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TR EL-82-4

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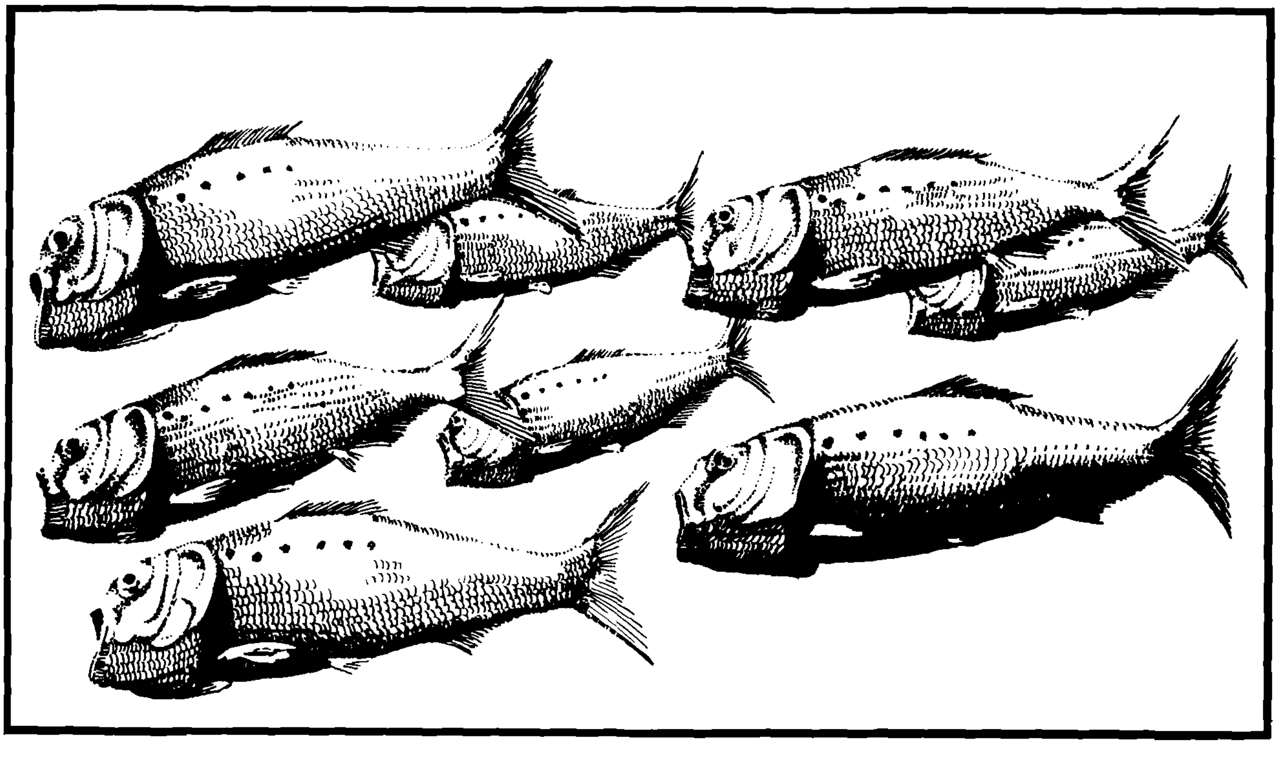

Waterways Experiment Station
Coastal Engineering Research Center
U.S. Army Corps of Engineers

Fish and Wildlife Service
U.S. Department of the Interior

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GULF MENHADEN

by

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Coastal Engineering Research Center

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Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

PREFACE

This series of profiles about coastal aquatic species of commercial, sport, and/or ecological significance is being jointly developed and funded by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service. It is designed to provide coastal managers, engineers, and field biologists with an introduction to the subject species and a synopsis of the information necessary to relate expected changes (associated with coastal development) in the physicochemical characteristics of estuaries to changes in these selected biological populations. Each profile includes brief sections on taxonomy and identification followed by a narrative of life history, environmental requirements, ecological role, and (where applicable) the fishery of the subject species. A three-ring binder is used for this series to facilitate additions as new profiles are prepared.

Suggestions or questions regarding this report should be directed to:

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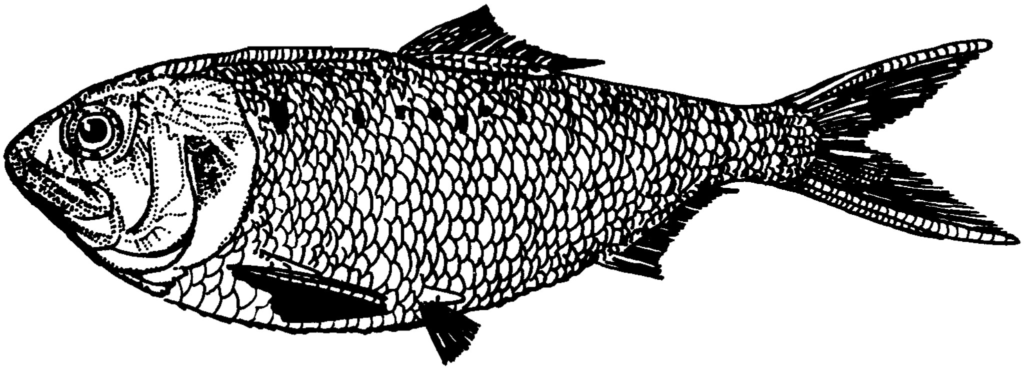

Figure 1. Gulf menhaden.

GULF MENHADEN

NOMENCLATURE/TAXONOMY/RANGE

Scientific name . . *Brevoortia patronus* Goode
Preferred common name. . Gulf menhaden (Figure 1)
Other common names . . . Pogy, sardine, large-scale menhaden
Class . . . . Osteichthyes
Order . . . . Clupeiformes
Family . . . . Clupeidae

Geographic range: Nearshore marine and estuarine waters from Cape Sable, Florida, to Veracruz, Mexico, with centers of abundance off Louisiana and Mississippi (Figure 2).

MORPHOLOGY/IDENTIFICATION AIDS[1]

D. 17-21; A. 20-23; P. 14-17; Sc. 36-50; Gr. 40-150. Scales large, in irregular rows; opercular striae long and distinct; predorsal scales enlarged as in other menhaden.

Color in life: Body silvery, greenish on back, with dark humeral spot and usually a series of smaller spots behind humeral one; caudal fin with dark margin; other fins often yellowish. Suttkus (1956) described the morphological changes during the transformation from larvae to juveniles in Gulf menhaden.

[1]Largely extracted from Walls (1975) and Hoese and Moore (1977). See these references for explanations of abbreviations and measurements.

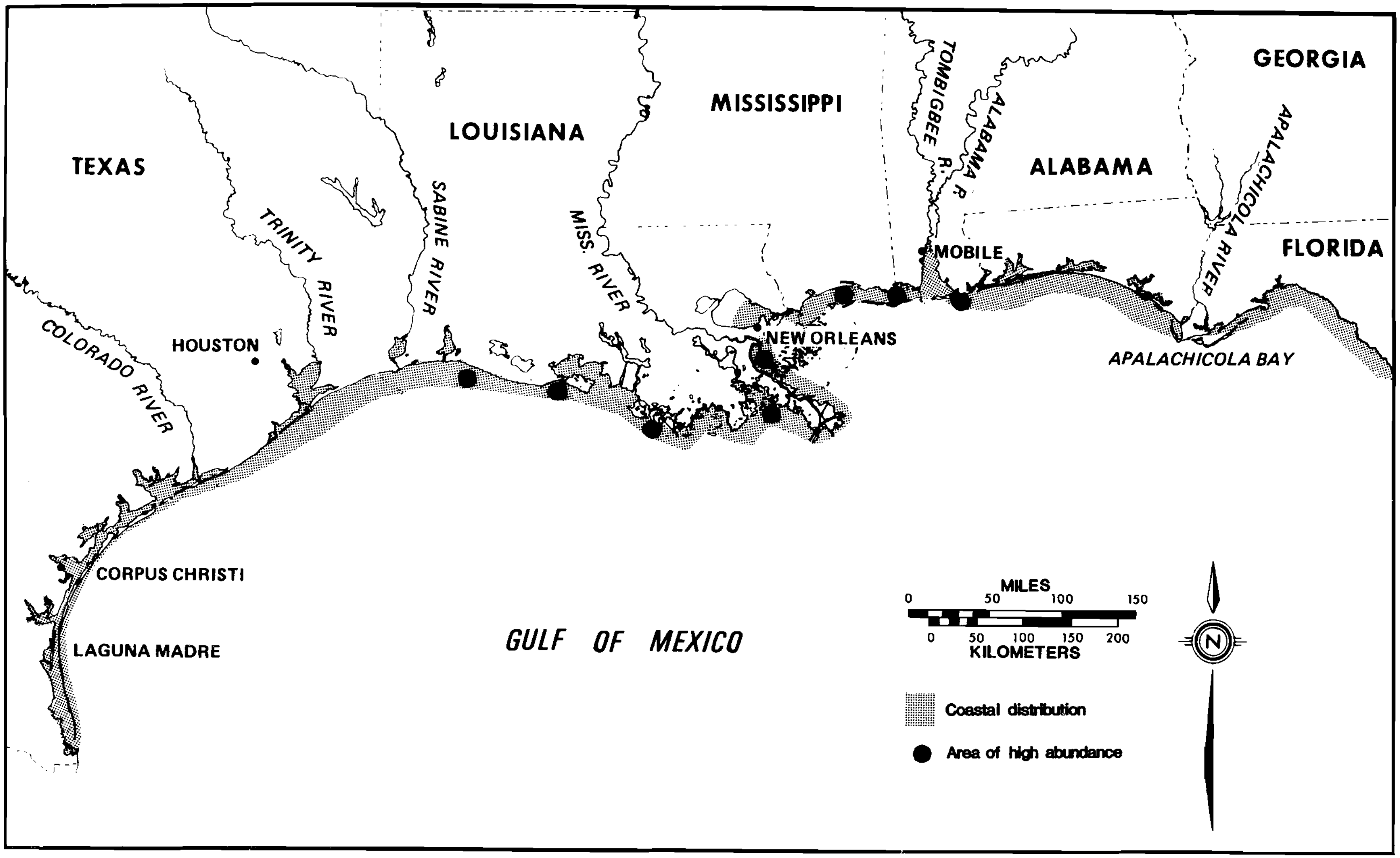

Figure 2. Distribution of Gulf menhaden along the coast of the Gulf of Mexico.

REASON FOR INCLUSION IN SERIES

Gulf menhaden support the largest single fishery (by weight) in the United States, and their young are prey to many other species of sport or commercial importance. The maintenance of large parcels of surrounding marsh and of inflowing freshwater tributary systems is considered necessary to the maintenance of an environment capable of supporting menhaden populations in estuaries.

LIFE HISTORY

Spawning

The actual spawning event in Gulf menhaden has not been observed. Statements regarding the site and time of spawning are therefore based upon the capture of eggs, larvae, or spent adults. Spawning is reported to occur in open Gulf of Mexico waters from 2 to 128 m (6 to 420 ft) deep (Roithmayr and Waller 1963; Etzold and Christmas 1979) up to 96 km (60 mi), but is apparently concentrated in waters of less than 18 m or 60 ft(Christmas and Waller 1975). Spawning has been reported from October through March (Turner 1969; Fore 1970), but is suspected to occur, at least in some years, from September through May (Etzold and Christmas 1979). Gulf menhaden may spawn up to four or five times during a single spawning season, each time releasing only that fraction of the developing ova which has matured (Combs 1969). Separate spawning peaks in late October and March have been suggested (Baldauf 1954; Tagatz and Wilkens 1973), but definitive data are lacking.

Eggs and Fecundity

Eggs of the Gulf menhaden are spherical and float near the surface. Although data on hatching in the Gulf menhaden were not found, the eggs of Atlantic menhaden (*B. tyrannus*) are reported to hatch within 2 days (at 15°C or 59°F), with yolk sac absorption completed within 5 days (Reintjes and Pacheco 1966). Fecundity-at-age data for the Gulf menhaden are given in Table 1. Lewis and Roithmayr (1981) gave the following equations for the estimation of fecundity:

$$\ln F = 9.971 + 0.366\ (A)$$
$$\ln F = -9.872 + 3.878\ (\ln L)$$
$$F = 12,064.3 + 374.9\ (W)$$

where: F = fecundity
A = age (yr)
L = fork length (mm)
W = wet weight (g)

Table 1. Fecundity-at-age for Gulf menhaden.

	Fecundity	
Age-class	E&C[a]	L&R[b]
I	21,860	37,000
II	68,655	47,900
III	122,062	61,900
IV	-	151,000[c]

[a]Etzold and Christmas (1979).
[b]Lewis and Roithmayr (1981).
[c]Based on a single specimen.

Larvae and Postlarvae

Larvae may spend 3 to 5 weeks in offshore waters before moving through the passes into the estuaries at 9 to 25 mm SL[2] (Reintjes 1970; Etzold and Christmas 1979). The reported timing of this movement extends from September (Dunham 1972) through May (Fore and Baxter 1972) with a peak from December through March (Suttkus 1956; Etzold and Christmas 1979). It is uncertain to what extent the movement into the estuaries is an active or passive process. Christmas (1981) stated that larval menhaden "require favorable currents to make their way into the estuary." Fore and Baxter (1972) believed that larval movement was related to water movement, but clearly suggested an active role. They stated that larvae avoid being swept out of the estuary in tidal currents by moving to slower current areas near shore either by swimming, finding favorable currents or both. No indication was given in their study of the current velocities which larvae were capable of withstanding. However, Wilkens and Lewis (1971) stated in their study of the Atlantic menhaden that 10- to 30-mm TL larvae "seemed able to maintain their position at velocities less than 10 cm/sec. Above this velocity they were carried by the current." Lewis and Mann (1971) presented some general comments on the effects of estuarine current patterns on the distribution, abundance, and condition of Atlantic menhaden larvae. No similar assessment for the Gulf menhaden or of the effects of current patterns on year-class strength for either species was found in the literature.

Postlarvae have been reported in the estuaries from November through June (Holcomb 1970) where they then disperse to shallow (0 to 2 m or 0 to 6.6 ft), quiet, low salinity areas near shore (Fore and Baxter 1972). In the estuary, transformation from postlarval to juvenile morphology occurs as the menhaden reach 30 to 33 mm TL (Tagatz and Wilkens 1973).

Juveniles

After transformation, juveniles remain in these low salinity, nearshore areas where they travel about in dense schools, often near the surface. This schooling behavior is retained throughout life. The morphological changes associated with transformation are also accompanied by a change in feeding behavior from selective, particulate-feeding carnivory to filter-feeding omnivory (see Ecological Role section).

The reported duration of the Gulf menhaden's juvenile stage and their stay in the estuary is variable. Combs (1969) stated that menhaden in the 0 age-class "are incapable of completing gametogenesis prior to the onset of the ensuing spawning season ... [and] do not participate in the annual migration to the spawning grounds in the offshore waters." Lewis and Roithmayr (1981) found no maturing ova in fish of less than 100 mm FL (fork length) and suggested that spawning first occurred at the end of the second year as age I fish. They did, however, report that young-of-the-year migrate from the estuaries to offshore waters. Etzold and Christmas (1979) stated that "menhaden migrate to offshore Gulf waters when they are about one year old (100 mm FL) to spawn," while Kroger and Pristas (1974) suspected that "many juveniles did not enter the fisheries as 1-year old fish . . . [but] may have remained in the estuary." Apparently, the largest of the young-of-the-year (0 age-class), which were probably spawned early in the previous spawning season, may develop mature gonads and emigrate to the gulf to spawn along with all older year-classes. It remains unclear to what extent other members of the 0

[2] 25.4 mm = 1 inch.

age-class make this migration or remain within the estuary.

Migration and Adults

Emigration of adults and maturing juveniles from estuarine to open gulf waters has been reported to occur over a wide time span from midsummer through winter. Gulf menhaden were reported to have begun emigrating from Tampa Bay, Florida, in June or July (Springer and Woodburn 1960, cited by Gunter and Christmas 1960), from Lake Pontchartrain, Louisiana, in August (Suttkus 1956), and from Pensacola Bay, Florida, by September (Tagatz and Wilkens 1973). Peak gulfward migration apparently occurs from October through January. Movement back into inshore waters by surviving members of all age groups following an overwintering and/or spawning season in open gulf waters occurs early the following spring, i.e., March to April (Christmas 1981; Lewis and Roithmayr 1981). The redistribution of returning fish is thought to be "by random movement, probably in search of high food concentrations" (Christmas 1981), with the net result being a movement back into the food-rich waters of the estuaries. As Gulf menhaden live to age-III (rarely IV), this cycle may be repeated some two to four times by an individual fish. The described pattern of inshore-offshore migration is the "normal" pattern, but juveniles and adults have both been taken in inshore areas in all months (Swingle 1971; Christmas and Waller 1973).

GROWTH CHARACTERISTICS

A synopis of age-length and age-weight data from ports throughout the Gulf of Mexico (Nicholson 1978) is presented in Table 2. The following equation for the length-weight relationship was derived from data presented in Nicholson's Table 7:

$$\ln W = 1.202 + .198L$$

where: W = round (live) weight (g)
L = fork length (cm)

Springer and Woodburn (1960) compared growth information from Louisiana and Florida. They stated that in both areas there was "a sudden burst of growth after May," but that the growth rate in Florida seemed somewhat slower. Combs (1969) detailed the development of ovaries, and Suttkus (1956) described the sequence of morphological changes at transformation in Gulf menhaden.

Table 2. Fork length (mm) and round (live) weight (g) by age of Gulf menhaden in samples of the catch from ports throughout the Gulf of Mexico, 1964-73 (Nicholson 1978).

Age	Length Range	Length Mean	Weight Range	Weight Mean
0	102-123	115	22- 47	32
I	147-165	155	65-101	78
II	181-188	184	122-148	133
III	201-214	207	170-217	190

THE FISHERY

The purse seine fishery for Gulf menhaden dates back to the turn of the century, but only developed into a major industry after World War II. The fishery for this single species today provides over one-quarter of the Nation's commercial fishery landings by weight.[3] In 1979 this fishery ranked first in tonnage landed (779,390 mt-live wt) and seventh in value ($73,426,000, exvessel price) among commercially fished species in the United States (National Marine Fisheries Service [NMFS] 1981). Fishmeal and oil produced from menhaden are in high demand for poultry feed, cosmetics, and margarine (Nicholson 1978). Young menhaden are sometimes used for bait by Mississippi fishermen.

The Gulf menhaden is a short-lived species, with age I and II fish constituting the majority of the commercial catch (Table 3). Fish as old as Age IV are also occasionally taken (Lewis and Roithmayr 1981). An overlap in predation upon the young menhaden by both man and several species of sport fish (see Ecological Role section), led Gowenlach (1965) to comment that there "is considerable speculation that menhaden are being overfished to the detriment of the sport fishery." Since this statement was made in 1965, the commercial menhaden catch has increased considerably while, for at least two menhaden predators, the spotted seatrout (Merriner 1980) and red drum (Matlock 1980), no clear evidence of a decreasing sport catch has been shown. No studies, however, of trends in abundance of the entire predator assemblage were found. As the menhaden fishery is a very "clean" fishery, there is little direct destruction of other species as discarded by-catch (Etzold and Christmas 1979).

Fisheries activities extend primarily from 1.6 to 4.8 km (1 to 3 mi) offshore from Florida to eastern Texas (Lewis and Roithmayr 1981) and are therefore subject to State rather than Federal regulation. The season runs from mid-April to October when the fish are inshore and sexually inactive. Etzold and Christmas (1979) concluded that Gulf menhaden from Florida to the Yucatan constituted a single, widespread stock. However, the results of tagging studies by Kroger and Pristas

[3] 1979 estimate.

Table 3. Mean percent contribution, in numbers and weight, by age to the commercial Gulf menhaden fishery from 1964-1973 (adapted from Nicholson 1978).

Age	Percent of total catch	
	Weight	Numbers
0	0.2	0.8
I	63.4	73.2
II	33.7	24.7
III	2.7	1.3

(1974) indicated more of a localization of populations with little movement between fishing grounds east and west of the Mississippi River Delta. Kroger and Pristas concluded that recruitment of age I menhaden "is dependent on the number of juveniles produced in estuaries in and adjacent to each fishing area." While this association of separate stocks with nearby estuarine systems now seems to be accepted (Christmas 1981), the relative importance of particular coastal sections as nursery areas is uncertain (e.g., see the varying opinions of Holcomb [1970] and Christmas and Waller [1975] regarding the upper Texas coast).

Present management of the Gulf menhaden fishery depends on the use of historic catch and effort data. Perhaps as a result of this management approach, few reports have been published on other types of modeling parameters. The only published estimates of instantaneous total (Z), natural (M), and fishing (F) mortality found in the literature were those of Ahrenholz (1981). His estimates of Z, M, and F for Gulf menhaden tagged as adults were 2.22, 1.05, and 1.17, respectively. A Z value of 2.22 corresponds to an actual mortality rate of 89%. Analysis of the data presented by Etzold and Christmas (1979) on the age structure of spawning females yields an estimated Z of 3.05, or an annual mortality of 95% (age II-III). Analysis of similar data presented by Lewis and Roithmayr (1981) yields a Z value of 1.3, or an annual mortality of 73% (age I-IV).

Chapoton (1971), based on a Schaeffer-type analysis of catch and effort data from 1946 to 1970, estimated a maximum sustainable yield (MSY) for Gulf menhaden of 430,000 mt. Schaaf (1975) incorporated additional data from the 1971 and 1972 seasons and re-estimated MSY as 478,000 mt with an 80% upper confidence limit of 520,000 mt. He warned, however, of the room for error in the use of catch-effort models (especially without sufficient data on the descending portion of the Schaeffer-type curve, as is still the case in the Gulf menhaden fishery) and of the need to continuously update the model. With the exceptions of 1973 and 1977, in all years since 1972 the catch has exceeded even the upper confidence limit of 520,000 mt. Schaaf listed what he perceived at that time to be the greatest needs of the fishery for proper management as:

1. Valid information on the age structure of the population from which we can deduce mortality rates.

2. An assessment of our measure of effort [vessel-ton week] to determine if it is proportional to apparent mortality and directly influences population abundance.

3. Valid techniques to quantify the strength of incoming year classes upon which quotas can be modified.

Recent doubt has been expressed as to the validity of the vessel-ton week as an effective measure of effort (W.R. Nicholson, NMFS, Beaufort, N.C.; pers. comm. 1981). In regard to the third point, Nelson et al. (1977) and Schaaf (1979) have since illustrated the importance of specific identification of spawning site and information on current patterns in determining survival from egg to recruitment at age I in the Atlantic menhaden fishery. Studies similar to Nelson et al. (1977) have apparently not been done in the gulf.

ECOLOGICAL ROLE

Gulf menhaden have two distinct feeding stages in their lifetime. Up to 30 to 33 mm TL, larvae have a slender body, large mouth and eyes, and relatively short gill rakers, and feed as selective carnivores on individual zooplankters. After transformation into juveniles and as adults, the body is deeper, gill rakers "elongate and branch to form a basket-like seive," and they feed as omnivorous filterers of phytoplankton, zooplankton, and organic detritus (Reintjes and Pacheco 1966). Darnell (1958) reported that the guts of adults collected from Lake Pontchartrain, Louisiana, contained 99% "ground organic material and silt." Juveniles in this same study were reported to have consumed 82% phytoplankton with the rest a mix of zooplankton, detritus, and plant fragments. He concluded that they had been straining plankton near the surface of the lake during an Anabaena bloom. This is consistent with the observation of Gunter (1938), who reported "large schools feeding near the surface in Caminada Bay, Louisiana where they wheeled, turned and swerved from side to side in perfect unison, all the while with mouths agape and lower jaws thrust forward." Although several species with similar feeding habits have been suggested to be important competitors, particularly the bay anchovy (Tagatz and Wilkens 1973), no experimental evidence of competition was found in the literature. In fact, mention by Tagatz and Wilkens (1973) of high abundance of both species at the same time may be interpreted as evidence to the contrary.

Heavy predation, particularly upon young Gulf menhaden, has been reported for several commercially and recreationally important fishes including mackerel, bluefish, sharks, white and spotted seatrout, longnose gars, and red drum (Simmons and Breuer 1964; Reintjes 1970; Etzold and Christmas 1979). They are also preyed upon by shorebirds and have been reported to constitute as much as 90% to 97% of the diet of the brown pelican (Arthur 1931, cited by Gunter and Christmas 1960; Palmer 1962). No quantitative information on the effects of such predation on menhaden population dynamics was found.

ENVIRONMENTAL REQUIREMENTS

Temperature and Salinity

Gulf menhaden have been taken in waters from 5° to 34.9°C (41° to 95°F) (Christmas and Waller 1973). Definitive data on thermal optima within this range, upper, and particularly on lower lethal limits are lacking. Avoidance of water temperatures above 30°C (86°F) has been reported (Hoss et al. 1971; Gallaway and Strawn 1974). Gunter and Christmas (1960) reported that fisheries activities for Gulf menhaden in Mississippi Sound began in the spring as water temperatures reached 23°C (73°F) and slowed in the fall at approximately this same temperature.

While Gulf menhaden have been reported to occur in waters from fresh to hypersaline (0 to 67 ppt, Etzold and Christmas 1979), there may be somewhat narrower salinity ranges with which various life stages are associated (Christmas 1981). Generally, gravid adults, fertilized eggs, and early larvae were associated with the higher salinity gulf and open bay waters. Postlarvae and juveniles appeared to tolerate a wide range, but were most often associated with nearshore, low salinity areas. Non-gravid or developing adults were associated with mid-range salinities of the estuary. Tagatz and Wilkens (1973) reported that juveniles entered freshwater, but never penetrated far (1.6 km or 1 mi) beyond the interface with low salinity estuarine water. Simmons (1957) reported that juveniles commonly occurred in waters from 20 to 60 ppt, but also noted mass mortalities of Gulf menhaden at salinities over 80 ppt.

Perhaps the most complete compilation of combined temperature and salinity data for Gulf menhaden is that of Christmas and Waller (1973) for Mississippi Sound. While their matrix covered a wide range of temperatures and salinities within those discussed above, it was apparent that consistently high catches were restricted to waters over 20°C (68°F), particularly 25° to 34.9°C (77° to 95°F), between salinities of 5 to 25 ppt. The highest mean catch was recorded at the 5 to 9.9 ppt X 30° to 34.9°C (86° to 95°F) cell of the matrix with a mean fish size of 57 mm TL. Collection techniques in this study may have favored the taking of young-of-the-year juveniles. It is possible then that the lower salinities often associated with postlarval and very young Gulf menhaden were underrepresented.

As no published accounts of controlled experimental testing of Gulf menhaden response to temperature and/or salinity (or any other environmental parameters) at any life stage were found, it is difficult to define causal mechanisms for the above-mentioned relationships. They should therefore not be regarded as statements of "optima" or "preferences," but simply as statements of frequently observed associations. For example, Copeland and Bechtel (1974) found that "swarms of young penetrate to upper limits [of the estuary], where inflowing detritus is abundant in low salinity waters." They concluded that a wide salinity tolerance is exhibited when other requirements were met and suggested that the common association of young menhaden with high temperature, low salinity waters may be more related to position in the estuary. Research in this area is sorely needed.

Substrate and System Features

Although Gulf menhaden inhabit the water column and no direct use of the substrate is apparent, they are most often captured over soft bottoms. Christmas (1981) incorporated substrate type as a parameter in his model of habitat suitability for Gulf menhaden with the highest value assigned to mud (vs. mud-sand or sand) substrates. He stated that "substrate is included in the estimate of food value because the estuarine and nearshore marine habitats are shallow; thus currents and wave action will resuspend nutrients and organic detritus which have been incorporated into the sediments .... [It was also] <u>assumed</u>[4] that muddy substrates, because of their more dense [prey] populations and absorptive chemical properties, have a higher food value than sandy substrates."

Another feature of the Gulf menhaden habitat not mentioned in previous sections is the importance of the surrounding marsh system. Results of a study by Copeland and Bechtel (1974) indicated that menhaden were not frequently found within marsh areas. However, they fully recognized the importance of these areas by stating, "In order to maintain an environment capable of supporting menhaden populations in estuaries, the tributaries, fringes and tertiary bays must be protected from destruction [and]. . . streamflow, which brings the freshwater required for low salinity maintenance and necessary foodstuffs for the small menhaden, will have to be maintained."

Dissolved Oxygen

Gulf menhaden are frequently among the species hardest hit by low dissolved oxygen (DO) "fish kills" in estuarine waters (Christmas 1973; Etzold and Christmas 1979). Postlarvae and juveniles in restricted bays and backwaters are particularly susceptible to such kills as their

[4]Emphasis added.

mobility and capacity to avoid low DO are limited. Christmas (1981) suggested a minimum DO level of 3 ppm although the empirical basis for this number was not given.

Other Environmental Factors

Available information on depth and water movement has largely been incorporated into above discussions. Data presented by Roithmayr and Waller (1963) on seasonal change in depth distribution of Gulf menhaden generally reflect the annual inshore-offshore migration pattern. Fish were taken from surface to bottom in 2 to 15 m (6 to 48 ft) from June through September; up to 27 m (90 ft) in October and November; from 7 to 33 m (24 to 108 ft), but occasionally to 88 m (288 ft) from December through February; and back to 2 to 26 m (6 to 84 ft), occasionally to 33 m (108 ft), from March through May.

No empirical information on the relationship of Gulf menhaden to turbidity was found. Tissue levels of aldrin and dieldrin in juvenile Gulf menhaden before and after treatment of nearby agricultural areas are presented by Ginn and Fisher (1974). Stout et al. (1981) reviewed the available information on chlorinated hydrocarbon levels in the products of menhaden fisheries. Levels have been decreasing with increasing restriction on their use and are now generally below U.S. Food and Drug Administration tolerance levels.

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16. Abstract (Limit: 200 words)

Species profiles are literature summaries of the taxonomy, morphology, range, life history, and environmental requirements of coastal aquatic species. They are prepared to assist in environmental impact assessment. The gulf menhaden, Brevoortia patronus, supports the largest fishery (by weight) in the United States; 779,390 mt were landed in 1979. Larval, juvenile, and adult menhaden are important prey for many fishes and birds. The species lives in estuaries and in the Gulf of Mexico to a maximum depth of about 70 m. Spawning takes place in the Gulf of Mexico from September to May and larvae are carried into estuaries within 3-5 weeks after hatching. Larvae inhabit the shallow marshy parts of estuaries and feed on microzooplankton. Larvae metamorphose into juveniles which are omnivorous filter feeders. As they grow, juveniles move from shallow parts of estuaries to deeper areas. Juveniles and adults migrate to the Gulf of Mexico as temperatures drop in the fall. Adults become sexually mature after two growing seasons. They have been collected in a temperature range of 5°-34.9°C and a salinity range of 0-67 ppt. Larvae and juveniles tolerate lower salinities than adults.

17. Document Analysis a. Descriptors

Estuaries
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Growth
Feeding

b. Identifiers/Open-Ended Terms

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Brevoortia patronus
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Temperature requirements
Life history
Spawning
Habitat requirements

c. COSATI Field/Group

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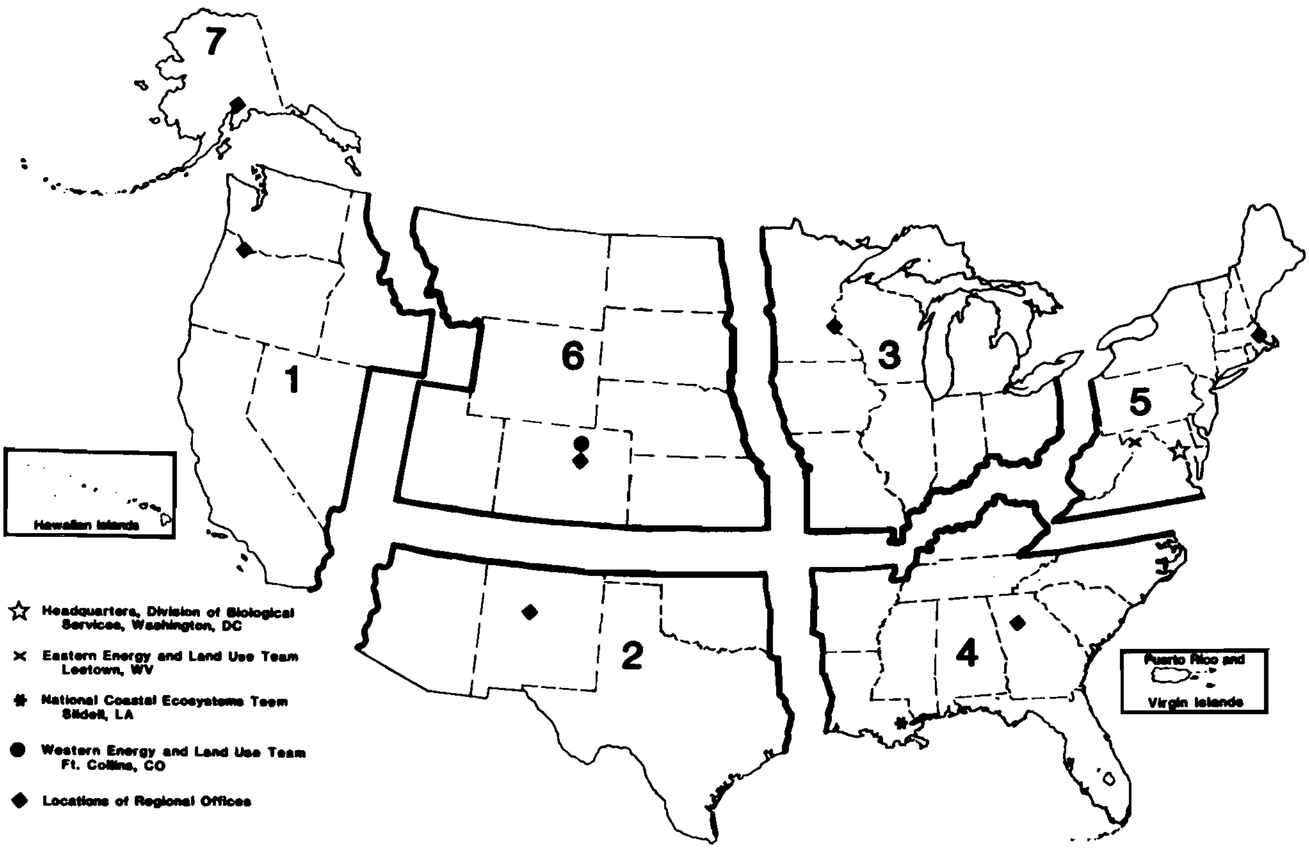

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