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Gulf Menhaden, *Brevoortia patronus*, Purse Seine Fishery: Catch, Fishing Activity, and Age and Size Composition, 1964-73

William R. Nicholson

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U.S. DEPARTMENT OF COMMERCE
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Gulf Menhaden, *Brevoortia patronus*, Purse Seine Fishery: Catch, Fishing Activity, and Age and Size Composition, 1964-73

WILLIAM R. NICHOLSON[1]

ABSTRACT

The menhaden purse seine fishery in the Gulf of Mexico, primarily for Gulf menhaden, *Brevoortia patronus*, extends from about early April to early October. From 1964 to 1973 the catch fluctuated between 317,000 and 728,000 t and the number of vessels ranged from 65 to 82. Larger and faster refrigerated vessels replaced most of the smaller nonrefrigerated vessels and modern methods of fishing were adopted. Population levels were high and there were no large fluctuations in year class abundance. Age-1 and -2 fish supplied from 95 to 99% of the catch by weight. Over 97% of the fish were between 120 and 225 mm fork length. The mean age and size generally were slightly greater in the center of the fishery (central and eastern Louisiana) than in the eastern (Mississippi) and western areas (western Louisiana and Texas). Mean age decreased as the season progressed.

INTRODUCTION

The menhaden purse seine fishery in the Gulf of Mexico, dating prior to 1900, underwent a rapid expansion after World War II. New plants for processing meal and oil were built and larger and more modern vessels were added to the fleet. By 1964 the annual catch had risen to 410,000 t, a 10-fold increase over the 1946 catch.

Although three species of menhaden inhabit the area, only the Gulf menhaden, *Brevoortia patronus*, is important to the fishery. Yellowfin menhaden, *B. smithi*, occurs east of the Mississippi delta, and finescale menhaden, *B. gunteri*, west of the delta (Christmas and Gunter 1960). These two species together, however, probably supply, on the basis of numbers observed in catches or found in catch samples, less than 1% of the menhaden processed.

Because of general concern that the resource would be overfished and that catches would undergo a decline similar to that of Atlantic menhaden, *B. tyrannus*, an investigation was begun in 1964 by the National Marine Fisheries Service and centered at the Beaufort, N.C., laboratory. Many of the procedures and techniques developed for collecting and compiling information on the Atlantic menhaden fishery were followed. Catches of individual vessels dating from 1945 were compiled from confidential company records, and information on improvements in fishing methods, such as the use of spotter planes, fish pumps, and power blocks, were collected. A systematic sampling of catches for age, size, and sex was begun in 1964 and still continues.

The purpose of this paper is to document changes that have occurred in the fishery, update records of landings, describe methods of sampling the catch and estimating the number of fish landed at each age, and discuss differences or similarities in age and size composition of catches throughout the fishery. Some preliminary data on catches, number of vessels and airplanes, and age composition of catches have been published in annual reports of the Beaufort Laboratory and by Chapoton (1972). Previous reports on age composition, however, were inaccurate, particularly for the years 1964-69, because a majority of fish had been over-aged during preliminary aging procedures. Subsequent reading showed a greater number of age-1 fish, fewer fish over age-2, and none over age-3.

THE FISHERY

Although a menhaden fishery has existed along the Gulf coast since the late 1800's, records of catches, the location and number of plants, and the number and types of vessels before 1946 are fragmentary. One plant is known to have operated in Texas from around the turn of the century until at least 1923. Another operated intermittently in the vicinity of Port St. Joe and Apalachicola, Fla., from at least 1918 until 1961. Another operated in the Pascagoula, Miss., area from sometime in the 1930's until 1959.

The modern purse seine fishery began after World War II as the world demand for fish meal and oil increased. Fishing usually begins in April and ends in early October. The first plant in Louisiana opened in 1946. In the next few years additional plants were built in Mississippi, Louisiana, and Texas (Fig. 1). Since 1950 the number of plants operating each year has fluctuated between 9 and 13 (Table 1), with some plants being closed or destroyed and new ones being built. The general trend has been toward larger and more efficient plants.

[1]Southeast Fisheries Center Beaufort Laboratory, National Marine Fisheries, NOAA, Beaufort, NC 28516.

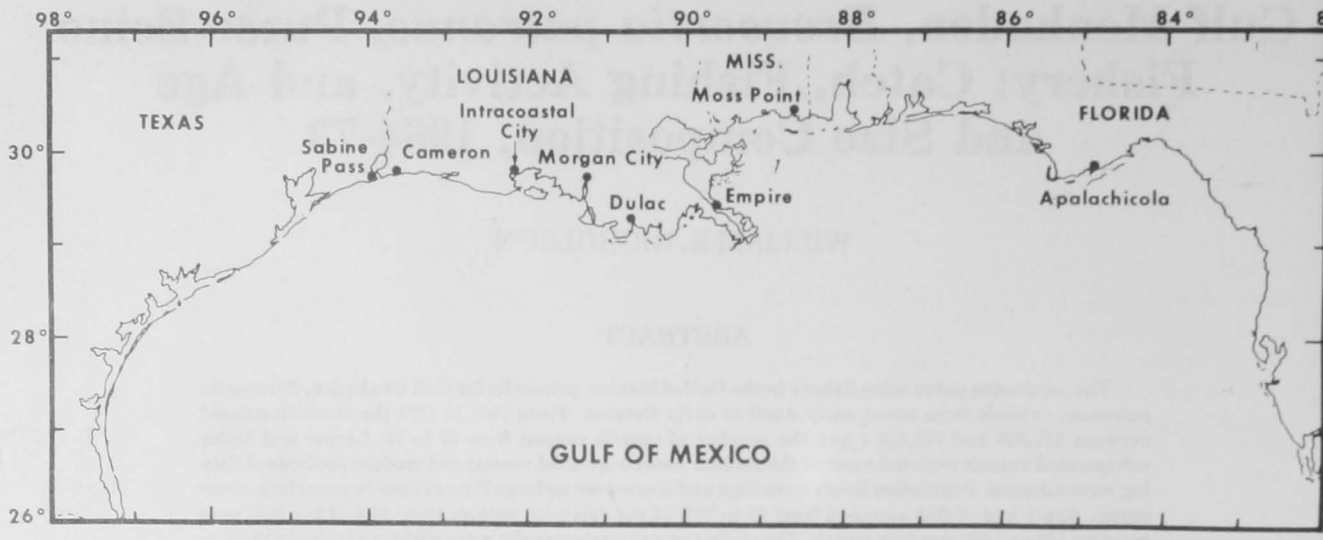

Figure 1.—Location of reduction plants for the Gulf menhaden fishery in the Gulf of Mexico.

Table 1.—Numbers of operating plants, airplanes, vessels by size, and vessels with fish pumps, power blocks, and refrigeration, Gulf menhaden fishery, 1945-73.

Years	No. of plants operating	No. of airplanes	No. of vessels[1]				No. of vessels with		
			Under 75 net tons	76-200 net tons	Over 200 net tons	Total	Fish pumps	Power blocks	Refrigeration
1945	2	0	10	0	0	10	0	0	0
1946	3	0	13	1	0	14	0	0	0
1947	4	0	21	9	0	30	0	0	0
1948	5	0	27	12	0	39	0	0	0
1949	7	1	36	17	0	53	0	0	0
1950	10	3	42	23	0	65	0	0	0
1951	10	4	42	26	0	68	6	0	0
1952	10	4	41	23	0	64	7	0	0
1953	10	5	46	24	0	70	12	0	0
1954	9	7	40	32	0	72	39	0	0
1955	9	8	39	31	2	72	43	0	0
1956	10	12	38	39	4	81	63	0	2
1957	10	15	32	35	6	73	72	4	9
1958	10	15	20	48	9	77	69	7	14
1959	11	17	18	44	11	73	66	16	23
1960	10	19	12	52	11	75	71	21	29
1961	10	19	6	52	11	69	66	21	32
1962	12	23	6	54	14	74	74	43	35
1963	11	25	5	53	15	73	73	56	36
1964	11	24	5	53	18	76	76	64	40
1965	13	27	4	48	30	82	82	79	57
1966	13	29	1	42	37	80	80	80	59
1967	13	31	1	32	43	76	76	76	70
1968	12	33	2	26	41	69	69	69	65
1969	12	33	2	27	43	72	72	72	68
1970	13	34	2	26	45	73	73	73	70
1971	13	35	1	29	52	82	82	82	77
1972	11	33	0	22	53	75	75	75	75
1973	10	31	0	14	51	65	65	65	65

[1]Number of vessels that landed fish 9 or more weeks.

Distribution of Fishing

From 1964 to 1969 logbooks and maps were placed aboard vessels and the captain or pilot was asked to record, among other things, the location of each purse seine set. Squares on the maps, formed by even degrees of latitude and longitude, were divided by 10 minute intervals into 36 subareas, identified by a letter (A to I and a number (1 to 6). The location of a given set could be referenced within a 100 mi^2 subarea, identified by latitude, longitude, and subarea (for example 29-84-B2). Although all vessels did not keep logs and some kept only

partial records, the locations of over 48,000 sets were recorded for the 6-yr period.

To show the relative distribution of fishing activity, particularly in reference to distance from shore, I organized the data by degrees of longitude to show the percentage of sets made less than 10, 20, 30, and 40 mi from shore (Table 2). Since longitude 89 is divided by the Mississippi Delta, I treated the data from east of the delta (89a) and west of the delta (89b) separately. West of the Mississippi delta (longitudes 89b-94), 44 to 93% of the sets were less than 10 mi from shore, 90 to 98% less than 20 mi, and 99 to 100% less than 30 mi. East of the delta (longitudes 84-89a), 100% of the sets were made less than 10 mi from shore.

In effect, the fishing area west of the delta is restricted to a narrower band adjacent to shore than is indicated by the data. Because the shoreline usually passes through subareas rather than along their boundaries, the actual distances from shore are considerably less than the maximum. Therefore, a majority of the sets are in reality less than the maximum possible distance. Probably 85 to 90% are made within 15 mi of shore. Undoubtedly many reported in subareas more than 20 mi were due to errors in recording.

Catches

Records of annual catches were compiled from confidential company sources of individual vessel landings for years 1945-73 (Table 3). In a few cases where plant records were missing (one plant in Mississippi 1949-50, one plant in Louisiana 1954-55, and one plant in Texas 1948-51), I estimated catches by multiplying the mean catch of similar vessels at nearby plants by the number of vessels that normally fished at plants whose records were missing. For Florida in 1946-47 and Mississippi in 1946 where only one plant operated, I was unable, however, to make any estimates and no published records were available.

Published records (Anonymous 1918-38, 1939-44) prior to 1945, although fragmentary and incomplete, suggest annual landings from 1918 to 1944 of about 2,000 to 12,000 t, all in Florida, Mississippi, or Texas. There was little increase until 1948, when the catch was 103,000 t, mainly as a result of new plants being built in Mississippi, Louisiana, and Texas. It had increased to 481,000 t by 1962 and thereafter fluctuated between 317,000 and 728,000 t. More vessels, larger and more efficient vessels, and improved fishing technology were primarily responsible for increased catches after 1947.

Table 3.—Purse seine catch of Gulf menhaden, in thousands of metric tons, by State, 1945-73.

Year	Florida	Mississippi	Louisiana	Texas	Total
1945	3.2	26.0	0.0	0.0	29.2
1946	[1]	[1]	8.9	0.0	[1]
1947	[1]	10.1	24.0	0.0	[1]
1948	15.4	34.8	40.0	12.7	102.9
1949	11.2	30.1	75.2	19.0	135.5
1950	0.6	31.1	94.3	21.2	147.2
1951	1.5	43.4	96.7	13.2	154.8
1952	4.8	70.7	129.2	24.0	228.7
1953	2.0	22.1	142.1	30.3	196.5
1954	0.0	36.0	121.8	23.4	181.2
1955	0.9	56.0	135.1	23.0	215.0
1956	0.0	70.3	144.6	29.9	244.8
1957	0.0	59.3	74.5	26.1	159.9
1958	4.6	56.1	109.5	31.3	201.5
1959	8.2	79.7	191.5	55.9	335.3
1960	2.8	99.1	213.2	65.6	380.7
1961	1.9	136.7	260.2	60.7	459.5
1962	0.0	119.5	314.1	47.1	480.7
1963	0.0	113.6	288.4	35.8	437.8
1964	0.0	107.8	271.4	30.2	409.4
1965	0.0	126.4	308.6	28.1	463.1
1966	3.1	86.4	252.0	17.6	359.1
1967	0.0	75.5	231.4	10.4	317.3
1968	0.3	67.8	282.2	23.2	373.5
1969	0.0	102.2	388.3	33.2	523.7
1970	0.0	93.4	435.2	19.5	548.1
1971	0.0	138.8	560.9	28.5	728.2
1972	0.0	80.8	420.9	0.0	501.7
1973	0.0	80.4	405.7	0.0	486.1

[1]Records not available.

Size and Number of Vessels

The number of vessels increased rapidly from 1945 to 1950, and then more slowly, reached a peak of 82 in 1965, and thereafter fluctuated between 65 and 82 (Table 1). Because many vessels often made only a few landings each year in the early years of the fishery, I have excluded all vessels that fished less than 9 wk. Including them would have indicated greater changes in the composition of the fleet than actually occurred.

Table 2.—Distribution of purse seine sets for Gulf menhaden, by degrees of longitude and relative distance from shore, 1964-69. Longitudes 84-89a are east of the Mississippi delta, 89b-94 are west.

	Longitude (°W)									
Sets	94	93	92	91	90	89b	89a	88	87-86	85-84
Number	598	4,310	4,672	10,328	1,730	2,539	14,486	9,050	94	767
% 0 to 10 miles of shore	68	57	44	48	85	93	100	100	100	100
% 0 to 20 miles of shore	91	93	90	98	98	98	0	0	0	0
% 0 to 30 miles of shore	99	99	99	100	100	100	0	0	0	0

The shift to larger vessels of greater carrying capacity was the most striking change. Vessels less than 75 net tons constituted over 50% of the fleet until 1956. In the following years the number of vessels in this size class declined continually, dropping to 1 in 1966 and finally disappearing completely in 1972. The number of vessels between 75 and 200 net tons increased until 1960, remained fairly stable through 1964, and then declined steadily. By 1973 they composed only 22% of the fleet. Vessels over 200 net tons first appeared in 1955, increased gradually over the years, and by 1973 numbered 51, or 78% of the fleet. Most of the vessels in this size class after 1965 were greater than 300 net tons, and one was more than 400 net tons.

Improvements in Fishing Methods

Fish pumps, power blocks, refrigeration, nylon purse seines, aluminum purse boats, and airplane spotting were introduced in the Gulf menhaden fishery in the 1950's (Table 1). These techniques and equipment increased efficiency by reducing the time spent searching for fish, steaming to and from fishing grounds, and completing purse seine sets.

Fish pumps replaced the time-consuming method of brailing fish from the purse seine to the hold of the carrier vessel (Robas 1959), and first appeared on gulf coast vessels in 1951. By 1960 they were standard equipment on nearly all vessels.

A power block is a mechanical device that retrieves the net and concentrates the fish in it so they may be pumped or brailed aboard the carrier vessel. Its use reduces the average time required to concentrate the fish by about 6 min and the crew by 6 to 10 men (Schmidt 1959a, b), and permits a quick retrieval of the net if a school of fish is missed. Power blocks were introduced in the Gulf menhaden fishery in 1956. Although their use did not spread rapidly, they were standard equipment on over 80% of the vessels by 1964.

Refrigerated vessels are able to fish greater distances from their home ports and to spend up to a week on the fishing grounds. Generally larger than nonrefrigerated vessels, they increased steadily in number after their introduction in 1957. Their use has been more extensive in the central and eastern Gulf regions, where vessels travel farther to the fishing grounds, than in the western Gulf.

Aluminum purse boats can encircle a school of fish faster and can operate in rougher waters better than wooden or steel boats. They were first employed in 1956, but their use spread slowly, and all vessels were not equipped with aluminum purse boats until about 1970.

Information was difficult to obtain on the use of nylon seines by individual vessels. A few were reported to have used them in 1956. The changeover was rapid in 1957 and 1958, and by 1959 nearly all vessels were using them.

The use of airplanes for locating schools of menhaden greatly reduced the amount of vessel searching time and was one of the more important improvements in fishing methods. Spotter planes were introduced in the Gulf menhaden fishery in 1949 and rapidly increased in number. Most plants chartered planes part time until about 1955, but employed two to four planes full time by 1960. Initially, planes only guided vessels to large concentrations of fish, but in recent years pilots have used two-way radios to direct the purse boats in setting the seine.

SAMPLING PROCEDURE

Catches of Gulf menhaden were sampled by seasonal employees who followed the procedures described for sampling catches of Atlantic menhaden (June and Reintjes 1960). For each vessel sampled, fish were taken

Table 4.—Number of samples taken from Gulf menhaden catches by plant and location, 1964-73.

Plant location	No. of samples in year									
	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Appalachicola, Fla.	[1]	[1]	4	[1]	0	[1]	[1]	[1]	[1]	[1]
Moss Pt., Miss.	76	98	33	25	29	53	43	19	58	[1]
	66	126	100	141	173	135	119	50	136	96
	56	88	53	89	53	71	66	56	102	102
Empire, La.	152	142	57	88	111	79	0	0	108	108
	18	25	63	71	70	75	0	0	153	166
Dulac, La.	1	2	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
	0	5	4	4	15	0	7	4	[1]	[1]
	[1]	7	10	37	79	0	69	57	68	133
Morgan City, La.	111	126	90	103	73	147	56	41	49	133
Intracoastal City, La.	[1]	11	3	1	36	36	35	23	22	14
Cameron, La.	14	8	32	45	23	1	28	29	102	87
	118	112	152	76	105	157	69	57	68	94
	[1]	[1]	[1]	27	0	0	22	41	68	71
Sabine Pass, Tex.	4	16	26	1	6	3	4	9	[1]	[1]
Total	616	766	623	708	773	757	518	386	934	1,004

[1]Plant did not operate.

from the top of the catch, which came from the last set made by the vessel, measured (millimeters, fork length), weighed (grams), and sexed. Scales were taken for aging (Nicholson and Schaaf in press). In 1964, 1965, and 1971, two samples of 20 fish (1 sample per boat) were taken daily. From 1966 to 1970, three samples of 20 fish were taken. Beginning in 1972, three samples of 10 fish each were taken. The location of the last set made by the vessel was recorded to the nearest 10 minutes of latitude and longitude.

All plants were not sampled equally. Usually, four samplers were employed and stationed at locations where they could cover two or more plants, arbitrarily grouped into ports. Locations were chosen so that plants throughout the entire range of the fishery could be sampled. The number of samples depended, in part, on the duty station of the sampler and ranged from 0 to over 150 per plant and from 386 to 1,004 per year (Table 4).

AGE AND SIZE COMPOSITION

The number of fish landed at each plant was estimated by dividing the total weight of fish landed weekly by the mean weight of fish in the weekly samples, either from that plant or from several plants arbitrarily grouped together. The number of each age was estimated by multiplying the total estimated number of fish by the percentage of each age in the samples. Weekly estimates were summed to obtain seasonal estimates. Since fish landed at plants in the eastern and western ends of the fishery tended to be smaller and younger than fish landed at plants in the middle, I summarized the data by grouping together plants in the eastern area (Mississippi and Florida), central area (Empire to Intracoastal City, La.), and western area (Cameron, La., and Sabine Pass, Tex.).

The total number of fish landed annually varied from 4,054.73 million in 1966 to 7,796.38 million in 1971 (Table 5). Age-1 and -2 fish together supplied from 97 to 99% of the fish caught, and ages 0 and 3 supplied the remainder. Age-1 fish supplied from 59 to 92% of the estimated number of fish caught annually, while age-2 fish supplied from 6 to 40%. These percentages are about the same, whether they are calculated from the estimated number of fish caught or from the number of fish in the samples (Table 6). The former method of calculating is more precise, since it corrects for differences in time and space between the ratio of weight of fish landed to number of fish in the samples.

There was remarkable little variation from year to year in the length range or mean length, either for individual ages or for all ages combined (Table 7). With few exceptions length ranged from about 115 to 215 mm. Mean annual lengths ranged from 147 to 165 mm for age-1 fish, 181 to 188 mm for age-2, 201 to 214 mm for fish over age-2, and 153 to 172 mm for all ages combined.

Weight also showed relatively little annual variation, ranging from about 20 to 250 g (Table 7). Means ranged from 65 to 101 g for age-1 fish, 122 to 148 g for age-2, 170 to 217 g for fish over age-2, and 74 to 117 g for all ages combined.

The contribution of each age group to the total weight of the catch was estimated by multiplying the number of fish caught at each age by the mean weight of fish in the samples. Two age groups, 1 and 2, accounted for over 95% of the total weight of the catch. The annual variation ranged from 95.0 to 99.3%. Age-1 fish contributed from 49 to 88%, and averaged 63% for the 10-yr period. Age-2 fish contributed from 12 to 50% and averaged 34%. Age-3 fish contributed an average of 2.6%, and age-0 fish 0.2% (Table 8).

Table 5.—Estimated number (in millions) of Gulf menhaden at each age landed annually, 1964-73, at plants in eastern area (Mississippi and Florida), central area (Empire to Intracoastal City, La.), and western area (Cameron, La., and Sabine Pass, Tex.).

Year	Plant location	Age 0	1	2	3	Total	Percent
1964	Eastern	0.52	1,194.52	219.84	5.65	1,420.53	31
	Central	0.33	744.39	768.45	88.23	1,601.40	34
	Western	5.42	1,196.65	376.86	18.04	1,596.97	35
	Total	6.27	3,135.56	1,365.15	111.92	4,618.90	100
1965	Eastern	0.35	1,702.82	297.33	8.34	2,008.84	34
	Central	41.01	1,830.84	627.35	62.04	2,561.24	43
	Western	5.27	1,354.41	41.58	1.01	1,402.27	23
	Total	46.63	4,888.09	966.26	71.39	5,972.35	100
1966	Eastern	5.13	846.22	193.10	7.00	1,051.45	26
	Central	39.17	858.08	413.77	18.53	1,329.55	33
	Western	2.54	1,422.49	243.26	5.44	1,673.73	41
	Total	46.84	3,126.79	850.13	30.97	4,054.73	100
1967	Eastern	1.32	1,007.79	84.97	4.34	1,098.42	25
	Central	17.38	1,759.82	198.98	6.21	1,982.39	44
	Western	0.00	1,361.63	25.93	0.00	1,387.56	31
	Total	18.70	4,129.24	309.88	10.55	4,468.37	100
1968	Eastern	0.00	463.78	276.61	4.46	744.85	18
	Central	23.87	1,105.98	529.02	21.22	1,680.09	40
	Western	11.53	1,741.75	44.36	1.53	1,799.17	42
	Total	35.40	3,311.51	849.99	27.21	4,224.11	100
1969	Eastern	3.16	1,320.30	150.70	6.68	1,480.84	22
	Central	7.62	2,309.13	628.31	21.77	2,966.83	44
	Western	0.00	2,137.41	232.04	1.94	2,371.39	34
	Total	10.78	5,766.84	1,011.05	30.39	6,819.06	100
1970	Eastern	0.89	690.35	299.14	2.51	992.89	19
	Central	20.89	1,050.08	1,416.42	26.07	2,513.26	48
	Western	27.60	1,515.92	481.62	5.84	2,030.98	33
	Total	49.18	3,256.35	2,197.18	34.42	5,537.13	100
1971	Eastern	1.75	952.68	532.99	65.88	1,453.30	19
	Central	7.21	2,486.21	988.76	95.04	3,577.22	46
	Western	16.30	2,424.43	316.32	9.01	2,766.06	35
	Total	25.26	5,763.32	1,838.07	169.73	7,796.58	100
1972	Eastern		788.13	171.57	11.56	971.26	20
	Central	15.31	717.13	1,223.77	52.65	2,008.86	41
	Western	2.26	1,640.99	220.33	7.43	1,871.01	39
	Total	17.57	3,146.25	1,615.67	71.64	4,851.13	100
1973	Eastern	55.66	432.33	224.56	9.39	721.94	17
	Central	1.56	1,246.38	656.45	94.92	1,999.31	47
	Western	0.00	1,333.64	201.64	5.17	1,540.45	36
	Total	57.22	2,012.35	1,082.65	109.48	4,261.70	100
Mean total		31.39	3,953.63	1,208.60	66.79	5,260.41	

Table 6.—Age composition, in percentage and numbers of fish, of Gulf menhaden in samples of the catch from all ports combined, 1964-73.

Year		Age 0	Age 1	Age 2	Age 3	Total
1964	Number	24	8,012	3,887	342	12,265
	Percent	0.2	65.3	31.7	2.8	100
1965	Number	114	12,370	2,510	213	15,207
	Percent	0.7	81.4	16.5	1.4	100
1966	Number	172	9,669	2,496	92	12,429
	Percent	1.4	77.8	20.1	0.7	100
1967	Number	93	12,590	1,320	62	14,065
	Percent	0.7	89.5	9.4	0.4	100
1968	Number	123	10,348	4,679	142	15,292
	Percent	0.8	67.7	30.6	0.9	100
1969	Number	62	12,241	2,633	103	15,039
	Percent	0.4	81.4	17.5	0.7	100
1970	Number	89	6,750	3,511	52	10,402
	Percent	0.9	64.8	33.8	0.5	100
1971	Number	20	5,402	2,092	138	7,652
	Percent	0.3	70.6	27.3	1.8	100
1972	Number	67	6,839	2,764	210	9,880
	Percent	0.7	69.2	28.0	2.1	100
1973	Number	132	5,769	2,892	153	8,946
	Percent	1.5	64.5	32.3	1.7	100

Table 7.—Mean fork length (mm) and weight (g) of Gulf menhaden in combined samples of the catch from all ports, by age, 1964-73.

	Length at age				Weight at age			
Year	0	1	2	3	0	1	2	3
1964	120	154	184	201	36	72	131	183
1965	116	147	181	204	33	65	131	192
1966	116	155	182	203	31	79	130	178
1967	102	151	181	203	22	69	122	170
1968	111	157	182	214	27	79	125	207
1969	123	147	186	207	42	66	137	198
1970	110	160	181	208	31	83	125	189
1971	119	157	188	204	31	79	140	180
1972	108	161	187	209	26	82	136	182
1973	121	165	187	213	36	101	148	217
Mean	115	155	184	207	32	78	133	190

AGE AND SIZE DISTRIBUTION BY LONGITUDE

To determine if fish were stratified by age and size along an east-west axis, I calculated the mean age and mean length of each age for each degree of longitude (dividing 89 into two parts: 89a east and 89b west of the delta) by month and year. For summarizing mean lengths I combined all months; for summarizing mean ages I grouped longitudes into three areas: eastern (84-89a), central (89b-91), and western (92-94). Too few samples were obtained from longitudes 84°-87° and 94° to calculate useful mean lengths for each longitude.

There were some differences in mean lengths by longitude, but they were small and not consistant for either age-1 or -2, although 10-yr means of age-2 fish were slightly greater for central longitudes (89b-91) than for the others (Table 9). Monthly means showed no trends.

The mean age tended to be highest in the central area and lowest in the western (Table 10). In all years it was lowest in the western area. In 6 of 10 yr it was higher in the central than in the eastern area and in the other 4 yr it was about the same in both areas. In 1967, when the mean age was about the same in all areas, the fishery was dominated by the 1966 year class, which composed 92% of the fish caught. Monthly means generally declined as the season progressed.

Table 8.—Estimated weights (thousands of metric tons) and percentages of each age of Gulf menhaden landed in the purse seine fishery and the actual weight of fish caught, 1964-73.

Year		Age 0	Age 1	Age 2	Age 3	Total	Actual weight
1964	Weight	0.23	225.76	178.83	20.48	425.30	409.40
	Percent	0.1	53.1	42.0	4.8	100.0	
1965	Weight	1.54	317.72	126.58	13.71	459.55	463.10
	Percent	0.4	69.1	27.5	3.0	100.0	
1966	Weight	1.45	247.02	110.52	5.51	364.50	359.10
	Percent	0.4	67.8	30.3	1.5	100.0	
1967	Weight	0.41	284.92	37.81	1.79	324.93	317.30
	Percent	0.1	87.7	11.6	0.6	100.0	
1968	Weight	0.96	261.61	106.25	5.63	374.45	373.50
	Percent	0.2	69.9	28.4	1.5	100.0	
1969	Weight	0.45	380.61	138.51	6.02	525.59	523.70
	Percent	0.1	72.4	26.4	1.1	100.0	
1970	Weight	1.52	270.28	274.65	6.51	552.96	548.10
	Percent	0.3	48.9	49.6	1.2	100.0	
1971	Weight	0.78	455.30	257.33	30.59	744.00	728.20
	Percent	0.1	61.2	34.6	4.1	100.0	
1972	Weight	0.46	257.99	219.73	13.04	491.22	501.70
	Percent	0.1	52.5	44.7	2.7	100.0	
1973	Weight	2.06	304.25	160.23	23.75	490.29	486.10
	Percent	0.4	62.1	32.7	4.8	100.0	
Mean	Weight	0.99	300.55	160.04	12.70	474.28	471.02
	Percent	0.2	63.4	33.7	2.7	100.0	

Table 9.—Mean lengths (mm) of age-1 and -2 Gulf menhaden in purse seine catches, by degrees of longitude, 1964-73. Longitude 89a is east of the Mississippi delta, 89b is west.

		Longitude (°W)						
Year	Age	88	89a	89b	90	91	92	93
1964	1	151	153	162	156	158	151	153
	2	175	178	189	182	182	181	183
1965	1	138	141	149	150	162	151	152
	2	170	176	186	182	187	179	183
1966	1	158	157	157	156	162	151	151
	2	175	178	183	183	184	177	179
1967	1	146	150	146	151	158	150	149
	2	181	181	178	181	183	175	179
1968	1	160	156	154	141	164	155	155
	2	176	183	186	183	185	182	180
1969	1	146	147	141	150	151	156	146
	2	184	185	187	184	188	187	184
1970	1	163	160	—	158	161	168	157
	2	177	179	—	183	185	178	178
1971	1	155	155	—	158	162	159	151
	2	186	186	—	190	191	188	185
1972	1	159	162	153	154	163	166	158
	2	177	182	187	191	193	186	183
1973	1	159	164	161	166	167	164	159
	2	183	186	195	186	184	184	180
Mean	1	154	155	153	154	161	157	153
	2	178	181	186	185	185	182	181

Table 10.—Mean ages of Gulf menhaden by month and area, 1967-73.

Area (long.)	Month	Year										Mean
		1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	
Eastern	Apr.	1.38	1.24	1.05	1.16	1.65	1.34	—	—	—	1.74	1.37
(84-89a)	May	1.31	1.26	1.14	1.15	1.64	1.16	1.32	1.68	1.42	1.61	1.37
	June	1.13	1.10	1.27	1.16	1.48	1.21	1.27	1.41	1.44	1.64	1.31
	July	1.15	1.08	1.36	1.14	1.45	1.14	1.22	1.51	1.40	1.62	1.31
	Aug.	1.09	1.11	1.14	1.18	1.44	1.11	1.19	1.46	1.36	1.53	1.26
	Sept.	1.01	1.13	1.06	1.06	1.17	1.02	1.22	1.27	1.36	1.58	1.19
	Oct.	1.11	—	—	—	1.26	1.05	—	1.33	1.20	1.56	1.25
	Mean	1.17	1.15	1.17	1.14	1.44	1.15	1.24	1.44	1.36	1.61	1.29
Central	Apr.	2.10	1.73	1.00	—	1.95	—	—	—	—	—	1.70
(89b-91)	May	1.82	1.59	1.60	1.13	1.52	1.18	1.89	—	1.38	1.88	1.53
	June	1.68	1.33	1.38	1.03	1.41	1.23	1.59	1.44	1.51	1.58	1.42
	July	1.50	1.27	1.45	1.03	1.43	1.23	1.56	1.47	1.81	1.54	1.43
	Aug.	1.51	1.29	1.28	1.10	1.47	1.14	1.31	1.37	1.68	1.65	1.38
	Sept.	1.36	1.00	1.25	1.07	0.99	1.48	1.61	1.46	1.48	1.17	1.29
	Oct.	—	—	—	1.00	1.06	1.30	1.13	—	—	—	1.12
	Mean	1.70	1.37	1.33	1.06	1.40	1.26	1.52	1.43	1.57	1.56	1.42
Western	Apr.	—	—	1.00	1.00	—	1.00	—	—	—	—	1.00
(92-94)	May	1.33	1.15	1.42	1.07	1.17	1.00	1.66	1.39	—	1.10	1.25
	June	1.53	1.03	1.04	1.13	1.15	1.26	1.44	1.28	1.29	1.03	1.22
	July	1.53	1.03	1.04	1.13	1.15	1.26	1.44	1.28	1.19	1.03	1.22
	Aug.	1.43	1.01	0.99	1.02	1.05	1.20	1.32	1.02	1.15	1.32	1.15
	Sept.	1.10	0.92	0.79	1.00	0.99	1.09	1.01	0.99	1.17	1.30	1.04
	Oct.	1.00	—	—	—	1.00	1.00	1.00	—	1.08	—	1.02
	Mean	1.30	1.03	1.05	1.05	1.09	1.12	1.13	1.19	1.18	1.16	1.13

Table 11.—Mean lengths (mm) of Gulf menhaden of all ages and percentages of age-1 fish in samples of purse seine catches, by port, 1964-73.

Year	Mean and percent	Port					
		Moss Pt. Miss.	Empire La.	Dulac La.	Morgan City, La.	Intracoastal City, La.	Cameron La.
1964	Mean length	156	176	—	168	—	161
	% Age-1	84	40	—	62	—	73
1965	Mean length	145	157	165	168	161	152
	% Age-1	85	70	69	70	89	97
1966	Mean length	162	166	170	169	—	152
	% Age-1	83	68	57	65	—	86
1967	Mean length	151	163	160	158	—	150
	% Age-1	91	79	90	87	—	99
1968	Mean length	166	169	175	174	159	154
	% Age-1	60	49	33	57	80	96
1969	Mean length	152	153	—	169	167	152
	% Age-1	85	85	—	69	71	86
1970	Mean length	168	—	168	173	173	165
	% Age-1	72	—	53	43	46	73
1971	Mean length	168	—	168	179	170	158
	% Age-1	60	—	71	63	71	84
1972	Mean length	164	173	182	186	185	162
	% Age-1	85	51	37	15	26	89
1973	Mean length	169	180	177	184	—	163
	% Age-1	57	45	75	55	—	87

Mean lengths and weights of all ages combined also tended to be greater in the center of the fishing area, since mean ages were greater and catches contained a higher proportion of older, larger fish. The variation was similar to, but less than that for mean ages. Monthly means showed similar trends.

At ports in the center of the fishery (Empire to Intracoastal City) mean lengths were greater than at ports in the eastern (Moss Pt.) or western (Cameron) areas, and the percentage of age-1 fish in most cases was less (Table 11). The tendency of fish to be older and larger at ports in the center of the fishery probably reflects the tendency of vessels to fish most often in areas close to their home ports. The percentage of age-1 fish tended to be greatest at Intracoastal City, the most western port in the central area, than at other ports in the central area, but smaller than at Cameron.

RECRUITMENT AND RELATIVE ABUNDANCE

Fish usually enter the fishery at age-1 at a minimum size of about 120 mm, although some age-0 fish enter at about the same size in September and October. Since some age-1 fish are still less than 100 mm in July, as shown by catch samples, a year class probably is not fully recruited until August or September. The removal of large and the recruitment of small age-1 fish during the fishing season tends to supress the amount of increase in the mean and modal lengths during the fishing season relative to actual growth.

If age groups are distributed equally in time and space throughout a fishery and if the distribution of fishing effort does not change each year, the catch per unit of effort (CPUE) for each age group is an estimate of relative year class abundance. Since these conditions are closely approximated in the Gulf menhaden fishery, I based estimates of year class abundance on the CPUE of each age group. As a measure of effort, I used the adjusted vessel week[2] which was calculated from the CPUE of a selected group of vessels and the total catch of all vessels.

For the period covered, there was relatively little variation in year class abundance (Table 12). The total CPUE of all ages in a year class combined ranged from 2.577 million fish per week for the 1965 year class to 5.377 million for the 1968 year class, with a mean of 3.742 million for all years. The most abundant year classes appeared to be the 1964, 1968, and 1970, the least abundant the 1965 and 1971. On the basis of the CPUE of age-2 fish only, the 1962 year class also was probably strong.

There also was little variation in overall abundance. The CPUE for total number of fish, regardless of age, averaged 3.63 million for the 10 yr and ranged from 2.95 (1973) to 4.60 million (1969). Years of greatest relative abundance were 1965, 1969, and 1971 (4.42, 4.60, and 4.38 million, respectively); years of least abundance were 1966, 1972, and 1973 (3.02, 3.01, and 2.95 million, respectively).

[2]Nicholson, W. R. 1977. Fishing effort, mortality, and MSY in the Gulf menhaden, *Brevoortia patronus*, purse seine fishery. Unpubl. manuscr., 20 p.

Table 12.—Catch per unit of effort (millions of fish) of Gulf menhaden, at each age, 1962-72 year classes.

Year class	Age 1	Age 2	Age 3	Total
1962	—	1.175	0.053	—
1963	2.698	0.715	0.023	3.436
1964	3.618	0.633	0.008	4.259
1965	2.330	0.227	0.020	2.577
1966	3.025	0.627	0.021	3.673
1967	2.442	0.682	0.022	3.146
1968	3.891	1.392	0.094	5.377
1969	2.062	1.034	0.045	3.141
1970	3.241	1.006	0.076	4.323
1971	1.959	0.750	—	—
1972	2.088	—	—	—

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694. Semiclosed seawater system with automatic salinity, temperature and turbidity control. By Sid Korn. September 1975, iii + 5 p., 7 figs., 1 table.

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