

## 5.—OBSERVATIONS ON THE SPAWNING HABITS OF THE SHAD.

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The object of this paper is to direct attention to the fact that shad (*Clupea sapidissima*), in certain river basins at least, exhibit a choice of localities in which to lay their eggs; and to point out that the areas preferred are well defined in their situation below creeks, being in the track of the currents therefrom.

The spawning-grounds of the shad are so well known that anything additional on the subject would possess little value as indicating the more remunerative localities for gathering their eggs. Discoveries in this direction would rather be of service in disclosing the spawning habits of other species less known, as, for example, the striped bass, striped mullet, and sturgeon. They might also serve a somewhat different though equally useful purpose in pointing out those areas in which necessary prohibitory measures would effect the greatest advantage.

While the claim is made that the greatest percentage of ripe shad are to be found immediately below and in the currents of creeks, it is not intended to create the impression that greater relative numbers of fish are caught at these points.

The spawning region of the shad is of large proportions, extending from the limit of the brackish water inland 50 to 100 miles or more. The fish captured anywhere in this region are liable to be ripe, and, indeed, it may be said that on one or perhaps two days in any given season ripe shad are common to all parts of the spawning region. This occurrence, however rare, has been very misleading to seine proprietors, who, hastily adopting the belief that their fisheries were valuable for the amount of eggs they would afford, were instrumental in causing many fruitless visits from spawn-takers. When we consider critically the fisheries as to their profitableness as contributors to the hatcheries, we find that the greater number are of no practical value and that many of the largest in catch are the poorest in egg-production.

The cost of shad ova on the Potomac River (including all items, as the amount paid in purchase money, salaries of experts and laborers, fuel, and transportation) is about \$85 per million, which is, I believe, about the average price at the several stations of the U. S. Fish Commission. I therefore take this cost as the standard or commercial rate, and all allusions to the scarcity or abundance of eggs will be with reference to such a basis. The number of eggs obtained on the Potomac has never exceeded 81,000,000 in any one season, and the number in the two next best seasons was about 60,000,000 each (in nine years' operations). The Fort Washington seine,

fished by the U. S. Fish Commission, was a large source of supply, yielding about 8 per cent of ripe fish, or at the rate of about 2,000 eggs to each fish caught, males and females combined, and was the highest producing of all the seines.\* Had all other fisheries been equally productive, the annual receipts at the Fort Washington collecting station would have easily reached 300,000,000. But we find that while this seine with a catch of 10,000 fish would afford 20,000,000 eggs, and another with a catch of 18,000 fish would produce 17,000,000 eggs, a third with a catch of 60,000 fish would yield only about 1,000,000 eggs.

These inequalities in production, at fisheries near together and surrounded by the same general conditions, led to an inquiry into the underlying causes, the effects of which were so apparent. A study of the subject demonstrated that not only was the largest production of eggs derived from seines operated in river areas traversed by creek currents, but also that the most constant supplies were from those areas, and also that the eggs from those sources were better in quality (though none from the seines were so good as those from gill nets, the latter ranking highest always). It was further observed that the greatest and most invariable egg supply from gill-net fishermen was derived from nets sweeping the channel bank below creeks and in the currents of creek mouths. It is to be regretted that exact data can not be presented here in support of the belief entertained, showing in comparative tabular form the catch and egg-production of the various fisheries, but the catch was either unrecorded by fishermen or else not reported by the agents frequenting the shores and gill boats.

Before reviewing the fisheries in respect to their egg-production and relative situation to creek mouths, I would call attention to another feature of the spawning, or rather non-spawning habit of shad, viz: that there are particular stretches of river, within the spawning region, which are apparently wholly barren of ripe fish. An example of this kind is witnessed in the Roanoke River, between its mouth and Kitty-Hawk and Slade's fisheries, situated above Plymouth, North Carolina, a distance of perhaps 15 miles. Between these points 10,000 to 15,000 shad are captured annually, in six or more seines, and among them no ripe fish are found. Striped bass, too, are caught in these seines by thousands, but while they are known to spawn only a few miles below, as well as many miles above, at Weldon, none spawn here. Fairly satisfactory examinations of the shad catch on the Neuse River also, from its mouth to a distance of 16 miles above, indicates an absence of ripe fish, they being so scarce as

\*The record of operations of this seine will serve a useful purpose for comparative studies. Twenty-three per cent of the Potomac eggs have been derived from it, the numbers secured during the first four years being as follows: 1,089,000 in 1883, 6,000,000 in 1884, 7,280,000 in 1885, and 11,848,000 in 1886. The details of subsequent production are shown in the statement which follows:

Year.	Total eggs obtained.	No. of spawning fish	Per cent of spawning fish.	Total catch of adult shad.	Catch of male fish.	Catch of female fish.	Per cent of male fish.	Per cent of female fish.	Average eggs per spawning fish.	Average eggs per female caught.	Average eggs per fish caught.
1887 ....	20,956,000	652	6.3	10,348	7,388	2,960	71.4	28.6	32,100	7,080	2,010
1888 ....	22,657,000	688	6.1	11,212	7,760	3,552	69.2	30.8	32,900	6,380	2,020
1889 ....	17,738,000	612	9.8	6,217	3,254	2,963	52.3	47.7	28,980	6,000	2,090
1890 ....	10,262,000	468	10.1	4,606	2,503	2,103	54.3	45.7	21,900	4,870	2,220
1891 ....	5,276,000	228	7.2	3,138	1,793	1,345	57.1	42.9	23,140	3,920	1,670
Annual average	15,377,000	530	7.9	7,104	4,540	2,585	60.8	39.2	27,800	5,650	2,122

to render doubtful the collection there of enough spawn to justify the establishment of an ordinary hatching station, while the large catch of fish and the natural surroundings would seem to guarantee such an investment against risk.

*Albemarle production.*—On the Albemarle Sound well-conducted examinations disclosed the fact that but one seine afforded a reasonably remunerative and regular supply of eggs. This was the Sutton Beach fishery (producing about 30,000 shad per season ten years ago), situated just below Salmon Creek. This creek, though it does not affect the argument, is unlike any of the others subsequently adverted to, in being above tide water and hence discharging a constant current of warmer water through the seine berth, except when occasionally shifted from its course by high winds. This shore yielded perhaps 5,000,000 eggs, a small enough number, but more than all others combined. This was the only seine operated in the influence of a creek current.

In striking contrast with this seine were four others on the east shore of the sound, between Edenton and Drummond Point, each of which caught 15,000 to 20,000 shad and produced so few eggs that they were abandoned by the spawn-takers at the expiration of the second season. In greater contrast (because situated higher up stream) were the four or more seines on the Chowan River, which, though principally alewife fisheries, made a catch of 5,000 to 10,000 shad per annum, and yet were so unproductive of eggs that they, too, were abandoned by spawn-takers. Equally unproductive were the three or more seines operated in the headwaters of Batchelor Bay by Mr. Nichols and others, as were also the Roanoke seines already referred to elsewhere.

There remains to be mentioned but one other seine in this region, that being Scotch Hall, operated near Black Walnut Point, at the confluence of Chowan River and Batchelor Bay. This seine produced a fair number of eggs, but probably there would have been none, so to speak, but for the fact that southerly and easterly winds brought the Roanoke water over to commingle with that of the Chowan, thus establishing, occasionally and for brief periods, the conditions more constantly maintained at Sutton Beach fishery by the agency of the creek current. The Chowan and Roanoke waters are essentially different in character and most probably in temperature. The spasmodic production of eggs at Scotch Hall fishery is most readily accounted for on the above conjecture.

*Potomac River Production.*—When we analyze the sources of production of shad eggs on the Potomac, we find, as on the Albemarle Sound, that the least variable and largest producing fisheries are coincident with the creek currents, as in the case of the Tulip Hill, Fort Washington, and Moxley Point seines, situated respectively below Broad, Swan, and Piscataway creeks.

In the case of the great seine at Stony Point we observe the reverse conditions, viz: a small and irregular egg supply and the absence of a creek current. The catch at this fishery is double that of the other three combined, while its egg product is only one-thirtieth (though the discrepancy in egg-production would be slightly less were it possible to have this seine landed every day about the sunset or spawning hour). Moreover the eggs obtained here present a very unfavorable characteristic (and one unknown at the three previously named shores) in that more than half of them, though to all external appearance good, are dead. This feature has proven embarrassing to government agents collecting them and to the proprietor whose expectations were invariably disappointed when the daily returns were sent him.

Along with this seine we find that Ferry Landing, not in a creek current, produced a relatively small number of eggs, which, though of more even occurrence, were worse in quality than those from Stony Point seine, the larger part being found dead soon after their introduction into the developing jars. The catch by this fishery was almost equal to the aggregate of Tulip Hill, Fort Washington, and Moxley Point seines, while its egg product was perhaps 15 times less. Little Hunting Creek, discharging into the river more than a mile above, probably has no tempering effect on this seine berth. In fact, the water in this berth, as well as in that swept by Stony Point seine, is probably already too warm, since both are on the flats.

Of the three remaining seines but two will be referred to in this immediate connection, Chapman Point seine ranking fourth in number, regularity, and quality of eggs. It is situated below Pomunky Creek, but this is a feeble stream and rather remotely situated to afford the constant effect produced by Broad, Swan, and Piscataway creeks, which are either of greater volume or in closer proximity to the three seines of most remunerative supply.

Pomunky seine, formerly visited by spawn-takers, is situated immediately above the mouth of a creek of the same name. It had no importance as a spawn-producing fishery.

In the following table will be found a fair comparative statement of the Potomac River shad-egg production, 1888-1891, with reference to the influence of creeks thereon:

Fishery.	No. of seasons covered.	Average annual egg production.	Largest annual egg production for the period.	Estimated annual average shad catch for period.	Average annual receipts from the four largest producing boats.
<b>Seines:</b>					
Fort Washington.....	4	13,999,000	22,657,000	*6,000	.....
Moxley Point.....	2	13,903,000	18,828,000	*15,000	.....
Tulip Hill.....	4	3,477,000	4,231,000	*4,000	.....
Chapman Point.....	5	2,771,000	6,834,000	*15,000	.....
Ferry Landing.....	2	1,983,000	2,250,000	†20,000	.....
Stony Point.....	2	952,000	1,067,000	†45,000	.....
<b>Gill fishermen:</b>					
Fort Washington to Bryan Point.....	2	1,083,000	*3,495,000	.....	8,229,000
White House.....	2	417,000	*1,453,000	.....	4,425,000
Sandy Bar.....	2	347,000	†1,198,000	.....	2,759,000
Greenway.....	1	313,000	†1,341,000	.....	2,213,000
Craneys Island.....	1	151,000	†414,000	.....	944,000

\* Below creeks.

† Not below creeks.

*Delaware River Production.*—On the Delaware but two of the six or more large seines situated on the New Jersey shore between Gloucester City and Billingsport have attained high rank in consequence of the egg yield. These are Howell Cove (operated immediately below the mouth of Big Timber Creek) and Faunce's, below Woodbury Creek, the other shores not being so situated as to creek mouths. In 1890 the egg-production by the Delaware seines was as follows:

Howell Cove .....	24,653,000
Faunce's Fishery.....	12,318,000
Gloucester Point .....	2,518,000
Rice's Fishery.....	922,000

Another seine, operated just below Oldman Creek, appears, in consequence of its detached situation, to have been passed over by spawn-collectors, and we have no data relating thereto. If this seine is not wholly without the spawning region by virtue of its seaward location, it will doubtless be found very productive of spawn and, should this prove to be the case, will probably afford the choicest site on the Delaware for a permanent shad station.

*The Potency of Creeks.*—That the higher temperature of the creek water is chiefly the controlling factor in drawing shad to these localities to spawn, I have no reasonable doubt. That the creek water, as a separate volume, is itself preferred as an element to spawn in, is evidently not the case; for observation on the catch of the seine operated by the Raum family in Broad Creek proper (2 miles above Fort Washington station, Potomac river) shows that this fishery possesses no value as an instrument of egg-production. Apparently the warmer water of the creeks becomes an active influence only when commingling with the colder river volume, or when effecting a mean between the two extremes in temperature. How far bottom may exert an influence I am unable to judge; it is not impossible that a greater amount of sand and gravel distributed over these areas by the creeks gives them a somewhat preferred character, but I do not think that this feature enters into the question except in a minor way, if at all.

Commissioner McDonald has pointed out that shad are controlled by temperature, they being always found within given limits of heat and cold; that they enter the estuaries as soon as these waters become warmer than that of the ocean, and that they ascend the fresh-water streams in quest of the higher zone of heat, the mean temperature sought being about 60° F. Now, since they spawn about or soon after the sunset hour (between the hours of 5 and 10 p. m.), it becomes evident that they prefer, for this act, neither the highest nor the lowest temperature of the 24-hour period, for the highest degree prevails earlier in the afternoon on the flats and in the creeks, while the lowest is existent in the early morning.

The fact that spawning shad caught in the warmer water on wide flats remote from the river channel are unaccompanied by sufficient bucks to afford milt for impregnating their eggs suggests that these localities are abnormal for spawning. It is possible, but rather improbable, that sufficient bucks do accompany the females, but, owing to their smaller size, escape the meshes of the gill nets.

On the other hand the spawning between midnight and noon, or in the coldest water of the 24-hour period, is very light. Experience satisfies me that even the low production by the Fort Washington seine is greater than at other fisheries (see two years' record of this seine below):

Year.	A. M. (12 o'clock midnight to 12 o'clock meridian) eggs.	P. M. (12 o'clock meridian to 12 o'clock midnight) eggs.	Total eggs.	Percentage of A. M. eggs.	Percentage of P. M. eggs.
1887.....	*3,095,000	17,861,000	20,956,000	14	86
1888.....	†1,858,000	20,799,000	22,657,000	8	92

\* Taken during 19 days, April 16 to May 23.

† Taken during 16 days, April 16 to May 26.

I therefore conclude that shad choose (or are impelled) to lay their eggs in the highest daily average temperature, a condition which would be realized about or soon after sunset, when the warmer water of the flats is intermingling with the colder channel water and establishing a balance. This suggestion is supported by the fact (at least on the Albemarle Sound and Potomac River) that the greatest number of ripe shad are taken off the edges of the channels.

It is but a step further to infer that fish so sensitively organized as to recognize the highest average of heat on its daily recurrence would readily perceive those tempered areas below creeks, which are relatively warmer. It is not impossible that they would detect an increase in heat here so slight that the ordinary thermometer would fail to record the advance. The air temperature during the run of the shad being on the increase, the creeks are naturally warmer than the river channels. The degree of heat increases from that of frosty mornings in the springtime to the hot days of June, or the time when tree foliage is full grown. The creeks, being sheltered from winds, absorb the sun's direct rays in a relatively greater ratio than the deeper waters of the river proper. The heat is imparted to the water volumes of the creeks on the flood tide and to their mud flats (and conserved) on the ebb tide.

Let the cause be what it may, it can not be denied that those river areas which are traversed by creek currents are the fields of preëminent adaptation for the natural spawning of shad.

The reason for not attempting an application of my observations to the Susquehanna spawning-grounds is that I am less familiar with the localities and have not made full studies of the charts in relation to the recorded receipts of eggs, the details of which form no part of the general office files at Washington. Apparently the large egg-production there (equal or perhaps superior to the amount obtained on any other of the rivers named) is in no way dependent upon creek currents. Since, however, the largest and most regular production of eggs on the Potomac is derived from the gill nets which are operated below and in the currents of creeks, viz, those at Moxley Point and White House, I can but infer that similar relative conditions are in force on the Susquehanna to effect such a great yield of eggs from the gill boats there. That the colder water in the channels and the warmer water on the contiguous flats or bars afford there the corresponding conditions seems altogether probable. The water from the two areas, commingling by gravity in the early part of the night would undoubtedly establish at about that time the temperature of highest daily average. The numerous deep channels and vast expanses of flats seem to be sufficient to account for the large egg-production below Havre de Grace.