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Biology and Management of the American Shad and Status of the Fisheries, Atlantic Coast of the United States, 1960

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ABSTRACT

This paper summarizes current information on the American shad, Alosa sapidissima, and describes the species and its fishery. Emphasis is placed on (1) life history of the fish, (2) condition of the fishery by State and water area in 1960 compared to 1896 when the last comprehensive description was made, (3) factors responsible for decline in abundance, and (4) management measures.

The shad fishery has changed little over the past three-quarters of a century, except in magnitude of yield. Types of shad-fishing gear have remained relatively unchanged, but many improvements have been made in fishing techniques, mostly to achieve economy.

In 1896 the estimated catch was more than 50 million pounds. New Jersey ranked first in production with about 14 million pounds, and Virginia second with 11 million pounds. In 1960 the estimated catch was slightly more than 8 million pounds. Maryland ranked first in production with slightly more than 1.5 million pounds, Virginia second with slightly less than 1.4 million pounds, and North Carolina third with about 1.3 million pounds.

Biological and economic factors blamed for the decline in shad abundance, such as physical changes in the environment, construction of dams, pollution, overfishing, and natural cycles of abundance, are discussed. Also discussed are methods used for the rehabilitation and management of the fishery, such as artificial propagation, installation of fish-passage facilities at impoundments, and fishing regulations.

With our present knowledge, we can manage individual shad populations; but, we probably cannot restore the shad to its former peak of abundance.

INTRODUCTION

The annual commercial yield of American shad, Alosa sapidissima (Wilson), on the Atlantic coast of the United States declined from more than 50 million pounds in 1896 to about 10 million pounds during the 1930's. Production increased slightly during World War II, but by 1949 had decreased to less than 10 million pounds. Alarmed by the continued decline, the Atlantic States Marine Fisheries Commission requested the Federal Government to investigate this resource. In 1949 Congress, in Public Law 249, authorized the Fish and Wildlife Service, U.S. Department of the Interior, to study the shad.

Since 1950 the Fish and Wildlife Service (including the Bureau of Commercial Fisheries) has been investigating the fishery to (1) discover causes for the decline, (2) determine conditions favoring recovery, and (3) provide information for scientific management of the species to obtain maximum continuing yields.

With available funds and personnel, it was not possible to investigate all Atlantic coast

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shad fisheries simultaneously; studies generally were confined to only one stream or area each year. Investigations began on the Hudson and Connecticut Rivers in 1950 and during the following 10 yr. (years) included the major producing areas along the coast. Because of the extensive coastwide nature of this program, field work in any one area necessarily was limited to 1 or 2 yr.

The purpose of this paper is to summarize current information on the shad with emphasis on (1) life history of the fish, (2) condition of the fishery by State and water area in 1960 compared with 1896 when the last comprehensive description was made, (3) factors responsible for decline in abundance, and (4) management measures to increase fish stocks and to produce optimum sustained yields.

Previous extensive investigations of this species included an exhaustive report on the shad fisheries of the Atlantic coast of the United States with emphasis on the year 1896 (Stevenson, 1899), a comprehensive study on the life history of shad (Leim, 1924), a general review on artificial propagation of shad (Leach, 1925), a detailed study on the marketing of shad (Johnson, 1938), and a historical review which summarized all available information on the fishery and presented the most comprehensive bibliography on the shad (Mansueti and Kolb, 1953). The works of the above authors were used extensively to complete this report. Throughout this report, all references to the fisheries of 1896, including tables, are from Stevenson (1899), and all 1960 data were collected during the present study.

In some respects, this report is similar to Mansueti and Kolb (1953). That paper, however, was a compilation of available literature, newspaper articles, interviews, and letters and contained unsubstantiated statements and opinions subsequently not clarified. In this paper we have sought to give only documented information and to describe the shad and its fishery in the light of recent scientific information.

DESCRIPTION OF ALOSA SAPIDISSIMA

The shad is the largest member of the herring family, Clupeidae, in the United States. The species has compressed fusiform shape, single soft-rayed dorsal and anal fins, deeply forked tail fin, strongly serrated ventral edge of abdomen, and large scales which are easily loosened; a dark spot close behind the rear edge of the operculum well up on either side of the body usually is followed by one or two longitudinal rows of dusky spots (fig. 1). When

Figure 1.--American shad, Alosa sapidissima. Upper: male - 18.8 in., 3.2 lb., and 5 yr. old. Lower: female - 19 in., 4 lb., and 5 yr. old.

shad enter rivers, their sides and bellies are white and silvery, and the backs have a green to dark-blue metallic luster. The color on the back fades to brown as the fish continue in fresh water. Fins are pale green, the dorsal and caudal fins somewhat dusky in the larger fish and darker at the tips. Adults have the following meristic characters (predominant numbers in parentheses): dorsal fin, 16 to 21 rays (18 or 19); anal fin, 19 to 24 rays (21 or 22); left pectoral fin, 14 to 18 rays (16 or 17); ventral scutes, 34 to 40 (35 to 37 with 21 or 22 anterior to the ventral fins and 14 or 15 posterior to the ventral fins); gill rakers on the lower limb of the first arch, 62 to 76 (68 to 72); lateral line scales, 52 to 64 (56 to 60); vertebrae, 53 to 59 (56 to 57); and no teeth. Hildebrand and Schroeder (1928), Leach (1925), and Leim (1924) gave characters to distinguish shad from other members of the same family.

DISTRIBUTION OF SHAD

The range of shad on the Atlantic coast is from the Gulf of St. Lawrence in Canada to the St. Johns River, Fla. They are most abundant from North Carolina to Connecticut.

The U.S. Fish Commission made many attempts to introduce shad in waters where they were not native (Hildebrand and Schroeder, 1928; Leach, 1925). They were introduced in streams of the Mississippi River drainage, rivers of peninsular Florida, Colorado streams, and tributaries to lakes, including the Great Lakes and Great Salt Lake, but these introductions were unsuccessful. Shad were successfully introduced in the Sacramento River, Calif., and in the Columbia River between Washington and Oregon. From these rivers they spread to other streams, and now they occur from the Mexican border to Cook Inlet, Alaska (Neave, 1954).

LIFE HISTORY OF SHAD

The American shad is anadromous, spending most of its life in the ocean but ascending coastal rivers to spawn. Fish attain sexual maturity at the age of 2 to 6 yrs. The young remain in the natal stream until autumn and then enter the ocean.

MIGRATIONS

Stevenson (1899) reported ". . . it was formerly considered that the entire body of shad wintered in the south and started northward in a vast school at the beginning of the year, . . ., sending a detachment up each successive stream, this division, by a singular method of selection, being the individuals that were bred in those respective streams, the last portion of the great school entering the Gulf of St. Lawrence.

"But zoologists now recognize . . . the young shad hatched out in any particular river remain within a moderate distance off the mouth of that stream until the period occurs for their inland migration . . . entering the rivers as soon as the temperature of the water is suitable."

Talbot and Sykes (1958) and Sykes and Talbot (1958) analyzed information from tagging studies carried out over a period of 19 yr. by the Fish and Wildlife Service and described the Atlantic coast migration of shad. Talbot and Sykes (1958) said ". . . tag recoveries have revealed a consistent migration pattern, . . . After spawning, adult shad in streams from Chesapeake Bay to the Connecticut River migrate northward and spend the summer and fall in the Gulf of Maine. Canadian shad migrate southward to the Gulf of Maine and also spend the summer and fall there. There is little evidence as to where shad spend the winter months; but it appears that they are scattered along the Middle Atlantic area, for beginning in January or February as the spawning season approaches, they move inshore. . . They then migrate either north or south to their native streams and spawn, . . . The young shad leave their native streams in the fall, probably spend the winters in the Middle Atlantic area, migrate to the Gulf of Maine each summer along with the adults, and when mature return to their native streams to spawn . . .

"From these studies it appears that shad, like salmon, migrate long distances in the sea . . . How or by what mechanism they are guided has not yet been satisfactorily determined."

Recent captures of shad in offshore waters have indicated further that they spend the winter along the Middle Atlantic area. Warren F. Rathjen, Exploratory Fishing and Gear Research Base, Gloucester, Mass., (written communication dated February 24, 1961) reported ". . . 49 shad ranging from 315 mm. to 473 mm. long were captured at 87 to 126 fathoms during Cruise 61-1 of the MV. Delaware operating along the 'edge' of the Continental Shelf between Nantucket Lightship and the Hudson Canyon (Lat. N. 40° 01' - Long. 70° 41') from January 23 to February 2, 1961."

Shad occasionally are captured in areas out of their general migration. A few adults are caught each year on eel racks in the Delaware River in late summer or fall (Sykes and Lehman, 1957). Others were reported in the lower Hudson River during fall and winter, and in Chesapeake Bay throughout the year. The vast majority of fish, however, followed a regular migratory pattern.

Considerable evidence is available to show that most shad return to their native streams to spawn. Significant differences in morphological characters indicate discrete spawning populations in rivers along the Atlantic coast (Hildebrand and Schroeder, 1928; Vladykov and Wallace, 1938; Warfel and Olsen, 1947; Hill, 1959; Fischler, 1959; Nichols, 1966). The Hudson River run reached peaks of abundance twice in the past 50 yr., while runs in neighboring streams such as the Connecticut River fluctuated independently and in the Delaware River remained low during the same period. Such variations indicated that most of the fish returned to their home streams to spawn (Fredin, 1954; Talbot, 1954). Significant differences in juvenile body lengths attained at the end of the young shads' stay in fresh water and differences in scale characteristics indicated populations peculiar to each Chesapeake Bay tributary (Hammer, 1942[3]).

Tagging and recovery studies revealed even more positive evidence of the return to their native streams. Hollis (1948) released about a thousand tagged juvenile shad at Edenton, N.C., in October 1941. During the spawning migration, 3 to 5 yr. later, three tagged fish were recaptured within a radius of 10 miles from the tagging site, and none was recaptured from any other area. Tagging carried out in Chesapeake Bay showed that adult shad returned to the same spawning areas during successive years (Truitt, 1940). During the spring following tagging in the Hudson and Connecticut Rivers, no recaptures were made from a spawning ground other than the one where the fish was tagged (Talbot and Sykes, 1958). Similar results were obtained from tagging on the spawning grounds in the York River (Nichols, 1961).

In 1896 no river on the Atlantic coast appeared to be too long for shad to ascend to the headwaters, provided the fish met with nothing to bar their upstream movement. In that year they ascended the St. Johns River about 375 miles, the Altamaha River 300 miles, the Santee River 272 miles, the Neuse River 300 miles, and the Susquehanna River 279 miles. These distances, however, did not equal the extreme range of the original limit of the runs (table 1).

[3]The homing instinct of the Chesapeake Bay shad, Alosa sapidissima (Wilson), as revealed by a study of their scales by Ralph C. Hammer. M.S. degree thesis (typewritten), 1942, University of Maryland, 45 p.

The difference in the range of shad in rivers between 1896 and 1960 is the result of several factors. Construction of insurmountable dams decreased the upstream range in certain rivers, e.g., in the Santee by more than 200 miles, in the Cape Fear and Neuse by more than 100 miles each, and in the Susquehanna by more than 50 miles. Runs were completely destroyed in the Housatonic, Kennebec, and Penobscot Rivers. Pollution of the Hudson probably was responsible for decreased upstream movement. Removal of dams and construction of successful fishways increased the range in certain rivers, e.g., the destruction of Burrows Dam in the Delaware River opened an additional 64 miles, and installation of a fish ramp at Windsor Locks and construction of a fish-lift at South Hadley Dam on the Connecticut River increased the upstream migration more than 40 miles (table 1).

Shad ascend the rivers when the water temperature is from 5° to 23° C., the peak movement is at 13° to 16° C. (Leach, 1925; Massmann and Pacheco, 1957; Talbot, 1961). This upstream migration is for the sole purpose of spawning, but the time of entry into fresh water varies along the coast. Shad appear in the St. Johns River about mid-November, are in greatest abundance from mid-January to mid-February, and the run is completed by the last of March. In Georgia and South Carolina rivers, the run begins early in January and ends the last of April. Shad enter the sounds and tributaries of North Carolina and Chesapeake Bay as early as mid-February, and the run usually continues until mid-May. In the Delaware River, the fish are most abundant in early May. They enter the Hudson and Connecticut Rivers by the last of March, and the run usually continues until June.

The sex ratio is not constant throughout the period of upstream migration. In the early part of the run, males usually dominate. Later, the sexes are about equal or females are more numerous.

Young shad spend their first summer in rivers and migrate to sea in the autumn. During their river residence, the young fish tend to disperse throughout the area, and juveniles nearest the spawning area are smaller on the average than those below the tidal stretches of the river (Leim, 1924). The findings from our studies were similar to those of Leim on the distribution of young by size gradient. Young collected in the St. Johns River in mid-August averaged 2 in. (inches) fork length (150 specimens) in the upstream spawning areas, and 2.3 in. fork length (100 specimens) in the lower river. In the Hudson River, the average fork length of young collected in mid-August was 2.5 in. (250 specimens) in the upstream spawning area, 2.7 in. (200 specimens) in the central section, and 2.8 in. (250 specimens) in the lower river. Young were distributed from the spawning

Table 1.--The original, 1896, and 1960 limits of shad range in 23 major rivers of the Atlantic coast of the United States. All data other than for 1960 from Stevenson (1899)

River	Distance of source above coastline	Original limit of shad run		1896 limit of shad run		1960 limit of shad run	
		Locality	Distance from coastline	Locality	Distance from coastline	Locality	Distance from coastline
	Miles		Miles		Miles		Miles
St. Johns. . . .	375	Sources.	375	Sources.	375	Lake Washington. . .	250
Altamaha	450	Macon.	370	Hawkinsville . .	300	Hawkinsville	300
Ogeechee	350	Ogeechee Shoals. .	200	Millen	100	Midville	125
Savannah	425	Tallulah Falls . .	384	Augusta Dam. . .	209	Savannah Lock and Dam.	180
Edisto	300	Sources.	300	Jones Bridge . .	281	Norway	120
Santee:							
Wateree. . . .	350	Great Falls. . . .	272	Great Falls. . .	272	Santee Dam	65
Congaree . . .	410	Green River. . . .	374	Columbia	233	Santee Dam	65
Pee Dee.	497	Wilkesboro	451	Grassy Island. .	242	Blewett Falls Dam. .	242
Cape Fear. . . .	290	Haywood.	210	Smiley Falls . .	181	Lock No. 1	65
Neuse.	340	Sources.	340	Fish Dam	300	Milburnie.	165
Pamlico-Tar. . .	252	Rocky Mount. . . .	157	Rocky Mount. . .	157	Rocky Mount.	157
Roanoke.	457	Weldon	249	Weldon	249	Spring Hill.	215
James.	420	. . . . .	370	Boshers Dam. . .	140	Boshers Dam.	140
Rappahannock . .	248	Falmouth	155	Falmouth Falls .	155	Falmouth Falls . . .	155
Potomac.	400	Great Falls. . . .	190	Great Falls. . .	190	Little Falls Dam . .	180
Susquehanna. . .	617	Binghamton	513	Clarks Ferry . .	279	Conowingo Dam. . . .	205
Delaware	457	Deposit.	256	Burrows Dam. . .	196	Deposit, N. Y. . . .	260
Hudson	314	Glens Falls. . . .	209	Troy	164	Coxsackie.	130
Housatonic . . .	202	Falls Village. . .	150	Birmingham . . .	92	. . . . .	No shad
Connecticut. . .	409	Bellows Falls. . .	204	Windsor Locks. .	89	Turners Falls. . . .	130
Merrimac	140	Winnepesaukee. . .	125	Lawrence	20	Lawrence	20
Kennebec	155	Carritunk Falls. .	108	Augusta.	44	. . . . .	No shad
Penobscot. . . .	255	. . . . .	90	Verona	35	. . . . .	No shad

grounds to the lower river but were most abundant over sand and gravel. Movement from the river usually begins after the water temperature has decreased to less than 15.5° C. It is not until near the end of November or the beginning of December that all the young have left the tributaries of Chesapeake Bay (Hildebrand and Schroeder, 1928). The downstream movement of young in the upper Delaware River occurs during September and October and appears to be expedited by a rapid lowering of the water temperature, or an increase in flow, or both (Sykes and Lehman, 1957).

SPAWNING RUNS

Most shad spawn for the first time when 4 or 5 yr. old; males mature and spawn at an earlier average age than females. A few males spawn for the first time at an age of 2 or 3 yr., and a few females spawn for the first time at 3 or 4 yr. Age distribution at capture and number of previous spawnings for shad from certain rivers of the Atlantic coast are given in table 2. No fish had spawned previously in the South Atlantic (St. Johns, Ogeechee, Edisto, and Neuse Rivers) except in the Neuse

Table 2.--Age distribution at capture, and number of previous spawnings, for shad from certain rivers, Atlantic coast of the United States[1]

[In percent]

Age and spawning group	River									
	St. Johns	Ogeechee	Edisto	Neuse	James	York	Potomac	Delaware	Hudson	Connecticut
Total age (years) at capture:										
2	(2)	---	---	---	---	(2)	---	---	---	---
3	4	2	5	9	12	7	5	1	2	1
4	72	41	16	43	61	55	62	16	23	17
5	22	48	56	34	20	30	28	41	29	42
6	2	9	23	12	7	6	5	30	22	30
7	(2)	---	---	2	(2)	1	(2)	10	14	7
8	---	---	---	---	---	(2)	---	2	6	2
>8	---	---	---	---	---	---	---	---	4	1
Number of times spawned previously[3]:										
0	100	100	100	97	73	76	83	98	49	51
1	---	---	---	3	22	15	15	2	19	31
2	---	---	---	---	5	7	1	---	18	13
3	---	---	---	---	(2)	1	(2)	---	10	4
4	---	---	---	---	---	1	---	---	2	1
5	---	---	---	---	---	---	---	---	2	(1)
>5	---	---	---	---	---	---	---	---	(2)	---

[1] Data for: St. Johns, 1958--Walburg (1960a); Ogeechee, 1954--Sykes (1956); Edisto, 1955--Walburg (1956); Neuse, 1953--Walburg (1957a); James, 1952--Walburg and Sykes (1957); York, 1959--Nichols and Massmann (1963); Potomac, 1952--Walburg and Sykes (1957); Delaware, 1944-45-47-52--Sykes and Lehman (1957); Hudson, 1950-51--Talbot (1954); Connecticut, 1956-59--Walburg (1961).

[2] Less than 0.5 percent.

[3] Determined by counting the number of spawning marks on scales.

River; in Chesapeake Bay tributaries (James, York, Potomac, and Delaware Rivers) from 17 to 27 percent had spawned previously; and in the Hudson and Connecticut Rivers, about 50 percent had spawned previously. In all streams north of North Carolina, many shad spawn more than once. Fish that have spawned for 5 yr. or more have been found in some more northerly streams.

Spawning in all streams south of Long Island, N.Y., usually is completed by June, and spawning in the Hudson and Connecticut Rivers usually has ended by July. Spawning occurs in June and as late as July in Maine and Canada. Usually fish enter the rivers and spawn a few days earlier during warm periods and a few days later when the weather is cold during the spawning migration. After spawning, the fish that survive leave the river (at which time they are called "back runners") and most migrate to the Gulf of Maine.

SPAWNING AND EARLY DEVELOPMENT

Spawning grounds of shad were located by the relative numbers of eggs collected in plankton nets (fig. 2) and the occurrence of ripe and running females in sport and commercial catches. Net samples of eggs indicated that spawning areas in rivers are large, extending sometimes 25 to 100 miles inland from the limit of brackish water. In the Connecticut River, eggs were collected from Haddam Island to Hadley Falls Dam, a distance of more than 100 miles; in the St. Johns

Figure 2.--Setting 1-m. plankton net to collect shad eggs, St. Johns River, Fla.

River, from Crows Bluff upstream to midway between Lake Harney and Lake Poinsett, a distance of 70 miles; and in the James River, from Newport News to Hopewell, a distance of 40 miles. Ripe females were taken throughout the spawning areas, but usually eggs were not collected in some stretches of river within these areas. Most spawning grounds were on flats or in adjacent river channels and, sometimes, below barriers. (These findings are similar to those reported by Gill, 1926; Massmann, 1952; Smith, 1907; and Worth, 1893.) Dissolved oxygen was 5 p.p.m. (parts per million) or more throughout spawning areas. Water conditions varied from clear to very turbid. The bottom generally was sand, gravel, or a combination of both. The water depth usually was from 3 to 30 ft. (feet), but ranged up to 40 ft. in the Hudson River. In the Connecticut River, 49 percent of the eggs were collected in water less than 10 ft. deep, 30 percent in water between 11 and 20 ft. deep, and the remainder in water from 21 to 30 ft. deep. The current ranged from less than 1 to more than 3 f.p.s. (feet per second) during normal flow. In some streams, river flow in spawning areas was always downstream, but in others it was affected by tide and current moving both upstream and downstream during the tidal cycle.

Shad spawn at water temperatures from 8° to 26° C., but usually between 14° and 21° C. In the Pamunkey River, Va., eggs were not taken in abundance until the water temperature reached 12° C. (Massmann, 1952). In the Shubenacadie River, Nova Scotia, Canada, Leim (1924) collected eggs at various temperatures but noted that spawning stopped when water temperature dropped suddenly from 16° to 10° C.

Gill (1926) observed that when shad reached suitable spawning grounds and were ready to deposit their eggs, they moved up the flats, seemingly in pairs. When spawning, they swam close together near the surface, their back fins projecting above the water. The rapid, vigorous, spasmodic movements that accompanied this activity produced a splashing in the water which fishermen characterized as "washing". Similar spawning actions were observed by Leim (1924), usually in places where the current was neither sluggish nor swift. Leim collected newly fertilized eggs with a plankton net placed downstream from the disturbance.

On two occasions in mid-May 1958, shortly after sundown, we observed a school of about one hundred shad in vigorous, intermittent movement below the Enfield Dam on the Connecticut River. The schooling fish swam in a close circle near the surface, and a wake was plainly visible. Then the speed of movement rapidly quickened, the circle narrowed, and fish broke the surface, producing a splashing or churning in the water. This frantic activity lasted only a few seconds, but minutes later the same, or a different school surfaced at another location and repeated the routine. The entire activity lasted about 15 min. (minutes). Undoubtedly this was some phase of the spawning cycle. Also in the afternoon and evening, schools of shad on several occasions moved in a "follow-the-leader" pattern, making energetic runs with a flashing of sides which was probably prespawning activity. Evidently heaviest spawning normally occurs in late afternoon and evening.

Shad eggs develop over a wide temperature range. Canfield[4] reported that the eggs developed gradually in the ovaries as the temperature of the water increased and that spawning occurred intermittently as the eggs ripened. At 13° to 17° C., the ovaries apparently developed a portion of the eggs at a time, and that portion was spawned. As the temperature increased from 17° to 20° C., the ripening of the ovaries was rapid; and as the water temperature increased from 20° to 24° C. the development was more rapid and soon was complete.

Shad deposit their eggs in the open waters, where they are fertilized by the males. When deposited, the eggs are transparent spheres, pale amber or pink, and about 0.05 in. in diameter. Immediately after fertilization, they absorb water and increase to a diameter of about 0.1 to 0.15 in. The eggs are carried by the currents and, being slightly heavier than water, gradually sink. Eggs which have been preserved in 5 percent Formalin[5] sink at a rate of 2.4 f.p.m. (feet per minute) in water of about 25° C. (Massmann, 1952).

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[4] Unpublished manuscript. Report on shad production in North Carolina by H. L. Canfield, 1937, U.S. Fisheries Agent, Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N.C. 9 p.

[5] Trade names referred to in this publication do not imply endorsement of commercial products.

The average number of eggs produced per female each season often has been given as about 25,000 or 30,000 (Worth, 1898). This figure referred to the number of eggs that could be taken by spawn-takers for hatchery purposes at any time and not the total number of eggs a shad could produce in a season (Lehman, 1953). Because only a part of the eggs are ripe and ready for spawning at one time, these earlier records represented but a fraction of the number of ova a female could produce naturally during a spawning season. The number per female depends upon the size and age of the fish as well as the stream in which spawning occurs. The fecundity in the St. Johns River was greater than in the Hudson River, for example, although females from the latter river were older and larger than those from Florida. The estimated egg production of shad collected in seven rivers along the Atlantic coast of the United States is given in table 3.

In general, shad eggs hatch in 4 to 6 days at about 15° to 18° C. The stages of early development of shad eggs were illustrated by Leach (1925). Time required for hatching was measured by various workers who reared eggs under artificial conditions. The hatching time ranged from 3 to 5 days at water temperatures from 20° to 23.4° C., to 17 days at 12.2° C. Eggs kept for 3 days at 9° C. died, but a few hatched into vigorous larvae when put in 24° C. water (Ryder, 1885). A temperature of 7° C. practically stopped development of the eggs and caused abnormalities to appear, 22° C. caused considerable abnormality, and 27° C. was definitely unsuitable (Leim, 1924).

Table 3.--Estimated egg production of shad collected in seven rivers, Atlantic coast of the United States[1]

River	Fork length	Total weight	Age	Estimated number of eggs
	Inches	Ounces	Years	Thousands
Hudson	13.9 - 21.9	28 - 107	3 - 9	116 - 468
Potomac	18.1 - 19.9	51 - 83	5 - 6	267 - 525
York	15.7 - 18.5	39 - 73	4 - 6	169 - 436
Neuse	17.6 - 19.6	64 - 96	4 - 6	423 - 547
Edisto	18.3 - 19.6	57 - 76	4 - 5	360 - 480
Ogeechee	18.0 - 18.7	60 - 76	4 - 6	359 - 501
St. Johns	14.5 - 18.1	21 - 65	4 - 6	277 - 659

[1] Data for: Hudson, 1951--Lehman (1953); Potomac, 1952--Davis (1957); York, 1959--Nichols and Massmann (1963); Neuse, 1953--Davis (1957); Edisto, 1955--Davis (1957); Ogeechee, 1954--Davis (1957); St. Johns, 1953--Walburg (1960a).

The usual period of incubation was 6 to 12 days at 12° to 19° C., and these temperatures were near the minimum and maximum for successful incubation of the eggs (Leach, 1925). Water temperature appears to be the governing factor during incubation, but other circumstances not well understood may also have an influence. Continuous dark, cloudy weather appears to retard development and strong light to accelerate it.

The appearance of the newly hatched larvae and the stages of development were described by Leach (1925), Leim (1924), and Worth (1898). The larvae are about 0.3 to 0.4 in. long at hatching. The body is slender, surrounded by a wide primitive fin-fold. In 4 to 7 days, the yolk sac is absorbed. Growth is rapid and transformation to the final form, at a length of about 1 in., occurs about 4 to 5 wk. (weeks) after hatching. The young swim vigorously by rapid and continuous vibrations of the tail from the moment they leave the eggs. Minute conical teeth appear in the lower jaw and in the pharynx about the second or third day after hatching. At 3 mo. (months), the jaws are armed with small, slightly curved teeth. Long, slender gill rakers develop and increase in number with age; shad 1.5 to 3.5 in. long have 21 to 31 on the lower limb of the first arch, and fish 4 to 5 in. long have 34 to 41.

FOOD AND FEEDING HABITS

Adult shad are primarily plankton feeders, characteristically they swim with their mouths open and their gill covers extended, straining the water for food. In the sea, they eat mysids and copepods (Leim, 1924; Willey, 1923). The mysids suggest that part of their life, perhaps much of it, is spent near the bottom of the sea. In the rivers, the young feed on ostracods, isopods, decapod larvae, insects, mollusks, algae, and fish eggs (Hildebrand and Schroeder, 1928).

Little food, if any, has been found in the stomachs of adults taken in fresh water (Leidy, 1868; Clift, 1874; McDonald, 1884; Smith, 1896; Moss, 1946; Nichols, 1959a), probably because the available food is too small to be collected. In salt water, adults feed to a large extent on plankters 0.3 to 1 in. long. In fresh water, the largest plankton in abundance are copepods, which rarely exceed 0.1 in. A direct relation exists between the fineness of the sieve formed by the gill rakers and the minimum size of the organisms that could be retained.

In some rivers, shad are taken on spawning grounds by artificial lures, but the absence of food in their stomachs suggests that they attack baits in defense of the grounds rather than as food. Stomachs of several adults that were examined had only green algae and fine detritus.

The food habits of young shad have been observed by many workers. Food was never found in the alimentary canal of young fish less than 10 to 12 days old (Leach, 1925). In about 11 days food was present, but the intestines were seldom densely packed with food. At 3 wk., an abundance of food was found. Gill (1926), however, found that in about 7 days after hatching, some fish were observed to pursue and feed upon copepods. Leim (1924) noted that in the Shubenacadie River, Canada, larval shad ate planktonic crustacea and chironomid larvae; the latter predominated until the young fish reached tidal water where copepods became most important. Juveniles took mostly insects and crustaceans (Mitchell, Philip H., and Staff: N. Borodin, R. L. Barney, and Edwin Linton, 1925; Walburg, 1957b). We observed that young shad fed actively from dusk to an hour after sunset and from first daylight to sunrise.

AGE AND GROWTH

Various works have described techniques for aging shad. Leim (1924) and Greeley (1937) counted winter rings or annuli on the scales and used the relation of scale size to body length; Borodin (1925) counted transverse grooves; and Barney (1925) read otolith markings. Cating (1953) reported that previous investigators had not established criteria for separating true from false annuli on scales and that these methods therefore gave erroneous results. Cating proposed a method for reading scales for total age and age at first spawning by counting the transverse grooves to identify true annuli and adding 1 yr. for the scale edge. Age of fish spawning for the second time or more was obtained by counting the number of annuli plus the number of spawning marks (year marks but different in form from the prespawning annuli) and adding 1 yr. for the scale edge. LaPointe (1958) validated the annulus as a true year mark on scales of fish spawning for the first time.

In 1952, 100,000 juvenile shad were marked by pectoral fin-clip in the Connecticut River to validate Cating's method or to establish a correct method for determining age of this species from their scales. Recapture of these marked fish 4, 5, and 6 yr. later validated the use of both annuli and spawning marks for age determination (Judy, 1961).

In South Atlantic rivers and Chesapeake Bay tributaries, 4- and 5-yr.-old fish make up the bulk of the catch; in the Middle Atlantic rivers, the catch is primarily 4- to 7-yr.-old fish.

Growth differs between northern and southern rivers as well as between sexes. The increases of length with age of shad was greater in northern rivers than in southern streams (table 4). Females grow slightly faster than males; hence females are consistently longer than males at all ages (table 5).

Average weight and length depend on river of origin. Weight of individuals of similar length varies according to condition of fish.

Shad as heavy as 12 to 14 lb. (pounds) have been reported (McDonald, 1884; Stevenson, 1899; and Worth, 1898). Pacific coast fish average a pound or more heavier than those on the Atlantic coast; many weigh 9 to 12 lb., and occasionally one attains a weight of 14 lb. Fish from less than 2 to more than 9 lb. have been observed in the commercial catch on the Atlantic coast. Males average between 2 and 3 lb. and females between 3 and 4 lb.

Table 4.--Average fork length of shad, by age and sex, from certain rivers, Atlantic coast of the United States[1]

[Age in years, length in inches and tenths]

River	Age											
	1		2		3		4		5		6	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
St. Johns	6.8	7.0	11.4	11.8	13.7	14.1	15.3	16.1	16.7	17.5	17.2	18.0
Neuse	7.0	7.2	11.3	11.6	14.5	14.8	16.6	16.9	--	18.6	--	20.2
Susquehanna	6.5	6.9	10.5	11.2	13.0	14.2	14.8	15.9	15.9	17.5	--	--
Connecticut	7.1	7.4	11.4	11.8	14.2	15.0	16.5	17.3	18.1	19.5	--	20.8

[1] Data for: St. Johns, 1957--Walburg (1960a); Neuse, 1953, and Susquehanna, 1952 --LaPointe (1958); Connecticut, 1957-58--Unpublished (Beaufort, N. C.)

Table 5.--Fork length and weight of shad, by age, from the St. Johns, York, and Connecticut Rivers, 1960

Age	Sex	Fork length range	Weight range
Years		Inches	Ounces
3	Male	13.5 - 14.5	17 - 33
	Female	14.3 - 15.0	22 - 38
4	Male	15.9 - 16.9	30 - 46
	Female	16.4 - 17.5	44 - 60
5	Male	16.5 - 17.5	44 - 50
	Female	17.3 - 18.3	58 - 64
6	Male	17.3 - 18.3	49 - 65
	Female	18.5 - 21.0	62 - 68
7	Male	19.0 - 22.5	56 - 68
	Female	21.5 - 23.0	68 - 83

Juvenile shad grow rapidly in fresh water, although the rate of growth and size at any given time may vary between areas. Young shad collected in early October in the Connecticut River below Hadley Falls Dam at Holyoke, Mass., ranged in fork length from 3.1 to 4.2 in. (250 specimens) whereas those collected above the dam ranged from 3.7 to 5 in. (255 specimens). Young caught in the Hudson River in late September ranged from 2.5 to 3.1 in. fork length (400 specimens); in Chesapeake Bay tributaries in mid-September, 2.7 to 3.5 in. (550 specimens); in southern streams in mid-August, 2 to 2.5 in. (400 specimens). Average lengths of juveniles from the Hudson River at the end of each month were: June, 0.6 in.; July, 1.9 in.; August, 2.4 in.; September, 3 in.; and October, 3.5 in.

MORTALITY

Mortality of adult shad is caused mainly by (1) fishing, (2) natural causes, or (3) predators and parasites.

Fishing Mortality

The annual fishing mortality rate within rivers is known for a number of shad populations. In the South Atlantic streams, the estimated rate varied from a low of 15 percent in the St. Johns River in 1957 (Walburg, 1960a) to a high of 57 percent in the Ogeechee River in 1954 (Sykes, 1956). In Chesapeake Bay tributaries, it varied from 45 percent in the York River in 1959 (Nichols and Massmann, 1963) to 73 percent in the James River in 1952 (Walburg and Sykes, 1957). In the Hudson River, the rate varied from 20 percent in 1916 to 79 percent in 1947 (Talbot, 1954). In the Connecticut River, the rate varied from 24 percent in 1956 to 85 percent in 1946.

Natural Mortality

Few studies have been made to determine natural mortality of adult shad. Fredin (1954) compared the abundance of 6- to 7-yr.-old fish taken from the Connecticut River in 1946 and 1947 and estimated that the extraneous mortality rate (deaths occurring between fishing seasons) was 36 percent. Walburg (1961), who studied age- and spawning-group frequencies for fish taken in the Connecticut River from 1956-59, estimated that the total annual mortality was 73 percent. The average annual natural mortality for these years was estimated to be 58 percent. Whitney (1961) estimated that the rate of survival of adult shad after spawning in the Susquehanna River, based on tag returns, was about 12 percent for males and 26 percent for females between 1958 and 1959, whereas the survival between 1959 and 1960 was estimated as 2 percent for males and 16 percent for females. A high mortality of adult shad in all Atlantic coast populations south of Cape Hatteras, N.C., is verified by the scarcity of older fish in the catch and the fact that all fish examined were spawning for the first time.

Predators

Shad are prolific spawners, but many eggs are not fertilized, and others are eaten by fish and other water animals. The American eel, Anguilla rostrata, and catfishes, Ictalurus spp, feed on the eggs. Eels often attack females caught in gill nets and devour the eggs. The development of fungus is one of the greatest dangers to eggs in the natural state. Mud brought down by heavy rains may bury and suffocate many eggs (Leach, 1925).

Young shad are caught by predators, and many do not survive their few months' stay in the rivers. During rearing at the Linlithgo station on the Hudson River, great care was needed to protect young shad from eels that entered the ponds through water-supply pipes (The New York Conservation Commission of Fisheries, 1911-12). Striped bass, Roccus saxatilis, prey heavily on the young (Shapovalov, 1936; Hollis, 1952).

After the young shad leave the rivers in the fall, and during their stay of 2 to 6 yr. in the ocean, many are victims of predaceous fishes--sharks, bluefin tuna, kingfish, and many others (Leach, 1925). North Carolina fishermen have observed porpoise feeding on adults in coastal waters. Although white pelican, Pelecanus erythrorhynchos, feed extensively on dead and dying spawned-out adults in the St. Johns River (Nichols, 1959a), in general, adult shad are comparatively free from predators other than man once they are in the river.

Parasites

Whether parasites cause or contribute to mortality of shad is unknown, but available evidence indicates that they have no significant effect. Although parasites have been observed in shad, the fish are generally free from severe infestations. Nematodes and distomes were found in the alimentary tract of young collected in the Shubenacadie River, Nova Scotia (Leim, 1924). Roundworms, Agamonema capsularia, frequently were encapsulated upon the ovary, intestine, or liver of adults caught near New York (Leidy, 1857; 1879). Fish taken in the Carolinas usually were free of parasites with the occasional exception of sea lice (Yarrow, 1874). Internal parasites (the roundworm, Ascaris aduncа, and the acanthocephalan, Echinorhynchus acus), and an external copepod parasite (Caligus rapax) were found in shad in the Woods Hole region (Sumner, Osburn, and Cole, 1913). Spawning shad taken in Scotsman Bay and Annapolis and St. Johns Rivers were infested with distomes, nematodes, and Acanthocephali (Leim, 1924). Hollis and Coker (1948) found that 25 percent of 519 fingerlings had cysts of a trematode parasite, Clinostomum marginatum. Ectoparasitic copepods, Argulus canadensis, were found on adults passed over the Hadley Falls Dam in the Connecticut River at Holyoke, Mass. (Davis, 1956). Both sea lamprey, Petromyzon marinus, and freshwater lamprey, Ichthyomzyon sp., were attached to adults taken in the Connecticut River.

HISTORY AND DESCRIPTION OF FISHERY

HISTORICAL NOTES

When New England was first colonized, shad and other fishes abounded in season in the rivers and tributaries, and the Indians had long used them for food. The headwater portions of rivers were, for the most part, accessible to anadromous fishes, and prior to the erection of obstructions on the streams, shad provided profitable fisheries from Maine to Chesapeake Bay.

When the English settled along the Connecticut River, shad were plentiful; they rejected this species, however, for nearly 100 yr. (McDonald, 1887e). Fishermen took the salmon from their nets and usually returned the shad to the streams. Reports indicated that shad were taken in large numbers in many places in Connecticut before 1760, but did not appear on the market until the early 1770's. At that time they sold for a penny each. From 1778 to 1781, thousands of barrels of shad were salted. The falls at South Hadley was one of the favorable places on the Connecticut River for taking fish, and many shad were caught in seines below the falls and in scoop nets on the falls. An account of 3,000 shad taken in one seine haul at East Haddam was reported in 1766 (Stevenson, 1899). In the early fishery on the Connecticut, mainly haul seines were used. Gill nets and pound nets gradually supplanted haul seines and were in general use by 1850.

In early Massachusetts, a great variety of fish abounded in the bays and rivers and their tributaries (True and Wilcox, 1887). As early as 1753, however, the people living along the banks of the river, particularly the Wareham River, observed that several fish, including shad, were not as plentiful as before.

The original range of shad in Maine included almost every large river, but in the smaller rivers they never had been plentiful (Atkins, 1887). From the first settlement of the country until 1825, there were big annual runs of shad, salmon, and alewives. The limits of the upstream migration of these fish were unknown because the entire upper portions of the rivers were wilderness until long after the occupation of the lower rivers and the construction of dams that blocked the upstream movement of anadromous fish. Shad were caught in great numbers in the Saint Croix River and its branches. Vessels of 100 to 150 tons from Rhode Island fished on this river and were never known to leave without full cargoes of fish. The Penobscot and Kennebec Rivers also were productive of shad.

As the demand for shad was limited, the early Maine settlers along the streams caught shad only in small weirs and salmon nets (gill nets, either drifted in midstream or set out from shore on stakes); later, however, the demand for shad rose, and special nets were set for them. Shortly after 1800, weirs with three pounds (enclosures) were introduced.

These weirs were constructed of stakes and brush or woven cedar mats. They had no floor except the river bottom and therefore were not extended beyond low-water mark because the fisherman had to take his catch out with a dip net. When a commercial demand for shad arose a few years later, floors were made for the fish pounds and netting for the walls.

From about 1820 to 1830, probably the greatest years for shad, drift gill net fisheries flourished in Maine rivers. By about 1835, however, enough dams had been built to obstruct the ascent of fish, and a rapid decline in the fisheries began. Since the mid-19th century, impassable dams have excluded shad from nearly the whole extent of the larger rivers.

For years before white people settled in the area, the Indians caught shad in the Chesapeake Bay tributaries in large quantities by a seine made of bushes (called a bush net--McDonald, 1887c). The early settlers used haul seines, and the shad supply was a great item of subsistence. One of the most bitter complaints made by the settlers against the Pennomites in 1784 during the 30 Years' War was that the Indian had destroyed the shad seines. The early fisheries used haul seines almost entirely. About 1835 gill nets were introduced from the north. They steadily grew in favor and have since been an important gear for capturing shad in the Chesapeake Bay area.

In the early 19th century, when the extension of railroads and water routes south from Norfolk, Va., provided easy and rapid communication with northern markets, the shad fisheries of the South Atlantic became important as far south as Florida. McDonald (1887a) reported that settlers caught shad in the St. Johns River, Fla., as early as 1840. Shad were first caught at Mayport, Fla., by Charles Waterhouse of Connecticut in 1858. He had fished previously in the Savannah River, Ga. In the 1860's shad were reported in the St. Marys River, but no one fished for them. At Jacksonville, Fla., gill nets were first used in the shad fisheries in 1868. C. B. Smith of Connecticut was the first to establish a shad fishery at Palatka, Fla., in 1872. In 1873, 94,000 shad were caught at New Berlin, Fla., and in 1874 the shad fisheries on the St. Johns River took 250,000 fish. The fishermen from Cape Ann, Conn., and Delaware Bay came south expressly for shad fishing.

DEVELOPMENT OF THE FISHERIES

During the 19th century, the shad fisheries developed to great importance along the entire Atlantic coast of the United States and supported commercial fishing in every coastal state. Spawning runs were known in every suitable river from the St. Johns River, Fla., to the St. Lawrence River, Canada. Since the species is anadromous, it was taken both inside and outside the rivers by all forms of gear, from seines, weirs, fyke nets, and pound nets near the coast to gill nets, bow nets, and traps in the headwaters of the streams.

The different kinds of gear introduced and developed in the shad fisheries were adapted to their native localities. From Cape Lookout, N.C., to Cape Cod, Mass., the rivers generally empty into large bays or sounds, such as Narragansett, New York, Delaware, and Chesapeake Bays and Long Island, Albemarle, and Pamlico Sounds. The river mouths usually are broad estuaries, resembling arms of sounds and bays rather than rivers, and extensive shoals around the shoreline grade into marshes or sandy beaches. The Delaware River and Bay and the Susquehanna, the James, the Potomac, and the Rappahannock Rivers of Chesapeake Bay and the Neuse River, N.C., are examples of this type. In these areas, mostly pound nets and long rows of stationary gill nets were used. Below Cape Lookout, N.C., the rivers, except for tributaries of Winyah Bay, S.C., empty directly into the ocean and generally maintain their fluvial characteristics to the mouth. In these areas, extensive gill net fisheries developed. In most rivers, because the headwaters were narrow and the fish concentrated on the spawning grounds, the fishermen used seines, traps, and bow and gill nets.

Haul seines, weirs, and drift gill nets and dip nets were used in the early shad fisheries, but the usual and most efficient method of capturing fish was with seines. Fishermen usually "paid out" the net in a semicircular course to surround the fish and then captured them by drawing both seine and fish ashore. Formerly seines were drawn in by manual labor alone with net crews of 15 to 25 men. Later, however, capstans and horses were used. It was necessary to have a smooth bottom and to fish near the channel where the fish swam. Seines never were used extensively in some areas, such as Maine and Rhode Island, where these conditions were lacking.

Weirs were used principally in Maine. This gear entrapped the fish in an enclosure from which they were removed by means of a small seine operated from a boat, which is pushed into the enclosure.

Drift gill nets were fished in all rivers and took shad by enmeshing them. These nets were straight and extended across the stream channel where they drifted with the tide or current.

Dip nets, which were used in rivers where natural or artificial obstructions existed, were hung on wooden frames with a long handle. When in use, the frames were held on the bottom of the stream in a narrow channel, and the nets were lifted when fish struck them.

In some areas where seine fishing was unproductive, stake and drift gill nets came into

general use. Stake nets, or set nets as they are sometimes called, were gill nets that stretched on poles anchored to the river bottom and set at a right angle with the current.

Gill nets were supplanted in some areas by pound nets. The principle of pound net fishing was to trap the fish by directing them into an impounding structure. The basic components consisted of a rectangular bowl or "head" which was the actual impounding structure, heart-shaped "bays" which concentrated and directed the fish toward the head, and finally a leader (or "hedging") which turned the fish toward the bays and head. The pound net differs from a weir, in that the river bottom serves as the floor for weirs, whereas pound nets have bottoms and are of the same material and of the same depth as the leader. Pound nets were first fished at Westbrook, Conn., in 1849 and from that area spread rapidly to other locations (True, 1887). They were introduced into New Jersey in 1855 but did not come into general use until 1873. In 1875 pound nets were scattered along both shores of Long Island, N.Y.; the fish most sought were shad and striped bass. By 1880 this gear occupied the west shore of New York Harbor to Sandy Hook and was fished in Delaware Bay between Cape May and Dyers Creek. Some nets also were set near Barnegat Inlet, N.J. Pound nets were introduced into Chesapeake Bay from New Jersey in 1858. They were first used in Albemarle Sound, N.C., in 1870 and took considerable numbers of shad. In 1880 this gear was introduced into the Ogeechee River, Ga., and two or three nets also were fished in the Neuse River, N.C.

Atkins (1887), McDonald (1887a-e), and True and Wilcox (1887) reported on the status of the shad fisheries in 1880. By that time, impassable dams in Maine had reduced shad to very small numbers. Although the shad fishery was important in the Kennebec River, fishing was attempted in only three other streams and a few bays. Shad was one of the most important fish taken in weirs. Seines were never used extensively, and drift gill nets and dip nets had lost nearly all their importance.

No regular shad fisheries existed in New Hampshire and Massachusetts in 1880, and the shad were incidental to the catches of other species.

In 1880 the fisheries of Connecticut, New York, and New Jersey were important. The Connecticut River yield was 1,105,340 lb., of which pound nets caught about 64 percent, gill nets 20 percent, and haul seines the remainder. Haul seines in the Housatonic River caught 28,600 lb. On the Hudson River, the fish were taken by stake gill nets from Jersey City to Fort Lee, N.J., and by drift gill nets and seines from Fort Lee to Troy, N.Y.; the catch was estimated at 2,556,000 lb.

The shad fisheries of Delaware and Chesapeake Bays and Albemarle and Pamlico Sounds became important about 1869, and their greatest development came in the following 25 years. Haul seines, pound nets, and stake gill nets were used extensively. The catch in 1880 was not given for Delaware and Chesapeake Bays; but the Delaware River produced more than 1 million pounds, and tributaries of Chesapeake Bay produced more than 5 million pounds. Seines and gill nets in the James River yielded 357,000 lb., gill nets in the York River 469,073 lb., and haul seines, pound nets, and gill nets in the Potomac and Susquehanna Rivers more than 4 million pounds. The shad catch in Albemarle Sound was 2,255,823 lb. Gill nets, pound nets, bow nets, and seines were used to catch shad in North Carolina rivers. The Cape Fear River produced 182,000 lb., the Neuse River about 250,000 lb., and the Pamlico-Tar River an equal quantity.

In 1880 the fisheries in the rivers of South Carolina and Georgia primarily used gill nets, but no estimate was given of the catch. Bow nets were fished in the rivers, but the catch was small and used for local consumption.

In 1880 the only organized fishery in Florida was on the St. Johns River, where gill nets and seines caught an estimated 251,700 lb.

In 1896 the total estimated shad catch of the Atlantic coast of the United States was 50,498,860 lb., of which about 46 percent was taken by drift gill nets, 14 percent by stake gill nets, 16 percent by seines, 23 percent by pound nets and weirs, and the remainder by fyke nets, bow nets, spears, fall traps, and miscellaneous gears. New Jersey ranked first in production with 13,909,826 lb., and Virginia second with 11,170,519 lb. Virginia usually ranked first and North Carolina second, but the catch in Virginia in 1896 was less than average, whereas that of New Jersey was considerably above average. Statistics on the fishing gear used and the catch by State are given in tables 6 and 7.

The estimated catch along the ocean shore was more than 400,000 lb., or slightly less than 1 percent of the total Atlantic coast yield. With the exception of a few shad taken incidentally in the catches of other species along the Virginia coast, no shad were reported taken along the ocean shore south of Barnegat, N.J., in 1896. Between Barnegat Inlet and Sandy Hook, N.J., pound nets caught 60,000 lb. Between the eastern end of Long Island, N.Y., and Cape Cod, Mass., 15,000 lb. were taken. Between Cape Cod and eastern Maine, mackerel boats caught about 325,000 lb. of shad.

In 1896 catches of shad in Florida, Georgia, South Carolina, and North Carolina were made principally by gill nets, seines, and pound nets; small catches were made with bow nets and other miscellaneous gear. Of the 11,349,453 lb. caught in this area, 56 percent was taken

Table 6.--Gear employed in shad fisheries, by state, Atlantic coast of the United States, 1896

State	Drift gill net	Stake gill net	Seine	Pound net and weir	Fyke net	Bow net	Miscellaneous
	Yards	Yards	Yards	Number	Number	Number	Number
Florida	91,550	850	7,150	---	---	---	---
Georgia	36,994	3,288	---	26	---	113	---
South Carolina	85,947	8,390	1,815	---	---	447	[1] 83
North Carolina	34,682	1,103,872	76,667	1,575	---	1,278	[2] 75
Virginia	298,043	90,214	24,361	1,156	72	---	[3] 22
Maryland	472,138	84,588	33,349	901	335	128	[4] 15
Delaware	107,361	2,700	8,307	4	---	10	---
Pennsylvania	70,770	---	19,305	---	---	51	[5] 30
New Jersey	546,807	56,826	19,190	---	245	---	---
New York	212,088	10,854	9,607	12	54	---	[5] 20
Connecticut	20,193	---	3,048	---	---	---	---
Rhode Island	---	---	---	3	---	---	---
Maine	56,298	---	[6] 1,230	133	---	---	---
Total	2,032,871	1,361,582	204,029	3,810	706	2,027	245

[1] Cast nets (3) and wheels and fall traps (80).
[2] Wheels.
[3] Hedges (3) and fall traps (19).
[4] Fall traps or fish pots.
[5] Spears.
[6] Purse seine (1) 960 yards long.

in gill nets, 23 percent in seines, 18 percent in pound nets, and the remainder in bow nets, traps, and cast nets. The principal production areas were St. Johns River, Fla.; Altamaha, Ogeechee, and Savannah Rivers, Ga.; Edisto and Pee Dee River, S.C.; and Albemarle and Pamlico Sounds, N.C.

The shad fisheries of Chesapeake Bay and tributaries were the most extensive on the Atlantic coast in 1896; the catch was about 33 percent of the total yield, or 16,712,018 lb. Of this catch, 49 percent was made by pound nets, 33 percent by drift gill nets, 9 percent by stake gill nets, 8 percent by seines, and the remainder by fyke nets, bow nets, and traps.

In Delaware, Pennsylvania, New Jersey, and New York, shad were caught principally in gill nets and seines; smaller catches came from pound and fyke nets and miscellaneous gear. Of the 20,604,809 lb. caught in this area in 1896, about 79 percent was taken in gill nets, 18 percent in seines, 1 percent each in pound and fyke nets, and the remainder by bow nets and spears. The principal production areas were Delaware Bay and tributaries (nearly 17 million pounds) and the Hudson River (more than 2 million pounds).

In Connecticut, Rhode Island, Massachusetts, and Maine, shad were caught principally by pound nets, weirs, drift gill nets, and seines. Of the 1,832,580 lb. caught in this area in

Table 7.--Shad catch by state and gear, Atlantic coast of the United States, 1896

[In pounds]

State	Drift gill net	Stake gill net	Seine	Pound net and weir	Fyke net	Bow net	Miscellaneous	Total
Florida	940,421	4,766	353,418	---	---	---	---	1,298,605
Georgia	487,990	37,773	---	---	---	10,678	186	536,627
South Carolina	381,182	153,886	19,519	---	---	113,650	3,276	671,513
North Carolina	350,093	3,983,520	2,247,641	2,018,077	---	234,943	8,434	8,842,708
Virginia	3,043,508	1,062,856	527,701	6,524,379	---	---	12,075	11,170,519
Maryland	2,501,509	463,996	803,152	1,616,612	49,739	99,289	7,202	5,541,499
Delaware	1,734,498	17,885	229,504	1,618	---	9,789	---	1,993,294
Pennsylvania	1,195,746	---	1,241,094	---	---	42,558	21,745	2,501,143
New Jersey	10,776,192	796,950	1,943,424	168,235	225,025	---	---	13,909,826
New York	1,467,780	339,616	277,080	91,414	22,703	---	1,953	2,200,546
Connecticut	207,066	---	27,766	26,358	---	---	---	261,190
Rhode Island	---	---	---	48,628	---	---	4,133	52,761
Massachusetts	44,160	---	49,085	20,907	---	---	---	114,152
Maine	262,051	---	175,494	966,932	---	---	---	1,404,477
Total	23,392,196	6,861,248	7,894,878	11,483,160	297,467	510,907	59,004	50,498,860

1896, about 58 percent was taken in pound nets and weirs, 28 percent in drift gill nets, and 14 percent in seines. The principal production areas were the Connecticut River, Conn., and the Kennebec River, Maine.

PRESENT FISHERIES

The shad fishery in 1960 had changed little from former years except in size of catch. The gear remained relatively unchanged, but improvements had been made in fishing methods with economy as an important factor. These improvements included the conversion from cotton and linen to nylon nets, except netting used in the construction of pound nets, seines, and fyke nets; adaptions of nets to the bottom contours, currents, and local conditions of the area in which used; replacement of tar as a preservative and antifouling compound by copper paint in the Chesapeake Bay pound net fishery (Reid, 1955); widened spacing of stakes which support stationary nets (to decrease costs); and use of continuous lengths of netting to replace single panels hung from stakes in some localities. Sundstrom's (1957) illustrations and descriptions of gear in commercial fisheries apply in general to shad gear in 1960.

The extent of the fisheries on the Atlantic coast of the United States during the 1960 season is given in tables 8 and 9. The estimated catch was 8,133,931 lb., of which about 35 percent was taken by stake and anchor gill nets, 28 percent by drift gill nets, 16 percent by pound nets, 4 percent by seines, 4 percent by bow nets, 4 percent by rod and reel, and the remainder by otter trawls, fyke nets, traps, fish wheels, and other miscellaneous gears.

The ocean shad catch in 1960 was about 865,300 lb., compared with 7,268,631 lb. taken within the coastline. With the exception of 159,700 lb. caught by anchor gill nets off the mouth of the St. Johns River, none was taken in the ocean south of New Jersey. Pound nets, anchor gill nets, and otter trawls took 42,700 lb. between Point Pleasant and Sandy Hook, N.J.; and about 662,900 lb. were taken incidentally by otter trawls, gill nets, and pound nets operated for other species, from Long Island to Maine.

The South Atlantic fisheries ranked first in yield with 3,026,233 lb., Chesapeake Bay fisheries second with 2,795,091 lb., New England fisheries third with 1,159,185 lb., and the Middle Atlantic fisheries fourth with 1,153,422 lb. Of the South Atlantic catch, gill nets caught 67 percent, seines 11 percent, bow nets 10 percent, rod and reel 7 percent, pound nets 4 percent, and fyke nets and miscellaneous gear the remainder. In Chesapeake Bay, gill nets took 64 percent of the catch, pound nets 33 percent, and seines, fyke nets, and rod and reel the remainder. In New England, miscellaneous gear produced 55 percent of the catch, rod and reel 7 percent, and gill nets and pound nets yielded only 36 and 2 percent, respectively. In the Middle Atlantic, gill nets caught 77 percent of the catch, pound nets 22 percent, and seines and otter trawls the remainder.

The rank in shad catch by states in 1960 was: first, Maryland, 1,408,953 lb.; second, Virginia, 1,386,138 lb.; and third, North Carolina, 1,266,328 lb.

Table 8.--Gear employed in shad fisheries, by state, Atlantic coast of the United States, 1960

State	Drift gill net	Stake and anchor gill net	Seine	Pound net	Fyke net	Bow net	Miscellaneous
	Yards	Yards	Yards	Number	Number	Number	Number
Florida	1,376	6,190	3,800	---	---	---	---
Georgia	26,130	17,460	---	---	---	111	---
South Carolina	12,920	27,585	50	---	---	318	[1] 18
North Carolina	70,885	273,155	2,850	868	19	1,760	[2] 8
Virginia	90,761	104,828	300	372	102	---	---
Maryland	64,908	181,896	38,398	226	---	---	---
Delaware	1,700	8,120	---	---	---	---	---
New Jersey	3,650	32,719	710	38	---	---	---
New York	20,800	30,467	500	25	---	---	---
Connecticut	19,497	---	392	---	---	---	---
Rhode Island	---	---	---	---	---	---	---
Massachusetts	---	---	---	---	---	---	---
Maine	---	---	---	---	---	---	---
Total	312,627	682,420	47,000	1,529	121	2,189	26

[1] Traps.
[2] Fish wheels.

Table 9.--Shad catch by state and gear, Atlantic coast of the United States, 1960

[In pounds]

State	Drift gill net	Stake and anchor gill net	Seine	Pound net	Fyke net	Bow net	Rod and reel	Miscellaneous	Total
Florida	50,065	162,721	298,700	---	---	---	198,000	---	709,486
Georgia	512,949	222,779	---	---	---	23,650	8,206	---	767,584
South Carolina	99,402	145,937	550	---	---	25,876	4,670	6,400	282,835
North Carolina	410,430	430,340	36,442	126,737	600	254,594	505	6,680	1,266,328
Virginia	307,913	467,099	192	598,195	12,739	---	---	[1] ---	1,386,138
Maryland	322,927	677,745	10,051	325,230	---	---	13,000	[1] 60,000	1,408,953
Delaware	2,000	40,000	---	---	---	---	---	300	42,300
New Jersey	8,170	566,866	1,000	116,500	---	---	---	1,100	693,636
New York	143,495	127,160	3,281	143,550	---	---	---	---	417,486
Connecticut	415,905	---	3,906	---	---	---	77,200	800	497,811
Rhode Island	---	[2] ---	---	[2] ---	---	---	---	3,163	3,163
Massachusetts	[2] ---	7,500	---	19,600	---	---	---	630,800	657,900
Maine	[2] 311	---	---	---	---	---	---	---	311
Total	2,273,567	2,848,147	354,122	1,329,812	13,339	304,120	301,581	709,243	8,133,931

[1] Legal unlicensed gill-net catch.
[2] Incidental catches.

The annual shad catch of every coastal State has fluctuated over the years, according to changing conditions within the rivers. The fisheries of each State are discussed by water area in the following sections and are compared with those of 1896. Throughout the discussion, distances are approximate and all mesh measurements are stretched.

SHAD FISHERIES OF FLORIDA

According to historical accounts of the shad fisheries of the Atlantic coast of the United States, the Florida fishery, which began in the 1850's, was the last to be developed (Stevenson, 1899). The commercial gears used in 1896, in order of importance, were drift gill net, seine, and set gill net (table 10). The total catch was 1,298,605 lb., of which drift gill nets took 72 percent, seines 27 percent, and set gill nets 1 percent (table 11).

The commercial gears for shad in Florida in 1960 were seine, set gill net, and drift gill net (table 10). The commercial catch was 511,486 lb., of which haul seines took 58 percent, set gill nets 32 percent, and drift gill nets 10 percent. In addition, sport fishermen in the St. Johns River took 198,000 lb. with rod and reel (table 11).

The amount of gear fished and the catch decreased markedly between 1896 and 1960.

Table 10.--Gear employed in shad fisheries, by water area, Florida, 1896 and 1960

Water area	1896			1960			
	Drift gill net	Set gill net	Seine	Drift gill net	Set gill net	Seine	Sport fisherman days
	Yards	Yards	Yards	Yards	Yards	Yards	Number
St. Johns River:							
Mayport to Jacksonville.	83,500	---	---	300	5,700	---	---
Palatka.	5,250	---	---	580	---	3,800	---
Upper St. Johns.	1,400	---	7,150	---	---	---	19,200
St. Marys River.	1,400	850	---	496	490	---	---
Total.	91,550	850	7,150	1,376	6,190	3,800	19,200

Table 11.--Shad catch, by water area and gear, Florida, 1896 and 1960
[In pounds]

Water area	1896			1960			
	Drift gill net	Set gill net	Seine	Drift gill net	Set gill net	Seine	Sport catch
St. Johns River:							
Mayport to Jacksonville.	821,450	---	---	22,000	159,700	---	---
Palatka.	105,255	---	---	24,600	---	298,700	---
Upper St. Johns.	7,384	---	353,418	---	---	---	198,000
St. Marys River.	6,332	4,766	---	3,465	3,021	---	---
Total.	940,421	4,766	353,418	50,065	162,721	298,700	198,000

Drift gill nets decreased from a total of 91,550 yd. (yards) of net to 1,376 yd., seines decreased from 7,150 to 3,800 yd., and set gill nets increased from 850 to 6,190 yd. The catches decreased from 940,421 to 50,065 lb. in drift gill nets and from 353,418 to 298,700 lb. in seines and increased from 4,766 to 162,721 lb. in set gill nets. The total catch decreased 45 percent, from 1,298,605 to 709,486 lb.

FISHERIES BY WATER AREA

Two rivers in Florida, the St. Johns and the St. Marys, support large shad fisheries (fig. 3). In addition, a few fish are taken each year in the Nassau River. The St. Marys River, for much of its length, is the boundary between Florida and Georgia, and fishermen from both States fish the river. For convenience the fishery of the St. Marys is discussed in this section, but the catch and amount of gear fished by Georgia fishermen are included in the discussion of the fishery in that State.

St. Johns River

This river originates in a grassy-plain section of Florida, 50 miles north of Lake Okeechobee and 15 miles inland from the east coast. It flows north through a chain of lakes for 260 miles to Jacksonville, Fla., and then east for 26 miles before emptying into the Atlantic Ocean at Mayport, Fla. The St. Johns differs from other large rivers along the Atlantic coast of the United States in that it originates close to the coast and flows northward, whereas the other rivers originate farther inland and flow south before entering the ocean.

The St. Johns is not a clearly defined river in its headwaters since it is shallow, winding, and diffuse. In its northward meandering through shallow lakes, it creates many diverse channels until it reaches Lake Harney. From here to its mouth, the river is deeper and has a distinct channel suitable for navigation. Lake George, the only sizeable lake between the river mouth and Lake Monroe, lies 25 miles south of Palatka, Fla., and is the head of tidal influence.

In 1896 the legal fishing season in the St. Johns was from December 1 to the end of the following March; fishing was closed each week from sundown on Saturday to sunrise on Monday. Fishing usually began at the opening of the legal season, fully a month before shad were caught in any other coastal water, and ended the second or third week of March. It was unlawful to fish for shad with gill nets having a mesh size less than 5 in., or any seine having a mesh size less than 3 in.

In 1896 only drift gill nets were fished for shad between Jacksonville, Fla., and the ocean; 146 nets with 5-in. mesh, 40 to 50 meshes deep, and with a total length of 83,500 yd. took 821,450 lb.

Nearly all of the catch was shipped to New York City and other distant markets.

In 1896 no fisheries were operated from Jacksonville to Bridgeport, Fla., a distance of 46 miles. The river in this area is 2 to 5 miles wide and sufficiently sluggish to preclude the use of drift nets.

Drift nets were used exclusively between Bridgeport and Welaka, Fla., a distance of 35 miles, and the fishery was centered in Palatka. In 1896, 22 nets with 5-in. mesh were fished; total length was 5,250 yd. The catch was 105,255 lb. Water hyacinth was so common in this section of the river that drift gill net fishing frequently became difficult or impossible.

The upper St. Johns River consists of a series of connected lakes; the more important are Lakes George, Dexter, Monroe, and Harney. Sanford, Fla., on the shore of Lake Monroe, was the center of the shad fishery. Seines were the principal gear in 1896, although most fishing was confined to the channels, since it was unlawful to fish seines in the lakes forming the St. Johns. Twenty-four seines, 200 to 700 yd. long (total length, 7,150 yd.) and 50 to 100 meshes deep, with 3- to 4-in. mesh, caught 353,418 lb. of shad. In addition, three operators caught a total of 7,384 lb. in 1,400 yd. of drift gill net.

In 1960 there were no obstructions to fish passage in this river, and shad ascended nearly to the headwaters. The major shad spawning area was between Crows Bluff, Fla., to 10 miles south of Lake Harney (Walburg, 1960a). Spawning occurred from late February until mid-April.

The fishery in 1960 was considerably different from that of 1896. The legal commercial shad fishing season on the St. Johns River was from November 15 to March 15. There was no closed season on sport fishing for shad; the daily creel limit was 15. The total commercial and sport catch of shad was 709,486 lb., of which the commercial fishery caught 70 percent. On the basis of catch-effort statistics, the estimated weight of the population was 2,199,000 lb., and the total fishing rate was 32 percent. Commercial fishing was prohibited south of Lake George (Walburg, 1960b).

The 1960 commercial fishery operated on widely separated and relatively short stretches of river. At the mouth anchor gill nets were fished both north and south of jetties which extend into the ocean 1 mile. During the 1960 season 5,700 yd. of anchor and set gill nets caught 159,700 lb. of shad in this area. Each net was 100 yd. long and 30 to 35 meshes deep and had 5- to 5 1/4-in. mesh. Three drift gill nets fished near Jacksonville caught 22,000 lb.

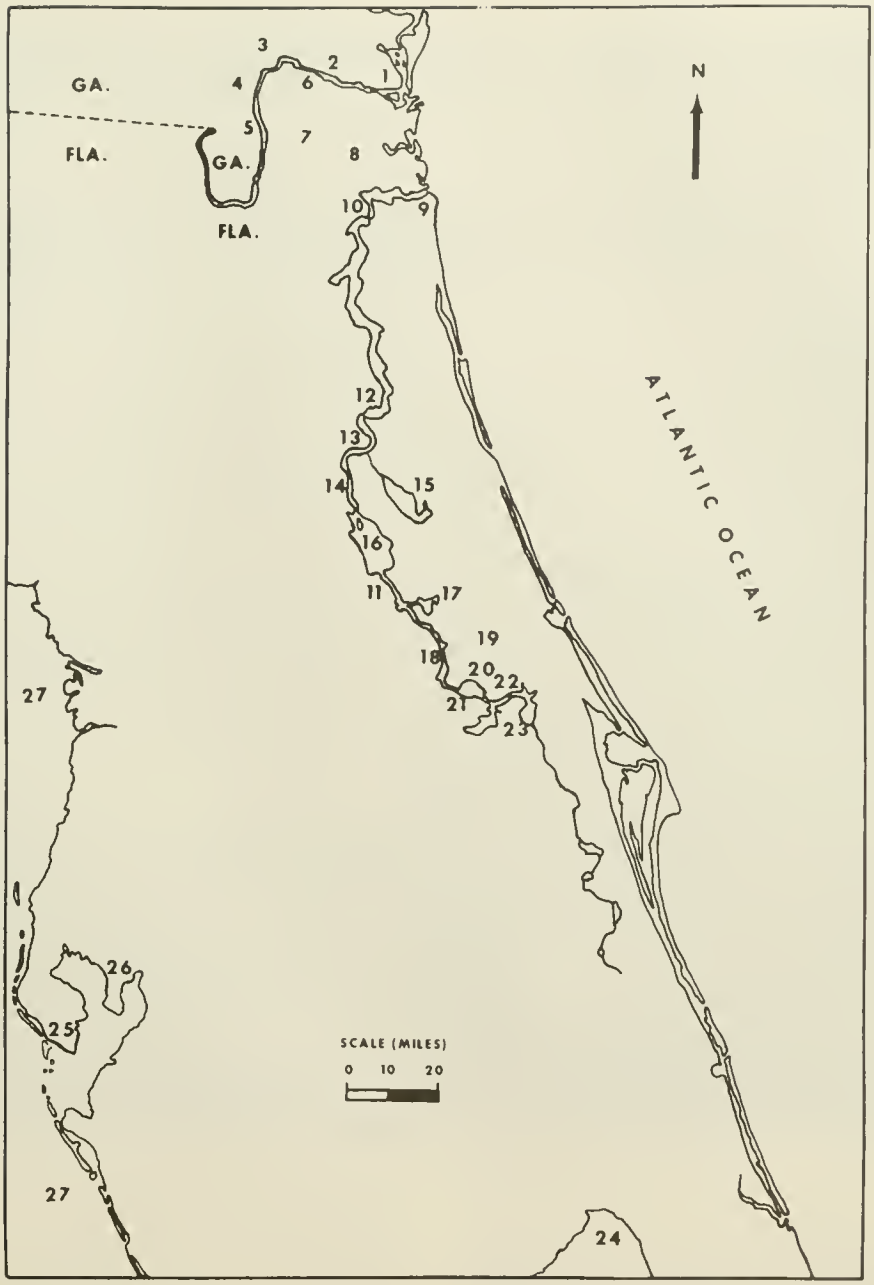

Figure 3.--Map showing St. Johns, St. Marys, and Nassau Rivers, northeastern Florida.

Key:

1 St. Marys	10 Jacksonville	19 DeLand
2 Kingsland	11 St. Johns River	20 Lake Monroe
3 Folkston	12 Bridgeport	21 Sanford
4 Traders Hill	13 Palatka	22 Lemon Bluff
5 Toledo	14 Welaka	23 Lake Harney
6 Kings Ferry	15 Crescent Lake	24 Lake Okeechobee
7 St. Marys River	16 Lake George	25 St. Petersburg
8 Nassau River	17 Lake Dexter	26 Tampa
9 Mayport	18 Crows Bluff	27 Gulf of Mexico

Each of these nets was 100 yd. long and 35 meshes deep; meshes ranged from 4 to 5 1/2 in. Between Palatka and Welaka, a distance of 20 miles, drift gill nets and haul seines (locally termed "shad nets"--see fig. 4) were used. Three gill net operators near Palatka caught a total of 24,600 lb. of shad. The nets were 80 to 100 yd. long and 25 to 50 meshes deep and had 5 1/4-in. mesh. Eleven haul seines fished between the Palatka gill net area and Welaka caught 298,700 lb. The seines were 300 to 380 yd. long and 20 to 30 ft. deep and had 2- to 4-in. mesh. There was no shad fishing in the 55-mile section of the St. Johns from Jacksonville to Palatka.

Sport fishing for shad by hook and line has become popular on the St. Johns River in recent years (Nichols, 1959b). The first fish taken in this manner reportedly was caught in 1942, west of DeLand. In 1960 the fishery was concentrated near Sanford, between Lakes Monroe and Harney, which was also the major spawning area. Fishing was done almost exclusively by trolling from boats with various types of small spoons and weighted jigs (fig. 5). The first shad were taken early in December, and the fishery continued into April. The best catches were made between mid-January and mid-March.

A comparison of gear and location fished for shad in 1896 and 1960 indicates a definite change in the fishery. Channel improvements at the mouth of the St. Johns required a change from drift gill nets fished in the river to anchor gill nets fished outside the river mouth. In 1896 haul seines were fished between Lake George and Lake Harney but in 1960 were confined to the Palatka-Welaka area. In 1960 sport fishermen caught shad in the area between Lake George and Lake Harney. In 1896 most fish were taken by drift gill nets, but in 1960 most were caught by haul seines. The catch was 1,287,507 lb. in 1896 and 703,000 lb. in 1960.

In 1896 Stevenson predicted that the spread and growth of water hyacinth would lead to abandonment of shad fishing near Palatka. This plant is still very much a nuisance on the St. Johns, where it has spread to areas south of Lake Harney despite a control program with 2, 4-D spray conducted by State and Federal agencies. Also, there is a large population of gizzard shad, Dorosoma cepedianum, in the Palatka area, and at times drift gill nets sink from the weight of these fish. Because of the abundance of water hyacinth and gizzard shad, drift gill net fishing upstream from Palatka has been reduced.

Figure 4.--Beaching a shad net on the St. Johns River, Fla.

St. Marys River

The St. Marys River is formed by the union of numerous streams that have their source in the Okefenokee Swamp. It forms a boundary between Florida and Georgia for 175 miles to its entrance into the Atlantic Ocean 3 miles below St. Marys, Ga. The river channel is narrow, and tidal currents are strong for much of its length. Pulp mills are located on both sides of the river near St. Marys.

In 1896, because of the greater abundance of shad in the St. Johns River, as well as meager shipping facilities on the St. Marys, little attention was given to the fish in the

Figure 5.--Trolling for shad at Lemon Bluff on the St. Johns River, Fla.

St. Marys River. In that year the river had 110 shad fishermen--40 from Florida and 70 from Georgia. Eighty fishermen used drift nets, and 30 fished set gill nets. Aggregate length of drift nets was 5,600 yd.; lengths of the nets in this narrow river ranged from 40 to 90 yd.; mesh size was 5 in., and depth was 14 ft. Catch by this gear was 21,470 lb. Aggregate length of set gill nets was 1,275 yd., and the catch was 7,291 lb. Total catch on the St. Marys River was 28,761 lb.

In 1960 the legal commercial shad fishing season was from December 15 to April 15. The river was free of obstructions to the passage of fish, and shad ascended 80 miles to the vicinity of Toledo, Ga. Ripe females in the catch indicated that shad spawn near Traders Hill and Folkston, Ga.

In 1960, 60 fishermen fished for shad in the St. Marys River--13 from Florida and 47 from Georgia. Most of the fishermen in the upper river fished occasionally, whereas most in the lower river fished full-time. Fishing began in mid-January and continued until the first week in April. The fishery extended from the mouth of the river to 10 miles upstream from Folkston, Ga., or 65 miles. In Georgia, by State regulation, the coastal commercial fishing area extends from the river mouth to the Camden-Charlton County line, and the inland commercial fishing area comprises the remainder of the river. Both drift and set gill nets were fished in the coastal area, and set gill nets in the inland area. Drift gill nets (55 to 65 yd. long, 35 to 45 meshes deep, and 4 1/2- to 5 1/2-in. mesh) were used from St. Marys to 5 miles west of Kingsland, Ga. Aggregate length of the nets was 1,302 yd., and the shad catch was 7,866 lb. Set gill nets (20 to 80 yd. long, 35 to 55 meshes deep, and 4 1/2- to 5 1/4-in. mesh) were fished from 3 miles upstream from Kingsland to the upper limit of the inland fishery. Aggregate length of the nets was 2,510 yd., and the catch was 16,150 lb.

Most of the coastal catch in 1960 was landed at Kings Ferry, Fla., and Kingsland, Ga. Florida landings were marketed locally, and Georgia landings were trucked to dealers in Brunswick and Darien, Ga. Most shad landed in the area between Folkston and Traders Hill were taken by occasional fishermen for home use; some were marketed locally in Folkston.

We estimated from samples of the catch that average weights of males and females were 2 and 3 lb., respectively. All dealers reported that fish from the St. Marys River were smaller than those from other Georgia and Florida waters.

A comparison of the St. Marys River fishery in 1896 and 1960 indicates that the amount of each type of gear fished has changed considerably. The amount of drift gill net fished has decreased from 5,600 to 1,302 yd., and set gill net has increased from 1,275 to 2,540 yd. Catch has decreased from 28,761 lb. in 1896 to 24,016 lb. in 1960.

TRENDS IN PRODUCTION

The shad fisheries of Florida were not as productive in 1960 as in earlier years. On the basis of incomplete statistics, the commercial catch during the early period of fishing increased from about 1,299,000 lb. in 1896 to over 2,800,000 lb. in 1908. After that time the catch decreased rapidly, and since 1918 it has fluctuated between 964,000 and 124,000 lb. (table 12). The average catch for the 14 yr. for which data were available between 1880 and 1930 was 1,247,000 lb. The average catch for the next 14-yr. period (1931-46) was 506,000 lb., and for the final 14 yr. (1947-60), 396,000 lb. It is evident that the average annual production of the fishery has continued to decline. In 1953, 124,000 lb. of fish were landed, the lowest commercial catch on record. Since that time the catch generally has increased. In 1960, 511,000 lb. were caught, which was less than 40 percent of the 1896 take.

Table 12.--Shad catch for certain years, Florida, 1896-1960[1]

[In thousands of pounds]

Year	Catch[2]	Year	Catch[2]
1896.	1,299	1942.	323
1897.	1,011	1943.	666
1902.	1,819	1944.	811
1908.	2,833	1945.	842
1918.	964	1946.	837
1923.	503	1947.	625
1927.	348	1948.	515
1928.	691	1949.	284
1929.	701	1950.	298
1930.	880	1951.	336
1931.	621	1952.	203
1932.	546	1953.	124
1934.	782	1954.	281
1936.	282	1955.	508
1937.	288	1956.	376
1938.	229	1957.	361
1939.	254	1958.	589
1940.	344	1959.	540
1941.	256	1960.	511

[1] Statistics for 1896-1940, 1945, and 1950-60 from U. S. Fish and Wildlife Service (1958-61), and for 1941-44 and 1946-49 from Florida State Board of Conservation.

[2] Does not include catch by sport fishery.

SHAD FISHERIES OF GEORGIA

In 1896 the shad fisheries of Georgia were not as extensive as those of Florida in terms of quantity and value of the catch. The species was abundant in rivers of Georgia, but in some areas shipping facilities were so unsatisfactory that fish were taken only for local use. The catch was 536,627 lb., of which drift gill nets took about 91 percent, set gill nets 7 percent, and bow nets and fall traps the remainder.

In 1960 the estimated catch was 759,378 lb., of which drift gill nets took about 68 percent, set gill nets 29 percent, and bow nets the remainder. Of this catch, an estimated 534,000 lb. were shipped to markets and 225,378 lb. were consumed locally. In addition, sport fishermen caught an estimated 8,206 lb. with rod and reel and set lines.

Shad were taken in the same river systems in 1896 and 1960, but changes have occurred in the amount of gear fished and size of catch. The extent of the fisheries is given for these years in tables 13 and 14. Almost all fish were caught by drift gill nets in 1896 but, in 1960 substantial numbers were taken in set gill nets and bow nets. Linear yardage of drift gill nets decreased about 29 percent from 1896 to 1960, whereas linear yardage of set gill nets increased more than fivefold. The number of bow nets fished remained nearly

Table 13.--Gear employed in shad fisheries, by water area, Georgia, 1896 and 1960

River	1896				1960		
	Drift gill net	Set gill net	Bow net	Fall trap	Drift gill net	Set gill net	Bow net
	Yards	Yards	Number	Number	Yards	Yards	Number
St. Marys. .	4,200	425	---	--	806	2,050	---
Satilla. . .	450	---	---	--	6,072	1,920	---
Altamaha . .	4,000	2,580	113	--	13,442	5,340	111
Ogeechee . .	10,667	---	---	--	2,510	3,450	---
Savannah . .	17,677	283	---	26	3,300	4,700	---
Total .	36,994	3,288	113	26	26,130	17,460	111

Table 14.--Shad catch, by water area and gear, Georgia, 1896 and 1960

[In pounds]

River	1896				1960			
	Drift gill net	Set gill net	Bow net	Fall trap	Drift gill net	Set gill net	Bow net	Rod and reel
St. Marys. .	15,138	2,525	---	---	4,401	13,129	---	---
Satilla. . .	5,591	---	---	---	17,600	4,594	---	---
Altamaha . .	65,153	35,110	10,678	---	376,530	108,240	23,650	---
Ogeechee . .	208,753	---	---	---	33,883	13,780	---	7,156
Savannah . .	193,355	138	---	186	80,535	83,036	---	1,050
Total .	487,990	37,773	10,678	186	512,949	222,779	23,650	8,206

constant, but the catch per bow net in 1960 was more than twice that of 1896. Since 1896 sport fishing for shad has been introduced in certain Georgia rivers.

FISHERIES BY WATER AREA

State regulations divide Georgia fishing waters into coastal areas (which are under the jurisdiction of the Coastal Fisheries Division of the Georgia State Game and Fish Commission) and inland areas (under the jurisdiction of the Inland Division of the Commission). In this report, the fishery in each river in Georgia is divided into coastal and inland areas.

In 1960 the legal commercial season for shad fishing was January 1 to April 1, except in the St. Marys River where it was December 15 to April 15. Fishing was not permitted during weekends, from sundown Friday to sunrise Monday. There was no closed season for taking shad with sport tackle, and the daily creel limit was eight shad.

Shad were taken by commercial gear in seven rivers: St. Marys, Satilla, Altamaha, Ocmulgee, Oconee, Ogeechee, and Savannah (fig. 6). In the latter two streams, shad were taken also by sport fishermen. The fishery in the St. Marys River was described in the fisheries of Florida.

Satilla River

The Satilla is the southernmost shad river completely within Georgia. It rises in Irwin County, flows 200 miles southeast, and enters the ocean 30 miles below Woodbine. In addition to other tributaries, the Satilla receives the White Oak River 18 miles below Woodbine.

The shad fishery on the Satilla River originated in 1894, although before then many were taken earlier for home use (Stevenson, 1899). In 1896, 5,591 lb. were caught by three drift gill nets, each 150 yd. long with 5-in. mesh, operated between Woodbine and Bailey Mills, a distance of 30 miles. The catch in excess of local use was sold in Brunswick, Ga.

In 1960 the river was free of obstructions to the passage of fish, and shad ascended 95 miles to Waycross. According to observations of ripe females in the catch, the major spawning grounds were near Owens Ferry in the Satilla River and near U.S. Highway 17 bridge in the White Oak River.

The coastal fishing area in 1960 extended from the river mouth to Owens Ferry, a distance of 40 miles, and the inland area comprised the remainder of the river. In both areas fishing began the first week in February and ended about mid-March when most females had spawned. In the latter part of the season, some netters shifted to the White Oak River.

Drift gill nets were fished in the coastal area, and set gill nets were fished in the inland area. The drift nets were 60 to 130 yd. long and 35 to 40 meshes deep and had 4 3/4- to 5 1/2-in. stretched mesh. Aggregate length of these nets was 6,072 yd., and the catch was 17,600 lb. of shad. Set gill nets were fished in the inland area; they ranged from 10 to 20 yd. long and 35 to 70 meshes deep and had 4 3/4- to 5 1/2-in. stretched mesh. Total length of these nets was 1,920 yd., and the catch was 4,594 lb. of shad. Drift gill net fishermen and some set gill net fishermen depended on shad for part of their livelihood. The catch was sold to dealers at Woodbine and shipped to northern markets. Fish taken in the inland area generally were for home consumption.

Altamaha River

The Altamaha River, with its many tributaries, is located entirely within Georgia. It is formed by the junction of the Ocmulgee and Oconee Rivers and flows 150 miles before entering the ocean below Darien. The Ocmulgee is formed by the union of the South and Yellow Rivers and flows 300 miles to its union with the Oconee. The Oconee is formed by the union of the North and Middle Forks and flows 280 miles before uniting with the Ocmulgee.

Shad were abundant in the Altamaha River in 1896, but shipping facilities were so unsatisfactory that the fishery was undeveloped except for local use. Drift gill nets were fished principally in the lower river below Doctortown, and set gill nets and bow nets were operated above this location. Drift gill nets were 45 to 55 yd. long and had 5- to 5 1/2-in. mesh; set gill nets ranged from 30 to 35 yd. long and had 5 1/2-in. mesh. The amount of gear fished and the catch by gear in 1896 are given in tables 13 and 14.

In 1960 the river and tributaries were free of obstructions to fish passage, and shad ascended the Oconee 100 miles to the vicinity of Dublin and the Ocmulgee 150 miles to the vicinity of Hawkinsville. Ripe fish in the catch indicated the major spawning grounds to be from State Highway 144 bridge in the Altamaha upstream into both tributaries.

The coastal fishing area in 1960 extended from the river mouth to the Seaboard Air Line Railroad Bridge between Everett City and Cox, a distance of 40 miles, and the inland area comprised the remainder of the river including tributaries. Drift gill nets in the coastal area were 35 to 200 yd. long and 35 to 50 meshes deep and had 4 1/2- to 5 1/2-in. mesh. The number of drift gill nets was 99, the aggregate length was 7,722 yd., and the catch was 237,898 lb. of shad. In addition six set gill nets, each 75 yd. long, 70 meshes deep, and with 5 1/2-in.

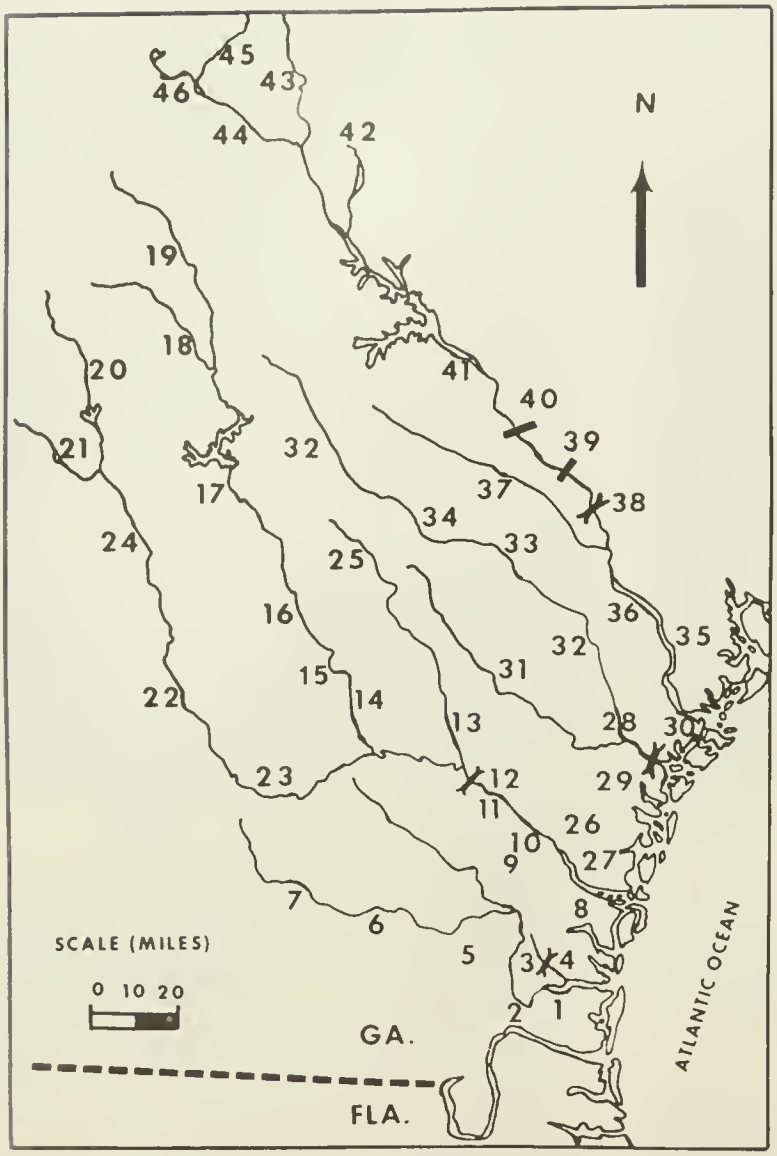

Figure 6.--Map of coastal Georgia.

Key:
1 Woodbine
2 Owens Ferry
3 Hwy. 17 Bridge
4 White Oak River
5 Hoboken
6 Waycross
7 Satilla River
8 Everett City
9 Jesup
10 Doctortown
11 Altamaha River
12 Hwy. 144 Bridge
13 Ohoopee River
14 Mt. Vernon
15 Oconee River
16 Dublin
17 Milledgeville
18 Middle Fork
19 North Fork
20 Yellow River
21 South River
22 Hawkinsville
23 Jacksonville
24 Ocmulgee River
25 Little Ohoopee River
26 Cox
27 Darien
28 Kings Ferry
29 ACL R.R. Bridge
30 Savannah
31 Canoochee River
32 Ogeechee River
33 Millen
34 Midville
35 Hardeeville
36 Savannah River
37 Brier Creek
38 Hwy. 501 Bridge
39 Savannah Lock and Dam
40 City Lock
41 Augusta
42 Anderson
43 Seneca River
44 Tugalloo River
45 Chattooga River
46 Tallulah Falls

mesh, were fished immediately below the railroad bridge. The catch by these nets was included with the inland set gill net fishery. In the inland area, 114 drift gill nets (35 to 90 yd. long, 35 to 45 meshes deep, and 5- to 5 1/2-in. mesh) with a total length of 5,720 yd. and 159 set gill nets (10 to 100 yd. long, 35 to 70 meshes deep, and 5- to 5 1/2-in. mesh) with a length of 3,247 yd. were fished from the Seaboard Air Line Railroad Bridge to the vicinity of Doctortown. The shad catch by drift gill net was 138,632 lb. and by set gill was 75,608 lb. From Doctortown to the vicinity of Jacksonville on the Ocmulgee River and to the vicinity of Mt. Vernon on the Oconee River, there were 194 set gill nets (5 to 30 yd. long, 35 to 45 meshes deep, and 5- to 5 1/2-in. mesh) with aggregate length of 2,093 yd., 111 bow nets, and an occasional small drift net. The bow nets were cone-shaped, 10 to 20 ft. long, with oval openings from 8 to 15 ft. in diameter (fig. 7). The shad catch by set gill nets in this area was 32,632 lb. and by bow nets 23,650 lb. A few shad were also taken by rod and reel on the Ohoopee River, a small tributary which enters the Altamaha 20 miles below the union of the Ocmulgee and Oconee.

In 1960 commercial gear operated about 36 days during the season. About 60 percent of the drift gill net fisherman and 50 percent of the set gill net fishermen who operated below Doctortown fished full time. The remaining fishermen fished about 2 days per week, and their catch was sold locally. The bow net fishermen fished an average of 20 days per season, and most of their catch was marketed locally. During the season, fish dealers from

Figure 7.--Bow net used for catching shad in southern rivers. (Photograph courtesy of North Carolina Wildlife Resources Commission)

Darien traveled by boat throughout the coastal area and bought shad directly from the fishermen. Catches in the inland area were purchased by dealers from Jesup, Ga. Some fish were marketed locally, but most of the catch was shipped to northern markets.

Fulton Lovell, Georgia State Game and Fish Commission, stated (Press release, March 15, 1956. "Altamaha River: More Pollution"), "... the shad catch in the Altamaha and tributaries was approximately 150,000 lb. in 1951 and 1952, and this river usually accounts for about 65 percent of the State's catch." The Altamaha River and its tributaries accounted for 67 percent of the State's catch in 1960 and 20 percent in 1896.

Ogeechee River

The Ogeechee River rises in Greene County, Ga., and flows southeast 350 miles to Ossabaw Sound, south of Savannah, Ga. It is a meandering stream, relatively free from silt and industrial effluents. The Canoochee River, its only important tributary, enters the river 25 miles above its mouth, but does not support a shad run.

In 1896 the Ogeechee ranked first among the shad streams of Georgia. Practically all commercial fishing was with drift gill nets in the lower 22 miles of river. The nets were 67 to 200 yd. long and had 5 to 5 1/2-in. stretched mesh. The catch was 208,753 lb. Most fishermen were nonresidents of the river basin, and many came from Savannah and New England. Savannah was the principal market for the catch. In the middle section of the river, several small set gill nets and bow nets took fish for local consumption, but no information was available on the catch. The uppermost limit of shad in 1896 was the Shoals of the Ogeechee, 200 miles from the river mouth, but few fish passed above Millen, Ga., 100 miles from the sea. The Ogeechee River was free of obstruction to fish passage, and shad ascended the river 125 miles to Midville, Ga. The major spawning area was between Midville and Kings Ferry, Ga. (Sykes, 1956).

In 1960 drift gill nets were fished in the coastal area and were interspersed with set gill nets in the inland area. In the coastal area, drift gill nets were operated from the river mouth to the Atlantic Coast Line Railroad Bridge 1 mile below Kings Ferry. These nets were 75 to 150 yd. long and 35 to 50 meshes deep and had 5- to 5 1/2-in. mesh. The number of nets fished was 27, the total length was 1,994 yd., and the shad catch was 31,860 lb. In the inland area, 200 set gill nets were used from the junction of the Canoochee and Ogeechee Rivers upstream to the vicinity of Midville. The set nets in the inland area were 25 to 100 yd. long and 35 to 65 meshes deep and had 5- to 5 1/2-in. mesh. Aggregate length of these nets was 3,450 yd., and the shad catch was 13,780 lb. The drift nets were 20 to 50 yd. long and 35 to 45 meshes deep and had 5- to 5 1/4-in. mesh. Total length was 516 yd., and the shad catch was 2,023 lb.

During the 1960 season gill net fishing began in mid-January, but fish did not appear in substantial numbers until the first week of February. Catches were good until the second week in March, when temperatures increased and gars, Lepisosteus spp., appeared in large numbers. Damage to nets by these fish forced most netters to discontinue fishing. The number of days fished by coastal drift gill nets ranged from 4 to 33; by inland drift gill nets, from 6 to 18; and by the inland set gill nets, from 9 to 48.

Sport fishermen took shad between Kings Ferry and Midville from mid-March until the end of May with artificial lures trolled from boats and attached to setlines. During this period, an estimated 1,666 rod-and-reel fishermen and 12 setline operators caught 7,156 lb. of shad.

The commercial catch in 1960 decreased about 77 percent from that in 1896.

Savannah River

The Savannah River, one of Georgia's largest streams, is formed by the union of the Tugaloo and Seneca Rivers at Anderson, S.C. It forms the boundary between Georgia and South Carolina for 325 miles and empties into the ocean a short distance below Savannah.

In 1896 the limit of the shad run in the Savannah River was Augusta Dam, 207 miles from the coast. A few fish passed through the sluices of the dam and were occasionally taken

in apparatus fished for other species 80 miles or more above Augusta.

The commercial catch of shad in 1896 was made almost wholly by drift gill nets. These nets were fished in the lower portion of the river along the Georgia shore and in tributaries below Savannah. Nets averaged 350 yd. long and 30 ft. deep and had 5 1/4-in. mesh. The catch by Georgia residents was 193,679 lb., of which about 5,650 lb. were taken with small drift and set gill nets and fall traps below the Augusta Dam. South Carolina residents caught 13,620 lb. with small drift gill nets and 98 lb. with bow nets below Augusta Dam.

In 1960 the Savannah Lock and Dam, located 35 miles below Augusta, Ga., obstructed the upstream movement of fish. Occasionally a few shad gain access to the river above this obstruction during a lockage or through sluices in the dam; however, none was reported above the City Lock, 10 miles upstream from the Savannah Lock. Shad spawned from U.S. Highway 301 bridge upstream to the Savannah Lock. Some fish spawned in Brier Creek, a tributary which enters the Savannah about midway between the mouth and the lower lock.

In 1960 drift gill nets were fished in the coastal area and set gill nets in the inland area. Fishing began in mid-January and was discontinued by mid-March. There were 33 drift gill nets in the coastal area, and fishing was concentrated in the lower 20 miles of river in the vicinity of Hardeeville, S.C. Aggregate length of these nets was 3,300 yd., and the shad catch was 80,535 lb. Nets were 90 to 200 yd. long and 35 to 40 meshes deep and had 5- to 5 3/4-in. mesh. Twenty-one nets were fished by full-time fishermen for 21 to 45 days; the remaining nets were fished for 2 to 12 days by occasional fishermen residing in Savannah. Most full-time fishermen resided in South Carolina, but most of their catch was sold to dealers in Savannah.

In the inland area, including Brier Creek, 200 set gill nets were fished. Total length of the nets was 4,700 yd., and the shad catch was 83,036 lb. The nets were 10 to 40 yd. long and 35 to 55 meshes deep and had 5- to 5 1/2-in. mesh in the lower section of this area; nets were 5 to 12 yd. long and 25 to 35 meshes deep and had 4 1/2- to 5 1/2-in. mesh in the upper section. Nets in the lower section were fished 10 to 48 days, and most of the catch was marketed; those in the upper section were fished 4 to 12 days, and the catch was used locally.

In addition to the commercial fishery, shad were taken by rod and reel immediately below the Savannah Lock and Dam where the fish congregated. Between mid-April and mid-May 1960, an estimated 1,050 lb. were caught. The Savannah River contributed 21 percent of the total Georgia shad catch in 1960 and 36 percent in 1896.

TRENDS IN PRODUCTION

The shad fisheries of Georgia were not as productive in 1880 as in earlier years (McDonald, 1887a). The decline was attributed to an increased number of drift gill nets in the lower sections of the rivers. In the Ogeechee and Savannah, the nets were sufficient in number to almost completely obstruct shad from the spawning grounds. In the Savannah, the dam above Augusta prevented use of spawning areas above this point. Attempts were made to pass shad above this obstruction, but they were not successful (Stevenson, 1899). Shad production in the Ogeechee River also decreased in 1880, but the reasons for this were not clearly understood.

From 1896 to 1908, commercial production increased progressively from 537,000 to 1,333,000 lb. (table 15). By 1902, with improved shipping facilities and expansion of towns along the rivers, shad became the most important commercial species in the State, and its capture constituted one of the leading industries of coastal rivers (Alexander, 1905). The bulk of the catch was taken within a few miles of the mouth of the rivers (Townsend, 1900); however, the quantity taken throughout the interior, not large at any one place, was important in the aggregate.

From 1908 to 1918, production declined more than 92 percent. The U.S. Bureau of Fisheries, in an effort to rehabilitate the fishery, liberated millions of shad fry in Georgia

Table 15.--Shad catch for certain years, Georgia, 1880-1960[1]

[In thousands of pounds]

Year	Catch	Year	Catch
1880. . . .	252	1936. . . .	236
1887. . . .	255	1937. . . .	193
1888. . . .	263	1938. . . .	98
1889. . . .	356	1939. . . .	75
1890. . . .	400	1940. . . .	150
1896. . . .	537	1945. . . .	222
1897. . . .	788	1950. . . .	180
1902. . . .	1,029	1951. . . .	206
1908. . . .	1,333	1952. . . .	243
1918. . . .	101	1953. . . .	214
1923. . . .	134	1954. . . .	180
1927. . . .	187	1955. . . .	158
1928. . . .	317	1956. . . .	168
1929. . . .	472	1957. . . .	247
1930. . . .	275	1958. . . .	319
1931. . . .	132	1959. . . .	391
1932. . . .	288	1960. . . .	534
1934. . . .	232		

[1] Statistics 1880-1959, U.S. Fish and Wildlife Service (1958-61).

streams. The stocking program began in 1875 and reached a peak between 1900 and 1904, when more than 10 million fry were released. The program was discontinued in 1916, after stocking was found ineffective to rehabilitate the fishery.

From 1918 and 1960, there were wide fluctuations in production. Between 1918 and 1940, production fluctuated from a high of 472,000 lb. in 1929 to a low of 75,000 lb. in 1939. From 1940 to 1954, production was fairly uniform, averaging about 200,000 lb. per year. Since that time, the commercial yield has increased from 158,000 lb. in 1955 to 491,000 lb. in 1960. The commercial catch in 1960 was slightly less than in 1896, when it was 537,000 lb.

The low production in Georgia during the past half century has been blamed on a variety of conditions. Siltation has altered the character of certain streams, and expansion of towns and increased industrialization have created pollution problems. Effluents from pulp and paper mills established on the Altamaha River have changed the water quality and affected the taste and odor of shad. Dealers have reported that oil pollutants in the Savannah River cause oily flavor in the fish. Oil and diesel fuel wastes from railroad shops at Waycross were evident in the Satilla River. The biological effects of pollutants on shad runs in Georgia streams have not been determined.

SHAD FISHERIES OF SOUTH CAROLINA

The shad catch in South Carolina in 1896 was 671,513 lb. Fish were taken primarily in drift gill nets; smaller catches were made in stake gill nets, seines, bow nets, cast nets, fish wheels, and traps. Gill nets took about 80 percent of the catch, bow nets 17 percent, and other gears the remainder.

The gears in the shad fisheries of South Carolina in 1960 were stake and set gill net, drift gill net, bow net, submerged trap, rod and reel, and seine. The estimated catch was 282,835 lb., of which gill nets took about 87 percent.

Shad were taken in the same areas in 1896 and 1960, except that in 1960 the Sampit River did not support a fishery (fig. 8). The extent of the fisheries by water area is given in tables 16 and 17. The only changes in gear were the introduction of rod-and-reel fishing on the Edisto and Santee Rivers and the discontinuance of fish wheels in the Pee Dee River and cast nets on the Savannah River. In both years, the most productive gear was the gill net. In 1960 the yardage of gill nets fished was about 57 percent less than in 1896; the major change was in drift nets. The catch by gill nets in 1960 was about 54 percent less than in 1896. In 1896, 447 bow nets caught 113,650 lb., but in 1960, 318 bow nets caught only 25,876 lb. Seines usually were operated in the Edisto and Pee Dee Rivers, but in 1960 high water and a late season discouraged operation of this gear.

FISHERIES BY WATER AREA

The legal season for taking shad and gear restrictions in 1960 varied between water areas. It was originally set from February 1 to March 25 for all coastal areas (waters up to a 40-mile limit in each river as established by the U.S. Army Corps of Engineers and the State) and February 1 to April 20 for all inland waters (above the 40-mile limit), except in Horry County where it was February 1 to May 4. The season subsequently was extended for 2 wk. in each area. The legal fishing period was from Tuesday noon to Saturday noon for all waters except the Edisto River, where it was from Wednesday noon to Saturday noon. Mesh size of nets was restricted to 6-in. mesh, except in the Savannah River (minimum legal mesh, 4 in.) and the Santee and Cooper Rivers (minimum mesh, 5 1/2 in.). Mesh size of bow nets was not restricted. Legal season for fishing with hook and line, rod and reel, and bow nets was February 1 to May 1, and the daily creel limit for sport fishing was eight shad. The U.S. Army Corps of Engineers required fishermen to obtain a permit to set nets in Bull Creek, Black River, Pee Dee River, Winyah Bay, Edisto River, Waccamaw River, and Santee River because of navigational difficulties.

During the 1960 shad season the coastal area produced 162,000 lb. and the inland area 120,835 lb. The catch by gear and amount of gear by water area are discussed in the following sections. The Savannah River fishery is described in the Shad Fisheries of Georgia.

Combahee and Ashepoo Rivers

The Combahee and Ashepoo Rivers are both within South Carolina. The Combahee rises in Aiken County and flows 110 miles to the sea. Above the entrance of Jackson Branch, 40 miles from the mouth, the Combahee is called the Salkehatchie River. The Ashepoo is entirely within Colleton County and is 60 miles long.

In 1896 shad ascended the Combahee River to Walker and the Ashepoo River to Waterboro, a distance of 85 and 50 miles, respectively. The fisheries were centered at the Charleston and Savannah Railroad bridge crossing. The shad season in these two rivers was January 15 to March 31. The catch in the Combahee was 14,151 lb. by 907 yd. of stake gill net. The

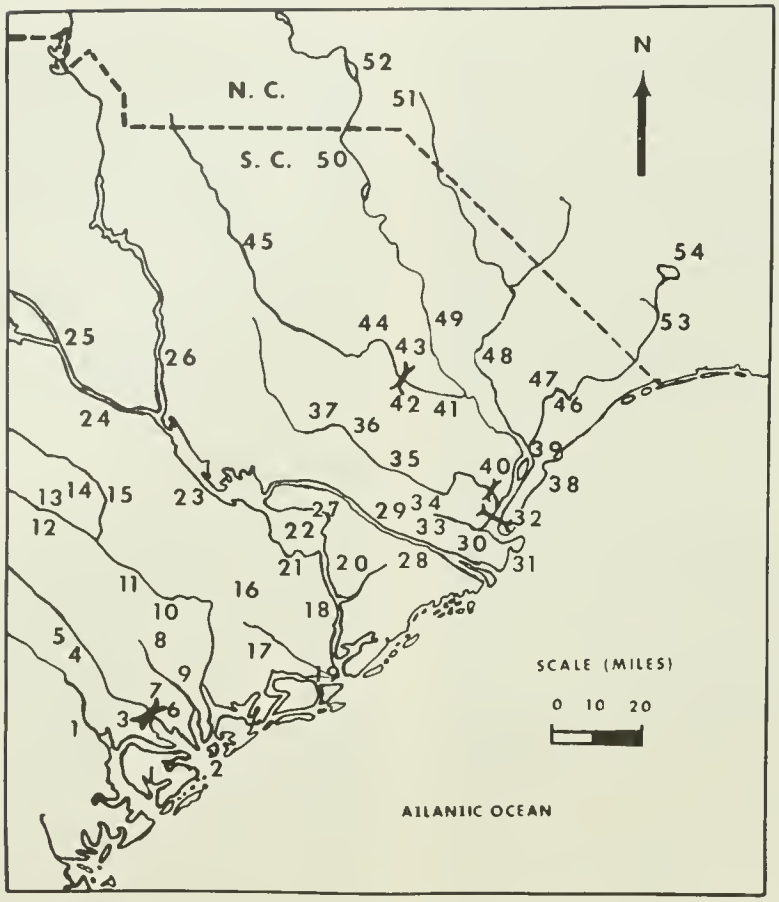

Figure 8.--Map of coastal South Carolina.

Key:
1 Coosawhatchie River
2 St. Helena Sound
3 Hwy. 17A Bridge
4 Salkehatchie River
5 Miley
6 Combahee River
7 Ashepoo River
8 Walterboro
9 Fishburn Landing
10 Canadys
11 Edisto River
12 South Edisto River
13 Norway
14 North Edisto River
15 Orangeburg
16 Givhans Ferry State Park
17 Ashley River
18 Cooper River
19 Charleston
20 Hwy. 52 Bridge
21 Cooper Dam
22 Lake Moultrie
23 Lake Marion
24 Congaree River
25 Columbia
26 Wateree River
27 St. Stephen
28 Jamestown
29 Santee River
30 Georgetown
31 Winyah Bay
32 Hwy. 17 Bridge
33 Sampit River
34 Andrews
35 Black River
36 Kingstree
37 Mouzon
38 Murrells Inlet
39 Bull Creek
40 Hwy. 701 Bridge
41 Johnsonville
42 Hwy. 378 Bridge
43 Pamplico
44 Effingham
45 Lynches River
46 Waccamaw River
47 Conway
48 Little Pee Dee River
49 Pee Dee River
50 Cheraw
51 Rockingham
52 Clewett Falls Dam
53 Freeland
54 Lake Waccamaw

Table 16.--Gear employed in shad fisheries, by water area, South Carolina, 1896 and 1960

Water area	1896					1960				
	Drift gill net	Stake gill net	Seine	Bow net	Miscellaneous	Drift gill net	Stake and set gill net	Seine	Bow net	Miscellaneous
	Yards	Yards	Yards	Number	Number	Yards	Yards	Yards	Number	Number
Savannah River	475	---	---	---	[1] 3	---	---	---	---	---
Combahee River	---	907	---	---	---	---	1,860	---	---	---
Ashepoo River	---	1,297	---	6	---	195	450	---	---	---
Edisto River	---	4,253	973	83	---	1,080	5,555	---	75	[2] 1,442
Cooper River	---	200	42	24	---	---	920	---	---	---
Santee River	---	1,733	---	55	---	520	3,420	---	15	---
Winyah Bay and tributaries:										
Waccamaw River	85,344	---	---	---	---	5,125	6,900	---	---	---
Pee Dee River	128	---	800	168	[3] 80	6,000	1,350	50	35	---
Lynches River	---	---	---	25	---	---	5,850	---	175	[4] 18
Black River	---	---	---	65	---	---	1,280	---	18	---
Sampit	---	---	---	21	---	---	---	---	---	---
Total	85,947	8,390	1,815	447	83	12,920	27,585	50	318	

[1] Cast nets.
[2] Fisherman days.
[3] Fish wheels and traps.
[4] Submerged traps.

Table 17.--Shad catch, by water area and gear, South Carolina, 1896 and 1960
[In pounds]

Water area	1896					1960				
	Drift gill net	Stake gill net	Seine	Bow net	Miscellaneous	Drift gill net	Stake and set gill net	Seine	Bow net	Miscellaneous
Savannah River	13,620	---	---	---	[1] 98	---	---	---	---	---
Combahee River	---	14,151	---	---	---	---	1,935	---	---	---
Ashepoo River	---	29,310	---	2,198	---	200	300	---	---	---
Edisto River	---	100,602	12,063	16,817	---	5,820	16,170	---	6,730	[2] 4,670
Cooper River	---	366	92	1,356	---	---	6,303	---	---	---
Santee River	---	9,457	---	24,016	---	12,044	31,471	---	10,740	---
Winyah Bay and tributaries:										
Waccamaw River	366,692	---	---	---	[3] ---	48,008	58,396	---	---	---
Pee Dee River	870	---	7,364	35,534	3,178	33,330	3,581	550	1,051	---
Lynches River	---	---	---	3,755	---	---	17,378	---	5,825	[4] 6,400
Black River	---	---	---	26,677	---	---	9,863	---	1,530	---
Sampit River	---	---	---	3,297	---	---	---	---	---	---
Total	381,182	153,886	19,519	113,650	3,276	99,402	145,937	550	25,876	11,070

[1] Cast nets.
[2] Sport fishing tackle.
[3] Fish wheels and traps.
[4] Submerged traps.

Ashepoo catch was 31,508 lb., of which 29,310 were taken in 1,297 yd. of stake gill nets, and 2,198 lb. in 6 bow nets.

A few shad were taken on the New Colleton and Coosawhatchie Rivers in 1896 by bow net and small stake gill nets for local use. The total catch was probably less than 3,000 lb.

Except for an occasional fish taken in the Coosawhatchie River, the Combahee and Ashepoo were the only streams between the Savannah and Edisto Rivers that produced shad in 1960. The fish ascended the Combahee River at least 60 miles to the vicinity of Miley and the Ashepoo River 50 miles to the vicinity of Walterboro. (No obstructions to upstream movement of fish existed in either river.) The localities of capture of ripe female fish indicated that the spawning grounds in each river were in the upper 20 miles of the range.

On the Combahee in 1960, fishing began the first week of February and was discontinued in mid-April. The 60 nets fished for shad were from 8 to 40 yd. long and 25 to 35 meshes deep and were concentrated near Highway 17A bridge. The catch was 1,935 lb. and was consumed locally.

Set and drift gill nets were used on the Ashepoo River. Drift nets were fished primarily below the Highway 17 bridge, and set nets above the bridge. Set nets were 10 to 60 yd. long and 20 to 25 meshes deep, and the drift nets were 40 to 75 yd. long and 25 to 35 meshes deep. The estimated catch was 500 lb., all of which was taken by local residents for home consumption.

The catches by gear and amount of gear fished in the Combahee and Ashepoo Rivers in 1896 and 1960 are given in tables 16 and 17. In 1960, compared with 1896, the amount of fishing gear was larger and the catch smaller.

Edisto River

The Edisto River is formed by the junction of the North and South Edisto Rivers near Branchville, S.C., and flows southeasterly 90 miles where it enters the ocean at St. Helena Sound. Each tributary is 70 miles long. The river is narrow and has numerous shoals and a generally sandy bottom. The water is brownish and relatively free from industrial effluents and pollution except for minor discharge of domestic sewage. The limit of tidal influence is 40 miles upstream near Fishburn Landing.

The fisheries on the Edisto in 1896 extended from the river mouth to Orangeburg on the North Edisto and were most extensive near Jacksonboro. Set gill nets were the principal gear; a few bow nets and seines were operated in the upper reaches of the river. The season opened about January 10 and closed the end of March; best catches were in February. Fishing with gill nets was restricted to 4 days each week, from Monday sunrise to Thursday sunset. The estimated catch was 129,482 lb., of which gill nets caught about 78 percent, bow nets 13 percent, and seines the remainder.

The river was unobstructed in 1896 and 1960, and shad ascended the river at least 100 miles to the vicinity of Orangeburg in the North Edisto and at least 120 miles to the vicinity of Norway in the South Edisto. Shad spawned from Fishburn Landing to the upper limit of the run in each tributary; major spawning grounds were near Givhans Ferry State Park (Walburg, 1956).

In 1960 drift and set gill nets were used for taking shad in the coastal (river mouth to Fishburn Landing) and inland (river and tributaries above Fishburn Landing) fishing areas. In the coastal area 38 set gill nets were the only gear used except for a few drift gill nets fished near Fishburn Landing. The catch by the latter nets was included with the drift net catch in the inland area. Set nets were 45 to 90 yd. long and 35 to 45 meshes deep. Aggregate length of the nets was 2,611 yd., and the shad catch was 6,807 lb. In the inland area 80 set and 18 drift gill nets were fished to the vicinity of Canadys, a distance of 40 miles. Set nets were 10 to 60 yd. long and 35 to 45 meshes deep; drift nets were 35 to 100 yd. long and 35 to 65 meshes deep. Total length of the set gill nets was 2,944 yd., and the shad catch was 9,903 lb. Aggregate length of the drift gill nets was 1,080 yd., and the shad catch was 5,820 lb. Seventy-five bow nets fished from Canadys to the upper limit of the run in each tributary took 6,730 lb. of shad. Haul seines normally are operated near Cottageville, but they were not fished during the 1960 season because of high water in the early season and low market price for shad thereafter.

In addition to commercial fishing, the river supported sport fishing for shad with rod and reel from West Bank to Canadys, a distance of 60 miles. The estimated catch by sport fishermen in 1960 was 4,670 lb. Most fish were taken between Fishburn Landing and Harts Bluff.

The total shad catch in 1960 was 33,930 lb.; 17 percent was taken by drift gill nets, 49 percent by set gill nets, 20 percent by bow nets, and 14 percent by rod and reel. Most fish were sold locally, but some were marketed in Charleston.

The shad fishery on the Edisto River changed little between 1896 and 1960 except in the amount of gear used and catch. In 1896 the Edisto ranked second among the shad streams of South Carolina and accounted for about 19 percent of the total catch; it ranked fourth and yielded about 12 percent of the total catch in 1960. The amount of gill net fished increased about 36 percent from 1896 to 1960, but the catch by this gear decreased 78 percent. The catch by bow nets and the number of nets fished also decreased. Cable (1944)

reported overfishing to be the primary cause for decline in production. This statement may be correct; but from the limited information available, this conclusion does not appear warranted.

Charleston Harbor and Tributaries

Streams between the Edisto and Santee Rivers have a common outlet into Charleston Harbor. The most important are the Ashley and Cooper.

Few shad ascended these streams in 1896, and fisheries were limited. The total catch was less than one thousand pounds by bow nets and stake gill nets for local use.

In 1960 these streams had shad runs; however, the fisheries were small. Shad ascended the Ashley River 25 miles to Summerville, S.C. Local residents caught about 50 shad with small set gill nets in the Live Oak Brook area, 4 miles south of Summerville. In the Cooper River shad ascended about 40 miles to the Cooper Dam at the outlet from Lake Moultrie. Observations of the catch indicated that spawning took place near Stony Landing, just below the canal tailrace of the dam. Fish were taken by 40 set gill nets, 15 to 30 yd. long and 25 to 35 meshes deep. Nets were operated from the canal tailrace to Cypress Gardens, S.C., a distance of 20 miles; 6,303 lb. of fish were caught, all of which were marked in Moncks Corner, S.C. Rod-and-reel fishermen took a few shad below the canal tailrace, but no estimate was made of the catch.

Santee River

The Santee River extends 130 miles, from the confluence of the Congaree and Wateree Rivers through Lake Marion to the ocean. Shad formerly ascended the Wateree to Great Falls, N.C., 272 miles from the ocean, and the Congaree to a point 28 miles above the boundary between North Carolina and South Carolina, or 374 miles from the ocean (Stevenson, 1899).

In 1896 a dam at Columbia, S.C., 233 miles from the ocean, prevented shad from ascending beyond that point. The fishery resources of the Santee River and tributaries were relatively undeveloped at that time, however, though shad were taken with stake gill and bow nets for local use. The catch was 33,473 lb.

A dam at the outlet of Lake Marion, 65 miles above the mouth of the Santee, prevented further ascent of fish in 1960. The presence of ripe females in the catch indicated that the major shad spawning ground was between Highway 52 bridge and the dam.

The commercial shad fishery in 1960 extended from Highway 17 bridge to one-quarter of a mile below the dam. Gill nets were the principal gear. Drift nets, 35 to 100 yd. long and 35 to 45 meshes deep, were fished from Highway 17 bridge to the vicinity of St. Stephens, S.C. Set gill nets, 10 to 60 yd. long and 25 to 45 meshes deep, were fished from Jamestown, S.C., to the upper limit of the fishery. A few bow nets were fished below Lake Marion Dam, and only female shad were kept. The estimated catch was 54,255 lb., of which 90 set gill nets caught 58 percent, 13 drift gill nets 22 percent, and 15 bow nets the remainder. Aggregate length of the set gill nets was 3,420 yd. and of drift gill nets 520 yd. Most of the catch was marketed locally in Moncks Corner and Andrews.

The amount of gear fished and the catch were greater in 1960 than in 1896. The number of bow nets was lower in 1960 than in 1896, but the catch per net was greater. The dam probably has limited the area for bow net fishing and caused a concentration of fish accessible to this type of gear. Rod-and-reel fishing was employed around the Santee tailrace, but no estimate was made of the shad catch. Shad taken by rod and reel were incidental to the catch of striped bass, Roccus saxatilis.

Winyah Bay and Tributaries

The fisheries of Winyah Bay and tributaries yielded 447,367 lb. of shad, in 1896, of which drift gill nets caught about 82 percent, bow nets 15 percent, seines 2 percent, and miscellaneous gear the remainder.

In 1960 Winyah Bay and its tributaries, the Waccamaw, Pee Dee, and Black Rivers, were the principal shad producing regions of South Carolina. The estimated combined catch from these areas was 185,912 lb., of which drift gill nets caught 44 percent, stake, set, and anchor gill nets 48 percent, bow nets 14 percent, and seines and miscellaneous gear the remainder (table 18). The 1960 catch was less than 42 percent of the 1896 catch.

Waccamaw River.--Winyah Bay is about 14 miles long and from 3/4 to 4 miles wide. Its largest tributary, the Waccamaw River, originates in Lake Waccamaw, Columbus County, N.C., and flows 149 miles into Winyah Bay near Georgetown. Forty miles above its mouth, the Waccamaw joins the Pee Dee River through Bull Creek. The lower 26 miles has numerous connections between these rivers.

The shad fisheries on Winyah Bay and lower portions of the Waccamaw River were important in 1896. The season began mid-January and continued to the end of March. The shad catch for both areas was 366,692 lb. by 85,344 yd. of drift gill net. The nets were 200 to 300 yd. long and 16 to 20 ft. deep and had 5 1/4- to 5 1/2-in. mesh. The amount of gear fished

Table 18.--Shad catch, by area and gear, Winyah Bay, S. C., and tributaries, 1960

Area and gear	Quantity	Length fished	Catch
	Number	Yards	Pounds
Winyah Bay:			
Stake gill net	6	2,000	29,836
Waccamaw River:			
Anchor and set gill net	120	4,900	28,560
Drift gill net	35	5,125	48,008
Pee Dee River:			
Anchor gill net	4	350	881
Great and Little Pee Dee Rivers:			
Anchor and set gill net	25	1,000	2,700
Drift gill net	125	6,000	33,330
Bow net	35	---	1,051
Haul seine	1	50	550
Lynches River:			
Set gill net	450	5,850	17,378
Bow net	150	---	5,825
Submerged trap	18	---	6,400
Black River:			
Set gill net	32	1,280	9,863
Bow net	15	---	1,530
Total	1,016	26,555	185,912

has decreased greatly since 1896 and has changed from drift gill nets to stake gill nets. The Bay channels used by drift net fishermen during earlier years have been dredged to an average depth of about 27 ft. and wind throughout the Bay in a manner that prevents drift net fishing.

In 1960 the coastal fishing area extended from the river mouth through Bull Creek, and the inland fishing area extended to the North Carolina-South Carolina boundary. No obstructions to the passage of fish existed, and shad ascended the river at least to Freeland, N.C., 130 miles from Winyah Bay. The ripe females in the catch indicated that the major shad spawning ground was near Conway, S.C.

The section fished in 1960 was from the entrance of the Bay to the Highway 17 bridge at the mouth of the Waccamaw River. The U.S. Army Corps of Engineers designated the fishing area so that shipping lanes were unobstructed. Stake gill nets, the only gear used, were 100 to 400 yd. long and 25 to 70 meshes deep. Two thousand yards of net caught 29,836 lb. of shad. The catch was sold to dealers in Georgetown who retailed some fish locally, but shipped most to northern markets.

The catch in the Waccamaw River in 1960 was 76,568 lb., of which drift gill nets took 63 percent and anchor and set gill nets 37 percent. Drift gill nets, 60 to 300 yd. long and 40 to 65 meshes deep, were the principal commercial gear, and fishing was concentrated near Sandy Island. Anchor gill nets, 40 to 100 yd. long and 25 to 45 meshes deep, were used from Sandy Island to the mouth of Bull Creek. A few anchor nets fished at the junction of Bull Creek and the Pee Dee River are included with the Pee Dee fishery. Most of the catch was sold to dealers in Georgetown and Murrells Inlet, S.C.

Set and anchor gill nets, 25 to 50 yd. long and 25 to 35 meshes deep, were the principal gear used in the inland area in 1960. A few smaller set gill nets and bow nets were fished between the North Carolina-South Carolina State line and the upper limit of the run, but the catch was negligible. Most of the catch in the inland area was marketed in Conway.

Pee Dee River and Tributaries.--The main tributary of the Pee Dee River system, Great Pee Dee, rises on the eastern slopes of the Blue Ridge, in Watauga County, N.C. It flows 496 miles--272 miles in North Carolina and 224 miles in South Carolina--before it enters Winyah Bay. In both 1896 and 1960, fish ascended the river to Blewett Falls Dam, 230 miles from the river mouth at Georgetown. From Blewett Falls Dam downstream to Cheraw, S.C., 26 miles, the river bed is rocky, and shad ascended this section of the river only during high flow. For this report, the fishery was divided into three sections: Pee Dee River, Great and Little Pee Dee Rivers, and Lynches River.

Pee Dee River.--This river is formed by the confluence of the Great and Little Pee Dee Rivers, 42 miles above the mouth. It is 150 to 300 ft. wide, the banks are low and swampy, and the lower 25 miles, from the junction of Bull Creek to Winyah Bay, are composed of a series of small creeks and ponds. Four anchor gill nets, 65 to 85 yd. long and 25 to 40 meshes deep, fished in this section during 1960 caught 881 pounds of shad. No shad were reported taken in this river in 1896.

Great and Little Pee Dee Rivers.--In 1896 shad were taken throughout the Great Pee Dee to Cheraw with drift gill nets, seines, bow nets, and fish wheels, but in no great abundance at any one point. The catch by all gears was 49,946 lb., of which bow nets took 75 percent. In the river between Cheraw and the Narrows, 71 miles, 16 fish wheel and fall-trap fisheries originally were constructed for catching shad; in 1896, however, the total yield was only 2,500 lb.

The Great Pee Dee, from the mouth to Cheraw, has a more definite channel and is better suited for net fishing than the lower 25 miles of the Pee Dee River. During the 1960 season shad were taken by anchor and set gill nets, drift gill nets, bow nets, and haul seines. From the mouth to Gresham, S.C., 13 anchor gill nets, 75 drift gill nets, 25 bow nets, and 1 haul seine were fished. From Gresham to Pamplico, S.C., 2 anchor gill nets, 30 drift gill nets, and 10 bow nets were fished. Between Pamlico and Cheraw, there was limited fishing by 20 drift gill nets. From Cheraw to Blewett Falls Dam, 200 set gill nets were fished (concentrated near Rockingham, N.C.). Anchor and set nets ranged from 10 to 40 yd. long and 25 to 45 meshes deep, and drift nets ranged from 25 to 100 yd. long and 35 to 45 meshes deep. The haul seine was 50 yd. long and was fished near Smith Mill at the mouth of the Lynches River. The estimated catch by all gears was 37,191 lb., of which gill nets took 96 percent. Most of the catch was sold to local markets in towns along the river.

The Little Pee Dee River rises in southern North Carolina and flows 75 miles before joining the Great Pee Dee, 56 miles above the mouth of the Pee Dee River. During the 1960 season 10 set gill nets fished in the lower 2 miles of river caught 440 lb. of shad. No shad were caught in this stream in 1896.

Lynches River.--The Lynches River rises in Union County, N.C., and flows 200 miles before entering the Great Pee Dee 86 miles above Georgetown.

In 1896 the Lynches River was well adapted to shad, which ascended as far as Tillery Ferry, 125 miles above the mouth. Only bow nets were fished, and since there were no large settlements on the river, the local fisheries were small. The total catch was 3,755 lb.

The river was free of obstructions in 1960, and shad ascended to at least 5 miles above Effingham, S.C., 45 miles from the mouth of the tributary. Ripe females in the catch indicated that the major spawning ground was near the Highway 378 bridge between Lake City and Hannah, S.C.

The total catch in 1960 was 29,603 lb., of which set gill nets caught 59 percent, bow nets (fig. 9) 20 percent, and submerged traps the remainder (table 18).

Set gill nets, 8 to 25 yd. long and 25 to 35 meshes deep, were fished 10 miles from the stream mouth to the vicinity of Johnsonville, S.C. Bow nets were fished throughout the shad range.

Black River.--The Black River has its source in Kershaw and Sumter Counties, S.C., and flows 150 miles before entering Winyah Bay near Georgetown.

Figure 9.--Landing a shad by bow net. When the fisherman feels a fish hit the net, he raises the net with a twisting motion, trapping the fish. (Photograph courtesy of North Carolina Wildlife Resources Commission)

In 1896 shad were taken in the Black River as far upstream as Mouzon, S.C., 130 miles from Georgetown. Sixty-five bow nets, the only gear fished, caught an estimated 26,677 lb.

In 1960 the river contained no obstruction and shad ascended to the vicinity of Kingstree, S.C., 100 miles from Winyah Bay. Ripe females in the catch indicated that shad spawned from near Andrews to Kingstree, S.C.

Set gill nets and bow nets caught an estimated 11,393 lb. of shad in 1960. The set gill nets were used from Highway 701 bridge upstream to Kingstree, and bow nets from Andrews to the upper limit of the run. They ranged from 20 to 60 yd. long and 25 to 55 meshes deep; the catch was 9,863 lb. The 18 bow nets caught 1,530 lb. Most fishermen were residents along the river, and the catch was consumed locally.

TRENDS IN PRODUCTION

The early shad fisheries in South Carolina were localized because of the small human population and the lack of transportation facilities (McDonald, 1887a). Productive fisheries could have been undertaken at the mouths of some rivers had markets not been so inaccessible.

In 1896 the fishery of Winyah Bay and tributaries was of comparatively recent origin, and its development was that characteristic of most South Atlantic streams. In the upper reaches of the rivers, increased dam construction reduced spawning areas, and fish populations decreased. Because fishing was concentrated near the river mouths, 85 percent of the fish caught, practically none of which had spawned, were taken within 30 miles of the ocean. Stevenson (1899) reported that natural reproduction was no longer sufficient to replenish the supply of fish and that artificial propagation was essential to the prosperity of the fishery. The seasonal catch per drift gill net near Georgetown was 1,417 lb.

Cable (1944) reported that in 1869 it was generally recognized that too much gear was being fished and that the shad run in some areas of South Carolina was in danger of depletion even though production continued to rise. From 1875 to 1938 millions of shad eggs and fry, obtained from Federal hatcheries, were liberated in South Carolina streams. This attempt to rehabilitate the run was augmented when a State hatchery was erected in 1880 at Orangeburg, S.C., and operated until the early 1900's.

Annual shad production increased from 1880 through the 1890's and remained at more than 400,000 lb. until 1908 (table 19). Some believed that the increased yield was the result of stocking, but a decline in production after 1908 indicated that high catches could not be maintained by this means. Shad ranked second in value and third in pounds of fish landed in South Carolina in 1908 (Bureau of the Census, 1911). After that year production declined steadily, although irregularly.

Table 19.--Shad catch for certain years, South Carolina, 1880-1960[1]

[In thousands of pounds]

Year	Catch	Year	Catch
1880	208	1936	177
1887	366	1937	138
1888	433	1938	59
1889	577	1939	42
1890	563	1940	50
1896	672	1945	89
1897	506	1950	73
1902	434	1951	96
1908	464	1952	136
1918	167	1953	110
1923	184	1954	196
1927	182	1955	88
1928	320	1956	116
1929	260	1957	80
1930	214	1958	71
1931	152	1959	80
1932	123	1960	162
1934	209		

[1] Statistics 1880-1959, U.S. Fish and Wildlife Service (1958-61).

In past years, pollution in some areas from domestic and industrial wastes killed spawn and fry and was thus a major factor in reducing shad abundance in South Carolina (Cable, 1944); obstructions that prevented adult fish from reaching spawning grounds also received much blame. Pollution and dams undoubtedly played a part in the decline, but their effects were obscured by overfishing. Lunz, Penney, and Lesesne (1944) pointed out that overfishing was the chief cause of depletion; in some areas pollution played a part. Pollutants were domestic sewage and waste materials from pulp mills, fertilizer factories, and other industrial plants. Young shad killed by pollution while enroute to salt water often littered the slips and the water under the docks in the Sampit River.

Rehabilitation programs by the South Carolina State Board of Fisheries have failed to increase production to former levels. Restrictive measures were introduced governing the amount and kind of gear and time of fishing, and a 5-cent tax was levied on each shad caught to finance the cost of annual production estimates. In the last 3 decades, commercial production has remained at a low level and in only 5 yr. has it exceeded 100,000 lb. The commercial catch in 1960 increased over that of any of the previous 5 yr., but was less than 24 percent of the catch in 1896.

SHAD FISHERIES OF NORTH CAROLINA

There are few early records on the shad fisheries of North Carolina besides McDonald's (1887b) report on the fishery in certain areas in 1880 and Stevenson's (1899) description by water area in 1896. The catch in 1896 was 8,842,708 lb.; gill nets took 49 percent, seines 25 percent, pound nets 23 percent, and bow nets and fish wheels 3 percent.

In 1960 the total shad catch was 1,266,328 lb., of which gill nets took 66 percent, pound nets 10 percent, bow nets 20 percent, haul seines 3 percent, and miscellaneous apparatus (fish wheels, fyke nets, rod and reel) 1 percent.

The catch and amount of gear fished by water area in 1896 and 1960 are listed in tables 20 and 21. The yardage of drift gill nets fished in 1960 was more than twice that in 1896 (The increase was primarily in the Pamlico-Tar River and Cape Fear River tributaries.), but the catch by drift gill nets in each major river was smaller than in 1896. The yardage of stake gill nets and anchor gill nets and the catches in these gears also were lower in 1960 than in 1896. The use of pound nets has declined in North Carolina since 1896 because of increased gear cost, operating expense, and decrease in catch of other species. Changes in the amounts of gill net and haul seine fished have also been influenced by the catch of other species since shad usually are taken incidental to other fish. The bow net fishery has remained nearly constant in number of nets fished and in catch.

FISHERIES BY WATER AREA

The fisheries of North Carolina are divided into coastal and inland areas. The coastal fishery is under the jurisdiction of the Division of Commercial Fisheries, North Carolina Department of Conservation and Development, and the inland fishery is under the jurisdiction of the North Carolina Wildlife Resources Commission. A map of coastal North Carolina is shown in figure 10.

In 1960 the legal fishing season for shad was from January 1 to May 1 in the coastal area and from January 1 to June 1 in the inland area. Few shad were taken in January and February, and they did not appear in substantial numbers until mid-March. The coastal area catch in 1960 was 701,544 lb.; the inland area catch, 564,784 lb. Most of the catch was handled by dealers who shipped the fish to northern markets. The remainder was taken home or sold locally by fish markets and peddlers.

Cape Fear River and Tributaries

The Cape Fear River is formed by the confluence of the Haw and Deep Rivers in Chatham County, N.C. It flows southeast for 200 miles and empties into the ocean 25 miles below Wilmington, N.C. The principal tributaries are the Black and North East Cape Fear Rivers, both important shad streams. The Brunswick River leaves the Cape Fear 4 miles above Wilmington and re-enters 5 miles below the city. A 3-mile long thorough-fare connects the Black with the Cape Fear 5 miles above their confluence.

In 1896 shad ascended the Cape Fear River 181 miles to Smiley Falls, N.C. During that year 113 drift gill nets, 150 to 425 yd. long, were used from the mouth of the Cape Fear to the junction of the Black; above this junction 124 bow nets, 99 drift nets, and 5 seines were operated. In the Black 21 seines and 60 bow nets were fished; most fish were taken between Point Caswell and Clinton, N.C., and on a tributary stream, the Six Runs Creek, below the Clinton and Warsaw Railroad Bridge. The principal fishery on the North East Cape Fear River was a seine fishery between Sandy Hill, N.C., 30 miles above the tributary mouth, and Kornegay, N.C., a distance of 83 miles. The

Table 20.--Gear employed in shad fisheries, by water area, North Carolina, 1896 and 1960

Water area	1896						1960					
	Drift gill net	Stake gill net	Haul seine	Pound net	Bow net	Miscellaneous	Drift gill net	Anchor and stake gill net	Haul seine	Pound net	Bow net	Miscellaneous
	Yards	Yards	Yards	Number	Number	Number	Yards	Yards	Yards	Number	Number	Number
Cape Fear River and tributaries:												
Below Black River. .	21,010	---	---	---	---	---	19,625	---	---	---	---	---
Above Black River. .	2,692	---	346	---	124	---	1,500	240	---	---	---	---
Black River.	---	---	630	---	60	---	5,340	625	---	---	40	---
North East Cape Fear River.	1,520	---	902	---	---	---	6,800	4,400	1,800	---	37	---
Pamlico Sound.	---	458,524	---	171	---	---	---	47,840	---	153	---	---
Neuse River.	4,280	66,745	20,459	87	529	---	7,500	59,260	450	15	991	[1]157
Pamlico-Tar River. . .	2,300	16,800	19,281	27	120	---	30,000	53,580	---	56	692	---
Croatan Sound.	---	108,420	2,300	140	---	---	---	14,500	---	44	---	---
Roanoke Sound.	---	4,500	---	3	---	---	---	2,700	---	20	---	---
Albemarle Sound[2] . . .	---	448,583	16,950	700	10	---	---	88,350	300	24	---	---
Roanoke River.	1,440	300	6,059	---	435	[3]75	---	420	---	---	---	[4]20
Chowan River	1,440	---	9,740	447	---	---	120	1,240	300	556	---	---
Total.	34,682	1,103,872	76,667	1,575	1,278	75	70,885	273,155	2,850	868	1,760	177

[1] Seven fish wheels and 150 sport fisherman days.
[2] Includes Pasquotank and Perquimans Rivers.
[3] Fish wheels.
[4] Nineteen fyke nets and 1 fish wheel.

Table 21.--Shad catch, by water area and gear, North Carolina, 1896 and 1960
[In pounds]

Water Area	1896						1960					
	Drift gill net	Stake gill net	Haul seine	Pound net	Bow net	Miscellaneous	Drift gill net	Anchor and stake gill net	Haul seine	Pound net	Bow net	Miscellaneous
Cape Fear River and tributaries:												
Below Black River.	191,344	---	---	---	---	---	96,139	---	---	---	---	---
Above Black River.	22,668	---	2,187	---	28,336	---	8,160	1,734	---	---	---	---
Black River.	---	---	15,794	---	10,058	---	30,026	1,188	---	---	12,160	---
North East Cape Fear River . . .	17,130	---	29,474	---	---	---	21,598	29,106	8,432	---	4,220	---
Pamlico Sound.	---	1,633,063	---	256,631	---	---	---	130,021	---	51,566	---	---
Neuse River.	77,955	111,685	481,089	94,765	107,691	---	63,037	105,690	24,960	3,900	183,614	[1]7,065
Pamlico-Tar River.	22,018	34,219	163,177	32,721	30,765	---	190,600	50,168	---	17,473	54,600	---
Croatan Sound.	---	289,412	84,345	311,375	---	---	---	12,750	---	27,016	---	---
Roanoke Sound.	---	21,086	---	8,776	---	---	---	4,224	---	11,280	---	---
Albemarle Sound [2].	---	1,868,330	609,537	796,795	1,160	---	---	88,145	2,300	4,392	---	---
Roanoke River.	16,869	25,725	606,476	---	56,933	[3]8,434	---	698	---	---	---	[4]720
Chowan River	2,109	---	254,932	517,014	---	---	690	6,616	750	11,110	---	---
Total	350,093	3,983,520	2,247,641	2,018,077	234,943	8,434	410,430	430,340	36,442	126,737	254,594	7,785

[1] Fish wheels, 6,560 pounds and rod and reel fishermen, 505 pounds.
[2] Includes Pasquotank and Perquimans Rivers.
[3] Fish wheels.
[4] Fyke nets, 600 pounds and fish wheels 120 pounds.

total catch in the Cape Fear River and tributaries in 1896 was 317,621 lb., of which drift nets caught about 73 percent, seines 15 percent, and bow nets the remainder.

The Cape Fear was free of obstructions in 1960 from the mouth to a 12-ft. dam and lock 65 miles above its mouth and 30 miles above Wilmington. Except during periods of extended high flow, this structure blocked fish from the river above. About 1925 a fishway was constructed in the dam, but it was ineffectual for shad. Occasional fish caught above the lock and dam probably passed the obstruction during high water or during shiplockage. Neither tributary had obstructions to fish passage. Shad ascended the North East Cape Fear to Kornegay, 175 miles from the ocean, and the Black to Clinton, 100 miles from the mouth of the tributary. The major spawning areas were immediately below the lock and dam in the Cape Fear; from Highway 53 bridge to Tomahawk, N.C., in the Black; and from Highway 53 bridge to Tin City, N.C., in the North East Cape Fear.

The coastal fishing area in 1960 extended from the mouth of the river to the lock and dam in the Cape Fear River, to the thoroughfare in the Black, and to Highway 53 bridge in the North East Cape Fear. Three types of gear were fished: drift gill nets in the Cape Fear from 9 miles below Wilmington to the lock and dam, in the Brunswick River and thoroughfare, and throughout the entire coastal

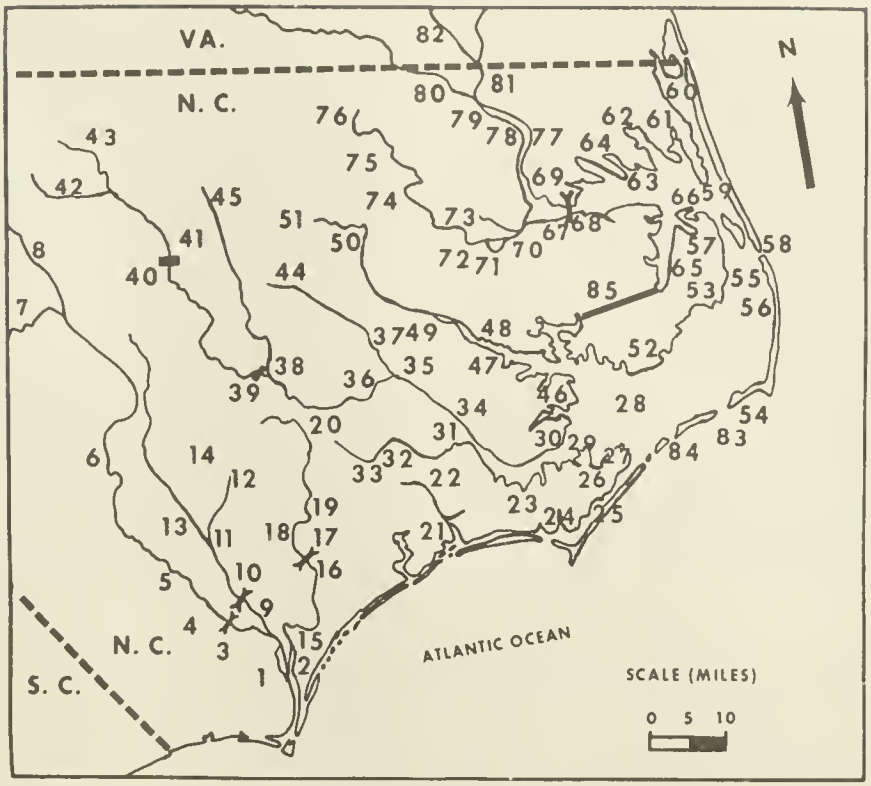

Figure 10.--Map of coastal North Carolina.

Key:
1 Brunswick River
2 Wilmington
3 Hwy. 53 Bridge
4 Lock and Dam No. 1
5 Cape Fear River
6 Fayetteville
7 Deep River
8 Haw River
9 Point Caswell
10 Hwy. 53 Bridge
11 Tomahawk
12 Six Runs Creek
13 Black River
14 Clinton
15 Castle Hayne
16 Sandy Hill
17 Hwy. 53 Bridge
18 Tin City
19 North East Cape Fear River
20 Kornegay
21 White Oak River
22 Maysville
23 Cherry Point
24 Beaufort
25 Core Sound
26 Atlantic
27 Cedar Island
28 Pamlico Sound
29 Neuse River
30 Oriental
31 New Bern
32 Trent River
33 Comfort
34 Streets Ferry
35 Pitch Kettle
36 Kinston
37 Contentnea Creek
38 Goldsboro
39 Goldsboro Dam
40 Raleigh
41 Millburnie Dam
42 Eno River
43 Flat River
44 Wilson
45 Little River
46 Hobucken
47 Pamlico-Tar River
48 Washington
49 Greenville
50 Tarboro
51 Rocky Mount
52 Engelhard
53 Stumpy Point
54 Hatteras
55 Croatan Sound
56 Roanoke Sound
57 Manns Harbor
58 Oregon Inlet
59 Point Harbor
60 Currituck Sound
61 North River
62 Pasquotank River
63 Little River
64 Perquimans River
65 Alligator River
66 Albemarle Sound
67 Mackeys Ferry
68 R.R. Bridge
69 Edenton
70 Plymouth
71 Jamesville
72 Williamston
73 Roanoke River
74 Palmyra
75 Spring Hill
76 Roanoke Rapids
77 Holiday Island
78 Harrellsville
79 Tunis
80 Murfreesboro
81 Black River
82 Nottoway River
83 Hatteras Inlet
84 Ocracoke Inlet
85 Inland Waterway

area in the Black and North East Cape Fear; anchor gill nets were intermingled with the drift gill nets from the junction of the Black to the lock and dam in the Cape Fear and the upper portion of the coastal area in the Black; and haul seines were used in the coastal area of the North East Cape Fear.

Four types of gear were used in the inland fishing area in 1960. Drift gill nets and stake gill nets were intermingled throughout the Black and North East Cape Fear; haul seines were fished from Highway 53 bridge to the vicinity of Tin City in the North East Cape Fear; and bow nets were used in the upper inland area of the Black and North East Cape Fear. Drift gill nets in the lower Cape Fear were 100 to 200 yd. long and 45 to 65 meshes deep and had 5- to 5 1/2-in. stretched mesh. Those in the upper Cape Fear were 25 to 90 yd. long and 25 to 35 meshes deep and had 5- to 5 1/2-in. mesh. In the Black, drift gill nets were 40 to 125 yd. long and 35 to 55 meshes deep and had 5- to 5 1/2-in. mesh. Anchor and stake gill nets in the Cape Fear and tributaries ranged from 10 to 40 yd. long and 25 and 35 meshes deep and had meshes of 4 1/2 to 5 1/2 in. Each seine in the North East Cape Fear was 120 yd. long and 45 meshes deep and had 2 1/2-in. mesh.

The catch in the coastal area was 126,353 lb., of which drift gill nets caught about 97 percent. The catch in the inland area was 86,410 lb., of which drift gill nets caught about 38 percent; stake gill nets 34 percent, bow nets 19 percent, and haul seines the remainder. The catch in the coastal area from the Cape Fear and Black Rivers was marketed in Wilmington; that from the North East Cape Fear, in Castle Hayne. Most of the catch of the inland area was consumed locally. The production by gear and amounts of gear in the Cape Fear River and its tributaries during the 1960 season are given in table 22.

The amount of drift gill nets fished in 1960 increased about 32 percent over 1896, whereas the catch decreased about 32 percent. The

Table 22.--Shad catch, by area and gear, Cape Fear River, N. C., and tributaries, 1960

Area and gear	Quantity	Length fished	Catch
	Number	Yards	Pounds
Coastal:			
Cape Fear River:			
Drift gill net	217	21,125	104,299
Anchor gill net	12	240	1,734
Black River:			
Drift gill net	18	1,620	6,957
Anchor gill net	7	525	528
North East Cape Fear River:			
Drift gill net	50	5,500	11,625
Seine	2	240	1,210
Inland:			
North East Cape Fear River:			
Drift gill net	33	1,300	9,973
Stake gill net	220	4,400	29,106
Seine	13	1,560	7,222
Bow net	37	---	4,220
Black River:			
Drift gill net	62	3,720	23,069
Stake gill net	10	100	660
Bow net	40	---	12,160
Total	721	40,330	212,763

amount of gear increased primarily in the tributaries and the catch decreased in the main river. The number of seines fished in 1960 decreased slightly and shifted from the Black to the North East Cape Fear. The number of bow nets and their catch also decreased in 1960. The Cape Fear River and its tributaries accounted for less than 4 percent of the total North Carolina shad catch in 1896, as compared with almost 17 percent in 1960.

Pamlico Sound

Pamlico Sound is an irregular body of water which lies in a northeast-southwest direction. It is 70 miles long and 10 to 30 miles wide. To the south it joins Core Sound, which extends southwest 36 miles to the vicinity of Beaufort, N.C., and to the north it connects with Albemarle Sound through Roanoke and Croatan Sounds. Two large rivers, the Neuse and the Pamlico-Tar, enter the Sound from the west, and the Inland Waterway connects Pamlico and Albemarle Sounds in the northeast portion. The waters of Pamlico Sound and its tributary streams enter the ocean through Ocracoke, Hatteras, and Oregon Inlets. Salinity varies with the location; it is highest near the inlets. Fish migrate to tributaries of Pamlico and Albemarle Sounds through these inlets. Water is as deep as 70 ft. in Pamlico Sound.

Several hundred shad were taken in 1896 in the mullet fisheries of the New River, Stone Bay, and other estuaries between the Cape Fear River and Pamlico Sound. None was landed in these areas in 1960, although a few were taken by dip nets and small stake gill nets in the White Oak River near Maysville, N.C.

Stake gill nets and pound nets were used in the northeast third of Pamlico Sound in 1896. Gill nets greatly outnumbered the pound nets. The catch by both gears was 1,889,694 lb.

In 1960 pound nets and stake gill nets were fished in shoal areas near inlets and between the mouths of tributaries. Seventeen pound nets were fished in Core Sound near Atlantic, N.C., 31 in the Bay west of Cedar Island, N.C., 4 outside the mouth of the Neuse River, 6 between the mouths of the Neuse and Pamlico-Tar Rivers, 21 from the mouth of the Pamlico-Tar to Croatan Sound, 18 in the northern portion of the Sound near Roanoke Island, and 56 near Oregon and Hatteras Inlets. The nets had leads from 100 to 150 yd. long and 2- to 3-in. mesh. Stake gill nets were fished throughout shallow water of the Pamlico Sound: 3,880 yd. in West Bay; 10,960 yd. on the west shore from the Neuse River to Croatan Sound; 11,400 yd. near Oregon and Hatteras Inlets; and 21,600 yd. from the mouth of the Pamlico-Tar to Croatan Sound. These nets were 12 to 30 yd. long and 30 to 40 meshes deep and had 5 1/4- to 5 3/4-in. mesh.

The total catch in 1960 was 181,587 lb., of which pound nets caught 28 percent and stake gill nets 72 percent. Fish taken in Core Sound were sold to dealers in Atlantic; those caught on the west shore were sold to dealers in Oriental, Hobucken, Engelhard, and Stumpy Point, N.C.; and those produced in the northern part of the Sound near Roanoke Island and near the inlets were sold to dealers in Wanchese and Hatteras, N.C. Ninety-five percent of the catch was shipped to northern markets; the remainder was consumed locally.

Neuse River and Tributaries

The Neuse River is formed by the confluence of the Eno and Flat Rivers in Durham County, N.C. It flows southeast 180 miles before entering the southern part of Pamlico Sound near Turnagain Bay. The principal tributary streams are the Little River, Contentnea Creek, and the Trent River. The Inland Waterway connects the south shore of the Neuse with the Beaufort Inlet by way of Adams Creek. In 1896 the Neuse was the most important shad stream between the St. Johns River, Fla., and the James River, Va. Shad formerly ascended the Neuse in great numbers, and profitable fisheries were operated upstream as far as Raleigh, N.C., 300 miles from the coast (McDonald, 1887b). Most of the catch, however, was made within 22 miles below and above New Bern.

Several types of commercial gear were used throughout the river and tributaries for taking shad in 1896. The gear used from the mouth to Contentnea Creek consisted of seines, drift gill nets, bow nets, stake gill nets, and pound nets; seines were the most important. From Contentnea Creek to the headwaters, bow nets, seines, and stake gill nets were fished. The gear in Contentnea Creek included seines, stake gill nets, and bow nets. Shad did not run far upstream in the Trent River; seines and drift nets operated only in the lower river.

The catch by all gear in 1896 was 873,185 lb., of which seines caught about 55 percent, stake gill nets 13 percent, bow nets 12 percent, pound nets 11 percent, and drift gill nets the remainder.

In 1960 the river was free of obstructions to Goldsboro, N.C., 110 miles, where a low-head dam equipped with a pool-type fishway was built in 1952 (fig. 11). During periods of high flow, fish moving upstream can swim over the dam, but in low flow, fish must use the fishway to gain access to the river above. Fish that passed above the dam could ascend the river to Millburnie Dam near Raleigh, N.C., 55 miles away. The Trent River also was free of obstructions, and shad ascended to Comfort, N.C., 25 miles from the mouth of the tributary. In Contentnea Creek, Wiggins

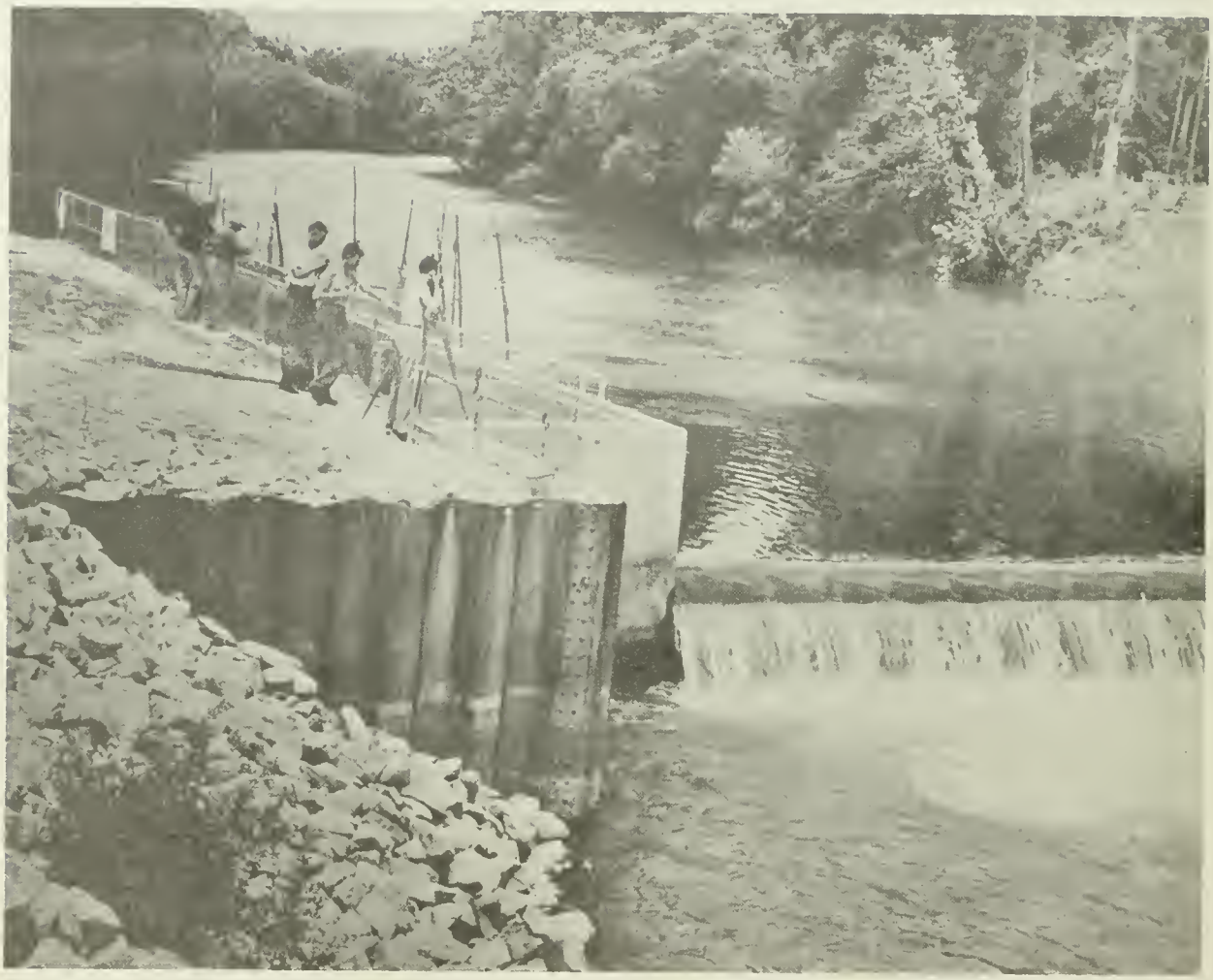

Figure 11.--Low-head dam, equipped with a pool-type fishway (left center), Neuse River near Goldsboro, N.C.

Mill Dam near Wilson, N.C., 30 miles from the mouth, prevented upstream movement of fish. The spawning grounds in the Neuse extended from New Bern, N.C., to the dam near Goldsboro and included the entire range in both tributaries.

The coastal fishing area of the Neuse River in 1960 extended from the mouth to Pitch Kettle Landing, about 20 miles east of Kinston, N.C. This stretch included Turnagain Bay, all creeks flowing into the river below New Bern, and the lower 5 miles of the Trent River. Three fishing gears were used in this area: pound nets, stake gill nets, and drift gill nets. Pound nets with 2- to 4-in. mesh leads 100 to 200 yd. long and 1 1/2- to 2-in.-mesh pockets were fished in the lower section from Turnagain Bay to Cherry Point, N.C. Stake gill nets were fished in the Neuse from the mouth to Streets Ferry, above New Bern, and in the Trent from Wilson Creek, 10 miles upstream from New Bern, to the vicinity of Comfort, N.C. The nets ranged from 8 to 50 yd. long, 25 to 35 meshes deep, and 4- to 5 1/2-in. mesh. Drift gill nets were fished in the upper section of the Neuse between New Bern and Pitch Kettle (figs. 12 and 13). These nets ranged from 35 to 100 yd. long, 35 to 45 meshes deep, and 5 1/4- to 5 1/2-in. mesh.

The inland fishing area extended from Pitch Kettle to the upper limit of shad range in the river and tributaries. Six fishing gears were used in this area: stake gill nets, haul seines, drift gill nets, bow nets, fish wheels, and rod and reel. Stake gill nets and bow nets were fished throughout the entire inland area. Bow nets had an oval opening 4 to 10 ft. wide and 6 to 8 ft. long. Haul seines and drift gill nets were used near Pitch Kettle. Seines averaged 90 yd. long with 1 1/4- to 2-in. mesh; the gill nets were similar to those in the coastal fishery.

Figure 12.--Drift gill net fishing, Neuse River, N.C.

Total catch by gear and amount of gear fished for shad in the Neuse River and tributaries during 1960 are given in table 23. The coastal catch was 145,272 lb., of which the Trent River contributed about 20 percent. The catch was sold to dealers in New Bern. The inland catch was 242,994 lb., of which bow nets accounted for about 76 percent. Shad from fish wheels were incidental to catches of other species. The catch was taken primarily for local consumption.

The amount of drift gill nets fished in 1960 was larger than in 1896, but the catch was smaller. The stake gill net fishery has remained relatively stable; and the catch and amount of gear have decreased only slightly. Catch and number of pound nets and haul seines have decreased since 1896. Both catch and number of bow nets have increased. The Neuse River catch accounted for less than 10 percent of the total North Carolina yield in 1896, but more than 30 percent in 1960.

Pamlico-Tar River

The Pamlico-Tar River is composed of the Pamlico River, which extends from a point immediately above Washington, N.C., to the mouth, and the Tar River, which is upstream from Washington. The Pamlico section is 37 miles long, and the Tar section is 180 miles long.

The shad fishery on the Pamlico-Tar in 1896 extended from the river mouth to a short distance below Rocky Mount, where a natural falls blocked further upstream movement. The gears were seines, stake gill nets, drift gill nets, pound nets, and bow nets. Seines were operated from Core Point, 16 miles below Washington, to Pillsboro Landing, 33 miles above the town. The length of the seines was 450 to 1,000 yd. in the Pamlico River and 50 to 200 yd. in the Tar River. The estimated catch was 282,900 lb. Seines caught about 135,437 lb. in the Pamlico and 27,740 lb. in the Tar. Stake gill nets in the Pamlico River caught an estimated 34,219 lb. These nets averaged 20 yd. long and 10 to 12 ft. deep and had 5-3/8- to 5 1/2-in. mesh. Drift gill nets fished near Washington averaged 100 yd. long and caught about 30,765 lb. Pound nets near the mouth of the river caught an estimated 32,721 lb.

The coastal fishing area extended from the mouth of the Pamlico River to the Highway 17 bridge at Washington. Gears fished were 56 pound nets and 53,580 yd. of stake gill nets (greatest concentration near Pamlico and Core Beaches). Pound net leads averaged 120 yd. long; the gill nets averaged 30 yd. long and 35 meshes deep and had 5 1/2-in. mesh. The catch in the coastal area was 67,641 lb., of which stake gill nets took 74 percent and pound nets 26 percent; the catch was marketed in Washington, N.C.

The inland fishing area was confined to the Tar River and extended from Washington to the dam at Rocky Mount. The dam, about 122 miles from the river mouth blocked further upstream movement of the fish. The fishing

Figure 13.--Drift gill net being lifted at end of a drift, Neuse River, N.C.

gear included 30,000 yd. of drift gill nets (30 to 80 yd. long, 35 to 45 meshes deep, and 5- to 5 1/2-in. mesh) and 692 bow nets. The greatest concentration of gill nets was near Greenville and that of bow nets was near Tarboro. The catch in the inland area was 245,000 lb., of which gill nets caught about 78 percent and bow nets 22 percent. About 50 percent of the inland area catch was marketed in Washington, and the remainder was consumed locally.

The gears and locations fished for shad in 1960 were the same as in 1896 except that no seines were operated in the Pamlico River in 1960. Twice as many pound nets were fished in 1960 as in 1896, but the catch was only half as large. The catch by gill nets and bow nets was larger in 1960 than in 1896.

Table 23.--Shad catch, by area and gear, Neuse River, N. C., and tributaries, 1960

Area and gear	Quantity	Length fished	Catch
	Number	Yards	Pounds
Coastal:			
Pound net	15	---	3,900
Stake gill net	2,460	57,900	84,638
Drift gill net	135	6,750	56,734
Inland:			
Stake gill net	160	1,360	21,052
Drift gill net	15	750	6,303
Haul seine	5	450	24,960
Bow net	991	---	183,614
Fish wheel	7	---	6,560
Rod and reel	150	---	505
Total	3,788	67,210	388,266

Croatan and Roanoke Sounds

Separated by Roanoke Island, these sounds parallel each other and extend south from eastern Albemarle Sound into northeastern Pamlico Sound. Roanoke Sound, west of the island, is 8 miles long, 1/2 to 2 miles wide, and 1 to 3 ft. deep over most of its area. Croatan Sound, east of the island, is 8 miles long, 2 to 4 miles wide, and generally 7 to 10 ft. deep. Most shad migrating from Pamlico to Albemarle Sound use the east channel; the fishery in Croatan Sound is more important, therefore, than in Roanoke Sound.

Stake gill nets and pound nets were the only gears fished in these waters in 1896 except for one seine in the extreme upper end of Croatan Sound. The estimated catch was 714,994 lb., of which Croatan Sound produced 96 percent.

Pound nets, stake gill nets, and anchor gill nets were used in both sounds in 1960. Twenty pound nets and 2,700 yd. of stake gill net and anchor gill net were fished in Roanoke Sound in 1960. Forty-four pound nets and 14,500 yd. of stake gill net and anchor gill net were fished in Croatan Sound. In both sounds, the gill nets ranged from 15 to 100 yd. long and 25 to 40 meshes deep and had 5 1/4- to 5-3/8-in. mesh. The nets were set primarily for striped bass, and shad catches were incidental. The shad catch was 39,766 lb. (72 percent) in Croatan Sound and 15,504 lb. (28 percent) in Roanoke Sound. Pound nets took 69 percent of the combined catch. The catch from both sounds was sold to dealers in Wanchese and Manns Harbor, N.C.

Although the areas fished and distribution of the catch in Croatan and Roanoke Sounds have changed little over the years, the amount of gear fished and the catch were much smaller in 1960 than in 1896.

Albemarle Sound

Albemarle Sound joins Pamlico Sound through Croatan and Roanoke Sounds and is joined with Currituck Sound to the northeast. Albemarle Sound has an east-west dimension of 55 miles and averages 7 miles wide and 16 to 20 ft. deep. Eight rivers empty into the Sound; since it receives such large river drainage and has only indirect exchange with the sea, it is essentially fresh water.

The shad fisheries of Albemarle Sound in 1896 were among the most important on the Atlantic coast. The season began about February 1 and lasted until mid-April. Of the 3,100,474 lb. caught, 58 percent was taken by stake gill nets, 24 percent by pound nets, and 18 percent by seines. Gill nets averaged 20 yd. long and 10 to 14 ft. deep, and had 5 1/4- to 5 1/2-in. mesh: they were set in strings of 50 to 500 nets. Pound nets were set along the shores, 1 to 25 nets on each string. Seines averaged about 2,500 yd. long and 12 to 16 ft. deep and had 2-in. mesh in the bunt and 3-in. mesh in the wings. Principal fishing centers in the Sound were Edenton, Peter Mashew's Creek, Mackeys Ferry and vicinity, and Pear Tree Point.

In addition to the fishery in the Sound proper in 1896, 175,348 lb. of shad were taken in the Pasquotank and Perquimans Rivers. The Pasquotank extends 15 miles inland and has an average width of 2 miles and a depth of 10 or 12 ft. This river yielded about 36,930 lb., of which seines caught 53 percent, pound nets 32 percent, stake gill nets 11 percent, and bow nets the remainder. The Perquimans is 12 miles long, and averages more than 1 mile wide and 10 to 12 ft. deep. It yielded about 138,418 lb., of which pound nets caught 39 percent, stake gill nets 38 percent, and seines 23 percent.

In 1960 stake and anchor gill nets, pound nets, and haul seines were used in the shad fisheries of Albemarle Sound. A total of 70,350 yd. of gill net was fished along the south shore; 4,050 yd. in the Alligator River and 18,000 yd. along the north shore (Currituck Sound and Pasquotank and Perquimans Rivers are included in totals for the north shore.). The fishing of gill nets was illegal in the Sound west of Highway 32 bridge. Twelve pound nets were fished along the south shore near Mackeys, 9 in lower Albemarle Sound, and 6 along the north shore off the mouth of the Pasquotank River. One haul seine was operated in western Albemarle Sound near the railroad bridge and one in the eastern part near Point Harbor, N.C.

Gill nets were 10 to 150 yd. long and 30 to 45 meshes deep, and had 4- to 5 1/2-in. mesh. Pound net leads were 100 to 200 yd. long, and each seine was 150 yd. long. The catch by all gears was 94,837 lb., of which gill nets caught 93 percent, pound nets 4 percent, and haul seines 3 percent. Most of the catch was marketed in Elizabeth City, Edenton, and Columbia, N.C.

Since 1896 the areas fished and the gear used in the fishery have remained essentially unchanged. The extent of the fisheries, however, both in amount of gear fished and catch, has decreased greatly, and the fishery could not continue if it were wholly dependent on shad.

Roanoke River

The Roanoke River, a narrow, rapid stream formed by the confluence of the Dan and Staunton Rivers in Mecklenburg County, Va., follows a winding course of 198 miles before entering Albemarle Sound below Plymouth, N.C.

The commercial fishery of the Roanoke in 1896 was confined to the lower river, from the mouth to Williamston. The gears were seines,

bow nets, stake and drift gill nets, and fish wheels. The estimated catch was 714,437 lb., of which seines caught about 85 percent, bow nets 8 percent, stake gill nets 4 percent, drift gill nets 2 percent, and wheels the remainder. The fisheries were centered principally at Plymouth, Jamesville, and Williamston, N.C.

In 1960 a dam at Roanoke Rapids, N.C., 137 miles from the river mouth, obstructed the stream. Shad ascended only to the vicinity of Spring Hill, N.C., however, about 60 miles above the river mouth. The location of spawning grounds is not known, although spawned-out fish were seen in catches between Palmyra and Williamston, N.C.

Shad were taken in 1960 from the mouth of the river upstream to a short distance above Palmyra. The gears were stake gill nets, fyke nets, and fish wheels (fig. 14). Shad catch from all gears was incidental to the catches of striped bass, Roccus saxatilis, and herrings, Alosa spp. Seines normally were operated from the mouth of the river to Williamston, but none were fished during 1960 because of high water. A few bow nets were fished near Palmyra, but the shad catch was negligible. Each stake gill net was 15 yd. long and 25 meshes deep and had 5 1/4-in. mesh. The shad catch was 1,418 lb., of which stake gill nets caught 49 percent, fyke nets 40 percent, and fishwheels 11 percent. The catch was consumed locally.

The fishery on the Roanoke River in 1960 had changed much since 1896. The 1896 yield of 714,437 lb. of shad represented about 8 percent of the total North Carolina production, but the 1960 catch was only about 0.1 percent. Since 1896 the amount of gear and the size of catch both have decreased enormously. Pulp mill wastes probably were the cause of low survival of anadromous fishes, particularly shad, in the lower Roanoke River (Taylor, C.C. 1951).

Figure 14.--Fishwheel operated on the Roanoke River, N.C. (The wire scoop revolves with the axle and captures fish in the water between the boats as it emerges from the water and dumps them into chutes leading to the boats.)

Chowan River

The Chowan River, formed by the junction of the Blackwater and Nottoway Rivers near the North Carolina-Virginia boundary, flows 55 miles to northwestern Albemarle Sound. From the mouth of the river to Holiday Island, 20 miles away, the river averages 1 1/2 miles wide and 15 to 20 ft. deep. In the upper 35 miles, the river narrows to about half the width of the lower section and is shallower.

In 1896, the difference was remarkable between the fishing gear used for taking shad in the Chowan and the gear in similar areas in North Carolina. Bow nets, stake gill nets, and fish wheels were not used. Ninety-eight percent of the catch was by pound nets and seines. The only other gear was drift gill nets. Most of the total catch of 774,055 lb. was made between the mouth of the river and Harrellsville, N.C.

In 1960 the river was free of obstructions, and shad ascended to the vicinity of Murfreesboro, N.C., 45 miles above the river mouth. The major spawning grounds were from the vicinity of Highway 13 bridge upstream to 10 miles below Murfreesboro.

The coastal fishery in 1960 extended from the mouth of the river to the Virginia line; various gears were used. Pound nets and seines were fished from the mouth of the river to Holiday Island; gill nets were illegal in this area. Above Holiday Island stake gill nets and pound nets were fished to Highway 13 bridge. Above the bridge drift gill nets, seines, and anchor gill nets were fished. The stake gill nets and anchor gill nets ranged from 30 to 60 yd. long and 40 to 60 meshes deep and had 4- to 5 1/4-in. mesh. Each drift gill net was 30 yd. long and 45 meshes deep and had 5 1/4-in. mesh. The seines averaged 150 yd. long and 148 meshes deep and had 2 1/4-in. mesh. Pound nets and seines were operated primarily for alewife, Alosa pseudoharengus, and blueback herring, A. aestivalis, whereas gill nets were fished almost exclusively for shad.

The total shad catch in 1960 was 19,166 lb., of which pound nets caught about 58 percent; stake and anchor gill nets 34 percent, and seines and drift gill nets the remainder. The pound net catch was marketed in Colerain, N.C.; the rest of the catch was consumed locally.

The shad in the Chowan River decreased drastically from 774,055 lb. in 1896 to 19,146 lb. in 1960. The largest decrease in catch was by pound nets and haul seines. The catch per pound net was about 1,156 lb. in 1896 and 20 lb. in 1960. The catch by haul seines decreased from 254,932 lb. in 1896 to 750 lb. in 1960.

TRENDS IN PRODUCTION

Few records are available on the shad production for North Carolina prior to 1880. Stevenson (1899), however, illustrated the

comparative abundance by the catch for a series of years at the Greenfield seine fishery on Albemarle Sound. The catch increased from 1852 to 1870; the average annual yield was 117,218 lb. for the first 5 yr. and 146,111 lb. for the last 5 yr. The catch decreased rapidly from 1876 to 1880 to an average annual yield of 60,148 lb.

The catch varied widely from 1880 to 1960. In 1880 to 1897, the shad fisheries of North Carolina had their greatest development, and production increased from about 3 million pounds to nearly 9 million pounds (table 24). From 1902 to 1918, however, production decreased, and the decline was more rapid than the increase had been. The catch in 1918 was only 18 percent of that in 1897. Between 1923 and 1928 production increased slightly, but by 1931 decreased to less than 10 percent of the 1897 take. From 1931 to 1945 production remained low, and the annual yield was about 12 percent of the 1897 yield. From 1950 to 1960 the annual production fluctuated from a high of 1,479,000 lb. in 1952 to a low of 419,000 lb. in 1959. The 1960 yield was greater than that of the 2 previous yr., but was less than 10 percent of the yield of 1897.

Table 24.--Shad catch for certain years, North Carolina, 1880-1960[1]

[In thousands of pounds]

Year	Catch	Year	Catch
1880. . . .	3,221	1934. . . .	1,274
1887. . . .	4,783	1936. . . .	1,095
1888. . . .	5,725	1937. . . .	698
1889. . . .	5,403	1938. . . .	1,032
1890. . . .	5,815	1939. . . .	859
1896. . . .	8,843	1940. . . .	801
1897. . . .	8,963	1945. . . .	912
1902. . . .	6,567	1950. . . .	1,100
1904. . . .	3,230	1951. . . .	1,244
1908. . . .	3,942	1952. . . .	1,479
1918. . . .	1,657	1953. . . .	1,188
1923. . . .	2,370	1954. . . .	1,445
1927. . . .	2,387	1955. . . .	649
1928. . . .	3,118	1956. . . .	773
1929. . . .	1,913	1957. . . .	837
1930. . . .	1,172	1958. . . .	493
1931. . . .	883	1959. . . .	419
1932. . . .	925	1960. . . .	702

[1]Statistics 1880-1959, U.S. Fish and Wildlife Service (1958-61); 1904 (Cobb, 1906).

Overfishing was thought to be chiefly responsible for the decline in catch, and various remedies were sought. In 1873 the State began artificial propagation of shad, and in 1878 the U.S. Fish Commission assisted in the attempt to restore the fishery (Smith, 1907). Early results indicated that stocking of shad fry accomplished its purpose since catch increased from 1880 to 1897. After that time the catch decreased in spite of continued plantings, and in 1943 it was decided that artificial propagation as practiced was of little value in maintaining the supply of shad; consequently, stocking was discontinued.

Cobb (1906) reported on the conditions of the fisheries which resulted in the early decline and recommended regulations to curtail fishing intensity. He stated that seines produced nearly 2 million pounds in 1897, but less than 1/2 million pounds by 1904. Gill nets produced nearly 5 million pounds in 1897, but only about 1 million pounds in 1904, even though the number of nets fished increased during this period. In 1887 the pound net catch was less than 1/2 million pounds, but by 1897 it had increased to more than 2 million pounds. From 1897 to 1904 the catch decreased each season, while the number of pound nets increased from 1,575 to 2,837.

A number of factors have been cited as contributors to fluctuations and general decline in North Carolina shad production. Roelofs (1951) reported that the history of the decline paralleled that of the entire Atlantic coast and that dams, overfishing, and pollution were the three pivotal factors. Mansueti and Kolb (1953) cited increased fishing intensity in North Carolina waters, and listed the probable causes as improved fishing methods, more fishermen, and better market and transportation facilities.

Pulpwood, petroleum products, and fertilizer materials have been important items of commerce on most North Carolina rivers for many years. The effect on shad abundance of oil from ships and waste effluents from industrial plants and pulpmills cannot be evaluated, however, because no measure of pollution is available to correlate with fish production.

SHAD FISHERIES OF VIRGINIA

In 1896 the principal shad fisheries of the United States were in Chesapeake Bay and its tributaries. The catch in Virginia waters was 11,170,519 lb., of which 4,507,184 were taken in the Bay and 6,663,335 in the rivers (including Potomac River landings by Virginia fishermen): drift gill nets produced about 42 percent, pound nets 37 percent, stake gill nets 13 percent, seines 7 percent, and miscellaneous gears the remainder.

Shad entered Chesapeake Bay in 1960 as early as January, and the run continued through May. The estimated catch in Virginia was 1,386,138 lb.; Chesapeake and Mobjack Bays yielded 488,200 lb., the Bay tributaries 892,938 lb., and the Atlantic shore 5,000 lb. Of the

total catch, pound nets produced about 43 percent, stake gill nets 34 percent, drift gill nets 22 percent, and seines and fyke nets the remainder.

The catch by gear and amount of gear fished in 1896 and 1960 are given by water area in tables 25 and 26. A map of the area is shown in figure 15.

FISHERIES BY WATER AREA

The fisheries of Virginia are regulated by the Virginia Commissioners of Fisheries. During the 1961 season the Commissioners licensed stake gill nets by 600-ft. rows, limited the length of drift gill nets to 600 ft., and permitted taking shad from inlets and rivers

Table 25.--Gear employed in shad fisheries, by water area, Virginia, 1896 and 1960

Water area	1896					1960				
	Drift gill net	Stake gill net	Seine	Pound net	Miscellaneous	Drift gill net	Stake gill net	Seine	Pound net	Fyke net
	Yards	Yards	Yards	Number	Number	Yards	Yards	Yards	Number	Number
Chesapeake Bay:										
Eastern Shore	---	---	---	50	---	---	---	---	2	---
Western Shore	---	12,470	---	404	---	---	---	---	132	---
Mobjack Bay	---	---	---	76	---	---	---	---	24	---
James River and tributaries:										
Below Chickahominy River	---	34,898	1,400	6	---	---	29,400	---	2	---
Above Chickahominy River	80,747	2,440	1,450	---	---	15,500	---	---	---	---
Chickahominy River	28,842	---	2,425	---	[1]3	8,400	---	---	---	---
Appomattox River	6,720	---	1,225	---	---	2,200	---	---	---	---
York River and tributaries:										
York River	---	6,461	475	90	[2]64	---	24,858	---	12	52
Pamunkey River	51,341	378	780	---	---	28,800	---	---	---	---
Mattaponi River	46,601	---	986	---	---	22,700	---	---	---	---
Rappahannock River	16,792	27,164	2,020	231	[3]27	4,700	44,400	---	40	15
Potomac River	67,000	6,133	13,600	299	---	8,461	6,170	300	160	35
Total	298,043	90,214	24,361	1,156	94	90,761	104,828	300	372	102

[1] Hedges (see text).
[2] Fyke nets.
[3] Eight fyke nets and 19 fall traps.

Table 26.--Shad catch by water area and gear, Virginia, 1896 and 1960

[In pounds]

Water area	1896					1960				
	Drift gill net	Stake gill net	Seine	Pound net	Miscellaneous	Drift gill net	Stake gill net	Seine	Pound net	Fyke net
Chesapeake Bay:										
Eastern Shore	---	---	---	126,954	---	---	---	---	[1]7,500	---
Western Shore	---	151,868	---	3,737,477	---	---	---	---	407,122	---
Mobjack Bay	---	---	---	490,885	---	---	---	---	78,578	---
James River and tributaries:										
Below Chickahominy River	---	320,027	19,116	10,875	---	---	195,559	---	740	---
Above Chickahominy River	683,586	34,619	63,491	---	---	61,835	---	---	---	---
Chickahominy River	459,035	---	61,057	---	6,276	39,965	---	---	---	---
Appomattox River	41,652	---	28,973	---	---	3,938	---	---	---	---
York River and tributaries:										
York River	---	148,684	872	484,333	2,057	---	173,462	---	12,545	9,511
Pamunkey River	629,893	4,467	8,138	---	---	103,162	---	---	---	---
Mattaponi River	592,084	---	35,278	---	---	65,957	---	---	---	---
Rappahannock River	140,714	363,056	33,963	915,343	3,742	14,100	54,884	---	18,880	1,500
Potomac River	496,544	40,135	276,813	758,512	---	18,956	43,194	192	72,830	1,728
Total	3,043,508	1,062,856	527,701	6,524,379	12,075	307,913	467,099	192	598,195	12,739

[1] Includes 5,000 pounds taken by pound and stationary gill nets in bays and inlets along the Atlantic shore.

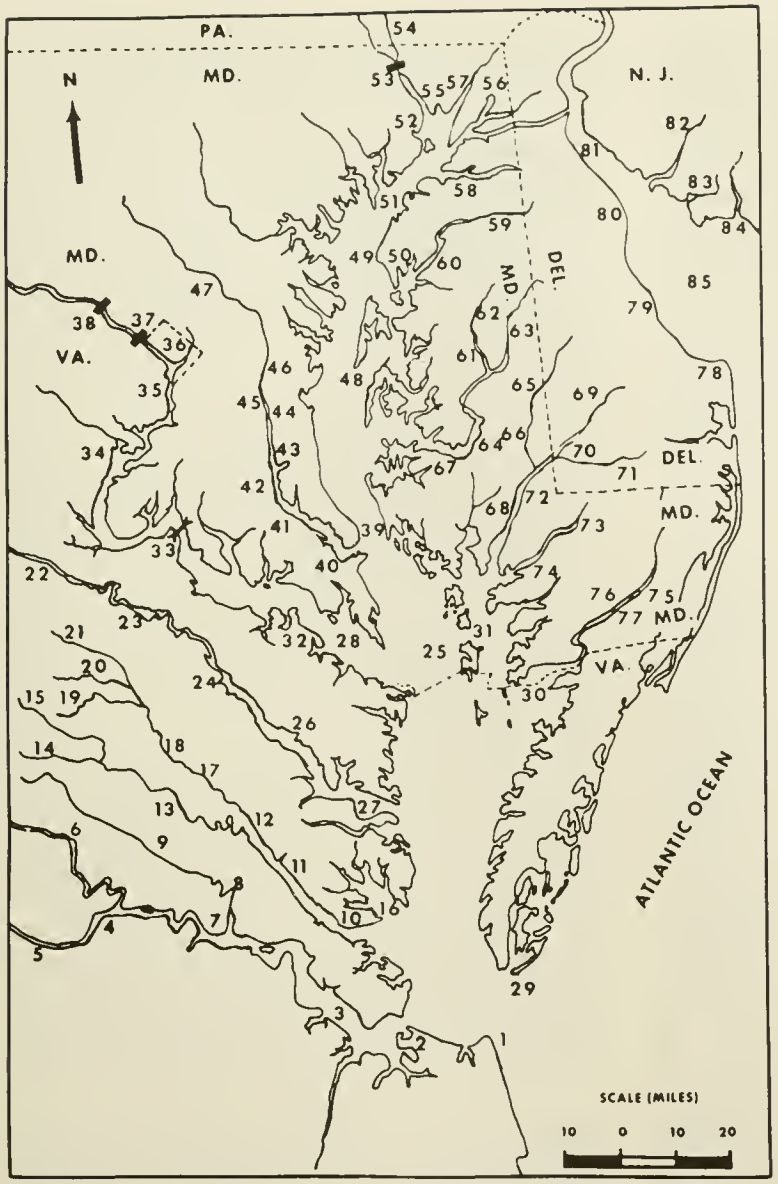

Figure 15.--Map of eastern Virginia and Maryland, and Delaware.

Key:
1 Cape Henry
2 Norfolk
3 James River
4 Hopewell
5 Appomattox River
6 Richmond
7 Lanexa
8 Walker
9 Chickahominy River
10 Gloucester Point
11 York River
12 West Point
13 Pamunkey River
14 South Anna River
15 North Anna River
16 Mobjack Bay
17 Mattaponi River
18 Walkerton
19 Matta River
20 Po River
21 Ni River
22 Fredericksburg
23 Port Royal
24 Portobago Bay
25 Chesapeake Bay
26 Monaskan
27 Rappahannock River
28 Potomac River
29 Cape Charles
30 Pocomoke Sound
31 Tangier Sound
32 Sandy Point
33 U.S. 301 Bridge
34 Occoquan Bay
35 Alexandria
36 Washington, D.C.
37 Little Falls
38 Great Falls
39 Cove Point
40 Patuxent River
41 Benedict
42 Lower Marlboro
43 Dunkirk
44 Leon
45 Upper Marlboro
46 Drury
47 Laurel
48 Kent Island
49 Swan Point
50 Rock Hall
51 Romney Creek
52 Havre de Grace
53 Conowingo Dam
54 Susquehanna River
55 Port Deposit
56 Elk River
57 Northeast River
58 Sassafrass River
59 Millington
60 Chester River
61 Tuckahoe Creek
62 Hillsboro
63 Greensboro
64 Choptank River
65 Federalsburg
66 Marshyhope Creek
67 Secretary
68 Vienna
69 Seaford
70 Woodland
71 Broad Creek
72 Nanticoke River
73 Salisbury
74 Wicomico River
75 Snow Hill
76 Pocomoke River
77 Pocomoke City
78 Lewes
79 Bowers Beach
80 Bombay Hook
81 Delaware River
82 Stow Creek
83 Cohansey Creek
84 Maurice River
85 Delaware Bay

from October 16 to May 25. Fishing was legal 7 days a week during the season. Because of possible navigational difficulties, locations fished by stationary nets in Chesapeake Bay and its tributaries were designated by the U.S. Army Corps of Engineers so that shipping channels were unobstructed.

During 1960 several types of commercial gear were used in the shad fishery. Pound nets were used principally on the western shore of Chesapeake Bay and in the mouths of tributaries. Stake gill nets were set in the lower sections of the tributaries, which are essentially arms of the Bay. A few fyke nets and haul seines were fished in the stake gill net areas, but caught few shad. Drift gill nets were the only gear in the upper section of the rivers, with the exception of a few stake gill nets and an occasional fyke net.

Chesapeake Bay in Virginia

Chesapeake Bay, located in Virginia and Maryland, is 190 miles long. The mouth of the Bay, between Capes Charles and Henry, Va., is 13.8 miles wide. The width of the Bay proper varies from 12 to 24 miles in Virginia and from 3 to 16 miles in Maryland. Tributaries supporting shad fisheries in Virginia in 1896 were the James, York, and Rappahannock Rivers, plus the Potomac River (see section on Potomac River.). Mobjack Bay, a lateral extension of the Chesapeake, was also an important production area. This Bay, located immediately north of the York River, is 12 miles long, 3 to 4 miles wide, and 18 to 25 ft. deep.

Shad migrate along the western shore of Chesapeake Bay, apparently attracted by the fresh water from the large tributaries that enter from the west (Stevenson, 1899). The shad season of 1896 began about March 20, and fish were taken until the end of June. During this period, more than 4 1/2 million pounds were caught in Virginia waters of the Bay--97 percent on the western shore. From the Bay entrance to the mouth of the Potomac River, excluding Mobjack Bay, 404 pound nets caught 3,737,477 lb., and 12,470 yd. of stake gill net took 151,868 lb. In Mobjack Bay, 70 pound nets produced 490,885 lb. On the Eastern Shore, 50 pound nets caught 126,954 lb.

In 1960, 158 pound nets were fished in Virginia waters of Chesapeake Bay. On the western shore, 132 nets were used--7 from Cape Henry to the mouth of the James River, 30 from the James to the mouth of the York River, 52 from the York to the mouth of the Rappahannock River, and 43 from the Rappahannock to the Maryland line at Smith Point, Va. Twenty-four pound nets were fished in Mobjack Bay. On the Eastern Shore, two pound nets were fished near Tangier Island, Md. The estimated catch in Virginia waters of the Bay in 1960 was 488,200 lb. In addition, pound nets and gill nets fished in bays and inlets along the Atlantic shore, exclusive of Chesapeake Bay, caught an estimated 5,000 lb.

The shad catch in the Virginia part of Chesapeake Bay, as in many other areas, declined over the past century. In 1896, 76 pound nets in Mobjack Bay produced an estimated 490,885 lb., whereas 24 nets in the same area in 1960 yielded 78,578 lb. The catch in the entire Bay declined from 4,507,184 lb. in 1896 to a low of 488,200 lb. in 1960.

James River

The James River, the southernmost tributary of Chesapeake Bay, lies entirely in Virginia. The river has its source in the Allegheny Mountains, where it is formed by the union of the Jackson and Cowpasture Rivers in Botetourt County. It is 350 miles long and flows through Richmond and into the Bay at Norfolk. The lower 42 miles of river form an arm of the Bay, which is from 2 to 6 miles wide. The main tributaries are the North, Buffalo, Slate, Rivanna, Willis, Appomattox, and Chickahominy Rivers; only the latter two support shad fisheries.

The Chickahominy River originates in Henrico County 12 miles northwest of Richmond and flows 60 miles before entering the James 42 miles from Chesapeake Bay. In 1943 a low-head dam, which obstructs the upstream movement of fish, was constructed at Walker, 20 miles above the mouth of the tributary.

The Appomattox River, the longest tributary of the James, rises in Appomattox County and flows 140 miles before entering the James at Hopewell, 72 miles from Chesapeake Bay. A dam built on the Appomattox at Petersburg during the mid-1800's did not seriously affect the shad runs because natural falls and rapids are located immediately upstream from the dam.

The shad catch of the James River and tributaries in 1896 was 1,728,707 lb., of which the river proper produced approximately 65 percent, the Chickahominy 30 percent, and the Appomattox 5 percent. The principal fishing gear below the Chickahominy was the stake gill net, with an occasional pound net or seine. From the Chickahominy to the Appomattox, drift gill nets were the principal gear, but some seines and stake gill nets were fished locally. Above the Appomattox, drift gill nets were fished except in the falls below Richmond where traps were used.

The Chickahominy River was one of the most productive shad streams for its size in the United States in 1896. Fish ascended this tributary to the vicinity of Providence Forge, 30 miles above the mouth. The estimated catch was 526,368 lb., of which 459,035 lb. were caught by 28,842 yd. of drift gill nets, fished

from Lanexa to the upper limit of the shad range. Eight haul seines, operated from the river mouth to Lanexa, caught 61,057 lb., and hedge [6] used above Providence Forge caught 6,726 lb.

Shad were taken in the Appomattox River in 1896 by drift gill nets and seines. The estimated catch was 70,625 lb., of which drift nets caught 59 percent and seines 41 percent.

In 1960 a dam in the James River near Richmond limited the upstream movement of shad to 105 miles; few fish were taken however, above Hopewell, 30 miles below the dam. Ripe females in the catch indicated that the shad spawning area extended 27 miles, from Sandy Point (43 miles from the river mouth) to Hopewell. In the Chickahominy River the major spawning area was near Lanexa, 5 miles below the Walker Dam (Massmann, 1952). In the Appomattox River the section between Hopewell and Petersburg was heavily polluted with industrial and domestic wastes and therefore was probably of little importance for shad spawning (Massmann, 1952).

The shad fisheries extended from the river mouth to Hopewell in the James River, up to the dam at Walker in the Chickahominy as far as 4 miles above the river mouth in the Appomattox. The fisheries were divided into two areas: the lower section, downstream from the mouth of the Chickahominy River; and the upper section, which included the James River from the mouth of the Chickahominy to Hopewell, and the Chickahominy and Appomattox Rivers.

In the lower section, two pound nets, fished near the James River Bridge, caught 740 lb. of shad. A total of 29,400 yd. of stake gill nets (fig. 16), 10 to 25 yd. long, 25 to 45 meshes deep, and with 5- to 5 1/2-in. mesh, caught 195,559 lb. In the upper section, 15,500 yd. of drift gill nets, fished from the Chickahominy to Hopewell, caught 61,835 lb. of shad; 8,400 yd. from the Chickahominy to the dam at Walker caught 39,965 lb.; and 2,200 yd. in the Appomattox caught 3,938 lb. The drift gill nets ranged from 75 to 150 yd. long and 45 to 65 meshes deep and had 5- to 5 1/2-in. mesh. Ten haul seines and 43 fyke nets, fished primarily for other species, took few shad. A rod-and-reel fishery for hickory shad, Alosa mediocris, at Walkers Dam on the Chickahominy took some shad, but no estimate was made of the catch.

In 1960 shad fishing began in the James River and tributaries the last week in February and continued to mid-May. The estimated catch was 302,037 lb., of which the lower section of the river produced 65 percent and the upper section 35 percent. Of the catch in the upper section, the James yielded 58 percent, the Chickahominy 38 percent, and the Appomattox 4 percent. Most of the catch was sold to dealers in Richmond.

Fishing methods on the James River and tributaries have changed little over the past half century; however, the catch and amount of gear fished have declined. In 1960, 29,400 yd. of stake nets were used as compared to 87,000 yd. in 1896. Two pound nets were fished in 1960, compared with three in 1896. The amount of drift gill nets fished was 116,309 yd. in 1896 and 23,700 yd. in 1960. The peak catch of shad in the James River and tributaries was in 1896, when more than 1.7 million pounds were reported; production remained high through 1931. In 1932, however, the yield decreased to 323,736 lb. and continued low until 1943. The catch increased to 904,300 lb. in 1944 and remained moderate until 1956. During 1956 to 1960, the annual yield averaged slightly more than 400,000 lb.

Figure 16.--"Riding-down" poles for stake gill nets, James River, Va. (Photograph courtesy of Virginia Institute of Marine Science, Gloucester Point, Va.)

[6] Hedge or pocket consisting of a crude dam, 2 or 3 feet high, permitting the passage of fish only through an opening. Fishermen took shad by dip net as the fish attempted passage.

York River

The York River is formed by the union of the Pamunkey and Mattaponi Rivers at West Point and flows southeast 28 miles before entering Chesapeake Bay at Tue Point. The Pamunkey is formed by the junction of the North Anna and South Anna Rivers in central Virginia and flows 100 miles to its union with the Mattaponi. The Mattaponi is formed by the Matta, Po, and Ni Rivers and flows 120 miles to unite with the Pamunkey. Tidal influence extends 45 miles up the Pamunkey and 30 miles up the Mattaponi. The change from brackish to fresh water occurs 10 miles above West Point in each tributary.

Shad ascended the York and tributaries in large numbers in 1896, and most were caught in the main river and in the lower 30 miles of each tributary. The estimated catch was 1,905,806 lb., of which the York produced 635,946 lb., the Pamunkey 642,498 lb., and the Mattaponi 627,362 lb. Pound nets and gill nets

were the principal gears, but some fish also were taken in fyke nets and seines. Pound nets were fished from the mouth of the York to Gloucester Point, and stake gill nets from Copahasic to West Point and in the mouth of the Pamunkey; fyke nets were intermingled with the stake gill nets. Drift gill nets were fished in both tributaries, and seines were scattered throughout the entire river system. Many seines were operated formerly in the Mattaponi, but by 1896 they had been replaced by the cheaper and more effective drift gill nets. The stake gill nets were from 6 to 9 yd. long and 35 meshes deep and had 5-in. mesh; they were set in strings of 10 to 20 nets in 11 to 14 ft. of water. The fishing season began the first week in March and closed about the end of May; the greater part of the catch was made in April. No fish were taken in the South Anna and North Anna Rivers.

The York River was free of obstructions to the passage of fish in 1960, and shad ascended each tributary at least 30 miles. The major spawning grounds in the Pamunkey were near White House Landing, 15 to 25 miles above West Point, and in the Mattaponi between the Mattaponi Indian Reservation and Walkerton, 20 miles above West Point (Massmann, 1952).

The fisheries of the York River and tributaries extended 60 miles from the mouth of the York to Tunstall in the Pamunkey and 50 miles to Walkerton in the Mattaponi. Four gears were used: pound nets from the mouth of the river to Gloucester Point, 6 miles; fyke nets and stake gill nets from Gloucester Point to West Point, 20 miles; and drift gill nets in each tributary from West Point to the upper limits of the fishery. In both the Mattaponi and Pamunkey, most fishing with drift nets was by Indians living on reservations (fig. 17). Pound and fyke nets were fished from early spring until fall; after the shad season, they were used for other species. Stake gill nets, 20 ft. long and 11 ft. deep, with 4-3/4- to 5 1/2-in. mesh, were fished in rows 60 to 150 yd. long. Drift gill nets were 50 to 235 yd. long and 35 to 65 meshes deep and had 5- to 5 1/2-in. mesh. Drift nets were fished during high- and low-slack waters, which permitted about 3 hr. of fishing on each tide.

Figure 17.--Lifting drift gill net, Mattaponi River, Va. (Photograph courtesy of Virginia Institute of Marine Science, Gloucester Point, Va.)

Shad fishing started in the York about February 15, 1960, and was discontinued May 6. In the tributaries it started March 8 and ended May 14. The bulk of the catch was made in a 4-wk. period from mid-March to mid-April. The amount of gear fished and the catch by gear and area in 1960 are given in table 27. On the basis of catch-effort statistics, the total population was estimated to weigh 777,000 lb., and the fishing rate was 46.9 percent (Nichols and Massmann, 1963). The total catch was 364,637 lb.; stake gill nets caught about 48 percent, drift gill nets 46 percent, pound nets 3 percent, and fyke nets the remainder. The catch in the lower York River was marketed to dealers in Perrin; from the upper York and tributaries, it went to dealers in West Point and Richmond.

The 1960 catch decreased about 81 percent from 1896. The size of the catch was similar in the different areas in 1896, but in 1960 the York produced 54 percent of the catch, the Pamunkey 28 percent, and the Mattaponi 18 percent. The amount of all types of fishing gear, except stake gill nets decreased from 1896 to 1960.

Rappahannock River

The Rappahannock River rises on the eastern slope of the Blue Ridge Mountains in Fauquier and Rappahannock Counties and crosses the fall line at Fredericksburg, 106 miles from its mouth. Fluvial characteristics extend to 40 miles below Fredericksburg. The river is navigable to that point. The lower 50 miles of river are 2 1/2 to 4 miles wide and form an arm of Chesapeake Bay.

The shad catch from the Rappahannock River in 1896 was 1,456,818 lb., of which pound nets caught 63 percent, stake gill nets 25 percent, drift gill nets 10 percent, and seines and miscellaneous gear the remainder. Pound nets, introduced in 1872, were operated mostly in the lower section of the river. The stake gill nets were 24 to 27 ft. long and 10 to 20 ft. deep and had 4 1/2- to 5-in. mesh; they were set in strings of 10 and 20 nets on the sides of the channel, at intervals of a few hundred feet. The drift gill nets were 75 to 200 yd. long and 60 meshes deep and had 5-in. mesh. Seines were 200 and 400 yd. long and had 2- and 2 1/2-in. mesh. Most of the catch was marketed in Baltimore, Md.

Shad ascended the Rappahannock River in 1960 to a dam at Falmouth, 2 miles above Fredericksburg. Shad eggs were collected in the river in 1951 from below Fredericksburg to Portobago Bay, 30 miles downstream from

Figure 18.--Fyke net fished for shad and other species, North Carolina and Virginia

Fredericksburg (Massmann, Ladd, and McCutcheon, 1952b).

The estimated shad catch in 1960 was 89,364 lb., of which approximately 61 percent was taken by stake gill nets, 21 percent by pound nets, 16 percent by drift gill nets, and the remainder by fyke nets. Pound nets were fished from the river mouth upstream 85 miles to Port Royal. The lower 10 miles had 25 standard-size pound nets; upstream the pound nets were smaller. Stake gill nets were fished from Monaskon to the outlet of Portobago Bay, a distance of 55 miles. Net strings were 30 to 200 yd. long. The nets were 35 to 55 meshes deep, had 5 1/4- to 5-7/8-in. mesh, and were concentrated mostly between Monaskon and Tappahannock. Drift gill nets were operated from Leedstown to Port Royal, a distance of 10 miles. Between Port Royal and Portobago Bay, the river was closed to all fishing except with drift nets; the nets were 75 to 125 yd. long, and 35 to 60 meshes deep and had 5- to 5-3/8-in. mesh. Fyke nets (fig. 18) were used from Weems to Tappahannock, but the shad catch was incidental to the catches of other species.

Table 27.--Shad catch, by area and gear, York River, Va., and tributaries, 1960

Area and gear	Quantity	Length fished	Catch
	Number	Yards	Pounds
York River:			
Pound net.....	12	---	12,545
Fyke net.....	52	---	9,511
Stake gill net..	4,143	24,858	173,462
Pamunkey River:			
Drift gill net..	288	28,800	103,162
Mattaponi River:			
Drift gill net..	227	22,700	65,957
Total.....	4,722	76,358	364,637

Potomac River

Although the Potomac River forms the boundary between Virginia and Maryland, the Maryland line follows the low-water mark on the Virginia side of the river. By an 1875

compact, fishermen from both States were given unrestricted fishing privileges in the river. The Maryland Management Plan, established in 1941, restricted commercial nets in Maryland waters, including the Potomac, to the number operating in 1941. In 1945 Maryland commercial fishermen who fished in the Potomac were granted unrestricted license so that they could compete on an equitable basis with the shad fishermen from Virginia (Walburg and Sykes, 1957).

The shad fishery in the Potomac River in 1896 is described in the section on shad fisheries of Maryland.

In 1960 Virginia fishermen caught 136,900 lb. of shad in the Potomac; 53 percent was taken by pound nets from the river mouth to the Potomac River bridge, 45 percent by gill nets fished above the bridge, and the remainder by seines and fyke nets.

TRENDS IN PRODUCTION

Shad production in Virginia decreased from 11.2 million pounds in 1896 to 1.4 million pounds in 1960 (table 28). The general trend has been downward since 1897 despite slight increases in certain years. In 1908 shad were the most important fish caught in Virginia and comprised about one-fourth of all shad taken in the United States (Bureau of the Census, 1911). As late as 1928, shad ranked third in quantity of fish landed in Virginia, and the catch was more than 7 million pounds (Hildebrand and Schroeder, 1928). After a production of 7,291,000 lb. in 1931, the yield drastically declined and was less than 2 million pounds in 1936. Production increased from 1937 to 1945 but declined after 1945; in 1960 only 1,386,000 lb. were landed. The 1960 catch was less than 13 percent of that of 1896.

The Commission of Fisheries of Virginia advised in 1949 against fish hatcheries as a method of improving shad production (Marshall, 1949). A limited operation was continued, however, on the Pamunkey, Mattaponi, and Chickahominy Rivers, but how these hatcheries affect production has not been evaluated (Meyer, 1959).

The State Water Control Board began a cleanup campaign in the 1950's on polluted rivers. Except for the James River from Hopewell to Richmond, however, pollution is probably not a major factor in decline of shad in Virginia.

Table 28.--Shad catch for certain years, Virginia, 1880-1960[1]

[In thousands of pounds]

Year	Catch	Year	Catch
1880.	3,172	1937.	3,086
1887.	3,815	1938.	3,607
1888.	7,057	1939.	3,559
1890.	7,266	1940.	2,811
1891.	6,498	1941.	2,126
1896.	11,171	1942.	2,430
1897.	11,529	1944.	4,665
1901.	6,972	1945.	5,299
1904.	7,420	1946.	3,599
1908.	7,314	1947.	4,086
1909.	6,030	1948.	3,206
1915.	4,714	1949.	2,801
1920.	7,294	1950.	3,031
1921.	6,909	1951.	3,295
1925.	6,104	1952.	4,007
1929.	7,977	1953.	3,054
1930.	6,183	1954.	3,169
1931.	7,291	1955.	3,500
1932.	4,848	1956.	3,191
1933.	4,817	1957.	2,918
1934.	4,105	1958.	2,254
1935.	2,883	1959.	1,774
1936.	1,615	1960.	1,386

[1]Statistics 1880-1959, U.S. Fish and Wildlife Service (1958-61).

It is difficult to evaluate the factors that may have caused fluctuations in shad production in Virginia waters since fish destined for Maryland waters make up a part of the catch. Before studies can be made to determine the cause of the long-term decline, it will be necessary to have accurate catch and effort statistics on the Chesapeake Bay fishery for a series of years.

The Virginia Institute of Marine Science (formerly the Virginia Fisheries Laboratory), although not specifically concerned with increasing fish production, has contributed much information on the shad fisheries of the State. It has identified the major spawning and nursery areas in all the rivers, tagged shad in certain rivers to ascertain fish movement and fishing rate, and initiated catch record programs in some areas.

SHAD FISHERIES OF MARYLAND

The estimated 1896 catch of shad in Maryland waters was 5,541,499 lb., of which Chesapeake Bay yielded 32 percent and its tributaries 68 percent, excluding Potomac River landings by Virginia fishermen. Gill nets produced about 54 percent of the catch, pound nets 29 percent, seines 14 percent, and fyke and bow nets the remainder.

Commercial fishermen caught an estimated 1,335,953 lb. of shad in Maryland waters in 1960; Chesapeake Bay yielded about 76 percent and its tributaries the remainder. Gill nets

produced approximately 75 percent of the catch, pound nets 24 percent, and seines the remainder. In addition to the commercial fisheries, an estimated 13,000 lb. were taken by sport fishermen with rod and reel on the Susquehanna River, and noncommercial (unlicensed) gear took more than 60,125 lb. in the Bay tributaries. The gear and catch by water area for 1896 and 1960 are given in tables 29 and 30. A map of Maryland waters is included in figure 15.

In 1941 the Maryland State Legislature passed a fishery management law entitled "The Maryland Management Plan." In general, the plan attempted to stabilize the fishing gear and effort at the pre-World War II level and at the same time to liberalize fishing when availability of shad increased. In the First Annual Report of the Maryland Board of Natural Resources, published in 1944, the Maryland Department of Tidewater Fisheries presented the history of the management plan.

Table 29.--Gear employed in shad fisheries, by water area, Maryland, 1896 and 1960

Water area	1896						1960			
	Drift gill net	Stake gill net	Haul seine	Pound net	Fyke net	Bow net	Drift gill net	Stake gill net	Haul seine	Pound net
	Yards	Yards	Yards	Number	Number	Number	Yards	Yards	Yards	Number
Chesapeake Bay:										
Lower	---	5,580	---	[1]108	---	---	600	8,142	17,540	72
Upper	249,030	32,900	12,200	[1]239	---	---	23,710	130,931	10,660	34
Potomac River	94,500	---	3,640	131	---	3	4,700	18,795	3,198	9
Patuxent River	1,205	---	1,700	33	---	---	200	1,700	---	---
Pocomoke River	2,180	---	462	---	16	97	---	600	---	2
Wicomico River	20,040	1,400	630	5	36	---	500	1,028	---	14
Nanticoke River	29,589	3,788	545	[2]38	143	---	10,040	7,040	---	15
Fishing Bay	1,840	6,930	---	[2]72	---	20	7,040	3,632	---	44
Choptank River	44,792	26,970	4,537	194	57	---	8,735	9,328	7,000	36
Chester River	290	7,020	3,835	[1]81	83	---	620	700	---	---
Susquehanna River	28,672	---	5,800	---	[3]15	8	8,763	---	---	---
Total	472,138	84,588	33,349	901	350	138	64,908	181,896	38,398	226

[1] Not set especially for shad and some catch very few of that species.
[2] Includes 12 "stick weirs".
[3] Fall traps or pots.

Table 30.--Shad catch, by water area and gear, Maryland, 1896 and 1960
[In pounds]

Water area	1896						1960			
	Drift gill net	Stake gill net	Haul seine	Pound net	Fyke net	Bow net	Drift gill net	Stake gill net	Haul seine	Pound net
Chesapeake Bay:										
Lower	---	16,613	---	572,755	---	---	411	17,335	4,800	127,818
Upper	873,316	132,254	120,778	58,876	---	---	161,286	571,718	4,066	130,875
Potomac River	492,210	---	158,435	185,902	---	2,157	1,090	27,783	50	3,353
Patuxent River	70,840	---	87,651	29,771	---	---	325	482	---	---
Pocomoke River	11,500	---	9,123	---	737	85,626	---	574	---	1,100
Wicomico River	163,248	16,991	14,578	45,078	4,682	---	153	6,437	---	1,660
Nanticoke River	315,708	63,522	25,819	150,536	33,575	---	65,321	19,448	---	10,023
Fishing Bay	13,305	29,361	---	83,353	---	5,753	6,567	30,099	---	47,346
Choptank River	432,449	134,811	241,808	413,679	2,150	---	3,296	3,644	1,135	3,055
Chester River	989	70,444	35,718	76,662	[1] 8,594	---	220	225	---	---
Suaquehanna River	127,944	---	109,242	---	[1] 7,203	5,753	84,258	---	---	---
Total	2,501,509	463,996	803,152	1,616,612	56,941	99,289	322,927	677,745	10,051	325,230

[1] Fall traps or pots.

Most of this information is given in the historical review of the shad fisheries of North America by Mansueti and Kolb (1953).

FISHERIES BY WATER AREA

It was unlawful in 1960 for the Commission of Tidewater Fisheries to license the use of any net or other devices for catching finfish for commercial purposes in the tidal waters of Maryland, except by pound nets, haul seines, and fyke nets more than 40 yd. long and gill nets more than 100 yd. long. The Commission has the power to determine each year whether additional licenses should be issued, basing its judgment on the condition of the fisheries as determined by statistical and biological studies. The legal shad season was from January 1 to June 5 in the tidal waters of Maryland, and from March 1 to May 26 in the Potomac River.

In the present study, the amount of gear fished includes only that fished for shad and not the total amount licensed. The shad catch by fyke nets, haul seines, and pound nets was, in some instances, incidental to the catch of other species; this fishing gear has not been counted.

Chesapeake Bay in Maryland

Chesapeake Bay extends northward into Maryland 120 miles and is 3 to 16 miles wide. It covers an area of 976 square miles, but if its numerous tributaries up to the limit of tidewater are included, it covers 2,359 square miles. Much of the water is less than 20 ft. deep, but depths may exceed 150 ft. The salinity of the water decreases from south to north, and the water is fresh at the head of the Bay. The Bay divides the State into the eastern and western shores, each with a number of important shad streams.

In describing the fishery of 1896, Stevenson divided the Bay into two geographical sections. The lower extended from the Virginia line to Swan Point, near Rock Hall, Md., and the upper included the remainder of the Bay. In the lower section, the fishery outside the rivers was comparatively small, and the gear was exclusively pound nets and a few stake gill nets. The catch by these nets was 589,368 lb., of which 108,090 lb. were taken by fishermen living on the Eastern Shore and 481,278 lb. by fishermen on the western side. The upper section was the principal shad-producing region of the Bay. The yield in 1896 was 1,185,224 lb., of which about 74 percent was caught by drift gill nets, 11 percent by stake gill nets, 10 percent by seines, and 5 percent by pound nets.

In 1896 pound nets in the lower Bay were concentrated in Pocomoke Sound and below the Little Annemessex River on the Eastern Shore; on the western side most were near the mouth of the Patuxent River, between Holland Point and Gibson Island. Most of these nets were of the "single heart" type with 4-in. mesh.

Stake gill nets fished along the shore in 1896 from Tilghman Island to Kent Island took shad almost entirely for local use. A few fish were caught between the Chester and Choptank Rivers in Eastern Bay. This Bay receives the waters of the St. Michael, Wye, and smaller rivers, but in 1896 only the St. Michael produced shad.

The 1896 drift net fishery in the upper Bay was the most productive on the Atlantic coast south of Delaware Bay. The nets operated from the mouth of the Susquehanna River to Pooles Island in the Northeast River and in the extreme lower portion of the Elk and Sassafras Rivers. Nets were 150 to 400 yd. long and had 5 1/4- to 5 1/2-in. mesh. Twenty-five years before Stevenson's investigation, stake gill nets were fished extensively in the upper Bay, but they gradually gave way to the more effective and less costly drift nets. The stake gill net fishery was limited to the shore of Kent County. These nets were about 25 yd. long and 40 meshes deep and had 5 1/2-in. mesh. Seines and pound nets were in the extreme northern end of the Bay.

In 1960 shad entered Maryland waters in March, and the run continued into June. The estimated catch in Chesapeake Bay was 1,018,309 lb., most of which was taken in the upper central and northern portions. Because of the different gears and the quantity of shad taken, each section of the Bay is discussed separately. The catch by water area is given in Table 31.

Chesapeake Bay, South.--In 1960 the lower portion of the Bay from the Virginia-Maryland line to Cove Point, including Pocomoke Sound, Honga River, and Tangier Sound, yielded 37,773

Table 31.--Shad catch, by water area and gear, in Maryland waters of Chesapeake Bay, 1960

[In pounds]

Water area	Gear				Total
	Drift gill net	Stake and anchor gill net	Haul seine	Pound net	
Chesapeake Bay south:					
Bay proper	---	783	2,000	5,200	7,983
Tangier Sound	---	613	---	7,805	8,418
Pocomoke Sound	---	14,789	---	4,908	19,697
Honga River	---	---	---	1,675	1,675
Chesapeake Bay lower central:					
Bay proper	161	800	2,800	108,230	111,991
Eastern Bay	250	350	---	---	600
Chesapeake Bay upper central:					
Bay proper	102,843	432,607	1,125	---	536,575
Chesapeake Bay north:					
Bay proper	58,443	139,111	2,941	130,875	331,370
Total	161,697	589,053	8,866	258,693	1,018,309

lb. of shad. Pound nets (figs. 19 and 20) caught 19,588 lb., anchor and stake gill nets 16,185 lb., and haul seines 2,000 lb.

The locations of pound nets and the catches in this area were: Chesapeake Bay proper, 14 nets, 5,200 lb.; Pocomoke Sound, 17 nets, 4,908 lb.; Honga River, 6 nets, 1,675 lb.; and Tangier Sound, 8 nets, 7,805 lb. The pound nets were of the "single heart" type, with 2 1/2- to 3 1/2-in. mesh and leads 100 to 300 yd. long.

Stake gill nets were fished in Pocomoke Sound and Tangier Sound, and anchor gill nets were operated along the Eastern Shore in the Bay proper. The length of net and catch by area were as follows: Pocomoke Sound, 3,602 yd., 14,789 lb.; Tangier Sound, 600 yd., 613 lb.; and the Bay proper, 2,100 yd., 783 lb. Nets ranged from 100 to 300 yd. long and 35 to 45 meshes deep and had 4- to 5 1/2-in. mesh. Fourteen haul seines took 2,000 lb. of shad in the Bay proper incidental to the catch of other species.

Chesapeake Bay, Lower Central.--Lower Central Chesapeake Bay from Cove Point to Sandy Point, including Eastern Bay, produced 112,591 lb. of shad in 1960. Twenty-seven pound nets, distributed throughout the Bay proper on both shores, yielded 108,230 lb.; 1,540 yd. of anchor gill net in the Bay proper took 800 lb.; 300 yd. of stake gill net fished in Eastern Bay took 350 lb.; 600 yd. of drift gill net in Eastern Bay and the Bay proper caught 411 lb. incidental to the catch of other species; and 18 haul seines used in the Bay proper for other species took 2,800 lb. Gears were practically the same as those in the extreme southern end of the Bay.

Chesapeake Bay, Upper Central.--The Upper Central Chesapeake Bay from Sandy Point to the entrance of Romney Creek on the western side produced 536,575 lb. of shad in 1960. This was the principal production area in the Bay. Stake gill nets (70,608 yd.) took 72 percent of the catch, drift gill nets (12,462 yd.) 19 percent, anchor gill nets (7,633 yd.) 8 percent, and 5 haul seines 1 percent, incidental to the catch of other species.

This stake and anchor gill net fishery was among the most productive on the Atlantic coast south of the Hudson River. Nets were set on both sides of the Bay but were concentrated on the western side. They ranged from 100 to 400 yd. long and 30 to 45 meshes deep and had 5- to 5 1/2-in. mesh.

Chesapeake Bay, North.--The extreme northern end of Chesapeake Bay receives the Susquehanna and Northeast Rivers from the

Figure 19.--Pound nets fished in Chesapeake Bay, Md. (Photograph courtesy of Virginia Institute of Marine Science, Gloucester Point, Va.)

Figure 20.--Pursing pound net in Chesapeake Bay, Md. (Photograph courtesy of Virginia Institute of Marine Science, Gloucester Point, Va.)

north and the Elk and Sassafras Rivers from the east. This area produced 331,370 lb. in 1960 of which stake and anchor gill nets took 42 percent, pound nets 39 percent, drift gill nets 18 percent, and haul seines 1 percent. Drift gill nets (11,248 yd.) were from 100 to 300 yd. long and 35 to 65 meshes deep and had 5- to 5 1/2-in. mesh. They were fished over the Susquehanna Flats at the head of the Bay and in the lower portions of the tributaries. Stake gill nets (10,267 yd.) and anchor gill nets (42,423 yd.) were 100 to 300 yd. long and 25 to 35 meshes deep and had 3 1/2- to 5 1/4-in. mesh; they were fished in the same general area as drift nets. Thirty-four pound nets were operated in the tributaries and Bay proper and 15 haul seines in the extreme upper end of the Bay.

Potomac River

The Potomac River is the largest tributary of Chesapeake Bay. It is formed by the union of its north and south branches on the Maryland-West Virginia line and flows 290 miles southeast to its entrance into Chesapeake Bay on the western shore, 75 miles from the Virginia Capes. Below Washington, D.C., the river is broad and sluggish, forming one of the largest estuaries on the Atlantic coast. This estuary is 100 miles long and 2 to 7 miles wide. Tidal influence extends upstream to Chain Bridge near Washington. From there to Great Falls, 11 miles upstream, are numerous shoals with several rapids, including Little Falls 0.8 mile above Chain Bridge.

The Great Falls had always prevented the upstream movement of fish. In 1882 an appropriation was made by Congress to erect suitable fishways at this obstruction, but after considerable damage by freshets the partially completed structure was abandoned in 1885 (Stevenson, 1899).

In 1896 the catch of shad in the Potomac River reached a peak of 2,462,627 lb., of which 838,704 lb. were taken by Maryland fishermen and 1,623,923 lb. by Virginia fishermen. Virginia residents employed 67,000 yd. of drift gill nets, which accounted for 32 percent of the Virginia catch; 13,600 yd. of haul seines, which took 18 percent; 6,133 yd. of stake gill nets, which produced 3 percent; and 299 pound nets, which took the remainder. Maryland fishermen fished 94,500 yd. of drift gill nets, which accounted for 59 percent of the Maryland catch; 3,650 yd. of seines, which took 19 percent; and 131 pound nets and 3 bow nets, which took the

remainder. The drift net fishery extended from Mathias Point to Alexandria, Va., a distance of 60 miles. Drift nets ranged from 300 to 1,000 yd. long and 30 to 90 meshes deep, depending on the width and depth of the reach in which they were operated. The stake gill net fishery was of little importance since it consisted only of a few nets operated in the lower half of the river. Each spring a few bow nets were fished at Great Falls from the last week in April to the first or second week of June.

Shad were believed to have ascended the Potomac to Great Falls before 1948, but since then a 9-ft. dam erected on Little Falls, 10 miles below Great Falls, has been a barrier to further upstream migration. A vertical, baffle-type fishway was completed in the dam in 1959 (fig. 21). Resident fishes use the fishway, but shad do not ascend the river beyond a point about three quarters of a mile below the structure.

The major spawning ground in 1960 was from Fort Washington downstream to Occoquan Bay, a distance of 20 miles.

Fishing began in the Potomac in 1960 in mid-March and continued through the end of May. The estimated catch was 169,176 lb., of which 81 percent was taken by Virginia fishermen and 19 percent by Maryland fishermen. The catch was marketed in Washington, D.C., and Baltimore, Md. The amount of gear used and catch by each State are given in table 32.

In 1960 pound nets, stake gill nets, and drift gill nets were the major gear used for taking shad. The pound net fishery extended 56 miles, from the river mouth to Highway 301 bridge (Potomac River Bridge). The nets produced 76,183 lb. of shad, of which Virginia landings, in turn, accounted for 96 percent. Stake gill nets were fished in about 26 miles of river, from Potomac bridge to Occoquan Bay. The nets were 100 to 200 yd. long and 35 to 45 meshes deep and had 3 1/2- to 5 1/2-in. mesh. This gear caught 83,718 lb. of shad, of which Virginia landings accounted for 67 percent. Drift gill nets were used, from Occoquin Bay to Alexandria, about 20 miles. They ranged from 150 to 300 yd. long and 45 to 75 meshes deep and had 5- to 5 1/2-in. mesh. Drift nets took 7,305 lb. of shad, of which Virginia fishermen accounted for 85 percent. Haul seines and fyke nets were used throughout the fishery, but the shad catch was small and incidental to the catches of other species.

Figure 21.--Little Falls Dam, Potomac River, Md. Fishway between dams was completed in 1959.

Table 32.--Shad catch, by gear, Potomac River, Md., 1960

Gear	Virginia			Maryland			Total		
	Quantity	Length fished	Catch	Quantity	Length fished	Catch	Quantity	Length fished	Catch
	Number	Yards	Pounds	Number	Yards	Pounds	Number	Yards	Pounds
Stake gill net. .	---	59,438	55,935	---	18,795	27,783	---	78,233	83,718
Drift gill net. .	---	2,466	6,215	---	4,700	1,090	---	7,166	7,305
Pound net	173	---	72,830	9	---	3,353	182	---	76,183
Haul seine. . . .	---	5,100	1,728	---	3,198	50	---	8,298	1,778
Fyke net.	22	---	192	---	---	---	22	---	192
Total	195	67,004	136,900	9	26,693	32,276	204	93,697	169,176

In addition to the commercial catch, shad were taken near the Chain Bridge with dip nets and rod and reel from the first of May through the first week of June. Six dip nets on the Virginia shore above the bridge took an estimated 750 lb., 90 percent of which were males. Rod-and-reel fishermen took an estimated 300 lb. below the Chain Bridge.

The total 1960 yield was the smallest ever recorded for the Potomac, except for 1958, and was less than 7 percent of the 1896 catch.

In 1919 the Bureau of Fisheries recognized the need for investigating the Potomac shad fishery to determine the relative importance of factors contributing to the decline in abundance. An annual statistical canvass was undertaken to provide information for determining changes in the fishery and to find means for possible restoration of favorable conditions for reproduction and growth of anadromous species (Bureau of Fisheries, 1919-40). Factors reported as contributing to depletion were: intensive fishing; changed conditions in the river resulting from the advance of civilization; and changed weather conditions affecting the migration of shad into and up the river. Because the annual canvasses did not provide information on fishing effort, these data could not be used in our studies of factors affecting size of run and their relation to fluctuations in abundance.

Patuxent River

The Patuxent River is located entirely in Maryland. It rises in Howard and Montgomery Counties and flows 110 miles to the western shore of Chesapeake Bay, 20 miles north of the Potomac River.

In 1896 shad ascended the Patuxent River to Laurel (95 miles from the mouth), where two dams prevented further upstream migration, but most were caught below Drury. The estimated catch was 188,262 lb., of which 87,651 lb. were caught by seines, 70,840 lb. by drift gill nets, and 29,771 lb. by pound nets. Pound nets, fished in the lower river, mostly between Point Patience and Drum Point, caught more alewives, Alosa pseudoharengus, than shad. Seines were operated in the upper reaches of the Patuxent in Prince Georges and Anne Arundel Counties where the river was 500 to 600 ft. wide. The nets ranged from 100 to 200 yd. long and had 2 1/2- or 2 3/4-in. mesh. Drift nets were operated near Dunkirk and Leon; each was about 200 ft. long and had 5- to 5 3/8-in. mesh.

The Patuxent was free of obstructions to passage of fish in 1960, and shad ascended the river at least 50 miles to Hills Bridge. The spawning grounds were from Drury to Lower Marlboro.

The estimated catch in 1960 was 807 lb., of which gill nets took 482 lb. and drift gill nets 325 lb. In addition, unlicensed gill nets caught slightly less than 2,000 lb. Stake gill nets that were 100 to 200 yd. long and 25 to 35 meshes deep and had 4 1/2- to 5 1/2-in. mesh were fished the first 32 miles from the mouth of the river to Lower Marlboro. The greater concentration was from the mouth to Benedict. Drift nets, 100 yd. long, 35 to 45 meshes deep, and with 5- to 5 1/2-in. mesh, were operated from Lower Marlboro halfway to Upper Marlboro. Unlicensed gill nets, ranging from 20 to 30 yd. long, were fished above the drift net area. Seines, pound nets, and fyke nets between Benedict and Lower Marlboro occasionally took shad, but none was reported during the 1960 season. It was illegal to fish drift nets from the mouth of the river to Highway 231 bridge near Benedict. In previous seasons, shad were taken by rod and reel in the Patuxent below Hardesty (Mansueti and Kolb, 1953), but none was reported in 1960.

The Patuxent has always been a minor contributor to Maryland shad production. The catches were 29,851 lb. in 1920 and 13,180 lb. in 1921, compared with 849 lb. in 1945 and 807 lb. in 1960. The decrease of production in this river may have been caused indirectly by the heavy gravel washings and buildup of alluvial deposits over the spawning grounds near Bristol, Md. (Mansueti and Kolb, 1953).

Susquehanna River

The Susquehanna is one of the largest rivers on the Atlantic coast, but only 12 miles of its length are within the limits of Maryland. It ranges from 1/2 to 1 mile wide and has an average fall of more than 5 ft. per mile. Since most of the river is in Pennsylvania, its physical characteristics and the shad fishery are described in the section on the fisheries of that State.

The gears used in the Maryland section of the Susquehanna in 1896 were drift nets and seines near the mouth and fall traps and bow nets in the rapids above Port Deposit, Md. Gill nets averaged 125 to 130 yd. long and had 5 1/2-in. mesh; a total of 28,672 yd. was fished. The seines, seven large and five small, were 100 to 800 yd. long and had 2 1/4- to 4 1/2-in. mesh. The estimated catch was 250,142 lb., of which drift nets took 51 percent, seines 44 percent, and fall traps and bow nets 5 percent.

In 1960 shad ascended 10 miles above the mouth, to Conowingo Dam, which completely obstructed the upstream movement of fish. Shad spawned throughout the lower river section and over the Susquehanna Flats at the head of the Bay. Spawning began in April and extended into June. The peak of the run was in the river about mid-May.

Drift gill nets were the only commercial gear used in 1960 for shad on the Susquehanna. Most nets were fished between the Baltimore and Ohio Railroad Bridge near Havre de Grace, Md., and Port Deposit, a stretch of 3 miles. Nets ranged from 100 to 150 yd. long and 45 to 65 meshes deep and had 5- to 5 1/2-in. mesh; the total yardage was 8,763. The estimated catch was 84,258 lb. Rod-and-reel fishermen caught 13,000 lb.--1,936 lb. in the Conowingo Dam tailrace and the remainder near the mouth of the river (Whitney, 1961).

Pocomoke River

The Pocomoke River is one of the numerous tributaries entering Chesapeake Bay on the Eastern Shore. These tributaries arise in western Delaware and flow in a general southwesterly direction, expanding in the lower reaches into broad estuaries. Their descent is so gradual that they are tidal nearly to the upper limits.

The Pocomoke rises on the Maryland-Delaware line and flows 45 miles to Pocomoke Sound. The shad fishery of 1896 extended from the mouth to above Snow Hill, Md. The yield was 106,986 lb.; bow nets took 80 percent, drift nets 11 percent, seines 8 percent, and fyke nets 1 percent. Bow nets were 14 to 16 ft. in diameter, and the average catch per net (833 lb.) far exceeded that in any shad fishery in the United States; the nearest approach to this catch per net was in the Santee River, S.C. (about 400 lb.).

The fishery extended to Snow Hill in 1960, and the estimated catch by licensed fishermen was 1,674 lb. Of the total catch, two pound nets between the mouth of the river and Pocomoke City, Md.--a stretch of 20 miles--caught 1,100 lb., and 600 yd. of stake gill net fished above Pocomoke City caught 574 lb. Unlicensed gill nets near Snow Hill took an estimated 300 lb. From 1957 to 1960, the average annual yield of the Pocomoke River was less than 2 percent of the yield in 1896.

Wicomico River

The Wicomico originates near the elevated shore of Great Cypress Swamp, flows 35 miles, and enters the northeast portion of Tangier Sound.

Stevenson (1899) reported that, considering the Wicomico's small size, the average annual yield of 250,000 lb. of shad was remarkable. The catch in 1896 was 244,577 lb., of which drift gill nets took about 67 percent, pound nets 18 percent, stake gill nets 7 percent, seines 6 percent, and fyke nets the remainder. Drift nets were 40 to 100 yd. long and 31 to 53 meshes deep and had 4 7/8- to 5 1/8-in. mesh. They were fished from White Haven, Md., to 1 mile below Salisbury, a distance of 12 miles. Stake nets, 20 yd. long and 40 meshes deep with 5- to 5 1/2-in. mesh, were fished near the mouth of the river and pound nets near White Haven. Seines, operated near the headwaters of the river to within 4 miles of Salisbury, were 145 to 340 yd. long and had 2 1/4-in. mesh in the bunt. Fyke nets were not set especially for shad, and the catch was incidental to that of other species.

Shad ascended to the headwaters of the Wicomico River in 1960. The catch was 8,250 lb., of which stake gill nets took 78 percent, pound nets 20 percent, and drift gill nets 2 percent. Pound nets were operated near the mouth of the river and in Monie Bay near Mt. Vernon and Salisbury. Drift nets were 100 to 150 yd. long and 45 to 55 meshes deep and had 5- to 5 1/2-in. mesh, and stake nets ranged from 100 to 125 yd. long and 25 to 35 meshes deep and had 4- to 5 1/4-in. mesh. In addition to the catch by licensed gear, unlicensed gill nets between Salisbury and the head of the river took an estimated 7,000 lb.

Nanticoke River

The headwaters of the Nanticoke River are in Kent and Sussex Counties, Del., and unite at Seaford, Del., 11 miles upstream from the Maryland-Delaware line. The total river length is 70 miles--30 miles in Delaware and 40 miles in Maryland. In the lower 10 miles, the river expands into a broad estuary. Above this expansion, the river width gradually diminishes and is less than 200 yd. at the Delaware boundary. About 25 miles from its mouth, the river receives Marshyhope Creek, which rises in Kent County and flows about 34 miles to its entrance into the Nanticoke.

In 1896 the Nanticoke ranked third among Maryland rivers in the shad catch and was surpassed only by the Choptank and Potomac. The fishery extended from the mouth of the river to several miles above Seaford; the estimated catch was 812,417 lb., of which 223,257 lb. were taken in Delaware, 140,000 lb. in Marshyhope Creek, and 448,760 lb. in the Maryland portion of the main river.

Drift gill nets, stake gill nets, pound nets, and fyke nets were the only gears used to take shad in the Maryland section of the Nanticoke in 1896. Drift nets, 115 yd. to 175 yd. long, 51 to 65 meshes deep, with 4 7/8- to 5 1/4-in. mesh, were fished from Quantico Creek to the Delaware line and took 225,852 lb. Stake nets in the extreme lower portion of the river from Roaring Point to Sandy Hill caught an estimated 63,522 lb. Pound nets, concentrated above Quantico Creek, were not set especially for shad, but 125,811 lb. were taken by 26 nets. The catch of 33,575 lb. in fyke nets in the lower river below Quantico Creek was incidental to the catch of other fish. Considering the size of Marshyhope Creek, its shad fishery was highly productive in 1896. The catch was about 140,400 lb., of which drift gill nets took about 64 percent, seines 18 percent, and pound nets 18 percent. Drift nets, 100 yd. long, from 49 to 53 meshes deep, and with 5- to 5 1/4-in. mesh, were fished from the mouth of the tributary to Federalsburg. Seines, 40 to 150 yd. long and with 2 1/2-in. mesh, were fished between Brookview, Md., and Federalsburg. Pound nets were set above Brookview.

Shad ascended the Nanticoke in 1960 at least 51 miles to Seaford and the Marshyhope to Federalsburg, Md., 55 miles from Tangier Sound. The river ranked first in shad production among Maryland rivers. The fishery extended from the river mouth to Seaford; the yield was 96,792 lb., of which 2,000 lb. were produced in Delaware, 23,698 lb. in Marshyhope Creek, and 71,094 lb. in the Maryland section of the river.

In 1960 gill and pound nets were the only gears in the fishery, and more than 90 percent of the catch was made by gill nets. In addition, unlicensed gill net fishermen took an estimated 43,000 lb. Drift gill nets were operated from Vienna to the Delaware boundary in the main river and throughout Marshyhope Creek; they averaged 145 yd. long, 45 meshes deep, and 5 1/4-in. mesh. The estimated catch was 65,321 lb., of which drift nets produced 15,024 lb. in Marshyhope Creek and 50,297 lb. in the main river. Stake gill nets from the mouth of the river to a few miles above Vienna and in the lower portion of Marshyhope Creek averaged 125 yd. long, 35 meshes deep, and 5-in. mesh. The estimated catch was 19,448 lb., of which the main river produced 10,774 lb. and Marshyhope Creek 8,674 lb. Fifteen pounds nets, fished in the lower portion of the Nanticoke River from the mouth to the vicinity of Vienna--a distance of 20 miles--caught 10,023 lb.

The production of the Nanticoke fishery has declined, but not as much as in other Maryland rivers. The 1960 catch was less than 13 percent of the 1896 take.

Fishing Bay

Fishing Bay is a broad estuary 11 miles long and from 2 to 3 miles wide. It connects the Transquaking and Blackwater Rivers with the northern portion of Tangier Sound.

The estimated catch of shad in 1896 was 131,772 lb., of which the Bay proper yielded 27 percent, the Transquaking River 37 percent, and the Blackwater River 36 percent. Of the Bay catch, stake gill nets caught 84 percent and pound nets the remainder. In the Transquaking, pound nets caught 75 percent of the catch, weirs 14 percent, and bow nets the remainder. Pound nets produced 62 percent of the catch in the Blackwater, drift gill nets 28 percent, and weirs 10 percent. Stake gill nets measured 16 to 18 yd. long, averaged 16 meshes deep, and had 5- to 5 1/2-in. mesh; they were set on the flats. Drift gill nets averaged 40 yd. long and 7 ft. deep, had 5-in. mesh, and were fished in the channels.

The 1960 catch in Fishing Bay was 84,012 lb. Pound nets produced 56 percent, stake gill nets 36 percent, and drift gill nets 8 percent. Pound nets were fished in the channel and near the mouths of both tributaries. Stake gill nets were 100 to 150 yd. long and 20 to 35 meshes deep and had 5- to 5 1/2-in. mesh; they were set on the flats. Drift gill nets were 100 to 125 yd. long and 35 to 45 meshes deep, had 5- to 5 1/2-in. mesh, and were fished near the mouths of the tributaries. Unlicensed gill nets were fished in the tributaries, but no information was obtained on the catch.

Choptank River

The Choptank River is the largest river on the Eastern Shore of Chesapeake Bay. From its mouth to Secretary, Md., a stretch of 25

miles, the river is a tidal estuary, 500 yd. to 5 miles wide. Twenty-five miles above tidal water, the river receives Tuckahoe Creek, a tributary nearly as long as the main stream above this point.

The 1896 catch in the Choptank was 1,224,897 lb., or nearly one-half of the total production of all Eastern Shore streams: 999,513 lb. were taken in the main stream and 225,382 lb. in Tuckahoe Creek. The gears were pound nets, drift gill nets, seines, stake gill nets, and fyke nets. The location and description of gears fished in the Choptank were as follows: pound nets, from the river mouth to 2 or 3 miles above the entrance of Tuckahoe Creek, but concentrated between Oxford and Windyhill, Md., a distance of 25 miles; drift gill nets, 60 to 200 yd. long and 40 to 60 meshes deep, from Windyhill to the head of the river; stake gill nets, 12 to 25 yd. long and 25 to 45 meshes deep (5-in.-mesh), from the lower limit of the drift net fishery to Castle Haven, a distance of 18 miles; seines, 120 to 325 yd. long, from Williston to Greensboro; and fyke nets from Dover Bridge to the entrance of Tuckahoe Creek.

The 1896 fishery in Tuckahoe Creek extended from the Choptank to Hillsboro. The gears were drift nets and seines, plus a few pound nets and weirs. The catch by gear and amount of gear fished are given in tables 29 and 30.

The main river was free of obstruction in 1960, and shad ascended at least 81 miles to a point 10 miles above Greensboro, Md., and 18 miles to Hillsboro, Md., in Tuckahoe Creek. Ripe female shad were taken from the entrance of Tuckahoe Creek to the upper limits of the run in the main river and tributary.

The Choptank ranked second in production in 1960 among rivers on the Eastern Shore, surpassed only by the Nanticoke. The fishery extended about 71 miles from the river mouth to Greensboro in the main river and to Hillsboro in Tuckahoe Creek. The estimated catch was 11,130 lb., of which drift gill nets caught about 30 percent, stake gill nets 33 percent, pound nets 28 percent, and seines the remainder. In addition, unlicensed gill nets took an estimated 7,380 lb. in the headwaters.

Drift gill and stake gill nets were fished in the main river and Tuckahoe Creek, and seines and fyke nets were used in the main river only. Drift gill nets were fished from Choptank, Md., to Greensboro, and were most numerous near the entrance to Tuckahoe Creek. They were 100 to 175 yd. long and 45 to 65 meshes deep, and had 4 1/2- to 5 1/4-in. mesh. Stake gill nets were fished from the mouth of the river to Choptank and in Tuckahoe Creek from Hillsboro to the main river; they ranged from 100 to 220 yd. long and 25 to 45 meshes deep, and had 4 3/4- to 5 1/4-in. mesh. Seines and fyke nets were operated near Denton, Md., and pound nets from the mouth of the river to Secretary.

The average annual production for the Choptank River and Tuckahoe Creek has steadily declined. The average catch in 1920 and 1921 was less than 10 percent of the 1896 yield of 1 1/4 million pounds. From 1944 to 1960, the annual yield was less than 50,000 lb. and reached a near record low of 11,130 lb. in 1960.

Chester River

The Chester River is the second largest stream entering Chesapeake Bay from the Eastern Shore; it is surpassed only by the Choptank. The Chester River rises in Kent and Newcastle Counties, Del., and flows 55 miles to the Bay. The width ranges from 2 to 3 miles near the mouth to 150 ft. near Millington, Md., 36 miles upstream.

The 1896 shad fishery of the Chester extended from the river mouth to the headwaters; most fish were taken in pound nets near the mouth and in stake gill nets set between Chestertown and Millington. Stake gill nets were 20 to 50 yd. long and 30 to 45 meshes deep and had 5- to 5 1/2-in. mesh. The aggregate length of 178 nets in 1896 was 7,020 yd., and the yield was 70,444 lb. A number of drift gill nets formerly were operated in the river, but they were gradually superseded by stake nets. The catch by drift nets was 989 lb. The pound net fishery was near the mouth of the river, and the catch was 76,662 lb. Seines between Island Creek and Crumpton, Md., took 35,718 lb. The catch of 8,594 lb. in numerous fyke nets fished below Chestertown was incidental to the catch of other species.

Shad ascended the Chester River 36 miles in 1960 to the vicinity of Millington. The estimated catch was 445 lb., of which 46 percent was taken by drift gill nets between Chestertown and Highway 17 bridge and 54 percent by stake gill nets between the mouth of the river and Highway 290 bridge near Crumpton. In addition, unlicensed gill nets caught an estimated equal quantity of shad.

The fishing effort and the availability of shad have declined in the Chester River. In 1920 and 1921 the catches were only 540 and 2,700 lb., respectively. From 1944 to 1960 the annual yield remained low, fluctuating from a peak of 45,755 lb. in 1947 to a record low of 445 lb. in 1960.

TRENDS IN PRODUCTION

Shad entered almost all Maryland waters of Chesapeake Bay in 1960, but in much smaller numbers than in 1896. In the intervening years, the catch in most of the Bay and its tributaries fluctuated widely, but production generally declined (table 33).

Table 33.--Shad catch for certain years, Maryland, 1880-1960[1]

[In thousands of pounds]

Year	Catch	Year	Catch
1880	3,774	1937	405
1887	4,041	1938	600
1888	4,868	1939	624
1890	7,128	1940	446
1891	6,225	1941	534
1896	5,541	1942	725
1897	5,800	1944	711
1901	3,111	1945	617
1904	2,912	1946	719
1908	3,937	1947	868
1909	3,253	1948	1,004
1915	1,455	1949	1,083
1920	1,867	1950	1,443
1921	1,807	1951	1,554
1925	1,260	1952	1,636
1929	1,549	1953	1,448
1930	998	1954	1,501
1931	1,196	1955	1,464
1932	1,667	1956	2,092
1933	1,374	1957	2,356
1934	885	1958	1,900
1935	800	1959	1,481
1936	570	1960	1,336

[1]Statistics 1880-1959, U.S. Fish and Wildlife Service (1958-61).

Prior to 1880 the Commission of Fisheries of Maryland noted a decrease in abundance of shad and other valuable food fishes (Ferguson and Downes, 1876; Ferguson and Hughlett, 1880). The decline in availability was attributed to overfishing, blocking of fish from their spawning grounds, and destruction of young by improper means and modes of capture. The primary remedies offered to arrest the decrease in abundance were artificial propagation and restrictions on fishing season and commercial gear.

From 1880 to 1890 shad production increased from less than 4 million pounds to more than 7 million pounds. Factors which contributed to this increase were principally an expansion in numbers of fishermen and amount of fishing gear, and in methods and effectiveness. Gill nets and pound nets were introduced by New England fishermen; haul seines had been the principal gear up to the mid-1880's.

Shad production decreased after 1890, and by 1915 was less than 1.5 million pounds (records for 9 yr.). For the next 20 yr., average annual production was less than 1.5 million pounds; the high was more than 1.8 million pounds in 1920 and the low was 0.8 million in 1935. From these figures it may be supposed that the fluctuations in production may have been due to changes in fishing pressure, reduction of spawning areas by construction of dams in some rivers, and other complex factors.

Production remained relatively low from 1936 to 1947 after which it again increased. The average annual production from 1948 to 1960 was slightly more than 1.5 million pounds; production in 1960 was less than average and less than 25 percent of the 1896 catch.

From a study of statistics on shad production in Chesapeake Bay, Hildebrand and Schroeder (1928) noted that larger and more effective fishing gear had been used from year to year, and they suggested that the decline in abundance prior to 1925 was attributable to overfishing and to pollution in the streams. No physical data were offered however, to support their views.

Quittmeyer (1957) made a comprehensive analysis on the economic conditions affecting the fisheries of Maryland and Virginia. He reported that the period 1935-51 offers a picture of supply during economic depression, war, and a postwar period. These conditions appeared to have little effect on the shad fishery, except that during World War II the shad were fished heavily because of the shortage of meat and catches were large.

The Maryland Management Plan was designed primarily to rehabilitate the fisheries for shad and other "herrings" in Maryland waters. Catch statistics do not indicate that the plan has been successful. One of the problems in administering it has been that increases in gear should take place only when the stock of fish increases, not necessarily when the catch increases. Also, the unit of effort has been difficult to assess. Furthermore, none of the catch and fishing effort is reported for legal unlicensed fishing. The catch by legal unlicensed gear in 1952 was about 68 percent as great as the total catch reported by all licensed Maryland shad fishermen (Walburg, 1955).

It is exceedingly difficult to evaluate the factors that might have caused changes in the size of the Maryland shad population because of the unknown effect of the Virginia shad fishery on the Maryland population (Walburg, 1955). Shad must pass through the Virginia fishery to enter Maryland waters of Chesapeake Bay. The number available to Maryland fishermen from a run of given size is in part a function of the fishing effort in Virginia waters of the Bay. The effect of the Virginia fishery may not be as serious, however, as some of the other complex factors affecting the availability of shad in Maryland waters, since Whitney (1961) estimated that only 3 percent of the catch of runs bound for the Susquehanna area in 1959 was made in Virginia waters. Successful management probably requires consideration of Chesapeake Bay stocks as units without regard to political boundaries.

The shad fisheries of Delaware are confined to the Delaware River, Delaware Bay, and the Nanticoke River (fig. 15). At the turn of the century, the fisheries of the Delaware River, Delaware Bay, and their tributaries were the most productive in the United States. Their annual yield was 12 to 18 million pounds, several times greater than on any other river or coast (Stevenson, 1899).

The total 1896 catch of shad in the Delaware River and Delaware Bay and their tributaries was 16,699,741 lb.; 1,770,037 lb. were taken by residents of Delaware, 2,217,900 lb. by residents of Pennsylvania, and 12,711,804 lb. by residents of New Jersey. In addition, Delaware fishermen caught 223,257 lb. in the Delaware section of the Nanticoke River to make the Delaware production 1,993,294 lb. (table 34). Principal gears in the fisheries were drift gill nets and haul seines; stake gill nets, pound nets, and bow nets also contributed to the catch.

In 1960 only residents of Delaware and New Jersey fished for shad in the Delaware River and Bay. The estimated catch was 148,200 lb., of which Delaware fishermen caught 40,200 lb. or 27 percent (table 35). In addition, Delaware fishermen caught an estimated 2,000 lb. in the Nanticoke River. Gill nets took more than 99 percent of the total of 42,200 lb., and miscellaneous gears the remainder.

FISHERIES BY WATER AREA

Discussion of the shad fisheries of the Delaware River and Bay includes that portion of the fishery prosecuted by residents of Delaware, New Jersey, and Pennsylvania.

Nanticoke River

The Nanticoke River is the only tributary of Chesapeake Bay which originates in Delaware and supports a shad fishery (fig. 15). The portion located in Delaware is small; the distance from Maryland to the headwaters in Sussex County is 30 miles. A more detailed description of the river and its shad fishery is given in the discussion of the shad fisheries of Maryland.

The 1896 catch of shad in the Delaware section of the Nanticoke was 182,250 lb., of which drift gill nets caught about 53 percent, seines 46 percent, and pound nets 1 percent (table 34). Drift nets were 70 to 90 yd. long and 49 to 55 meshes deep and had 5 1/8- to 5 3/4-in. mesh. These nets were fished from the Delaware line to Seaford, Del., a distance of 8 miles. Seines near Seaford and Woodland, Del., were 125 to 200 yd. long and 20 to 30 ft. deep and had 2 1/4- or 2 1/2-in. mesh. In addition to the river catch, drift nets and seines in Broad Creek, a tributary which enters the Nanticoke a short distance above the Maryland line, caught 41,007 lb.

The Delaware section of the Nanticoke River yielded an estimated 2,000 lb. in 1960, of which 900 yd. of drift gill nets took 65 percent and 300 yd. of stake gill nets the remainder. Drift nets fished near Seaford were 50 to 90 yd. long and 45 to 55 meshes deep and had 5- to 5 1/2-in. mesh. Stake nets in the lower area of the Delaware section of the river and in the mouth of Broad Creek averaged 30 yd. long and 45 meshes deep and had 5-in. mesh.

Delaware Bay

Near Bombay Hook, the Delaware River increases in width and merges into Delaware Bay, forming an estuary 45 miles long and 4 to 30 miles wide. A line from Bombay Hook on the Delaware shore to the mouth of Stow Creek on the New Jersey shore forms the head of the Bay.

The 1896 shad fishery in Delaware Bay and tributaries was prosecuted by fishermen of Delaware, New Jersey, and Pennsylvania. The estimated yield was 4,600,736 lb., of which residents of Delaware took 202,255 lb., residents of New Jersey 4,323,595 lb., and residents of Pennsylvania 74,886 lb. Gill nets were the principal gear of Delaware fishermen. Drift nets were fished in the channel and along the edges of the channel, and stake nets on the flats immediately above the mouth of the Mispillion River, in 6 to 10 ft. of water. The principal fishing centers were at Bombay Hook and Bowers Beach, Del. Fishing began about the second week of March and continued until May 1. During this period, 13,540 yd. of drift gill net caught 183,944 lb., and 2,700 yd. of stake net caught 17,885 lb. (table 34). Two pound nets took 426 lb. incidental to the catch of other species.

Seines and drift gill nets were the only gears used for shad in 1896 on the New Jersey shore. The total catch was more than 4 million pounds, of which drift nets caught 99 percent. These nets averaged more than 1,100 yd. each; the aggregate length of the 230 nets of New Jersey fishermen was 271,200 yd.; the usual mesh size was 5 1/8 in. Two seines used on the New Jersey side of the Bay in 1896 were each 425 yd. long; they caught 2,916 lb. of shad incidental to the catch of other species.

Pennsylvania fishermen operated 6,000 yd. of drift gill nets in 1896, principally in the head of the Bay, and caught an estimated 74,886 lb. of shad.

In 1896 shad were caught in a number of short Delaware Bay tributaries (The longest barely exceeded 25 miles.) situated entirely

Table 34.--Shad catch, by water area and gear, Delaware, 1896

Water area	Drift gill net		Stake gill net		Seine		Pound net		Fyke net	
	Length	Catch	Length	Catch	Length	Catch	Nets	Catch	Nets	Catch
	Yards	Pounds	Yards	Pounds	Yards	Pounds	Number	Pounds	Number	Pounds
Nanticoke River	7,184	96,866	---	---	1,674	84,192	2	1,192	---	---
Broad Creek	1,540	28,558	---	---	296	12,449	---	---	---	---
Delaware Bay	13,540	183,944	2,700	17,885	---	---	2	426	---	---
Broadkiln Creek	600	11,470	---	---	1,580	58,754	---	---	---	---
Mispillion Creek	2,500	202,160	---	---	320	13,589	---	---	---	---
Murderkill Creek	500	14,896	---	---	480	12,342	---	---	10	9,789
St. Jones Creek	---	---	---	---	500	17,279	---	---	---	---
Leipsic Creek	250	7,235	---	---	320	4,673	---	---	---	---
Duck Creek	---	---	---	---	427	6,384	---	---	---	---
Delaware River	80,767	1,186,815	---	---	2,250	8,563	---	---	---	---
Appoquinimink Creek	---	---	---	---	160	1,490	---	---	---	---
Christiana Creek	480	2,554	---	---	300	9,789	---	---	---	---
Total	107,361	1,734,498	2,700	17,885	8,307	229,504	4	1,618	10	9,789

Table 35.--Shad catch, by gear and state, Delaware River and Bay, 1960

Gear	Delaware		New Jersey		Total	
	Length fished	Catch	Length fished	Catch	Length fished	Catch
	Yards	Pounds	Yards	Pounds	Yards	Pounds
Drift gill net	800	2,000	3,200	8,000	4,000	10,000
Stake gill net	7,820	38,000	20,410	99,000	28,230	137,000
Haul seine	--	--	710	1,000	710	1,000
Miscellaneous	--	200	--	--	--	200
Total	8,620	40,200	24,320	108,000	32,940	148,200

within Delaware (table 34); none of these supported a fishery in 1960.

William F. Moore of the Delaware Game and Fish Commission (written communication dated June 13, 1961) reported that in 1960 shad entered Delaware Bay on March 28 and the run continued until early June. The estimated shad catch was 140,000 lb.; 32,000 lb. were taken by Delaware fishermen and 108,000 lb. by New Jersey fishermen. On the Delaware shore, stake gill nets (aggregate length 6,670 yd.) were fished from Lewes to Bombay and caught 32,000 lb. of shad. On the New Jersey shore, stake gill nets fished from the mouth of the Maurice River to the head of the Bay caught 99,000 lb., drift gill nets 8,000 lb., and haul seines 1,000 lb. The drift gill net and haul seine shad catches were taken incidental to the catch of other species. Stake gill nets fished near Bowers Beach on the Delaware shore were the most productive, and those fished near Cahonsey Creek on the New Jersey shore were the most productive.

Delaware River

The Delaware River originates on the western slope of the Catskill Mountains in New York at an elevation over 1,800 ft. above sea level (fig. 15). It is formed by the union of the East and West Branches 80 miles below the headwaters, where it becomes the eastern boundary of Pennsylvania. From this union the river flows southeast to Port Jervis, N.Y., south to Trenton, N.J., and then southeast again into the upper end of Delaware Bay near Bombay Hook--a distance of 368 miles. The

river crosses the fall line near Trenton, where a low natural falls limits upstream tidal influence. The gradient of the river bed decreases as the river approaches the tidal estuary.

Prior to construction of a dam at Lackawaxen in the early 1800's, shad migrated regularly to Shavertown, N.Y., on the East Branch and to a short distance above Deposit, N.Y., on the West Branch--each more than 350 miles from the coast (Bishop, 1935). Areas above the Delaware Water Gap served as spawning and nursery grounds. Most important was the stretch of river above Barryville, N.Y., including both branches. For 25 yr. prior to 1872, no shad was seen farther upstream than Milford, Pa., 30 miles below Lackawaxen (Smiley, 1884). In 1875 the catch at Milford increased. The species reappeared as far upstream as the dam at Lackawaxen in 1876. The dam blocked upstream movement of fish until about 1890 when a fishway was erected in the obstruction and shad again ascended to the headwaters of the river. About 1905 the dam was destroyed by ice, and shad had free passage to the entire river.

The fishery on the Delaware River and tributaries dates back to colonial times, but statistics on production were not available until 1880. The usual and most efficient method of taking shad was with seines (fig. 22) and gill nets. The estimated catch in 1880 was 1,500,000 lb. (McDonald, 1887d). The catch was 11,740,434 lb. in 1896 of which Delaware fishermen took 1,209,211 lb., Pennsylvania fishermen 2,143,014 lb., and New Jersey fishermen 8,388,209 lb. Drift gill nets produced about 75 percent of the catch, seines about 25 percent, and spears less than 1 percent. The tidewater section from the head of the Delaware Bay to the fall line at Scudder Falls produced 10,983,027 lb. The upriver section from the fall line to the head of the river yielded 743,575 lb., and the tributaries 13,833 lb.

The shad fisheries of the Delaware River and tributaries in 1896 are reviewed by area.

Appoquinimink Creek.--This stream is 20 miles long and empties into the Delaware River 5 miles below Port Penn, Del., and 46 miles below Philadelphia. Two seines, each

Figure 22.--Binghamton Shad Club haul seine fishery in May 1905 on upper Delaware River. (Photograph courtesy of Frank Bowen, Hancock, N.Y.)

80 yd. long, caught an estimated 1,490 lb. of shad in 1896 (table 34).

Christiana Creek.--This stream forms the harbor of Wilmington, Del., and is navigable for 8 miles. Above Wilmington were several dams. Six seines averaging 50 yd. long took an estimated 9,789 lb. of shad; four drift nets, each 120 yd. long, caught an estimated 2,554 lb. in 1896 (table 34).

Delaware River below Scudder Falls.--In the tidal portion of the river, 414,044 yd. of drift net and 45 seines were used in 1896. Of the total yardage of drift gill net fished, 80,767 yd. were fished by 164 Delaware fishermen, 64,670 yd. by 340 Pennsylvania fishermen, and 268,607 yd. by New Jersey fishermen. Drift gill nets in the lower portion of this section averaged 800 yd. long, and those in the upper portion 200 to 300 yd. long. The drift net catch was 8,759,188 lb. (table 34). The seines were used from the head of Delaware Bay to the falls above Trenton, of which 4 were in Delaware, 15 in Pennsylvania, and 26 in New Jersey. The seine fishery in the lower part of the river below Fort Delaware took few shad because their catch was incidental to that of other species; the yield of eight nets in this area was about 16,000 lb. Seines above Fort Delaware were more productive; their total catch was about 2,207,839 lb.

Scudder Falls to the Headwaters.--The 1896 shad fishery above tidewater was more extensive than in any similar area of any river of the United States. It extended 140 miles from Scudder Falls to Lackawaxen, but was most extensive in the 40-mile section of river just above Scudder Falls Dam. With the exception of one drift net, which took 4,000 lb. a short distance above the falls, seines and spears were the only gears. Most of the available locations on the upper Delaware were occupied by seine fisheries which took 717,829 lb. (table 34). Spears, used mostly at Lackawaxen dam, took 21,745 lb.

Shad entered the Delaware River in 1960 in the latter part of March and remained until early June. A few shad ascended the river at least to Lackawaxen, 296 miles from the coast, and probably spawned in that vicinity. In May 1944, biologists of the Fish and Wildlife Service found the greatest concentration of eggs above Lackawaxen, Pa.; none was located below Lumbertville, Pa. Live shad eggs and newly hatched fry were found in 1945 only at the mouth of the Lackawaxen River (Ellis, Westfall, Meyer, and Platner, 1947).

Gill nets (5-in. or longer mesh) were the only commercial gear in the Delaware River in 1960. Five stake nets and 10 drift nets were fished from the mouth of the river to Delaware City, Del. The catch was 8,000 lb., of which 2,000 lb. were taken in 800 yd. of drift gill net and 6,000 lb. in 1,150 yd. of stake gill net. In addition to the commercial yield, about 200 lb. were taken incidentally in crab nets and by hook and line near Wilmington.

TRENDS IN PRODUCTION

Statistics on the shad catch in Delaware are available for certain of the years, 1880-1960 (U.S. Fish and Wildlife Service, 1958-61). Annual yield for 9 yr. in 1880-1901 was more than 1 million pounds; peak production of nearly 2 million pounds was in 1896. Production declined to 87,000 lb. by 1921. The annual production remained low in 1921-60; the record low of 3,000 pounds was in 1957 (table 36). The 1960 catch was slightly more than 2 percent of the 1896 take.

The Delaware River and Bay produced about 70 percent of the total Delaware catch in 1896, the Nanticoke River about 11 percent, and tributaries to the Bay and river about 19 percent.

In 1960 the Delaware River and Bay produced more than 98 percent of the total catch, the Nanticoke River less than 2 percent, and tributaries to the Bay and river less than 1 percent.

The principal shad fisheries of Delaware have changed little from the operations prior to 1900, except a decline in size of catch. With minor exceptions, the same gear and locations are fished. The causes for the decline in

Table 36.--Shad catch for certain years, Delaware, 1880-1960[1]

[In thousands of pounds]

Year	Catch	Year	Catch
1880. . . .	1,050	1939. . . .	44
1887. . . .	1,270	1940. . . .	31
1888. . . .	1,389	1942. . . .	14
1889. . . .	1,498	1943. . . .	24
1890. . . .	1,797	1944. . . .	41
1891. . . .	1,500	1945. . . .	133
1896. . . .	1,993	1947. . . .	68
1897. . . .	1,621	1948. . . .	53
1901. . . .	1,368	1949. . . .	57
1904. . . .	951	1950. . . .	102
1908. . . .	870	1951. . . .	110
1921. . . .	87	1952. . . .	65
1926. . . .	147	1953. . . .	60
1929. . . .	94	1954. . . .	55
1930. . . .	54	1955. . . .	32
1931. . . .	39	1956. . . .	12
1932. . . .	16	1957. . . .	3
1933. . . .	22	1958. . . .	59
1935. . . .	25	1959. . . .	28
1937. . . .	20	1960. . . .	42
1938. . . .	14		

[1] Statistics 1880-1959, U. S. Fish and Wildlife Service (1958-61).

abundance of shad in the Delaware River and Bay were not determined with certainty, but Sykes and Lehman (1957) stated that: (1) the decline was brought about, at least in part, by overfishing; (2) increased pollution of the Delaware estuary had become an important and apparently dominant cause of the diminution of the stock (Adults migrating upstream through the industrial sections of the river during April and May sometimes were killed by pollution blocks as was witnessed in May 1951.); (3) heavy mortality occurred among young downstream migrants in and near the industrial sections where the water was most heavily polluted; and (4) legally operated eel racks in the river destroyed young fish.

The Atlantic States Marine Fisheries Commission and the Interstate Commission on the Delaware River Basin recommended in 1949 to Delaware authorities certain measures designed to manage a restored fishery to produce maximum continued yields. These measures, similar to the Maryland Management Plan, would be implemented by New Jersey, New York, and Pennsylvania. Preservation of the remnant shad population that spawns in the upper reaches of the Delaware River depended upon freedom from dams that would prevent access to spawning and nursery grounds (Sykes and Lehman, 1957). The success of shad rehabilitation programs on the Delaware also depends on the reduction and continued control of pollution. If these objectives are accomplished, there appears to be no reason why the shad runs in Delaware could not be rehabilitated.

SHAD FISHERIES OF PENNSYLVANIA

The shad fisheries of Pennsylvania formerly were limited to the Susquehanna River, the Delaware River and Delaware Bay, and their tributaries. The estimated catch in 1896 was 2,501,143 lb., of which gill nets caught about 48 percent, seines 50 percent, and bow nets and spears the remainder. The catch by gear and amount of gear are given by water area in table 37.

There was no commercial shad production in Pennsylvania waters in 1960.

FISHERIES BY WATER AREA

Susquehanna River

The Susquehanna River is situated partly in Maryland and New York, but principally in Pennsylvania; it traverses that State from north to south. The Susquehanna flows south for 422 miles into the head of Chesapeake Bay. Eighty-three miles upstream from its mouth, the Susquehanna receives the Juniata River, and 126 miles above its mouth (at Sunbury, Pa.), it receives its principal tributary, the West Branch, 175 miles long. Above Sunbury, the Susquehanna is called the North Branch. The Susquehanna drains an area of 27,500 square miles--the largest drainage of any United States Atlantic coast river.

The original limit of the shad run in the Susquehanna was 318 miles from the mouth of the river and 513 miles from the coast (Stevenson, 1899). Fish spawned in the upper reaches of the river and its tributaries. In the early part of the 19th century, at least 2 million pounds of shad were caught each year in Pennsylvania waters of the Susquehanna. This abundance continued until a canal with dams was constructed during the 1830's.

Table 37.--Shad catch, by water area and gear, Pennsylvania, 1896

Water area	Drift gill net		Seine		Bow net		Spear		Total
	Length	Catch	Length	Catch	Number	Catch	Number	Catch	Catch
	Yards	Pounds	Yards	Pounds		Pounds		Pounds	Pounds
Susquehanna River:									
Below Columbia Dam. . .	---	---	6,360	214,226	51	42,558	---	---	256,784
Above Columbia Dam. . .	---	---	2,260	23,639	---	---	---	---	23,639
Juniata River	---	---	170	2,820	---	---	---	---	2,820
Delaware Bay.	6,000	74,886	---	---	---	---	---	---	74,886
Delaware River:									
Below Scudder Falls . .	64,670	1,116,027	5,300	613,742	---	---	---	---	1,729,769
Above Scudder Falls . .	100	4,833	5,215	386,667	---	---	30	21,745	413,245
Total	70,770	1,195,746	19,305	1,241,094	51	42,558	30	21,745	2,501,143

The period of canal-dam construction on the Susquehanna was 1830-1909. In 1896 four dams were on the 174 miles of river between the mouth and Wilkes-Barre, Pa. The first, 7 or 8 ft. high and 6,800 ft. long, at Columbia, Pa., was the principal cause for the decline of the upriver fisheries. Breaks that frequently occurred in the dam, permitted shad to pass upstream to the second canal dam at Clarks Ferry, Pa., just above the entrance of the Juniata River and 40 miles above Columbia. The second dam was 7 ft. high and nearly 2,000 ft. long. At Sunbury, 38 miles above Clarks Ferry, was a third canal dam, 7 1/2 ft. high and 2,600 ft. long. The fourth was the Nanticoke canal dam, 6 ft. high and 900 ft. long, 7 miles below Wilkes-Barre. Attempts were made to provide fish passage over the canal dams, but none was successful.

There were a dozen or more old dams between the Nanticoke Dam and the New York line. At Binghamton was a crib dam 5 1/2 ft. high and 450 ft. long extending entirely across the stream. Above this structure were several primitive crib dams that had falls of 3 to 10 ft.

During the canal-dam period the number of shad reaching the river above Columbia lessened and then became irregular, depending upon breaks in the obstructions. In 1896, 14 seines fished between the dam at Columbia and Clarks Ferry caught an estimated 23,639 lb., and 2 seines fished on the Juniata caught an estimated 2,820 lb. (table 37). The seines ranged from 80 to 250 yd. long and had 4 1/2- to 5 1/2-in. mesh. Below the Columbia dam the estimated catch was 256,784 lb., of which 6,360 yd. of seine took 83 percent and 51 bow nets the remainder.

The catch of shad in 1908 represented 79 percent of the total landings and 73 percent of the total value of fish caught in the Susquehanna River. About 67 percent of the catch was made by dip and bow nets and the remainder by seines and gill nets (Bureau of the Census, 1911).

After 1900 four hydroelectric power dams were built on the Susquehanna River between its mouth and Harrisburg, Pa., 65 miles upstream (Whitney, 1961). The first was built in 1904 at York Haven, Pa., but the power plant section was not completed until 1916. Its height varied from 6 ft. at the western shore to 22 ft. at the eastern shore; at river stages above 6 ft., fish could pass upstream. In 1910 a second hydroelectric power dam was constructed--Holtwood Dam. A fishladder was included in this structure, and another was installed in 1913, but both failed to pass fish. In 1909 the estimated shad catch in the Susquehanna was 217,000 lb.; in 1915 it was 33,000 lb. A third dam was constructed in 1928 at Conowingo. It is the farthest downstream and is also the highest--about 95 ft. at normal head. This structure is 8 miles below the Pennsylvania-Maryland line and completely obstructs the upstream movement of fish. A fourth hydroelectric power dam, the Safe Habor Dam, was constructed in 1931 between the Holtwood and York Haven Dams.

The Joint State Government Commission of Pennsylvania in 1949 investigated fishway problems on the Susquehanna River (Whitney, 1961). The Commission reported that the shad fisheries in the Pennsylvania part of the river had been economically important before 1900. Dam construction, overfishing, and pollution were suggested as causes for decline in catch. The Commission recommended that a resolution be introduced into the General Assembly of the Commonwealth of Pennsylvania asking that the Congress of the United States direct a general study of the biological and hydraulic factors that need to be understood if effective fishways are to be built for shad.

In 1952 a total of 1,176 adult shad were planted--209 above Conowingo Dam and 967 above Safe Harbor Dam. No evidence of successful spawning above these structures was found (Walburg, 1954).

From 1957 to 1960 the Maryland Department of Research and Education authorized a study on the desirability and feasibility of passing fish at Conowingo Dam (Whitney, 1961). Conclusions reached in this study were: "Although small spawning runs of shad reach Conowingo Dam, provision of passage for them over the dam is unlikely to result in successful spawning in the reservoir with consequent increase in total shad stocks; and is also unlikely to provide significant catches of shad in the reservoir."

The Pennsylvania Fish Commission has completed engineering and biological studies on fish passage at dams on the Susquehanna River (Bell and Holmes, 1962). At the time of this report, steps are being taken to develop further studies to determine the feasibility of passing shad above the dams.

Delaware River

Residents of Pennsylvania caught more than 2 million pounds of shad in the Delaware River and Bay in 1896 (table 37). In the Bay 6,000 yd. of drift gill net took 74,886 lb. Of the 2,143,014 lb. taken in the river, drift gill net fishermen took about 52 percent, seine fishermen 47 percent, and spear fishermen the remainder.

In recent years the abundance of shad in the Pennsylvania portion of the Delaware River has been so low that commercial fishing has practically stopped. In 1946 the fisheries on the Delaware River were limited mainly to the lower reaches of the river and Bay below Pennsylvania (Ellis et al., 1947). The Milford (Pa.) Shad Club reported that their annual

catches formerly had ranged up to 5,000 shad, but with the general decrease of this species, they caught less than a dozen in 1948 and consequently stopped fishing (Sykes and Lehman, 1957). Seining was tried again in May 1950, but only eight fish were taken. Other seining clubs, located in Hancock, Pa., also ceased fishing because of the lack of fish.

A detailed discussion of the fisheries in the Delaware River and Bay is given in the description of the shad fisheries of Delaware.

TRENDS IN PRODUCTION

Information is available on the shad catch by water area in Pennsylvania for certain years in 1880-1960 (table 38). Production was high from 1887 through 1901, when the average annual yield was 2,289,000 lb. The year of peak production was 1901, when about 3 million pounds were taken. After 1901 production decreased until 1921, when the catch was only 19,000 lb. By 1921 no shad were taken in Pennsylvania waters of the Susquehanna River, and the yield was from the Delaware River and Bay only. From 1921 to 1942 production ranged from 22,000 lb. in 1929 to 2,000 lb. in 1932 and 1933. By 1943 the run in the Delaware River was so depleted that commercial fishing was abandoned in the Pennsylvania portion. There has been no commercial production of shad in Pennsylvania waters since 1943.

Table 38.--Shad catch for certain years, Pennsylvania, 1880-1960[1]

[In thousands of pounds]

Year	Susquehanna River	Delaware River and Bay	Total	Year	Susquehanna River	Delaware River and Bay	Total
1880	---	---	559	1929	---	22	22
1887	---	---	1,424	1930	---	5	5
1888	---	---	1,387	1931	---	7	7
1889	---	---	2,753	1932	---	2	2
1890	205	2,693	2,898	1933	---	2	2
1891	201	2,492	2,693	1935	---	10	10
1896	283	2,218	2,501	1937	---	13	13
1897	203	1,804	2,007	1938	---	14	14
1901	---	---	2,983	1939	---	---	11
1904	257	579	836	1940	---	10	10
1908	312	281	593	1942	---	7	7
1921	---	19	19	1943	---	---	0
1926	---	21	21	1960	---	---	0

[1] Total catch, U. S. Fish and Wildlife Service (1958-61); catch by water area, Mansueti and Kolb (1953).

Pollution and overfishing were cited as responsible for the decline of the Delaware River shad population, but construction of dams that prevent fish from reaching original spawning and nursery areas was the dominant factor in eliminating shad from Pennsylvania waters of the Susquehanna River. Factors affecting abundance of shad in the Pennsylvania portion of the Delaware River are discussed in the section on the shad fisheries of Delaware.

SHAD FISHERIES OF NEW JERSEY

The shad fisheries of New Jersey are supported by Delaware Bay, Atlantic Ocean shore, Lower New York Bay, and the Hudson River (fig. 23). In 1896 New Jersey ranked first among the States in pounds of shad caught. It ranked fifth in 1960.

The fisheries produced 13,909,826 lb. in 1896, of which Delaware Bay yielded about 31 percent, Delaware River 60 percent, Hudson River 5 percent, Lower New York Bay 3 percent, and the ocean shore the remainder. Drift gill nets took about 77 percent of the catch, seines 14 percent, stake gill nets 6 percent, and fyke and pound nets the remainder.

The 1960 yield was 693,636 lb. The Hudson River produced about 65 percent, Delaware Bay 16 percent, Lower New York Bay 13 percent, and the ocean shore 6 percent. Stake gill nets took slightly less than 82 percent of the catch, pound nets less than 17 percent, drift gill nets 1 percent, and otter trawls and seines the remainder. The gear fished and the catch by gear and water area in New Jersey in 1896 and 1960 are given in tables 39 and 40.

FISHERIES BY WATER AREA

New Jersey fishermen formerly caught shad in both Delaware Bay and Delaware River, but in 1960 only Delaware Bay produced fish. (A description of the fisheries in both areas is given in the section on the fisheries of Delaware.) New Jersey fishermen caught 109,000 lb. on the Jersey side of the Bay in 1960, of which 99,000 lb. were taken by stake gill nets, 8,000 lb. by drift gill nets, and 1,000 lb. by seines operated for other species.

In 1896 several New Jersey streams tributary to Delaware Bay and Delaware River, such as the Maurice, Oldmans, Rancocas, Woodbury, and Cooper Rivers, produced a few shad for local use. In 1960, however, only the Maurice yielded shad, but the catch was small, and no estimate was made of the quantity taken.

Ocean Shore and Bays

A few shad were caught in 1896 in several of the small sounds and bays along the ocean shore of New Jersey. These fish were taken by seines, stake gill nets, and fyke nets used for other fishes. The estimated catch was 10,687 lb. (table 40). In addition, numerous pound nets along the coast from Barnegat Bay to Sandy Hook took about 56,977 lb. incidental to the catch of other species. This point was the southernmost on the Atlantic coast where shad were taken in considerable numbers beyond the coastline.

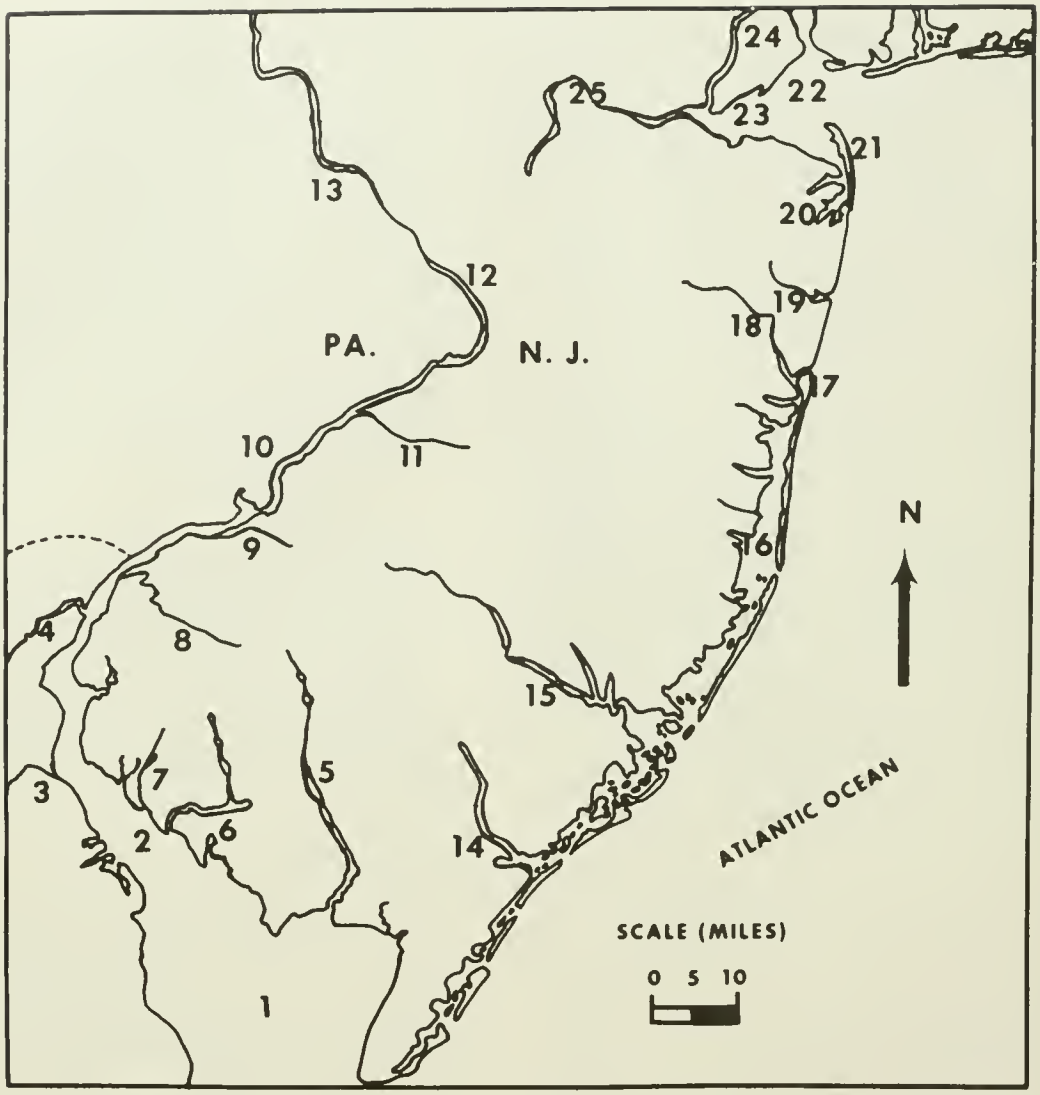

Figure 23.--Map of coastal New Jersey.

Key:
1 Delaware Bay
2 Delaware River
3 Appoquinimink Creek
4 Christiana Creek
5 Maurice River
6 Cohansey Creek
7 Stow Creek
8 Oldmans River
9 Woodbury Creek
10 Philadelphia
11 Rancocas Creek
12 Trenton
13 Lambertville
14 Great Egg Harbor River
15 Mullica River
16 Barnegat Bay
17 Point Pleasant
18 Manasquan River
19 Shark River
20 Shrewsbury
21 Sandy Hook
22 Sandy Hook Bay
23 Raritan Bay
24 Staten Island
25 Raritan River

Table 39.--Gear employed in shad fisheries, by water area, New Jersey, 1896 and 1960

Water area	1896				1960			
	Drift gill net	Stake gill net	Seine	Fyke net	Drift gill net	Stake gill net	Seine	Pound net
	Yards	Yards	Yards	Number	Yards	Yards	Yards	Number
Delaware Bay. . . .	271,200	---	850	---	3,200	20,410	710	--
Delaware River. . .	275,607	---	16,718	---	---	---	---	--
Ocean Shore	---	400	1,622	20	---	4,509	---	8
Lower New York Bay.	---	41,144	---	225	---	---	---	30
Hudson River. . . .	---	15,282	---	---	450	7,800	---	--
Total	546,807	56,826	19,190	245	3,650	32,719	710	38

Table 40.--Shad catch, by water area and gear, New Jersey, 1896 and 1960

[In pounds]

Water area	1896					1960				
	Drift gill net	Stake gill net	Seine	Fyke net	Pound net	Drift gill net	Stake gill net	Seine	Pound net	Otter trawl
Delaware Bay.	4,320,679	---	2,916	---	---	8,000	99,000	1,000	---	---
Delaware River.	6,455,513	---	1,932,696	---	---	---	---	---	---	---
Ocean Shore	---	833	3,604	6,250	[1] 56,977	---	18,400	---	23,200	[1] 1,100
Lower New York Bay. . .	---	90,809	14,208	218,775	[1] 111,258	---	---	---	93,300	---
Hudson River.	---	703,308	---	---	---	170	449,466	---	---	---
Total	10,776,192	796,950	1,943,424	225,025	168,235	8,170	566,866	1,000	116,500	1,100

[1] Caught incidentally in gears employed for other species.

Shad were taken in 1960 in anchor gill and pound nets along the ocean shore from the last of March until mid-May. Anchor nets were used principally in the small bays and sounds near the mouths of the Manasquan, Shark, and Shrewsbury Rivers. They averaged about 100 yd. long and 45 meshes deep and had 5-in. mesh. The catch by 4,509 yd. of net was 18,400 lb. Eight pound nets, near Point Pleasant, N.J., took 23,200 lb. In addition 1,100 lb. were taken incidental to the catch of other species by otter trawls fishing in the ocean. From a previous study it was concluded that of the pound net catches, 76 percent were Hudson River fish, 13 percent Connecticut River fish, and 11 percent fish from other Atlantic coast streams (Nichols, 1958).

Lower New York Bay

Stevenson (1899) divided the Lower New York Bay area into Sandy Hook Bay and Raritan Bay. Sandy Hook Bay forms part of the waterway tributary to the harbor of New York City and is separated from the ocean on the east by a narrow sand beach known as Sandy Hook. The fishery in Sandy Hook Bay in 1896 was confined to stake gill nets which averaged between 150 and 160 yd. long and had 5 1/4- to 6-in. mesh. The 107 rows of net had an aggregate length of 16,840 yd.; they yielded an estimated 27,499 lb. of shad. In Raritan Bay, which occupies the triangular area between Staten Island, N.Y., and the coast of Middlesex and Monmouth Counties, N.J., including Raritan River estuary, 427,050 lb. were taken by pound nets, stake gill nets, seines, and fyke nets (table 40). Gill nets were fished especially for shad, but the other gears were used principally for other species. The take in Raritan Bay proper was 181,815 lb., of which 61 percent was obtained in pound nets, 36 percent in gill nets, 2 percent in seines, and the remainder in fyke nets. Fyke nets took an estimated 207,316 lb. in the section bordering New York Bay and 10,420 lb. in the lower section of the Raritan River.

Thirty pound nets concentrated in the Raritan Bay section of Lower New York Bay caught 93,300 lb. of shad in 1960. These nets were not set especially for shad and depended principally on the catch of other fishes. The annual shad yield by this fishery depends on the size of run to the Hudson River (Nichols, 1958).

Hudson River

Many shad are caught each year in the New Jersey section of the Hudson River. The 1960 yield was 449,636 lb., most by stake gill nets. This fishery is prosecuted by residents of New Jersey and New York; a description of the fishery is given in the section on the fisheries of New York.

TRENDS IN PRODUCTION

The shad fisheries of New Jersey have undergone extreme fluctuations in production (table 41). The catch increased from 750,000 lb. in 1880 to more than 14 million pounds in 1901. The catch declined to 4 million pounds by 1904 and to 168,000 lb. by 1921. The production continued low until 1935, when 818,000 lb. were landed. From 1937 to 1945, production was relatively high; the annual average yield was about 3.5 million pounds. Production again decreased, and in 1947-60 the annual average yield was slightly more than 1 million pounds. The 1960 production was less than 5 percent of the 1896 catch.

To protect the fishery, New Jersey initiated management measures and enacted laws restricting the fishing season and certain types of gear. Artificial propagation and stocking of shad, practiced as early as 1875, continued until 1941. Stocking did not, however, increase the commercial yield.

Table 41.--Shad catch for certain years, New Jersey, 1880-1960[1]

[In thousands of pounds]

Year	Catch	Year	Catch
1880	750	1939	2,699
1887	6,495	1940	3,365
1888	6,523	1942	4,826
1889	10,424	1943	3,348
1890	10,623	1944	4,314
1891	10,225	1945	2,917
1896	13,910	1947	1,574
1897	13,001	1948	1,853
1901	14,031	1949	1,407
1904	4,338	1950	1,072
1908	3,004	1951	682
1921	168	1952	1,402
1926	553	1953	679
1929	342	1954	826
1930	224	1955	1,326
1931	257	1956	1,316
1932	224	1957	1,384
1933	458	1958	964
1935	818	1959	1,026
1937	3,340	1960	694
1938	2,492		

[1] Statistics 1880-1959, U. S. Fish and Wildlife Service (1958-61).

The success of shad rehabilitation in the Delaware River must depend on the reduction and continued control of pollution and the prevention of dam construction on the main stem of the river or provision of main-stem dams with fishways (Sykes and Lehman, 1957). In the Hudson, the most important single factor of fluctuations in stocks is the number of shad escaping the fishery to spawn (Talbot, 1954). Factors of fluctuations in abundance of shad in these rivers are discussed in the sections on fisheries of Delaware and New York.

SHAD FISHERIES OF NEW YORK

The 1896 shad fisheries of New York yielded 2,200,546 lb.; Hudson River and New York Bay produced more than 98 percent. The river produced 1,703,066 lb., of which drift gill nets caught 71 percent, stake gill nets 13 percent, seines 16 percent, and miscellaneous gear less than 1 percent. The Bay produced 461,865 lb., of which drift gill nets caught 56 percent, stake gill nets 26 percent, pound nets 14 percent, and miscellaneous gear 4 percent. Great South Bay, Long Island Sound, and Gardiner Bay and tributaries produced 35,615 lb., but most was incidental to the catch of other species.

The shad fisheries of New York in 1960 yielded 472,261 lb., of which the Hudson River and New York Bay produced 95 percent. The river produced 328,711 lb., of which drift gill nets caught about 41 percent, stake gill nets 58 percent, and seines 1 percent. The Bay produced 118,200 lb., all caught by pound nets. Great South Bay, Long Island Sound, and Gardiner Bay yielded 25,350 lb. incidental to the catch of other species. A map of the Hudson River from Castleton, N.Y., to the Atlantic Ocean is shown in figure 24.

The extent of the fisheries by water area in 1896 and 1960 is given in tables 42 and 43. Formerly, most shad were taken by drift gill net, but in recent years pound nets have become relatively more important. The amounts of drift gill net and seines decreased, and yards of stake gill nets and numbers of pound nets increased.

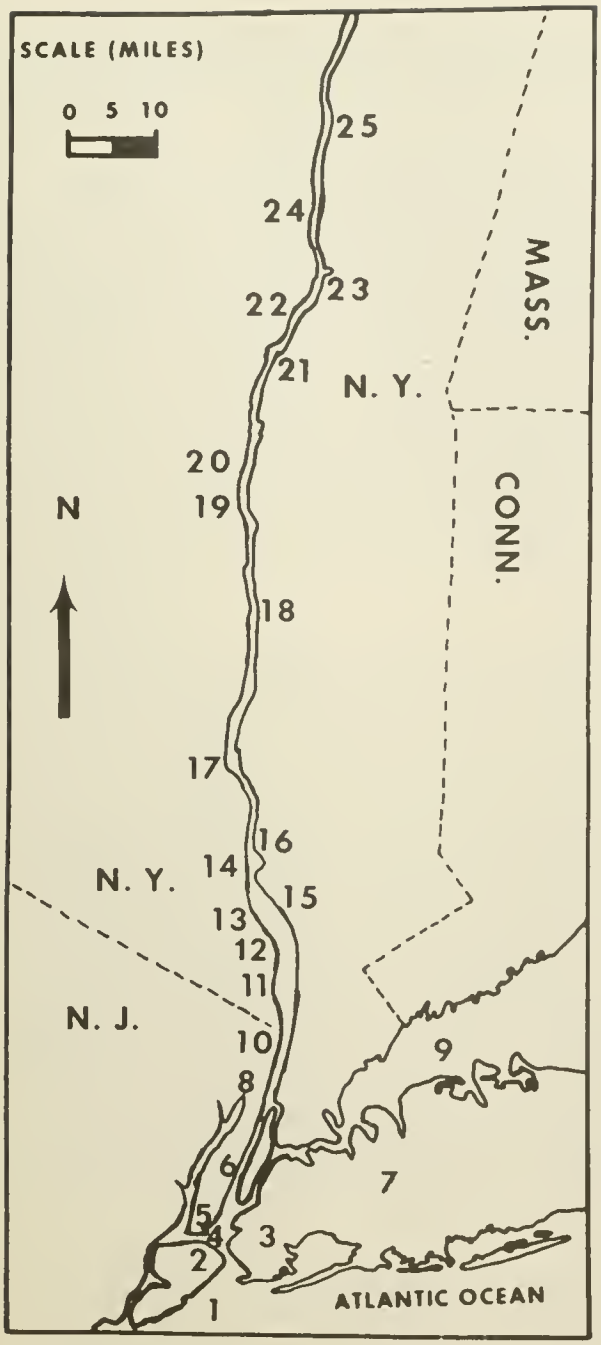

Figure 24.--Hudson River from Castleton, N.Y., to the Atlantic Ocean.

Key:

1 Lower Bay
2 The Narrows
3 New York City
4 Upper Bay
5 Jersey City
6 Weehawken
7 Long Island
8 Fort Lee
9 Long Island Sound
10 Alpine
11 Piermont
12 Nyack
13 Haverstraw
14 Stoney Point
15 Croton Point
16 Verplanck Point
17 Hudson River
18 Poughkeepsie
19 Port Ewen
20 Kingston
21 Germantown
22 Catskill
23 Hudson
24 Coxsackie
25 Castleton

FISHERIES BY WATER AREA

Since 1915 New York has instituted, as a conservation measure, closed weekends or "lift periods", during which shad fishing is not permitted. From 1915 through 1917 the weekly closure was 2 1/2 days, but this applied only to fishing in the Hudson River from the headwaters to Verplanck Point 18 miles upriver from the New Jersey line. After 1917 the closure applied to the entire Hudson under the supervision of New York. In 1951 a 72-hr. "lift period" was set for the river and New York side of New York Bay. From 1952 to 1958, the "lift periods" were 60 hr., and in the following 2 yr., 48 hr. The State of New Jersey did not establish closed days in its section of the Hudson River until 1940. Since that time the two States have cooperated, and the "lift period" each year has been uniform in the Hudson River and in New York Bay.

Table 42.--Gear employed in shad fisheries, by water area, New York, 1896 and 1960

Water area	1896					1960			
	Drift gill net	Stake gill net	Seine	Pound net	Miscellaneous	Drift gill net	Stake gill net	Seine	Pound net
	Yards	Yards	Yards	Number	Number	Yards	Yards	Yards	Number
New York Bay. . .	46,900	2,416	---	6	[1]34	---	---	---	25
Hudson River. . .	164,020	8,438	9,607	--	[1]20	37,333	40,467	500	--
Great South Bay .	---	---	---	--	---	---	---	---	--
Gardiner Bay. . .	---	---	---	--	---	---	---	---	--
Long Island Sound	1,168	---	---	6	[2]20	---	---	---	--
Total	212,088	10,854	9,607	12	74	37,333	40,467	500	25

[1] Fyke nets.
[2] Spears.

Table 43.--Shad catch, by water area and gear, New York, 1896 and 1960

[In pounds]

Water area	1896					1960			
	Drift gill net	Stake gill net	Seine	Pound net	Miscellaneous	Drift gill net	Stake gill net	Seine	Pound net
New York Bay. . . .	257,425	121,618	---	63,363	19,459	---	---	---	118,200
Hudson River. . . .	1,204,745	217,998	277,080	---	3,243	134,436	190,994	3,281	---
Great South Bay . .	---	---	---	[1]1,475	---	---	---	---	[1]18,900
Gardiner Bay. . . .	---	---	---	[1]17,800	---	---	---	---	[1]6,400
Long Island Sound .	5,610	---	---	[1]8,776	1,954	---	---	---	[1]50
Total	1,467,780	339,616	227,080	91,414	24,656	134,436	190,994	3,281	143,550

[1] Incidental catch.

New York Bay

New York Bay includes the numerous bodies of water between the ocean and the mouth of the Hudson River, from Sandy Hook to the Battery, New York City. The narrows between Staten Island and the western tip of Long Island divide the Bay into Lower New York Bay and Upper New York Bay. This area resembles an equilateral triangle with 15-mile sides. In 1896 shad were taken in the Lower Bay, in the Narrows between Long Island and Staten Island, in the Upper Bay, and in Gravesend Bay at the extreme upper end of the Lower Bay. The shad season usually began in March or April and continued until mid-May or the first of June.

The 1896 and 1960 fisheries are described in the following subsections.

Lower Bay.--The 1896 fishery was limited to four pound nets operated on the shore of Staten Island between Elmtree Beacon and Fort Tompkins Light. These nets were set separately in 12 to 15 ft. of water. The estimated catch was 56,735 lb.

Gravesend Bay.--This fishery was represented in 1896 by two large pound nets and two rows of fyke nets. Each of the fykes had five 14-ft. hoops with two funnels to the net. Pound nets caught 6,628 lb. and fyke nets 19,459 lb.

The Narrows.--The 1896 fishery included many drift nets, which averaged 400 yd. long and had 5 1/8- to 5 1/2-in. mesh. About 46,900 yd. of net caught 257,425 lb.

Upper Bay.--Fish were taken in this area in 1896 by stake gill nets along the western side of the Bay on the New Jersey Flats. These nets, each 24 ft. long by 28 ft. deep with 5 1/4-in. mesh, were set with the tops from 10 to 12 ft. below the water surface in 4 strings containing 151 "stations." The poles were 60 to 70 ft. long. The estimated yield was 121,618 lb.

Shad were taken in 1960 only in Lower New York Bay, by pound nets fished off Staten Island. The season began about April 10 and ended the last of May. Twenty-five pound nets produced 118,200 lb. No shad fishing was permitted during a 48-hr. closed weekend.

Hudson River

The Hudson River rises in the Adirondack Mountains in Essex County, N.Y., flows south 300 miles, and empties into New York Bay at the Battery, New York City. The river is tidal from its mouth upstream 160 miles to Troy, N.Y. From New York Bay to Piermont, N.Y., it is 1 to 2 miles wide; between Piermont and Haverstraw, N.Y., it expands into a bay 12 miles long and 4 to 5 miles wide; and from Haverstraw 34 miles upstream from the mouth of the river to Troy, it is 300 to 900 yd. wide. Above Troy are numerous falls and rapids. A masonry dam at Troy, originally a wooden structure completed in 1826, is the upper limit of fish migration. The fresh-water section of the river extends downstream to a few miles below Poughkeepsie, N.Y. The major spawning area in the Hudson is between Port Ewen and Coxsackie, N.Y.; the greatest concentration of eggs in 1940 was just below the town of Catskill, N.Y. (New York Conservation Department, 1943). Collection of eggs in 1950 and 1951 from Kingston to Coxsackie was most productive between Germantown and Hudson, N.Y. (Talbot, 1954).

Fishing was limited in 1896 above Castleton, N.Y., a short distance below Albany, N.Y., and few fish were taken above the town of Hudson. The legal season extended from March 14 to June 15; fishing was prohibited from sunset on Saturday until sunrise on Monday of each week. The estimated catch by New Jersey fishermen was 703,307 lb.; residents of New York caught 1,703,066 lb. Total production was 2,406,373 lb.

Of the total 1896 yield, about 50 percent was taken in drift gill nets, 37 percent in stake gill nets, 12 percent in seines, and the remainder in miscellaneous gears. Drift nets were fished from the New Jersey line almost to Troy Dam and were most numerous near Verplanck Point. The nets were 450 to 1,000 yd. long, and the aggregate length was 206,590 yd. The length and depth of each net depended on the size of the channel in which it was fished. The upper limit of the stake net fishery on the east side of the river was Croton Point, near Ossining, N.Y.; on the west side the uppermost limit was Nyack, N.Y. The stake gill nets north of the New Jersey line were small and were set on the flats in shallow water. None of these nets was more than 15 ft. deep. Nets between Alpine, N.J., and the mouth of the river were much larger and were set on the edge of the channel in water 20 to 50 ft. deep. These nets usually were 90 meshes long and 100 meshes deep; mesh size was 5-in. The total number of stake nets in 1896 was 2,631, and the aggregate length was 21,615 yd. The catch was 921,305 lb. New Jersey fishermen fished 1,530 nets and took about 76 percent of the catch; New York fishermen fished 1,101 nets and took 24 percent. Seines ranged from 120 to 500 yd. long and had 2- to 2 1/2-in. mesh in the bunt and 4- to 5-in. mesh in the wings. The most extensive seine fishery was near Kingston Point. The total yield of the 41 seines fished in 1896 was 277,080 lb.

In 1960 the commercial shad fishery of the Hudson River extended 120 miles from Weehauken, N.J., to Hudson, N.Y. The total yield was 778,349 lb., of which stake gill nets took about 82 percent, drift gill nets 17 percent, and haul seines 1 percent. The catch by New Jersey fishermen was 449,636 lb. New York fishermen caught 328,711 lb. Most of the catch by New Jersey and New York fishermen was marketed in New York City. The catch by gear and State are listed in table 44.

In the New York section of the Hudson River drift gill nets were fished from Haverstraw Bay to the city of Hudson. Nets ranged from 150 to 600 yd. long, had 5 1/4- to 5 3/4-in. mesh, and were 10 to 15 ft. deep. The drift net area was entirely within the State of New York, and the fishermen were licensed by that State, except for one net, fished in New Jersey waters, which caught 170 lb. of shad incidental to other species.

In the lower section of the Hudson River, bounded by both New York and New Jersey, nearly all of the stake gill nets were fished in New Jersey waters, but some were across the river in New York waters. The upper limit of the stake gill net fishery was Stony Point, N.Y. These nets averaged 1,600 ft. and had 6-in. mesh. They were set on the edge of the channel in waters 20 to 50 ft. deep and were suspended from long poles spaced about 30 ft. apart. They were usually fished only during floodtide. The fish were removed just before high-slack water, and the net was fastened above water or removed until the next low-slack water. These nets are installed and operated during the shad season only. In Haverstraw Bay the stake nets are smaller

Table 44.--Shad catch, by gear and area, Hudson River, 1960

Gear	New York			New Jersey			Total		
	Number	Yards	Pounds	Number	Yards	Pounds	Number	Yards	Pounds
Haul seine	2	500	3,281	---	---	---	2	500	3,281
Drift gill net	52	37,333	134,436	1	450	170	53	37,783	134,608
Stake gill net	55	40,467	190,994	13	7,800	449,466	68	48,267	640,460
Total	109	78,300	328,711	14	8,250	449,636	123	86,550	778,349

than those fished in the lower river and are set on the flats in water not more than 15 ft. deep. Because of navigational difficulties in the river from the mouth to Haverstraw Bay, the U.S. Army Corps of Engineers since 1940 has designated areas and lengths of nets that can be used.

The seine fishery of the Hudson is of little importance. Two seines in the upper areas caught 3,281 lb. of shad in 1960.

On the basis of catch-effort statistics, the weight of the total population in 1960 was estimated at 1,987,000 lb. and the fishing rate was 39 percent.

Great South Bay and Gardiners Bay

Shad were caught incidentally in 1896 in pound nets in Great South and Gardiners Bays. The estimated catch was 19,275 lb., of which 31 pound nets in Great South Bay caught 1,475 lb. and 105 pound nets in Gardiners Bay took 17,800 lb.

The 1960 catch of 25,300 lb. of shad also was incidental in pound nets in these areas; 18,900 lb. were taken in the ocean from Jones Inlet to Moriches Inlet, and 6,400 lb. in Gardiners, Peconic, and adjacent bays.

Long Island Sound

Most of the shad entering Long Island Sound pass along its northern shore and enter the large tributaries flowing into it from Connecticut; very few are taken on the New York shore (Stevenson, 1899). More than 300,000 lb. of shad were caught in the Sound and tributaries in 1896. About 95 percent was taken along the northern shore and the rivers flowing therein, and only 5 percent was taken along the southern shore. In the Nissoquogue River, which enters Smithtown Bay, drift nets and spears took an estimated 7,564 lb. Pound nets in Little Neck Bay and tributaries caught about 6,801 lb., and an estimated 1,975 lb. were taken by this gear in the eastern end of the Sound. Only 50 lb. of shad were reported from Long Island Sound in 1960.

TRENDS IN PRODUCTION

Since the major shad fisheries of New York are located in the Hudson River, fluctuations in annual yield in the State are a reflection of the conditions in this river. The New York shad catch for certain years from 1880 to 1960 is given in table 45. The fishery had its maximum yield from 1880 to 1901, averaging more than 3 million pounds per year. Production then decreased, and from 1904 to 1935 the annual yield was only 11 percent of that in 1880-1901. Production increased after 1935, and from 1937 to 1948 the annual yield fluctuated between 1 million pounds in 1937 and 3 million pounds in 1945. Production again declined, and from 1949 to 1960 the annual yield

Table 45.--Shad catch for certain years, New York, 1880-1960[1]

[In thousands of pounds]

Year	Catch	Year	Catch
1880	2,734	1939	1,378
1887	3,586	1940	1,382
1889	4,332	1943	2,245
1890	3,777	1944	2,130
1891	3,045	1945	2,850
1896	2,201	1946	1,744
1897	1,884	1947	1,267
1901	3,432	1948	1,393
1904	498	1949	900
1908	360	1950	628
1921	116	1951	462
1926	231	1952	773
1929	164	1953	491
1930	167	1954	707
1931	357	1955	615
1932	401	1956	704
1933	352	1957	627
1935	476	1958	644
1937	1,021	1959	672
1938	1,072	1960	472

[1] Statistics 1880-1959, U. S. Fish and Wildlife Service (1958-61).

fluctuated between 900,000 lb. in 1949 and 472,000 in 1960. The 1960 production was about 21 percent of the 1896 catch.

Many factors have been suggested as causes for the decline in production at the turn of the century, for its subsequent sudden recovery beginning in 1936, and for the decline in the last decade. Talbot (1954, 1956) examined a number of factors that might affect fluctuations in Hudson River shad runs. No correlation was found between the size of the shad population and stream flows, water temperatures, channel improvements, ship traffic, or hatchery operations. Available information gave no evidence that runs fluctuated in natural cycles of abundance. Pollution was a serious problem, but there are no records to show changes in pollution on the spawning and rearing grounds. Limited tagging experiments indicated that Hudson River shad were caught outside the river from Maine to North Carolina but were taken in large numbers only along the New Jersey coast and off Staten and Long Islands.[7] Although pollution and catches outside the river may have had some effect on the fishery, the largest single factor affecting abundance of shad in the river was the number of fish escaping the fishery to spawn (Talbot, 1954). By control of fishing effort, the desired number of shad could be allowed to escape the fishery and spawn, and the fishery managed to produce optimum yields.

SHAD FISHERIES OF CONNECTICUT

The 1896 shad fisheries of Connecticut were in Long Island Sound, Connecticut River, Housatonic River, Bridgeport Harbor, and Pine Creek. Major production was from the Connecticut and Housatonic Rivers and Long Island Sound, though the catch in the Sound was incidental to that of other species. The total catch was 261,190 lb. About 79 percent by 20,193 yd. of drift gill net, 11 percent by 2,048 yd. of seine, and the remainder by pound net (tables 46 and 47).

The Connecticut River was the only major shad producing area in Connecticut waters in 1960 (fig. 25). Small catches were taken in Long Island Sound, but other formerly productive waters had ceased to yield more than an occasional fish. The commercial yield was 420,611 lb., of which about 99 percent was taken by 19,497 yd. of drift gill net and the remainder by 392 yd. of seine and by miscellaneous gear (tables 46 and 47). In addition to the commercial yield, 77,200 lb. were taken by sport fishermen.

Table 46.--Gear employed in shad fisheries, by water area, Connecticut, 1896 and 1960

Water area	1896		1960		
	Drift gill net	Seine	Drift gill net	Seine	Sport fisherman days
	Yards	Yards	Yards	Yards	Number
Connecticut River. .	13,858	1,883	19,497	392	[1]22,000
Housatonic River . .	5,640	1,165	---	---	---
Bridgeport Harbor. .	540	---	---	---	---
Pine Creek	155	---	---	---	---
Total.	20,193	3,048	19,497	392	22,000

[1] Includes both Connecticut and Massachusetts waters.

Table 47.--Shad catch, by water area and gear, Connecticut, 1896 and 1960

[In pounds]

Water area	1896			1960			
	Drift gill net	Seine	Pound net	Drift gill net	Seine	Miscellaneous	Sport catch
Long Island Sound . .	---	152	26,358	---	---	800	---
Connecticut River . .	170,382	21,698	---	415,905	3,906	---	[1] 77,200
Housatonic River. . .	30,791	5,916	---	---	---	---	---
Bridgeport Harbor . .	3,779	---	---	---	---	---	---
Pine Creek.	2,114	---	---	---	---	---	---
Total.	207,066	27,766	26,358	415,905	3,906	800	77,200

[1] Includes both Connecticut and Massachusetts waters.

FISHERIES BY WATER AREA

Regulations on shad fishing in Connecticut are established by the State Board of Fisheries and Game. During 1960 the legal commercial fishing season was from April 1 to June 15; fishing was prohibited from sunset Friday until sunset Sunday. The legal sport fishing season was from April 16 to June 26, and the daily creel limit was six. Sport fishing was permitted 7 days per week.

Long Island Sound

Long Island Sound, occupying the coastal depression between Long Island and the shore of Connecticut, is 115 miles long and 15 to 25 miles wide. At its eastern end a chain of islands extends northeasterly from Long Island to Rhode Island, through which the waters of the Sound mix with the ocean. At its western end the Sound connects with New York Bay through the East River. Throughout its length, except near the mouths of large rivers, the salinity approaches that of the ocean. The principal tributaries of the Sound are the Thames, Connecticut, and Housatonic Rivers.

[7] Nichols (1958) reported that the New Jersey-New York pound net catch in 1956 was composed of 76 percent Hudson River shad.

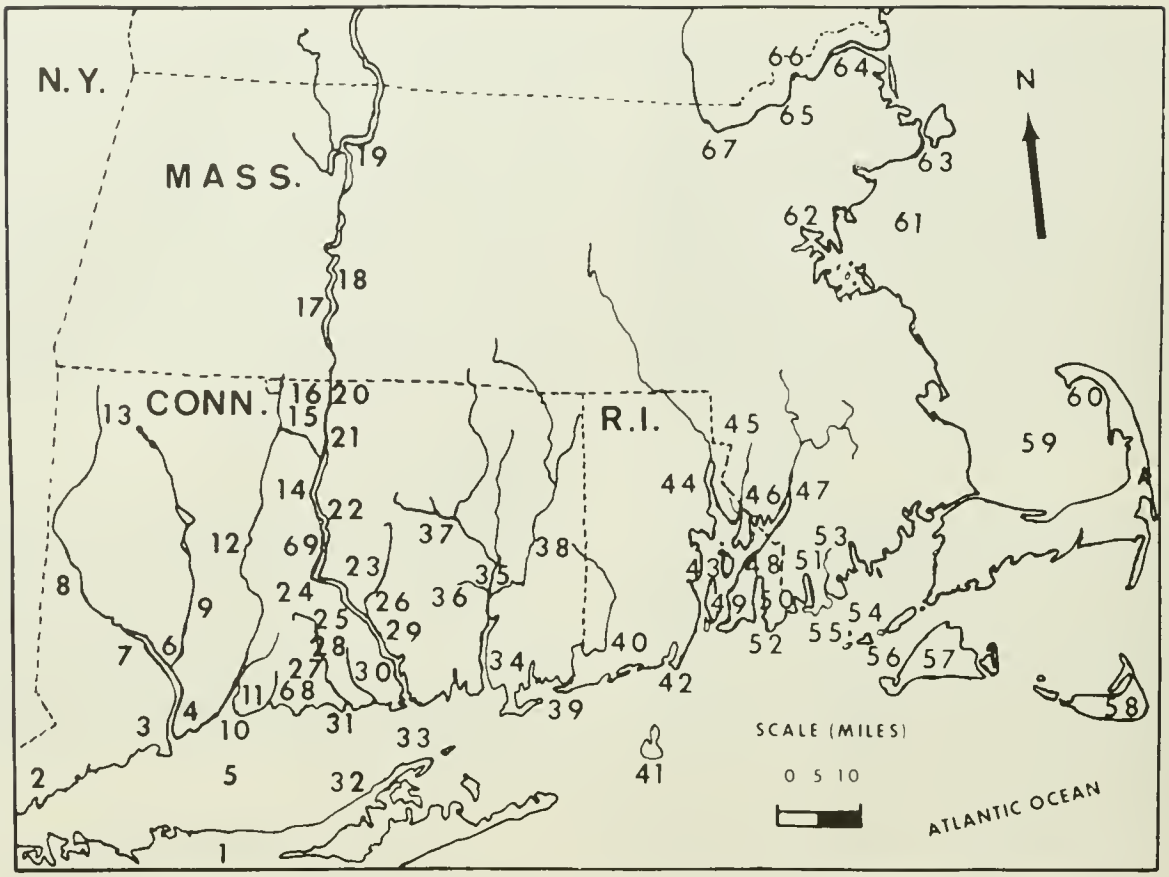

Figure 25.--Map of Connecticut, Rhode Island, and Massachusetts.

Key:

1 Long Island
2 Stamford
3 Bridgeport
4 Milford
5 Long Island Sound
6 Derby
7 Housatonic River
8 Lanesville
9 Naugatuc River
10 Farm River
11 New Haven
12 Farmington River
13 Falls Village
14 Hartford
15 Poquonock
16 Suffield
17 Holyoke
18 South Hadley
19 Turners Falls
20 Enfield
21 Windsor Locks
22 Wethersfield
23 Salmon River
24 Higganum
25 Haddam
26 Leesville
27 Hammonasett River
28 Memunketesuck River
29 Hadlyme
30 Essex
31 Hammonassett Point
32 Horton Point
33 Orient Point
34 Thames River
35 Norwich
36 Yantic River
37 Shetucket River
38 Quinnebaug River
39 Watch Hill
40 Powgatuck River
41 Block Island
42 Point Judith
43 Narragansett Bay
44 Providence River
45 Palmer River
46 Warren River
47 Taunton River
48 Tiverton
49 Newport Island
50 Sakonnet River
51 Pamansett River
52 Sakonnet
53 New Bedford
54 Apponagasett Bay
55 Buzzards Bay
56 Vineyard Sound
57 Martha's Vineyard
58 Nantucket
59 Cape Cod Bay
60 Provincetown
61 Massachusetts Bay
62 Boston
63 Gloucester
64 Newburyport
65 Lawrence
66 Merrimac River
67 Lowell
68 Branford River
69 Connecticut River

Stevenson (1899) stated: "While some shad doubtless enter Long Island Sound through East River, the great bulk passes through the Race at the eastern end. They appear usually about the second week of April and are taken first in the pound nets set immediately west of the mouth of Connecticut River. Most of them pass up the Connecticut, but a large number proceed westward, a few being caught in the pound nets set along the shore, while others enter the Housatonic and some of the smaller streams of Connecticut and Long Island. The run into these waters during recent years appears to be much smaller than formerly....." [p. 251].

No fishery in the Sound operated exclusively for shad in 1896; catches were incidental to other species. Shad were caught in pound nets at: the southeastern end of the Sound along the Long Island shore, from Orient Point to Horton Point, along the Connecticut shore of Long Island Sound east of the Connecticut River, and between the Connecticut River and New Haven Harbor. Three pound nets fished near the mouth of the Connecticut River caught more shad than all the others. Formerly the fishery from the mouth of the Connecticut west to Kelsey Point, a distance of 8 miles, was one of the most profitable on the coast. Stevenson reported that a single pound net fished between 1856 and 1885 at Money Point, 6 miles west of the mouth of the Connecticut River, caught from 11,100 to 74,400 lb. of shad annually. By 1896, however, this fishery had declined because of the scarcity of fish, and less than 20,000 lb. were landed. Only a few were taken in pound nets and seines between Hammonasset Point and New Haven Harbor. West of New Haven, Conn., small fisheries were located at Welch Point near Milford, Conn. Total catch in the Sound was 26,150 lb.

In recent years only an occasional shad has been taken in the Sound by commercial nets fished for other species. William J. Murphy, Fishery Marketing Specialist, Bureau of Commercial Fisheries, Warren, R.I. (personal interview), estimated that about 800 lb. were caught in 1960.

Thames River

This river is an estuary of Long Island Sound extending 15 miles northward to Norwich, Conn., where it receives the waters of the Shetucket, Quinebaug, and Yantic Rivers. Prior to 1880 considerable numbers of shad were caught in the Thames, but by 1896 numerous dams on these rivers blocked the ascent of fish and none was taken.

According to the Connecticut State Board of Fisheries and Game, an occasional shad is caught in the Thames, and in 1960 about a dozen were caught below Greenville Dam above Norwich in a fishery for other species.

Connecticut River

The Connecticut River originates in northern New Hampshire near the Canadian border and flows south 400 miles, forming the boundary between New Hampshire and Vermont and traversing Massachusetts and Connecticut before entering Long Island Sound. Above Hartford, Conn., are numerous falls. Those which concern shad are at Enfield, Conn., Holyoke, Mass., Turners Falls, Mass., and Bellows Falls, Vt.; dams have been constructed at all of them.

Shad formerly ascended the Connecticut as far as Bellows Falls, 170 miles above its mouth (Stevenson, 1899). In 1798, however, a dam was built at Turners Falls, 35 miles above Holyoke and 115 miles from the river mouth. This dam prevented shad from passing above this point but apparently had no injurious effect on the fishery, since adequate spawning area remained between Holyoke and Turners Falls.

About 1880 a 5-ft.-high dam was built at Enfield, 66 miles above the river mouth (Stevenson, 1899). Shad were unable to ascend this barrier at low water; the dam irritated the fishermen greatly above that point. The State of Massachusetts adopted a resolution in 1886 suggesting mutual measures by Massachusetts and Connecticut toward overcoming the obstruction, but no satisfactory result was accomplished.

In 1849 the Hadley Falls Dam at Holyoke, 18 miles upstream from Enfield, was completed. This 30-ft. obstruction cut off 36 miles from the upper limit of the shad run, including important spawning grounds. Although it was provided with a fishway in 1873, fish were unable to ascend the barrier.

The 1896 fishery in the Connecticut River extended 40 miles from Long Island Sound to Wethersfield, Conn. Most fishing was from Essex to Haddam, Conn. The yield was 192,080 lb., of which 170,382 lb. were taken by 13,858 yd. of drift gill net, and 21,698 lb. by 1,883 yd. of seine. Gill nets averaged 150 yd. long, and several were used only for catching river herring (Alosa sp.). The fishing season in the Connecticut depended on movement of ice in the river, but it usually began by the second week in April and continued to the third week of June. The legal season in 1896 was from March 1 to June 20; fishing was prohibited from sunset Saturday until sunset Sunday.

The Farmington River is one of several tributaries to the Connecticut River. It rises in Berkshire County, Mass., and flows 75 miles before entering the Connecticut 3 miles above Hartford. At Poquonock, Conn., 5 miles above the mouth, a 55-ft. dam crosses the river, blocking ascent of fish. The fishery in the Farmington formerly was locally important, and in 1896, 1,800 lb. of shad were taken for use in hatcheries.

After 1896, several changes took place in the Connecticut River which affected the shad fisheries. In 1900 the original Hadley Falls Dam at Holyoke was replaced with a 55-ft. dam. A fishway was built on the dam in 1940, but this failed to pass anadromous fish. In 1951 a hydroelectric plant was constructed at this location, and an experimental pressure-lock fishway was included in the structure.[8] This method of fish passage proved feasible, but in 1955 the pressure lock was replaced by a trap and mechanical lift. This device has been moderately successful; 15,076 adult shad were passed above the dam in 1960. In 1933 the dam at Enfield was modified and a ramp installed in the center of the dam so that migrating fish had access to the river above. Observations at the ramp showed that fish could pass freely, except at extreme low water levels.

Shad entered the Connecticut River in mid-March 1960 and remained until early June. The species spawned throughout the river from Windsor Locks to Turners Falls. The spawning season extended from May through June and reached its peak from mid-May to early June.

Shad were taken commercially in 1960 from Long Island Sound to and including the Farmington River, a distance of 48 miles. The major fishing area was from the river mouth to Higganum, Conn. After the middle of the season, however, lower river fishermen moved upstream, and fishing was concentrated between Hadlyme and Higganum. The catch was 415,905 lb. by 19,497 yd. of drift gill nets, and 3,906 lb. by 392 yd. of seine. Drift gill nets were 200 to 300 yd. long and 35 to 50 meshes deep and had 5 1/2- to 5 3/4-in. mesh. Total commercial yield in 1960 was 419,811 lb.; 3,906 lb. were taken in the Farmington River by one seine fished 2 miles downstream from Poquonock. Some shad also were taken in this river by sportfishermen.

Seines formerly were the only gear used for taking shad in the Connecticut, but they gradually have been superseded by gill nets. In 1960 only one seine was fished in the Farmington River. In recent years, up to six seines were used during the shad season, but they were fished primarily for river herring. The small demand for herring has almost eliminated seines from the river.

Sport fishing for shad has been popular on the Connecticut River for years (Nichols and Tagatz, 1960). It was first developed in the spawning grounds of the Salmon River at Leesville, Conn., located south of Hartford, and continued there until the flood of 1938 washed out the dam at Leesville. Since then the center of sport fishing has shifted to the Enfield Dam area on the Connecticut River at Suffield, Conn.[9] (fig. 26). The sport fishing area in 1960 extended from the Farmington River to Holyoke, a distance of 30 miles. The major sport-fishing areas were in Farmington River and at Windsor Locks, Enfield Dam, Williamansett Bridge, and South Hadley Bridge. Lures and angling methods used were varied. Lead-bodied feathertailed jigs usually were fished from boats, small metal spoons from bridges, and plain hooks garnished with colored beads from river banks. Estimated sport catch in 1960 was 24,800 fish (77,200 lb.), of which 17,900 were taken in Connecticut and 6,900 in Massachusetts.

The Connecticut River commercial shad catch has fluctuated widely over the years. In 1950 the Fish and Wildlife Service began an investigation of the fishery to learn causes for decline in yield, to determine conditions favoring recovery, and to provide information for management of the fishery to obtain maximum sustained yields (Fredin, 1954). Results indicated that over 80 percent of the fluctuations in size of the Connecticut River shad population was attributable to variations in the number of fish allowed to escape the fishery and spawn. On the basis of catch-effort statistics, the number of shad entering the river in 1960 was estimated at 340,000 fish, fishing rate was 34 percent, and spawning escapement was 224,000 shad. Studies by Walburg (1963) indicate that the optimum escapement is between 125,000 and 175,000 spawners annually. Escapements in this range suggest a theoretical maximum sustainable yield of about 150,000 fish.

Housatonic River

This river originates near Pittsfield in western Massachusetts and flows 123 miles before entering Long Island Sound 4 miles east of Bridgeport, Conn. In the early 1880's, before dam construction on this river, shad ascended to Falls Village, Conn., 73 miles from Long Island Sound, where a natural falls barred further ascent. A 22-ft.-high dam was built on the Housatonic in 1870 at Birmingham, 1 mile above Derby, Conn., and 15 miles above the river mouth (Stevenson, 1899). By 1896, the river had several dams above Birmingham. The most important was at Lanesville, Conn., where the fall was 12 ft. Very few fish passed above the Birmingham Dam, and none went beyond Lanesville, 40 miles above the mouth. Stevenson reported that the largest catch in the Housatonic was made in 1884, when about 187,000 lb. were landed. After that time the catch declined and in 1896 was only 36,700 lb. No shad were taken in the Housatonic in 1960. Dams and pollution probably eliminated this run.

[8] Unpublished report. Report of the investigation for and tentative design of the fishway at Holyoke, Masschusetts by A. D. Mugnier and A. H. Swartz, 1951, Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N.C., 64 p.

[9] Unpublished manuscript. Shad fishery of the Connecticut River, 1944 by Douglas D. Moss, Connecticut State Board of Fisheries and Game, Hartford, Conn. 46 p.

Figure 26.--Sport fishing for shad below Enfield Dam on the Connecticut River, Conn.

The Housatonic's main tributary, the Naugatuck River, enters the river below the Derby Dam. James P. Galligan, Connecticut State Board of Fisheries and Game, Hartford, Conn. (personal communication dated June 28, 1960), reported that because of raw sewage and industrial wastes, the Naugatuck is one of the most polluted streams in Connecticut. No shad were taken in this river in 1896 or 1960.

Bridgeport Harbor and Pine Creek

In 1896, 3,779 lb. of shad were taken in the harbor of Bridgeport, Conn., 3 miles west of the Housatonic River, and 2,114 lb. were taken in Pine Creek and other areas between Bridgeport and Stamford, Conn.

No shad were reported in 1960 in any stream in this area. There were, however, reports that shad taken in several streams between New Haven, Conn., and the mouth of the Connecticut River. Two were collected in the Farm River at the outlet of Lake Saltonstall by personnel of the Connecticut State Board of Fisheries and Game. An occasional fish was caught by sport fishermen in the Branford River near Branford, Conn., in the Hammonasset River, and in the Menumketesuck River.

TRENDS IN PRODUCTION

Statistics are available on the commercial shad catch in Connecticut waters for certain years from 1887 to 1960 (table 48). During this period, catch fluctuated from 46,000 lb. in 1923 to 1,146,000 lb. in 1946. Average annual catches during different periods were 279,000 lb. in 1887-1911, 193,000 in 1912-36, and 463,000 in 1937-60. In 1937-60, except for 1944-48 when the highest catches on record were made, the catch remained between 200,000 and 550,000 lb. The commercial yield was 62 percent greater in 1960 than in 1896.

Except for a few fish taken in Long Island Sound, only the Connecticut River has produced shad in recent years. Destruction of the fishery in other areas has been attributed to the construction of dams near river mouths and to pollution (Stevenson, 1899). Fredin (1954) found that overfishing was the major cause for fluctuations in the Connecticut River catch.

Table 48.--Shad catch for certain years, Connecticut, 1887-1960[1]

[In thousands of pounds]

Year	Catch[2]	Year	Catch[2]	Year	Catch[2]
1887	337	1912[3]	210	1937	383
1888	282	1913[3]	184	1938	427
1889	196	1914[3]	203	1939	409
1890[3]	120	1915[3]	148	1940	360
1891[3]	78	1916[3]	184	1941	438
1892[3]	63	1917[3]	226	1942	373
1893[3]	143	1918[3]	241	1943	553
1894[3]	252	1919	463	1944	747
1895[3]	218	1920[3]	176	1945	772
1896	261	1921[3]	72	1946	1,146
1897[3]	256	1922	47	1947	793
1898	499	1923[3]	46	1948	622
1899[3]	331	1924	89	1949	471
1900[3]	490	1925	146	1950	264
1901[3]	434	1926	111	1951	338
1902	480	1927[3]	120	1952	474
1903[3]	616	1928	199	1953	360
1904[3]	603	1929	318	1954	295
1905	485	1930	54	1955	210
1906[3]	253	1931	75	1956	197
1907[3]	136	1932	70	1957	329
1908	122	1933	133	1958	456
1909[3]	122	1934[3]	525	1959	401
1910[3]	98	1935	403	1960	421
1911[3]	96	1936[3]	385		

[1] Statistics 1887-1959, U. S. Fish Commission, U. S. Bureau of Fisheries, and U. S. Fish and Wildlife Service

[2] Does not include catch by sport fishery.

[3] Catch converted from numbers to pounds by factor of 3.5 from table prepared by Douglas D. Moss, Connecticut State Board of Fisheries and Game.

SHAD FISHERIES OF RHODE ISLAND

Except in the Warren River, the 1896 catch of shad in Rhode Island was taken by gears used for other species. The catch in 1896 was 52,761 lb. of which about 8 percent came from pound nets fished along the ocean shore, 16 percent from pound nets fished in Narragansett Bay, and 76 percent from pound nets and miscellaneous gear in tributaries of the Bay (table 49).

Table 49.--Shad catch, by water area and gear, Rhode Island, 1896

[In pounds]

Water area	Pound net	Miscellaneous	Total
Atlantic Ocean	4,098	---	4,098
Narragansett Bay	8,433	---	8,433
Warren River	36,097	---	36,097
Pawcatuck River	---	1,560	1,560
Providence-Blackstone River	---	1,950	1,950
Greenwich River	---	623	623
Total	48,628	4,133	52,761

Shad were taken in 1960 incidental to the catch of other species. The total catch was 3,163 lb., all caught in floating traps fished in the ocean near Narragansett Bay (fig. 25).

FISHERIES BY WATER AREA

The shad taken off the coast in Rhode Island in 1960 probably were not native. The following discussion, therefore, concerns primarily the 1896 fisheries.

Atlantic Ocean

Fourteen pound nets between Watch Hill and Point Judith, R.I., and four pound nets fished near Block Island, R.I., caught shad during the spring of 1896. The combined catch in these

areas was 4,098 lb. In 1960 a floating trap fished near Point Judith caught 400 lb.

Narragansett Bay

A few shad were taken by pound nets formerly on the southern shore of Rhode Island, in Western Channel, and between Sakonnet and Tiverton, R.I., in the Sakonnet River, but rarely in sufficient numbers to receive special attention from fishermen. The largest catch in a single net, 577 lb., was taken in 1896 off Rumstick Neck at the northern end of Narragansett Bay near the mouth of the Providence River. Total poundage of shad caught in the Bay in 1896 was 8,433. In 1960 two floating traps off Sakonnet Point and one off Newport Island, together caught 2,763 lb.

Warren River

This stream, a tidal arm of Narragansett Bay near its northern limit, was the only river in Rhode Island with a substantial shad run in 1896. It is a few hundred feet wide, about 10 miles long, and in 1896 contained no obstructions to fish passage. In that year, several pound nets fished in the river near the Massachusetts State line caught 36,097 lb.

No commercial landings have been reported in the Warren River in recent years. This river has a small shad run, however. According to Frederick C. Wilbour, Jr., Director, Division of Marine Fisheries, Department of Natural Resources (personal communication dated June 20, 1960), fish are taken by hook and line in Massachusetts, where this stream is known as the Palmer River; no estimate of the catch was made.

Pawcatuck River

The Pawcatuck formerly yielded many shad, but by 1896 it was obstructed by numerous dams which completely blocked passage of fish. A few, however, were taken each year in the lower portion of the river as well as in Old Warwick Cove and Patowomut River. The 1896 catch in this area was 1,560 lb. taken by seines, dip nets, and other gears. According to Warren J. Murphy, Fishery Marketing Specialist, Bureau of Commercial Fisheries, Warren, R.I., (personal interview), no shad were caught in this area in 1960.

Providence-Blackstone River

Numerous dams, and sewage from the city of Providence, had almost exterminated the shad in this river by 1896, but a few fish were taken by seines, dip nets, and other gears. The estimated catch was 1,950 lb. Two seines caught 623 lb. in 1896 in Greenwich Bay. No shad were reported from these areas in 1960 nor have any been reported in recent years.

TRENDS IN PRODUCTION

The industrial development of tidewater Rhode Island in the late 1800's resulted in the location of textile and metal-product industries on the fresh-water streams flowing into Narragansett Bay. Increased pollution and dam construction since that time have eliminated shad populations. The exception was the Warren (Palmer) River, which continued to maintain a small run.

Shad landed in this State are caught during their coastal migration. Fluctuations in production in recent years probably resulted from changes in the size of runs migrating past Rhode Island, amount and type of fishing gears used, and weather which affected inshore-offshore movement of shad during their northward migration.

Statistics available on the Rhode Island catches from 1887 to 1960 show that annual production fluctuated between 1,000 and 54,000 lb. The average annual catch for the 20 yr. between 1887 to 1940 for which landing figures are available was 18,000 lb. (table 50). Since 1940, the annual catch has ranged from 1,000

Table 50.--Shad catch for certain years, Rhode Island, 1887-1960[1]

[In thousands of pounds]

Year	Catch	Year	Catch
1887. . . .	17	1942. . . .	1
1888. . . .	17	1943. . . .	2
1889. . . .	17	1944. . . .	4
1896. . . .	53	1945. . . .	2
1898. . . .	25	1946. . . .	3
1902. . . .	31	1947. . . .	2
1905. . . .	17	1948. . . .	2
1908. . . .	4	1949. . . .	3
1924. . . .	11	1950. . . .	2
1928. . . .	6	1951. . . .	6
1929. . . .	15	1952. . . .	5
1930. . . .	4	1953. . . .	4
1931. . . .	18	1954. . . .	2
1932. . . .	8	1955. . . .	5
1933. . . .	11	1956. . . .	1
1935. . . .	6	1957. . . .	5
1937. . . .	5	1958. . . .	2
1938. . . .	10	1959. . . .	3
1939. . . .	28	1960. . . .	3
1940. . . .	54		

[1] Statistics 1887-1959, U. S. Fish Commission, U. S. Bureau of Fisheries, and U. S. Fish and Wildlife Service.

to 6,000 lb. and averaged 3,000 lb. Most shad were taken by pound nets and floating traps fished near the coast. In 1929, 139 of these gears were fished, but by 1958 only 19 were in use; this decline may partially explain the decreased production in Rhode Island during recent years. The catch in 1960 was less than 6 percent of the 1896 take.

SHAD FISHERIES OF MASSACHUSETTS

The shad fisheries of Massachusetts have changed little over the years except in magnitude. No shad fishery existed in the State in 1896, but an estimated 114,152 lb. were taken incidental to the catch of other species. The estimated 1960 catch was 657,000 lb., of which 96 percent was caught by purse seines, 3 percent by pound nets, and 1 percent by stake gill nets and trawls.

FISHERIES BY WATER AREA

Many areas that produced shad in 1896 reported none in 1960.

Taunton River

The Taunton River is formed by the union of the Satucket and Matfield Rivers in Bridgewater, Mass., from whence it flows into Narragansett Bay (Fig. 25). It is navigable 18 miles to East Taunton, (Bristol County) Mass., where a 9-ft. dam blocks upstream passage of fish. Shad entered the river in 1896 about the latter part of March and remained until some time in June although few were taken after the end of May. It does not appear that shad were ever commercially important in this river. In the 1890's they were taken incidental to catches of alewife. From 1878 to 1896, the catch ranged from 5,900 to 32,000 lb. In 1896 haul seines took 13,225 lb. Only occasional fish have been reported in recent years.

Buzzards Bay

This Bay is a coastal indentation of 225 square miles on the southern shore of Massachusetts (fig. 25). In 1896 pound nets set along the shore west of Apponagansett Bay, at the mouth of Pamansett River, between that river and the Goose Neck, and near Elizabeth Islands, caught 2,845 lb. of shad incidental to the catch of other species. Pound nets in Vineyard Sound (Dukes County) adjacent to Buzzards Bay caught 10,150 lb. Only 400 lb. were landed in 1960 in Bristol County, all by otter trawl. This figure includes fish caught in Buzzards Bay and offshore and landed in New Bedford, Mass. Most fish were captured in late April and May before spawning occurs in most northern rivers.

Cape Cod and Massachusetts Bay

The shad catch in Cape Cod and Massachusetts Bay in 1896 was taken principally by fishermen operating from Provincetown (Barnstable County) in drift nets fished for mackerel, Scomber scombrus. During June, 44,160 lb. of shad were landed. Because of the small mesh of the nets used, fish were small, averaging only about 2 lb. each. Shad were taken also by mackerel seine fishermen; in 1896 the catch was 35,820 lb. A few fish (6,882 lb.) were taken in pound nets in Cape Cod Bay. Total catch in Barnstable County was 86,862 lb. In addition, 670 pounds were caught in Massachusetts Bay (Suffolk County).

The 1960 catch in Barnstable County, which includes Cape Cod Bay and Nantucket Sound, was 19,600 lb. The decline of the mackerel fishery between 1896 and 1960 undoubtedly caused the decrease in shad catch in this area.

Merrimack River

The sources of the Merrimack are in east-central New Hampshire; the main stream is formed by the junction of the Pemigewasset and Winnipesaukee Rivers (fig. 25). It flows 110 miles to the sea near Newburyport, Mass. At Lawrence, Mass., 27 miles above its mouth, the stream was crossed obliquely by a dam 32 ft. high and 900 ft. long with a wooden fishway at the south end. The dam and fishway were built in 1848. At Lowell, Mass., 12 miles above Lawrence, there was a second dam about 30 ft. high, built in 1830 and enlarged in 1876. A third dam was constructed in 1871 at Manchester, N.H. Its length was 420 ft. and its height about 12 ft. Three other dams were located above Manchester at Hooksett, Garvin Falls, and Sewell Falls. Before the construction of these dams, the annual shad catch was about 500,000 lb. It was apparent, however, that after the completion of the dam at Lawrence in 1848, the catch declined drastically, and by 1882 it was insignificant. Only 30 lb. were landed in 1896.

The present shad run in the Merrimack is small, since the only area available for spawning, the lower section of the river, is heavily polluted with industrial waste and domestic sewage. The fishway in the Essex Company Dam at Lawrence was rebuilt in 1919 after the previous fishway had been destroyed by ice. Shad were able to ascend this fishway and

proceed to the dam at Lowell, which was impassable (Collins, 1951). The number of shad annually ascending the fishway was from 1,500 to 3,000 fish. In 1946 a catch of 75,000 lb. was made in Newburyport Harbor, though these may have been migrating fish from another area which had moved inshore. Commercial shad fishing at the mouth of the river is sporadic, and in some years there is none at all. In 1960 no fish were reported taken.

Most of the catch in Essex County, Mass., which includes the Merrimack River, was landed in Gloucester. In recent years, large numbers of shad have been landed during the summer by purse seiners fishing for Atlantic menhaden, Brevoortia tyrannus, and river herring, Alosa aestivalis, and sold to reduction plants. The 1960 landings of shad were a little above 0.5 million pounds (Dwight L. Hoy, Bureau of Commercial Fisheries, Gloucester, Mass., personal communication dated September 26, 1960). Mature and immature fish from all Atlantic coast streams, Florida to Canada, spend their summers in the Gulf of Maine, but their schooling habits in this area are unknown. If the purse seine fishery continues to take large quantities of shad, it could have a disastrous effect on coastal stocks, especially if the catch is composed of fish from only two or three rivers. The impact of this take perhaps can be realized from the fact that the estimated annual sizes of shad populations during the past 5 yr. have averaged 3.5 million pounds in the Hudson River and 1.0 million pounds in the Connecticut River.

Connecticut River

The Connecticut River crosses Massachusetts in its southward flow from northern New Hampshire to Long Island Sound (fig. 25). The Massachusetts section of the river had an intensive sport fishery for shad in 1960, which extended 16 miles from the Connecticut border northward to the Hadley Falls Dam in Holyoke, Mass. Fish were landed near the Willimansett and South Hadley Bridges by fishermen fishing from bank, boat, and bridge. Although most fishermen fished from bridges, most fish were taken by boat fishermen. In 1960, 6,800 fish were taken in this area. Additional information on the Connecticut River is included in the discussion of the fisheries of Connecticut.

TRENDS IN PRODUCTION

Industrial development of Massachusetts during the 1800's resulted in the construction of many dams that essentially eliminated shad runs by barring fish from their spawning grounds. Fish caught subsequently in Massachusetts waters were largely native to other areas and were taken incidental to the catch of other species.

Massachusetts landings have fluctuated widely over the years (table 51). From 1887 to 1955 the catch ranged from 9,000 to 389,000 lb. After 1955 the catch increased severalfold, reaching a maximum of 2,214,000 lb. in 1957. As pointed out in a previous section, this catch was made by purse seines fishing for Atlantic menhaden. The catch was almost six times greater in 1960 than in 1896.

Table 51.--Shad catch for certain years, Massachusetts, 1887-1960[1]

[In thousands of pounds]

Year	Catch	Year	Catch
1887	133	1940	95
1888	260	1942	33
1889	234	1943	114
1896	114	1944	20
1898	29	1945	29
1902	21	1946	10
1905	91	1947	52
1908	389	1948	34
1919	62	1949	11
1924	172	1950	28
1928	31	1951	72
1929	92	1952	48
1930	54	1953	40
1931	150	1954	9
1932	46	1955	37
1933	63	1956	724
1935	306	1957	2,214
1937	48	1958	425
1938	54	1959	1,383
1939	85	1960[2]	658

[1] Statistics 1887-1960, U. S. Fish Commission, U. S. Bureau of Fisheries, and U. S. Fish and Wildlife Service.

[2] Data for 1960 from Dwight L. Hoy, U. S. Bureau of Commercial Fisheries, Gloucester, Mass. (personal communication dated September 26, 1960).

SHAD FISHERIES OF NEW HAMPSHIRE

The Connecticut and Merrimack Rivers in New Hampshire formerly supported shad fisheries. No fish have been reported in these waters, however, for more than 100 yr. Shad formerly ascended the Connecticut to Bellows Falls near Walpole, N.H., but a dam built in 1798 at Turners Falls, Mass., completely blocked their upstream passage (Stevenson, 1899). They ascended the Merrimack to Franklin, N.H., and the junction of the Pemigewasset

and Winnipesaukee Rivers, where they reportedly entered the latter river and continued on to Lake Winnipesaukee. Since 1847, dams in the Massachusetts waters of the Merrimack River have prevented shad from reaching New Hampshire (Bailey, 1938).

SHAD FISHERIES OF VERMONT

Shad formerly ascended the Connecticut River to Bellows Falls, Vt., 170 miles above the river mouth (Evermann and Kendall, 1896; Stevenson, 1899). Before 1798 shad reportedly were taken in great numbers below Bellows Falls, said to be a favorite spawning area for the species (McDonald, 1887e). In 1798 a dam built at Turners Falls, Mass., 50 miles downstream from Bellows Falls, completely blocked passage of fish to Vermont waters. From historical accounts it appears that the Vermont shad fisheries were among the earliest destroyed by construction of dams.

SHAD FISHERIES OF MAINE

Shad were taken in the following waters in 1896: Kennebec River and its two tributaries, Androscoggin and Eastern Rivers; Casco Bay; Penobscot River; Harrington River; Pleasant River; and St. Croix River (table 52). The catch in 1896 was about 1,404,477 lb. of which traps and weirs took 69 percent, drift nets 19 percent, and seines the remainder. Most fish were taken in the Kennebec River.

No commercial fishery has existed for shad in Maine streams for many years (Taylor, C.C., 1951). Because shad from Atlantic coast streams spend their summers in the Gulf of Maine, they are liable to capture by other fisheries operated in this area (fig. 27).

The commercial catch of shad in 1960 in Maine was about 311 lb.

FISHERIES BY WATER AREA

Since shad have all but disappeared from Maine streams, the following discussion concerns primarily those areas that were formerly productive.

Table 52.--Shad catch, by water area and gear, Maine, 1896

[In pounds]

Water area	Drift gill net	Seine	Trap and weir	Total
Casco Bay	23,399	154,429	69,143	246,971
Kennebec River	175,349	---	787,156	962,505
Androscoggin River	5,859	21,065	24,433	51,357
Eastern River	11,489	---	85,718	97,207
Penobscot River	---	---	436	436
Harrington River	11,489	---	---	11,489
Pleasant River	34,466	---	---	34,466
St. Croix River	---	---	46	46
Total	262,051	175,494	966,932	1,404,477

Saco River

This river's source is in the White Mountains, 100 miles from its entrance into the ocean near Biddeford Pool. From Biddeford, Maine, 6 miles from the sea, to Hiram Falls, 45 miles from the sea, there are eight dams. Shad formerly abounded in the lower river, but apparently could not pass above Biddeford Falls (Stevenson, 1899). By 1896 the species was absent, and its disappearance was attributed to textile mill wastes drained into the river (Taylor, C.C. 1951).

Nonesuch River

No mention is made of the Nonesuch in the various accounts of the history of the shad fishery in Maine, and therefore it is assumed that this river never supported a fishery of any consequence. It is of interest, however, because the river has a small but well-established shad run that does not appear to have fluctuated notably during recent years (Taylor, C.C. 1951).

The Nonesuch rises in southwestern Saco Township and flows through sandy, rolling country to enter the sea between Pine Point and Prouts Neck on Saco Bay. Habitation is limited along the river and the stream is practically free of pollution. Because of the steep gradient of the Nonesuch, it is doubtful that shad ever ascended above Thurston Mills, 18 miles above the river mouth.

Shad enter the Nonesuch in early May and are caught until mid-June. Capture is restricted by law to dip or bag nets not exceeding 19 ft. in circumference, or artificial fly. Fishing is permitted only in the tidal portion of the river south of U.S. Route 1. The daily catch limit is five fish per person. It is estimated that between 200 and 400 fish are taken each season (Taylor, C.C. 1951).

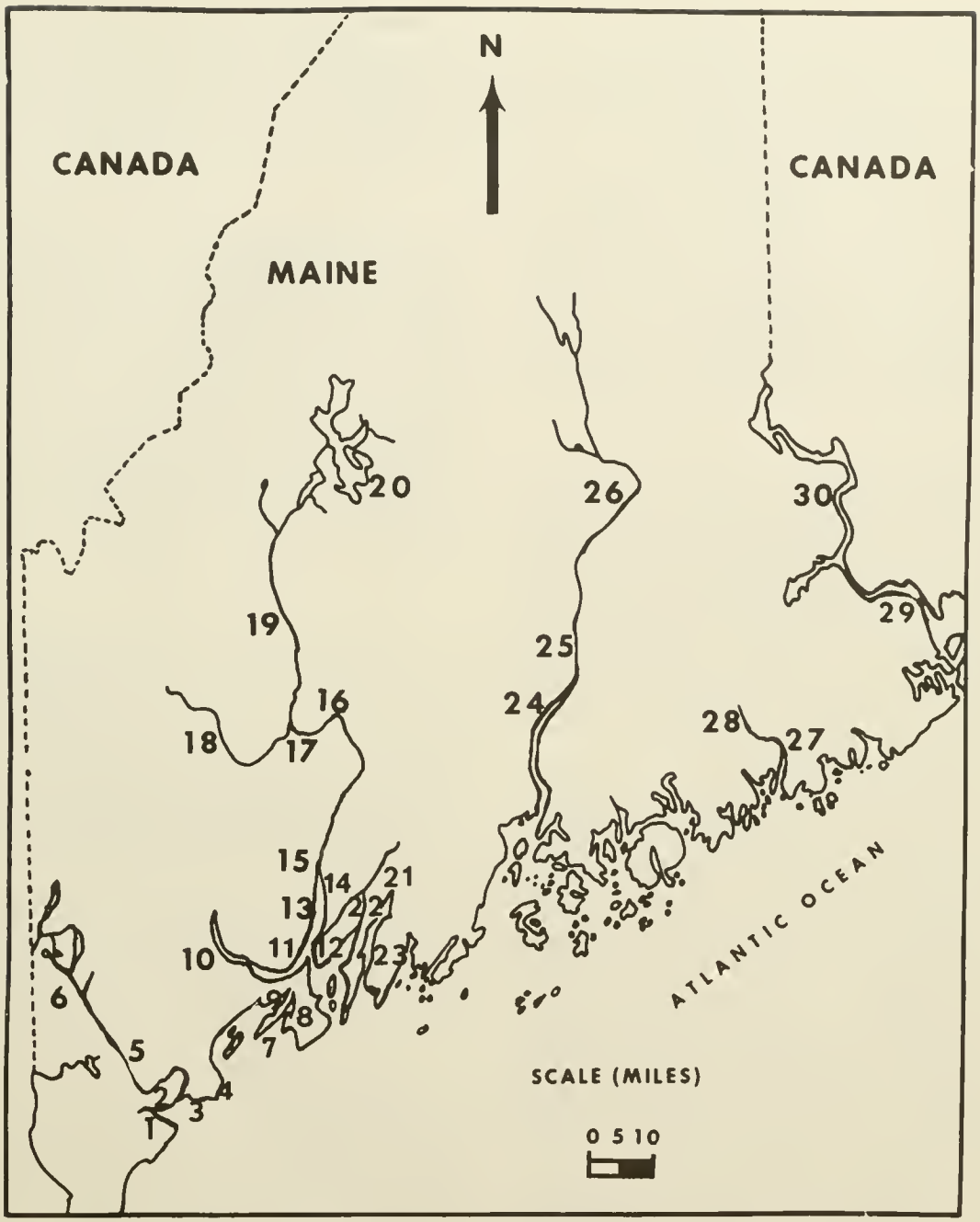

Figure 27.--Map of Maine.

Key:
1 Biddeford
2 Pine Point
3 Saco Bay
4 Prouts Neck
5 Nonesuch River
6 Hiram
7 Casco Bay
8 Georgetown
9 Brunswick
10 Androscoggin River
11 Bowdoinham
12 Swan Island
13 Merrymeeting Bay
14 Iceboro
15 Augusta
16 Skowhegan
17 Norridgewock
18 Sandy River
19 Kennebec River
20 Moosehead Lake
21 Eastern River
22 Alna
23 Sheepscot River
24 Bangor
25 Oldtown
26 Penobscot River
27 Columbia Falls
28 Pleasant River
29 Calais
30 St. Croix River

Casco Bay

Shad were taken in Casco Bay from 1855 to 1895, but the yield decreased considerably during the 1890's (Stevenson, 1899). They appeared in these waters from about May 1 until the end of September. The fish were smaller and presumably younger than those in the rivers, and were commonly known as "sea shad." In 1896, 246,971 lb. were taken in the Bay, of which 154,429 lb. were caught by seines, 69,143 lb. by traps and weirs, and 23,399 lb. by drift gill nets.

The only commercial shad landings reported for Maine in 1960 were from Casco Bay. Gill nets caught 311 lb., and an occasional fish was captured by otter trawl.

Kennebec River

The Kennebec River has its source in Moosehead Lake, the largest body of fresh water in Maine. It flows south 155 miles to the sea, entering immediately east of Casco Bay. Shad formerly ascended the Kennebec River as far as Norridgewock Falls, 84 miles from the sea, where they turned aside into a small tributary known as Sandy River (Stevenson, 1899). Dip net fisheries were productive at Ticonic Falls and at Skowhegan, Maine, and weirs were operated at Abagodasset Point and in Merrymeeting Bay.

The fishery of the Kennebec in 1896 was the most important on the Atlantic coast north of the Hudson River. The yield was greater than all the remaining waters of the New England States. The fishery extended from the mouth of the river to near Augusta. The total catch was 962,505 lb., of which weirs took 787,156 lb. and drift nets 175,349 lb. Weir fishing was carried out in the Kennebec chiefly between Iceboro, Maine, 3 miles above Swan Island, and the Chopps, a narrow part of the river below Swan Island. Numerous drift gill nets were fished in Merrymeeting Bay, but most extensively near Bowdoinham, North Bath, and Georgetown, Maine. These nets averaged slightly more than 300 ft. long, and the mesh size was from 4 5/8 to 5 1/4 in. Shad were taken from May 1 to June 25.

The decline of the fishery in the Kennebec was gradual and did not become serious until the early 1900's. The eventual disappearance was believed to have been caused by industrial pollution from Augusta to Merrymeeting Bay. Vast quantities of sawdust were run into the river from numerous sawmills; the river bottom was covered in many places. Industrial pollution from the Androscoggin River, a tributary of Merrymeeting Bay, also was carried through the Bay and probably up the Kennebec by tidal action. By 1918 the catch was so small that the species was no longer mentioned in the Reports of the Maine Commissioner of Sea and Shore Fisheries (Taylor, C.C. 1951).

Merrymeeting Bay Tributaries

Merrymeeting Bay is a broad expanse of water in the lower Kennebec River. It is formed by the confluence of the Androscoggin, Cathance, Abagadasset, and Eastern Rivers. All but the Abagadasset formerly contained shad.

Androscoggin River.--This river, the principal tributary of the Kennebec has its sources partly in Maine and partly in New Hampshire and flows 160 miles to Merrymeeting Bay. Although it was never considered a shad river because of impassable falls at Brunswick, Maine, the 5-mile section between Brunswick and the Bay was fished regularly. In 1896, 51,357 lb. of shad were taken, of which 24,433 lb. were caught in weirs, 21,065 lb. in seines, and 5,859 lb. in drift nets. Industrial pollution, a serious problem in the Androscoggin for many years, made it unsuitable for fish. The Androscoggin was believed to be the chief source of pollution in the Merrymeeting Bay area (Taylor, C.C. 1951).

Cathance River.--The Cathance River enters the western side of Merrymeeting Bay. This river in early 1900's was an important shad fishing area, both below and above Bowdoinham (Taylor, C.C. 1951). The most productive fishing was from 1 1/2 miles above the town to the Bay. In the early 1940's, the river was fished with gill nets, and as many as 13 shad were taken nightly. Nets have not been fished here in recent years, but it is believed that small numbers of shad enter the river each year.

Eastern River.--The Eastern River, although it does not flow directly into Merrymeeting Bay, usually is considered a part of the Bay district. This river, with a 10-mile tidal portion, enters the Kennebec on the eastern side of Swan Island. It was formerly one of the most productive shad areas in the district. In 1896 this river yielded 97,207 lb. of shad--85,718 lb. in weirs and 11,489 lb. in drift nets. A few shad were taken in this river in the early 1940's, but it has not been fished since (Taylor, C.C. 1951). This stream probably supports a remnant run.

Sheepscot River

The Sheepscot River enters the ocean through a long tidal estuary east of the entrance of the Kennebec River. The two rivers are connected between Bath, Maine, and Hockomock Bay by a navigable channel, the Sasanoa River. The Sheepscot originally contained more shad than any other stream between the Kennebec and the Penobscot (Atkins, 1887); however, no information was given on the number of shad

taken. Impassable dams at Alna, Maine, the head of tidal waters, blocked movement of fish for many years. The Sheepscot River, below Alna, has maintained a small run through the years, and a few shad were taken by gill nets in 1950 (Taylor, C.C. 1951).

Penobscot River and Bay

This stream is the largest on the Atlantic coast of the United States north of Connecticut. Its sources are in extreme western Maine near the Canadian boundary, from whence it flows over 200 miles to its entrance into Penobscot Bay, 30 miles below Bangor, Maine.

Originally, shad was the most abundant fish in the Penobscot. In the early 1800's more fish were taken than could be locally consumed. Abundance declined rapidly after the construction of the dam at Bangor in 1830 because of the decrease in the extent of spawning grounds. Only 114 fish (436 lb.) were taken in 1896.

Pleasant and Harrington Rivers

Neither of these rivers maintained shad populations. A dam at Columbia Falls on the Pleasant River is only a few feet from salt water. The Harrington River is small and has a steep gradient (Taylor, C.C. 1951). Shad fisheries in these areas depended on annual runs entering bays and estuaries during their coastal migrations. The 1896 catch in the Pleasant River was 34,466 lb.; in the Harrington River it was 11,489 lb.

Some shad were taken in the Pleasant and Harrington River estuaries each year by drift nets that were fished in late May and early June (Taylor, C.C. 1951). Fish caught were consumed locally, and no estimate of the catch was available in 1960.

Saint Croix River

The Saint Croix River, for a portion of its length the boundary between Maine and New Brunswick, Canada, formerly abounded in shad and other anadromous fishes (Atkins, 1887). Beginning in 1825, the fishery declined when the river was closed off by dam construction. The first dam was at Calais, Maine, just above the head of tide. A few fish were caught each year in herring weirs of the lower river. In 1896, 46 pounds were taken in the Saint Croix. None has been reported in recent years.

TRENDS IN PRODUCTION

The catch records for shad in Maine are available for most years 1887 to 1960 (table 53). The highest recorded catch was in 1912, 3,296,000 lb.; the lowest was in 1960, 311 lb. The catch was high between 1887 and 1919, from 414,000 to 3,296,000 lb. Later, except for 1,107,000 lb. in 1946, the annual catch has been small, ranging from 311 to 441,000 lb. Since 1948 the annual catch has averaged 15,000 lb.

The disappearance of shad in Maine was due almost entirely to their exclusion from spawning areas by dam construction (Taylor, C.C. 1951). The major exceptions were the Kennebec River and Merrymeeting Bay systems, where pollution was believed to be the major cause. Very few shad have been taken in Maine rivers since 1918. The catch has been composed largely of fish from Atlantic coast streams that spend the summer in the Gulf of Maine.

Table 53.--Shad catch for certain years, Maine, 1887-1960[1]

[In thousands of pounds]

Year	Catch	Year	Catch	Year	Catch
1887. . . .	1,096	1914[2] . . .	2,086	1944. . . .	441
1888. . . .	839	1916[2] . . .	667	1945. . . .	15
1896. . . .	1,404	1919. . . .	414	1946. . . .	1,107
1898. . . .	862	1924. . . .	244	1947. . . .	304
1900[2] . . .	820	1928. . . .	110	1948. . . .	3
1901[2] . . .	731	1929. . . .	36	1949. . . .	5
1902. . . .	849	1930. . . .	89	1950. . . .	2
1903[2] . . .	1,144	1931. . . .	158	1951. . . .	76
1904[2] . . .	1,259	1932. . . .	108	1952. . . .	50
1905. . . .	667	1933. . . .	179	1953. . . .	27
1906[2] . . .	470	1935. . . .	13	1954. . . .	2
1907[2] . . .	873	1937. . . .	9	1955. . . .	7
1908. . . .	770	1938. . . .	12	1956. . . .	2
1909[2] . . .	980	1939. . . .	8	1957. . . .	8
1910[2] . . .	847	1940. . . .	65	1958. . . .	10
1911[2] . . .	1,386	1941. . . .	48	1959. . . .	2
1912[2] . . .	3,296	1942. . . .	161	1960. . . .	([3])
1913[2] . . .	2,088	1943. . . .	272		

[1] Statistics 1887-1959, U. S. Fish Commission, U. S. Bureau of Fisheries, and U. S. Fish and Wildlife Service, except 1914, 1916, and 1960.

[2] Taylor (1951).

[3] Catch 311 pounds (U. S. Fish and Wildlife Service, 1961b).

TRENDS IN SHAD PRODUCTION OF THE ATLANTIC COAST OF THE UNITED STATES

The shad catch in each river or State fluctuates independently with local conditions, and only by comparing the yield from the entire coast or a large area of the coast can changes in total production be demonstrated. Complete catch statistics for the Atlantic coast of the United States are available only for certain years. The long-range trends are nevertheless evident (table 54 and fig. 28).

According to Stevenson (1899), 1880 was the earliest year for which reliable data were available on shad production for the entire

Atlantic coast. The total catch in that year, 18,068,102 lb., was reported to be a decline in yield. After 1880, however, improved methods of capture and more vigorous prosecution of the fisheries resulted in a considerable increase in production. In 1888 the yield was 35,636,618 lb. (97-percent increase over 1880). In 1896 the fishery reached its peak production of 50,498,860 lb. Productivity was still high in 1908 when more than 25 million pounds were taken. After 1908 production declined, and by 1932 was less than 10 million pounds. Since 1932 the catch has remained low--between 14,699,000 lb. in 1945 and 7,799,000 lb. in 1953. The 1960 yield showed an increase of 5 percent from 1953, but was only 16 percent of that in 1896.

In the first half of this report, we gave an account of the comparative abundance of shad in each river or area, and conditions in each locality were described. In the final portion, the factors responsible for the decline in production are discussed, as well as the methods that are or might be used to rehabilitate and manage the fishery.

Table 54.--Shad catch for certain years, Atlantic coast of the United States, 1880-1960[1]

[In thousands of pounds]

Year	New England states	Middle Atlantic states	Chesapeake Bay states	South Atlantic states	Total Atlantic coast
1880	2,096	5,093	6,946	3,933	18,068
1887	1,622	12,775	7,856	7,377	29,630
1888	1,398	12,745	11,925	7,869	33,397
1896	1,833	20,605	16,712	11,349	50,499
1908	1,285	4,827	11,251	8,572	25,935
1929	461	622	9,526	3,346	13,955
1930	201	450	7,181	2,541	10,373
1931	401	660	8,487	1,788	11,336
1932	232	643	6,515	1,882	9,272
1937	445	4,394	3,491	1,317	9,647
1938	503	3,592	4,207	1,418	9,720
1939	530	4,132	4,183	1,230	10,075
1940	574	4,788	3,257	1,345	9,964
1945	818	5,900	5,916	2,065	14,699
1950	296	1,802	4,474	1,651	8,223
1951	492	1,254	4,849	1,882	8,477
1952	577	2,240	5,643	2,061	10,521
1953	431	1,230	4,502	1,636	7,799
1954	308	1,588	4,670	2,102	8,668
1955	259	1,973	4,964	1,403	8,599
1956	924	2,032	5,283	1,433	9,672
1957	2,556	2,014	5,274	1,525	11,369
1958	893	1,667	4,154	1,472	8,186
1959	1,789	1,726	3,255	1,430	8,200
1960	1,159	1,154	2,795	3,026	8,134

[1] Data 1880-1959, statistical publications of the U. S. Bureau of Fisheries, and U. S. Fish and Wildlife Service.

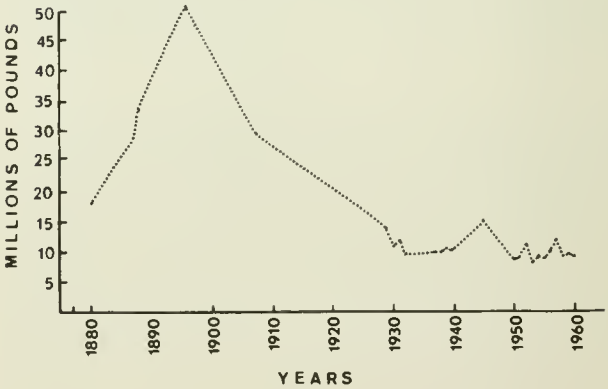

Figure 28.--Shad catch, Atlantic coast of the United States, for certain years, 1880-1960.

FACTORS AFFECTING DECLINE IN ABUNDANCE

Stevenson (1899) stated that the fishery had undergone great changes during the 19th century and that there were few fishes other than the shad whose geographical range and local abundance were more easily affected by man. In some areas a decline in abundance had begun previous to 1880, though this change was not well documented. Construction of dams had excluded shad from many of the historical spawning grounds. Sawdust, chemicals, assorted refuse, and agricultural operations had greatly impaired the utility of available spawning grounds. In his comparison of the yield of the entire coast in 1880 and 1896, Stevenson pointed out, however, that the catch had increased more than 57 percent. He further stated that increased yield followed an increase in the quantity of gear used. In 1896, 45 percent of the catch was from areas which half a century before had yielded no shad. Thus, it appears that one of the principal changes in the fisheries prior to Stevenson's study was location of exploitation rather than the change of total yield.

The commercial production of shad on the Atlantic coast has decreased about 84 percent since 1896. Many factors have been blamed for the decline. Among these were: physical changes of the environment which rendered it unsuitable for spawning or which influenced survival of eggs and larvae; construction of dams which barred fish from fresh-water spawning areas; pollution which rendered rivers unsuitable for reproduction and survival of this species; overfishing which did not allow enough fish to spawn and replace those taken by the fishery; and natural cycles of abundance.

One of the purposes of the shad investigation begun by the Fish and Wildlife Service in 1950 was to determine causes for decline in abundance of the species and to suggest

management measures whereby the populations might yield sustained high catches. In general, before factors affecting abundance of this fish could be determined, information on size of runs or populations for a period of years was necessary. Scientific evaluation of population changes and of factors that could affect abundance were used to determine if any significant cause-and-effect relation existed.

The following discussion of factors of shad abundance includes the most recent information available.

PHYSICAL CHANGES

Decrease in shad abundance on the Atlantic coast has paralleled many physical changes in the river environment (natural and man-made) such as channel improvements, changes in stream flow, siltation, and changes in water temperature. Few data existed on which to base a valid evaluation of the effects of these physical changes on the entire coastal production. One exception was data on the Hudson River, for which catch and effort data for 37 yr., plus information on physical changes in the environment, were available (Talbot, 1954).

The Hudson River fishery declined at the turn of the century, recovered beginning in 1936, and again declined beginning in 1945. Many factors have been suggested for these changes in the fishery.

Dredging in the spawning grounds would change the physical condition of the area and possibly render it unsuitable for spawning. Also, careless placing of spoil from disposal of dredged material could affect abundance by reducing the spawning grounds and limiting nursery areas. In the Hudson, one of the most extensively dredged rivers on the Atlantic coast, Talbot (1954) concluded that these operations had no measurable adverse effect on shad abundance from 1915 to 1951. Any changes prior to 1915 could not be documented however.

Variation in stream flow could affect shad abundance directly by influencing survival of eggs and larvae, or indirectly by diluting or flushing pollutants into the river. From studies on the Hudson River, Talbot (1954) concluded that any effect this variable had on fish abundance was obscured by other conditions.

Variation in water temperature during time of spawning conceivably could affect survival of eggs and larvae, hence population size in subsequent years. Talbot's (1954) investigation of the influence of this factor on abundance of Hudson River shad stocks, 1929-51, indicated no relation. Neither trends in water temperature nor variations in average temperature could be found which might account for the deviations between predicted and calculated population sizes.

In the Connecticut River water temperature and stream flow exhibited no changes or trends that would account for the changes in the total shad population or the deviations from the predicted populations (Fredin, 1954).

DAMS

The construction of dams is recognized as an important factor in the decline of shad on the Atlantic coast. Obstructions built on rivers ascended by shad have been discussed in the geographical section of this report.

How dam construction affects shad depends on the location of dams in relation to spawning areas. Runs were eliminated in rivers where dams were built immediately above salt water. Dams built within spawning areas probably reduced populations in proportion to the amount of natural spawning area destroyed. Dams built above natural spawning areas probably had little or no effect on fish abundance, provided normal river flows were maintained.

Most dams were constructed during the 19th century, and they were most common in the New England States, where development of water resources played an important role in industrial growth. The terrain allowed development of a large amount of waterpower with relatively small structures. Southern rivers were not so suitable because of the flat coastal areas. In recent years, however, dams were built in the south for power, flood control, navigation, and more recently for cooling, particularly for steam-electric plants.

The disappearance of shad from such rivers in Maine as the Mousam, Kennebec, Penobscot, and Saint Croix was almost entirely the result of their exclusion from spawning areas by dams (Atkins, 1887; Taylor, C.C. 1951). In 1896 dams had closed about 3,700 miles of rivers along the Atlantic coast which shad had formerly used, and these obstructions were one factor that had helped reduce natural reproduction almost to insignificance.

Mansueti and Kolb (1953) stated that dams apparently were not the major factor in the decline of shad production along the Atlantic coast for the past 50 yr. Some areas, however, offered exceptions. The Holtwood and Conowingo Dams on the Susquehanna River completely eliminated shad from Pennsylvania waters. Lock and Dam No. 1 on the Cape Fear River in North Carolina closed off more than 100 miles of spawning and nursery area. Santee-Cooper Dam on the Santee River in South Carolina blocked more than 200 miles of spawning and nursery area.

Fish-passage facilities have alleviated in some measure the loss of spawning and nursery areas by dam construction. These facilities are discussed in another section of this report.

POLLUTION

Industrial and domestic pollution has been cited by many workers as a major factor in the decline of shad abundance (fig. 29). The decline in the shad fishery in the Saco River in Maine was attributed to the pouring of dyes from cotton and woolen mills into the river (Atkins, 1887). Industrial pollution from textile and paper mills destroyed the fishery in the lower Androscoggin River in Maine as early as 1884 (Taylor, C.C. 1951). Stevenson (1889) cited many examples of individual river populations destroyed or severely reduced by pollution prior to 1896. In the lower Delaware River, the dissolved oxygen in autumn was too low for safe passage of downstream migrant juveniles (Ellis, Westfall, Meyer, and Platner, 1947). Later information of Sykes and Lehman (1957) proved that oxygen content of the lower Delaware River during both summer and fall remained low because of continued pollution; safe passage of juvenile fish to the sea depended on river flow sufficient to dilute pollution. Heavy pollution in the lower Delaware during the migration of adults into the river for spawning resulted in high mortality.

Pollution of the Hudson River has offered a serious problem and perhaps has been an important factor of shad abundance (Talbot, 1954). Unfortunately, lack of records to show changes in pollution in the spawning and nursery grounds prevents any possible demonstration of a cause-and-effect relation.

It is certain that pollution has increased over the years in most streams. No exact measure of it exists that might be studied along with population statistics; hence no definite conclusions can be drawn for most streams.

Figure 29.--Thousands of dead young American shad, spawned in the spring of 1954, in the Anacostia River near Sousa Bridge, Washington, D.C. (Photograph courtesy of Charles Del Vecchio, Washington Post-Times Herald)

OVERFISHING

For many years, decline in shad stocks has been attributed to overfishing. Numerous examples have been cited where overfishing was blamed for decreased catch even before 1850 (Stevenson, 1899). Stevenson theorized that in 1896 heavy fishing in river mouths which prevented fish from reaching their spawning grounds was a major cause of depletion. Although overfishing has been named as a major cause for decline, proof of this allegation in specific areas was not forthcoming until recent years.

Shad must migrate up rivers enroute to spawning grounds and are particularly vulnerable to fishing. Rivers can be so heavily fished that much of the migrating population is captured. A certain minimum number of fish must escape capture and spawn to replace those taken by the fishery, or depletion follows.

Most shad mature and spawn at an age of 4 or 5 yr., and fish native to streams from Virginia northward may spawn more than once. The run in any year, therefore, generally is composed of fish hatched 4 or 5 yr. earlier, plus those surviving from the previous spawning or spawnings. If appropriate population statistics are available on a fishery for a period of years, statistical methods usually can be used to evaluate the effect of fishing on the population.

Recent studies on the Connecticut and Hudson Rivers, both of which formerly produced at a high level but have fluctuated greatly, revealed that over 80 percent of the annual variation in population size was caused by changes in the size of the spawning escapement (Fredin, 1954; Talbot, 1954). These studies clearly indicated that overfishing caused the decline of these shad populations, at least during recent years. A decrease in fishing effort led to an increase in abundance in both rivers. Since catch and effort statistics were available for only these two rivers, the effect of fishing on the entire Atlantic coast population could not be evaluated. It can be suspected strongly, however, that abundance of shad populations in the other rivers could be influenced by changes in fishing effort.

NATURAL CYCLES IN ABUNDANCE

Populations of marine animals fluctuate widely in abundance; but causes for these changes are poorly understood. They may be due to the effects of man, changing environment, or natural factors that operate independently of others. It has been suggested that cyclical fluctuations in abundance of shad stocks have occurred which may not be related to man's activity and that the period is

not entirely irregular. Talbot (1954) showed that no cycles of abundance were indicated by available Hudson River data. In the present study, available statistics on the shad catch for the entire Atlantic coast, and for individual States, were examined to see whether a regular pattern of natural fluctuation had occurred; none was found.

REHABILITATION AND MANAGEMENT

To obtain sustained yields in the shad fishery, factors affecting abundance must be determined and in turn manipulated so that the population may increase to the optimum size. Studies on management of fishery resources have indicated that the economics of the fishery also must be considered in any plan to obtain maximum yields. It appears that the maximum sustained yield may not offer the maximum economic yield and that the best management of the resource probably can be accomplished by a compromise between these interests (Graham, 1956; Crutchfield, 1960).

Methods used to rehabilitate and manage shad are artificial propagation, improving passage of fish over barriers, and regulations of the fishery. In addition, a program of pollution control has been adopted by most States, and this control may influence abundance.

HATCHERIES

The systematic development and extension of the technique of shad culture were undertaken to test the value of artificial propagation in maintaining an important fishery that was being rapidly depleted (Brice, 1898; Leach, 1925). As early as 1848, eggs were artificially taken and fertilized. Rearing experiments were undertaken in the Connecticut River area in 1867 and later in the Potomac with encouraging results. The attention of many States was attracted to the work, and in 1872 it was taken up by the Federal Government. Experiments were conducted with various kinds of floating boxes and jars for hatching, and in 1882 the McDonald universal hatching jar was adopted as standard equipment. Prior to 1872 deposits of a few thousand fry were made in as many different streams as possible, but by 1880 shad culture was established on a large scale, and it was possible to ship and plant several hundred thousand. From 1872 to 1880, 97,471,700 shad fry were planted in streams, beginning with 850,000 in 1872; in 1880, 26,626,000, were distributed. Federal shad-culture was centered in the Chesapeake and Delaware Bays, and State commissions from Massachusetts to South Carolina operated hatcheries. Every river on the Atlantic coast from Massachusetts southward was examined by agents of State commissions, the Federal Government, or both to determine the natural spawning grounds of shad. Hatcheries were located on nearly every stream at one time or another, and the Bureau of Commercial Fisheries and its predecessors followed a policy of stocking shad fry regularly in important streams of the Atlantic seaboard.

The hatchery methods were very simple. In advance of the spawning season, fishermen operating within a reasonable distance of the hatchery were provided with pans and other necessary equipment to take and care for the eggs. When females in spawning condition were caught, ripe eggs were stripped into pans. After milt was stripped from ripe males, water was added, and the pan was given a slow rotary motion for thorough mixing of the sex products. After this mixing, the eggs were washed and held in water until the end of the day's fishing, and then delivered to the hatchery. After the eggs had been in the hatchery for 48 hours (at the expiration of which time mortality has practically ceased), all good eggs remaining were placed in hatching jars. After hatching, the young passed from the jars by an overflow spout to collection tanks, from which they were distributed to the streams. The time from egg collection to fry distribution was usually 5 to 10 days.

Leach (1925) reported on the difficulties of large-scale hatchery operations. Ripe fish seldom could be found except from 4 to 10 p.m. Fish taken earlier were not sufficiently ripe for stripping, and those taken later usually were spent. As a rule, the best eggs were secured from fish caught by gill nets. This gear, most effective at night, customarily was lifted during the last stages of the ebb tide and the beginning of the flood. Hence, even though other conditions may have been favorable, eggs were obtained only when the proper stage of tide coincided with the spawning hours of the fish. The scarcity of male fish toward the end of the season often terminated operations when eggs were plentiful. Fry in transit had to be kept in containers with smooth surfaces. About 2,000 to 3,000 were allowed to a gallon of water, and the water in the vessels had to be well aerated and kept at 58° to 65°F.

Over a period of about 60 yr., the Federal Government planted shad in most of the Atlantic coast rivers, but the results did not justify continuing the work. Despite hatchery operations, the runs declined. Consequently, all shipments of eggs and fry to areas outside the location of hatcheries were ended, and all fry were returned to local spawning grounds. Federal operation of shad hatcheries generally was curtailed in 1935 and ceased entirely in 1950 when the Fort Belvoir hatchery was

released to the Maryland Department of Research and Education. The scarcity of shad in the early thirties and the difficulty of obtaining enough fish in spawning condition to fill hatcheries caused many States to abandon or greatly deemphasize their programs by 1940. In 1960 only Virginia was hatching shad, and these operations were limited to a small scale in the Pamunkey, Mattaponi, and Chickahominy Rivers.

Hatcheries, as operated, did not maintain shad runs--as shown by the steady decline in populations. To evaluate the effect of shad propagation on subsequent runs, Talbot (1954) studied factual information on hatchery operations and estimated the size of the total populations entering the Hudson River in 1915-50; he found no correlation between the two variables. Talbot also reported that the number of eggs obtainable for hatchery operations is only a minute fraction of the amount spawned naturally; the increased survival rate, if one exists from current shad hatchery practices, has not produced and cannot be expected to produce an increase in the shad population. Studies on the Connecticut River revealed findings similar to those on the Hudson.

Progress might be made in hatchery techniques that would justify their re-establishment for propagation of shad. As practiced in past years, however, propagation cannot now be justified as a means of sustaining or increasing the catch.

FISHWAYS

It was recognized early that where dams obstruct upstream passage of anadromous fish, fishways should be provided to enable adults to reach upstream spawning areas. Fishways constructed during the late 1800's and the early 1900's failed to pass fish (fig. 30). One exception was a fishway constructed in the Lackawaxen Dam on the Delaware River in 1890, which reportedly passed large numbers of shad for a period of about 10 yr. before the dam was destroyed by ice (New York Conservation Commission of Fisheries, 1891). Unfortunately, no records were available to indicate the design of this structure. In the early 1900's because of the failure of fishways, it was generally thought that shad would not use fish-passage devices. For this reason, no fishway was included in Conowingo Dam, which was completed in 1928 on the Susquehanna River in Maryland. With the continued decline in production during the 1930's, conservationists explored means of restoring this fish to greater abundance. Successful passage of shad through fishways at Bonneville Dam, completed in 1937 on the Columbia River on the West Coast, brought renewed efforts for workable fishways in Atlantic coast dams.

Figure 30.--Ineffective fishway on a lock and dam, Cape Fear River, N.C. The structure is on the far river shore, and little if any water passes through the transportation chamber during the months adult shad would be present.

One of the aims of the shad investigation begun in 1950 was to determine suitable methods for passing this fish over obstructions. The only fishway in operation on the East Coast which successfully passed shad was in the Essex Company Dam, completed in 1919 on the Merrimack River, at Lawrence, Mass. Collins (1951) outlined the distinctive features of this ladder-type fishway, built to pass fish over a 30-ft. rise, and estimated that the number of shad ascending the fishway annually ranged from 1,500 to 3,000. Talbot (1953) presented a summary of observations on the use of the Bonneville fishways by shad and the physical factors associated with passage. The total head of Bonneville Dam, that is, the height to which fish must climb in the fishways, ranges from 40 to 60 ft. but most commonly is about 50 ft. During the 22-yr. period, 1938-59, the average annual passage of shad at this structure was 15,475. In 1960, 93,368 shad passed the dam (U.S. Army Corps of Engineers, 1959, 1961).

A system for passing shad was completed at Hadley Falls Dam on the Connecticut River at Holyoke, Mass. in 1952 (fig. 31). The average distance between headwater and tailwater elevation at this structure is 50 ft. This system consisted of an attraction chamber, a pressure lock device which enabled fish to reach the forebay level, and an exit flume. After 3 yr., the pressure lock device was abandoned because it failed to pass migrating fish in sufficient numbers to justify its operation; it was replaced with a trap and a bucket lift. Fish were dip netted manually from the trap to buckets (fig. 32), hoisted to the forebay level, and dumped into the exit flume (fig. 33).

Figure 31.--Hadley Falls Dam, Connecticut River, Holyoke, Mass. Entrance and fish attraction channel on right of power plant tailrace.

Figure 32.--Dip netting shad from trap to buckets for hoisting fish to fish-lift flume, Hadley Falls Dam, Connecticut River, Holyoke, Mass.

Figure 33.--Dumping shad into exit flume, Hadley Falls Dam fish-lift, Connecticut River, Holyoke, Mass.

Although a crude operation, it has passed considerable numbers of fish. The number of shad passed has increased progressively from 35 in 1952 to 15,076 in 1960. To increase efficiency, the present system could be converted to an automatic operation, whereby the complete trap is raised to forebay level and the fish automatically released directly into the exit flume.

A pool-type fishway was installed in a 7-ft. high dam on the Neuse River at Goldsboro, N.C., in 1952; the estimated shad passage in 1953 was 440 fish (Walburg, 1957).

A vertical, baffle-type fishway was completed in 1960 in the Little Falls Dam, Potomac River, immediately north of Washington, D.C. This fishway was designed to pass fish over a maximum headwater-tailwater elevation of 9 ft. In the spring of 1960, the fishway passed resident species of fish, but shad did not migrate upstream to this structure.

Most modern fishways have a collection system or channel which collects fish from one to several entrances and attracts them to a single fish-passing facility. Collection systems for shad should have a minimum width of 8 ft. and a minimum water depth of 4 ft. Velocities in the system should not exceed 2 to 3 f.p.s. (feet per second). The entrance to the collection system should be at least 4 ft. wide, preferably 6 ft., and have a depth of at least 1 ft., preferably 3 ft. The velocity through the entrance of the collection system should be about 6 f.p.s. but should not exceed 7 f.p.s. nor be less than 5 f.p.s. These flows, which are usually more than required in the fishway, can be maintained through diffusion grates in the floor of the collection system.

Attraction of fish from a large river into a comparatively small collection system is the most difficult problem to overcome. Once it has been accomplished, several methods can be used to pass fish over a dam. The pool-type fishway, consisting of a series of pools, each higher than the next pool downstream, is probably one of the oldest. Fish ascend by swimming against the water flow from one pool to the next. For shad, the difference in pool elevation should be 0.75 ft. Minimum size pools should be 8 ft. long and 8 ft. wide, and minimum water depth should be 4 ft. Size of pools depends on the number of fish expected to use the facility. The weir over which water flows from one pool to the next can be full width or half width or can have almost any arrangement that allows adequate space for fish passage. Each pool must be hydraulically balanced so that there is no energy carryover by the cascading water from one pool to the next. Velocity in resting areas of pools should not exceed 1 f.p.s. This type fishway usually requires some adjustment with changes in tailwater and forebay elevations. The adjustment is made by having a level flume at the upper end into which stoplog baffles can be placed to add additional weirs as forebay elevations increase.

Fish locks also are used in some areas for passage of migrating fish over obstructions. These structures are similar to boat locks. At tailwater, attraction water is supplied through the floor of the lock and flows out through a gate into the tailrace. Fish are attracted into the lock chamber by this flow, and a trap device prevents them from leaving. At regular intervals, or when sufficient fish are trapped, the lower gate is closed and the lock filled until forebay elevation is reached. An upper gate is then opened, and the fish are free to leave. To speed operation, a brail may be used to force the fish from the lock chamber into the river above. When the fish are out, the upper gate is closed, the lock is dewatered, the lower gate is opened, and the cycle repeated. Minimum size for fish locks and traps for shad passage is 8 ft. by 8 ft. with a minimum water depth of 4 ft. Actual size of the lock depends on the number of fish to be passed.

On the Pacific coast, several different types of devices are used to enable shad to migrate upstream past dams. Shad ascend pool-type fishways at Bonneville, The Dalles, and McNary Dams on the Columbia River to elevations of 40 to 90 ft. (U.S. Army Corps of Engineers, 1959). They probably would ascend higher dams if fishways were installed. Fish locks in McNary Dam also have passed shad, and locks in Bonneville Dam were almost as effective as the pools in assisting shad over the dam (Talbot, 1953). Shad in the Sacramento-San Joaquin Delta water developments in California used in experimental vertical-baffle-type fishway, the type first developed at Hells Gate on the Fraser River in British Columbia, Canada (Fisk, 1959).

At the present stage of engineering and biological knowledge, the problem of passing shad over obstructions to upstream spawning areas is not too difficult. The problem of safe passage of young and adults back downstream has not yet been adequately solved, however. Usually they must pass through turbines or over spillways of the dam. Both means of descent can cause considerable mortality. Limited studies on migrant juvenile shad through a system of canals by way of low-head turbines at the Hadley Falls Dam on the Connecticut River indicated that the fish descended with little mortality[10].

Progress in devising methods for safe passage of downstream migrant fish at dams has not been very successful. Many guiding

[10] Unpublished report. Mortality of downstream migrant juvenile shad, Holyoke Water Power Company canal system, Connecticut River, 1957-59 by C. H. Walburg and P. R. Nichols, Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N.C. 24 p.

mechanisms have been tried, and some have shown great promise in pilot studies, but none has proved successful at full-scale installations. These guides included electrical screens, sound, air bubbles, and skimmer nets. Considerable work currently is in progress by both Federal and State agencies to find a safe method of passing young salmon downstream over dams (Andrew and Geen, 1960). These methods, if perfected, will probably be applicable to shad and other species.

REGULATIONS

Fishery management has been defined as the institution of various measures or regulations to establish or permit a fishery to produce the optimum yield from a given stock of fish (Herrington, 1943).

Restrictions on shad fishing were among the earliest fishery management measures established in the United States. By 1896 almost every Atlantic Coast State had laws setting seasons, regulating size and meshes of nets, and sometimes restricting catch (Stevenson, 1899). The purpose of these laws was to prevent the decline in shad, which began as early as 1830 in New England (Atkins, 1887; True and Wilcox, 1887). Laws varied from State to State, but adjacent States usually had similar regulations.

Management of shad resources to obtain high yields has been attempted through regulations and licensing schemes which seek to reduce size of catch by limiting the number of fishermen and kind, amount, and mesh size of gear fished; establishing location of fishing areas, fishing seasons and rest days; and establishing size limits on fish landed. Regulations in effect in 1960 are given in the discussion of the fisheries of each State. Establishment of rest days to reduce fishing effort, and thereby allow more fish to spawn, has been used effectively by New Jersey, New York, and Connecticut. The Maryland Fishery Management Plan, begun in 1941, was established to stabilize fishing effort by limiting the number of fishermen and the amount of gear and to maintain the fish population at a high level. When the plan was established, no biological studies were made to determine the size of the Maryland shad population and the spawning escapement necessary to maintain abundant fish stocks. The Maryland Plan has merit, but it apparently was not put into effect successfully, however, because fishing effort was not stabilized (Walburg, 1955).

In recent years, many Atlantic Coast States have established regulations to reduce or prohibit deposition of industrial and domestic pollution into rivers and streams. These regulations indirectly benefit shad populations by improving the water quality in spawning and nursery areas.

The Interstate Commission on the Delaware River Basin (INCODEL) was established in 1936 by the States of New York, New Jersey, Delaware, and Pennsylvania to formulate and administer a program for utilizing the waters of the Delaware River Basin. This organization has sponsored many conservation developments including a stream-pollution control program. For many years the Philadelphia-Camden area of the Delaware River has been heavily polluted with industrial waste and domestic sewage. This condition caused the extinction of the Delaware River shad population (Sykes and Lehman, 1957). Since Sykes and Lehman's study, water quality has improved in the Philadelphia-Camden area of the Delaware; yet, the dissolved oxygen ranged from 1.5 to 3.5 p.p.m. from May to September in 1959 (written communication from Water Department of the City of Philadelphia, dated May 4, 1961). These values are below those tolerable to shad (Tagatz, 1961). Through the efforts of INCODEL, more than 300 municipal and industrial waste-treatment plants were constructed along the river and tributaries between 1946 and 1957. Further pollution abatement is expected, and stocks of anadromous fish may eventually increase in the Delaware River.

ECONOMICS AND MARKETING

Shad were abundant in colonial times and were a staple food for many years. As the fishery developed, so many fish were taken each season that they could not all be marketed as food and some were sold for fertilizer. As the human population increased and shipping facilities improved, the demand for shad also increased.

No fish was more important than the shad to residents of the Atlantic seaboard in 1896. The yield was more than 50 million pounds, valued in excess of $1.6 million. In 1908 the shad ranked third in value among the fisheries of the United States and was surpassed only by salmon and cod (Bureau of the Census, 1911). Shad ranked second in volume, surpassed only by cod. The catch in 1908 was slightly less than 25 million pounds, valued at more than $2 million. Most of the catch was marketed fresh, although a considerable quantity was salted. Since 1908 the production has decreased, and consequently the value of the fishery has also decreased (table 55). By 1935 the species ranked 42nd in volume and 20th in value among fishery products of the United States; in 1960 the fishery ranked 48th in volume and 34th in value (U.S. Fish and Wildlife Service, 1962).

Table 55.--Commercial shad catch and value for certain years, Atlantic coast of the United States, 1880-1960[1]

[In thousands of pounds and thousands of dollars]

Year	Quantity	Value
1880	18,068	$ 995
1888	33,937	1,665
1896	50,499	1,651
1908	25,941	2,092
1935	8,236	860
1940	9,964	905
1945	14,699	2,500
1950	8,223	1,596
1955	8,599	1,422
1959	8,200	1,086
1960	5,965	1,107

[1] Statistics: 1880, 1888, 1896, Stevenson (1899); 1908, Bureau of the Census (1911); 1935, Johnson (1938); remainder, U. S. Fish and Wildlife Service (1943, 1949, 1953, 1957, 1961, 1962).

In an extensive market survey of shad, which included the status of the wholesale and retail trade, methods of preparing the fish for table use, and factors affecting consumption, Johnson (1938) found that the major economic problems primarily were those concerned with decreased supply. A problem existed also in the declining popularity among consumers for the more commonly marketed forms of the fish. This lowered demand resulted in lower average price to the producer than could have been realized if the popularity had been maintained. Of the shad marketed, practically all reaching Philadelphia, Baltimore, and Washington were consumed locally, whereas reshipment was considerable from New York to the other named cities since excessive supplies frequently were available on the New York market. This oversupply was especially obvious in years when the catch was low in southern rivers and high in northern rivers. Johnson's findings generally are applicable to the present-day economics and marketing of the product.

The principal commercial shad production on the Atlantic coast in 1960 was in Maryland, Virginia, North Carolina, Georgia, Florida, New Jersey, Connecticut, and New York. Generally, fish were marketed shortly after capture, and those not sold locally were shipped to New York City, Philadelphia, Baltimore, and Washington.

Formerly, large quantities of fresh and frozen shad were shipped to New York from the Pacific coast. In recent years, however, receipts of frozen shad and shad roe from this area have dropped sharply (written communication, dated June 5, 1961, from T. J. Risoli, Bureau of Commercial Fisheries Market News Reporter, Fulton Market, New York City). Shipments of frozen shad decreased from 35,400 lb. in 1945 to 500 lb. in 1960, and shipments of frozen shad roe dropped from 6,000 lb. in 1945 to none in 1960. It is not known whether the decrease resulted from economic factors or decrease in demand for the products.

Shad usually are marketed fresh, although quantities of both shad and shad roe are marketed frozen and canned. Some smoked and kippered fish also are produced. During the early part of the season, prices usually are high and wholesale dealers ship whole fish, but as the season progresses it frequently is more profitable to remove the roe and sell it separately. Thus in midseason, quantities of dressed female shad reach distributing markets. A few fish are filleted by wholesale dealers before shipment, but generally fresh shad reach retail markets in the round. Some retail stores sell half shad or fillets if the whole fish is larger than the customer requires. A few also sell boned shad.

Shad dealers at the Fulton Market, New York City, report that the roe is removed from most females, and from 75 to 80 percent of the roe is consumed within the New York metropolitan area. Only about 10 percent of the males and drawn (eviscerated) females is consumed in New York City; the balance is shipped to other market areas.

The price of shad on the eastern markets is affected not only by variation in shad abundance but also by the variation in price and abundance of other fishes. When fish from Florida reach the market in February and March, prices normally are high. In April and May when fish are caught in quantity from North Carolina to New Jersey, the supply reaches a maximum and prices are moderately low. Prices reach their lowest point toward the end of the fishing season in late May and early June. According to the Fishery Products Report, issued daily by the Bureau of Commercial Fisheries for the Fulton Market, the highest price for shad in 1960 was paid in March during Lent.

Females always bring higher prices because they contain the roe, which is much in demand as a delicacy. In 1960 Georgia fishermen received from as much as 65 cents per pound for female shad and 25 cents per pound for male shad. Average price paid the fishermen for shad from Virginia, Maryland, and New Jersey during April was 35 cents per pound for females and 7 cents per pound for males. Lowest prices were paid to Connecticut fishermen in June, when females sold for 15 cents per pound and males for 4 cents per pound. At times the price paid for males was so low that fishermen marketed only females.

In recent years restaurant sales have increased and retail store sales have decreased The reasons for this change are: demand for prepared fishery products free from bones and other inedible portions--a condition which

shad as now handled in retail stores does not meet, and requirement of most present-day families for portions of shad smaller than usually featured in retail stores.

Sales have improved in some areas by the marketing of fish from which all bones have been removed. Boning shad is considered commercially impractical by some wholesalers and retailers, though in recent years the practice has been adopted in some areas, especially as more persons have become proficient at the task. When boned fish were featured by several producers on the Connecticut and Hudson Rivers and in Chesapeake Bay, the demand for the product was much greater than the supply. The demand could not be met in 1960 because good shad boners were relatively scarce. The seasonal nature of the fishery tends to discourage fish cutters from learning the method.

RECOMMENDATIONS

Shad probably cannot be restored to the abundance that existed at the beginning of the 20th century. Changes in spawning and nursery areas by encroachment of civilization have reduced, and in some localities destoryed, the ability of rivers to produce fish as abundantly as in former years. Physical and chemical changes in river environments from deforestation of watershed, siltation, pollution, and dam construction have combined to reduce the capacity of rivers to produce anadromous fish.

Annual production of shad on the Atlantic coast of the United States over the past 50 yr. has not exceeded 20 million pounds and generally has averaged less than 12 million pounds. Production can be increased by proper management, as was indicated by investigations of the Hudson and Connecticut Rivers populations (Talbot, 1954; Fredin, 1954). Analysis of catch and effort statistics on these fisheries for a series of years, plus comprehensive biological studies, showed that more than 80 percent of the fluctuations in abundance of these populations was caused by the number of fish allowed to escape the fishery and spawn. In other words, fishing was the single most important factor affecting abundance. As a result of these studies, it was possible to predict abundance of fish a year in advance within desired confidence limits. By controlling fishing effort, the desired number of shad can be allowed to escape the fishery, and the size of future runs can be regulated to produce maximum sustained yields.

Causes of fluctuations in abundance of other shad fisheries on the Atlantic coast of the United States could not be determined from recent studies because the size of the population for an extended period was not known. Population size can be determined from catch and effort statistics collected over a period of years and by well-planned tagging and recovery experiments. When these data become available, possible factors that affect population size can be studied to determine their relation to population fluctuations. If factors affecting these changes can be determined and controlled, the population can be managed on an optimum-sustained-yield basis. If the factors cannot be controlled, however, their effect probably could be predicted and the fishery managed accordingly.

Our recommendations are as follows:

1. States interested in managing their shad fisheries should collect catch and effort statistics on the fishery. This collection could be accomplished by requiring fishermen to report their fishing activities as prerequisite to obtaining a future fishing license. Information required on each river, in addition to catch, is amount of each type of gear and number of days fished. After catch and effort statistics have been obtained for a series of years, studies can proceed to determine population sizes and factors responsible for fluctuations in abundance, and management measures can be formulated. Fisheries involving two or more States should be studied and managed as a unit without regard to political boundary. An example of cooperative interestate management of shad is the Hudson River where New Jersey and New York work together to regulate the fishery.

2. Ineffective fishways should be replaced by effective fish-passage facilities where practicable, and new dams constructed on shad-producing streams should be provided with workable fishways to ensure that the river above the dam will not be completely lost to fish production.

3. States should take action to reduce or eliminate pollution of rivers. Toxic industrial wastes and low dissolved oxygen decrease the productive capacity of streams by reducing survival of eggs and larvae; in some rivers populations have been severely reduced or eliminated.

4. Industry should improve methods of handling and packaging shad to increase public demand for this product.

The projected growth of the human population both in this country and the world during the coming years makes it desirable that conservation authorities take the necessary steps to maintain and increase this natural, renewable resource.

SUMMARY

1. The range of shad on the Atlantic coast is from the St. Johns River in Florida to the Gulf of St. Lawrence in Canada. The species is anadromous, spending most of its life in the ocean and ascending coastal rivers to spawn. After spawning it returns to the ocean, provided it escapes fishing gear or does not die in the stream. The following years it returns to the rivers to spawn again. The young remain in the natal stream until fall and then enter the ocean. They probably spend the winters in the Middle Atlantic area, migrate to the Gulf of Maine each summer along with the adults, and when mature, return to the native stream to spawn. Fish attain sexual maturity at 2 to 6 yr. Those spawning in streams south of Chesapeake Bay, and particularly south of North Carolina, die after spawning.

2. During the 19th century, important shad fisheries were developed along the entire Atlantic coast of the United States. Every suitable river had a spawning run and fish ascended far upstream. The different kinds of gear introduced and developed by shad fisheries were adapted to their native localities. The species was taken both inside and outside the rivers by gill nets, seines, weirs, fyke nets, and bow nets and in the headwaters by traps. The estimated catch in 1896 was more than 50 million pounds; production in New Jersey ranked first with about 14 million pounds and that in Virginia ranked second with 11 million pounds. Seines were the usual and most efficient method of capturing fish.

3. The shad fishery had changed in 1960 little except in size of the catch. The gear has remained relatively unchanged, but many improvements have been made in techniques of fishing, largely in the interest of economy. The estimated catch by both commercial and sport fisheries in 1960 was slightly more than 8 million pounds; Maryland ranked first with 1.5 million pounds, Virginia second with 1.4 million pounds, and North Carolina third with 1.3 million pounds. Gill nets were the most extensively used gear and the most efficient method of capturing fish.

4. Many factors have been blamed for the decline in shad. Among them were: Physical changes of the environment which rendered it unsuitable for spawning or which influenced survival of eggs and larvae; dams which prevented shad from reaching spawning grounds; pollution which rendered rivers unsuitable for the species; overfishing which did not allow enough fish to spawn and replace those which died or were taken by the fishery; and natural cycles which could cause long-term fluctuations in abundance. Recent studies of factual data, where available, have indicated that declines in shad abundance have been caused by dams, pollution, and overfishing; if other factors have had an effect on fish abundance their effect could not be demonstrated.

5. Methods used to rehabilitate and manage shad fisheries have been: Artificial propagation, provisions for fish passage, and fishing regulations. In addition, pollution control can benefit shad abundance. Hatcheries, as operated in former years, failed as a conservation measure. Present engineering and biological knowledge is solving and in some areas has solved the problem of passing shad over artificial obstructions to upstream spawning areas. Measures to manage the shad fisheries through regulations and licensing measures have included week-end closure on fishing, limiting of seasons, establishment of location of fishing area, creel limits on the sport fishery, and limiting of amount and mesh size of fishing gear.

6. Shad probably cannot be restored to the abundance of the late 19th century, but our present knowledge should permit individual shad runs to be managed scientifically on a sustained-yield basis.

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