CHANGES IN CATCH AND EFFORT IN THE ATLANTIC MENHADEN PURSE-SEINE FISHERY 1940-68

WILLIAM R. NICHOLSON[1]

ABSTRACT

The catch, number of vessel weeks, and catch per vessel week in the Atlantic menhaden fishery increased during the 1950's. During this period fishing methods improved and the efficiency of vessels increased. Improvements included use of airplanes for spotting schools, aluminum purse boats, nylon nets, power blocks, and fish pumps for catching and handling fish, and larger and faster carrier vessels that could range farther from port. The catch and catch per vessel week began declining north of Chesapeake Bay in the early 1960's. By 1966, fish north of Chesapeake Bay had become so scarce that plants either closed or operated far below their capacity. In Chesapeake Bay the number of vessel weeks increased, and the catch and catch per vessel week decreased through the early and mid 1960's. Variations in catch, effort, and catch per unit of effort showed no trends in the South Atlantic. The annual mean number of purse-seine sets per day varied in different areas and ranged from about 2.0 to 4.5. The annual mean catch per set ranged from about 11 to 25 metric tons.

Catch and effort statistics are important in evaluating and managing any fishery. They may be used in measuring changes in actual or apparent abundance, estimating population sizes and mortality rates, and determining optimum fishing rates.

When investigations of the Atlantic menhaden (*Brevoortia tyrannus*) fishery were begun in 1955 by the Bureau of Commercial Fisheries, provisions were made for collecting and compiling catch and effort statistics. The number and locations of daily purse-seine sets were obtained from logbooks placed aboard vessels at the beginning of the fishing season, and daily catches of individual vessels were copied from plant records.

The objectives of the present study were: (1) to analyze logbook data and vessel landing records to determine differences and changes in the number of purse-seine sets, mean number of sets per day, and the mean catch per set, both between and within geographical divisions of the fishery, (2) to develop a method of measuring fishing effort, and (3) to document changes that have occurred in the fishery.

[1] National Marine Fisheries Service, Center for Estuarine and Menhaden Research, Beaufort, N.C. 28516.

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BRIEF HISTORY OF THE FISHERY

Atlantic menhaden are found from central Florida to Nova Scotia and at one time or another have been exploited over most of this range. Fishing began in the early part of the 19th century in waters off Massachusetts and Maine. Following improved methods of fishing, extracting oil, and processing meal, the fishery expanded in this area in the latter part of the 19th century. When the scarcity of menhaden in waters north of Cape Cod caused the collapse of the fishery in that area, about 1895, the industry shifted to the Middle and South Atlantic coast. By the 1930's processing plants were located in approximately the same areas where they occur today (Figure 1).

Although in some areas pound nets capture menhaden incidentally with other species, purse seines catch nearly all of the fish that are reduced for meal and oil.

Purse seining began in the late 19th century and by present standards was inefficient and laborious. Purse boats were rowed and carrier vessels were sailed. Gradually, sailing vessels were replaced by larger, coal burning steam ships, purse boats were equipped with gasoline

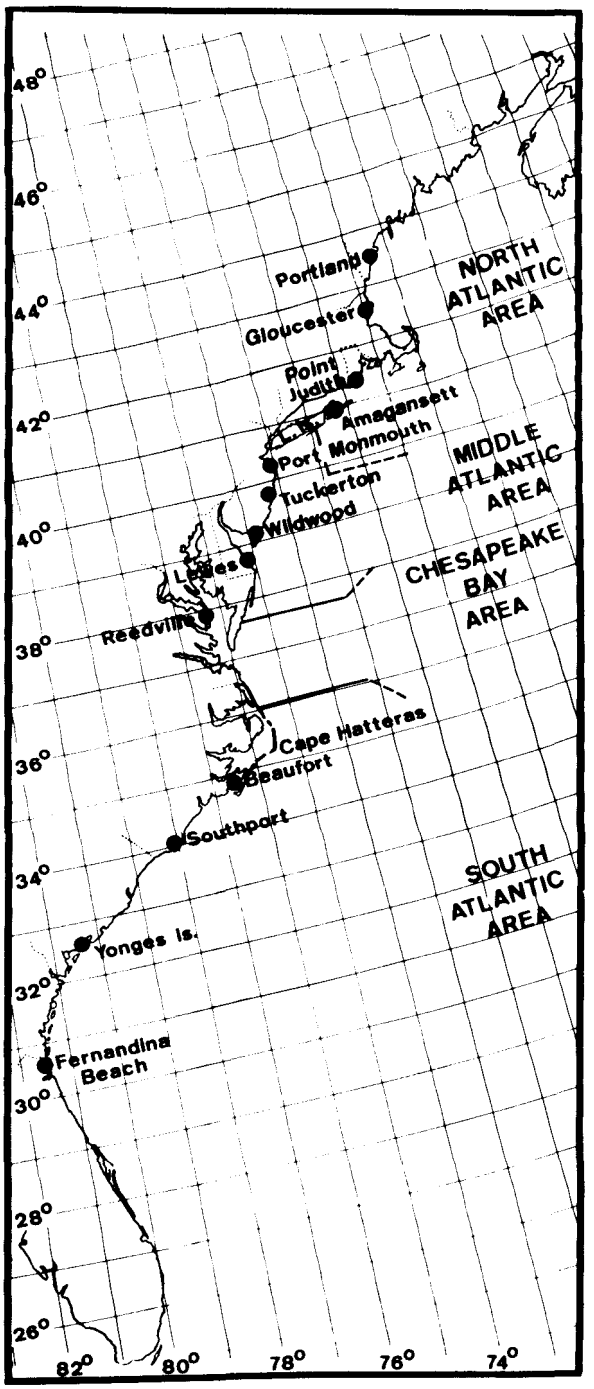

FIGURE 1.—Ports and major fishing areas, Atlantic menhaden fishery.

engines, and seines were made larger. Following World War I, diesel and gasoline engines gradually replaced steam engines in the carrier vessels. Methods of catching and processing menhaden, however, changed very little between World Wars I and II.

After World War II the increased demand for fish meal and oil initiated changes in the industry. Numbers and sizes of vessels increased, methods of fishing changed, processing facilities expanded, and processing efficiency increased.

A major change in fishing methods occurred in 1946 when airplanes were introduced to locate concentrations of fish. Plant operators found this practice so successful that they rapidly added more planes in following years (Table 1). Initially, airplanes scouted wide areas and directed vessels to places where menhaden were abundant. Later, after captains were given portable radios, the airplane pilot directed the actual setting of the net. Since about 1950 airplanes have been an integral part of fishing operations (Robas, 1959; June, 1963).

Fish pumps, initially installed on carrier vessels in 1946, were the first significant advance

TABLE 1.—Number of airplanes used in the Atlantic menhaden fishery.[a]

Year	North Atlantic	Middle Atlantic	Chesapeake Bay	South Atlantic	Total
1945	0	0	0	0	0
1946	0	1	1	0	2
1947	0	7	1	2	10
1948	1	8	1	2	12
1949	1	11	1	2	15
1950	1	10	1	3	15
1951	1	10	1	3	15
1952	2	11	1	4	18
1953	4	11	1	4	20
1954	4	12	3	4	23
1955	5	15	5	4	29
1956	6	15	8	4	33
1957	8	15	9	4	36
1958	8	17	10	4	39
1959	7	17	12	5	41
1960	5	16	7	4	32
1961	6	16	8	4	34
1962	6	16	9	3	34
1963	5	16	11	3	35
1964	4	18	13	4	39
1965	3	6	18	4	31
1966	1	4	18	4	27
1967	0	2	16	4	22
1968	1	2	16	4	23

[a] Exact data are not available for the North Carolina fall fishery. Estimates indicate that 20 to 25 were used each year after about 1955.

in fishing methods after World War II (Robas, 1959). Pumping fish directly from the purse seine to the hold replaced the time-consuming method of brailing and left more time for scouting and making additional sets. By 1955 nearly all vessels were equipped with fish pumps (Table 2).

Before fish in the seine can be pumped or brailed aboard the carrier vessel, they must be concentrated, or "hardened-up." This can be done by crewmen in the purse boats pulling in the net by hand, but it is a laborious process that requires approximately 22 men. A mechanical device, or "power block," for "drying-up" the net, used experimentally in 1955, became operational in 1956 (Schmidt, 1959a). Its use reduced the crew by 6 to 10 men and the average time to "harden-up" the fish by about 6 min (Schmidt, 1959a, 1959b), and enabled the crew to retrieve the net quickly if the fish were missed. Power-blocks were used extensively for the first time in 1958 and by 1966 were installed on nearly all vessels from Long Island southward (Table 2).

Large sets are sometimes lost when the net cannot be raised manually or mechanically to concentrate the fish so that they may be pumped. But the pump head, if positively charged with electricity, becomes an electrode that attracts and concentrates menhaden without the necessity of raising the bunt (Kreutzer 1959). Such a device, commonly called a "fish shocker," was first installed on vessels in 1956, but its use did not spread beyond the Middle and North Atlantic areas. By 1966 it had fallen into disuse (Table 3).

Beginning in 1954, nylon nets gradually replaced cotton or linen nets (Table 3). Although more expensive initially, nylon nets last longer and do not split or tear when filled with fish as other nets sometimes do.

Aluminum purse boats began replacing wooden purse boats in 1957 (Table 3). Being lighter, more maneuverable, and more stable than wooden boats, they can encircle a school of fish easier

TABLE 2.—Percent of vessels equipped with fish pumps and power blocks in the Atlantic menhaden purse-seine fishery.

Year	Middle Atlantic[a]		Chesapeake Bay		South Atlantic	
	Fish pumps	Power blocks	Fish pumps	Power blocks	Fish pumps	Power blocks
1946-49	0	0	10-20	0	0	0
1950	6	0	24	0	0	0
1951	13	0	25	0	0	0
1952	32	0	31	0	0	0
1953	44	0	22	0	9	0
1954	48	0	25	0	10	0
1955	81	0	90	0	11	0
1956	78	2	92	0	23	0
1957	91	2	88	16	23	0
1958	96	100	100	57	25	0
1959	100	100	100	68	45	0
1960	100	100	100	95	45	0
1961	100	100	100	74	45	0
1962	100	100	100	66	50	31
1963	100	100	100	83	69	31
1964-68	100	100	100	100	64-74	42-69

a Includes Amagansett from North Atlantic Area.

TABLE 3.—Percent of vessels equipped with fish shockers, nylon nets, and aluminum purse boats in the Atlantic menhaden purse-seine fishery.

Year	Middle Atlantic[a]			Chesapeake Bay			South Atlantic		
	Fish shockers	Nylon nets	Aluminum purse boats	Fish shockers	Nylon nets	Aluminum purse boats	Fish shockers	Nylon nets	Aluminum purse boats
1954	0	2	0	0	0	0	0	0	0
1955	0	5	0	0	0	0	0	0	0
1956	47	19	0	0	4	0	0	0	0
1957	45	18	0	0	44	0	0	13	0
1958	85	100	66	0	82	4	0	14	0
1959	85	100	85	0	94	23	0	20	0
1960	82	100	82	0	100	32	0	45	0
1961	82	100	82	0	100	30	0	58	0
1962	82	100	89	0	100	63	0	81	33
1963	82	100	100	0	100	83	0	100	50
1964	78	100	100	0	100	100	0	100	50
1965	86	100	100	0	100	100	0	100	58
1966	0	100	100	0	100	100	0	100	69
1967	0	100	100	0	100	100	0	100	100
1968	0	100	100	0	100	100	0	100	100

a Includes Amagansett from North Atlantic Area.

and faster, and can operate more easily in rough seas.

Three jet-propelled purse boats were introduced in 1962. Adjustable jet nozzles on each end gave the boats excellent maneuverability, and there was no propeller or guard to entangle nets. They lacked the power to close up the seine rapidly, however, and were abandoned.

With the exception of airplanes for spotting, none of the improvements were adopted by vessels in the Point Judith, Gloucester, or Portland fleets. All vessels fishing from these ports were small to medium-sized otter trawlers that were converted to purse seining for only about 2 months during the summer.

DESCRIPTION OF THE FISHERY

The purse-seine season for menhaden extends from late spring through fall, but the time varies in different localities. South of Cape Hatteras, N.C., it begins in April or May and lasts until late December or early January. From Chesapeake Bay to the southern shore of Long Island it begins in late May and usually ends about the third week in October. North of Cape Cod the season lasts only from about late June to early September.

To facilitate summarizing and discussing annual changes in the fishery, June and Reintjes (1959) divided the range of Atlantic menhaden into four areas, the North Atlantic, Middle Atlantic, Chesapeake Bay, and South Atlantic (Figure 1). Although the boundaries are arbitrary, they were drawn to take advantage of natural separations in the fishing areas. Similarities in age and size composition of the catches, time and duration of fishing, and range of vessels from the home port tended to set each area apart. The North Carolina fall fishery, a specialized fishery that occurs only during November and December from Cape Hatteras to Cape Fear, is distinct from the summer fishery in the South Atlantic and was treated as if it were an area. This classification, which provides a convenient way of expressing statistics of the fishery, is used in the present analysis. Ports in the South Atlantic area are Fernandina Beach, Fla.; Yonges Island, S.C.; and Southport and Beaufort, N.C.; in the Chesapeake Bay area—Reedville, Va.; in the Middle Atlantic area, Lewes, Del.; and Wildwood, Tuckerton, and Port Monmouth, N.J.; in the North Atlantic area—Amagansett, N.Y.; Point Judith, R.I.; Gloucester, Mass.; and Portland, Maine; and in the North Carolina fall fishery—Beaufort and Morehead City, N.C.

A disadvantage of the fishery area concept is that all of the fish landed at a port in a particular area may not have been caught in that area. The problem is not serious, however, because vessels seldom fish in areas other than the one in which their home port is located. Port Monmouth vessels, which sometimes go through the East River to fish in western Long Island Sound, and Amagansett vessels, which sometimes fish off the northern New Jersey coast, contradict this general rule more often than do vessels at other ports.

The number and location of daily purse-seine sets each year from 1955 to 1966 were obtained from logbooks placed aboard vessels at the beginning of each fishing season. Port samplers were instructed to pick up copies of each page every 2 weeks, answer questions pertaining to the methods of keeping the logs, and stimulate interest of the pilots to keep the logs complete and up to date. From 25 to 100% of the boats fishing at each port kept logs. Although generally over 60% of the fleet was covered each year, many vessels did not keep complete records.

Daily landings of each vessel were copied from plant records. Although some records extended back as far as 1912, records at most plants were not available for years prior to 1940.

ANNUAL CATCH

No trends were evident in the annual catches in the South Atlantic area or North Carolina fall fishery, but the catches in the other three areas reflected an increase in fishing effort after 1945 and a decline in abundance after 1956 (Table 4). After reaching a peak in 1956 of 378,300 metric tons in the Middle Atlantic area and 98,500 tons in the North Atlantic area, the catch declined to 6,000 and 1,800 tons, respectively in 1966. In the Chesapeake Bay area the catch decreased from 196,800 metric tons in

1959 to 115,600 tons in 1966. In the North Atlantic area, the Point Judith, Gloucester, and Portland fleets, which began menhaden fishing about 1949, accounted for most of the increases between 1950 and 1960. Menhaden were not landed at Portland after 1957 or at Gloucester and Point Judith after 1962.

CALCULATION OF FISHING EFFORT

In any searching fishery where the sizes and types of vessels vary, the unit of fishing effort is difficult to define. Marr (1950) found a positive linear relation between mean catch per boat week and boat length in the Pacific sardine (*Sardinops sagax*) fishery off Oregon. He selected the modal boat-length group as a standard, calculated the catch per boat week of boats in this group for each year, and based his estimates of apparent abundance on this index. He was unable, however, to estimate total effort except by dividing the total catch of all vessels by the catch per unit of the standard group.

Silliman and Clark (1945), studying the Pacific sardine fishery off California, linked groups of identical vessels and estimated apparent abundance from the catch per boat week of these groups. They estimated the total effort by dividing the total catch by the catch per boat week of the linked group, assuming that the catch per boat week of the selected vessels was representative of the catch per boat week of the fleet, and using a base season for each of the three areas they studied. Recognizing the effect of differences in vessel size on catch per unit of effort, they used a standard multiple regression to estimate total effort in each area by relating in a single equation the length and horsepower of each vessel, the number of vessels, and the number of weeks.

Clark and Daugherty (1950) extended the study by Silliman and Clark through the 1948-49

TABLE 4.—Atlantic menhaden purse-seine catch by year and area.

Year	Area					Total
	North Atlantic	Middle Atlantic	Chesapeake Bay	South Atlantic	North Carolina fall fishery	
	thousands of metric tons					
1940	16.8	91.1	35.3	37.9	36.6	217.7
1941	33.5	104.1	60.2	45.2	34.9	277.9
1942	14.6	77.7	21.9	32.9	20.1	167.2
1943	9.8	96.8	42.1	59.7	28.8	237.2
1944	27.5	122.6	32.2	46.9	28.7	257.9
1945	34.0	136.4	35.1	58.5	31.9	295.9
1946	42.9	183.8	57.6	40.8	37.3	362.4
1947	44.2	185.8	81.2	34.2	32.9	378.3
1948	44.4	137.4	68.3	55.8	40.6	346.5
1949	52.2	149.8	62.8	59.3	39.7	363.8
1950	49.3	143.0	63.1	20.0	21.8	297.2
1951	51.0	168.6	56.1	54.6	31.1	361.4
1952	58.1	193.7	45.7	86.0	26.4	409.9
1953	59.7	363.2	77.8	52.8	39.7	593.2
1954	64.9	335.7	126.0	39.6	41.9	608.1
1955	83.3	317.6	132.7	43.4	64.4	641.4
1956	98.5	378.3	94.0	68.6	72.7	712.1
1957	83.5	304.5	126.4	36.4	52.0	602.8
1958	36.0	211.1	151.3	41.3	70.3	510.0
1959	66.0	250.9	196.8	63.1	82.3	659.1
1960	66.4	256.0	108.5	36.7	62.2	529.8
1961	58.6	274.6	128.7	44.1	69.9	575.9
1962	64.7	249.9	155.1	42.2	25.8	537.7
1963	35.2	111.7	104.0	34.2	62.8	347.9
1964	15.0	35.2	134.1	46.5	38.4	269.2
1965	11.9	45.8	126.1	36.7	52.9	273.4
1966	1.8	6.0	115.6	24.5	71.7	219.6
1967	0	17.1	91.1	34.1	51.2	193.5
1968	6.7	26.2	115.5	33.6	52.8	234.8

season. They also used linked groups of vessels, but simplified calculations by using catch per lunar month rather than catch per week.

June and Reintjes (1957), studying the menhaden fishery off Delaware Bay, used the linkage method to determine the catch per boat week for selected boats from 1939 to 1953. They estimated the total number of boat weeks by dividing the total catch by the catch per boat week.

In the yellowfin tuna (*Thunnus albacares*) bait-boat fishery in the eastern tropical Pacific, Shimada and Schaefer (1956) grouped vessels by carrying capacity. They computed the catch per days absence from port for each group and established one group as a standard. They standardized effort by dividing the catch per days absence of the standard group by the catch per days absence of each other group. Broadhead (1962) related the catch per day of bait boats to the catch per day of purse-seine vessels by using regression analysis.

Menhaden plant records, while showing the date and amount of fish landed by each vessel, do not list days when vessels fish and catch nothing, and do not indicate whether a catch represents 1 or more days' fishing. While vessels generally land their catch daily, quite often in the Middle and North Atlantic areas they land 2 or 3 days' catch at one time, particularly in late spring and early fall, a practice which has increased in recent years as fish have become scarce and daily catches smaller.

There is no satisfactory way of getting the complete daily history of each vessel. Even if port samplers recorded each vessel's daily activity, the records still would be incomplete because not all ports are sampled and because no ports were sampled prior to 1955. Logbook records also are incomplete. Any effective method of measuring effort, therefore, must use vessel landings as they are recorded at the plants.

Fortunately, menhaden vessels generally operate continuously throughout all or part of the fishing season and fish every day that weather permits, unless in port for repairs. Except in the North Carolina fall fishery, which lasts only 6 to 8 weeks, the number of days that bad weather prohibits menhaden fishing is relatively small and is relatively constant from year to year. Any time period, therefore, that assumes continuous fishing and accounts for unproductive fishing days should be a satisfactory unit of basic fishing effort. Because the vessel week satisfies these conditions and may be readily computed, it was selected as the basic unit.

Because variations in the catch per unit of effort among vessels may necessitate adjusting the basic unit to a common standard, the relative efficiency of vessels fishing from each port was examined.

No clear correlation could be shown between catch per week and vessel length or weight, so the relation between mean catch per week and vessel carrying capacity was explored. Carrying capacity, determined for each vessel by averaging the 10 largest catches for 3 consecutive years, ranged from about 100 to 350 short tons (90-317 metric tons). Vessels were grouped, according to their carrying capacity in short tons, into six classes:

Class	Carrying capacity
1	<141
2	141-180
3	181-220
4	221-260
5	261-300
6	>300

The relative efficiency of vessels at each port was examined by plotting the mean catch per week of each vessel and by plotting the catch per week against carrying capacity.

In the South Atlantic area all vessels were class 3 at Fernandina Beach, Yonges Island, and Southport, and class 1 or 3 at Beaufort. Variation in the catch per week among vessels was evident at all ports, but there was no distinct tendency for any group to have larger or smaller catches per week than another.

Until about 1963 nearly all vessels in Chesapeake Bay were class 3, although a few were class 2, 4, or 5. After 1961 the number of class 5 vessels increased. Although the large capacity vessel tended to have greater mean catches per week than small capacity vessels, the variation was extreme among all vessels, both between and within years. As the catch per week declined after 1961, the variation between vessels of small and large capacities decreased.

In the Middle Atlantic area vessels ranged from class 2 to 6, but no more than two classes occurred at any port. At Port Monmouth and Tuckerton, class 6 vessels did not show substantially greater catches per week than class 5 vessels. Class 5 vessels at Lewes clearly had greater catches per week than class 3 vessels, while class 5 vessels at Wildwood had greater catches per week than class 2 vessels.

Because the increases in the catch per vessel week that accompanied the increases in vessel carrying capacity were small and inconsistent and the variability between ports was great, no vessel class was designated as a standard for the fishery. Effort was simply left unadjusted at all except five ports—Lewes, Wildwood, Point Judith, Gloucester, and Portland.

Effort at Lewes and Wildwood was adjusted because the differences in the catch per unit of effort between the two classes at each port were large. At these ports the 10-year mean of the ratio of the catch per week of the group of larger vessels to that of the group of smaller vessels was computed for 1950-59. Annual effort of the smaller vessels was adjusted by multiplying the total number of weeks fished each year by the mean ratio, 0.610 for Wildwood and 0.573 for Lewes.

Effort at the other three ports was adjusted because many of the vessels, which were small to medium-size otter trawlers temporarily converted to purse seiners during the summer, fished intermittently, usually only when menhaden were plentiful. Because effort could not be measured very precisely under these conditions, it was estimated in terms of Amagansett units by dividing the annual catches at these ports by the mean catch per week of Amagansett vessels.

Most menhaden vessels were class 3, 4, or 5. At most ports the relative proportions of one class to another changed very little each year and the number of vessels remained fairly constant (Table 5). Under such conditions the number of vessel weeks, with minor adjustments, was as precise an estimate of total fishing effort as was possible to obtain. Various other adjustments might have been made, but with doubtful improvement in the overall estimate of fishing effort.

Henceforth, vessel weeks will refer to units of fishing effort and will include these adjustments.

NUMBER OF VESSEL WEEKS

After World War II ended in 1945, the number of vessel weeks rose sharply in the Chesapeake Bay, Middle Atlantic, and North Atlantic areas (Table 6). The increase resulted from the addition of vessels in all areas and from an increase in the number of weeks that plants in the North and Middle Atlantic operated.

After 1959 in the North Atlantic and 1962 in the Middle Atlantic, the number of vessel weeks dropped sharply. Much of the decrease in the North Atlantic between 1959 and 1962 can be attributed to a reduced number of converted trawlers at Portland, Gloucester, and Point Judith, where no menhaden were landed after 1962. After 1962 the number of vessels at Amagansett also declined. Reduced effort in the Middle Atlantic after 1962 was due to a decrease in the number of vessels. The Tuckerton plant and one of the Lewes plants closed during the 1964 season and never reopened. The Wildwood plant operated only a few weeks each year after 1964, and the boats were transferred to plants in Chesapeake Bay. The remaining plant at Lewes closed after the 1965 season.

Effort in the Chesapeake Bay area fluctuated between approximately 300 and 400 vessel weeks from 1944 to 1954; thereafter it generally increased (except when fishing was restricted in 1960 because of a poor market) until about 800 vessel weeks were reached in 1964-66. Additional vessels accounted for most of the increase through 1963. In 1964-68, fishing terminated approximately 7 weeks later (mid-November) than in previous years.

In the South Atlantic area, effort fluctuated between 245 and 530 vessel weeks from 1941 to 1968. Although some fluctuation was due to variation in the length of the fishing season, particularly in Florida, most was due to variations in the number of vessels. The annual number of vessels, and vessel weeks, generally was less from 1960 to 1968 than in previous years.

In the North Carolina fall fishery, the number of vessel weeks varied from 97 to 457 and

TABLE 5.—Number of menhaden vessels fishing at Atlantic coast ports, by class capacity.

Year	Amagansett, N.Y.		Port Monmouth, N.J.		Tuckerton, N.J.		Lewes, Del.		Wildwood, N.J.		Reedville, Va.				Beaufort, N.C.			Southport, N.C.		Fernandina Beach, Fla. and Yonges Is., S.C.
	Class		Class		Class		Class		Class		Class				Class			Class		Class
	5	6	5	6	5	6	3	5	2	5	2	3	4	5	1	2	3	2	3	3
1940	a	a	a	a	0	0	15	4	3	0	2	7	1	0	10	4	0	4	0	a
1941	9	0	a	a	0	0	12	3	5	0	2	12	1	0	6	1	0	5	0	15
1942	9	0	a	a	0	0	16	3	3	0	2	12	1	0	6	1	0	3	0	10
1943	5	0	a	a	0	0	12	1	3	0	1	6	0	0	5	0	0	2	0	15
1944	6	0	a	a	0	0	20	4	3	0	1	9	1	0	6	0	0	3	0	13
1945	6	0	a	a	4	0	10	5	2	0	1	10	1	0	5	0	0	3	0	12
1946	7	0	a	a	5	0	12	7	2	0	1	8	1	0	6	0	0	3	0	8
1947	8	0	a	a	5	0	14	6	2	0	1	13	1	0	5	0	1	3	0	8
1948	9	0	a	a	5	0	20	11	3	0	2	14	1	0	9	2	2	3	0	12
1949	7	2	a	a	6	0	15	10	3	0	1	13	1	0	7	1	2	3	3	14
1950	7	2	a	a	6	0	12	11	3	1	1	13	1	2	5	2	3	3	3	8
1951	8	2	a	a	6	0	12	13	2	2	1	13	1	1	5	2	1	2	3	9
1952	7	2	a	a	6	0	7	11	2	2	1	10	1	1	6	1	2	3	5	10
1953	7	2	a	a	5	1	10	14	3	3	1	16	1	0	6	1	2	3	5	12
1954	7	2	a	a	5	1	10	12	4	3	2	17	1	0	6	1	2	2	5	11
1955	8	2	8	2	5	1	9	16	3	4	2	16	1	1	6	11	2	1	6	14
1956	9	2	7	3	4	2	6	18	2	5	3	19	1	1	6	1	3	1	7	12
1957	8	2	6	4	4	2	6	16	3	5	4	18	1	2	6	1	3	0	7	14
1958	8	2	6	4	4	2	5	15	2	6	4	19	1	4	6	1	3	0	7	9
1959	8	2	6	4	4	2	4	17	2	6	5	21	1	4	7	0	3	0	8	7
1960	8	2	6	4	4	2	4	17	2	8	2	16	1	3	6	0	3	0	8	3
1961	8	2	6	4	4	2	4	17	2	8	3	17	1	2	6	0	3	0	8	3
1962	8	2	6	4	4	2	4	17	2	8	3	17	1	8	5	0	3	0	4	3
1963	8	2	6	4	4	2	3	18	2	7	3	18	1	14	5	0	3	0	5	3
1964	7	2	3	4	4	2	0	15	2	7	2	16	1	19	5	0	3	0	5	3
1965	4	2	1	5	0	0	0	7	0	b	2	13	1	22	5	0	3	0	5	6
1966	3	2	1	4	0	0	0	5	0	b	2	8	1	25	5	0	3	0	3	5
1967	0	0	1	3	0	0	0	0	0	b	0	8	1	23	6	0	2	0	3	5
1968	0	2	1	3	0	0	0	0	0	b	0	6	1	18	6	0	2	0	3	5

a Records not available.
b Variable.

TABLE 6.—Number of vessel weeks per season in the Atlantic menhaden fishery, by year and area.

Year	Area					Total
	North Atlantic	Middle Atlantic	Chesapeake Bay	South Atlantic	North Carolina fall fishery	
1940	a	337	329	a	a	a
1941	141	392	417	506	227	1,683
1942	89	323	251	376	194	1,233
1943	49	287	202	419	166	1,123
1944	84	397	296	316	224	1,317
1945	89	477	302	394	234	1,496
1946	132	528	294	343	291	1,588
1947	134	552	418	322	333	1,759
1948	130	675	405	430	288	1,928
1949	156	691	385	473	457	2,162
1950	155	614	403	322	187	1,681
1951	157	676	369	379	222	1,803
1952	150	580	333	474	220	1,747
1953	161	819	376	474	244	2,074
1954	189	838	408	488	262	2,185
1955	334	890	451	475	342	2,492
1956	298	888	466	530	391	2,573
1957	262	949	527	412	311	2,461
1958	227	734	559	354	380	2,254
1959	301	897	668	474	312	2,652
1960	280	854	410	292	163	1,999
1961	249	946	482	395	224	2,296
1962	264	990	582	327	97	2,260
1963	238	823	666	264	286	2,277
1964	134	376	803	277	249	1,839
1965	96	300	786	359	259	1,800
1966	79	87	795	254	220	1,435
1967	0	124	757	253	212	1,346
1968	23	113	601	245	246	1,228

a Records not available.

depended primarily on the number of vessels, the season generally lasting about 7 or 8 weeks.

CATCH PER VESSEL WEEK

Despite sharp fluctuations that occurred annually, there were pronounced trends in the catch per vessel week in three areas (Table 7). In the North Atlantic area, the catch per vessel week remained at a high level through 1957, dropped sharply in 1958 and continued to decline thereafter. From a peak of 385 metric tons per week in 1952, it dropped to 23 in 1966. The high figure for 1968 (292) reflects the fact that two vessels, one fishing from late June until mid-October and another during August and early September, caught most of the fish available.

The most significant changes occurred in the Middle Atlantic and Chesapeake Bay areas. From 348 metric tons per week in 1946, the catch per vessel week in the Middle Atlantic area dropped to 203 in 1948, and thereafter rose steadily, attaining 444 tons in 1953. From 1954 to 1957 it remained high, between 320 and 426 tons. Between 1958 and 1961, it declined relative to the previous 4 years, but still remained between 279 and 299 tons. It dropped to 253 tons in 1962, and 70 tons in 1966. By contrast, the catch per vessel week in the Chesapeake Bay area was low from 1943 to 1953, fluctuating between 109 and 207 tons, and high from 1954 to 1962, fluctuating, except for 1956, between 239 and 309 tons. In 1963 the catch per week dropped to 156 tons and then continued a downward trend.

In the South Atlantic the catch per vessel week showed no trends. The figures generally ranged from about 86 to 136 metric tons, with extreme fluctuations of from 39 to 180 tons.

In the North Carolina fall fishery the catch per vessel week from 1941 to 1954 fluctuated

TABLE 7.—Mean catch of Atlantic menhaden per vessel week, in metric tons, Atlantic menhaden fishery.

Year	Area				
	North Atlantic	Middle Atlantic	Chesapeake Bay	South Atlantic	North Carolina fall fishery
1940	a	273	107	a	a
1941	237	266	144	89	154
1942	164	240	88	88	104
1943	200	337	208	142	173
1944	327	309	109	149	128
1945	383	286	116	148	136
1946	325	348	196	119	128
1947	329	336	194	106	98
1948	342	203	169	130	141
1949	335	217	163	125	87
1950	318	233	157	62	117
1951	325	249	137	144	140
1952	387	333	136	181	120
1953	371	444	207	111	162
1954	343	401	309	81	160
1955	249	357	294	91	188
1956	330	426	201	130	186
1957	319	320	239	88	167
1958	159	288	270	117	185
1959	219	279	295	133	263
1960	237	299	265	126	381
1961	235	290	267	111	312
1962	245	253	267	129	266
1963	148	135	156	130	220
1964	112	93	167	168	154
1965	124	152	161	102	203
1966	23	69	145	96	326
1967	0	138	121	135	241
1968	292	232	192	137	215

a Records not available.

between 87 and 173 metric tons and averaged 132 tons, and from 1955 to 1968 fluctuated between 156 and 381 and averaged 239 tons. The increased use of airplanes and other improvements in fishing methods, rather than any increases in the abundance of menhaden, probably were responsible for the large catches per vessel week in the later years.

While the catches per vessel week were lower for ports in the South Atlantic area than for ports in the Middle Atlantic, the variation between ports in each area was of about the same magnitude (Table 8). In the South Atlantic the figures for Southport and Fernandina Beach were about equal to each other but higher than for Beaufort. In the Middle Atlantic the catch per vessel week usually was highest at Tuckerton.

The monthly catch-per-vessel-week figures were computed for each area, but they showed no consistent trends or variation worth noting.

NUMBER OF PURSE-SEINE SETS

The number of purse-seine sets was estimated from logbooks and reduction plant records by the formula:

$$S_t = L_t(S_1/L_1)$$

where:

S_t = number of estimated monthly sets,
S_1 = number of sets from logbooks,
L_1 = number of days for which number of sets is known,
L_t = total number of landings days from plant records.

Vessels at each port were stratified by months and by loading capacity, on the assumption that the number of sets per day varied with both time and capacity. The number of monthly sets was estimated for vessels in each stratum.

TABLE 8.—Mean catch of Atlantic menhaden per vessel week, in metric tons, landed at ports in the South and Middle Atlantic areas.

Year	Fernandina Beach, Fla., and Yonges Is., S.C.	Southport, N.C.	Beaufort, N.C.	Lewes, Del.	Wildwood, N.J.	Tuckerton, N.J.	Port Monmouth, N.J.
1940	a	73	27	255	165	b	318
1941	106	88	36	292	211	b	257
1942	109	84	34	261	243	b	217
1943	170	119	51	337	309	b	344
1944	170	148	107	319	269	b	302
1945	134	164	97	331	309	198	256
1946	121	181	80	413	331	306	278
1947	73	180	103	382	234	343	252
1948	129	158	118	189	210	216	226
1949	78	207	110	238	200	213	186
1950	71	54	57	256	164	270	188
1951	193	82	70	266	140	279	233
1952	247	154	75	367	177	412	259
1953	140	98	75	444	505	524	374
1954	100	93	72	438	359	457	327
1955	85	107	80	404	333	433	258
1956	138	148	103	436	346	518	399
1957	86	104	73	301	255	368	377
1958	63	193	74	366	268	221	194
1959	194	161	70	301	253	252	273
1960	184	143	86	346	259	278	259
1961	157	132	64	332	259	258	258
1962	180	133	92	247	240	254	269
1963	149	108	127	115	150	137	155
1964	129	227	140	34	80	61	56
1965	105	137	69	131	103	b	187
1966	137	67	72	50	238	b	48
1967	173	172	192	b	171	b	122
1968	122	260	189	b	175	b	261

a Records not available.
b Plant closed.

Monthly totals at each port were obtained by summing the estimates for each stratum, seasonal totals by summing the monthly estimates, and area totals by summing the totals of each port. The mean number of sets per day for either month or season was calculated by dividing the total number of estimated sets by the total number of fishing days.

Because of the difficulty of maintaining good logbook records in recent years, the analysis was not continued beyond 1966. By that time little fishing was done north of Chesapeake Bay.

At ports where more than one size class of vessels fished, the larger vessels generally averaged slightly more sets per day than the smaller ones (Table 9). The differences were greater at ports where the vessel classes were not adjacent (Lewes and Wildwood) than they were at ports where the vessel classes were adjacent (Amagansett, Port Monmouth, and Tuckerton). Because data were insufficient to calculate the mean catch per set for each vessel class in Chesapeake Bay, the data were combined for classes 2 and 3, and 4 and 5. After 1964 the lack of data made meaningful comparisons impossible.

The slightly greater mean number of sets per day for the larger vessels may reflect the ability of these vessels to steam faster and range farther from their home port, and to carry more fish when fully loaded. More than likely, these figures reflect the ability and aggressiveness of the vessel captains, since the better ones generally are assigned to the larger vessels.

The annual or monthly number of sets (Table 10) reflected the abundance of fish and the amount of fishing effort. Excluding the North Carolina fall fishery, the most sets per season through 1963 were usually made in the Middle Atlantic area and the fewest sets in the South Atlantic. After 1963, following the drastic decline of the fishery and the decrease in effort in the Middle and North Atlantic areas, the number

TABLE 9.—Mean number of purse-seine sets per day, Atlantic menhaden fishery, by port and vessel class.

Year	Amagansett, N.Y.		Port Monmouth, N.J.		Tuckerton, N.J.		Lewes, Del.		Wildwood, N.J.		Reedville, Va.	
	Class		Class		Class		Class		Class		Class	
	5	6	5	6	5	6	3	5	2	5	2-3	4-5
1955	2.49	2.91	3.23	3.71	--	--	3.46	3.93	3.07	3.93	--	--
1956	2.82	2.88	3.43	4.03	4.41	4.68	3.38	3.98	3.15	3.99	--	--
1957	3.34	3.17	3.98	4.00	4.44	4.54	3.67	4.52	3.22	3.75	4.56	5.25
1958	2.63	2.83	3.26	2.71	2.78	3.67	3.79	3.07	--	--	4.12	3.76
1959	2.72	3.06	3.75	3.58	3.86	4.21	3.19	3.92	2.88	3.43	4.40	4.84
1960	2.79	2.81	3.69	3.54	4.29	4.57	--	4.84	3.61	3.96	3.86	4.38
1961	3.00	3.35	3.40	3.85	3.98	3.75	3.28	4.21	3.07	3.50	3.92	4.40
1962	2.78	3.29	3.49	3.85	3.49	3.61	3.53	3.46	2.74	3.09	2.86	3.42
1963	2.51	3.03	2.60	3.17	3.16	3.27	2.14	3.34	2.96	2.95	3.09	3.39
1964	2.30	2.91	2.41	2.65	--	3.85	--	--	--	--	2.95	3.62
Mean	2.74	3.02	3.32	3.51	3.80	4.02	3.31	3.92	3.09	3.58	3.72	4.13
Difference	0.28		0.19		0.22		0.61		0.49		0.41	

of sets in Chesapeake Bay, reflecting the increase in effort, was more than double the number in any other area.

There also were differences in the mean number of sets per day between areas (Table 11). Generally, the greatest number of sets per day was made in Chesapeake Bay, where vessels averaged about 0.10 set per day more than vessels in the Middle Atlantic. The fewest sets per day were made in the South Atlantic, where the tendency of schools to disappear by midday limited fishing to the forenoon, and in the North Carolina fall fishery, where the huge schools of fish enabled the vessels to load with relatively few sets.

CATCH PER SET

The mean catch per set varied monthly and annually in each area (Table 12). In all areas except the North Atlantic, it tended to be smaller during the middle part of the season than during the early or later part. In the Middle and North Atlantic areas, it averaged 9 tons more in October than in any other month. Annually, it fluctuated randomly in all areas except the Middle Atlantic, where it decreased after 1962.

Since purse seines tend to capture an entire school, the mean catch per set is an estimate of mean school biomass.

The school biomass appears to increase as the average age of the fish constituting the school increases. The catch per set in the North Atlantic, where 3-year and older fish constitute the bulk of catch, was higher than in the South Atlantic and Chesapeake Bay, where 1- and 2-year-old fish compose most of the catch (Nicholson and Higham, 1964). In the South Atlantic in 1960 and 1961, and in Chesapeake Bay in 1958, 1960, and 1961, when 2- rather than 1-year-old fish composed an unusually high percentage of the catch (Nicholson and Higham, 1964), the mean catch per set was relatively high. In the Middle Atlantic area in 1955 and 1956, when the catch contained a large percentage of fish older than age 2 (June and Reintjes, 1959, 1960), the mean catch per set was relatively high. Both the mean catch per set and the average age were low in the North Atlantic in 1957 and 1958. In the Middle Atlantic both the average age and the mean catch per set tended to decrease from June to September and then increase sharply in October, while in the North Atlantic both tended to increase from June to October.

Except for the South Atlantic area, where the disappearance of schools by midday limits the number of sets, the mean number of sets per day (Table 11) and the mean tons per set (Table 12) were inversely correlated, implying that fewer sets were necessary to load a vessel in areas where the school biomass was large, that schools became more numerous as their biomass decreased, or that heavy fishing pressure tended to keep school size small.

Relative abundance also appears to influence school biomass, but the relationship is not clear. When the catch per vessel week, a measure of

TABLE 10.—Estimated number of purse-seine sets in the Atlantic menhaden fishery, by year, month, and area.

Area	Year	Month							Total	North Carolina fall fishery
		Apr.-May	June	July	Aug.	Sept.	Oct.	Nov.		
South Atlantic and North Carolina fall fishery	1955	640	1,422	716	303	77	196	0	3,354	1,477
	1956	1,421	817	463	572	411	197	0	3,881	2,358
	1957	606	761	435	564	315	85	0	2,766	1,556
	1958	704	708	574	365	561	118	0	3,030	2,354
	1959	812	1,260	1,129	847	506	225	0	4,779	1,827
	1960	126	506	590	847	131	105	0	2,305	1,408
	1961	310	512	420	512	457	131	0	2,342	1,316
	1962	432	648	454	573	806	259	0	3,172	2,568
	1963	513	354	380	606	449	140	0	2,442	2,121
	1964	403	634	540	496	216	--	0	2,289	1,412
	1965	270	531	392	393	309	246	0	2,141	1,826
	1966	120	298	257	387	235	62	0	1,359	1,603
Chesapeake Bay	1955	--	--	--	--	--	--	--	--	
	1956	0	2,025	1,485	2,444	1,361	376	0	7,691	
	1957	0	2,697	2,501	2,880	2,292	762	0	11,132	
	1958	0	1,916	2,093	2,208	2,423	550	0	9,190	
	1959	0	3,060	3,036	2,914	2,657	1,328	0	12,995	
	1960	0	1,450	1,468	1,878	1,525	899	0	7,220	
	1961	0	2,376	1,713	1,874	1,257	802	0	8,022	
	1962	0	1,306	2,751	1,346	1,491	1,227	0	8,121	
	1963	0	2,150	1,374	1,567	1,411	979	0	7,481	
	1964	0	2,253	1,798	1,925	1,747	1,334	1,037	10,094	
	1965	0	1,927	1,137	1,912	1,633	1,533	795	8,937	
	1966	0	1,473	1,484	2,460	1,386	1,550	888	9,241	
Middle Atlantic	1955	0	3,857	3,483	2,693	2,304	920	0	13,257	
	1956	0	3,740	3,258	4,264	2,130	950	0	14,342	
	1957	0	3,589	3,991	4,637	2,641	2,045	0	16,903	
	1958	0	1,216	2,352	3,098	2,919	243	0	9,828	
	1959	0	2,884	3,496	3,184	2,448	805	0	12,817	
	1960	0	2,894	3,889	4,707	2,162	1,556	0	15,208	
	1961	0	3,529	3,780	5,085	2,233	888	0	15,515	
	1962	0	5,243	1,987	2,732	1,839	1,088	0	12,889	
	1963	0	3,086	1,952	2,083	1,025	618	0	8,764	
	1964	0	1,035	832	663	576	111	0	3,217	
	1965	0	1,083	733	937	432	152	0	3,337	
	1966	0	359	168	162	63	--	0	752	
North Atlantic	1955	0	647	1,319	881	413	198	0	3,458	
	1956	0	579	1,195	1,228	557	302	0	3,861	
	1957	0	590	1,435	1,332	689	340	0	4,386	
	1958	0	184	519	654	432	280	0	2,069	
	1959	0	350	1,085	996	764	265	0	3,460	
	1960	0	611	800	1,092	382	236	0	3,121	
	1961	0	584	750	1,259	403	269	0	3,265	
	1962	0	624	344	419	409	347	0	2,143	
	1963	0	453	422	624	301	217	0	2,017	
	1964	0	94	233	183	125	30	0	665	
	1965	0	171	190	198	150	0	0	709	
	1966	0	9	19	125	70	0	0	223	

abundance, declined drastically in the Middle Atlantic area in 1963, the mean tons per set also declined. But in the North Atlantic area, where the catch per vessel week also dropped sharply in 1963, the mean tons per set did not drop until 1965. Where the decline in the catch per vessel week was not so severe, no changes in the catch per set were noted. Perhaps population density must reach a rather low level before it can cause a significant decrease in school size. A factor which may contribute to an ostensible decrease in school size is selectivity by vessel captains, who have a tendency to pass by the smaller schools when fish are abundant. When fish are scarce, captains are less discriminate.

VARIATION IN ABUNDANCE

Atlantic menhaden are pelagic, but they rarely range far from shore. Most are caught within 20 miles of the coast. People have speculated that a large population, unavailable to the fishery,

TABLE 11.—Mean number of purse-seine sets per vessel day in the Atlantic menhaden fishery, by year, month, and area. Raw means are weighted, column means are unweighted.

Area	Year	Month							Mean	North Carolina fall fishery
		Apr.-May	June	July	Aug.	Sept.	Oct.	Nov.-Dec.		
South Atlantic and North Carolina fall fishery	1955	--	2.42	2.54	2.04	--	--	0	2.40	2.14
	1956	2.00	2.64	1.36	2.00	3.00	--	0	2.07	2.49
	1957	1.65	2.44	--	2.30	1.67	1.20	0	1.97	2.79
	1958	3.12	2.75	2.00	1.54	2.36	--	0	2.47	2.35
	1959	2.30	2.67	2.43	2.46	2.60	--	0	2.50	2.42
	1960	2.36	2.45	2.82	2.97	--	--	0	2.70	2.76
	1961	2.69	1.79	2.88	--	--	--	0	2.20	2.11
	1962	2.65	2.69	3.24	2.85	3.60	2.88	0	2.88	2.39
	1963	2.32	2.21	2.50	3.00	3.40	3.50	0	2.41	2.62
	1964	2.25	2.43	2.40	2.35	2.63	--	0	2.41	2.60
	1965	1.71	2.39	2.23	1.90	2.32	3.33	0	2.17	2.78
	1966	1.72	2.24	1.95	2.51	2.06	2.00	0	2.09	2.76
	Mean	2.25	2.43	2.40	2.36	2.62	2.58	0	2.36	2.52
Chesapeake Bay	1955	--	--	--	--	--	--	--	--	
	1956	0	3.70	3.49	3.98	3.82	3.33	0	3.72	
	1957	0	4.43	4.81	4.72	4.89	3.10	0	4.56	
	1958	0	3.45	3.89	4.08	5.08	2.85	0	3.99	
	1959	0	4.13	4.10	5.32	5.27	3.73	0	4.50	
	1960	0	3.82	4.19	3.95	4.34	3.72	0	4.00	
	1961	0	4.57	4.00	3.68	3.65	3.48	0	4.01	
	1962	0	2.93	3.15	3.30	2.76	2.71	0	2.98	
	1963	0	3.75	2.34	2.82	3.20	3.69	0	3.25	
	1964	0	3.21	3.00	3.75	3.63	3.09	4.03	3.38	
	1965	0	3.22	2.69	3.08	2.88	3.31	4.07	3.06	
	1966	0	2.67	2.92	3.53	2.79	3.05	3.07	3.03	
	Mean	0	3.62	3.51	3.84	3.85	3.28	3.72	3.68	
Middle Atlantic	1955	0	3.38	4.15	3.83	3.38	2.68	0	3.61	
	1956	0	3.79	4.17	4.40	3.51	2.41	0	3.87	
	1957	0	3.50	4.50	4.67	4.03	3.21	0	4.07	
	1958	0	2.63	3.19	3.41	3.89	2.53	0	3.33	
	1959	0	3.30	3.93	4.16	3.45	2.65	0	3.68	
	1960	0	4.22	4.68	4.51	4.00	2.89	0	4.26	
	1961	0	3.24	4.04	4.48	3.68	2.96	0	3.82	
	1962	0	3.84	3.03	4.21	3.15	2.12	0	3.45	
	1963	0	3.15	3.13	3.30	3.20	1.96	0	3.07	
	1964	0	2.41	3.19	3.56	3.01	--	0	2.98	
	1965	0	3.35	3.28	4.01	2.78	3.62	0	3.40	
	1966	0	2.79	--	3.95	2.75	--	0	3.08	
	Mean	0	3.30	3.75	4.04	3.40	2.70	0	3.55	
North Atlantic	1955	0	2.49	3.23	2.45	1.98	2.28	0	2.48	
	1956	0	2.63	2.89	3.41	2.53	2.25	0	2.84	
	1957	0	3.80	3.55	2.96	2.89	2.97	0	3.28	
	1958	0	2.13	2.93	2.83	2.66	2.37	0	2.70	
	1959	0	2.14	2.53	3.46	2.60	1.97	0	2.73	
	1960	0	2.70	2.74	3.64	2.07	2.11	0	2.79	
	1961	0	2.75	3.24	3.77	2.54	2.60	0	3.12	
	1962	0	3.06	2.77	3.56	2.73	2.61	0	2.96	
	1963	0	2.54	3.42	2.96	2.61	1.67	0	2.75	
	1964	0	1.87	3.26	2.48	2.33	1.92	0	2.58	
	1965	0	2.87	2.96	2.54	2.39	--	0	2.71	
	1966	0	1.40	2.78	5.00	--	--	0	2.24	
	Mean	0	2.53	3.03	3.26	2.48	2.28	0	2.77	

may occur far offshore. There is no available evidence to support this view.

There is evidence, however, that the entire population is fished. Since 1945 Atlantic menhaden have been exploited from northern Florida to the Gulf of Maine, an area constituting nearly their entire range. With the advent of airplanes that could search larger areas and vessels that could range up to a hundred miles from port, no areas have been unsearched or unfished, except where prohibited by local restrictions.

Under these conditions changes in the catch per unit of effort are assumed to reflect changes in actual, rather than apparent, abundance. Even though the figures have been influenced by changes in vessel efficiency, they are sensitive

TABLE 12.—Mean catch per purse-seine set of Atlantic menhaden, in metric tons, by year, month, and area. Row means are weighted, column means are unweighted.

Area	Year	Month						Mean	North Carolina fall fishery
		Apr.-May	June	July	Aug.	Sept.	Oct.		
South Atlantic and North Carolina fall fishery	1955	16.4	11.9	11.3	7.4	15.9	16.9	12.6	44.4
	1956	19.4	21.9	16.1	12.7	13.6	13.6	17.7	31.2
	1957	10.7	17.3	14.5	10.0	12.2	11.1	13.1	35.6
	1958	10.4	15.3	21.4	8.4	9.1	21.4	13.5	29.8
	1959	16.8	16.9	11.2	10.0	9.5	9.7	13.2	44.8
	1960	13.2	12.0	13.8	16.5	13.0	48.7	16.0	44.2
	1961	22.6	24.9	15.4	14.6	17.9	15.3	18.6	53.3
	1962	14.2	15.3	12.4	16.4	9.3	13.4	13.2	45.5
	1963	16.4	18.5	18.9	13.4	7.5	3.2	14.0	28.3
	1964	25.6	22.5	23.6	15.5	3.6	--	20.0	27.6
	1965	17.4	25.7	17.2	15.0	10.7	10.3	17.2	28.8
	1966	20.2	15.3	19.2	18.4	21.1	12.3	18.2	44.7
	Mean	17.0	18.1	16.2	13.2	12.0	16.0	15.6	38.2
Chesapeake Bay	1955	--	--	--	--	--	--	--	
	1956	--	12.6	14.3	10.8	12.9	9.1	12.2	
	1957	--	11.8	11.9	9.6	13.1	11.1	11.4	
	1958	--	11.9	20.7	18.9	16.0	8.8	16.4	
	1959	--	15.3	13.2	14.8	16.0	18.1	15.2	
	1960	--	21.8	14.2	14.1	11.2	14.0	15.1	
	1961	--	16.1	20.0	12.2	16.9	11.1	16.1	
	1962	--	29.1	15.2	16.9	13.2	23.6	18.5	
	1963	--	12.9	16.2	15.8	12.4	11.9	13.9	
	1964	--	14.2	13.4	13.3	9.3	15.3	13.2	
	1965	--	15.9	15.7	13.6	11.9	13.0	13.9	
	1966	--	11.9	11.7	8.4	10.5	13.8	12.6	
	Mean	--	15.8	15.1	13.5	13.1	13.6	14.4	
Middle Atlantic	1955	--	23.0	23.8	21.3	23.3	37.4	24.0	
	1956	--	29.1	25.7	25.6	22.2	30.7	26.4	
	1957	--	16.5	18.4	15.5	14.6	30.0	18.0	
	1958	--	18.1	19.1	24.0	22.7	15.0	21.5	
	1959	--	22.8	18.1	18.8	16.6	26.1	19.6	
	1960	--	15.6	17.3	16.2	15.3	21.7	16.8	
	1961	--	19.4	22.8	15.2	12.7	15.5	17.7	
	1962	--	22.6	16.8	8.3	15.1	48.7	19.8	
	1963	--	17.2	9.5	6.3	10.1	16.5	12.7	
	1964	--	10.7	10.8	13.3	11.2	11.0	11.3	
	1965	--	13.0	10.2	14.2	17.1	27.2	13.7	
	1966	--	7.0	4.7	10.3	16.3	--	8.0	
	Mean	--	18.0	16.4	15.8	16.4	25.4	17.4	
North Atlantic	1955	--	12.9	21.2	31.2	26.9	41.6	24.0	
	1956	--	23.2	24.4	25.1	26.8	33.9	25.5	
	1957	--	17.7	15.4	18.1	24.1	29.6	19.1	
	1958	--	14.4	10.5	16.9	18.6	16.7	15.4	
	1959	--	19.5	18.9	18.9	17.1	26.0	19.0	
	1960	--	24.3	19.2	18.8	19.8	34.7	21.2	
	1961	--	14.3	19.5	18.9	16.7	24.9	18.0	
	1962	--	22.9	21.3	17.6	22.8	44.7	25.1	
	1963	--	18.6	9.4	20.1	19.7	19.9	17.4	
	1964	--	22.8	30.2	19.3	23.8	34.3	25.1	
	1965	--	13.2	14.3	20.8	18.5	--	16.7	
	1966	--	4.4	4.3	8.5	9.5	--	8.3	
	Mean	--	17.3	17.4	19.5	20.3	30.6	19.6	

enough to reflect real differences in population abundance.

Variations in year-class strength have contributed to fluctuations in population abundance. Estimates of year-class strength prior to 1952 have been based on catch-per-unit-of effort figures and since 1952 on catch samples. From 1950 to 1958 there were four exceptionally large year classes, the largest occurring in 1958 (June and Reintjes, 1959; Nicholson and Higham, 1964). Most of the year classes after 1958 have been smaller than any of the year classes prior to 1958. This series of small year classes occurred simultaneously with the general decline in abundance, which began about 1956 and became more noticeable in 1963, after the large

1958 year class had nearly passed from the fishery.

The greatest decline in abundance has been in the Middle and North Atlantic areas, where older fish constitute the bulk of the catches. Fish pumps and airplane spotters, two of the improvements having the most impact on fishing effectiveness, increased sharply in both areas after 1949. Yet the catch per vessel week, after reaching a peak in about 1952, declined thereafter in both areas, despite other fishing improvements added in the middle 1950's. In the North Atlantic, the catch per vessel week, except for 1952 and 1953, was no greater from 1950 through 1962 than it had been from 1941 to 1950. In the Middle Atlantic, the catch per vessel week, although being substantially greater from 1952 to 1962 than it had been up until 1951, began a steady decline in 1957, and from 1963 to 1966 was much lower than in the years prior to 1950. From these data one may conclude that the abundance of menhaden in these two areas was no greater from 1950 to 1962, and considerably less after 1962, than it had been prior to 1950.

The decline in abundance in Chesapeake Bay, where 1- and 2-year-old fish compose most of the catches, has not been as great as in the North and Middle Atlantic. The catch per vessel week was substantially greater from 1954 to 1962 than it was prior to 1954 or after 1962. Since the major improvements in fishing methods came a few years later than in the Middle and North Atlantic, the higher catches per vessel week after 1953 probably reflect an increase in fishing efficiency, although they could reflect an increase in menhaden abundance. The decrease after 1962 probably resulted from a true decrease in menhaden abundance.

Abundance in the South Atlantic, where age-1 fish compose most of the catch, appears to have remained unchanged. The catches per vessel week varied widely, but showed no trend. In this area the fisheries at the three ports are small, geographically distinct, and dependent on relatively small numbers of fish, principally of one age group, that are dispersed over a large area. If the carrying capacity is less in the South Atlantic than in other areas, the abundance of fish in the area is less likely to reflect changes in the total Atlantic menhaden population than is the abundance of fish in areas of high density and high carrying capacity, such as Chesapeake Bay.

In the North Carolina fall fishery menhaden nearly always will appear to be abundant, because they are concentrated in a small area for a short period of time and are easy to catch. But since weather is more variable than in other areas, it influences the catch per vessel week more than it does elsewhere. The wide fluctuations in the catch per vessel week, therefore, do not necessarily reflect variations in abundance.

The relation between the decline in abundance and the high levels of fishing effort can be understood only if the spawning age, the age and size distribution, and the seasonal movements of the fish are considered. Atlantic menhaden spawn after they have completed three growing seasons (Higham and Nicholson, 1964), and rarely survive past seven growing seasons. Their age and size distribution and seasonal movements have been described by June and Nicholson (1964) and Nicholson,[2] and are briefly summarized here.

During the fishing season from about May to October, the population from Florida to Chesapeake Bay is composed primarily of age-1 and age-2 fish. Although the proportion of each age group varies with the strength of individual year classes, age-1 fish are usually more abundant, particularly south of Cape Hatteras. From the mouth of Chesapeake Bay to Long Island, age-2 fish gradually replace age-1 fish as the dominant age group. Age-3 fish, dominant in Long Island and Nantucket Sounds, become less abundant north of Cape Cod, where age-4 to age-7 fish predominate. A southward movement begins among fish at the northern end of the range in late summer and extends to all fish north of Cape Hatteras by early November. By mid-January nearly all menhaden have moved into the offshore area between Cape Lookout and northern Florida. In late winter these fish begin a northward movement.

[2] Nicholson, William R. Movements of Atlantic menhaden as inferred from changes in age and size distribution. (Unpublished manuscript.)

As older fish decreased in abundance, fisheries dependent on them declined. No menhaden were landed after 1958 at Portland, after 1962 at Gloucester, or after 1963 at Point Judith. After the 1958 year class ceased to contribute large numbers to the catch, the Amagansett, Port Monmouth, and Tuckerton catches dropped sharply. As catches declined and plants closed or reduced fishing, effort also dropped. By 1968 only 136 vessel weeks were expended in the North and Middle Atlantic, as compared with 1,265 in 1962.

Effort in areas where age-1 and -2 fish were predominant continued to be high. In 1968, 846 vessel weeks were expended in the South Atlantic and Chesapeake Bay, as compared with 909 in 1962.

Changes in the catch and the catch per vessel week suggest that the decline in numbers of fish older than age 2 was much greater than the decline in numbers of fish younger than age 3.

If recruitment is dependent on spawning population size, and spawning population size is dependent on the escapement of prespawning age fish, the total yield will be limited by the amount of escapement. Schaaf and Huntsman[3] have shown that with present levels of fishing effort, the spawning stock of Atlantic menhaden is inadequate for recovery of the population.

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[3] Schaaf, William E., and Gene R. Huntsman. Population dynamics of the Atlantic menhaden: An analysis of the purse seine fishery, 1955-69. (Unpublished manuscript.)