THE RESTRICTED INLAND RANGE OF SHAD DUE TO ARTIFICIAL OBSTRUCTIONS AND ITS EFFECT ON NATURAL REPRODUCTION.

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There is no species of fish more important to residents of the Atlantic seaboard than the shad, and none whose preservation so immediately concerns a larger number of persons—24,768 men being actively engaged in this fishery in 1896. True, the yield of codfish is heavier and sells for a greater value, but the fishery for that species is confined to one section of the coast, gives employment to less than half as many men, and its prosecution requires costly vessels and appliances, necessitating lengthy trips from port, with much exposure and loss; whereas, shad occur more or less abundantly along the entire coast, ascending the rivers as far as they permit, almost to the very doors of fishermen and consumers, several hundred miles from the sea, and are caught by all forms of apparatus, from the costly pound nets and seines near the coast to the roughly constructed bownets and falltraps in the headwaters. Yet, there are few species whose geographical range and local abundance are more easily affected by artificial agencies or which require greater attention for their maintenance, and as most of the important shad streams border or traverse two or more States and are thus subject to more than one jurisdiction, the agencies affecting their range and abundance present an appropriate subject for consideration in a gathering of representatives from the different States.

No river on the Atlantic seaboard appears too long for shad to ascend to its headwaters, provided they meet with nothing to bar their progress. They ascend the St. Johns in Florida a distance approximating 375 miles; the Altamaha, 300 miles; the Edisto, 281 miles; the Santee, 272 miles; the Neuse, 300 miles, and the Delaware River a distance of 240 miles from the sea. However, these distances do not equal the extreme ranges in the early part of the present century. Then shad ascended the Savannah to Tallulah Falls, a distance of 384 miles, instead of 209 miles as at present. They ran up the Pee Dee to Wilkesboro, a distance of 451 miles, whereas the present limit on that river is Grassy Island, 242 miles from the sea, and only one shad was reported from that point in 1896. On the James River the former run was 350 miles in length, while the present limit is Boshers Dam, 120 miles. The greatest decrease exists in Susquehanna River, in which shad formerly ascended to Binghamton, 318 miles from the mouth and 513 miles by water-course from the sea, whereas at present they do not appear to pass beyond Clarks Ferry, 84 miles from the mouth of the river.

From Table A, on page 270, it appears that in 23 of the principal Atlantic coast rivers, aggregating 8,113 miles in length, shad formerly existed throughout 6,052 miles, or 74 per cent of the length; whereas at present they are to be found in only 4,107 miles, a decrease of nearly 2,000 miles. This summary comprises only the principal rivers, and if minor streams and tributaries were included, the total length from which shad have been excluded would doubtless appear more than twice as great. In much of that length shad were quite numerous, the catch in many instances exceeding the yield in the portion to which the fisheries are now confined. The upper section of the Pee Dee is supposed to have yielded over 100,000 annually. In the James River, according to the late Colonel McDonald, the annual catch of shad in the 230 miles from which they are now excluded "was at one time far in excess of the now (1880) entire catch for the whole river." The present excluded length of the Susquehanna formerly yielded several hundred thousand annually. In a report of the special commissioners of Massachusetts appointed in 1865 to investigate the fisheries of that State, it was estimated that at the beginning of the present century the annual shad yield in the Merrimac River ranged from 500,000 to 1,000,000 in number, whereas none ascend that river at present.

The limitation in the range of shad in the rivers is the result of several agencies in addition to the size of the stream, the most important of which are (1) natural falls, (2) artificial dams, (3) pollution of water, (4) agricultural operations, and (5) extensive fisheries.

Natural falls exist at the escarpment line in all of the rivers having their sources above the coastal plane, but in only a few instances are they of sufficient height to form insurmountable obstacles to the range of the shad, among these being Great Falls on the Potomac and Bellows Falls on the Connecticut, which form absolute barriers to the further progress of shad that may reach these points, excluding them from the whole of the river above. Most of the other Atlantic coast streams having their sources above the coastal plane have been made impassable at a short distance above the escarpment line by means of artificial dams for developing water-power or for navigation improvements. In this class are the Savannah, the Santee, the Cape Fear, the James, the Susquehanna, the Housatonic, the Connecticut, the Merrimac, the Kennebec, and the Penobscot. The lengths from which shad are excluded appear in Table A on page 270.

Access to suitable spawning areas being a physiological necessity for the maintenance of the fisheries if natural reproduction is depended on, and as many of the spawning-grounds are located in the headwaters of the rivers, it follows that while the exclusion of shad from the upper sections is the immediate it is not the most important effect of those obstructions. It has been the common experience in all the shad rivers that whenever a high dam or other obstruction has been erected across the stream the fisheries above that point have at once ceased, and those immediately below have for a year or two flourished on the large number whose ascent has been stopped by the barrier and then they, too, have declined. It also appears that the extent of this decrease below the dam is largely dependent on the distance of the obstruction from the mouth of the river and the proportion of the spawning-grounds to which they are denied access, and if all the breeding-grounds have been cut off in a definite coastal region the shad have almost entirely disappeared.

This is clearly illustrated by the conditions on the Connecticut River. The erection of the Holyoke dam in 1849 prevented the fish from ascending above that point and as they strayed about in the river below the obstruction they were taken in greater abundance than formerly. At the Parsonage fishery near the mouth of the river and 40 miles below the dam, the average shad yield during the 20 years preceding the erection of the obstruction was 9,854 annually; during the 5 years following 1849 the annual catch averaged 19,490; during the next 10 years it was but 8,364, and for the following 6 years, 1864–1870, the annual average was but 4,482 shad, less than one-half the former yield. The record of the total catch on the Connecticut from 1853 to 1896 shows that the yield below the dam decreased from nearly half a million annually to an average of less than one-tenth of that number. In a few rivers the development of water-power has resulted in completely exterminating the anadromous fishes, this being the case in the Thames, the Blackstone, the Merrimac, the Saco, and other rivers. However, instead of the employment of a few hundred persons in taking fish each spring, the water-power on those streams affords employment to thousands of mill operatives.

Numerous attempts have been made by the erection of fishways to enable shad to pass above these obstructions, among the costly contrivances being those in the Savannah at Augusta, the Santee at Columbia, the Potomac at Great Falls, the Susquehanna at Clarks Ferry, the Housatonic at Birmingham, the Connecticut at Holyoke, the Merrimac at Lawrence, and the Kennebec at Augusta. The fishway in the dam across the Santee at Columbia, built in 1883, consists of 3½ sections, 36 feet long, with a total rise of 9 feet, and is of the type known as the McDonald fishway, consisting of two sets of buckets, straight wooden buckets to receive the water in its downward flow and curved iron buckets to direct this water back upstream, thus affording a comparatively quiet waterway. It is fairly efficient for certain species when kept free from trash, but shad do not appear to use it.

In 1882 an appropriation of $50,000 was made by Congress for the erection of suitable fishways at Great Falls in the Potomac where the river descends almost abruptly 35 or 40 feet. In 1885 the work of construction was begun, but it was soon abandoned, it being decided that "the fishways were not found sufficiently strong to withstand the effects of the violent floods of the locality in which they were placed."

The fishway over the Holyoke dam on the Connecticut River, one of the largest and most expensive in the country, was built in 1873 after the Brackett plan, a modification of the Foster fishway. It is 440 feet in length, so divided into compartments or bays, by means of T-shaped partitions extending at right angles to the sides, that the water winds through a long, circuitous course, running about 1,500 feet before it emerges at the lower end. As the height of the dam is 30 feet, the fall of the water averages about 1 foot in 50, with little momentum. But it does not appear that shad have ever passed through this fishway in any numbers.

An account of the construction of fishways in the Columbia dam on the Susquehanna River illustrates the difficulties of making these obstructions passable. This dam is only 7 or 8 feet high, and its disastrous effect on the shad fisheries of the Susquehanna has attracted very general attention to it. The original charter required that a rafting channel should be left in the obstruction. In 1865, in accordance with an act of the Pennsylvania legislature, the company removed a 40-foot section of the dam, and in that space built a new subdam, the top of which was about level with the water below. The lower slope of the subdam was placed at an inclination of 1 in 15, and the sides of the aperture in the main dam were dentated, so as to promote the formation of eddies in the current. This construction did not appear to answer its purposes, and in 1873 the State made an appropriation for another fishway at that point after plans modified from numerous designs submitted in competition. That also proved ineffectual, and in 1880 a fourth passageway was placed in the dam, this one consisting simply of an opening 125 feet wide, this plan being chosen because it conformed to a natural break, experience having shown that shad passed through such an opening more readily than through any regular fishway that had been constructed. But it is only in very low and little-used dams that such breaks can be made without injury to the original purpose.

Although the above-described fishways are modern constructions, designed by engineers of ability, familiar with the principles of hydraulics and the habits of fish, yet none of them appears to be successful for shad, this fish being so timid that it will not enter fishways readily used by salmon, alewives, and other species. True, a few individuals may pass through some of the fishways, but the number is not sufficiently large to be of any practical value, and in a majority of instances where shad are reported above a dam they have swum over the crest during freshets or have passed through breaks in the obstruction.

The utility of the spawning areas below the dams has also been impaired by chemical, sawdust, and other refuse from mills and towns on the river banks. In a number of small streams these have almost completely destroyed the spawning and feeding areas, but regulations against this practice now exist in most States.

Increased agricultural operations have also had some effect on limiting the range of shad up the rivers. At the time of the settlement of the river valleys most of those areas were covered with forests and the ground was carpeted with leaves and moss, which checked the surface flow of water and restricted its evaporation, thus tending to constancy in the flow of rivers; and freshets were rare and of insignificant proportions. With increase of population the forests were cleared away and large areas of land brought under cultivation, causing injurious meteorological changes and more numerous and destructive floods. During heavy rains the plowed soil upon the hillsides is easily washed into gullies, through which the water is quickly conveyed to the rivers, filling them beyond their capacity and bringing into them masses of earth and other débris, thus covering the spawning-grounds. The freshets are soon over, and the flow of water in the streams becomes so small that shad are not induced to proceed so far up as formerly.

On some of the southern streams decreased navigation has resulted in reducing the length of shad range. This is especially true of the Combahee, the Ashepoo, the Edisto, the Chickahominy, the Mattaponi, and the Pamunkey, the channels of which are now much encumbered with drifting logs, overhanging trees, brushwood, and shoals of loose, shifting sand, through which a passageway for the ascent of fish was formerly maintained by navigation and the rafting of timber.

The most important factor in reducing the inland range is the extensive fisheries near the coast. In the first half of the present century shad were caught all along the river course, every point yielding its quota for local use and the limited demand not warranting the prosecution of the fisheries so vigorously as to cut off the "run" at points above. But the profits derived from shipping shad to populous centers resulted in a concentration of the fisheries at points near the mouths of the rivers where most convenient shipping facilities exist, resulting in certain narrow streams in practically excluding shad from the middle and upper sections where the spawning-grounds are located. The effect is not so apparent as in the case of impassable dams and natural falls, for the latter form absolute barriers, whereas extensive fisheries merely limit the number of fish ascending to the extreme range of the river and not the length of that range; yet in many cases they affect the future abundance of the species even more than the dams and natural falls. This is particularly noticeable in those narrow streams whose fluvial characteristics extend nearly or quite to the sea, as in most of the rivers between the St. Johns and the Neuse, and to some extent in the Susquehanna, the Hudson, the Connecticut, etc. In the Ogeechee, Savannah, Edisto, Pee Dee, and Cape Fear, the great bulk of the catch is obtained in the extreme lower end within 30 or 40 miles of the sea, and comparatively few shad ascend as far as the spawning-grounds. In the Connecticut nearly all the shad are caught within 20 miles of the mouth. The dams in those rivers perform a very unimportant part in limiting the run of fish, for few shad ever reach those obstructions.

In the broad estuaries tributary to the sounds of North Carolina and to the Chesapeake and Delaware bays the effect of netting is not so apparent, yet even in those waters only a small percentage of the shad ever reach the spawning-grounds. Formerly the great bulk of the yield was obtained from the middle and upper sections of the rivers, while at present nearly all the catch is obtained in the lower section and in the salt water of the estuaries. The extension of the fisheries into the estuaries is of recent origin, dating only from the middle of the present century, and their development has been principally during the past twenty years. It requires large and costly apparatus to prosecute the fisheries there, and forms suitable have come into use only quite recently. With the exception of drift nets in Delaware Bay, New York Bay, and one or two less important places, and the mackerel purse-seines, which take a few shad on the New England coast, pound nets and stake nets are the only forms of apparatus employed in catching shad in salt water. Over 90 per cent of the shad caught in the salt water of the Chesapeake region are taken in pound nets, yet the use of that apparatus there dates only from 1865, and not until 1875 were they extensively employed. Stake nets and pound nets, which catch practically all the shad taken in the salt water of North Carolina, have been used in that region only since 1865.

At present nearly one-half of the total shad yield on the Atlantic seaboard is obtained in salt water, and those fisheries are becoming more extensive each year. Table B, on page 271, shows that in 1896, 6,252,464 shad, over 47 per cent of the total yield, were caught in regions which half a century ago yielded none whatever; this in some measure compensating for the 4,000 miles of river-course from which they are now wholly excluded and the lengths from which the exclusion is partial. It thus appears that the principal change in the fisheries during the past fifty years has been one of location rather than extent of the total yield, the great increase in the estuaries compensating for the decrease in the headwaters. This change in the fishing-grounds results in a large portion of the fish being taken before they reach the spawning areas in fresh water, thereby preventing them from adding their quota to future supply almost as effectually as though they were excluded therefrom by means of dams or otherwise. But the same result is accomplished when the fish are caught after they have reached those areas and before they have spawned. Furthermore, moving the seines and other apparatus of capture over the spawning-grounds disturbs and drives away the fish from those areas, and also destroys many of the eggs and young shad already there.

Access to suitable spawning-grounds in sufficient numbers to compensate for loss by capture and natural causes is a physiological necessity for the maintenance of the fisheries if dependence is placed on natural reproduction. But from the foregoing it appears that the construction of dams has excluded shad from a large portion of the spawning-grounds, notwithstanding the erection of fishways in those obstructions; sawdust, chemicals and other refuse and agricultural operations have greatly impaired the utility of the spawning areas even now available, and the extensive fisheries have very largely decreased the number of the shad reaching those areas. These adverse agencies have reduced natural reproduction to almost an insignificant factor in the maintenance of the present fisheries and have rendered artificial propagation essential to their prosperity. During the seventies the returns of the fisheries reached a minimum; then the results of artificial propagation began to appear, not only restoring the former abundance of shad, but even increasing the catch.

The total shad yield on the Atlantic coast and rivers in 1880 numbered 5,162,315; in 1888 it was increased to 10,181,605; in 1896 it was further increased to 13,067,469, 29 per cent greater than in 1888 and nearly three times as great as in 1880. While this increased yield was preceded by an increase in the quantity of apparatus used, yet it was made possible by the greater abundance of shad, due to artificial propagation. Comparing 1880 with 1896, it is observed that the increase in the yield numbered 7,905,154. At 20 cents each, which is the average price paid by consumers, this represents an increase of $1,581,030 in the value, over 50 times the expenditures for shad propagation; a result probably unsurpassed in any other line of public appropriation. The large number of persons employed in this fishery and the present inability of natural reproduction to maintain the supply make it essential that no decrease be made in this important branch of fish-culture.

A.—*Summary of the original and of the present limit of shad range in twenty-three of the principal rivers of the Atlantic seaboard.*

Rivers.	Distance of sources above coast line.	Original limit of shad run.		Present limit of shad run.	
		Locality.	Distance from coast line.	Locality.	Distance from coast line.
	Miles.		*Miles.*		*Miles.*
St. Johns	375	Sources	375	Sources	375
Altamaha	450	Macon	370	Hawkinsville	300
Ogeechee	350	Ogeechee Shoals	200	Millen	100
Savannah	425	Tallulah Falls	384	Augusta Dam	209
Edisto	300	Sources	300	Jones Bridge	281
Santee {Wateree	350	Great Falls	272	Great Falls	272
Santee {Congaree	410	Green River	374	Columbia	233
Pee Dee	497	Wilkesboro	451	Grassy Island	242
Cape Fear	290	Haywood	210	Stanley Falls	181
Neuse	340	Sources	340	Fish dam	300
Pamlico-Tar	252	Rocky Mount	157	Rocky Mount	157
Roanoke	457	Weldon	249	Weldon	249
James	420		370	Boshers Dam	140
Rappahannock	248	Falmouth Falls	155	Falmouth Falls	155
Potomac	400	Great Falls	190	Great Falls	190
Susquehanna	617	Binghamton	513	Clarks Ferry	279
Delaware	457	Deposit	256	Burrows Dam	
Hudson	314	Glens Falls	209	Troy	164
Housatonic	202	Falls Village	150	Birmingham	92
Connecticut	409	Bellows Falls	204	Windsor Locks	89
Merrimac	140	Winnepesaukee	125	Lawrence	20
Kennebec	155	Caralunk Falls	108	Augusta	44
Penobscot	255		90	Verona	35

B.—*Comparative statement of the total yield and of the salt-water yield of shad on the Atlantic seaboard during 1896.*

Water areas.	Total yield.		Yield in salt water.	
	Number.	Value.	Number.	Per cent.
St. Johns River	456, 281	$61, 924	291, 116	63. 59
St. Marys River	10, 193	1, 754	....	0. 00
Satilla River	1, 500	240	....	0. 00
Altamaha River	29, 377	10, 096	....	0. 00
Ogeechee River	55, 425	19, 514	12, 054	21. 75
Savannah River	54, 406	19, 236	7, 480	13. 54
Combahee River	3, 090	622	....	0. 00
Ashepoo River	6, 880	1, 381	....	0. 00
Edisto River	28, 273	5, 843	....	0. 00
Cooper River	396	126	....	0. 00
Santee River	7, 309	1, 547	....	0. 00
Winyah Bay and tributaries	97, 685	23, 031	53, 379	54. 95
Cape Fear River	75, 315	18, 964	29, 151	38. 71
Pamlico Sound	448, 089	109, 727	448, 089	100. 00
Neuse River	207, 052	39, 067	82, 238	39. 72
Pamlico-Tar River	67, 082	13, 316	18, 873	28. 13
Croatan and Roanoke Sounds	169 541	33, 201	169, 541	100. 00
Albemarle Sound	735, 192	140, 159	186, 290	25. 34
Roanoke River	169, 409	20, 489	....	0. 00
Chowan River	183, 545	34, 422	....	0. 00
Pasquotank and Perquimans rivers	41, 579	7, 898	....	0. 00
Chesapeake Bay	1, 638, 844	167, 929	1, 428, 327	87. 15
James River and tributaries	495, 762	51, 247	100, 379	20. 25
York River and tributaries	546, 548	50, 361	182, 375	33. 69
Mobjack Bay	140, 777	13, 874	140, 777	100. 00
Rappahannock River	417, 789	35, 371	194, 067	46. 45
Potomac River	684, 013	63, 608	210, 480	30. 76
Nanticoke River and tributaries	216, 288	20, 667	42, 405	19. 60
Choptank River and tributaries	338, 420	35, 810	136, 972	40. 44
Susquehanna River	140, 087	20, 153	....	0. 00
Miscellaneous	249, 021	31, 736	29, 851	13. 59
Delaware Bay	1, 103, 821	104, 761	1, 103, 821	100. 00
Delaware River	2, 778, 803	300, 598	976, 669	35. 13
Miscellaneous rivers	134, 838	21, 147	....	0. 00
Ocean Shore of New Jersey	16, 240	3, 518	13, 765	84. 75
New York Bay	216, 425	30, 941	213, 925	98. 89
Hudson River	602, 858	83, 237	....	0. 00
Great South Bay and Gardner Bay	4, 755	1, 092	4, 755	100. 00
Long Island Sound	9, 427	2, 399	9, 427	100. 00
Connecticut River	51, 690	9, 508	....	0. 00
Miscellaneous Rivers	13, 202	3, 324	....	0. 00
Ocean Shore of Rhode Island	1, 151	287	1, 151	100. 00
Narragansett Bay and tributaries	15, 836	4, 071	2, 163	12. 17
Buzzards Bay and Vineyard Sound	3, 385	834	3, 385	100. 00
Cape Cod and Massachusetts bays	33, 082	1, 468	33, 082	100. 00
Casco Bay	64, 490	3, 580	64, 490	100. 00
Kennebec River and tributaries	290, 122	26, 357	55, 987	19. 30
Penobscot and other Maine rivers	12, 126	941	6, 000	49. 48
Total	13, 067, 469	1, 651, 376	6, 252, 464	47. 85

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