their Habitat Suitability Index (HSI) models for gulf menhaden, identified optimum temperature and salinity conditions for the egg and larval stages:

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

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*lowest mean monthly winter value

4.3 Dissolved Oxygen

Mass mortalities attributed to low concentrations of dissolved oxygen have occurred in estuaries (Crance 1971, Christmas 1973, Etzold and Christmas 1979). Postlarvae and juveniles are frequently killed by anoxic conditions in backwaters (e.g., dead-end canals) during summer months. Hypoxic and anoxic conditions may also occur in more open estuarine areas as a result of phytoplankton blooms and are called "jubilees."

Low dissolved oxygen areas occur in offshore areas of Louisiana and Mississippi, and they are believed to be caused by discharges from the Mississippi River (Rabalais et al. 1991). This area is the largest and most persistent zone of hypoxia in coastal waters of the U.S., and it varies greatly from year to year (Hanifen, personal communication). Its effects on menhaden populations are, however, unknown.

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

5.1 Management Institutions

Menhaden are estuarine-dependent species that spawn in Gulf waters and move to nearshore and inshore areas in the spring. Larval and juvenile stages are completed in territorial and inland waters, and adults are found in inland waters, the territorial sea, and Gulf waters. Because of this variance in geographic range, menhaden are directly and indirectly affected by numerous state and federal management institutions through their administration of state and federal laws, regulations, and policies. The following is a partial list of some of the more important agencies, laws, and regulations that affect menhaden and their habitat. These may change at any time, and the individual agencies, particularly the marine fishery management agency in the individual states, should be contacted for specific, current laws and regulations.

5.1.1 Federal

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

5.1.1.1 Regional Fishery Management Councils

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

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

The Gulf of Mexico Fishery Management Council 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 fishery management plans prepared by regional fishery management councils. Where a council fails to develop a plan, or to correct an unacceptable plan, the Secretary may do so. The NMFS also collects data and statistics on fisheries and fishermen. It performs research and conducts management authorized by international treaties. The NMFS has the authority to enforce the Magnuson Act and the Lacey Act and is the federal trustee for living and nonliving natural resources in coastal and marine areas.

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

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

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

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

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

The NPS under the DOI may regulate fishing activities within park boundaries. Such regulations could affect menhaden harvest if implemented within a given park area.

5.1.1.5 Fish and Wildlife Service (FWS), DOI

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

In certain refuge areas, the FWS may directly regulate fishery harvest. Special use permits may be required if commercial harvest is to be allowed in refuges.

5.1.1.6 Environmental Protection Agency (EPA)

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

5.1.1.7 Corps of Engineers (COE), Department of the Army

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

5.1.1.8 U.S. Coast Guard

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

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

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

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

5.1.2 State

Table 5.1 outlines the various state management institutions and authorities.

5.1.2.1 Florida Department of Environmental Protection and Florida Marine Fisheries Commission

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

Table 5.1. State management institutions - Gulf of Mexico.

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

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

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

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

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

5.1.2.2 Alabama Department of Conservation and Natural Resources

Alabama Department of Conservation and Natural Resources (ADCNR)
Alabama Marine Resources Division (AMRD)
P.O. Box 189
Dauphin Island, Alabama 36528
Telephone: (334) 861-2882

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

Most regulations are promulgated through the Administrative Procedures Act approved by the Alabama Legislature in 1983; however, bag limits and seasons are not subject to this act. The Administrative Procedures Act outlines a series of events that must precede the enactment of any regulations other than those of an emergency nature. Among this series of events are: (a) the advertisement of the intent of the regulation, (b) a public hearing for the regulation, (c) a 35-day waiting period following the pubic hearing to address comments from the hearing, and (d) a final review of the regulation by a joint house and senate review committee.

Alabama also has the Alabama Conservation Advisory Board (ACAB) that is endowed with the responsibility to provide advice on policies of the ADCNR. The board consists of the governor, the ADCNR commissioner, and ten board members.

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

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

5.1.2.3 Mississippi Department of Marine Resources

Mississippi Department of Marine Resources (MDMR)
2620 Beach Boulevard
Biloxi, Mississippi 39531
Telephone: (601) 385-5860

The MDMR administers coastal fisheries and habitat protection programs. Authority to promulgate regulations and policies is vested in the Mississippi Commission on Marine Resources, the controlling body of the MDMR. The commission consists of five members appointed by the governor. The commission has full power to "manage, control, supervise and direct any matters pertaining to all saltwater aquatic life not otherwise delegated to another agency" (Mississippi Code Annotated 49-15-11).

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

5.1.2.4 Louisiana Department of Wildlife and Fisheries

Louisiana Department of Wildlife and Fisheries (LDWF)
P.O. Box 98000
Baton Rouge, Louisiana 70898
Telephone: (504) 765-2623

The LDWF is one of 21 major administrative units of the Louisiana government. A seven-member board, the Louisiana Wildlife and Fisheries Commission (LWFC), is appointed by the governor. Six of the members serve overlapping terms of 6 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 sole authority to establish management programs and policies; however, the legislature has delegated certain authority and responsibility to the LDWF. The Secretary of the LDWF is the executive head and chief administrative officer of the department and is responsible for the administration, control, and operation of the functions, programs, and affairs of the department. The LDWF Secretary is appointed by the governor with consent of the senate.

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

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

5.1.2.5 Texas Parks and Wildlife Department

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

The Texas Parks and Wildlife Department is the administrative unit of the state charged with management of the coastal fishery resources and enforcement of legislative and regulatory procedures under the policy direction of the Texas Parks and Wildlife Commission. The commission consists of 9 members appointed by the governor for 6-year terms. The commission selects the TPWD Executive Director who serves as the chief administrative officer of the department. A Director of the Coastal Fisheries Division and a Director of the Law Enforcement Division are named by the TPWD Executive Director.

5.2 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.

5.3 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.

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

The MFCMA mandates the preparation of fishery management plans for important fishery resources within the EEZ. It sets national standards to be met by such plans, and each plan attempts to define, establish, and maintain the optimum yield for a given fishery.

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

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

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

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

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

The FDCA prohibits the sale, transfer of 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.

5.3.5 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 effect marine populations. The NMFS is the federal trustee for living and nonliving natural resources in coastal and marine areas under United States jurisdiction pursuant to the CWA.

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

MARPOL Annex II governs the discharge at sea of noxious liquid substances primarily derived from tank cleaning and deballasting. Most categorized substances are prohibited from being discharged within 12 nautical miles of land and at depths of less than 25 meters.

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

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

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

The ESA provides for the listing of plant and animal species that are threatened or endangered. Once listed as threatened or endangered, a species may not be taken, possessed, harassed, or otherwise molested. It also provides for a review process to ensure that projects authorized, funded, or carried out by federal agencies do not jeopardize the existence of these species or result in destruction or modification of habitats that are determined by the Secretary of the DOI to be critical.

5.3.9 National Environmental Policy Act of 1970 (NEPA)

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

5.3.10 Fish and Wildlife Coordination Act of 1958

Under the Fish and Wildlife Coordination Act, the FWS and NMFS review and comment on fish and wildlife aspects of proposals for work and activities sanctioned, permitted, assisted, or conducted by federal agencies that take place in or affect navigable waters, wetlands, or other critical fish and wildlife habitat. The review focuses on potential damage to fish, wildlife, and their habitat; therefore, it 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 FWS and NMFS.

5.3.11 Fish Restoration and Management Projects Act of 1950

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

5.3.12 Lacey Act of 1981, as amended

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

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

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

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

MARPOL Annex V is a product of the International Convention for the Prevention of Pollution from Ships, 1973/78. Regulations under this act prohibit ocean discharge of plastics from ships, restrict discharge of other types of floating ship's garbage (packaging and dunnage) for up to 25 nautical miles from any land, restrict discharge of victual and other 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.

5.3.15 Fish and Wildlife Act of 1956

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

5.4 State Authority, Laws, Regulations, and Policies

5.4.1 Florida

5.4.1.1 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. Rules promulgated under Chapter 370 are contained in Chapters 16R and 16N of the Florida Administrative Code. In 1983 the Florida Legislature established the FMFC and provided the commission with various duties, powers, and authorities to promulgate regulations affecting marine fisheries including menhaden. Rules of the FMFC are codified under Chapter 46, Florida Administrative Code.

5.4.1.2 Reciprocal Agreements and Limited Entry Provisions

5.4.1.2.1 Reciprocal Agreements

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

5.4.1.2.2 Limited Entry

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

5.4.1.3 Commercial Landings Data Reporting Requirements

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

5.4.1.4 Penalties for Violations

Penalties for violations of Florida laws and regulations are established in Florida Statutes, Section 370.021. Additionally, upon the arrest and conviction of any license holder for violation of such laws or regulations, the license holder is required to show just cause as to reasons why his saltwater license should not be suspended or revoked.

5.4.1.5 Annual License Fees

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

Resident wholesale seafood dealer	
• county	$ 300.00
• state	450.00
Nonresident wholesale seafood dealer	
• county	500.00
• state	1,000.00
Alien wholesale seafood dealer	
• county	1,000.00
• state	1,500.00
Resident retail seafood dealer	25.00
Nonresident retail seafood dealer	200.00
Alien retail seafood dealer	250.00
Saltwater products license	
• resident-individual	50.00
• resident-vessel	100.00
• nonresident-individual	200.00
• nonresident-vessel	400.00
• alien-individual	300.00
• alien-vessel	600.00

5.4.1.6 Laws and Regulations

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

5.4.1.6.1 Size Limits

No size limits have been promulgated for menhaden in Florida.

5.4.1.6.2 Seasons

There is no closed season for menhaden in Florida.

5.4.1.6.3 Fishing Methods, Area, and Gear Restrictions

5.4.1.6.3.1 Gear Restrictions

Nonspecific gear (i.e., gill nets, trammel nets, and haul seines) 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, the maximum mesh size is 2 inches, stretched mesh. In Region 1 (Escambia and Santa Rosa counties) landward of the COLREGS Demarcation Line, purse seines with a total length longer than 1,200 feet are prohibited. In Pinellas, Hillsborough, and Manatee counties, purse seines may not exceed 1,800 feet in length and 1,500 meshes in depth.

5.4.1.6.3.2 Closed Areas

In Region 1 (waters of Escambia and Santa Rosa counties landward of the Colregs Demarcation Line), if the total commercial harvest of menhaden by all gears during the period beginning on June 1 and ending on October 31 of each year is not projected to reach 1,000,000 pounds, then these waters shall be closed on November 1. If the total commercial harvest of menhaden from this area is projected to reach 3,000,000 pounds before May 31, the menhaden purse seine fishery in these waters shall be closed on the date such harvest is projected to reach that amount. Other area restrictions include: (1) no person shall fish with, set, or place any purse seine in the waters of Big Lagoon, Santa Rosa Sound, Escambia Bay north of the railroad trestle across the bay just north of the Interstate 10 bridge, Blackwater Bay north of the respective Interstate 10 bridge across the bay, or in any bayou in the inside waters of these counties, except Bayou Texar 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 3 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 9 nautical miles). Purse seines are also prohibited within the Everglades National Park.

5.4.1.6.3.3 Other Regulations

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

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

5.4.2 Alabama

5.4.2.1 Legislative Authorization

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

5.4.2.2 Reciprocal Agreements and Limited Entry Provisions

5.4.2.2.1 Reciprocal Agreements

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

5.4.2.2.2 Limited Entry

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

5.4.2.3 Commercial Landings Data Reporting Requirements

Alabama law requires that wholesale seafood dealers file monthly reports at quarterly intervals to the department; 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.

5.4.2.4 Penalties for Violations

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

5.4.2.5 Annual License Fees

The following is a list of license fees current to the date of publication; however, they are subject to change at any time. Nonresident fees may vary based on the charge for similar fishing activities in the applicant's resident state.

Gill nets, trammel nets, seines* 0-200 fathoms in length	
• resident	$100.00
• nonresident	500.00

201-400 fathoms in length	
• resident	150.00
• nonresident	750.00
Purse seine	500.00
Seafood dealer license**	126.00

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

5.4.2.6 Laws and Regulations

Alabama laws and regulations regarding the harvest of menhaden primarily address the type of gear used and seasons for the commercial fishery. The following is a general summary of these laws and regulations. They are current to the date of this publication and are subject to change at any time thereafter. The ADCNR, MRD should be contacted for specific and up-to-date information.

5.4.2.6.1 Size Limits

No size limits have been promulgated for menhaden in Alabama.

5.4.2.6.2 Seasons

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

5.4.2.6.3 Fishing Methods, Area, and Gear Restrictions

5.4.2.6.3.1 Gear Restrictions

Menhaden are primarily caught with purse seines that are required to have a minimum mesh size of ¾" bar. There are no restrictions on the length of purse nets.

Gill nets and other entangling nets are sometimes used to catch menhaden for bait. During the period January 1 through February 28/29 of each year, gill nets, trammel nets, and other entangling nets used in Alabama coastal waters must have a minimum mesh size of 2¾" stretched mesh. A minimum mesh size of 3½" stretched mesh is required for these nets during the period March 1 through October 31 of each year. A minimum mesh size of 3¾" stretched mesh is required for such nets from November 1 through December 31 of each year.

The above restrictions do not apply to coastal rivers, bayous, creeks, or streams. In these areas (with the exception of those portions of the Blakely and Apalachee Rivers south of the I-10 Causeway), the minimum mesh size shall be 6" stretched mesh. The minimum mesh for nets used in the Blakely and Apalachee Rivers south of I-10 shall be the same as previously described by season for other coastal waters.

5.4.2.6.3.2 Closed Areas

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

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

5.4.2.6.3.3 Other Restrictions

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

5.4.3 Mississippi

5.4.3.1 Legislative Authorization

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

5.4.3.2 Reciprocal Agreements and Limited Entry Provisions

5.4.3.2.1 Reciprocal Agreements

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

5.4.3.2.2 Limited Entry

Mississippi has no specific statutory provisions for limited entry.

5.4.3.3 Commercial Landings Data Reporting Requirements

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

5.4.3.4 Penalties for Violations

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

5.4.3.5 Annual License Fees

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

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

5.4.3.6 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.

5.4.3.6.1 Size Limits

There are no minimum or maximum size limits on menhaden.

5.4.3.6.2 Seasons

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

5.4.3.6.3 Fishing Methods, Area, and Gear Restrictions

5.4.3.6.3.1 Gear Restrictions

Purse seines used to catch menhaden must have a minimum mesh size of ½" bar, 1" stretch, and they may not exceed 1,500 feet in length.

5.4.3.6.3.2 Closed Areas

Purse seines used to catch menhaden are prohibited within one (1) mile of the shoreline of Harrison and Hancock counties.

5.4.3.6.3.3 Other Restrictions

It is unlawful for any boat or vessel carrying or using a purse seine to have any quantity of red drum on board in Mississippi territorial waters. It is unlawful for any person, firm, or corporation using a purse seine or having a purse seine aboard a boat or vessel within Mississippi territorial waters to catch in excess of five percent (5%) by weight in any single set of the net or to possess in excess of ten percent (10%) by weight of the total catch any of the following species: spotted seatrout, bluefish, Spanish mackerel, king mackerel, dolphin, pompano, cobia, or jack crevalle.

5.4.4 Louisiana

5.4.4.1 Legislative Authorization

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

5.4.4.2 Reciprocal Agreements and Limited Entry Provisions

5.4.4.2.1 Reciprocal Agreements

5.4.4.2.1.1 Licenses

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

5.4.4.2.1.2 Management

The Commission 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.

5.4.4.2.2 Limited Entry

Louisiana law presently does not provide for limited entry.

5.4.4.3 Commercial Landings Data Reporting Requirements

R.S. 56:345 dictates mandatory reporting to the state by wholesale/retail dealers who buy fish from anyone other than a licensed wholesale/retail dealer. It does not apply to the vertically integrated menhaden companies who do not purchase fish from others.

5.4.4.4 Penalties for Violations

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

5.4.4.5 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	400.00
Vessel license	
• resident	15.00
• nonresident	65.00
Wholesale/retail Dealer	
• resident	105.00
• nonresident	405.00
Gear license	
• resident (per net)	500.00
• nonresident (per net)	2,000.00

5.4.4.6 Laws and Regulations

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

5.4.4.6.1 Minimum Size

There are no minimum size restrictions on menhaden.

5.4.4.6.2 Seasons

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

5.4.4.6.3 Fishing Methods, Area, and Gear Restrictions

5.4.4.6.3.1 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.

5.4.4.6.3.2 Area Restrictions

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

> Beginning at the most northerly point on the south side of Taylor Pass, Lat. 29°23'00"N, Long. 89°20'06"W which is on the inside-outside shrimp line as described in R.S. 56:495; thence westerly to Deep Water Point, Lat. 29°23'36"N, Long. 89°22'54"W; thence westerly to Coquille Point, Lat. 29°23'36"N, Long. 89°24'12"W; thence westerly to Raccoon Point, Lat. 29°24'06"N, Long. 89°28'10"W; thence northerly to the most northerly point of Sable Island, Lat. 29°24'54"N, Long 89°28'27"W; thence northwesterly to California Point, Lat. 29°27'33"N, Long. 89°31'18"W; thence northerly to Telegraph Point, Lat. 29°30'57"N, Long. 89°30'57"W; thence northerly to Mozambique Point, Lat. 29°37'20"N, Long. 89°29'11"W; thence northeasterly to Grace Point (red light no. 62 on the M.R.G.O.), Lat. 29°40'40"N, Long. 89°23'10"W; thence northerly to Deadman Point, Lat. 29°44'06"N, Long. 89°21'05"W; thence easterly to Point Lydia, Lat. 29°45'27"N, Long. 89°16'12"W; thence northerly to Point Comfort, Lat. 29°49'32"N, Long. 89°14'18"W; thence northerly to the most easterly point on Mitchell Island, Lat. 29°53'42"N, Long. 89°11'50"W; thence northerly to the most easterly point on Martin Island, Lat. 29°57'30"N, Long. 89°11'05"W; thence northerly to the most easterly point on Brush Island, Lat. 30°02'42"N, Long. 89°10'06"W; thence northerly to Door Point, Lat. 30°03'45"N, Long. 89°10'08"W; thence northerly to the most easterly point on Isle Au Pitre, Lat. 30°09'27"N, Long. 89°11'02"W; thence north (grid) a distance of 19214.60 feet to a point on the Louisiana-Mississippi Lateral Boundary, Lat. 30°12'37.1781"N, Long. 89°10'57.8925"W; thence S60°20'06"E (grid) along the Louisiana-Mississippi Lateral Boundary a distance of 31555.38 feet, Lat. 30°09'57.4068"N, Long. 89°05'48.9240"W;

> thence S82°53'53"E (grid) continuing along the Louisiana-Mississippi Lateral Boundary a distance of 72649.38 feet, Lat. 30°08'14.1260"N, Long. 89°52'10.3224"W; thence South (grid) a distance of 32521.58 feet to the Chandeleur Light, Lat. 30°02'52"N, Long. 88°52'18"W, which is on the inside-outside shrimp line as described in R.S. 56:495; thence southeasterly along the inside-outside shrimp line as described in R.S. 56:495 to the point of beginning.

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

5.4.4.6.3.3 Other Restrictions

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

The possession of red drum at any time is prohibited. Spotted seatrout may be taken under the 5% restriction during the commercial season (September 15 to April 30, except from sunset Friday through sunset Sunday of each week) unless the commercial quota is met prior to May 1.

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 on board and have the permit in possession at all times when using permitted gear.
8. No gear other than permitted gear may be on board 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 metric tons has been reached, or is projected to be reached, the LDWF shall close the bait menhaden season at least 72 hours after public notice. Commercial landing of bait menhaden in Louisiana regardless of where caught, is prohibited after the closure. Bait menhaden legally taken prior to the closure may be legally possessed.
16. Menhaden landed for bait during the regular season will not be considered as part of the special bait quota.

Menhaden caught in Louisiana waters cannot be transported to and processed in another state, unless that state permits menhaden caught within its waters to be transported to and processed in Louisiana.

5.4.5 Texas

5.4.5.1 Legislative Authorization

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

5.4.5.2 Reciprocal Agreements and Limited Entry Provisions

5.4.5.2.1 Reciprocal Agreements

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

5.4.5.2.2 Limited Entry

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

5.4.5.3 Commercial Landings Data Reporting Requirements

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

5.4.5.4 Penalties for Violations

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

5.4.5.5 Annual License Fees

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

Menhaden fish plant	$ 150.00
Menhaden fish boat	3,500.00
Menhaden net (per 100 feet)	2.00

5.4.5.6 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.

5.4.5.6.1 Size Limits

No size limits have been promulgated for menhaden in Texas.

5.4.5.6.2 Seasons

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

5.4.5.6.3 Fishing Methods, Area, and Gear Restrictions

5.4.5.6.3.1 Gear Restrictions

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

5.4.5.6.3.2 Closed Areas

Menhaden may not be fished in any bay, river, or pass within 0.5 mile from shore in Gulf waters or within 1 mile of any jetty or pass.

5.4.5.6.3.3 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.

6.0 DESCRIPTION OF FISHING ACTIVITIES AFFECTING THE STOCK(S)

6.1 Reduction Fishery

6.1.1 History

The menhaden fishery of the U.S. Gulf of Mexico is almost exclusively a single species fishery for gulf menhaden, *B. patronus*. Small and relatively insignificant amounts of other menhaden species may occasionally be taken in the directed fishery along with other clupeids, e.g., Atlantic thread herring (*Opisthonema oglinum*).

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

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

Historically, the menhaden resource has been primarily used by the reduction industry to produce fish meal, oil, and fish solubles. The reduction fishery has historically relied on purse seines for the harvest of menhaden. Fishing equipment and methods used in the menhaden purse-seine fishery have a long history and have been described by Lee (1953), June and Reinjes (1976), Simmons and Breuer (1950), Perret (1968), Whitehurst (1973), Frye (1978), and Nicholson (1978). From the mid-1800s until World War II, there were very few fundamental changes in fishing gear and techniques. After World War II, a number of important changes took place including: (1) the use of aircraft in the late 1940s to spot menhaden schools; (2) the switch from natural to synthetic fibers in the nets making them stronger and longer lasting; (3) hydraulic power blocks for retrieval of the net; (4) elimination of the striker boat; (5) refrigerated fish holds in the mid-1950s; (6) aluminum, diesel-powered purse (or seine) boats in the 1960s that added speed and maneuverability; (7) hydraulic davits to speed up launching and retrieving of purse boats; and (8) pumps to transfer the catch from the net to the carrier vessel. Some of these where pioneered in the Gulf.

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

In 1940, only six menhaden vessels were reported operating in the Gulf of Mexico. After World War II, the fleet grew rapidly and reached a near-maximum number of 81 in 1956. Thereafter, the fleet size remained relatively stable until the late 1980s averaging approximately 76 vessels per year. In the early 1990s, however, the number of vessels drastically declined (Table 6.1).

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

While the number of vessels was relatively stable from the late 1950s until 1990, their ability to catch fish increased. Increased catch per vessel primarily resulted as the fleet evolved from small boats (under 75 net tons) to large boats (over 200 net tons) and the employment of aircraft in 1949.

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

6.1.2 Fishing Methods, Gear, and Vessels

6.1.2.1 Fish Spotting Aircraft

Spotter planes are used to locate fishable schools of menhaden. 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 a bonus based on the amount of fish landed.

Table 6.1. Total number of purse-seine vessels and reduction plants by port.

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

Source: National Marine Fisheries Service, NOAA, DOC; Menhaden Program, Beaufort Laboratory.

A = Apalachicola, FL: Fish Meal Co. (1966, 1968-1969)

MP = Moss Point, MS: Seacoast Products Co. (1964-1972, 1975-1984), AMPRO Fisheries, Inc. (formerly Standard Products) (1964-1990), Zapata Haynie, Inc. (1964-1993)

E = Empire, LA: Empire Menhaden Company (1964-1991), Daybrook Fisheries (formerly Petrou Fisheries, Inc.) (1964-1993)

D = Dulac, LA: Dulac Menhaden Fisheries (1964-1968, 1970-1971), Fish Meal and Oil Co. (1964-1965), Zapata Haynie, Inc. (1965-1993)

MC = Morgan City, LA: Seacoast Products Co. (1965-1984), Gulf Protein (1989-1993)

IC = Intracoastal City, LA: Seacoast Products Co. (1965-1984), Zapata Haynie, Inc. (1985-1993)

C = Cameron, LA: Louisiana Menhaden Co (1964-1990), Seacoast Products Co. (1964-1984), Zapata Haynie, Inc. (1967-1993)

SP = Sabine Pass, TX: Texas Menhaden Co. (1964-1971)

Spotter pilots make reconnaissance flights prior to the beginning of the fishing season to determine the general location, movement, and size of menhaden schools. During the fishing season a spotter pilot usually departs about dawn to rendezvous with the fishing vessels for which he is spotting. The spotter pilot makes radio contact with the carrier vessels and maintains visual contact with the school or schools of menhaden. When the carrier vessel arrives in the fishing area, the spotter pilot directs it to the best available school and directs the purse boats in the setting of the purse seine. One spotter aircraft usually serves several carrier vessels.

6.1.2.2 Purse Boats

Purse boats are used to set the net on schools of menhaden. They are aluminum with an open-construction design, approximately 40 feet long and 11 feet wide. Purse boats are capable of speeds from 5-8 knots.

6.1.2.3 Carrier Vessels

Menhaden carrier vessels are specialized craft that transport the catch from the fishing grounds to the reduction plants. They carry the purse seine and the two purse boats. The vessels also serve as crew quarters. A high bow, a low stern, and a tall mast with a crow's nest are common characteristics. The fish are stored below deck in central holds that are refrigerated. The wheel house, crew quarters, and mess halls are usually located forward and the engine room aft. The vessels range from 140 to nearly 200 feet in length and may carry approximately 600 tons of menhaden.

6.1.2.4 Purse Seines

Purse seines used by gulf menhaden fishermen are conventional in design. The size and material may vary, but usually a seine is about 1,200 feet long, 10 or more fathoms deep and made of ¾" or 7/8" bar-mesh synthetic twine. The curtain-type net is hung between lines containing surface floats, bottom leads, and noncorrosive purse rings. The bottom of the net is closed by drawing a line through the rings along the bottom line. This is accomplished by dropping the ends of the net overboard adjacent to a heavy lead weight (tom) to which pulleys or blocks are attached and through which the purse line passes thereby allowing the net to be closed at or near its extended depth.

6.1.2.5 Fishing Operation

Carrying a crew of about 14 men (captain, mate, pilot, chief engineer, second engineer, cook, and 8 fishermen), carrier vessels depart from various plants and arrive on the fishing grounds near daybreak. Up to twelve purse-seine sets may be made during a fishing day. Depending on their catch, the weather, and other factors, a vessel may make several trips during the week.

The search for menhaden is conducted by three persons, the spotter pilot, the vessel captain, and the vessel pilot. Once a "color" or "whip" is sighted indicating that a school of appropriate size is within range, the carrier vessel crew goes into action. On orders from the captain, the purse-boat crews (fishermen) rush to stations at the davits on either side of the ship near the stern. Some carrier vessels, however, use ramps instead on davits to load and unload purse boats, and they are often more expedient and safer to board and disembark. The purse boats are lowered into the water and join at the stern of the carrier.

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

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

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

6.1.3 State Reduction Fisheries

Presently, the menhaden reduction fishery is the largest fishery in the Gulf in terms of pounds of fish landed (Table 6.2). Monthly landings fluctuate within seasons, and peaks occur from May to August in various years (Figure 6.1). Monthly catches primarily depend on weather and other factors that affect the availability and catchability of fish. In addition to weather effects on fishing time, seasonal abundance, and quality of the food supply as they vary with environmental factors are probably major reasons for the broad, annual, and areal fluctuations in landings.

Effort is measured on the basis of vessel-ton-weeks, and it is calculated by multiplying the vessel tonnage by the number of weeks in which at least one landing was made. Statistics for 1961-1993 are shown in Table 6.2; however, this type of effort measurement is not useful in assessing fishing pressure because single and multiple landings during a given week would be counted the same. Preliminary analyses of the Captain's Daily Fishing Reports from the Gulf for the 1993 fishing season indicate that approximately 15,000 purse seine sets were made and average harvest per set was 24 metric tons (Smith, personal communication).

Table 6.2. Gulf menhaden landings and effort (reduction fishery), 1961-1993.

Year	Fishing Effort (1000 vessel-ton-weeks)	Landings (1000 metric tons)
1961	241.6	455.9
1962	289.0	479.0
1963	277.3	437.5
1964	272.9	407.8
1965	335.6	461.2
1966	381.3	357.6
1967	404.7	316.1
1968	382.8	371.9
1969	411.0	521.5
1970	400.0	545.9
1971	472.9	728.5
1972	447.5	501.9
1973	426.2	486.4
1974	485.5	587.4
1975	538.0	542.6
1976	575.8	561.2
1977	532.7	447.1
1978	574.3	820.0
1979	533.9	777.9
1980	627.6	701.3
1981	623.0	552.6
1982	653.8	853.9
1983	655.8	923.5
1984	645.9	982.8
1985	560.6	881.1
1986	606.5	822.1
1987	604.2	894.2
1988	594.1	623.7
1989	555.3	569.6
1990	563.1	528.3
1991	472.3	544.3
1992	408.0	421.4
1993	455.2	539.2

Source: National Marine Fisheries Service, NOAA, DOC; Menhaden Program, Beaufort Laboratory

Processing plants for the reduction fishery have been located around the northern Gulf from Apalachicola, Florida, to Sabine Pass, Texas. Prior to the development of refrigerated holds, fishing was limited to areas near operating plants, and most catches are still landed at processing plants near fishing grounds.

Although there are now only six plants located from Moss Point, Mississippi, to Cameron, Louisiana (one in Mississippi and five in Louisiana), the fishing area extends from Apalachicola, Florida, to Freeport, Texas. Fishing in the eastern and western extremes of the fishing area has occurred only when large concentrations of fish are observed there. In general, vessels from Moss Point, Mississippi, fish areas off Apalachicola, Florida, and vessels from Cameron, Louisiana, fish areas off Freeport, Texas.

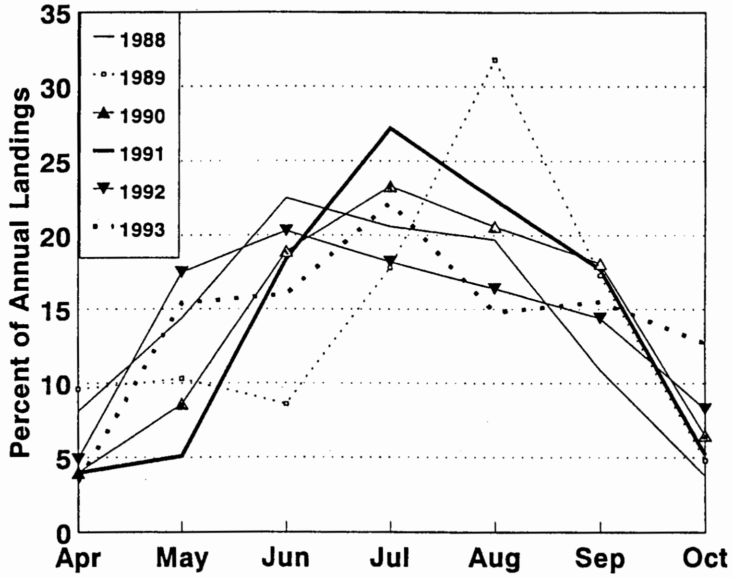

Figure 6.1. Percent of gulf menhaden landings by month, 1988-1993 (NMFS, Beaufort Laboratory).

Nicholson (1978) estimated that from 1964 to 1969, 45% of the fishing sets occurred west of the Mississippi River delta, and 44% to 93% of those were made less than 10 miles from shore. East of the delta, 100% of the sets were made less than ten miles from shore. He also noted that fishing west of the delta was probably "restricted to a narrower band adjacent to shore than is indicated by the data." Comparable data for the 1970s and 1980s are unavailable. Captain's Daily Fishing Reports (CDFRs) were established in 1979, but the data exist only on paper through the 1980s and have not been analyzed. Table 6.3 shows estimated percents of catches from areas east and west of the Mississippi River delta from 1990 through 1993, and Table 6.4 shows estimated percents of catches off each of the five Gulf States. Table 6.5 shows the percents of catch and sets by distance from shore.

Table 6.3. Estimated percent of total gulf menhaden landings for reduction caught east and west of the Mississippi Delta, 1990-1993, plus 4 year mean.

	1990	1991	1992	1993	4 year mean
East	29.5	23.7	22.9	17.7	25.4
West	70.5	76.3	77.1	82.3	74.6

Source: National Marine Fisheries Service, NOAA, DOC; Menhaden Program, Beaufort Laboratory

Table 6.4. Estimated percent of total gulf menhaden landings for reduction caught off Gulf Coast states, 1990-1993, plus 4 year mean.

	1990	1991	1992	1993	4 year mean
Florida	0.2	0.4	0.2	0.0	0.2
Alabama	5.9	1.5	3.5	1.6	3.1
Mississippi	5.7	3.2	5.0	4.5	4.6
Louisiana	81.6	88.5	85.4	89.5	86.3
Texas	6.6	6.4	5.9	4.4	5.8

Source: National Marine Fisheries Service, NOAA, DOC; Menhaden Program, Beaufort Laboratory

Table 6.5. Percent of reduction catch and sets by distance from shore, 1992 and 1993.

	Percentage of Catch		Percentage of Sets	
Distance from Shore	1992	1993	1992	1993
0-1 mile	25	21	29	24
1.1-2.0 miles	20	19	20	19
2.1-3.0 miles	14	17	13	16
3.1-10.0 miles	33	33	31	31
>10 miles	7	9	7	9

Source: National Marine Fisheries Service, NOAA, DOC; Menhaden Program, Beaufort Laboratory

Historically, the majority of menhaden landings in the Gulf occurred in Louisiana followed by Mississippi. Menhaden have not been landed for reduction in Alabama since 1931, in Texas since 1971, and in Florida since 1972. Of the total menhaden landed in the Gulf States from 1948 through 1975, 70.1% were landed in Louisiana, 22.3% in Mississippi, 7.2% in Texas, and 0.4% in Florida. From 1975 to 1987, 18% of total Gulf landings were landed in Mississippi, 37% in east Louisiana, and 45% in west Louisiana. Similarly, between 1988 and 1993, 18% of total annual gulf menhaden landings were made in Mississippi, 39% in east Louisiana, and 43% in west Louisiana (Smith, personal communication).

Total landings in the Gulf increased from approximately 960 million pounds in the 1960s to 1.3 billion pounds in the 1970s and 1.7 billion pounds in the 1980s. Peak landings in excess of 2.2 billion pounds occurred in 1984. Following this peak-production year, landings declined by approximately 10% then remained relatively stable until 1988 when they dropped an additional 30%. Production from 1988 through 1990 continued to decline, and after a slight increase in 1991 landings, production in 1992 reached its lowest point since 1968 (Table 6.2). Landings rebounded to about 1.2 billion pounds in 1993, and estimates for 1994 were approximately 1.5 billion pounds. The gulf menhaden purse-seine fishery was the largest fishery in the U.S. until the late 1980s when Alaska's pollack fishery superseded it.

Variations in landings are primarily caused by yearly changes in environmental conditions that affect recruitment. Favorable estuarine conditions for larval and juvenile survival and growth usually result in successful catches in the following year and visa versa. A second but perhaps slightly less significant variable is weather conditions that affect fishing. Inclement weather, especially hurricanes, reduce fishing time during some seasons; and as in 1992, poor weather early in the season coupled with a hurricane (Andrew) late in the season, drastically reduced fishing time and subsequent landings. Other less significant factors are variations in economic conditions, markets, and the manner in which the fishery was conducted.

The latter factors became much more significant after 1984 when the number of operating reduction plants dropped from 11 in 1984 to 7 in 1985 (Table 6.1). By 1989, 2 additional plants were operating, but the number declined to 6 in 1992 and 1993.

The number of operating vessels also declined from 81 in 1984 to 73 in 1985 (Table 6.1). An average of 74 vessels operated from 1985 to 1990, then drastically dropped to 58 in 1991, 51 in 1992, and 52 in 1993.

The reduction fishery season basically extends from mid-April to November of each year, and it has been consistent among Gulf States, except Florida, since about 1980. As shown in Figure 6.1, production usually peaks in June, July, or August.

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

6.2 Bait Fishery

6.2.1 History

The bait fishery for menhaden has historically accounted for only a minute portion of the total Gulf landings of menhaden. Until the mid 1980s, the bait fishery for menhaden occurred almost exclusively in Florida. Louisiana and Alabama began landing menhaden for bait in 1984, and Louisiana's landings increased substantially through the mid to late 1980s. Neither Mississippi nor Texas has recorded commercial bait production in recent years.

6.2.2 Fishing Methods, Gear, and Vessels

Although the menhaden bait fishery is primarily conducted in Florida and Louisiana, the prosecution of the fishery is quite different in these two areas. In Florida, menhaden are primarily caught using ¾" to 1" bar purse seines 1,950 to 2,400 feet in length that are fished from relatively small boats 35 to 65 feet in length. Currently, there are approximately 13 purse-seine boats operating on the west coast of Florida. In Louisiana, menhaden are caught for bait using the same type gear, vessels, and methods as previously described for the reduction fishery. In the Gulf, small amounts of menhaden are also caught with other gear, e.g., gill nets and trawls.

6.2.3 State Bait Fisheries

Table 6.6 shows menhaden commercial bait landings from 1980 through 1993 for the total U.S. Gulf of Mexico. Further breakdown of landings by state is not possible due to the confidentiality of data; however, Florida and Louisiana are the major producers. Table 6.7 shows the percentage of menhaden landings for bait by region in Florida from 1986 through 1992. Florida's landings have principally come from the Gulf-Escambia Region, and the percentage of Florida landings from this region may increase in the future due to regulatory closures in the Tampa Bay Region.

Table 6.6. Gulf menhaden landings for bait, 1980 to 1993.

Year	**Total Gulf Landings** (pounds)
1980	2,201,790
1981	2,368,801
1982	3,475,932
1983	3,834,350
1984	5,108,901
1985	6,608,884
1986	18,785,685
1987	38,052,888
1988	35,325,159
1989	29,769,739
1990	24,437,974
1991	19,036,425
1992	24,056,542
1993	26,540,567

Source: National Marine Fisheries Service, Southeast Science Center, unpublished data

Table 6.7. Percentage of menhaden bait fishery landings by region, Florida west coast, 1986 through 1992.

Year	Sarasota-Collier	Tampa Bay	Pasco-Franklin	Gulf-Escambia	Total
1986	0.1%	35.1%	0.4%	64.4%	100%
1987	0.1%	38.3%	0.3%	61.3%	100%
1988	0.1%	19.0%	6.6%	74.3%	100%
1989	0.3%	12.7%	7.1%	79.9%	100%
1990	0.4%	1.5%	4.1%	94.0%	100%
1991	2.5%	14.6%	6.7%	76.2%	100%
1992	2.5%	6.8%	7.8%	82.9%	100%

Source: Florida Department of Environmental Protection, Florida Marine Research Institute

Menhaden are caught for bait from March through December, usually within 2 to 3 miles of shore, and largest catches usually occur from April through August. In 1989, however, Louisiana established a special winter season for bait production that is described in Section 5.4.4.6.2.

In 1993, Florida had 4 bait processors/dealers operating in the Panhandle Region. Louisiana only had one major processor/dealer, but smaller amounts were handled by some reduction plants and a few other small companies.

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

6.3 Incidental Catch

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

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 10 species in order of abundance comprising over 90% of the total bycatch: striped mullet (*Mugil cephalus*), Atlantic croaker (*Micropogonias undulatus*), spot (*Leiostomus xanthurus*), threadfin shad (*Dorosoma petenense*), gafftopsail catfish (*Bagre marinus*), hardhead catfish (*Arius felis*), sand seatrout (*Cynoscion arenarius*), harvestfish (*Peprilus alepidotus*), *Cynoscion* spp. (not *C. nebulosus*), and pinfish (*Lagodon rhomboides*). Guillory and Hutton (1982) found 35 fish species with the most abundant species of fish by number being Atlantic croaker (25.2%), sand and silver seatrout (*Cynoscion* spp.) (19.7%), threadfin shad (13.2%), Atlantic bumper (*Chloroscombrus chrysurus*) (12.6%), hardhead catfish (8.3%), and spot (5.8%). These 6 species comprised approximately 85% of the total weight of bycatch. Condry (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%).

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.

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

7.1 Reduction Fishery

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

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

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

In summary, the economic structure of the gulf menhaden reduction industry is unlike most fisheries in the United States. There are only a few firms, the capital costs are larger than commonly found in other fisheries, and the industry uses an advanced technology.

7.1.1 Value and Price

7.1.1.1 Dockside

In the gulf menhaden industry, processors own their vessels and contract crews to catch fish based on agreed share costs. Each company markets their products, and as such, the menhaden industry is vertically integrated. Since each company is using raw production landed by its own vessels, no true market price or ex-vessel price can be established. Consequently, reports of the ex-vessel value by the U.S. Department of Commerce are only useful to examine trends or compare relative values from year to year. Landings and ex-vessel values for the reduction fishery, 1980-1993, are shown in Table 7.1.

Table 7.1. Landings and ex-vessel value of the gulf menhaden reduction fishery, 1980-1993.

Year	**Landings (lbs x10^6)**	**Value ($ x10^6)**
1980	1,545.7	69.1
1981	1,217.9	47.7
1982	1,882.0	72.3
1983	2,635.4	82.5
1984	2,166.1	88.0
1985	1,941.9	67.3
1986	1,811.9	67.0
1987	1,970.8	69.9
1988	1,374.6	71.3
1989	1,255.4	52.0
1990	1,164.4	55.6
1991	1,199.6	57.7
1992	928.8	50.2
1993	1,188.4	57.8

Source: National Marine Fisheries Service, Southeast Science Center, unpublished data

Statistics concerning volume, value, and price of menhaden products may be misleading because production figures may be actual or in some cases estimated. Also, production from a given year may be stored and sold at a later time causing variation in price and value.

7.1.1.2 Products

Gulf menhaden are one of the several species of fish used to produce fish meal and oil in the U.S. Menhaden, however, are the major source averaging 80% of the meal and 98% of the oil for 1987 through 1992 (National Marine Fisheries Service, Fisheries of the United States, Current Fisheries Statistics, various issues). Table 7.2 shows the production, value, and price of menhaden meal from the Gulf of Mexico for the period 1962-1993. In recent years, total domestic utilization has exceeded domestic production by the menhaden industry. The real price per ton undergoes large variations from year to year primarily because of variations in the price of soybean meal.

Table 7.3 lists the volume, value, and price of menhaden oil from the Gulf for the period 1962-1993. As with fish meal, the real price per pound demonstrates considerable variation. The market factors influencing price are particularly complex primarily because almost all menhaden oil is exported and is competing in the international marketplace (Table 7.4).

Table 7.5 lists the volume, value, and price of menhaden solubles from the Gulf for the period 1962-1993. These figures can be misleading because most producers add solubles back to fish meal and sell it as "whole meal," rather than liquid solubles. Consequently, the volume reported may be significantly different from the actual production. Stringent water quality regulations and discharge requirements are the main reasons for production and marketing of solubles because of their low value.

7.1.2 Processing and Wholesaling

7.1.2.1 Costs

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

Table 7.2 Production, value, and price of menhaden meal from the U.S. Gulf of Mexico, 1962 to 1993. (Consumer Price Index base years 1982-1984)

Year	Production (lbs x1000)	Value ($ x1000)	Deflated Value ($ x1000)	Dockside Price ($/lb)	Deflated Dockside Price ($/lb)
1962	194,296	11,493	38,056	.06	.20
1963	182,614	11,020	36,013	.06	.20
1964	175,164	10,737	34,635	.06	.20
1965	203,940	14,952	47,467	.07	.23
1966	163,816	12,724	39,272	.08	.24
1967	144,470	9,468	28,347	.07	.20
1968	171,382	11,655	33,491	.07	.20
1969	240,882	19,888	54,191	.08	.22
1970	252,322	23,181	59,745	.09	.24
1971	330,498	26,126	64,509	.08	.20
1972	226,536	20,492	49,024	.09	.22
1973	215,340	52,025	117,173	.24	.54
1974	273,944	42,459	86,124	.15	.31
1975	256,000	30,634	56,941	.12	.22
1976	264,000	45,250	79,525	.17	.30
1977	220,000	41,827	69,021	.19	.31
1978	396,000	68,684	105,344	.17	.27
1979	376,000	70,115	96,577	.19	.26
1980	348,000	65,161	79,079	.19	.23
1981	280,000	55,268	60,801	.20	.22
1982	416,000	67,880	70,342	.16	.17
1983	440,000	76,677	76,985	.17	.17
1984	476,000	75,990	73,138	.16	.15
1985	450,000	54,048	50,230	.12	.11
1986	450,000	56,718	51,750	.13	.12
1987	399,538	85,571	75,327	.21	.19
1988	346,790	79,454	67,163	.23	.19
1989	309,204	59,903	48,309	.19	.16
1990	266,962	43,355	33,171	.16	.12
1991	292,910	54,464	39,988	.19	.14
1992	230,214	44,955	32,042	.20	.14
1993	294,548	50,807	35,161	.17	.12

Source: Compiled from data contained in Fisheries of the United States (various issues) and unpublished National Marine Fisheries Service data

Table 7.3. Production, value, and price of menhaden oil from the U.S. Gulf of Mexico, 1962 to 1993. (Consumer Price Index base years 1982-1984)

Year	Production (lbs x1000)	Value ($ x1000)	Deflated Value ($ x1000)	Dockside Price ($/lb)	Deflated Dockside Price ($/lb)
1962	112,265	4,968	16,450	.04	.15
1963	90,747	5,331	17,422	.06	.19
1964	99,174	7,535	24,306	.08	.25
1965	116,365	9,095	28,873	.08	.25
1966	100,622	8,229	25,398	.08	.25
1967	61,612	2,996	8,970	.05	.15
1968	94,877	4,129	11,865	.04	.13
1969	120,105	6,638	18,087	.06	.15
1970	140,034	12,756	32,876	.09	.23
1971	190,688	15,024	37,096	.08	.19
1972	119,617	7,840	18,756	.07	.16
1973	158,790	17,430	39,257	.11	.25
1974	175,599	38,517	78,128	.22	.44
1975	186,000	25,816	47,985	.14	.26
1976	151,641	23,670	41,599	.16	.27
1977	82,857	18,689	30,840	.23	.37
1978	244,330	51,400	78,834	.21	.32
1979	214,334	44,781	61,682	.21	.29
1980	252,413	46,646	56,609	.18	.22
1981	133,407	24,218	26,642	.18	.20
1982	299,099	46,749	48,445	.16	.16
1983	334,572	55,345	55,567	.17	.17
1984	320,868	54,394	52,352	.17	.16
1985	241,427	35,723	33,200	.15	.14
1986	302,276	40,263	36,736	.13	.12
1987	250,745	29,321	25,811	.12	.10
1988	180,053	27,905	23,588	.15	.13
1989	185,550	19,614	15,818	.11	.09
1990	205,496	19,478	14,903	.09	.07
1991	222,624	24,763	18,181	.11	.08
1992	136,882	21,044	14,999	.15	.11
1993	219,126	30,696	21,243	.14	.10

Source: Compiled from data contained in Fisheries of the United States (various issues) and unpublished National Marine Fisheries Service data

Table 7.4. U.S. production and exports of fish oil in pounds x1000, 1987 to 1992.

Year	Domestic Production	Exports
1987	298,496	249,246
1988	224,733	150,002
1989	225,478	198,009
1990	281,949	236,589
1991	267,345	254,525
1992	180,899	177,446

Source: Fisheries of the United States, 1992 DOC, NOAA, NMFS

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

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

7.1.2.2 Operation

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

Table 7.5. Production, value, and price of menhaden solubles from the U.S. Gulf of Mexico, 1962 to 1993. (Consumer Price Index base years 1982-1984)

Year	Production (lbs x1000)	Value ($ x1000)	Deflated Value ($ x1000)	Dockside Price ($/lb)	Deflated Dockside Price ($/lb)
1962	69,832	1,751	5,798	.03	.08
1963	74,890	2,213	7,232	.03	.10
1964	68,094	2,041	6,584	.03	.10
1965	77,428	2,224	7,060	.03	.09
1966	69,894	2,043	6,306	.03	.09
1967	58,764	1,776	5,317	.03	.09
1968	60,140	1,620	4,655	.03	.08
1969	92,598	2,308	6,289	.02	.07
1970	88,546	2,163	5,575	.02	.06
1971	60,002	2,444	6,035	.04	.10
1972	96,070	1,707	4,084	.02	.04
1973	109,054	7,011	15,791	.06	.14
1974	120,184	4,807	9,751	.04	,08
1975	84,000	2,717	5,050	.03	.06
1976	88,000	4,969	8,733	.06	.10
1977	70,000	4,986	8,228	.07	.12
1978	138,000	9,814	15,052	.07	.11
1979	114,000	6,603	9,095	.06	.08
1980	80,000	3,905	4,739	.05	.06
1981	72,000	4,293	4,723	.06	.07
1982	130,000	6,760	7,005	.05	.05
1983	124,000	6,395	6,421	.05	.05
1984	65,140	7,958	7,659	.12	.12
1985	196,000	11,478	10,667	.06	.05
1986	178,000	10,687	9,751	.06	.05
1987	182,179	11,248	9,901	.06	.05
1988	103,256	8,555	7,232	.08	.07
1989	101,247	7,435	5,996	.07	.06
1990	84,307	7,079	5,416	.08	.06
1991	108,140	7,867	5,776	.07	.05
1992	74,787	6,987	4,980	.09	.07
1993	102,384	8,396	5,810	.08	.06

Source: Compiled from data contained in Fisheries of the United States (various issues) and unpublished National Marine Fisheries Service data

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

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

Figure 7.1 illustrates the processing of 100 metric tons of raw menhaden. Numbers used for this figure are based on data developed from the proximate components of gulf menhaden (Dubrow et al. 1976). The numbers represent averages since proportions of water, protein, fat, and ash in raw fish vary considerably by the area that they are caught and from year-to-year and during a season. Causes of these variations are unknown.

7.1.3 Markets and Product Distribution

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

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

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

Menhaden oil has been used for many years in edible products for human consumption in Europe and South America. The oil is refined, hydrogenated, deodorized, and then blended with other fats to make cooking oils, shortening, margarine, and other products.

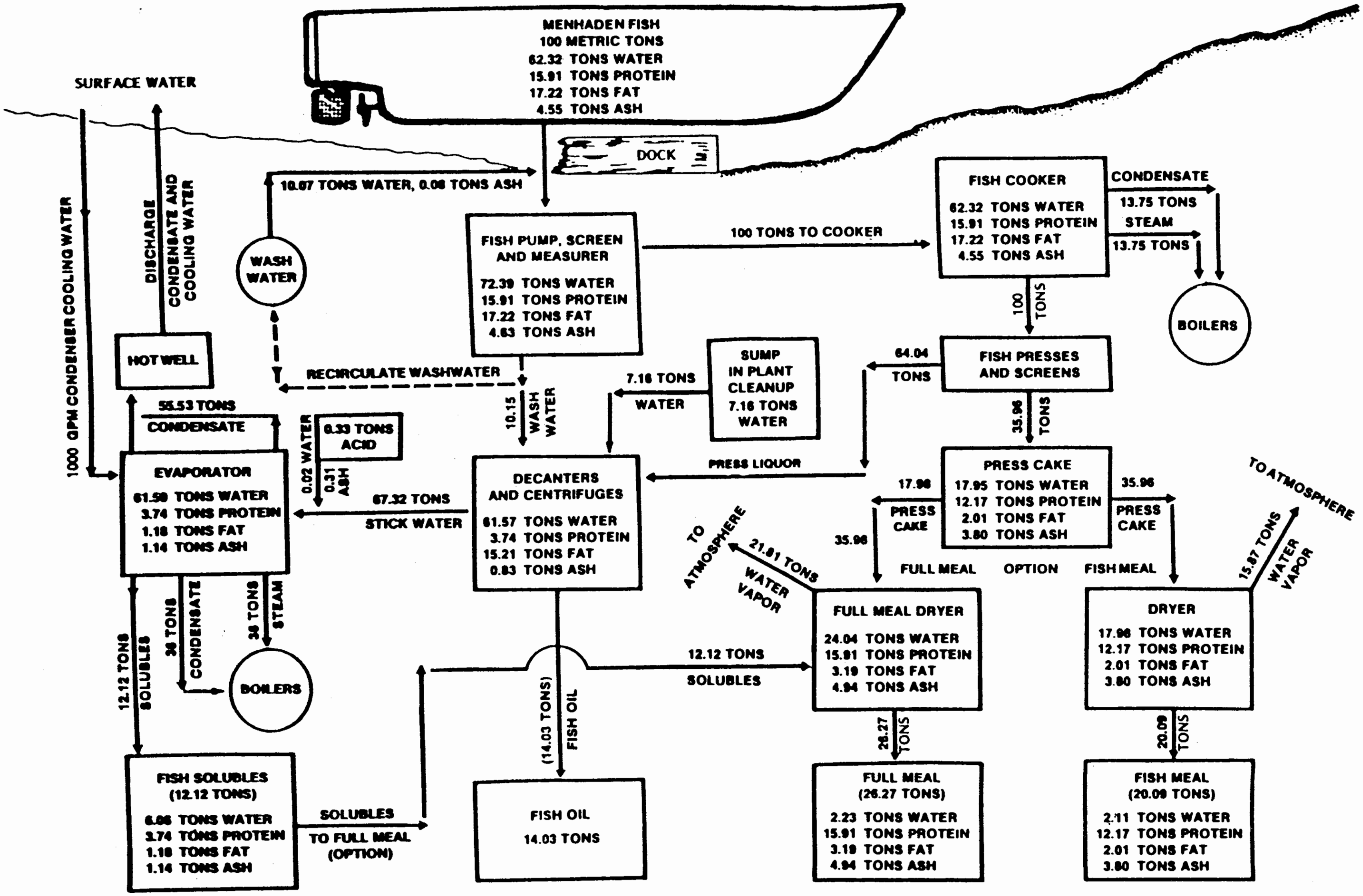

Figure 7.1. The processing of 100 metric tons of raw menhaden through a modern plant.

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

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

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

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

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

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

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

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

7.2 Bait Industry

Menhaden caught for bait have primarily been used in the blue crab, *Callinectes sapidus*, and crawfish, *Procambarus clarki*, fisheries. Smaller amounts have also been sold to recreational finfishermen. Menhaden that are caught for bait in the Gulf are almost exclusively sold in the Gulf Region. In recent years, dockside prices ranged from $0.05 to $0.11 per pound, averaging about $0.09 (NMFS, Fisheries of the United States, 1990 through 1993 issues); while wholesale dealers received from $0.14 to $0.18 per pound (Raffield, personal communication). Blue crab fishermen pay approximately $0.19 to $0.23 per pound for menhaden.

Whole menhaden are sold for bait in 50-100 pound boxes and packaged and frozen in 5 to 7 pound boxes. Some are ground and sold for "chum" to recreational fishermen.

7.3 Organizations

7.3.1 International

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

7.3.2 National

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

7.3.3 Regional

State-Federal Fisheries Management Committee
Gulf States Marine Fisheries Commission
P.O. Box 726
Ocean Springs, Mississippi 39566-0726
Phone: (601) 875-5912
Fax: (601) 875-6604

Menhaden Advisory Council for the Gulf of Mexico
7412 Lakeshore Drive
New Orleans, Louisiana 70124
Phone: (504) 288-8211
Fax: (504) 288-8426

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

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

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

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

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

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

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

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

9.0 MANAGEMENT CONSIDERATIONS

9.1 Definition of the Fishery

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

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

9.2 Management Unit

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

9.3 Stock Assessment

The NMFS has maintained a sampling program from 1964 to present that provides detailed information on daily vessel landings and fish sampled for length, weight, and age (from scales). This information has been used to estimate the number of fish landed at age, 1964-1992 and to periodically assess the status of menhaden stocks in the Gulf of Mexico (Vaughan et al. 1994). The following is a summary of the current status of menhaden stocks based on various analyses. Section 15.0 (Appendix) provides a more detailed account.

9.3.1 Virtual Population Analysis

Estimates of population numbers and fishing mortality rates by age are obtained from virtual population analysis (VPA) on catch-at-age data (or catch matrix). Two general methods of VPA are used in Vaughan et al. (1994). The first method, that of Murphy (1965), is described in Vaughan (1987). The second method, that of Doubleday (1976), is referred to as "separable" VPA. The latter method assumes that age- and year-specific estimates of fishing mortality rates (F) can be partitioned into the product of an age component (partial recruitment) and a year component (two variations of this method are used: one based on the entire catch matrix [all] and the second based on splitting the catch matrix into two time periods [split]). The annual instantaneous natural mortality rate (M) was estimated from analysis of mark-recapture data (Ahrenholz 1981). This estimate of M (1.1 per year or 0.275 per quarter) was assumed constant for all ages (>0.5) and years.

Fishing mortality rates appear to have been slightly higher during the earlier period (1964-1975). All three VPA approaches produce very similar results for the later period (1976-1992). Exploitation rates (u) for age 1 fish, or the proportion of the population removed due to fishing, have generally declined since 1964, although this trend is less obvious in the exploitation rates for ages 1-4 combined. Exploitation rates for age 1 fish ranged between 14% in 1986 and 45%

in 1966; ranges for age 2 fish were between 30% in 1981 and 72% in 1966. Overall exploitation rates (ages 1-4) ranged between 21% in 1981 and 54% in 1966.

Recruitment to age 1 and population biomass were highest on average during the 1980s regardless of VPA method used, although peak recruitment and population biomass estimated from the separable approach peaked in 1974 with 55.8 (all) or 42.1 (split) billion recruits to age 1 and with 2.2 (all) or 1.7 (split) million tons of population biomass. Recent estimates of recruits to age 1 are still reasonable (20 to 25 billion). Spawning stock biomass for recent years is on average well above those of the 1960s and higher than those of the 1970s regardless of VPA approach.

9.3.2 Biological Reference Points

Two modeling approaches are used to estimate biological reference points to assess whether estimated F are too high (Vaughan et al. 1994). Reference points from yield-per-recruit analysis ($F_{0.1}$ or F_{max}) have been used for several decades but are not directly related to the reproductive ability of the stock. Reference points from maximum spawning potential (F_{20} or F_{30}) depend on the relative available spawning stock biomass (SSB) at 20% or 30%, respectively) have been used recently by the fishery management councils and commissions. Biological reference points from yield per recruit ($F_{0.1}$: 0.7-0.9 yr^{1}) and maximum spawning potential (F_{20}: 1.6-2.9 yr^{1} and F_{30}: 1.0-2.1 yr^{-1}) were obtained for comparison with recent estimates of F (0.4-0.8 yr^{-1}).

Annual estimates of yield per recruit ranged between 20 and 40 g with values generally lower since the late 1970s. Yield per recruit based on estimates of F using the Murphy (1965) VPA declined from an average of 32 g during the 1960s, 30 g during the 1970s, and 23 g during the 1980s. A value of 26 g was estimated for the 1990 fishing year.

Annual estimates of maximum spawning potential ranged between 20% and 50% with values generally higher since the late 1970s. Maximum spawning potential (female biomass) based on estimates of F using the Murphy (1965) VPA increased from an average of 24% during the 1960s to 38% during the 1970s and 39% during the 1980s. A value of 48% was estimated for the 1990 fishing year.

Recent estimates of fishing mortality (for M = 1.1) compare favorably with the different estimates of biological reference points. Generally, estimates of $F_{0.1}$ are similar to, but slightly smaller than, estimates of F_{30} but are much smaller than estimates of F_{20}. Recent estimates of F (ages 1-4) are comparable to or below $F_{0.1}$, the most conservative of the above biological reference points.

When lower estimates of natural mortality (M) are assumed, the estimated biological reference points decrease while estimates of fishing mortality increase. For M of 0.9, recent estimates of F (mean of 0.5 for 1990-1992) are about the same as for $F_{0.1}$ (0.5) and well below estimates of F_{20} (1.4-2.7) and F_{30} (0.6-2.0). Based on tagging, the best point estimate of M is 1.1.

9.3.3 Population Modeling

Estimates of recruits to age 1 are described earlier. Based on estimated F from the Murphy (1965) VPA, spawning biomass was highest during the 1980s when it averaged 410,200 t and lowest during the 1960s when it averaged 105,700 t. Intermediate values were obtained during the 1970s when SSB averaged 292,200 t, and 334,000 t was estimated for 1990.

Estimates of maximum sustainable yield (MSY) based on 1946-1992 fishing years range from 664,000 t based on Murphy (1965) VPA to 708,000 t and 897,000 t based on separable VPAs (all and split data in catch matrix, respectively). Variability associated with all model parameters was large, and corresponding comparisons of data to model fits show considerable lack of fit (as noted in Vaughan [1987] to which these estimates can be compared). Usefulness of these models beyond suggesting order-of-magnitude level of MSY is debatable; however, because gulf menhaden are a short-lived species with few ages contributing to landings, surplus production models are probably of greater use than for long-lived species with many ages contributing to the landings.

Landings and nominal efforts were high during the 1980s but declined precipitously during the late 1980s and early 1990s. Landings peaked in 1984 with 982,800 t, while nominal fishing effort peaked in 1983 with 655,800 vessel-ton-weeks. In 1992, landings were 421,400 t with 408,000 vessel-ton-weeks. Landings between 1982 and 1987 were very high exceeding estimates of long-term MSY, but they were supported by generally high recruitment to age 1. More recent landings (421,400 to 623,700 t) with average recruitment and reduced fleet size are comparable to or somewhat below recent estimates of MSY (600,000 to 700,000 t based on the generalized production model for the Murphy [1965] VPA results). An upward trend in historical estimates of MSY noted by Vaughan (1987) was no longer maintained in this assessment.

9.3.4 Management Implications

The gulf menhaden has higher natural mortality and is shorter lived than the Atlantic menhaden which can result in rapid, annual changes in the fishable stock. The gulf menhaden fishery is currently fully exploited, and the population appears reasonably stable in view of the age composition, life span, and effects of environmental factors. Annual production, fishing effort, and fleet size appear reasonably balanced; although there is sufficient excess catch capacity to crop the high year-class surpluses. Given the variability in the model estimates, estimates of F at or below our biological reference points, and recent landings below long term MSY (and well below high landings of the mid-1980s); the stock appears to be healthy. Risk of overfishing is relatively low with 1992-1993 fleet size and recent mean levels of recruitment.

9.4 Problems in the Fishery

9.4.1 Habitat Problems

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

1. construction and maintenance of navigation channels;
2. construction of dams, marinas, and levees;
3. dredging and filling activities;
4. ditching, draining, or impounding wetlands;
5. other alterations of freshwater inflows to estuaries;
6. discharges from wastewater plants and other industries;
7. oil and gas production;
8. thermal discharges;
9. agricultural operations;
10. mining activities other than for oil and gas; and
11. nonpoint source discharges of contaminants.

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

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

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

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

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

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

In addition to loss of wetlands, alterations to salinity and temperature regimes and degradation of water quality may also adversely impact gulf menhaden in estuarine habitats. Industrial and chemical wastes from point sources and agricultural and urban runoff from non-point sources can be laden with toxic substances or nutrients. Excessive nutrient loading can cause accelerated eutrophication and hypoxia; whereas other substances may directly cause mortality.

9.4.2 Lack of Adequate Data for Predictive Modeling

Effort data from Captain's Daily Fishing Reports have been collected for many years; however, past reductions in funding for the NMFS precluded its computerization and ultimate use by scientists and the industry for modeling menhaden populations. Since 1992, the acquisition of relatively inexpensive personal computers and new software has enhanced efforts to digitize these annual data sets. Limited, preliminary analyses have been performed on the 1992-1994 data bases; however, most of the data remain unedited. These data could help improve predictive models of catch as well as assessments of the effects of fishing on menhaden stocks.

9.4.3 Increased Costs

9.4.3.1 Insurance

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

9.4.3.2 Inability to Secure a Qualified and Willing Labor Force

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

9.4.4 Inability to Secure Financing

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

9.4.4.1 Aging Fleet

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

9.4.4.2 Inefficiency of Operation

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

9.4.5 Unfair Competition Practices

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

9.4.6 Limited Markets for Menhaden Oil

Since menhaden oil is not yet extensively used in products for human consumption in the U.S., it must be exported at increased cost. In addition to the increased cost, menhaden oil must compete with other fish oil on foreign markets thus reducing profits.

10.0 AVAILABLE MANAGEMENT MEASURES

10.1 Quotas and Trip Limits

Quotas and trip limits are two management measures that have traditionally been used to control catch over a specified period. Quotas have most often been identified as a total allowable catch (TAC) based on an estimate of allowable biological catch (ABC). An acceptable TAC may occur within a range of ABC (sometimes outside the ABC range) depending on the status of the stock and the management goals. Quotas could be identified for the entire menhaden fishery of the Gulf, for individual states, or separately for the reduction fishery and the bait fishery. Quotas could be unmanaged or managed through trip limits or individual quota systems, e.g., individual transferable quotas (ITQs).

10.2 Gear Restrictions

Gear restrictions are a very common and popular method used by management to regulate the size and amount of fish harvested. A disadvantage of such restrictions is that they often reduce the efficiency of harvest. Current gear restrictions in the menhaden fisheries of the Gulf States do not effect harvest efficiency, but they do preclude the use of certain gear in designated areas.

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

10.3 Area and Seasonal Closures

Areas have been closed by various states to protect juvenile stocks from premature harvest and for other reasons. In most cases, areas are closed because: there is insufficient room for net operations (rivers, bayous, and bays); sensitive habitat might be negatively impacted by commercial gear; and potential conflicts with other water-related uses, e.g., recreational boating, shipping, and other commercial and recreational fisheries. States could reevaluate their use of closed areas, to reduce conflicts among water-related users, promote water safety, and for other reasons.

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

10.4 Limited Access Considerations

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

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

10.5 Monitoring Programs

10.5.1 Fishery-Independent Monitoring

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

10.5.2 Fishery-Dependent Monitoring

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

10.5.2.1 Catch Data

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

10.5.2.2 Effort Data

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

10.5.3 Habitat Monitoring

Since menhaden depend on various estuarine habitat during their early life stages, states could increase efforts to identify critical habitat and monitor potentially negative changes. States could more vehemently oppose activities that have the potential to damage or destroy critical menhaden habitat and more actively support activities that could develop or enhance it. These actions could be taken through more focused habitat management programs that review proposals for dredging, filling, channelization, and various other construction in or near critical habitat. The habitat management programs could also include monitoring of effluent discharges, marine debris, and other contamination.

10.6 Cooperative Management Program

Pinkerton (1989) and Troadec (1989) observed that cooperative management or co-management of marine fishery resources could help increase the reliability of data, decrease enforcement costs, increase sustainability of fisheries, and improve the relationship between users and regulators. Cooperative management, however, requires that managers and users share the responsibility for maintaining viable fishery stocks.

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

10.7 Measures to Support Management

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

11.0 MANAGEMENT RECOMMENDATIONS

- States with reduction fisheries should establish consistent seasons Gulf-wide that are timely and of sufficient length to harvest available annual stocks at optimum sustainable yield.

- If any state fishery management agency, the NMFS, or other agencies determine that a proposed activity will have a deleterious effect on menhaden resources, they should advise the S-FFMC MAC.

- The NMFS should actively seek sufficient staff and funding to complete computerization of the Captain's Daily Fishing Reports and to maintain this data base in a manner consistent with other fishery data collection and utilization programs.

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

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

12.0 RESEARCH AND DATA NEEDS

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

  - bio-economic models to determine the best use allocation of the resource,
  - appropriate supply and demand models for harvested and processed products,
  - relevant cost functions for the harvesting and processing sectors, and
  - market analyses of processed products.

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

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

- Computerize Captain's Daily Fishing Reports and develop a new effort index.

- Evaluate the impacts of habitat changes in coastal Louisiana (marsh loss, salinity change, etc.) on menhaden.

- Determine the social and cultural aspects of the fishery.

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

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

13.0 REVIEW AND MONITORING OF THE PLAN

13.1 Review

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

13.2 Monitoring

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

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15.0 APPENDIX

Population Characteristics of Gulf Menhaden, *Brevoortia patronus*

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ABSTRACT

The status of the gulf menhaden, *Brevoortia patronus*, fishery was assessed with purse-seine landings data from 1946 to 1992 and port sampling data from 1964 to 1992. These data were analyzed to determine growth rates, biological reference points for fishing mortality from yield per recruit and maximum spawning potential analyses, spawner-recruit relationships, and maximum sustainable yield (MSY). Virtual population approaches were used to obtain point estimates of stock size, recruits to age 1, spawning stock size, and fishing mortality rates. Age-1 exploitation rates ranged between 14% and 45%, for age-2 fish between 30% and 72%, and for age-3 fish between 36% and 71%. Biological reference points from yield per recruit ($F_{0.1}$: 0.7-0.9 yr^{-1}) and maximum spawning potential (F_{20}: 1.6-2.9 yr^{-1} and F_{30}: 1.0-2.1 yr^{-1}) were obtained for comparison with recent estimates of F (0.4-0.8 yr^{-1}). Parameters from Ricker-type spawner-recruit relations were estimated, although considerable unexplained variability remained. Estimates of long-term MSY from fits of the generalized production model ranged between 664,000 t and 897,000 t. Declines in landings since 1988 have raised concerns about the status of the gulf menhaden stock. However, gulf menhaden are short lived and highly fecund. Thus, variation in recruitment to age 1 largely mediated by environmental conditions, influences fishing success over the next two years (as age-1 and -2 fish). Comparisons of recent estimates of fishing mortality to biological reference points do not suggest overfishing.

INTRODUCTION

Gulf menhaden, *Brevoortia patronus*, is a euryhaline species found in coastal and inland tidal waters from the Yucatan Peninsula in Mexico to Tampa Bay, Florida (Christmas et al. 1988, Nelson and Ahrenholz 1986). Adult menhaden are filter feeders (feeding primarily on phytoplankton) and, in turn, support predatory food fishes. Gulf menhaden form large surface schools which appear in nearshore Gulf waters from about April to November. Although no extensive coastwide migrations are known to occur, there is evidence that older fish move towards the Mississippi River delta (Ahrenholz 1981). Spawning peaks during December and January in offshore waters (Lewis and Roithmayr 1981). Eggs hatch at sea and the larvae are carried to estuaries by ocean currents where they develop into juveniles (Christmas et al. 1988). Juveniles migrate offshore during winter and move back to coastal waters the following spring as age-1 adults.

Gulf menhaden are subject to an extensive purse-seine fishery in the northern Gulf of Mexico from mid-April through mid-October as regulated by interstate compact (Christmas et al. 1988). Since 1964 the National Marine Fisheries Service has maintained a sampling program for gulf menhaden. During this period the number of active reduction plants where menhaden are processed for meal and oil has varied between 6 and 14, with 6 plants active in 1992 (Table 1). The number of purse-seine vessels has varied between 51 and 92, with 51 vessels active during the 1992 fishing season. Annual landings and nominal fishing effort (vessel-ton-weeks), available since 1946, show an upward trend in landings from 1946 through 1984 when landings peaked at 982,800 t (Fig. 1). Nominal effort peaked the previous year (1983) at 655,800 vessel-ton-weeks. Since that time landings and nominal effort have declined to 421,400 t and 408,000 vessel-ton-weeks in 1992, respectively. Between 1984 and 1992, the number of reduction plants declined from 11 to 6 and the number of purse-seine vessels from 81 to 51.

Detailed information on daily vessel landings and fish sampled for length, weight, and age (from scales) is available from 1964 to the present. This information is used to estimate the number of fish landed at age, 1964-1992 (Table 2). The fishery depends primarily on age-1 fish (comprising 44% to 92% of the landings) and on age-2 fish (7% to 53%) (Fig. 2). The remaining ages (age-0, -3, and -4+) generally contribute insignificantly to the landings (<1% to 13%), although age-3 contributed 10% in 1975. In some years age-2 menhaden comprise almost 50% of the landings, presumably because the cohort represented by the age-2 fish is strong relative to the subsequent cohort (i.e., age-1 fish).

Table 1. Number of gulf menhaden (*Brevoortia patronus*) reduction plants by port and total, number of purse-seine vessels, and number of fish sampled for age and size for fishing years, 1964-1992.

Fishing Year	Ports								No. Reduction Plants	No. Reduction Vessels	No. Fish Sampled
	A	MP	E	D	MC	IC	C	SP			
1964	0	3	2	2	1	0	2	1	11	78	12,457
1965	0	3	2	3	1	1	2	1	13	87	15,819
1966	1	3	2	2	1	1	3	1	13	92	13,016
1967	0	3	2	2	1	1	3	1	13	85	14,519
1968	1	3	2	2	1	1	3	1	13	78	16,499
1969	1	3	2	1	1	1	3	1	12	75	15,281
1970	0	3	2	2	1	1	3	1	12	76	10,560
1971	0	3	2	2	1	1	3	1	12	85	7,859
1972	0	3	2	1	1	1	3	0	11	75	10,030
1973	0	2	2	1	1	1	3	0	10	66	8,958
1974	0	2	2	1	1	1	3	0	10	71	10,120
1975	0	3	2	1	1	1	3	0	11	78	9,529
1976	0	3	2	1	1	1	3	0	11	82	13,586
1977	0	3	2	1	1	1	3	0	11	80	14,918
1978	0	3	2	1	1	1	3	0	11	80	12,985
1979	0	3	2	1	1	1	3	0	11	78	11,620
1980	0	3	2	1	1	1	3	0	11	79	9,961
1981	0	3	2	1	1	1	3	0	11	80	10,408
1982	0	3	2	1	1	1	3	0	11	82	10,709
1983	0	3	2	1	1	1	3	0	11	81	14,840
1984	0	3	2	1	1	1	3	0	11	81	16,001
1985	0	2	1	1	0	1	2	0	7	73	13,240
1986	0	2	2	1	0	1	2	0	8	72	16,530
1987	0	2	2	1	0	1	2	0	8	75	16,530

1988	0	2	2	1	0	1	2	0	8	73	12,410
1989	0	2	2	1	1	1	2	0	9	77	13,970
1990	0	2	2	1	1	1	2	0	9	75	11,670
1991	0	1	2	1	1	1	1	0	7	58	11,690
1992	0	1	1	1	1	1	1	0	6	51	15,590

Table 1 (legend):

A = Appalachicola, FL: Fish Meal Co. (1966, 1968-69).

MP = Moss Point, MS: Seacoast Products Co. (1964-72, 1975-84), AMPRO Fisheries, Inc. (formerly Standard Products (1964-90), Zapata Haynie, Inc. (1964-92).

E = Empire, LA: Empire Menhaden Co. (1964-91), Daybrook Fisheries (formerly Petrou Fisheries, Inc. (1964-92).

D = Dulac, LA: Dulac Menhaden Fisheries (1964-68, 1970-71), Fish Meal and Oil Co. (1964-65), Zapata Haynie, Inc. (1965-92).

MC = Morgan City, LA: Seacoast Products Co. (1965-84), Gulf Protein (1989-92).

IC = Intracoastal City, LA: Seacoast Products Co. (1965-84), Zapata Haynie, Inc. (1985-92).

C = Cameron, LA: Louisiana Menhaden Co. (1964-90), Seacoast Products Co. (1964-84), Zapata Haynie, Inc. (1967-92).

SP = Sabine Pass, TX: Texas Menhaden Co. (1964-71).

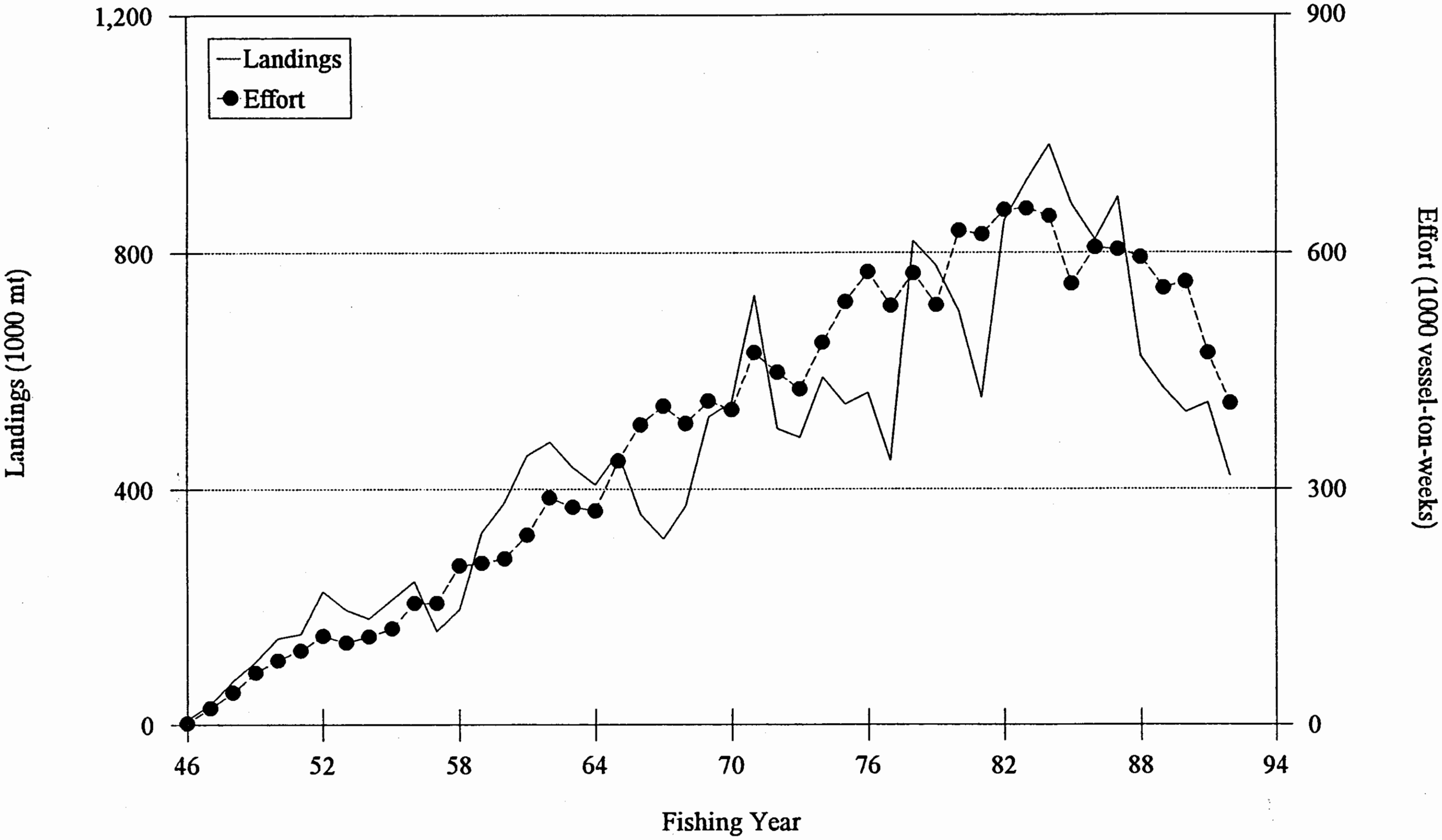

Figure 1. Landings and nominal fishing effort by the gulf menhaden (*Brevoortia patronus*) reduction fishery, 1946-1992.

Table 2. Estimated landings of gulf menhaden (*Brevoortia patronus*) in numbers at age (0-4+), total numbers landed (ages 0-4+), total landings by weight and nominal fishing effort (vessel-ton weeks) for the fishing years, 1964-1992.

Fishing Year	Landings in Nos. at Age (10^9)						Total Landings (1000 t)	Nominal Fishing Effort[a]
	0	1	2	3	4+	Total		
1964	0.0	3.33	1.50	0.12	0.0	4.95	409.4	272.9
1965	0.4	5.03	1.08	0.08	0.0	6.23	463.1	335.6
1966	0.03	3.31	0.87	0.03	0.0	4.24	359.1	381.3
1967	0.02	4.27	0.34	0.01	0.0	4.64	317.3	404.7
1968	0.07	3.48	1.00	0.04	0.0	4.58	373.5	382.3
1969	0.02	6.08	1.29	0.03	0.0	7.41	523.7	411.0
1970	0.05	3.28	2.28	0.04	0.0	5.65	548.1	400.0
1971	0.02	5.76	1.96	0.18	0.0	7.92	728.2	472.9
1972	0.02	3.05	1.73	0.09	0.0	4.89	501.7	447.5
1973	0.05	3.03	1.11	0.10	0.0	4.29	486.1	426.2
1974	0.0	3.85	1.47	0.06	0.0	5.38	587.4	485.5
1975	0.11	2.44	1.50	0.46	0.0	4.51	542.6	538.0
1976	0.0	4.59	1.37	0.20	0.0	6.17	561.2	575.8
1977	0.0	4.66	1.33	0.11	0.01	6.11	447.1	532.7
1978	0.0	6.79	2.74	0.05	0.01	9.59	820.0	574.3
1979	0.0	4.70	2.88	0.34	0.01	7.92	777.9	533.9
1980	0.07	3.41	3.26	0.44	0.05	7.22	701.3	627.6
1981	0.0	5.75	1.42	0.33	0.03	7.54	552.6	623.0
1982	0.0	5.15	3.30	0.50	0.06	9.01	853.9	653.8
1983	0.0	4.69	3.81	0.38	0.03	8.90	923.5	655.8
1984	0.0	7.75	2.88	0.44	0.05	11.12	982.8	645.9
1985	0.0	8.13	2.72	0.28	0.02	11.15	881.1	560.6
1986	0.0	4.26	5.04	0.18	0.03	9.51	822.1	606.5
1987	0.0	5.94	4.53	0.40	0.01	10.87	894.2	604.2
1988	0.0	5.57	2.80	0.16	0.01	8.55	623.7	594.1
1989	0.0	5.98	1.56	0.06	0.0	7.61	569.6	555.3
1990	0.0	3.93	1.89	0.14	0.01	5.97	528.3	563.1
1991[b]	0.0	2.10	2.38	0.25	0.03	4.77	544.3	472.3
1992[b]	0.0	2.16	1.49	0.22	0.03	3.90	421.4	408.0

[a] Units are 1000 vessel-ton weeks.

[b] Preliminary estimates of catch in numbers at age for 1991 and 1992 fishing years.

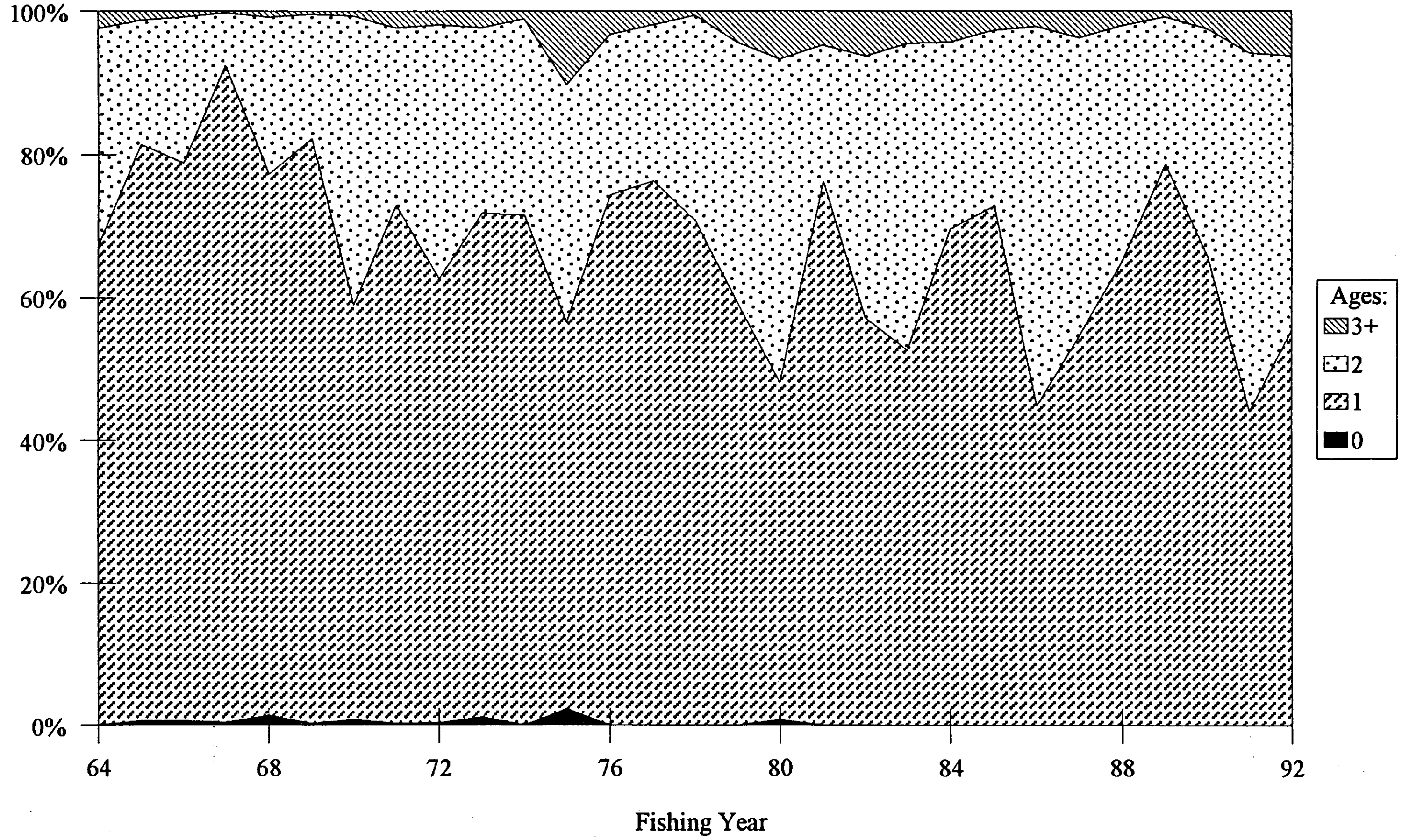

Figure 2. Percent of numbers for ages 1-4+ estimated from landings by the gulf menhaden (*Brevoortia patronus*) reduction fishery, 1964-1992.

Vaughan (1987) last analyzed coastwide gulf menhaden data for the 1964-1985 fishing years. However, landings have declined sharply since then. The purpose of this paper is to reevaluate the status of the gulf menhaden stock using seven additional fishing years (through 1992 fishing year). The analyses that follow parallel to some extent those presented in Nelson and Ahrenholz (1986) and Vaughan (1987) with modifications as described. Estimates of population numbers and fishing mortality rates by age are obtained from virtual population analysis (VPA). For each fishing year, length at age is estimated by fitting the von Bertalanffy growth curve to obtain parameter estimates; weight at age is obtained by relating weight to length. Biological reference levels of fishing mortality are obtained from yield per recruit and spawning stock biomass per recruit approaches. Spawning stock biomass is compared with subsequent recruitment to age 1, from which Ricker spawner-recruit model parameters are estimated. Effective fishing effort is obtained by adjusting nominal effort for estimated variability in the catchability coefficient, from which parameters for the Pella-Tomlinson generalized production models are estimated (with annual landings data) and used to estimate maximum sustainable yield (MSY). The results from these models are used to evaluate the status of the gulf menhaden stock.

VIRTUAL POPULATION ANALYSES

Two general methods of virtual population analysis (VPA) are used in this assessment. The first method, that of Murphy (1965), is described in Vaughan (1987). In applying this method, the calendar year was divided into four periods (or quarters) of approximately equal duration as described in Nelson and Ahrenholz (1986), with the first quarter beginning on 1 January. Catches in numbers at age were summarized quarterly. The annual instantaneous natural mortality rate (M) was estimated from analysis of mark-recapture data (Ahrenholz 1981). This estimate (1.1 per year or 0.275 per quarter) was assumed constant for all ages (>0.5) and years. Because of uncertainties in ageing, especially of older fish (Nicholson and Schaaf 1978), estimates of fish older than age 4 in the landings were assumed to be unreliable. Therefore, fish older than age 4 were pooled with age-4 fish. As in Nelson and Ahrenholz (1986) and Vaughan (1987), estimates of the annual instantaneous fishing mortality rate (F_i) for age-2 fish were derived separately for each year class (cohort) by comparing catches of age-2 and age-3 fish,

$$F_i = (\underline{\ln}\, C_i - \underline{\ln}\, C_{i+1}) - M, \qquad (1)$$

where C is the annual catch in numbers at age (i or i+1), and M is the instantaneous natural mortality rate. This procedure assumed equal selectivity for ages 2 and 3 and that fishing mortality rates are approximately equal for adjacent fishing years. Initial terminal values of F for the oldest age group landed in a year class (or cohort) were adjusted by trial and error until the sum of the quarterly F's for age-2 fish was nearly equal to the annual estimates of F_2 obtained from Eq. (1) (Table 3). Estimates of population size and fishing mortality rates were only made through the 1989 year class (age 1 in 1990, age 2 in 1991, and age 3 in 1992), so estimates of population size, recruits to age 1, and fishing mortality for age 1 were only available for 1964 through 1990 fishing years (referred to as 'Murphy').

The second method, that of Doubleday (1976), is referred to as 'separable' VPA. This method assumes that age- and year-specific estimates of F can be partitioned into the product of an age component (partial recruitment) and a year component. The computer program (SVPA.EXE) used was developed by Clay (1990) from Pope and Shepherd (1982). This method was applied in two ways to the catch-in-numbers-at-age matrix (or catch matrix) based on annual (not quarterly as in the Murphy VPA, ages 1-4) aged fish. The first approach used the entire catch matrix for 1964-1992 (referred to as 'SVPA/All'). Because of large log catch ratio residuals obtained during the early years, the first year in the observed catch matrix was gradually increased from 1964 to 1988, and the approximate coefficient of variation of catch data and sum of squared deviations (output produced by the SVPA.EXE program) were plotted against initial year of data appearing in the catch matrix (Fig. 3). Because of the rapid drop which occurred in both variables between 1975 and 1976, discrete fits of the separable VPA to the catch matrix for 1964 through 1975 and 1976 through 1992 were also conducted (referred to as 'SVPA/Split').

Table 3. Estimated convergent F, age of convergent F, and ages used in Murphy-type virtual population analysis (VPA) for gulf menhaden (*Brevoortia patronus*) by year classes, 1960-1989.

Year Class	Convergent F[a]	Age of Convergence	VPA Ages
1960	2.90[b]	4	4
1961	1.69[c]	3	3-4
1962	1.83	2	2-4
1963	2.36	2	1-3
1964	3.10	2	0-4
1965	1.10	2	0-3
1966	2.35	2	0-3
1967	2.47	2	0-4
1968	1.43	2	0-4
1969	1.99	2	0-4
1970	1.76	2	0-3
1971	1.83	2	0-4
1972	3.56[d]	3	0-3
1973	0.89	2	0-4
1974	1.42	2	0-4
1975	2.13	2	0-4
1976	1.00	2	1-4
1977	0.79	2	1-4
1978	1.19	2	1-4
1979	1.95	2	1-4
1980	1.05	2	0-4
1981	1.06	2	1-4
1982	1.22	2	1-4
1983	1.59	2	1-4
1984	1.44	2	1-4
1985	2.21	2	1-4
1986	2.75	2	1-4
1987	1.32	2	1-4
1988	0.93	2	1-4
1989	1.29	2	1-3

[a] Convergent F calculated from: $F = \underline{\ln}(C_i) - \underline{\ln}(C_{i+1}) - M$, where i = age of convergence and M is the instantaneous natural mortality rate ($1.1\ yr^{-1}$).

[b] Convergent F for 1960 year class was obtained from the mean F for age-4 fish for year classes, 1964-1979.

[c] Convergent F for 1961 year class was obtained from the mean F for age-3 fish for year classes 1964-1979.

[d] Convergent F for 1972 year class was obtained from the mean F for age-3 fish for year classes 1971 and 1973.

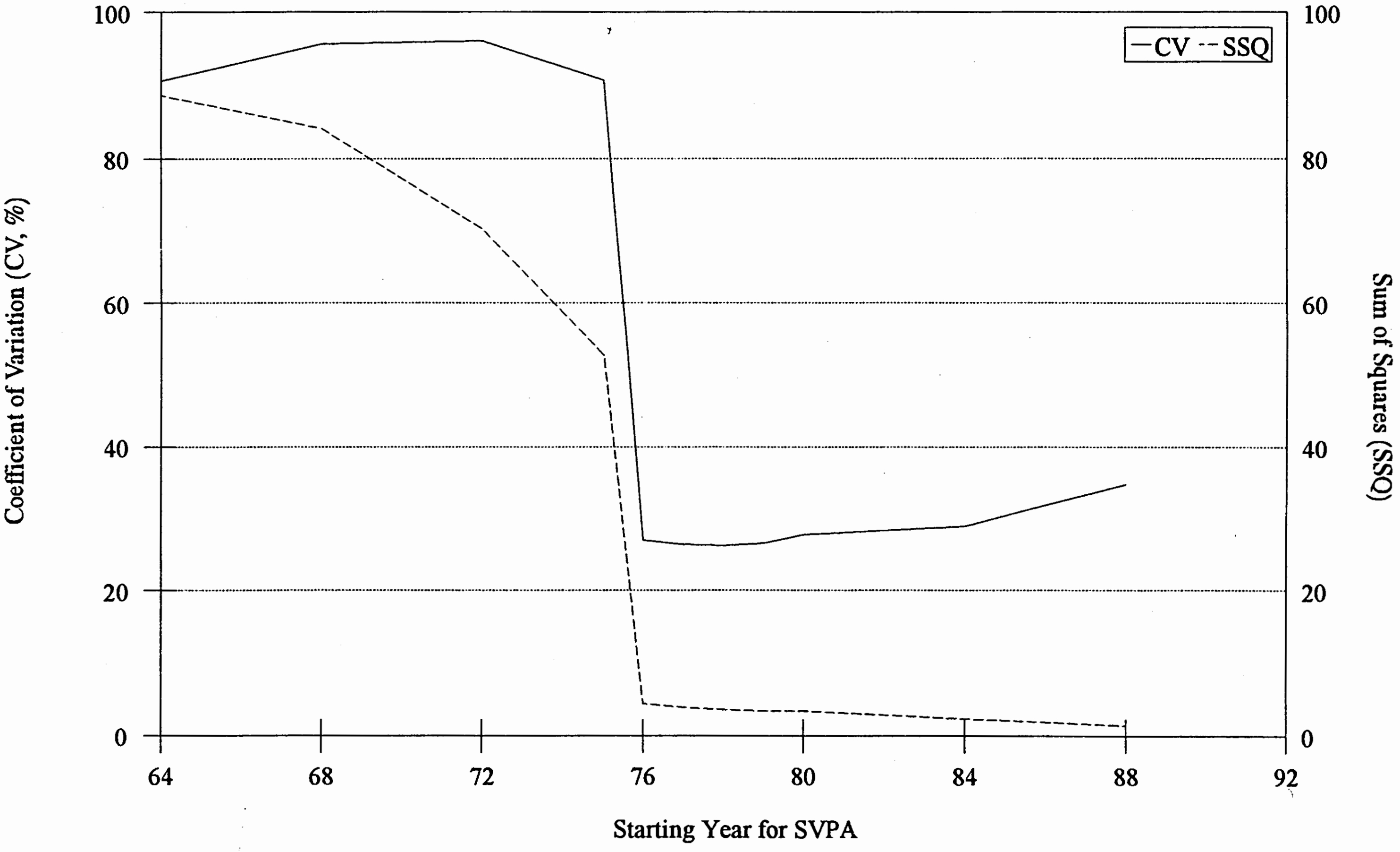

Figure 3. Coefficient of variation (CV) of catch data and sum of squared (SSQ) deviations of log catch ratios plotted against increasing starting year of the gulf menhaden (*Brevoortia patronus*) catch matrix used in the separable VPA approach. Starting year varies between 1964 and 1988, and final year in the catch matrix for all computations is 1992.

Historically, ageing gulf menhaden from scales has been problematic, in that during certain sampling years only about 50% of the sampled fish showed legible annuli on their scales. The remainder showed no annuli or annuli with odd spacings. These fish were generally assigned ages based on length frequencies and date of capture; moreover, the presence of fish older than age-3 in the population was questioned (Nicholson and Schaaf 1978). During 1988-1989, paired otolith and scale samples were examined from over 500 gulf menhaden[1]. Results of this study indicated that: 1) by mounting 10 gulf menhaden scales (versus 6 scales under former programmatic guidelines) the chances of the scale reader finding a legible scale were greatly increased, 2) based on otolith analyses, age 4 gulf menhaden exist in the population, and 3) assigning ages based on length frequencies was discontinued.

Weighted mean fishing mortalities over ages 1 through 4 from the three VPA approaches were calculated, and were weighted by catch in numbers at age (Fig. 4a). The three values of weighted mean fishing mortality agree closely since 1976. However, estimates prior to 1976 vary considerably among the three approaches (Murphy and the two separable VPAs). Prior to 1977 there were few, if any, age-4 fish in the catch matrix. Because convergence was to F at age-2 in the Murphy VPA method, F at older ages were in effect made by forward calculations. Although these potentially can diverge from "true" values, when averaged across the ages 1 through 4, they show less year-to-year variability than comparable estimates of F from the separable VPAs. Although the assumptions embedded in Eq. (1) may tend to smooth year-to-year variability in the Murphy VPA method, estimated weighted mean F for all VPA methods agree closely for 1976-1992 (Fig. 4). This suggests that the separable VPAs, in minimizing log catch ratio residuals for ages 3 and 4 where aging errors may be greatest, more profoundly effects resultant fishing mortality estimates at the younger, more crititcal ages than the Murphy VPA method.

An estimate for natural mortality (M) of 1.1 yr^{-1} has been used in previous assessments (Nelson and Ahrenholz 1986, Vaughan 1987). However, estimates of M are often difficult to obtain with precision. Ahrenholz (1981) obtained a range of estimates between 0.7 and 1.6 from tagging studies. Life history approaches suggest estimates of M in the lower part of this range. The method of Hoenig (1983)[2] is based on maximum age in the unfished stock, yielding estimates of M ranging from 0.7 for a maximum age of 6 to 1.1 for a maximum age of 4. The maximum age of gulf menhaden found using otoliths from about 500 fish was 4 years, suggesting 1.1 as an upper bound on M. Similarly, the method of Pauly (1979)[3], which uses estimates of L_∞ and K (see next section) and mean temperature (23° to 30° C), suggests a range in M of 0.9 to 1.1. The lower temperature (23° C) is approximately that when fishing begins in the spring and ends in the fall, while avoidance of temperatures above 30° C has been noted (Lassuy 1983). However, life history approaches for estimating M do not reflect additional mortality due to other sources (e.g., losses to a small bait fishery or as bycatch in other fisheries). Hence, most analyses that follow assume M equals 1.1.

To investigate sensitivity of fishing mortality estimates to assumed values of natural mortality, additional estimates of fishing mortality were made using the separable VPA on the entire catch matrix (SVPA/All) with lower estimates of M (0.7 and 0.9). Estimates of annual weighted mean F are compared between estimates of M for 0.7, 0.9, and 1.1 from SVPA on the entire catch matrix (Fig. 4b). As M is decreased, consistently higher estimates of annual weighted mean F are obtained. Although differences do not appear large, they are not insignificant, especially if the present value of M is a gross overestimate (<< 0.7 compared to 1.1).

Weighted mean fishing mortality from the Murphy VPA ranged between 0.4 in 1981 and 1.5 in 1966. Similarly, weighted mean fishing mortality from the separable VPAs ranged from 0.3 in 1981 to 1.9 in 1975 (all data) and from 0.4 in 1981 to 2.7 in 1975 (split data). Weighted mean fishing mortality rates were highest in the 1960s and declined during subsequent decades (Table 4).

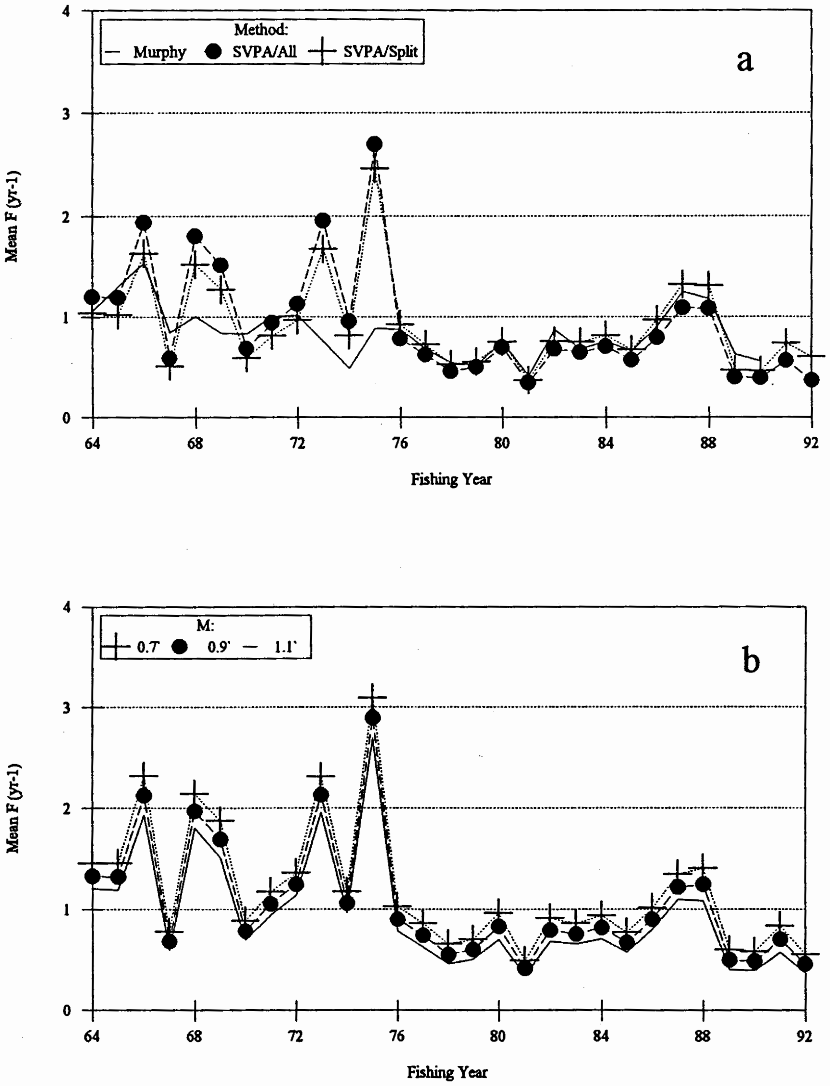

Figure 4. Mean fishing mortality (F) over ages 1-4 for gulf menhaden (*Brevoortia patronus*) compared by method (a: Murphy, SVPA/All, and SVPA/Split) and by natural mortality (b: 0.7, 0.9, and 1.1 yr^{-1}), 1964-1992.

Table 4. Decadal and overall averages and range of weighted mean fishing mortality rates (F, ages 1-4) for gulf menhaden (*Brevoortia patronus*), 1964-1992.

		Separable	
Period	Murphy	All	Split
1960s	1.1	1.4	1.2
1970s	0.8	1.1	1.0
1980s	0.8	0.7	0.8
1990s	0.6	0.5	0.6
Overall	0.9	0.9	0.9
Range	0.4 (1981)	0.3 (1981)	0.4 (1981)
	1.5 (1966)	2.7 (1975)	2.5 (1975)

For comparison with and as a continuation of Vaughan (1987), exploitation rates u [proportion removed annually: $u = F(1-e^{-Z})/Z$, where Z is the total instantaneous mortality rate (M+F)] for ages 1, 2, and 3, and ages 1-4 combined are plotted against year based on the Murphy VPA (Fig. 5). Exploitation rates for age-1 fish have generally declined since 1964, although this trend is less obvious in the exploitation rates for ages 1-4 combined. Exploitation rates for age-1 fish ranged between 14% in 1986 and 45% in 1966; ranges for age-2 fish were between 30% in 1981 and 72% in 1966; and for age-3 fish were between 36% in 1976 and 71% in 1966. Overall exploitation rates (ages 1-4) ranged between 21% in 1981 and 54% in 1966.

The pattern of recruitment results among the three VPA approaches is similar to that of fishing mortality (Fig. 6). Recruits to age 1 are only slightly higher from the Murphy VPA than those from the separable VPAs since 1976. The separable VPA approaches suggest recruits to age 1 were much more variable prior to 1976 than the Murphy VPA estimates. As suggested earlier in discussing weight mean fishing mortality rates, increased variability in recruitment estimates from the separable VPA approaches may be due to aging problems during 1964-1975, or reduced variability in recruitment from the Murphy VPA approach may be due to assumptions inherent in Eq. (1). Because age-1 menhaden form a large component of the population size, the total population (ages 1-4) shows a similar pattern. Recruitment to age 1 and population biomass were highest on average during the 1980s regardless of VPA used, although peak recruitment and population biomass estimated from the separable approach peaked in 1974 with 55.8 (all) or 42.1 (split) billion recruits to age 1 and with 2.2 (all) or 1.7 (split) million tons of population biomass.

SIZE AT AGE AND GROWTH ANALYSES

Interpolated lengths and weights of gulf menhaden at age are needed for estimating optimum fishing yield and spawning stock biomass. Estimates of annual mean weight-at-age for gulf menhaden in the purse-seine catches were calculated to determine any trends in yield-per-recruit that could be expected in the fishery. No specific upward or downward trends in mean weight-at-age are noted (Fig. 7).

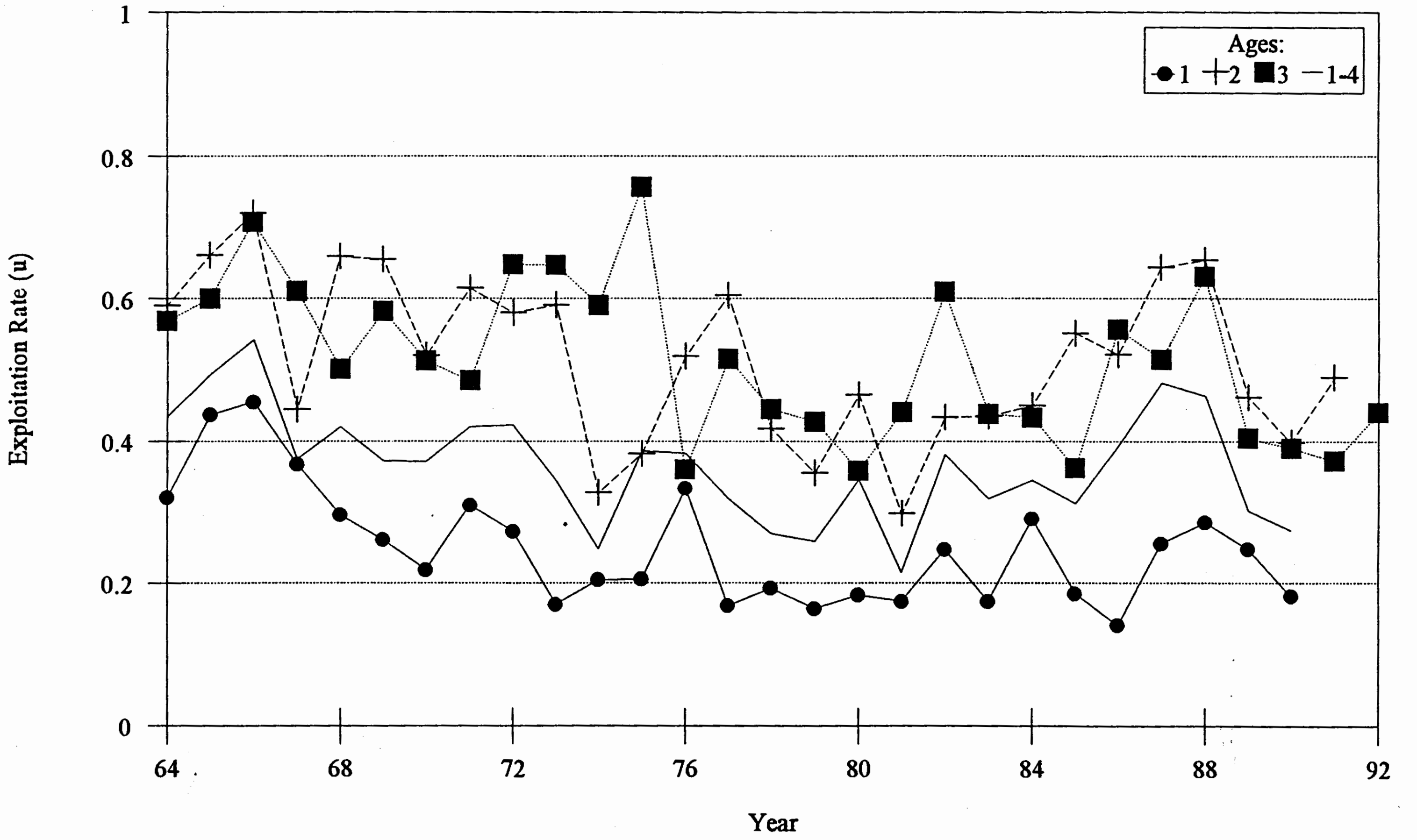

Figure 5. Gulf menhaden (*Brevoortia patronus*) exploitation rates (u) for ages 1, 2, 3, and ages 1-4 combined obtained from Murphy VPA approach, 1964-1992.

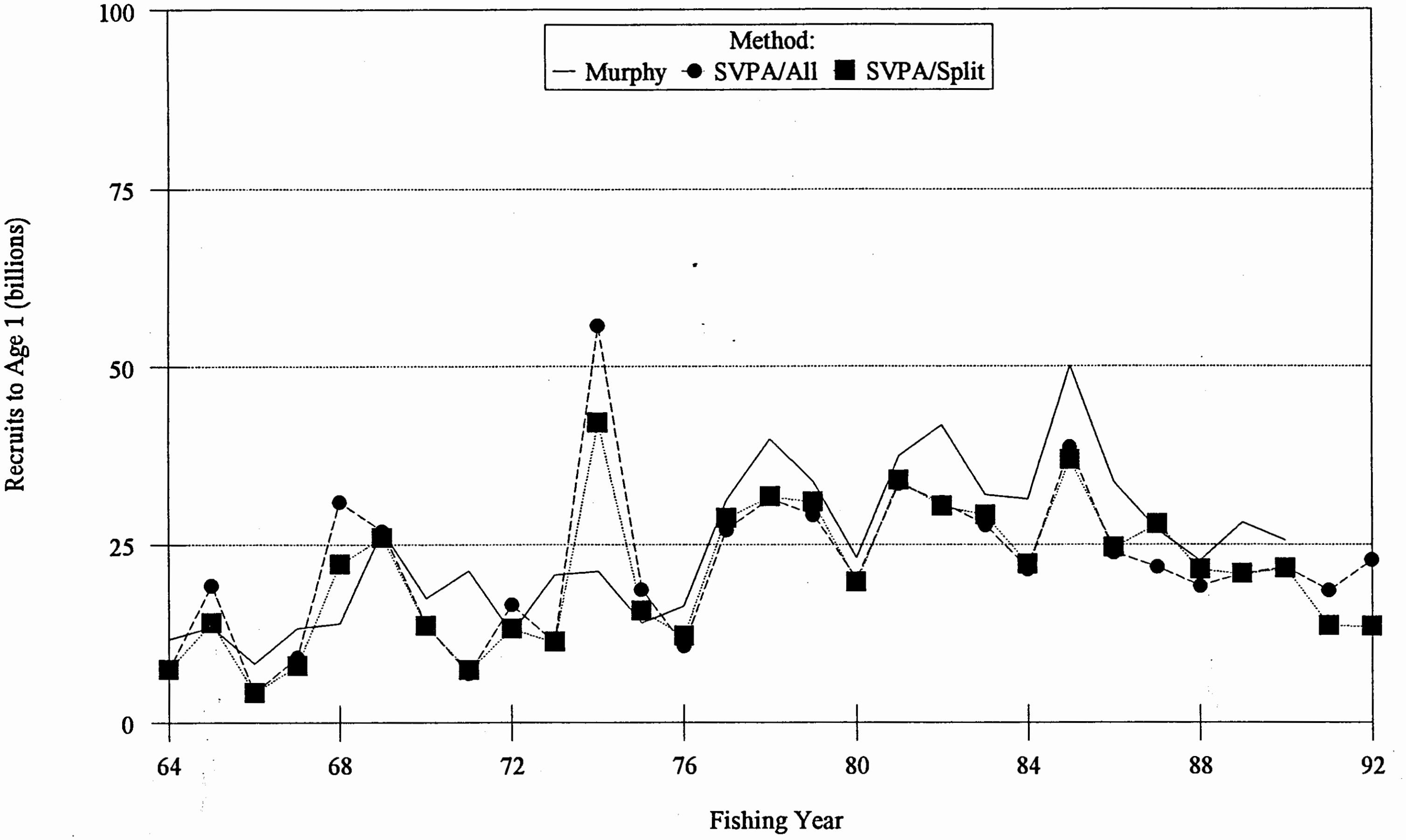

Figure 6. Recruits to age 1 gulf menhaden (*Brevoortia patronus*) compared from three VPA approaches (Murphy, SVPA/All, and SVPA/Split), 1964-1992.

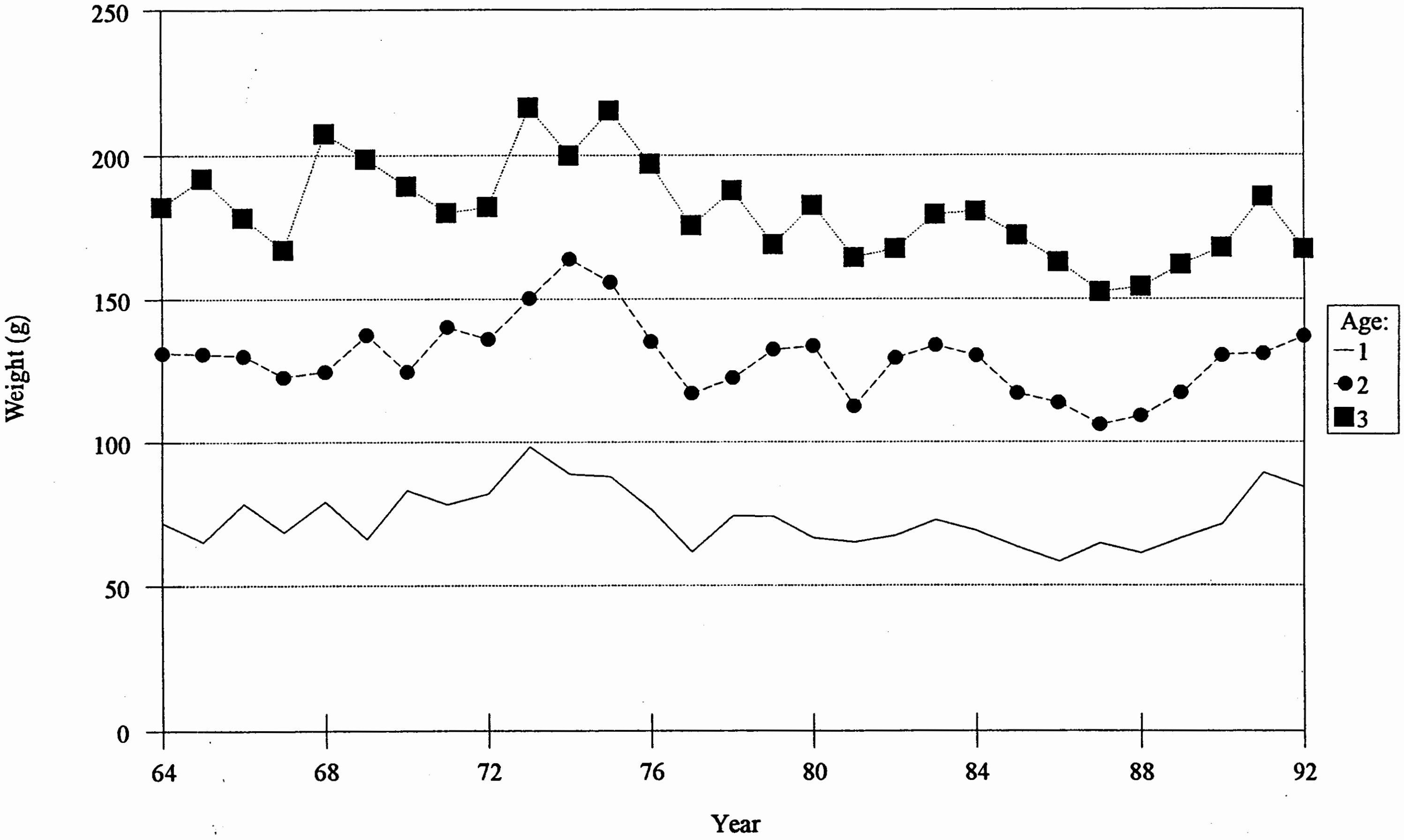

Figure 7. Gulf menhaden (*Brevoortia patronus*) mean weight age, 1964-1992.

Weight (W, in g) is estimated from the weight-length relationship expressed in the linear form of the power function,

$$\underline{\ln}\ W = \underline{\ln}\ a + b\ \underline{\ln}\ L, \qquad (2)$$

where L is fork length (mm), and ln a and b are parameters estimated by linear regression for each fishing year (Table 5). Decadal and an overall means of the parameters were calculated across corresponding years with only small differences between decadal means (Table 5). A correction factor ($\sigma^2/2$), where σ^2 is the variance, based on the mean squared error (MSE = 0.01) was used when retransforming from ln W to W based on properties of the lognormal distribution (Beauchamp and Olson 1973).

Fork length (L, in mm) can be estimated from age (t, in yr) on the basis of the von Bertalanffy (1938) growth equation,

$$L_t = L_\infty(1 - \underline{\exp}(-K(t - t_0))), \qquad (3)$$

where L_∞, K, and t_0 are parameters that in this case were estimated by nonlinear regression (PROC NLIN, MARQUARDT OPTION, SAS Institute Inc. 1987). The maximum length (L_∞) is approached asymptotically, at a rate described by parameter K, with t_0 shifting the curve to the left or right. For earlier data (1964-1979), annual parameter estimates were based on mean length at age (calculated quarterly) (Table 6). For more recent data (1980-1992), annual estimates were based on all individual fish weighted by the inverse of numbers at age to improve convergence and correct for parameter bias and poor precision resulting from too few older fish compared to large numbers of young fish noted in Vaughan and Kanciruk (1982). More confidence should be placed in parameters estimated for the more recent years (1980-1992). Mean fork length in quarterly age increments for 1990-1992 are compared to the von Bertalanffy growth curve fit to 1990-1992 annual quarterly mean lengths (Fig. 8). The nonlinear regression failed to converge for data from four fishing years (1969, 1976-1978), so any biological interpretations from the parameter estimates are not valid, although these parameter fits permit interpolation of length at age. Converged estimates of L_∞ ranged from 224.0 mm to 462.7 mm in fork length, with most annual estimates between 230 and 260 mm. Converged estimates of K ranged from 0.12 to 0.72 yr^{-1}, with most annual estimates between 0.3 and 0.6 yr^{-1}. One should note that because of the typically high correlations among the parameters, ranges in estimates of L_∞ and K can give an exaggerated impression of their variability.

BIOLOGICAL REFERENCE POINTS FOR FISHING MORTALITY

Two modeling approaches are used to estimate biological reference points to assess whether estimated fishing mortality rates are too high. Reference points from the first modeling approach (yield-per-recruit analysis) have been used for several decades, while those from the second modeling approach (spawning-stock-biomass-per-recruit) have been used recently by the fishery management councils and commissions.

Yield-per-Recruit Analysis. The trade off between decreasing numbers of fish and increasing biomass per average individual fish forms the conceptual basis for yield-per-recruit analysis. The Ricker (1975; eq. 10.4) formulation was used for estimating yield per recruit [this was the basis for MAREA used in previous gulf menhaden stock assessments (Nelson and Ahrenholz 1986, Vaughan 1987)]. Data required includes age-specific estimates of fishing mortality (from VPA) and weight (relationships given in Tables 5 and 6). Yield per recruit for gulf menhaden was estimated from estimates of fishing mortality for the three VPA approaches for 1964-1992 (Fig. 9).

Table 5. Weight-length regression parameters (and standard errors) for gulf menhaden (*Brevoortia patronus*) by fishing year, 1964-92 (ln W = ln a + b ln L). Sample size (n) and mean squared error (MSE) also given. Decadal and overall parameters estimates are weighted means (by annual catch in numbers) of parameters from corresponding years.

Fishing Year	n	ln a	b	r^2	MSE
1964	12,420	-12.6 (0.04)	3.3 (0.007)	0.94	0.010
1965	15,768	-12.5 (0.03)	3.3 (0.005)	0.97	0.009
1966	12,830	-11.5 (0.03)	3.1 (0.006)	0.95	0.007
1967	14,450	-11.3 (0.03)	3.1 (0.006)	0.94	0.008
1968	15,939	-11.6 (0.03)	3.2 (0.006)	0.95	0.008
1969	15,076	-11.4 (0.03)	3.1 (0.006)	0.95	0.009
1970	10,544	-11.9 (0.04)	3.2 (0.007)	0.95	0.006
1971	7,848	-12.2 (0.04)	3.3 (0.009)	0.95	0.008
1972	10,025	-11.7 (0.04)	3.2 (0.008)	0.94	0.008
1973	8,954	-11.7 (0.05)	3.2 (0.009)	0.94	0.008
1974	10,115	-10.8 (0.04)	3.0 (0.009)	0.92	0.010
1975	9,528	-11.6 (0.03)	3.1 (0.007)	0.96	0.008
1976	13,572	-10.8 (0.03)	3.0 (0.006)	0.95	0.008
1977	14,910	-11.4 (0.02)	3.1 (0.005)	0.97	0.006
1978	12,983	-12.1 (0.03)	3.2 (0.006)	0.96	0.006
1979	11,618	-12.2 (0.03)	3.3 (0.005)	0.97	0.005
1980	9,948	-13.0 (0.05)	3.4 (0.010)	0.92	0.023
1981	10,405	-11.7 (0.03)	3.2 (0.006)	0.96	0.010
1982	10,678	-12.7 (0.04)	3.4 (0.007)	0.95	0.011
1983	14,837	-12.3 (0.03)	3.3 (0.005)	0.96	0.008
1984	15,955	-11.9 (0.03)	3.2 (0.005)	0.96	0.007
1985	13,227	-11.5 (0.03)	3.1 (0.006)	0.96	0.007
1986	16,495	-11.8 (0.02)	3.2 (0.005)	0.97	0.006
1987	16,458	-11.7 (0.03)	3.2 (0.005)	0.96	0.006
1988	12,403	-11.4 (0.04)	3.1 (0.008)	0.93	0.011
1989	13,951	-11.8 (0.03)	3.2 (0.007)	0.95	0.007
1990	11,500	-11.7 (0.04)	3.2 (0.007)	0.95	0.012
1991	11,637	-12.2 (0.04)	3.3 (0.009)	0.93	0.008
1992	15,231	-10.4 (0.03)	2.9 (0.006)	0.94	0.009
1960s	--	-11.8	3.2	--	0.009
1970s	--	-11.7	3.2	--	0.007
1980s	--	-11.9	3.2	--	0.009
1990s	--	-11.5	3.1	--	0.010
Overall	--	-11.8	3.2	--	0.008

Table 6. Estimated von Bertalanffy growth parameters (and asymptotic standard errors) for gulf menhaden (*Brevoortia patronus*) obtained from quarterly mean lengths for fishing years, 1964-1992. Estimates (and sample sizes, n) based on quarterly mean lengths for 1964-1979 and individual lengths for 1980-1992, for use in estimating weight and egg production from spawners. Decadal and overall parameter estimates from quarterly mean lengths at age for corresponding years. Note that asymptotic standard errors for parameter estimates based on mean lengths not given. [a] SAS PROC NLIN failed to converge, useful for interpolation only

Year	n	L∞	K	t_0
1964	12	256.2	0.30	-1.51
1965	13	324.9	0.20	-1.53
1966	9	269.4	0.30	-1.28
1967	9	230.8	0.53	-0.48
1968	12	434.2	0.12	-2.26
1969[a]	10	753.8	0.06	-2.45
1970	9	227.9	0.53	-0.68
1971	10	262.7	0.33	-1.20
1972	11	227.8	0.57	-0.52
1973	13	315.3	0.22	-1.62
1974	9	229.0	0.72	-0.20
1975	12	462.7	0.12	-2.00
1976[a]	8	493.6	0.11	-1.97
1977[a]	11	508.8	0.09	-2.12
1978[a]	11	427.1	0.11	-2.43
1979	11	235.1	0.45	-0.89
1980	9,883	232.1 (0.45)	0.61 (0.006)	-0.04 (0.009)
1981	10,273	241.0 (0.67)	0.41 (0.007)	-0.67 (0.032)
1982	10,341	263.3 (0.99)	0.29 (0.005)	-1.29 (0.037)
1983	14,523	245.9 (0.75)	0.40 (0.006)	-0.85 (0.031)
1984	15,936	241.9 (0.52)	0.44 (0.005)	-0.54 (0.021)
1985	13,225	233.7 (0.65)	0.51 (0.008)	-0.37 (0.022)
1986	16,494	227.7 (0.43)	0.54 (0.006)	-0.18 (0.018)
1987	16,458	262.9 (2.23)	0.27 (0.007)	-1.47 (0.049)
1988	12,402	224.0 (0.78)	0.51 (0.010)	-0.41 (0.029)
1989	13,950	241.1 (1.17)	0.37 (0.008)	-0.94 (0.035)
1990	11,456	234.4 (0.43)	0.44 (0.006)	-0.67 (0.026)
1991	11,378	234.4 (0.73)	0.42 (0.008)	-1.06 (0.043)
1992	14,214	235.0 (0.43)	0.44 (0.006)	-0.87 (0.029)
1960s	65	296.2	0.24	-1.47
1970s	102	263.9	0.35	-1.01
1980s	129	242.0	0.40	-0.75
1990s	42	240.4	0.37	-1.21
Overall	341	244.6	0.40	-0.92

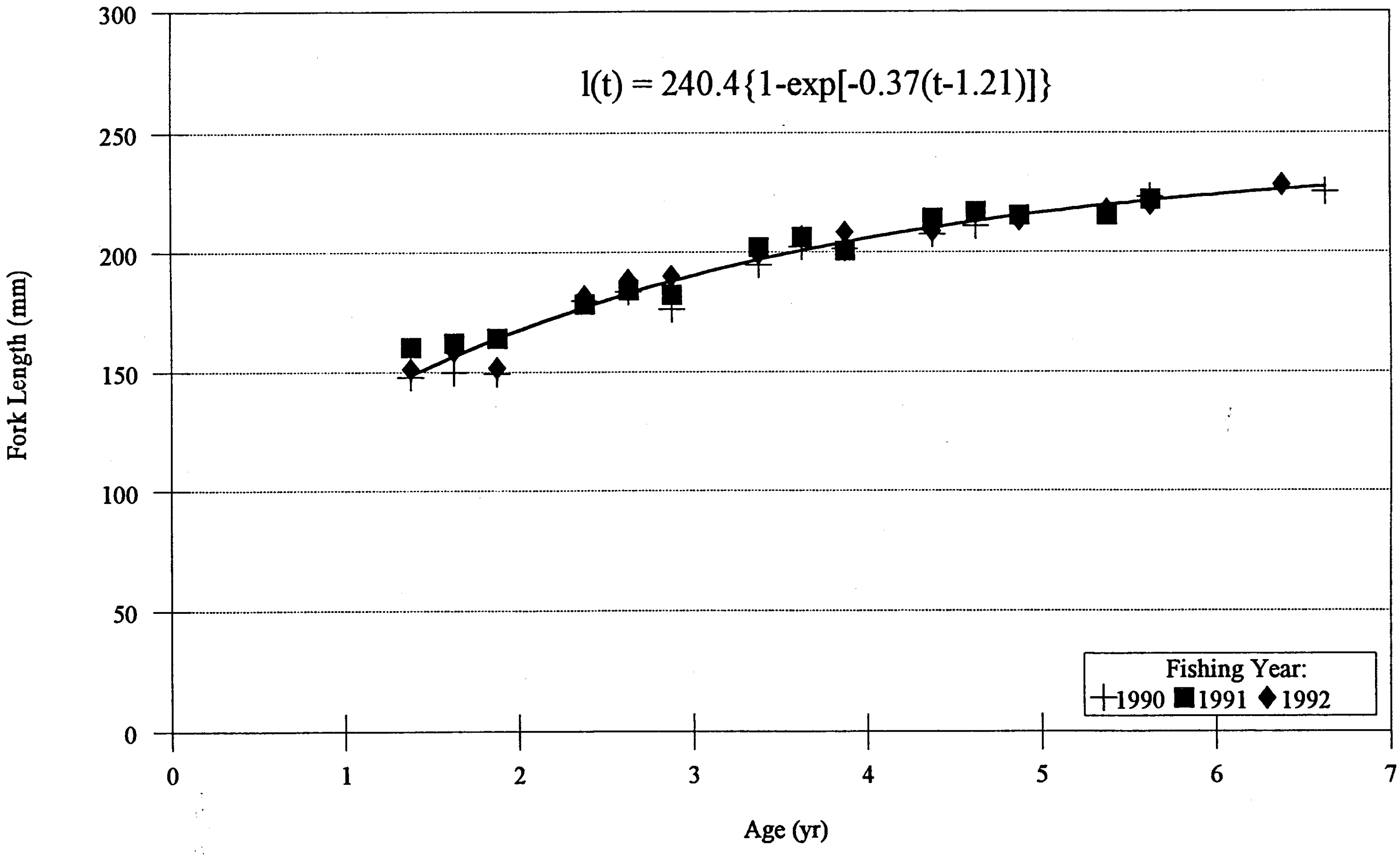

Figure 8. Gulf menhaden (*Brevoortia patronus*) mean length at age and corresponding von Bertalanffy growth curve for 1990-1992 fishing years.

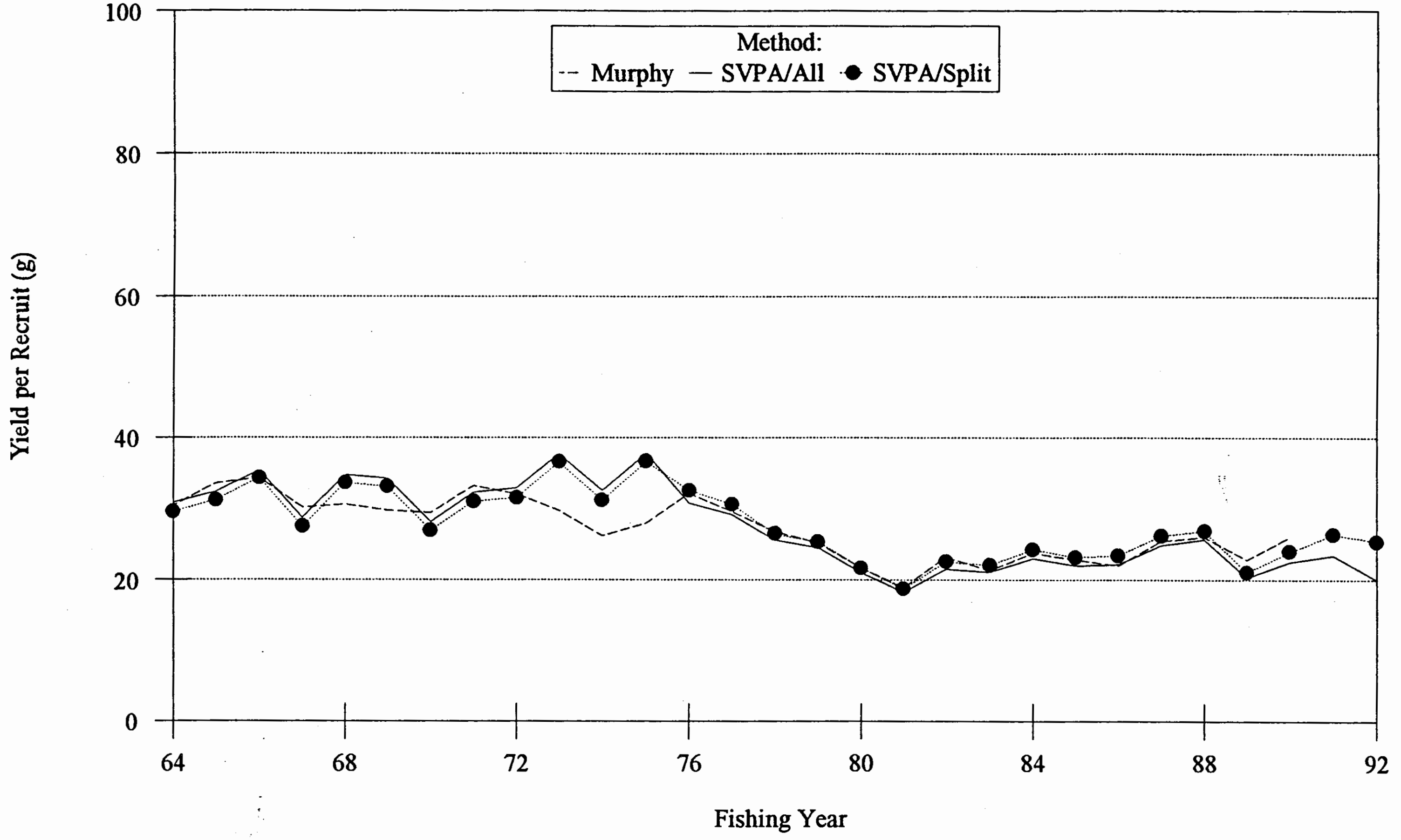

Figure 9. Yield per recruit for gulf menhaden (*Brevoortia patronus*) from three VPA approaches (Murphy, SVPA/All, and SVPA/Split), 1964-1992.

Two important biological reference points are typically obtained from this approach: F_{max} and $F_{0.1}$. F_{max} represents the level of fishing mortality which maximizes yield per recruit, while the latter represents the level of fishing mortality where the slope of the increasing yield per recruit curve is 10% of the slope at the origin (Sissenwine and Shepherd 1987). $F_{0.1}$ was developed because it is more conservative than the former, so as to protect against possible recruitment overfishing. Estimates of F_{max} were not obtained for the gulf menhaden data because yield per recruit continues to rise with increasing F (>4.0 yr^{-1}). Estimates of $F_{0.1}$ range between 0.7 (Separable VPA approach) and 0.9 (Murphy VPA approach) (Table 7).

Annual estimates of yield per recruit ranged between 20 and 40 g with values generally lower since the late 1970s (Fig. 9). Yield per recruit based on estimates of F using the Murphy VPA declined from an average of 32 g during the 1960s, 30 g during the 1970s, and 23 g during the 1980s. A value of 26 g was estimated for the 1990 fishing year. Similar decadal mean values were obtained for yield per recruit from estimates of F using the two separable VPAs.

Maximum Spawning Potential. Gabriel et al. (1989) refer to the percent maximum spawning potential (%MSP) as the ratio of spawning stock biomass per recruit with and without fishing mortality. Hence, the equilibrium spawning stock with an estimated level of fishing mortality is compared to a maximum potential spawning stock as if no fishing had occurred (ignoring adjustments to population parameters through compensatory mechanisms).

Percent maximum spawning potential was calculated in two ways. The first method, described by Gabriel et al. (1989), accumulates female spawning stock biomass per recruit across all ages. The second method accumulates the corresponding number of eggs produced by the female biomass, using the relationship of Lewis and Roithmayr (1981).

Values of %MSP below 20 or 30 are typically considered evidence of recruitment overfishing for many Exclusive Economic Zone species (Mace and Sissenwine 1993). Levels of fishing mortality (with $M = 1.1$) that produce 20 or 30 %MSP are summarized in Table 7. Estimates of fishing mortality from additional runs of the separable VPA on the complete catch matrix (all data) using lower estimates of natural mortality ($M = 0.7$ and 0.9) were used to estimate the same biological reference points. A maturation schedule of 0% for ages 0 and 1 and 100% for ages 2 and older was used for gulf menhaden (Nelson and Ahrenholz 1986).

Annual estimates of maximum spawning potential ranged between 20 and 50% with values generally higher since the late 1970s (Fig. 10). Maximum spawning potential (female biomass) based on estimates of F using the Murphy VPA increased from an average of 24% during the 1960s, to 38% during the 1970s, and 39% during the 1980s. A value of 48% was estimated for the 1990 fishing year. Similar decadal mean values were obtained for maximum spawning potential from estimates of F using the two separable VPAs.

SPAWNER-RECRUIT RELATIONSHIPS

An important question in population dynamics and in fisheries management concerns the degree of dependency between spawning stock and the number of subsequent recruits to the stock. If there is no such dependency (except in the extreme; e.g., no spawners implies no recruits), then there is little that a manager can do to control the number of recruits (and hence future stock sizes), other than to assure that there are sufficient spawners to produce subsequent recruits to the population and to preserve the quality of the habitat utilized by the pre-recruit juveniles. If there is a quantifiable relationship between spawning stock and recruits, then management can be designed to maximize the landings or some other objective based on this relationship. To investigate the relationship between spawners and recruits, the Ricker (1954) model was used [see arguments by Nelson and Ahrenholz (1986) for a dome-shaped spawner-recruit relationship].

Table 7. Biological reference points from yield-per-recruit (Y/R) and maximum-spawning-potential (% MSP) analyses based on different virtual population analyses (Murphy and separable for M = 1.1, and separable for M = 0.7 and 0.9) for gulf menhaden (*Brevoortia patronus*). Differences in estimates of biological reference points from separable VPA between splitting catch matrix into two time periods and using all data were very slight, so only results from separable VPA using all data is presented. The mean fishing mortality rate (ages 1-4) for the most recent three years (Murphy: 1988-1990; SVPA: 1990-1992) is given for comparison.

VPA	Murphy	Separable		
Approach	(M=1.1)	M=0.7	M=0.9	M=1.1
Most Recent Mean F:	0.8	0.7	0.5	0.4
Y/R: $F_{0.1}$	0.9	0.4	0.5	0.7
% MSP (Biomass):				
F_{20}	1.6	1.0	1.4	1.7
F_{30}	1.0	0.6	0.9	1.1
% MSP (Eggs):				
F_{20}	2.6	2.6	2.7	2.9
F_{30}	2.0	2.0	2.0	2.1

Estimation of recruits to age 1 has been described in the VPA section (Fig. 6). Estimation of spawning stock in numbers was estimated as the number of adults (ages 2 through 4 on 1 January). Spawning stock biomass in weight is calculated annually from the above numbers at age times the weight at age calculated from the weight-length (Table 5) and length-age (Table 6) relationships. Potential egg production was also estimated as an index of spawners. Estimates of egg production as a function of fish length were obtained from the equation (Lewis and Roithmayr 1981):

$$\underline{\ln}\,(\mathrm{EGGS}) = -9.872 + 3.877\ \underline{\ln}\ L, \qquad (4)$$

where EGGS equals total numbers of eggs produced per female, L equals estimated fork length (mm), $n = 70$, $s_{y.x} = 0.375$ (root mean squared error), and $r^2 = 0.65$. Expected egg production per female of a given age was calculated using Eq. (4) and lengths from Table 6. This is intended more as a relative, rather than absolute, measure of egg production because the possibility of batch spawning is not considered. Assuming a 1:1 sex ratio, spawning stock as potential eggs (PE) is calculated by

$$\mathrm{PE} = \tfrac{1}{2} \Sigma\, \mathrm{EGGS}_i\, N_i, \qquad (5)$$

where EGGS_i is egg production per female at age i, and N_i is population numbers at age i. Since 1964, the egg production by age-2 spawners has contributed greater than 70% to the total spawning egg production (Fig. 11); ranging between 70 and 97% for the Murphy VPA approach and 72 to 99% for the SVPA approaches.

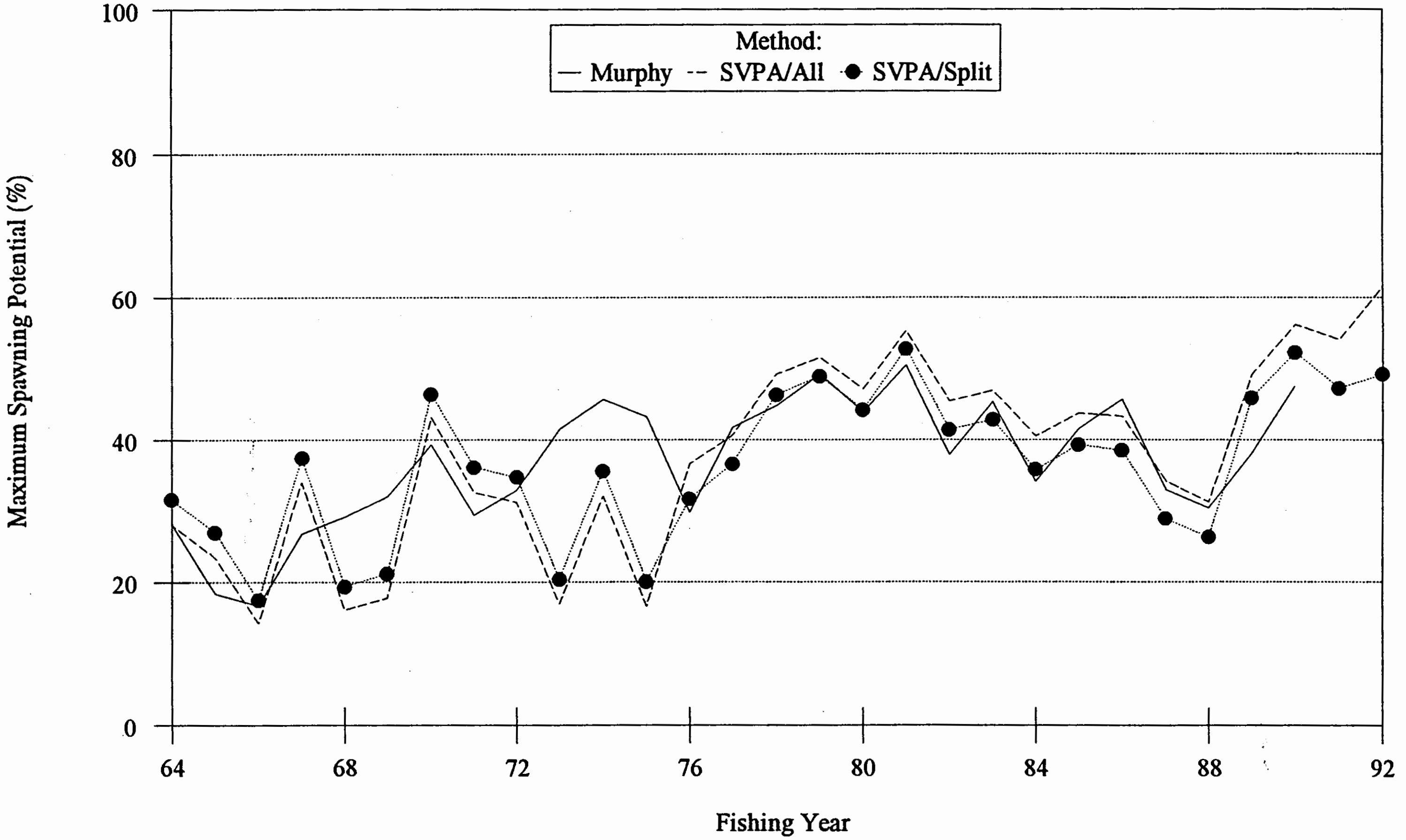

Figure 10. Percent maximum spawning potential for gulf menhaden (*Brevoortia patronus*) from three VPA approaches (Murphy, SVPA/All, and SVPA/Split), 1964-1992.

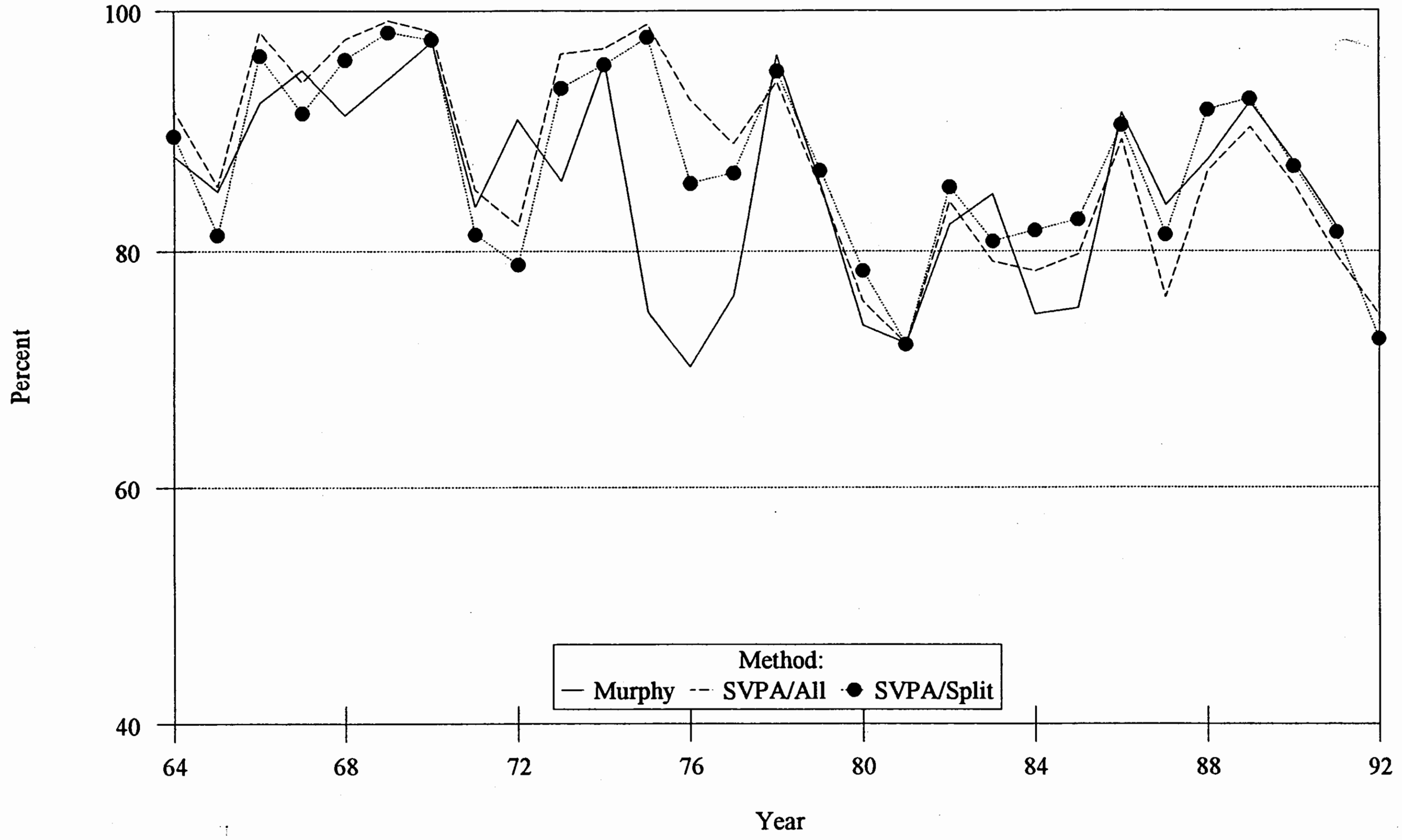

Figure 11. Percent contribution to age 2 gulf menhaden (*Brevoortia patronus*) egg production to total egg production from three VPA approaches (Murphy, SVPA/All, and SVPA/Split), 1964-1992.

Based on estimated F from the Murphy VPA, spawning biomass was on average highest during the 1980s when it averaged 410,200 t, and lowest during the 1960s when it averaged 105,700 t. Intermediate values were obtained during the 1970s when spawning stock biomass averaged 292,200 t, and 334,000 t was estimated for 1990. Estimated mean spawning stock biomass by decade based on estimated F from the separable VPA using all the catch matrix were: 108,000 t (1960s), 234,200 t (1970s), 343,600 t (1980s), and 324,000 t (1990-1992). Similarly, estimated mean spawning stock biomass by decade based on estimated F from the separable VPA which splits the catch matrix were: 102,800 t (1960s), 234,000 t (1970s), 321,600 t (1980s), and 275,400 t (1990-1992).

Parameters of the Ricker model were estimated by nonlinear regression (SAS Institute Inc. 1987) from the equation:

$$R = \alpha S\, e^{-\beta S}, \qquad (6)$$

where R equals recruits to age 1, S equals spawners (numbers, biomass, or potential egg production), and α and β are parameters to be estimated. Plots of the fitted model overlayed with observed data are compared for the three VPA approaches (Fig. 12).

Although the density-dependent parameter (β) is significantly different from 0 for all three VPA approaches, there is only an 18% improvement in mean squared error from the nonlinear fit of the spawner-recruit Ricker model for data from the Murphy VPA approach over the variance of the mean number of recruits to age 1 (thereby suggesting number of recruits is independent of spawning stock size). The mean squared errors associated with the nonlinear fit of the Ricker model for the two SVPA approaches were actually lower than the corresponding variances of the mean number of recruits to age 1. As illustrated in Fig. 12, considerable variability remains due to environmental conditions or measurement error. Given the variability evident from these regressions, their use is of limited value (e.g., not useful for predicting future absolute population sizes). However, the density dependence parameter is significant (H_0: $\beta > 0$), so that the number of future recruits does depend to some extent upon the size of the spawning stock which produced them, albeit weakly.

Parameter estimates (and asymptotic standard errors) for the Ricker spawner-recruit model were obtained from estimates of spawning stock biomass and recruits to age 1 from the three VPA approaches (Table 8). Also estimated were the maximum number of recruits and spawning stock biomass that produced them (Ricker 1975). For the Murphy VPA, mean recruitment during the 1980s (33 billion) exceeded the maximum predicted by the Ricker curve by 2 billion recruits to age 1. During that time (1980s), spawning stock biomass averaged 410,200 t (or 34,200 t less than the "optimal" size). The most recent estimate of spawning stock biomass is 334,000 t (in 1990) which is 110,000 t below the estimate of spawning stock biomass giving maximum recruitment. However, because of the large unexplained error remaining from fitting the Ricker curve, the predicted value of 29.6 billion recruits from 334,000 t of spawners has a very large confidence interval (approximate 95% confidence interval is between 10.1 and 49.1 billion recruits to age 1).

SURPLUS PRODUCTION MODELS

Surplus production models relate historical landings and fishing effort data to obtain estimates of maximum sustainable yield. Catch per unit effort (CPUE) is assumed proportional to population abundance, and fishing effort is assumed proportional to fishing mortality. Under equilibrium assumptions, plotting landings against effort gives a dome-shaped curve. This does not appear to be the case for gulf menhaden data, although the points may lie along the ascending limb of such a curve (Fig. 13).

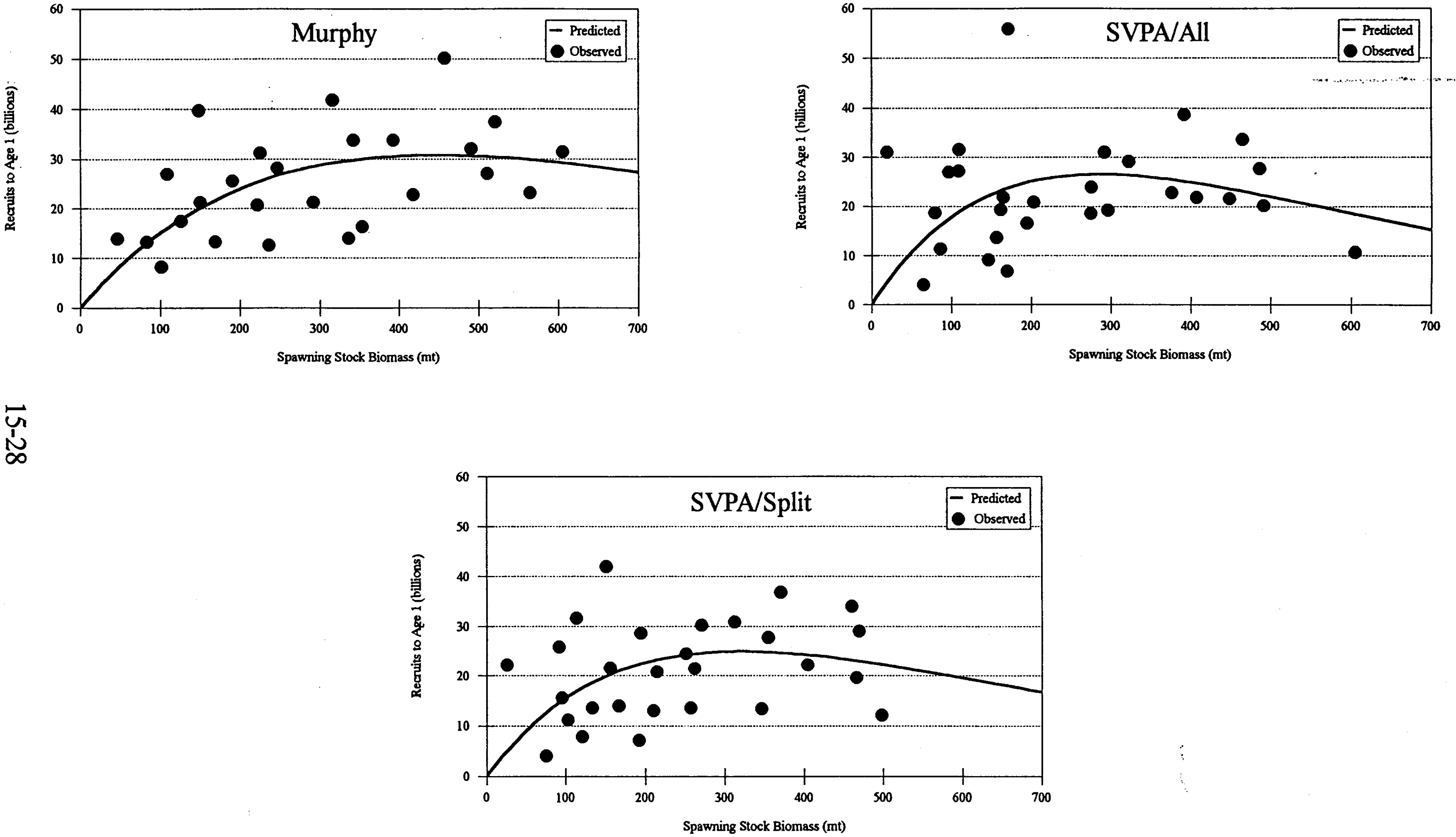

Figure 12. Spawner-recruit relations for gulf menhaden (*Brevoortia patronus*) from three VPA approaches (Murphy, SVPA/All, and SVPA/Split), 1964-1992.

Table 8. Parameter estimates (and asymptotic standard error, ASE) for the Ricker spawner-recruit model applied to gulf menhaden (*Brevoortia patronus*) using estimates of the recruits to age 1 (in millions) and spawning stock biomass (in thousands of metric tons) from three VPA approaches. Also estimated is the maximum number of recruits to age 1 and spawning stock biomass that produces them (Ricker 1975).

Parameter	Murphy	SVPA All	 Split
α	187.7	252.2	211.0
ASA (α)	36.2	55.7	46.3
β	0.00225	0.00349	0.00311
ASA (β)	0.00051	0.00072	0.00072
Maximum Recruits: $\alpha/\beta e$	30,700	26,600	25,000
Corresponding Spawning Stock Biomass: $1/\beta$	444.4	286.5	321.5

Specifically, when relating fishing effort (E) to instantaneous fishing mortality rate (F), the catchability curve (q) is assumed to be constant; i.e.,

$$F = qE, \tag{7}$$

where the unit of fishing effort, E, is defined as vessel-ton-weeks for gulf menhaden. As noted in Nelson and Ahrenholz (1986), the above unit of fishing effort, referred to as nominal effort, is not a reliable measure of fishing mortality. A unit of fishing effort that is reliable is referred to as effective effort. The difficulty in directly obtaining a reliable unit of fishing effort results from the schooling nature of clupeid fishes, which are more susceptible to fishing effort than non-schooling species [see discussion of "dynamic aggregation process" in Clark and Mangel (1979)]. The concern is that severe stock depletion could occur before it was indicated by an analysis of landings and CPUE data.

To demonstrate that the population catchability coefficient, q, for gulf menhaden is not constant but dependent upon population size, it was estimated by solving Eq. (7) for q (= F/E) for each fishing year since 1964 and compared with the population size (ages 1-4) for the same fishing year (Fig. 14; separate estimates based on Murphy and Separable VPAs). As noted in Nelson and Ahrenholz (1986) there is a pronounced inverse relationship between the catchability coefficient and population size. The natural logarithm of q was regressed against population size for each VPA (Murphy and two separable: all and split catch matrices). The highest r value (0.74) was obtained using estimates of population size and weighted mean F from the Murphy VPA; lower values of r were obtained from the two separable VPAs (0.43 and 0.52 for all and split catch matrices, respectively). Using the Murphy VPA approach, Eq. (7) involves the estimates of F, and so estimates of q will be sensitive to assumptions embedded in Eq. (1). However, we believe these effects are minor. Greater effect is likely from the aging error in the earlier years (1964-1975) on the separable VPA estimates of F and hence estimates of q.

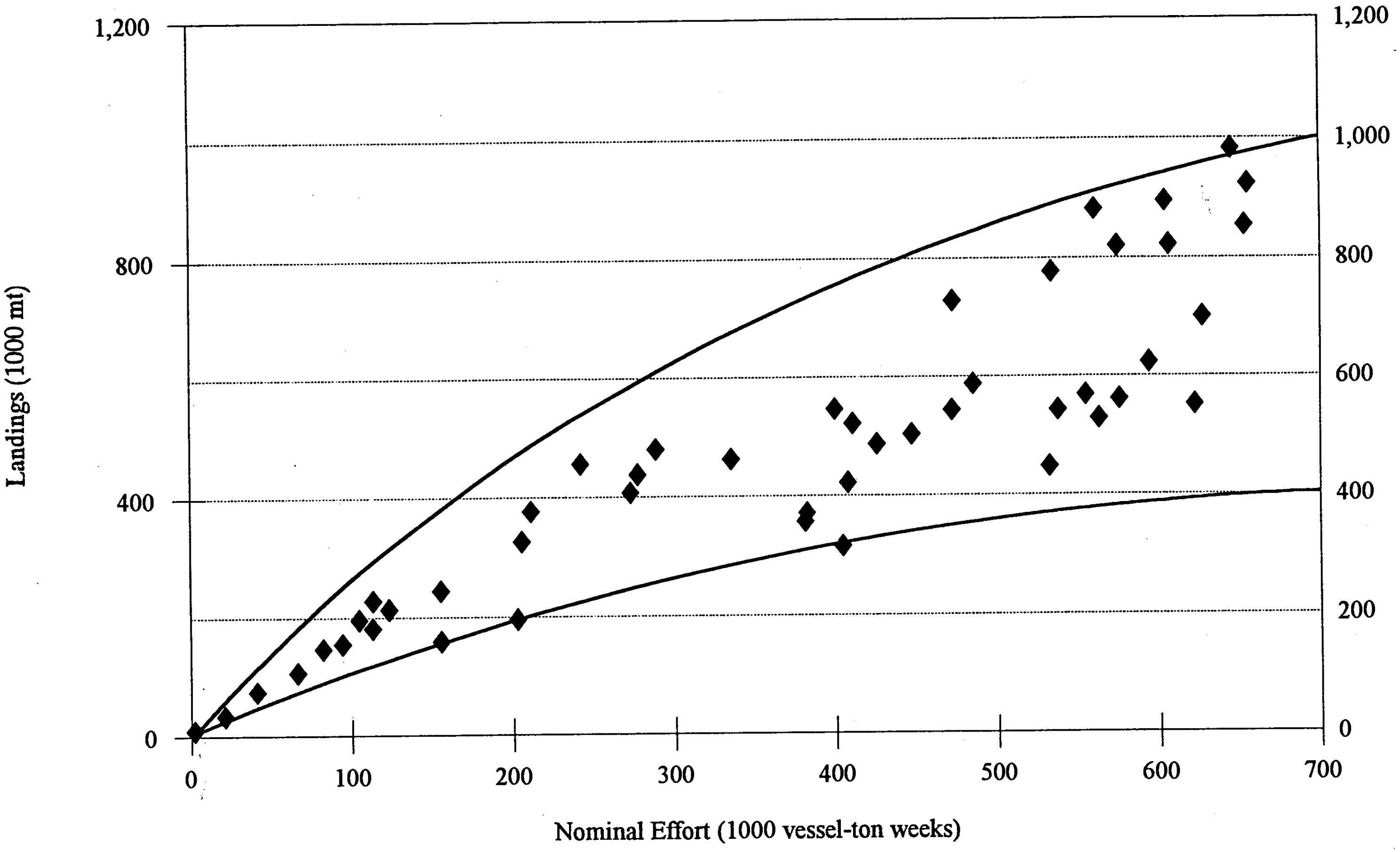

Figure 13. Gulf menhaden (*Brevoortia patronus*) landings plotted against nominal fishing effort, 1964-1992.

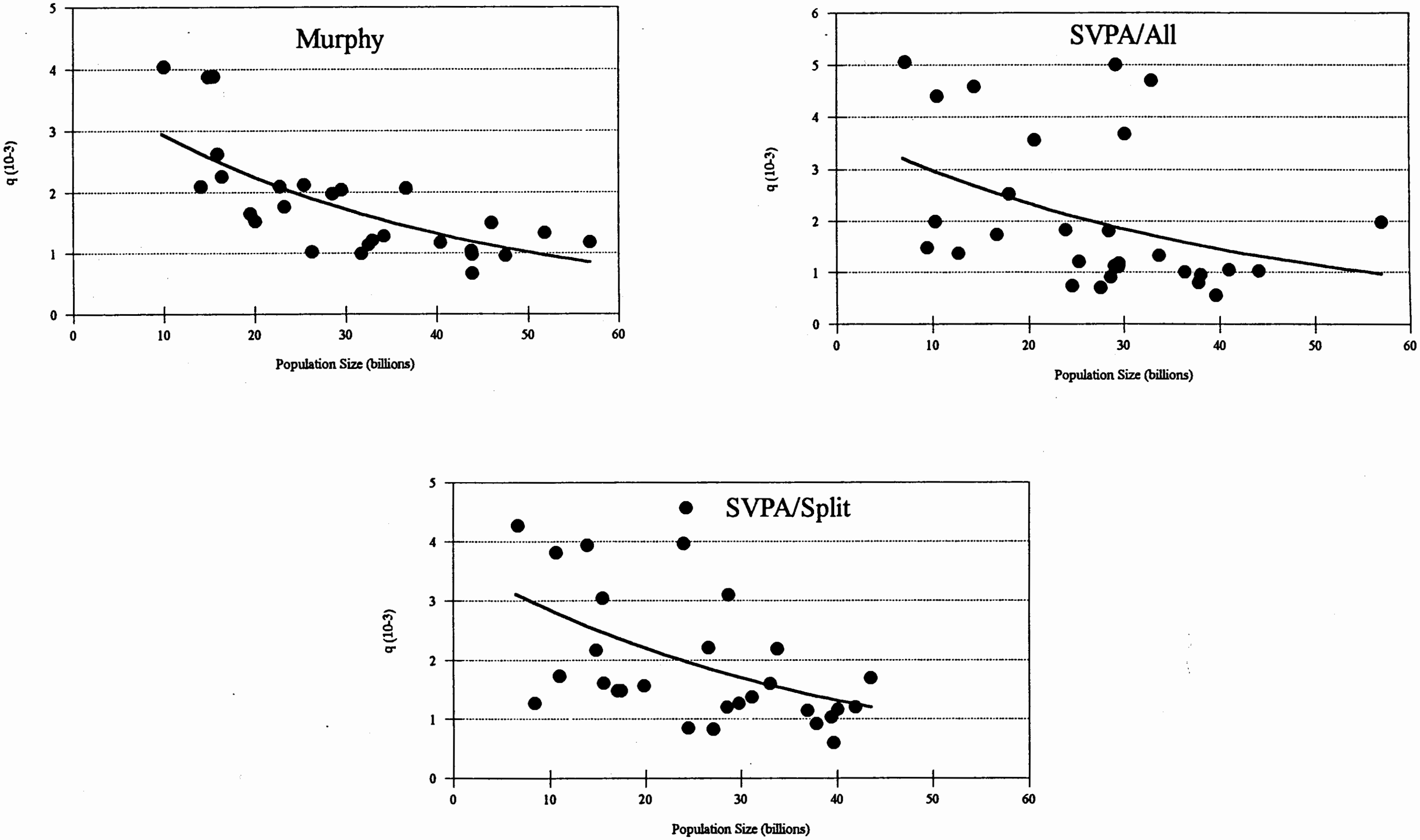

Figure 14. Catchability coefficient (q) versus estimated population size for gulf menhaden (*Brevoortia patronus*) from three VPA approaches (Murphy, SVPA/All, and SVPA/Split), 1964-1992.

To adjust nominal fishing effort to account for variations in q, the 1964 value of q (q_a) was used to adjust nominal effort (E) so that q is constant (q_a); i.e.,

$$E' = E\, q/q_a, \tag{8}$$

where E' is a unit of "effective" fishing effort (Fig. 15; separate estimates based on Murphy and Separable VPAs). Note that while nominal effort was increasing from 1964 through the mid-1980s, effective fishing effort has remained low.

The computer program PRODFIT (Fox 1975), which attempts to account for non-equilibrium conditions through a smoothing process is used to estimate parameters (and MSY) for the Pella-Tomlinson generalized production model (Pella and Tomlinson 1969):

$$U = (A + B\, E')^{1/(m-1)}, \tag{9}$$

where U is catch-per-unit-effort, and A, B, and m are parameters to be estimated. In using PRODFIT, principally two ages are assumed to contribute to the landings (Fig. 2). Parameter estimates and associated square root of the variability index (Fox 1975) for the three VPA approaches are summarized in Table 9. Estimates of MSY based on 1946-1992 fishing years range from 664,000 t based on Murphy VPA, to 708,000 t and 897,000 t based on Separable VPAs (all and split data in catch matrix, respectively). The estimated generalized production curves are compared to observed data in Fig. 16. Only with the estimated model based on the separable VPA with split catch matrix would there be significant concern that if effort rose too high, the stock might potentially collapse because of the steepness of the right-hand side of the curve. For this model m was estimated as 1.2. An m of 2.5 was obtained for the Murphy VPA, and 6.6 for the SVPA (all).

Variability associated with all model parameters (A, B, and m) was large, and corresponding comparisons of data to model fits show considerable lack of fit [as noted in Vaughan (1987) to which these estimates can be compared]. Usefulness of these models beyond suggesting order-of-magnitude level of MSY is debatable. However, because gulf menhaden are a short-lived species with few ages contributing to the landings, surplus production models are probably of greater use than for long-lived species, with many ages contributing to the landings. However, other methods are available which more adequately address the problem of nonequilibrium conditions (e.g., GENPROD).

MANAGEMENT IMPLICATIONS

The gulf menhaden fishery is conducted within the territorial sea and offshore of five coastal states (Florida to Texas). All states, except Florida, enacted the cooperative management plan under the Gulf States Marine Fisheries Commission (GSMFC) in 1977 (Christmas and Etzold 1977). The plan was revised in 1983 and 1988 (Christmas et al. 1983, 1988), and is under revision during 1993. Because management authority is vested in the individual states, some regulations are area-specific on a state or county basis, but other regulations, such as length of fishing season (mid-April through mid-October), are common to all states, except Florida. A proposal to extend the fishing season through November 1 was adopted by the GSMFC at their March 1993 annual meeting. No state controls or limits the catch or fishing effort of vessels.

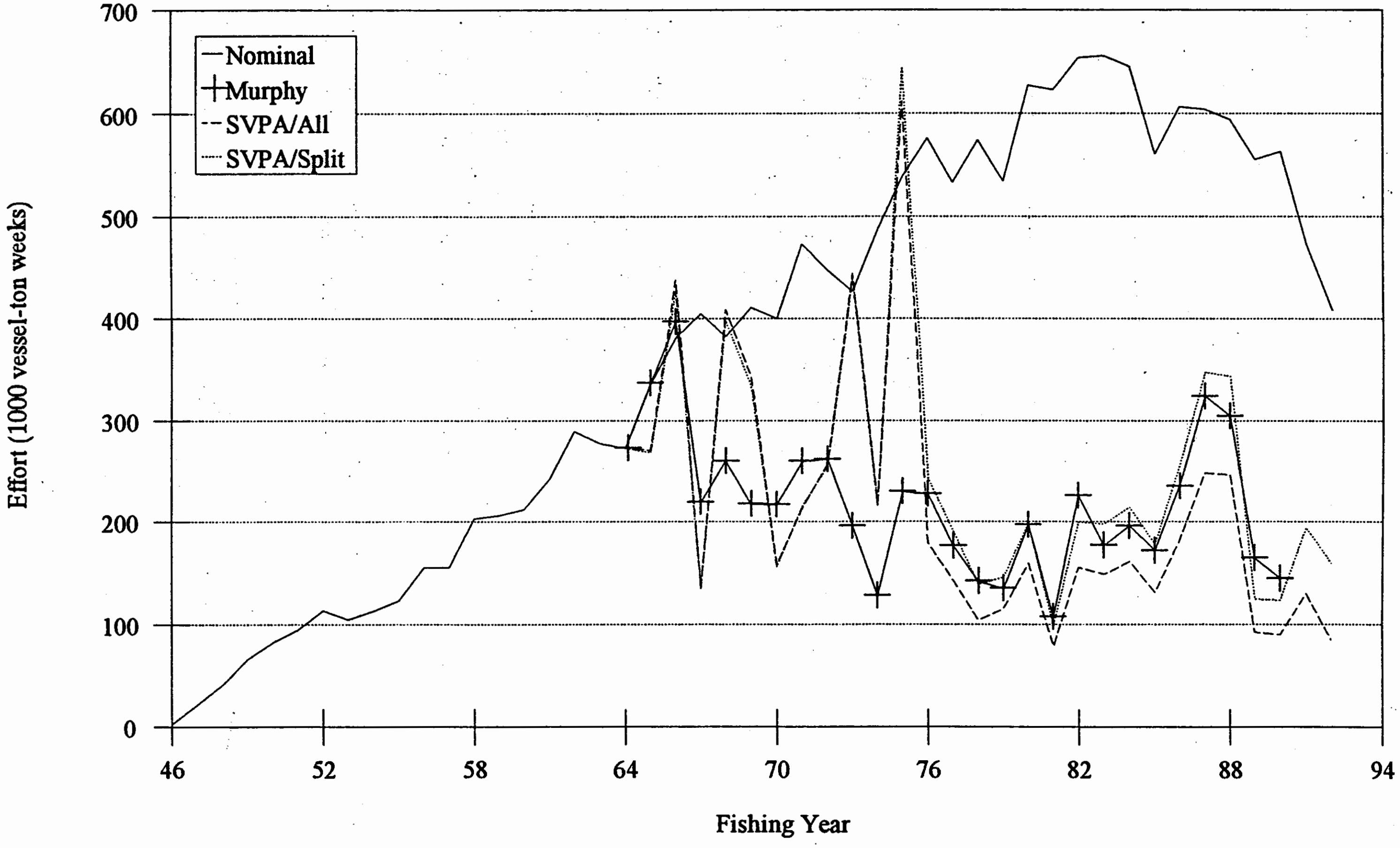

Figure 15. Gulf menhaden (*Brevoortia patronus*) nominal and effective fishing effort from three VPA approaches (Murphy, SVPA/All, and SVPA/Split), 1946-1992.

Table 9. Parameter estimates for the generalized surplus production model using PRODFIT (Fox 1975) with nominal fishing effort for 1946-1963 and effective fishing effort from 1964-1992 applied to gulf menhaden (*Brevoortia patronus*). Square root of variability index in parentheses beside point estimate.

Parameter	Murphy	SVPA All	 Split
A	10.8 (10.3)	1.44 (1.29)	142.8 (453.6)
B	-0.027 (0.028)	-0.001 (0.003)	-0.232 (0.744)
m	2.46 (0.71)	1.17 (0.43)	6.66 (4.08)
MSY	664.1 (57.0)	708.1 (64.5)	879.4 (136.6)
f_{MSY}	241.5 (25.9)	209.7 (29.1)	522.2 (44.2)

Landings and nominal effort were quite high during the 1980s, but have declined precipitously during the late 1980s and early 1990s. Landings peaked in 1984 with 982,800 t, while nominal fishing effort peaked in 1983 with 655,800 vessel-ton-weeks. Most recently (1992), landings were 421,400 t with 408,000 vessel-ton-weeks. Landings between 1982 and 1987 were very high, exceeding estimates of long-term MSY, but were supported by generally high recruitment to age 1. More recent landings (421,400 to 623,700 t) are comparable to, or somewhat below, recent estimates of MSY (600,000 to 700,000 t based on the generalized production model for the Murphy VPA results). Vaughan (1987) noted an upward trend in historical estimates of MSY, which is no longer maintained in this assessment.

The quality of the catch matrix for fishing years 1964-1976 is questioned as a result of the information presented in Fig. 3. The number of age-4+ menhaden during this early period are probably underestimated. Numbers of fish in the landings for all ages (except age 0) were higher during the peak landings of the mid-1980s than earlier during the 1960s and 1970s. Fishing mortality appears to have been slightly higher (and %MSP slightly lower) during this early period (1964-1975) when the lack of age-4+ menhaden in the catch matrix contributed to highly variable estimates of F from the SVPA (Fig. 4 and 10). The Murphy VPA estimates of F (and %MSP) are more stable during this early period, as noted earlier, because the analysis hinges on the slope between the catch of age-2 and age-3 menhaden [see Eq. (1)]. All three VPA approaches produce very similar results (F and recruits to age 1) for the period 1976-1992.

Recent estimates of recruits to age-1 are still reasonable (20 to 25 billion). Spawning stock biomass for recent years is on average well above those of the 1960s and higher than those of the 1970s regardless of VPA approach.

Recent estimates of fishing mortality (for $M = 1.1$) compare favorably with the different estimates of biological reference points. Generally, estimates of $F_{0.1}$ are similar to (but slightly smaller than) estimates of F_{30}, but are much smaller than estimates of F_{20}. Recent estimates of F (ages 1-4) are comparable to or below $F_{0.1}$, the most conservative of the above biological reference points.

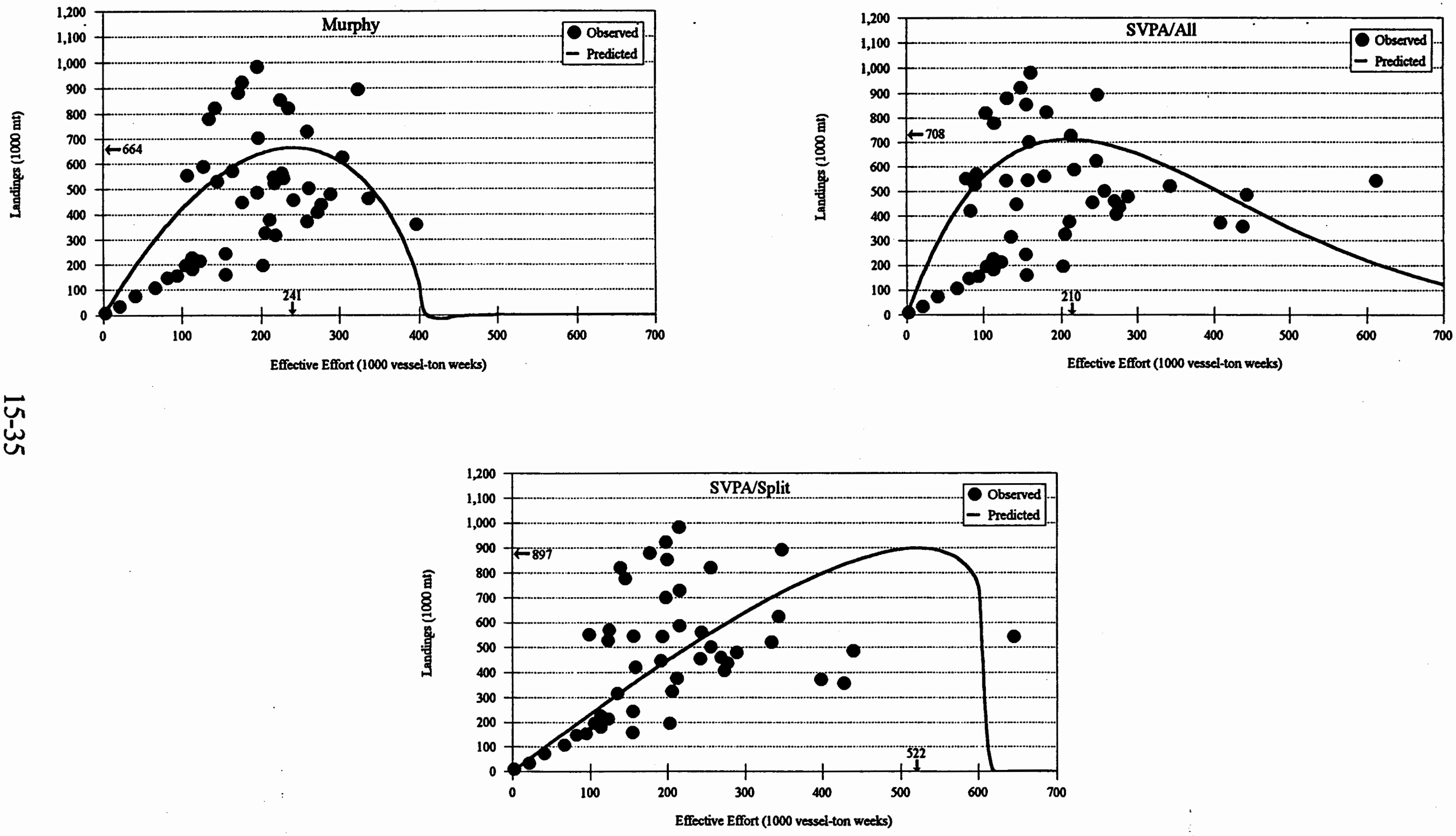

Figure 16. Surplus production models for gulf menhaden (*Brevoortia patronus*) from three VPA approaches (Murphy, SVPA/All, and SVPA/Split), 1964-1992.

When lower estimates of natural mortality (M) are assumed, then the estimated biological reference points decrease while estimates of fishing mortality increase. For M of 0.9, recent estimates of F (mean of 0.5 for 1990-1992) are about the same as for $F_{0.1}$ (0.5), and well below estimates of F_{20} (1.4-2.7) and F_{30} (0.9-2.0). Only when M is assumed even lower (0.7), do recent estimates of F (mean of 0.7 for 1990-1992) fall below $F_{0.1}$ (0.4), although the mean is still generally below estimates of F_{20} (1.0-2.6) and F_{30} (0.6-2.0). We still consider M equal to 1.1, based on tagging, as the best point estimate.

In summary, the gulf menhaden has higher natural mortality and is shorter lived than the Atlantic menhaden, which can result in rapid annual changes in fishable stock. The gulf menhaden fishery is currently fully exploited and the population appears reasonably stable in view of the age composition, life span, and effects of environmental factors. Annual production, fishing effort, and fleet size appear reasonably balanced and risk of overfishing relatively low with 1992-1993 fleet size and recent mean recruitment. Given the variability in the data and model estimates, recent landings below long term MSY (and well below high landings of the mid-1980s) do not suggest that the stock is in trouble.

ACKNOWLEDGMENTS

The authors wish to acknowledge the many past and present employees of the Southeast Fisheries Science Center, Beaufort Laboratory, who were involved in the many aspects of the menhaden program, especially Ethel Hall and Dean Ahrenholz. We are grateful to Charles Krouse for assistance in downloading earlier data sets from the mainframe computer. We thank Dean Ahrenholz, James Waters, Charles Manooch, John Merriner, and two anonymous reviewers for reviewing this manuscript.

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FOOTNOTES

[1] Smith, J. W., and E. J. Levi. Ageing gulf menhaden, *Brevoortia patronus*, using sagittal otoliths, with a critique of scale reading criteria for the species. NMFS, Beaufort Laboratory, 101 Pivers Island Road, Beaufort, NC 28516, unpublished manuscript, 12 p.

[2] $\underline{\ln}\ M = 1.46 - 1.01\ \underline{\ln}(t_{max})$, where t_{max} is maximum age in unfished stock.

[3] $\log_{10} M = 0.0066 - 0.279 \log_{10} L_\infty + 0.6543 \log_{10} K + 0.4634 \log_{10} T$, where L_∞ is total length in cm and K in yr^{-1} are from the von Bertalanffy growth equation, and T is mean water temperature (Celsius).