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U. S. COMMISSION OF FISH AND FISHERIES,
GEORGE M. BOWERS, Commissioner.

ARTIFICIAL PROPAGATION

OF THE

SHAD AND PIKE PERCH.

Extracted from the Revised Edition of the Fish Manual. Pages 121-145 and 165-179
Plates 40-46 and 51-52.

WASHINGTON:
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1903.

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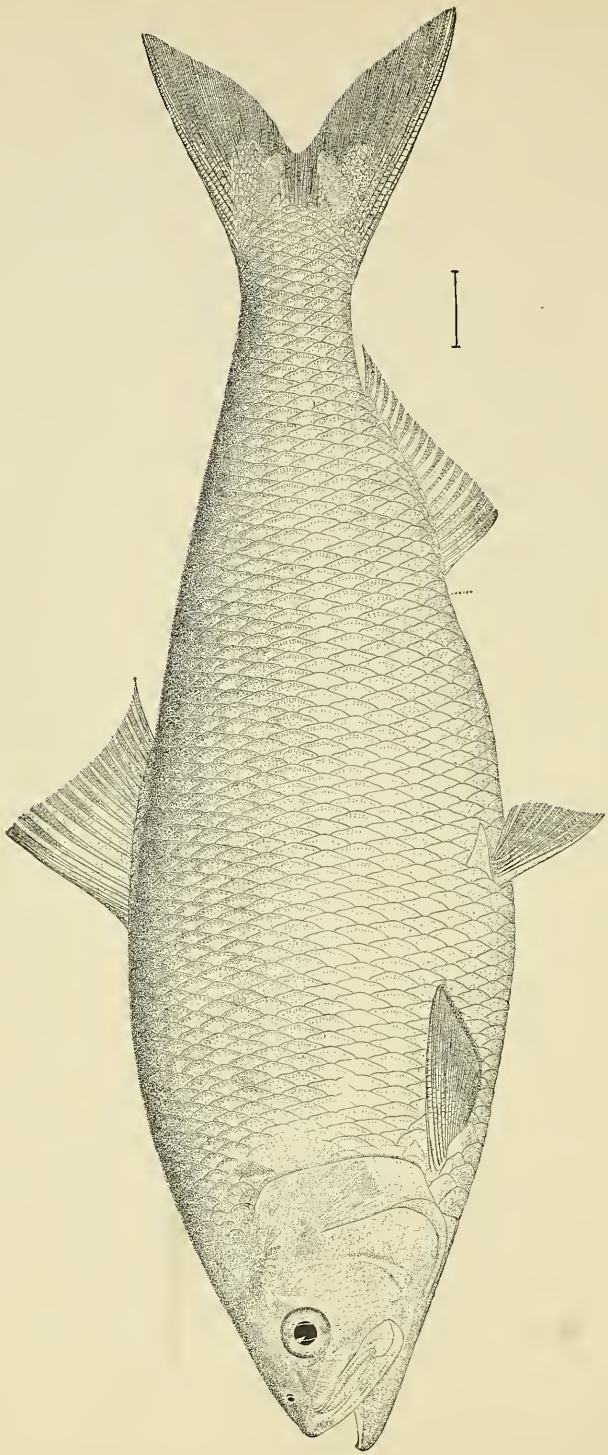


ALOSA SAPIDISSIMA. *Common Shad.*

THE SHAD.

DESCRIPTION OF THE SHAD.

The shad (*Alosa sapidissima*) is the largest, best-known, and most valuable member of the herring family in the United States. The body is deep and compressed, the depth varying with the sex and spawning condition, but averaging about one-third the body length. The head, contained about $4\frac{1}{4}$ times in the body length, is quite deep; the cheek is deeper than long. The jaws are about equal, the lower jaw fitting into a deep notch on the tip of the upper. Teeth are present in the young, but are not found on the jaws in the adult. The eye is contained $5\frac{2}{5}$ to 6 times in the length of head. The gillrakers are long, slender, and numerous, there being from 93 to 120 on the first arch. The fins are small and weak, the dorsal containing 15 rays and the anal 21. The lower edge of the body is strongly serrated, the plate-like scales numbering 21 before the ventral fin and 16 behind it. The scales in the lateral line number 60. The body is dark-bluish or greenish above, silvery on the sides, and white beneath. There is a dark spot behind the gill-opening and sometimes a row of smaller spots along the side. The vertical fins often have black or dusky edges. The peritoneum is white. Supposed structural and color peculiarities in shad from different regions or basins have not been verified.

From the other clupeoids with which the shad is frequently associated in the rivers, it may be readily distinguished. In all of them the cheek is longer than deep. The hickory shad or hickory jack (*Pomolobus mediocris*) has a projecting lower jaw and a very straight profile. The river herrings or alewives are much smaller than the shad, have fewer and shorter gillrakers, and a larger eye ($3\frac{1}{2}$ in head). In the branch herring (*P. pseudoharengus*) the peritoneum is pale, while in the glut herring (*P. æstivalis*) it is black.

The female shad is larger than the male, the average difference in weight being more than a pound. The mature males taken in the fisheries of the Atlantic coast weigh from $1\frac{1}{2}$ to 6 pounds, the average being about 3 pounds; the females usually weigh from 3 to 6 pounds, the average being $4\frac{3}{4}$ pounds. The general average for both sexes is between $3\frac{3}{4}$ and 4 pounds. In the early history of the fisheries, shad weighing 11, 12, and even 14 pounds were reported, but 9-pound shad are very rare on the Atlantic coast, and 10 pounds seems to be the maximum. Some seasons an unusual number of large shad (7 to 9 pounds) appear in certain streams. On the Pacific coast shad average a pound or more heavier than on the Atlantic, occasionally attaining a weight of 14 pounds; many have been reported weighing 9 to 12 pounds.

DISTRIBUTION AND ABUNDANCE.

The shad is distributed along the entire east coast of the United States, and northward and eastward to the Gulf of St. Lawrence. It has gradually spread from the Sacramento River, California, where it was introduced by the California Fish Commission, and is now taken from southern California (Los Angeles County) to southeast Alaska. In the early history of the country its abundance excited unbounded astonishment. Nearly every river on the Atlantic coast was invaded in the spring by immense schools, which, in their upward course, furnished an ample supply of good food. Notwithstanding greatly increased fishing operations and the curtailment of the spawning-grounds, the supply in recent years has not only been generally maintained, but owing to fish-cultural efforts has been largely augmented in certain streams, notably in the Kennebec, Hudson, Delaware, Susquehanna, Choptank, Potomac, Nanticoke, Rappahannock, York, James, Chowan, Roanoke, Neuse, and St. Johns rivers, and in Chesapeake Bay, Albemarle Sound, Croatan Sound, and Pamlico Sound, and the Sacramento and Columbia rivers.

SHAD IN THE OCEAN.

The shad passes most of its existence at sea, and little is known of its habits and movements when out of the rivers. The ocean areas to which it resorts are unknown, and what its salt-water food consists of has not been determined. In the Gulf of Maine it is known to associate in large numbers with mackerel and herring during the months of June, September, and October, being most numerous in June. It has been taken at North Truro, Massachusetts, in the fall, when the ocean temperature was from 43° to 49°. In the month of November, one year after another, it has been found on the west side of Sakonnet River, Rhode Island. In May and June it has been captured with mackerel a few miles northeast of Cape Cod Light. Some instances of capture indicate that under certain conditions the adults may remain in the fresh-water rivers a whole year. In November, 1890, 600 were taken in the Chesapeake Bay. It has been found in the Potomac in considerable abundance in August and September, and even during the last week in December. Its movements are largely controlled by the water temperature. It is believed that it seeks to occupy an area having a temperature of 60° or 70°, and that its migrations are determined by the shifting of this area.

SHAD IN THE RIVERS.

The annual migration of the shad from the ocean to the rivers is for the sole purpose of reproduction. It ascends to suitable spawning-grounds, which are invariably in fresh water, occupying several weeks in depositing and fertilizing its eggs in any given stream.

Its migrations from the sea are in quite a regular succession of time with relation to latitude. It first appears in the St. Johns River,

Florida, about November 15, the season of greatest abundance being February and March. In the Savannah River, Georgia, and the Edisto, South Carolina, the run begins early in January and ends the last of March. In the North Carolina rivers these stages of the migration are a little later. In the Potomac River advance individuals appear late in February, but the fish is most numerous in April. In the Delaware River the maximum run is about the 1st of May. It reaches the Hudson River the last of March, and is found in the Connecticut toward the end of April, is most abundant the last of May, and leaves the stream late in July. In the Kennebec and Androscoggin rivers, Maine, it is first taken in April and has left by the middle of July. In the St. John River, New Brunswick, it appears about the middle of May, and in the Miramichi River, New Brunswick, late in May.

The main body of shad ascends the rivers when the temperature of the water is from 56° to 66°, the numbers diminishing when the temperature is over 66°. Successive schools enter the Potomac from February to July, the males preceding the females. Of 61,000 shad comprising the first of the run received at Washington, D. C., from March 19 to 24, 1897, 90 per cent were males. Toward the close of the season males are extremely scarce.

The movement of the shad up the rivers is not constant, but in waves, causing a rise and fall in the catch. In some of the rivers the fishermen claim that a fairly well-defined run occurs late in the season, consisting of a somewhat different fish, known as "May shad."

The erection of impassable dams along the rivers and streams was probably the first thing to curtail the natural spawning-grounds of these fish and to seriously check their natural increase.

As shad enter the rivers only for the purpose of spawning, the fisheries are necessarily prosecuted during the spawning season, and often upon the favorite spawning-grounds. The increase of population necessitates a larger supply of fish and requires the use of more apparatus, and the number of shad that reach fresh water is therefore greatly curtailed by assiduous fishing with all kinds of contrivances in the estuaries and in the mouths and lower parts of rivers. Under these conditions of a restricted spawning area and increased netting shad would soon be exterminated without artificial propagation; or the fishery, at least, would greatly diminish and become unprofitable. Such a crisis was fast approaching in 1879, when the Fish Commission entered upon systematic work in shad propagation.

From their birth until their return to the rivers shad are preyed upon incessantly by other fish, so that the larger portion of the young do not survive their few months' sojourn in fresh water, and of those which leave the rivers each season probably not one in one hundred reaches maturity to deposit its eggs and contribute to the perpetuation of its species. In the rivers striped bass, white perch, black bass, and other predaceous fishes devour the young, and when they reach salt water, sharks, horse-mackerel, kingfish, etc., undoubtedly destroy many

adults. It has been observed by North Carolina porpoise fishermen that as the shad swim close along the shore the porpoises follow and feed on them till they pass into fresh water. In the rivers the adult shad is comparatively free from enemies.

To what extent the pollution of the waters has reduced the numbers of shad is not known, but acids, sawdust, garbage, oils, gas tar, and refuse from dye-works all tend to make the water of rivers unsuitable for them.

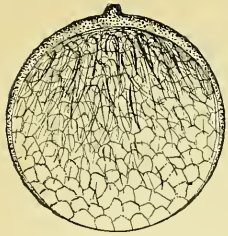
FOOD.

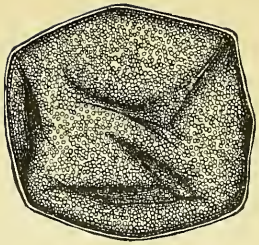
After entering the rivers, the shad takes but little, if any, food previous to spawning, but after casting its eggs it bites at flies or any small shining object, and has been known to take the artificial fly. The mouth of the adult is practically toothless, and its throat contains no functionally active teeth. The water which passes through the branchial filter—the gillrakers—is deprived of the small animals which are too large to pass through its meshes. It is a common remark with fishermen and others that food is rarely found in the stomach of the adult shad in fresh water, but examinations have shown that the shad does, in some instances, eat small crustacea, insects, etc. The only substance commonly found in its stomach in fresh water has the appearance of black mud. It is held by some that the shad swims with its mouth open and may unintentionally swallow the small organisms found in its stomach under such circumstances, but as far as observation of fish in aquaria and experiences of net fishermen go, the shad does not swim with its mouth open.

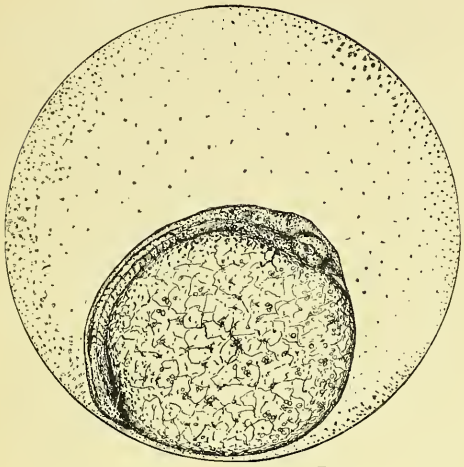
NATURAL SPAWNING.

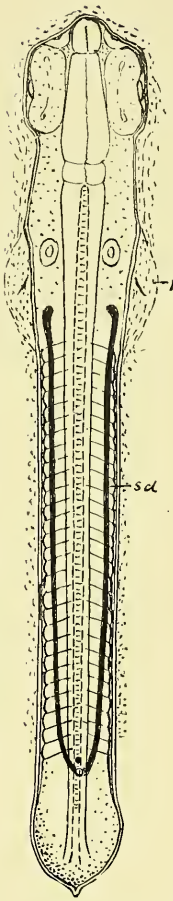
Shad are liable to be ripe anywhere above brackish water, and under favorable temperature conditions spawn wherever they happen to be, but in some river basins they exhibit a well-defined choice of spawning-places, preferring localities below the mouths of creeks, where the warmer water of creeks mingles with the colder channel water. The shad lays its eggs during the highest daily average temperature, a condition realized about sunset, when the warmer shoal water commingles with the colder channel water, establishing a balance. The principal spawning occurs from 5 p. m. to 10 p. m. Observations on the Potomac River show that of the eggs from shad caught in a seine only 11 per cent were taken between midnight and noon, the percentage in the morning being 14 one year and 8 another.

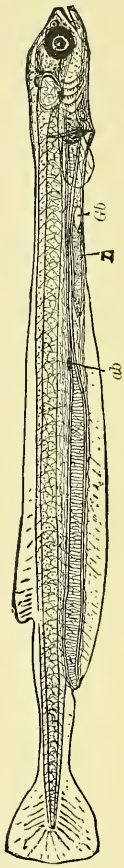
The eggs in the ovaries remain in a compact mass until they ripen, at first occupying but a small space, but gradually increasing until they distend the whole abdomen, the average weight of the ovaries being about 13 ounces. Close examination at the approach of the spawning time will disclose large maturing eggs of rather uniform size and others smaller and of variable size. Whether the latter are the forming eggs for the next year, for two or three succeding years, or for the lifetime of the fish has not been determined, nor is it known whether shad spawn every year. The small and shrunken ovaries of a spent fish are still

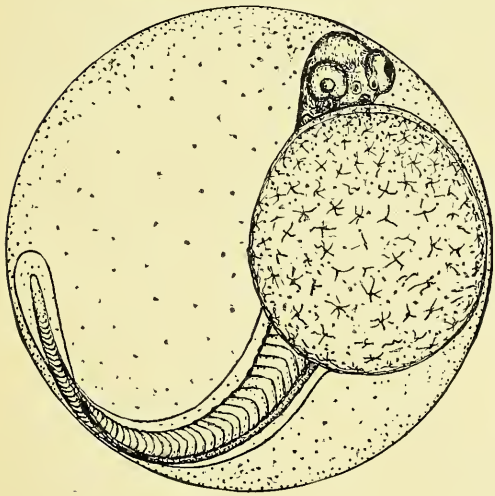




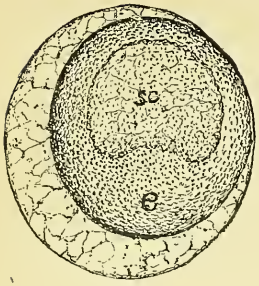








A. Freshly extruded egg enlarged, showing its envelope much wrinkled and its surface covered with small round vesicles.
B. Shad egg, showing vitellus and distended egg-membrane, natural size.
C. Shows the gradual accumulation of germinal matter at one pole of egg, the polar prominence externally, and presence of plasmic processes extending down through the vitellus.
D. Embryo shad in its natural position in its spacious enveloping membrane. From a photograph.
E. Diagrammatic representation of an embryo to show course of segmental ducts *sd* and extension outward of pectoral plates *pp*, which are intimately concerned in the development of pectoral fins.
F. Side view of a young shad 13 days old, viewed as a transparent object. *ab*, rudimentary air-bladder; *L*, liver; *Gb*, gall-bladder.
G. An embryo in its envelope, on the third day of development, nearly ready to hatch.



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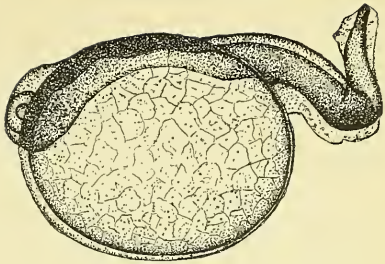

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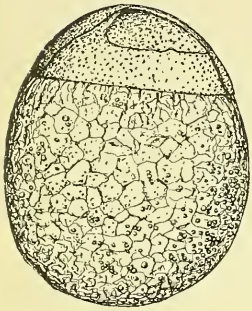

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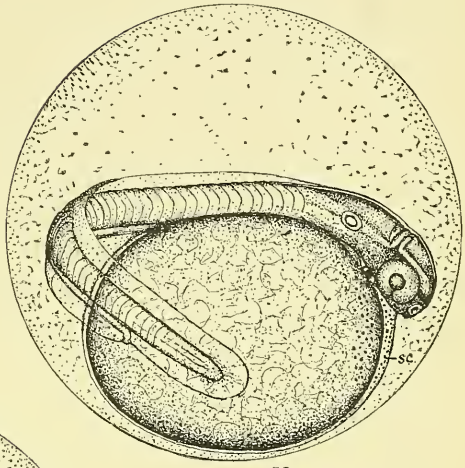

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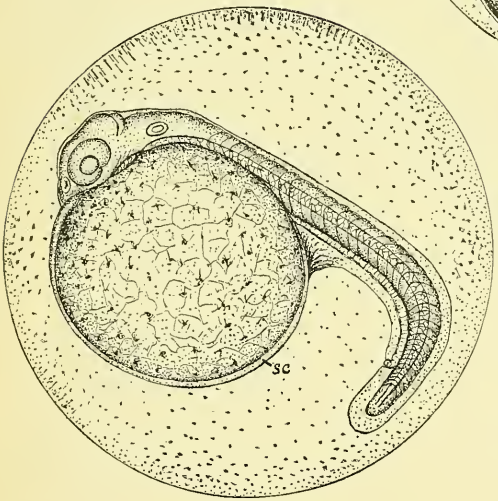

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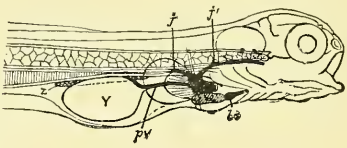

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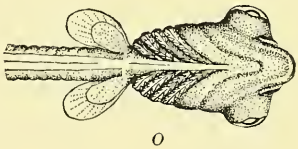

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H and *I*. Two views of an egg after the blastoderm has spread considerably and the embryonic area *e* is well defined.

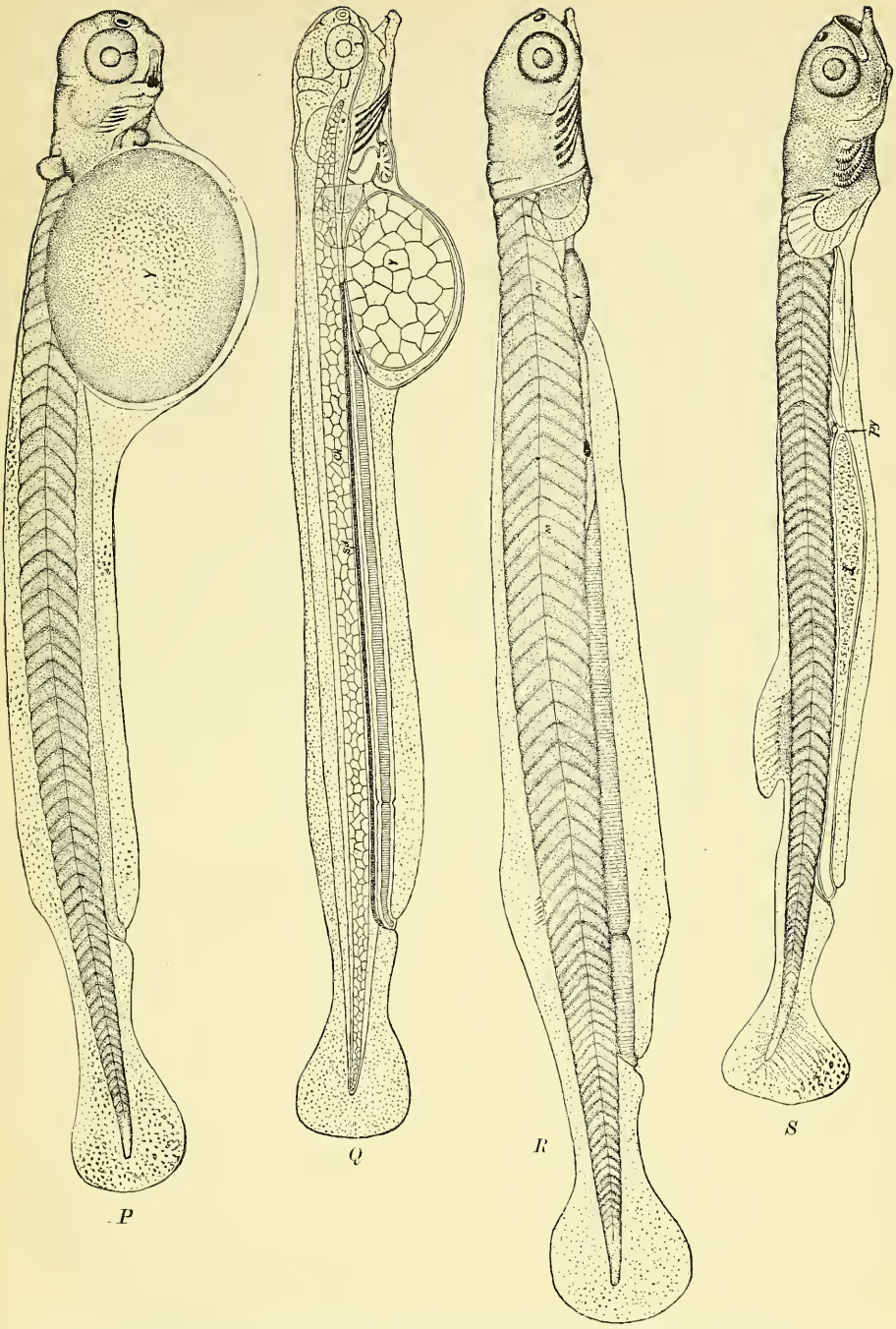
K. View of unhatched embryo, which developed in a temperature of 45° F., producing distortions of tail and notochord.

L. An egg-envelope with its contained embryo, forty-four hours after impregnation, viewed as a transparent object.

M. An egg-envelope with its contained embryo at the beginning of the third day of development. From a photograph.

N. Anterior portion of a young fish on fourth day. To show relations of liver *L* to yolk *Y*, over which the portal vessel *pv* passes forward to empty into the venous sinus, in common with the anterior and posterior jugulars *j'* and *j*, *ba* bulbus aortæ, *ve* ventricle.

O. View of fore part of a young fish 17 days old, from ventral side.



P. Young fish immediately after hatching, viewed as an opaque object and somewhat obliquely from one side, to display the relations of branchial and hyomandibular arches, and position of pectoral fin.

Q. Young fish third day after hatching, viewed as a transparent object to show extension of segmental duct forward; chorda *ch.*

R. Young fish 5 days after hatching, very much enlarged, and viewed as an opaque object. Only a slight remnant of the yolk-sac *Y* remains.

S. Young fish 17 days after hatching, viewed partly as an opaque and partly as a transparent object; *py* pylorus and rudimentary air-bladder above it; *I* intestine, filled with the remains of ingested food. The opercula are already so far developed as partly to conceal the gills.

found full of these eggs of different sizes. Shortly before spawning, transparent eggs of large size, contrasting strongly with the opaque golden hue of less mature ones, will be found scattered through the still compact ovarian mass, and, becoming more and more numerous, the ovaries disintegrate, the eggs fall apart, and extrusion begins, a liquid stream of eggs and mucus flowing from the oviduct on the slightest pressure of the abdomen.

Freshly deposited shad eggs are of a pale amber or pink color, and are transparent. They are about $\frac{1}{14}$ inch in diameter and somewhat flattened and irregularly rounded in form. The egg membrane is much wrinkled and lies in close contact with the contained vitellus. Immediately after fertilization the egg becomes spherical through the absorption of water and apparently gains very much in bulk, measuring about $\frac{1}{7}$ of an inch in diameter; but this gain is only the distended egg membrane, the vitellus or true germinal and nutritive portion not having increased. The vitellus is heavier than water, and a large space filled with fluid now exists between it and the membrane, the vitellus rolling about and changing its position as the position of the egg membrane is altered. No adhesive material is found on the outside of the membrane, though when first extruded the eggs are covered with a somewhat sticky ovarian mucus.

In a state of nature the shad deposits its eggs loosely in the rivers without building a nest, the two sexes running along together from the channel towards the shore, and the eggs and milt being ejected simultaneously. On quiet evenings, at the height of the season, spawning shad may be heard surging and plunging along the shores. By fishermen this is termed "washing."

Shad are very prolific, but much less so than many other food-fishes. The quantities of eggs taken by spawn-takers do not represent the actual fecundity, for many are cast in advance of stripping. The average number is not more than 30,000. Single fish have been known to yield 60,000, 80,000, 100,000, and 115,000 eggs; and on the Delaware River, in 1885, one yielded 156,000. Many eggs fail to be fertilized, and but a comparatively small percentage of those impregnated are hatched. After being extruded, the eggs sink to the bottom, where they remain until hatched, subject to the attacks of fish and other water animals. Eels are very destructive to shad spawn and often attack shad caught in gill nets, devouring the undeposited eggs and sometimes mutilating half the catch of a gill net fisherman.

The development of fungus is one of the greatest dangers to shad eggs in a natural state, and another potent agency for their destruction is the mud brought down by heavy rains, burying and suffocating the eggs.

After spawning, shad are denominated "down-runners," "racers," and "spent fish." They are then very lean and hardly fit for food, but they begin to feed and have become fatter by the time they reach salt water in the summer or fall.

YOUNG SHAD.

In the Middle States the young fish remain in the rivers, feeding and growing, until the cool weather of fall comes on. They then begin to drop downstream, and by the last of November have passed out into the ocean or bays, and are lost sight of until they come back three or four years after, full-grown and ready to spawn. They leave the Potomac River when the water falls to about 40°. By that time they are about 3 inches long. For the last two or three years they have been observed in great abundance about Bryan Point, feeding and jumping out of the water about sunset. They keep within the open streak of water between the shores and the water-grass which covers the flats, in water 2 to 5 feet deep. After mild winters young shad have been found in the Potomac River in April, 30 miles above brackish water and 160 miles from the ocean, associated with young alewives and sturgeon. Some immature shad, apparently 2 years old, are caught each year in seines operated in the fresh water of the Potomac River, and undersized shad are frequently caught in the New England rivers, where the tidal waters are of little length.

COMMERCIAL VALUE.

The shad is one of the most palatable and popular of fishes. Its flesh is rich, but not oily, and the roe is considered a delicacy. It is the most valuable river fish of the Atlantic coast, and, next to the Pacific salmon, the most important species inhabiting the fresh waters of North America. In every Atlantic State from New Jersey to Florida, inclusive, it is the most valuable fish, and in New York it is second only to the bluefish. Among all the economic fishes of the United States only the salmon and cod exceed it in value, and, considering all branches of the fishing industry, only the whale fishery and the oyster fishery, besides the foregoing, are financially more important than the shad.

In 1896 the shad catch of the Atlantic seaboard numbered 13,145,395 fish, weighing 50,847,967 pounds, and worth to the fishermen $1,656,580. The value of the shad catch of the Pacific States in 1895 was $5,600, a sum representing 366,000 pounds.

EARLY ATTEMPTS AT SHAD-CULTURE.

The systematic development and extension of shad-culture were undertaken with the definite purpose of testing the value of artificial propagation in maintaining an important fishery which was being rapidly depleted. As early as 1848 shad eggs were artificially taken and fertilized, and in 1867 more extensive experiments were made on the Connecticut River, and later on the Potomac, with encouraging results. The attention of many States was thus attracted to the work, and in 1872 it was taken up by the general government. Prior to the experiments on the Connecticut, certain species of the salmon family had been principally dealt with in fish-culture, and different methods from those in use were necessary for shad-hatching, owing to the less specific gravity of shad ova and the much shorter period of time required for the development of the fish from the egg.

The "Seth Green box," a modification of the floating-box used for hatching trout and salmon eggs, was first tried with great success, but floating-boxes were subject to various accidents when used in tidal waters, and in rapid succession devices of various kinds were brought forward to supplant them. The most important were hatching-cones and the plunger-buckets, which, though imperfect, rendered larger operations possible. At this period the apparatus was arranged on flat-bottomed barges and towed from point to point along the coast from Albemarle Sound to the Susquehanna River, a slow and expensive method. The Chase whitefish jar worked with considerable efficiency, but required modifications, and finally the "universal" hatching jar now in use was adopted in 1882.

During the years of experimental work from 1872 to 1880, 97,471,700 shad fry were planted, beginning with 859,000 in 1872, while in 1880, 28,626,000 were distributed. Prior to 1880 deposits of a few hundred thousand each were made in as many different streams as possible, but the increased production of young fish made it possible to ship and plant the fry by the carload, and by 1884 shad-culture was established on a large scale, barge operations were abandoned, and the work conducted on shore. The basins of the Chesapeake Bay and Delaware River had meanwhile been selected by the United States Commission as the natural seat of operations, though the State commissions from Massachusetts to South Carolina were actively engaged on their own account. At present the States, except Connecticut, New York, Pennsylvania, and Maryland, have practically abandoned shad-hatching, leaving the work to the general government.

EGG-GROUNDS.

Every river on the Atlantic coast from Massachusetts southward has been examined by the agents of some State commission or the United States, or by both, in order to determine the natural spawning-grounds of the shad. On nearly every stream hatcheries have been operated at one time or another, but usually eggs were not obtained in sufficient numbers to justify continued operations, except in the Chesapeake and Delaware basins. However, it is not unlikely that after further investigation it will be found practicable to maintain hatcheries on rivers which have long since been abandoned. It is certain that work on the Albemarle Sound can be successfully conducted, and though operations on the Hudson River have not been on a large scale, better results may be there obtained in the future.

In certain river stretches, apparently favorable, no ripe fish are found; for example, in the Roanoke River for 15 miles above its mouth, where 10,000 to 15,000 shad are taken annually, mature eggs can not be found, though the fish spawn just below there, as they do many miles above at Weldon. In the Sutton Beach seine, the one in North Carolina waters which has afforded the most spawn, only about one spawning shad to each 100 is caught, and the annual catch of this seine is 30,000 to 75,000 per annum. In view of such facts, it is not remarkable that difficulty

has been experienced and time consumed in deciding on permanent locations for hatcheries.

The spawning period varies widely in different seasons; in some years shad are numerous and in spawning condition two or three weeks after the time when they have ordinarily disappeared. They deposit eggs at some point along the coast for six continuous months.

The following streams have been occupied by hatcheries, as some of them are now, and it will be observed that the approximate spawning periods, beginning early in the South, become gradually later toward the North.

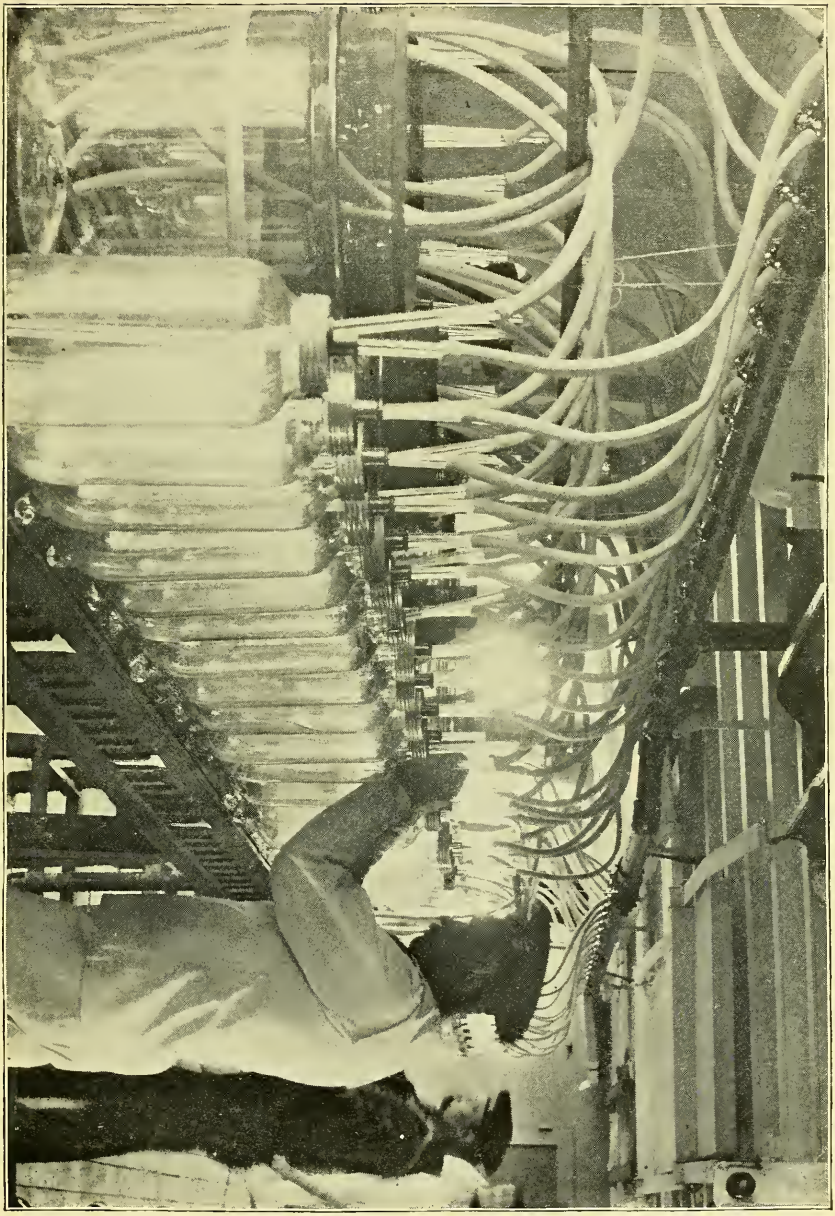
Waters.	Place.	Period.
Edisto River	Jacksonboro, S. C	Mar. 5-26.
Albemarle Sound	Avoca, N. C	Apr. 1-30.
Potomac River	Below Washington, D. C	Apr. 15 to June 10.
Susquehanna River	Below Havre de Grace, Md	Apr. 17 to June 15.
Delaware River	Gloucester, N. J	May 10 to June 20.
Hudson River	Below Albany, N. Y	May 15 to June 30.
Housatonic River	Birmingham, Conn	Do.
Connecticut River	Holyoke, Mass	June 15 to July 5.
Merrimac River	North Andover, Mass	June 1 to July 15.

The United States Fish Commission operates stations at Bryan Point, 12 miles below Washington on the Potomac, and at Battery Island at the mouth of the Susquehanna, while the steamer *Fish Hawk*, fitted up as a floating hatchery, is engaged during the shad season on the Delaware River. These two stations and the vessel can receive respectively 16,000,000, 40,000,000, and 12,000,000 eggs. On more than one occasion each has been taxed to its utmost capacity, but as the average hatching period is 8 days, and four of the special cars of the Commission are hatcheries in themselves and capable of taking 2,000,000 to 4,000,000 eggs aboard at a time, the hatcheries can be quickly relieved in case of emergency.

In 1897, 205,000,000 eggs were taken, from which 134,545,000 fry were hatched. In 1898, the total of shad fry hatched was 156,150,000, and in 1899 it was 210,493,000.

In 1900, a permanent hatchery located on an arm of Albemarle Sound, near Edenton, North Carolina, was operated for the first time. This station is adjacent to one of the most important shad fishing-grounds in the country, and is intended to replenish the waters of Albemarle, Croatan, Roanoke, and Pamlico sounds, and their tributaries—the Pasquotank, Chowan, Roanoke, Pamlico, Neuse, and various minor rivers. This region annually yields upward of 8,500,000 pounds of shad, valued at about $350,000, and contributes the principal part of the shad found in the northern and eastern markets in winter and early spring.

Potomac River.—The Potomac River, immediately adjacent to Fort Washington (12 miles below Washington, D. C.), is probably more productive of ripe shad than any other area of the same size. This was



MAIN DECK OF THE STEAMER FISH HAWK, EQUIPPED FOR HATCHING SHAD.

discovered as early as 1880, and a station was soon developed there with steam pumps, tanks, and hatching vessels. The seine operated at this point between 1887 and 1891 furnished 23 per cent of all eggs from the river.

The following table, taken from the records of the station, shows the value of the spawning-grounds:

Years.	Number of eggs taken.	Years.	Number of eggs taken.
1880	20, 749, 000	1891	32, 980, 000
1881	43, 200, 000	1892	13, 446, 000
1882	21, 800, 000	1893	9, 423, 000
1883	24, 274, 000	1894	32, 393, 000
1884	19, 000, 000	1895	66, 065, 000
1885	22, 576, 000	1896	64, 788, 000
1886	36, 362, 000	1897	39, 707, 000
1887	59, 435, 000	1898	68, 724, 000
1888	81, 177, 000	1899	49, 283, 000
1889	58, 233, 000	1900	67, 904, 000
1890	35, 202, 000		

In 1889 immense collections of eggs were made on certain days—8,368,000 on May 6 and 6,311,000 on May 7, and during seven days there was an average of over 5,000,000 per day. This was before and just after a freshet.

To increase the supply of eggs, seine fishing has been attempted by the Commission on both the Susquehanna and Potomac, but the efforts were only partially successful and were finally abandoned. The extension of egg-taking by seines can not be relied upon, especially as this method of fishing has been declining for many years, owing to its greater expense, and a corresponding growth has taken place in the gill-net fishery. It is often difficult to obtain the ripe eggs when the shad are taken in a seine on account of the great numbers of alewives taken at the same time.

The following comparative table shows the shad-egg production from a Potomac River seine, together with the proportion of males, females, and spawning fish, and the number of eggs per fish:

Year.	Total number of eggs obtained.	Total ripe fish.	Total shad caught.	Per cent of males.	Per cent of females.	Average number of eggs per fish spawned.	Per cent ripe.
1887	20, 956, 000	652	10, 348	71. 4	28. 6	32, 100	6. 3
1888	22, 657, 000	688	11, 212	69. 2	30. 8	32, 900	6. 1
1889	17, 738, 000	612	6, 217	52. 3	47. 7	28, 980	9. 8
1890	10, 262, 000	468	4, 606	54. 3	45. 7	21, 900	10. 1
1891	5, 276, 000	228	3, 138	57. 1	42. 9	23, 140	7. 2

Had all other fisheries furnished an equal percentage of eggs, the annual Potomac collections would have reached about 300,000,000. But while the Fort Washington seine, with a catch of 10,000 shad, gave 20,000,000 eggs, and another, capturing 18,000, gave 17,000,000, a third catching 60,000 shad, gave only 1,000,000.

Eggs taken by gill fishermen are usually superior to those from seines, and the gillers attach enough value to the market for eggs to save almost all within reach. At the commencement of the season many of them secure spawning-pans, which they keep in their boats, taking and fertilizing the eggs themselves, and when accidentally overlooked by the regular spawn-takers they sometimes row several miles to bring in pans of eggs. In 1896 a giller who laid out his net with the special object of securing spawning shad, caught 3,300 fish and sold over 6,000,000 eggs to the Commission. About 1,100 of his fish were roe shad; of the total, about 6 per cent were ripe; of the 1,100 roe, about 20 per cent were ripe.

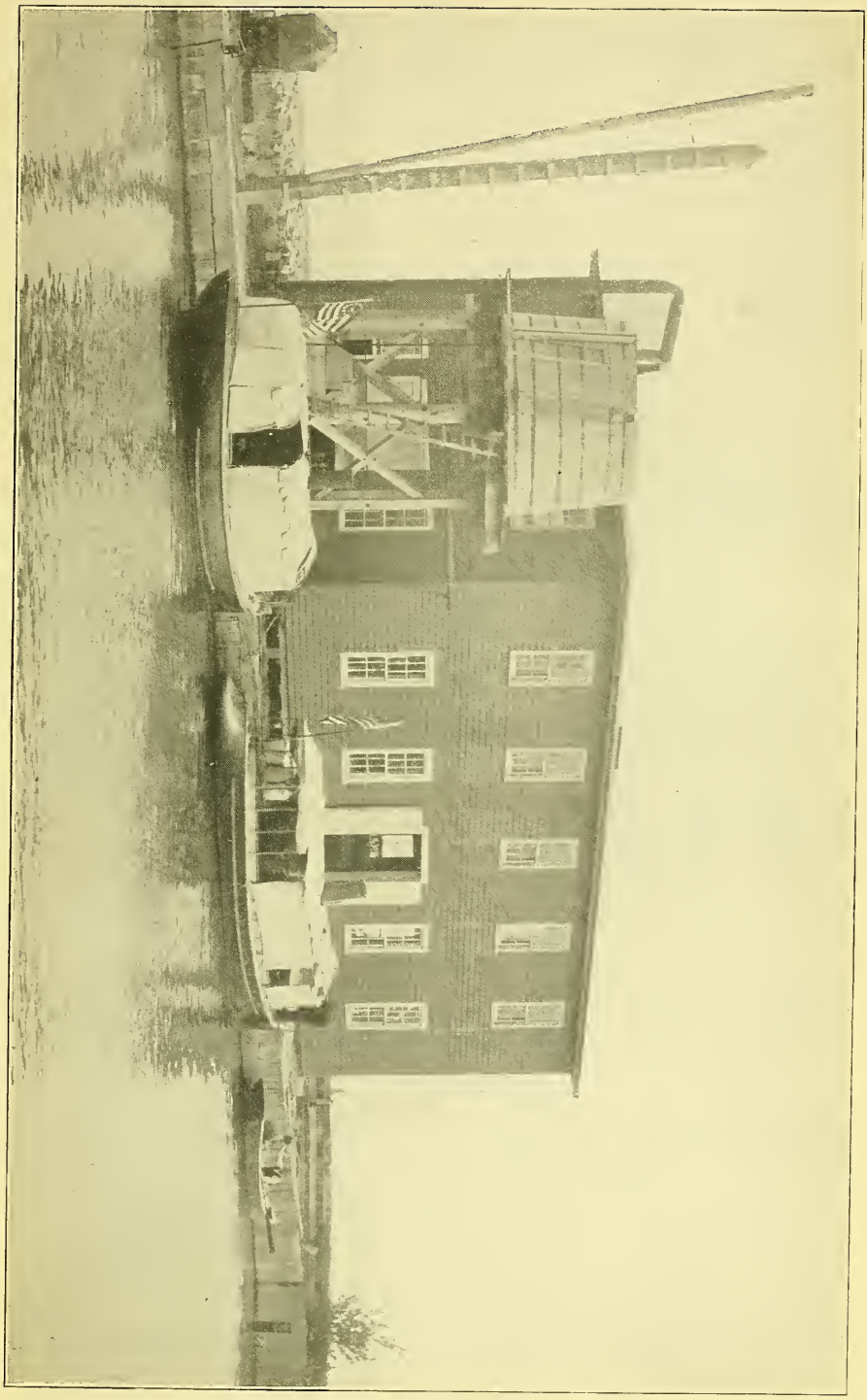
The average catch of shad by the gillers who supply eggs is 1,600 to 1,800 per season; but they do not all operate specially for the capture of spawning fish, though this work is profitable and gillers are fast turning attention to it. The Fort Washington gilling boats furnish on an average about 1,000,000 eggs each a season, those at White House 400,000, Sandy Bar 350,000, Greenway 300,000, and Craney Island 150,000, the average being about 500,000 per boat.

Susquehanna River.—The shoal water in the neighborhood of Battery Station is an extensive and valuable spawning-ground. The station is conveniently situated on an island and the possibilities in egg-collecting appear to be almost unlimited. Hundreds of gill fishermen are engaged and large seines are operated within easy distance. In 1886 the station was overrun with eggs; 170 universal hatching-jars and 58 cones would not contain them, large numbers being held in cylinders, buckets, and pans. In 1888 over 105,000,000 were taken, and in 1889 7,600,000 were obtained in one night. Both egg-collecting and hatching are carried on, and the establishment is complete in itself. There is no transfer of the eggs except for occasional car shipments, and the fry are carried to Havre de Grace in 10-gallon cans for railroad transfer to the places of deposit.

Delaware River.—The steamer *Fish Hawk* has been employed in shad-hatching on this river nearly every season since 1887, the egg-collecting and other labor being performed by the crew. An interesting feature of the work is the large yield of eggs per fish. Eggs from this river have been saved regularly since 1887 from seines, but the available product among the gill fishermen has never been fully ascertained.

The eggs collected by the *Fish Hawk* numbered 51,983,000 in 1899.

The methods pursued at the different shad hatcheries are very similar. The following description applies particularly to the work on the Potomac River at Bryan Point.



BATTERY STATION HATCHERY, HAVRE DE GRACE, MARYLAND.

EGG-COLLECTING.

Collecting eggs is the work of experienced watermen, who must be prepared to endure all kinds of weather in open boats. The boats are towed out to the fishing-grounds by steam-launches, where the spawn-takers visit the nets of the market fishermen, obtaining from them the spawning fish. After eggs have been obtained a ticket is dropped into each panful, with the date and the name of the fisherman, for entry on the books of the station. The price for eggs is always above the market price of the shad, and payment is made at the end of the season on the basis of 28,000 to the liquid quart, the price being $10 to $20 per 1,000,000. On the Potomac 40 to 50 spawn-takers are employed at the station, besides 12 or 15 men who are engaged as hatching attendants, machinists, firemen, and cooks.

The spawn-taker uses a 16-foot flat-bottomed bateau and is provided with a lantern, six small and four large spawn pans, and a dipper of suitable size. The pans are made of tin and are of two sizes, 11-inch and 18-inch diameters, the latter with handles. The smaller are for receiving eggs on delivery from the fish, and the larger for carrying them. The pans are thoroughly washed each night after use and not allowed to become rusty or indented. The dippers are round-bottomed, hold nearly a quart, and have handles with open ends, with 5 inches of the free end wrapped with seine twine. To obtain eggs from a seine, double the above number of spawn vessels may be required.

Spawn-taking tubs of indurated wood fiber have been introduced in Potomac River operations and found superior to tin, being without hoops or joints, non-corrosive, and non-conductors of heat. They have wood covers which fit inside the rims, and the tops fit tightly by means of a soft rubber joint: 4 inches of the central part of the cover is cut away to admit air.

As the shad manipulated are sold and consumed in a fresh state, fishermen waste no time in transferring them to market boats, which are in waiting, and rapidity of execution is therefore required on the part of the spawn-taker, who must be alert and exact in his methods.

In gill-net fishing there is usually ample time to assort the fish, which are taken into the boat one at a time, except when sudden squalls or exceptional captures force the premature hauling in of the net with the fish wound up in the meshes. Unskilled spawn-takers are liable to the mistake of stripping eggs without having the necessary milt to impregnate them, for several spawners may be taken over a period of ten or twenty minutes without the capture of a male fish. In such cases (of great frequency late in the season) the female fish must be placed conveniently, backs down, to prevent the eggs from running out, and the males may have to be obtained from other boats. When ripe shad are taken in seines, two or three large baskets should be in readiness to receive them.

Sometimes the number of ripe fish will be sufficient to occupy all the attention that can be devoted to them; at other times the run of fish

is greatly reduced by local conditions. Even when other conditions are satisfactory, if neither high nor low water occurs about sunset but few ripe fish are caught. The large seines land toward the last of the ebb tide, and gill net fishermen can do nothing except on the change of the tide—on slack water. The fish spawn at a certain time of day, and when taken at other hours are not in spawning condition. Thunderstorms sometimes occur for days in succession about sunset, the very hour when most disastrous.

A scarcity of male fish toward the end of the season often cuts short operations when eggs are plentiful. Unsuccessful attempts have been made to capture the males at such times by using gill nets with meshes smaller than those in the nets of market fishermen. Attempts have been made to pen the adults, but without success, as the fish become diseased and their eggs spoil within them. In gill nets the adult is entangled in the mesh and can not escape by struggling, and it therefore remains comparatively quiet.

The quality of shad eggs is generally impaired where the fish are held for an hour or more in trap nets or seines. The eggs from fish taken in large seines are usually of bad quality, but those from short seines, which are landed quickly after the fish have been surrounded, are usually good; and those from trap nets, in which the fish have been held for some hours, are valueless. Eggs are rarely susceptible to fertilization longer than 20 minutes after the fish are taken from the water, though there are exceptions to this rule. On May 23, 1895, Potomac shad were stripped which had been out of the water about 1¼ hours; they were kept separate, and at the end of 48 hours produced 100,000 eggs, which yielded 98,000 fry.

The shad dies very quickly after capture and is immediately responsive to electrical storms, the catch of seines and nets of all kinds falling off promptly when a thunderstorm develops. Even in seines already laid out in the water, with lead line on the bottom, there is an appreciable decrease in such event. On the Delaware River, May 29, 1887, nearly 50 per cent of the shad eggs on board the steamer *Fish Hawk* perished during an electrical storm which continued from 6 p. m. to midnight. There were 4,481,000 eggs with embryos well formed, and without perceptible change in water temperature 1,918,000 were killed, many turning white by 8 p. m.

Heavy freshets cause an abrupt suspension of fishing, but the effect of a single freshet is usually temporary. The shad which have gone above are backed down before the muddy water, but reappear upon its outward passage. An occurrence of this kind will effect a great increase in egg receipts if the water temperature before muddy water comes is suitable. The shad that were scattered above being thrown back in a body, reascend in a body.

A season of clear water is undesirable both for fishermen and hatching work, as the fish see the nets and avoid them, gill nets being put out only on the night tide and half the fishing being thus lost. The water

should be discolored enough to prevent the fish from seeing the nets, but not thick, say from 10 to 20.* An occasional freshet reduces the temperature and prolongs the season; however, with an equal number of fish in the rivers, clear water is probably more advantageous for natural increase, as a large proportion of naturally deposited eggs must perish from suffocation under the mud in seasons of freshet.

THE WEATHER AND SPAWN.

The development of eggs within the ovaries is hastened by heat and retarded by cold. In a warm season fish ready to spawn are more numerous early in the season than in a cold one, and the period for obtaining them is apt to close earlier. The eggs, not only after they are deposited and impregnated, but before they leave the body of the fish, are affected by the temperature of the water, often being "blighted" or "rotten ripe." This phenomenon was observed as far back as 1873. It occurs on the water reaching 80° to 81°, or with a rapid rise. On the other hand, a sudden fall in temperature has been observed to arrest natural spawning, produce blighted eggs, and to destroy those in the hatching vessels. Continued low temperature is also disastrous to fishing.

An abnormally inferior quality of the Potomac River eggs was noticed during the full period of operations in 1896. The bulk of the run of shad made their appearance on a rapidly ascending temperature, and the eggs were injured within the parent fish, more than half perishing before conversion into fry. The rise in temperature was greater than had been recorded in the eleven years preceding. The run of shad increased proportionately, the catch at one seine increasing from 100 to 800 in 24 hours. A snowstorm on April 7—morning air temperature 35° F. and mean air temperature 46°—was followed by heavy frost on April 9, the morning air temperature on the last-named date being 34°. The river water on April 10 was 46°, rising to 48° on April 12 and to 71° in the afternoon of April 21, thus gaining 25° in 10 days. After April 21 the catch of shad fell off to such an extent that fishing was no longer profitable.

The water of the Potomac early in March is usually of a temperature of 36° to 40°, rising to 52° to 58° about the middle of April, when the spawning period begins, and at the end of May, the close of the period, it averages from 65° to 70°.

STRIPPING AND FERTILIZING THE EGGS.

In stripping the eggs the shad is lifted with the right hand and caught above the tail with the left. All slime and loose scales are removed by going over the fish two or three times in quick succession with the right hand. The head is carried to the left side under the

* The condition that permits the discernment of objects at a distance of 10 to 20 inches beneath the water surface, the method of registration employed by the Washington (D. C.) aqueduct office.

arm and there retained by the arm, the tail being bent slightly upward with the left hand. When the fish is properly adjusted its head is nearly concealed. The fish is held firmly over a moist pan, and with a moderate downward pressure of the right hand the eggs will flow freely if mature. The strokes are continued until there are signs of blood, which usually accompany the last eggs. The fingers should not touch the gills of the fish, as laceration of these organs causes a flow of blood injurious to the eggs. Two fish may be stripped into each pan.

As soon as the spawn is all obtained, the shad is discarded, it being impossible to preserve the life of such a delicate fish, even with the utmost care. But though it has slight tenacity of life when taken from the water, the shad is a very muscular fish, and if not firmly held it will flounder and splash in the pan of eggs and probably throw a large proportion out and damage some of those that remain.

The first half teaspoonful of eggs should be pressed out into the palm of the left hand and inspected. Skilled operatives can usually discern ripeness by general outward appearance. A slow and yet almost positive test consists in running some of the eggs into water, when, if dead, they will have the appearance of boiled rice. But bad eggs are sometimes beyond the detection of the most skilled fish-culturists. If the eggs are white, opaque, or of milky appearance, the fish is put aside. Immature eggs are white, small, and adhering in clots; or they may be transparent and yet unyielding to pressure. The former are valueless, while the latter can sometimes be utilized by putting the fish aside to soften. Both ripe and green eggs sometimes occur in the same fish, but only expert operatives can hope to take the one and leave the other. If eggs are mature, but little pressure is necessary to start them, and if not, they are only injured by squeezing, and will either not flow at all, or will come away with difficulty in clotted masses and generally with a little blood. After the spawn is taken away, the fish has a soft and flaccid appearance about the abdomen, which after natural spawning becomes contracted and drawn up, tapering slenderly toward the tail.

Eggs of the best grade may be impaired by intermixture of overripe or green ones, lumps of milt, tissues of the sperm sac, or fish scales. The overripe and unfertilized ones can be discarded, and a tiny net, an inch square, or a straw or twig, may be used in removing foreign substances. The spawn-taker should clean the eggs before delivering them at the hatchery, and no subsequent care can compensate for his neglect. Experienced men rarely bring in bad eggs, unless as a result of variable and unfavorable weather conditions.

To obtain the milt the spawn-taker catches the fish by the back, taking hold of the under side with the right hand. Without relaxing pressure at any point the milt is forced out with the thumb and forefinger. Good milt is so thin that it flows in a steady stream, and from some fish it can be ejected widely over the surface of the eggs, but in

fish which have been dead some minutes the milt is lumpy and flows only in drops. A teaspoonful will fertilize 40,000 to 75,000. After the milt has been applied, from half a pint to a pint of water from the river is added and the pan given a slow rotary motion, continued till the milt is thoroughly mixed, when a milky appearance is imparted to the water. When the river water is turbid, clear water must be obtained before work is commenced.

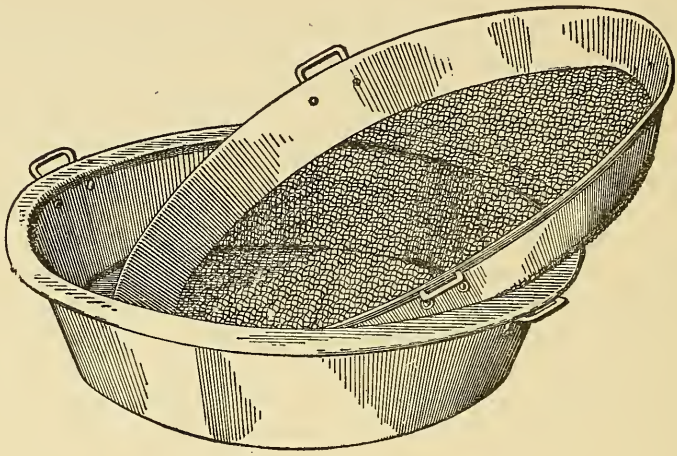
In gill-net boats eggs thus treated will expand without further immediate attention, for there is sufficient motion from the boat to prevent clotting; shad eggs do not "cement" when the milt is applied to them, as in the case with salmon and trout eggs; but they adhere, and if left perfectly quiet, as on shore, a large proportion will be lifeless. Those comprising the lower strata may either lack sufficient expansive power to absorb water under weight of the others, or in the suction of each separate egg, in the natural tendency to absorb water, they may have a cupping effect upon one another, thus preventing water contact. Whatever the cause, they stick together in one mass, and only those of the upper layers receive sufficient water; the others remain undersized and die. Large quantities of eggs must be separated, either by agitating the water already in the pan or by the addition of more.

In one minute after thorough mixing the milt can be washed off with safety, but usually several pans are to be looked after, when the milt may be allowed to remain 5, 10, or even 15 minutes. After the last pan of eggs has been fertilized, they are rinsed, beginning with those first taken, by pouring in a quart of water, placing the edge of the dipper so that the stream is directed between the eggs and the sides of the pan, as the eggs may be injured if the water is poured directly upon them. Then the pan is oscillated, the water being drained over the edge slowly, and, the operation being repeated, the third quart of water is left upon the eggs. The eggs must be well stirred with the inflowing water.

There need be no fear of applying too much milt. The amount obtained from one fish may be ample for the eggs from two, but it is always better to employ two males. Eggs may look promising for two or three hours, yet never expand to full size or produce fish. They lie at the bottom, and underneath any good ones which may be in the pan; they stick to the fingers, while the good ones will not, nor can they be successfully removed from hatching-jars until after several days' decomposition. By using two pans, good eggs may be separated from bad by pouring, but the process is slow and there is usually no time in the hatcheries for such operations.

Good eggs are very transparent and so soft and light that they are not apparent to the touch when the fingers are moved among them. When the temperature is about 70°, no change is observed for about 12 or 13 minutes after the milt is added, but about this time a careful movement of the fingers in the pan discloses their presence, and in a

little more than 20 minutes from the time the milt is applied they feel like shot against the fingers, and to an experienced eye are observed to increase slightly in size; when a day old, they will not break if dropped to the floor. In transferring to other vessels, the rim of the smaller pan should be gently immersed beneath the water surface in the larger one, and the pouring take place gradually. To prevent splashing, in boats, a small pan should be put on the water surface of the larger pan. Sudden jars must be avoided, all foreign substances excluded, and the pans be free from grease and salt. After the application of milt they expand to full size in 20 to 60 minutes, depending partly on temperature, and at this stage they may be doubled up in the larger pans, the question of safety in moving them being determined by their hardness.



Pans used in cleaning eggs.

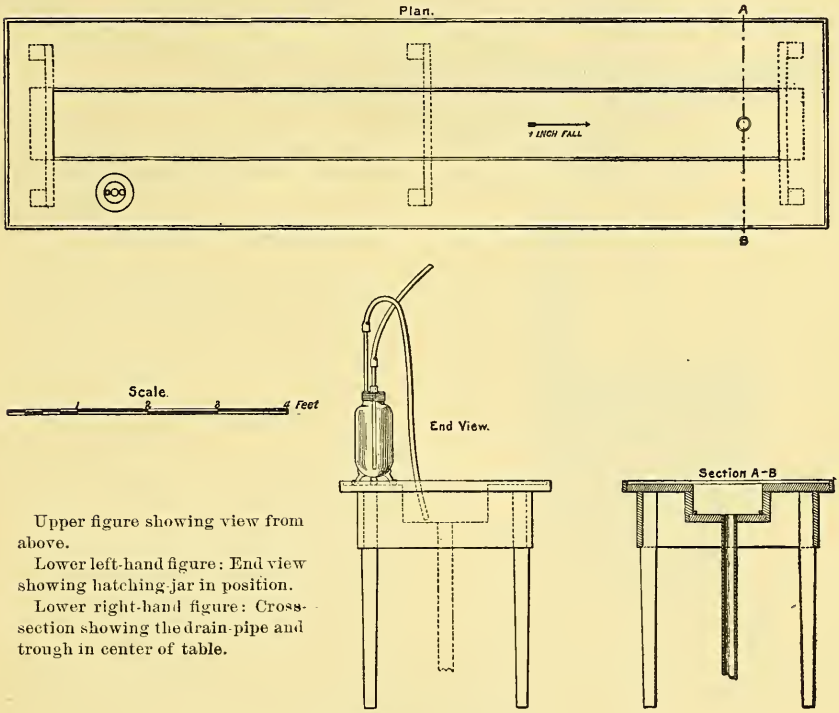
When eggs are received at the station, in order to thoroughly remove all impurities they are passed through netting, and for this purpose, two 18-inch flared tin pans with handles, one pan fitting within the other, are employed; 2 inches of the bottom part of the inner pan are evenly cut off and replaced with quarter-inch (bar) twine netting. The lower pan is filled with water to a point just above the netting, and then several quarts of eggs are gently poured in, when they drop through the meshes, leaving the fish scales, etc., behind. Thus they are also given a change of water, which should be clean and fresh and of about the same temperature as that in the hatchery and river.

If the eggs have absorbed sufficient water in the spawn-pan, they swell and adhere to each other, forming a compact mass, and are ready to be transferred to the hatching-jars, but if they are not sufficiently expanded or "water-hardened," they must remain in the pans, from 30 to 60 minutes being required for their full expansion.

HATCHERIES AND EQUIPMENT.

The building for a shad-hatchery may be of a temporary character, as it is used only about two months each year, but ample light, space, ventilation, and arrangements for moderate heating are necessary. The steam boiler and pumps should be in a separate structure.

In exceptional cases, as at Central Station, in Washington, river water from city pipes can be utilized. If the water supply is taken directly from the river the suction should be put below low-water mark, and the end provided with a strainer and kept off the bottom to avoid sediment. The water should be supplied from an open tank, not by a force-pump, but if it is taken from municipal pipes a regulator may be employed. A fall of 16 feet is desirable, or 8 pounds pressure per square inch at the top of the hatching-jars. The amount required is 2 quarts per minute to each jar.



Upper figure showing view from above.

Lower left-hand figure: End view showing hatching-jar in position.

Lower right-hand figure: Cross-section showing the drain-pipe and trough in center of table.

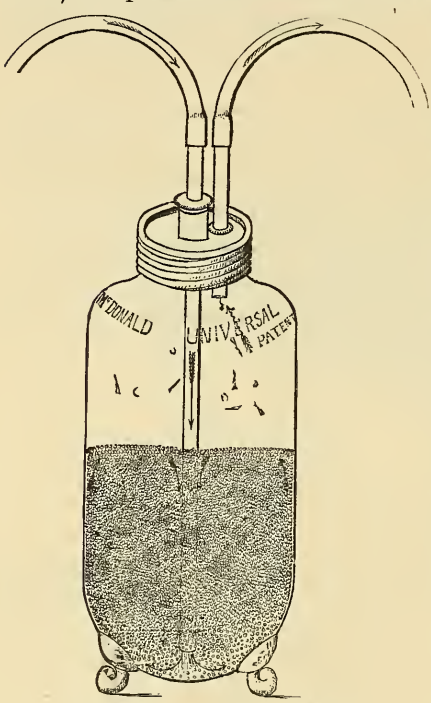
Shad-hatching table.

The jars are arranged on tables, as shown in the cut. From a large iron pipe, branch piping of $1\frac{1}{2}$ to 2 inches diameter is run over each table, where $\frac{1}{4}$-inch brass pet-cocks are inserted 6 inches apart. The jars are connected with the supply-pipes by half-inch rubber tubing. Tight drains are required to carry away the waste water. Collector-tanks for fry are rectangular and may be of glass or wood, the former possibly preferred.

The overflow from the collectors is guarded by a wire-gauze or cheese-cloth strainer. A safe and interchangeable device consists of a stout wire frame, over which a cheese-cloth bag is drawn and tied. A $\frac{3}{4}$-inch rubber hose is attached to the opening in the frame. The strainer is put inside among the fry, and the outflow in an overflow cup. The overflow cup is set at the proper height to control the water level in the collector-tank. Long-handled nets of $\frac{3}{16}$-inch mesh are required to remove egg lumps or other matter from the jars.

THE AUTOMATIC HATCHING-JAR.

The United States Fish Commission, in the development of its work, had presented to it the necessity of dealing with the eggs of the whitefish and the shad upon a scale unprecedented in the history of fish-culture. Millions were to be handled instead of thousands, and the removal of dead eggs by hand picking was no longer to be considered. After successive experiments the McDonald automatic hatching-jar was devised, and it is now generally employed.



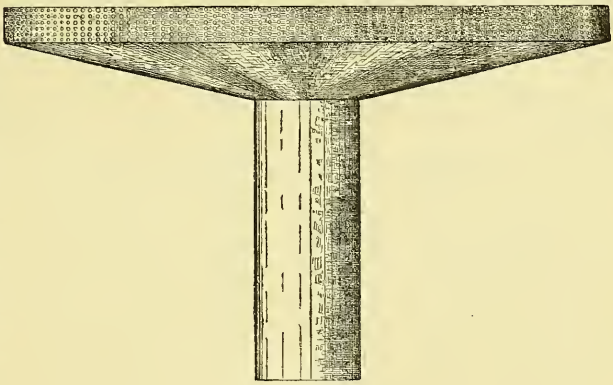
Automatic shad-hatching jar.

The most meritorious feature of this apparatus is that it prevents the development of the saprolegnious fungus, which caused so great a mortality in some other forms of hatching contrivances in which all the ova were not in continual movement. The very gradual, gentle, and continual rolling movement of the ova upon each other in the jar apparently prevents the spores of the fungus from adhering. The cleanliness of the apparatus is also advantageous, and as the material of which it is made is glass, the progress of development can be watched satisfactorily from the outside of the jar with a hand glass or pocket lens of moderate power.

The jar is a cylindrical glass vessel, of about 7 quarts' capacity, with hemispherical bottom, supported upon three glass legs. The top is made with threads to receive a screw cap. It is closed by a metallic disk perforated with two holes five-eighths inch in diameter—one in the center admits the glass tube that introduces the water into the jar, the other, equally distant from the central hole and the edge of

the metal plate, admits the glass tube which carries off the waste water. The central tube is connected by half-inch rubber tubing with the pet-cock, which regulates the supply of water. A groove in the inner surface of the metallic plate carries a rubber collar, and when the plate is in place the tightening of the metallic screw-cap seals the opening hermetically. Both the inlet and outlet tubes pass through stuffing-boxes provided with gum-washers and binding-screws. The central or feed tube is provided with stuffing-boxes, one on the top of the disk and one on the bottom, the better to hold it to a true center. The outlet tube is provided with only one stuffing-box, and the binding-ring is beveled.

In preparing the jar for work the side tube is fitted first. The glass tube should be wet, the gum-washer slipped on the tube about an inch from the end and introduced into the opening. Holding the tube perpendicularly to the face of the plate, press fairly on the tube, and the washer, rolling on itself, will fall into the seat provided for it. Screw on the binding-ring, and test by seeing that the tube slides freely back and forth in the stuffing-box; if not, it should be refitted with a heavier or lighter washer, as may be required. Glass tubes can not be procured of absolute uniformity in size. Water is the only lubricant that should be used about the jar fittings.



Egg Funnel.

The jar, after being washed clean, is filled with fresh water. A shallow tin funnel with a perforated rim is inserted, so that the water will stand as high in the funnel-throat as possible, and the eggs are poured in by dipperfuls, or when taken from transportation trays are washed in by a jet of water. Care is used to have the eggs fall but a short distance, and no fish scales or other foreign matter should enter the jar with them, as the presence of anything but water and eggs renders a proper motion of the mass impossible, and usually results in the loss of a large proportion of the eggs. The requisite number of eggs, 80,000 to 100,000, being in the jar, it is put in position and closed, care being taken that both the inlet and outlet tubes slide freely in their stuffing-boxes. If the tubes become gummed, let water trickle down around the binding-screws. To close the jar, turn on the water, place the feed-tube in the jar, turning off the water immediately after the feed-tube has passed beneath the surface of the water in the jar,

thus expelling all the air from the feed-tube; otherwise it would rise in bubbles, throwing a portion of the eggs out through the outlet-tube.

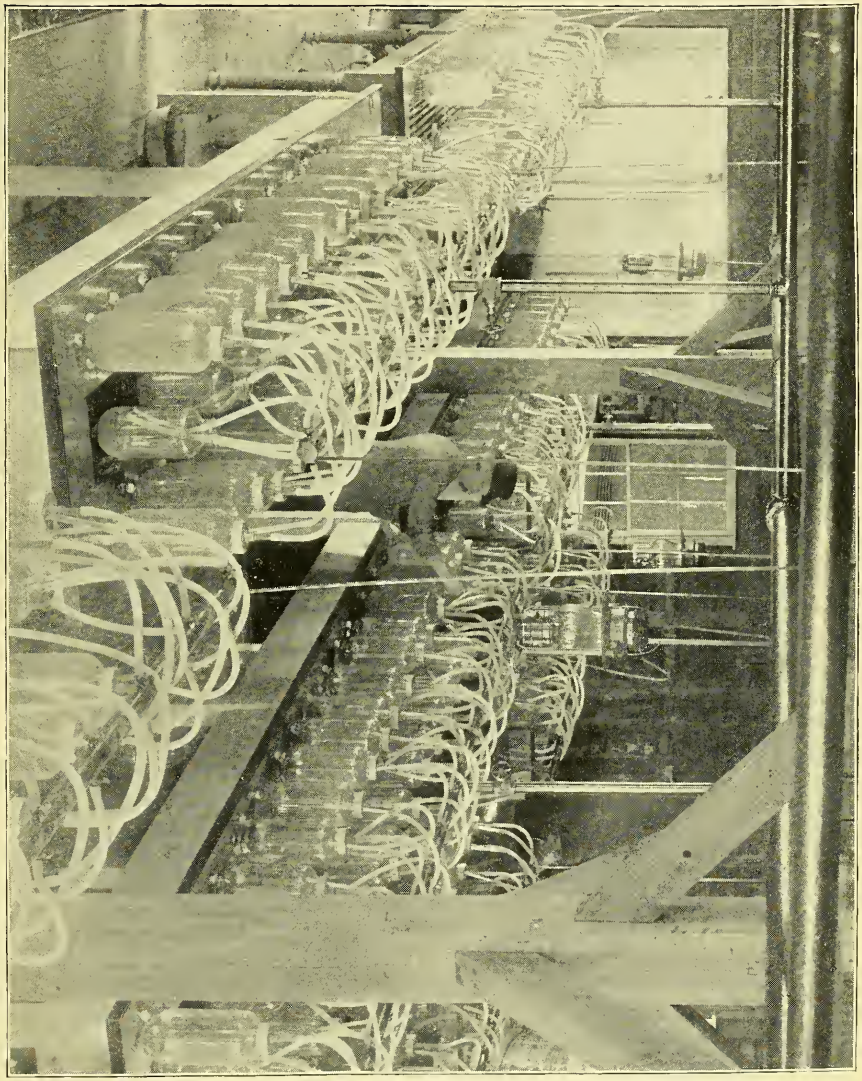
With a proper quantity of semi-buoyant eggs in the jar and the water turned on and regulated, the movement of the current establishes a regular boiling motion in the mass of eggs, which brings each in succession to the surface. This motion may be regulated without altering the quantity of water. By loosening the upper binding-screw of the central stuffing-box, and pushing the feed-tube down until it almost comes in contact with the bottom of the jar, the motion of the eggs is increased. If the jar is working properly, the dead eggs when brought to the surface remain on top, forming a distinct layer, and by pushing down the outlet tube a suitable distance they are lifted up by the escaping current and taken out.

When the water is turned on for the first time the jar should be watched closely until a regular motion has been established. When eggs have stood 15 or 20 minutes in the jar before the water is turned on they do not readily yield to the boiling motion, but tend to rise in a solid mass to the top of the jar. By quickly starting and stopping the current the mass is readily disintegrated. The degree or intensity of motion of the eggs varies not only with their age and condition, but also with the condition of the water. If the water is muddy, the motion should be rapid enough to prevent mud settling either on the eggs or in the bottom of the jar. Ordinarily the best motion is that which readily brings the dead eggs to the surface. After the hatching has progressed far enough to dispose of a portion of the eggs there is less resistance to the current, and it should be reduced by shutting off part of the supply or by slightly lifting the central tube. If the motion is not reduced from time to time as the hatching progresses, shells will be carried over into the receiving-tank with the fish and, being very light, will be drawn against the outlet screen, causing an overflow. The motion should be so gentle at the time of the greatest hatching as barely to induce the fish to swim out of the jar and leave their cast-off shells behind.

Very healthy eggs, exposed to bright direct sunshine, hatch so rapidly that the combined effort of the swarming mass of young fish will establish sufficient current to draw some shells over into the receiving-tank. This may be modified by placing a screen between the jar and the light. The shells under normal conditions remain and form a cloud-like layer above the mass of working eggs. As they accumulate they should be removed by shoving down the outlet-tube until they are drawn up with the escaping water. A good plan is to draw several jars in succession into a large pan, whence any fish coming over with the shells may be ladled into the receiving-tank.

A remnant of eggs may be long in hatching, and they should be poured into a large, clean, bright pan and exposed to bright sunlight, when they will hatch in five or ten minutes.

If the connection of the jar must be broken, it is essential that the rubber feed-tube does not drop down and siphon the eggs from the jar.



INTERIOR OF HATCHERY AT BATTERY STATION, EQUIPPED WITH HATCHING-JARS.

In reconnecting, the air may be expelled with the metal top screwed down in position. To effect this, draw both glass tubes up to the top of the jar and turn on a full head of water, when the air will be forced out in bubbles above the eggs, the bubbles escaping through the outlet tube. The central tube is now restored to its former position. The automatic action permits entire separation of bad from good eggs, though some days may be required to accomplish the full result. The dead become lighter from gases arising from decomposition. A net, small enough to easily enter the mouth of the jar and fixed to a handle several inches longer than the jar, is convenient for removing particles of foreign matter.

Shad eggs are semi-buoyant, and those which will not rise commence lumping on the third or fourth day. The usual period of hatching is from 6 to 10 days, sometimes longer, according to temperature of water, but with high temperature they will hatch in 3 days. Fry hatched in less than 5 days are usually, though not always, weak. In general, the period of incubation varies inversely with the prevailing temperature, but continuous dark and cloudy days will retard and strong light will accelerate development under precisely the same conditions of water temperature, and other circumstances not well understood may also have their influence.

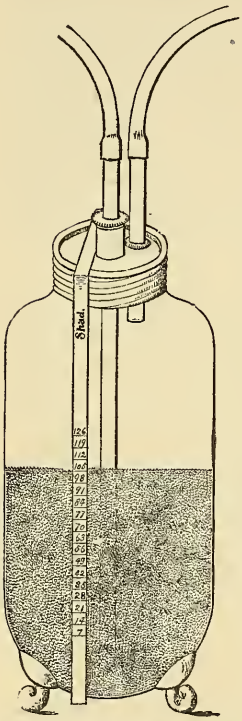
Fry when hatched are about 0.37 inch long. They have been measured at intervals of from 5 to 15 days, from late in May to the middle of October. Toward the middle of August the rate in growth diminishes. When 9 days old they are about 0.62 inch long. Fry 0.5 inch long July 20th were 0.75 inch long 8 days later; on August 14th, 2 to 2.25 inches; September 20th, 3 to 4 inches; October 1st, 4 to 4½ inches; November 4th, 5 to 7 inches. Some years they grow faster than others, and in some streams more rapidly than in others. From the State fish-ponds at Raleigh, North Carolina, 33 were removed in November, 1884, which measured 8 to 9 inches. Their usual size in the Potomac in the fall is 3 to 4 inches.

MEASURING THE EGGS AND FRY.

To estimate the number of eggs and of the young fry was for years rather a difficult matter to accomplish satisfactorily. The standard made use of at the outset was undoubtedly much too high. The scale most used at present is a light square, made of wood, the longer leg being 15 inches and the shorter 7½ inches long. The material is ½ inch wide and ¼ inch thick. The graduations are on the longer leg, and read from the lower end upward. The first line is at a height corresponding to the level attained in the jar by a measured half-pint of water, and the succeeding lines are determined by the introduction of additional half-pints of water. When the scale is being constructed, the central glass tube is stopped at the lower end that it may displace an amount of water equal to the amount of eggs it will displace in

practice. Each line on the measuring stick registers 7,000 shad eggs. The number of eggs in a liquid pint is established by actual count. Those which are very young or have been lately on trays are not of normal size and not qualified for measurement. The eggs are at rest when measured.

The jar contents are determined by placing the short leg of the measuring-stick over the top, with the other pointing downward and touching the side of the jar. The number is indicated on the scale at the point opposite the surface of the bulk of the eggs. Scarcely any semi-buoyant eggs die, under proper conditions, after hatching out has commenced, and a close approximation to the number of fry may be obtained from the last measurement, which is made after the careful removal of all dead eggs and the bursting forth of the first young.



Application of a measuring scale to a jar of shad eggs.

FEEDING AND REARING.

The young shad swims vigorously, by rapid and continuous vibration of the tail, from the moment it leaves the egg. It is colorless, transparent, and gelatinous. Several hundred in a dipper are scarcely discernible. It has a relatively large yolk-sac, but supports it with ease during the first four or five days after hatching, the small quantity remaining after this time not being visible externally, although found in shad fry 14 to 16 days old. Minute conical teeth make their appearance on the lower jaws and in the pharynx about the second or third day after hatching. The jaws at three months are armed with teeth slightly curved.

Young shad feed on other minute organisms, such as exceedingly small crustaceans. Food has never been observed in the alimentary canal until ten or twelve days after the young fish had left the egg. At about the middle of the second week considerable may be seen, but the intestine is then not often very densely packed. At the age of three weeks an abundance of food is found. They have been known at this early age to eat their own kind, and later the young carp and salmon. When cold, raw winds drive the crustaceans into deeper water, the young shad follow them, and in aquaria they take crustacea freely. In salt-water aquaria they may be fed upon chopped oysters and canned herring-roe.

Experiments with young shad have been carried on for several years at Central Station in salt-water aquaria. On one occasion about 250 were received in October, at which time they were about five months old. They were put in brackish water, specific gravity 1.005, which

was added to from day to day for nearly a week, when it was brought up to 1.018, or the same specific gravity as the water used in the marine aquaria. At the time these were placed in the brackish water others were put into fresh-water aquaria, but the latter died within three days. Those in salt water began in two or three days to take food, consisting of chopped oysters, clams, and beef, the preference being for oysters. At first they would take food only when it was sinking, later they began taking it off plants where it had lodged, and finally from the bottom. Nearly all remained healthy, plump, and active for six months, some living until about midsummer.

For ten years past two or three million shad fry have been reared annually at the Fish Ponds, Washington, D. C. A 6-acre pond is used, the water supply being taken from the city water-works. The depth varies from 2 to 3 feet, and throughout the whole extent there is a dense growth of water-plants, among which crustacean food multiplies—new supplies being brought in from the water-pipes. Fingerling shad are so tender that the numbers annually liberated can not be ascertained; they can not withstand the handling consequent upon counting them, not even undergoing transfer in dippers of water, and their scales drop off on being touched; consequently at high tide they are liberated into the Potomac through a sluice-gate with an outlet pipe about 2 feet in diameter. They require some days to make their escape. By conservative estimate 50 to 60 per cent are held safely until about October.

Rearing has been experimentally tested at Wytheville and Neosho with good results. At Neosho on the 3d of June, 1892, 700,000 fry were received from Gloucester, N. J.; their growth was satisfactory. In preparing for their release the hatchery branch was cleared of shoals, drifts, and aquatic plants for three-quarters of a mile, and early in November, when the branch was swollen with rain water, 200,000 6-months-old fish were allowed to pass through open gates; they were some hours in escaping, in a continuous silvery mass. These were the first fingerling shad planted in waters tributary to the Gulf of Mexico.

TRANSPORTATION.

Good, healthy fry will pass from the jar to the collector-tank as fast as hatched, and unless too thick will not lie on the bottom of the tank, although they sometimes crowd on the side nearest the strongest rays of light. As many as 500,000 to 800,000 are collected in each tank. In transporting, they must be kept in vessels with smooth surfaces, preferably tin-lined cans. Zinc vessels are destructive, and galvanized cans are not recommended.

About 2,000 to 3,000 fry are put to a gallon of water, which must be pure enough for ordinary drinking purposes and well aerated. The water in the cans must be kept at 58° to 65°, though in rivers and ponds the fry endure a temperature of 90° F.

As early as 1874, experiments were carried on to retard the development of eggs, in order to provide a longer period between the delivery

of the eggs from the parent fish and the absorption of the yolk-sac. Eggs, when transported, were placed on trays and put under melting ice, and later experiments have been conducted inside refrigerator boxes.

Pathological changes or deformities are induced in the embryos when subjected to too low a temperature or when held long enough on damp flannel trays (ordinary air temperatures) to hatch.

It would appear that 55° to 53° is the lowest temperature in which ova will safely undergo their normal development and 9 days is the longest period of incubation attainable at that temperature—time sufficient, when added to the several days required for the young to absorb the yolk-sac, to ship them to Europe, though efforts in this direction have thus far failed. One drawback is the rapid development of fungus, which grows over the eggs, penetrates the membranes, and kills the ova.

The eggs are shipped in crates of 20 shallow trays, the frames of the latter being of wood with bottoms of wire mesh about 8 to the linear inch. Wood and wire are painted with asphaltum. Each tray is covered with cheese-cloth, somewhat overlapping the edges, the cloths being hemmed, to avoid ravelings. There are two frames of wood, connected with leather straps; one the base and the other the cover for the stack of trays. The trays, after being filled with eggs, are wrapped in a long, cotton-goods apron and strapped together. There is an iron handle on the top frame, and the lowermost tray is put down empty with the wire surface upward. Then follow the trays containing eggs, the uppermost one being put on empty with the wire surface up. The top and bottom trays are merely to protect the others.

The greater part of the water above the eggs is poured off from the jars and the remainder poured into tin pans along with the eggs. The cloths, after soaking in water, are arranged one by one on the trays and tucked closely into the four corners. The trays are stacked up and eggs poured evenly over the surface of the top one with a large dipper, and each tray, when filled, is put on the crate base. The surplus water drains away to the manipulating table. Tray cloths which are made of material too closely woven to let the water through are unsuitable.

The eggs are bailed up in dippers with the water that they are in, and usually spread two layers deep, but may be put on more thickly. When eighteen trays are filled they are wrapped in the outer cloth, previously soaked in water, and tightly buckled together. The crate covers and tray cloths are boiled in water each time after use.

Each tray—14 by 19 inches area, with two layers of eggs—holds about 20,000 eggs, the contents of a full crate representing from 300,000 to 400,000 eggs. While in transit the crates are sprinkled with river water on the sides at least once an hour, and kept in the shade, away from the cooling influence of the wind, to preserve even temperature.

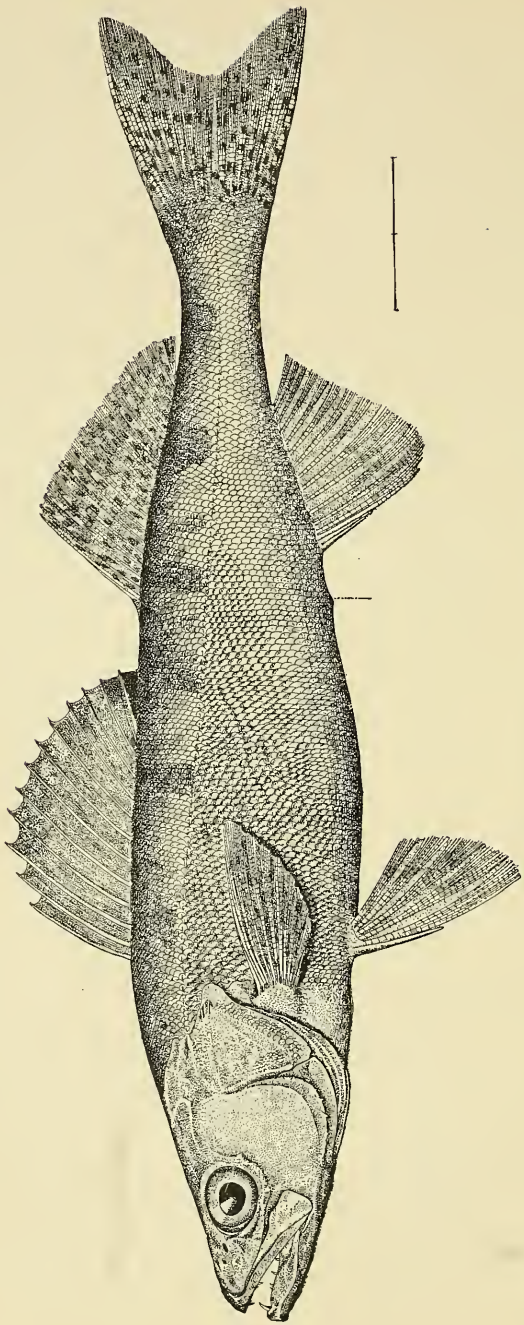
TRANSPLANTING.

The propagation of shad is mainly carried on to maintain or increase the supply in rivers where the species is native, but this fish has also been planted in waters in which it was either unknown or found in small quantities. Large numbers of fry have been liberated in tributaries of the Gulf of Mexico, but without marked results. Between 1873 and 1892 several million fry were experimentally placed in Great Salt Lake, Utah Lake, and Bear Lake, Utah; and from 1884 to 1886, 3,000,000 fry were liberated in the Colorado River at the Needles, in Arizona, but these experiments were unsuccessful.

Remarkable success has, however, attended the stocking of the waters of the Pacific coast. In 1871, 12,000 shad fry from the Hudson River were liberated in the Sacramento River by the California Fish Commission, and in 1873 the United States Commission made a second deposit of 35,000. Subsequent plants in the Sacramento, aggregating 609,000, were made by the United States Commission from 1876 to 1880. From these small colonies, amounting to less than 1 per cent of the number now annually planted in the Atlantic Slope rivers, the shad have multiplied and distributed themselves along nearly 3,000 miles of the coast from southern California to southeastern Alaska. They reached Rogue River, Oregon, in 1882. In the Columbia a few were taken as early as 1876 or 1877. About 1881 or 1882 they were on the coast of Washington, reaching Puget Sound in 1882. They appeared in the Fraser River, British Columbia, in 1891; in the Stikine River, near Wrangell Island, Alaska, the same year, and are now found along the entire coast from Los Angeles County, Cal., to Chilkat, Alaska, covering 22 degrees of latitude. Their distribution, from the standpoint of commercial importance, is from Monterey Bay to Puget Sound.

On the northern part of the coast the first shad fry were introduced in 1885, the number being 60,000. Of these, 50,000 were put in the Willamette River and 10,000 in the Snake River. The following year 850,000 were introduced into the Columbia River.

The shad is now one of the most abundant fishes of California. As a result of the liberation of the first two consignments, adult shad were caught in 1874, and by 1876 this fish had become numerous. In 1880 specimens of all sizes were taken in the Sacramento River and Monterey Bay, and it was evident that the shad had begun to multiply, its increase up to 1883 being marvelous. It is most numerous on the west coast in San Francisco Bay and its tributaries, where, contrary to its habits in Atlantic waters, it is found throughout the year. It is not common above Sacramento, owing to the low water temperature. In the Columbia it is regularly found as far as the Cascades, about 150 miles above the mouth of the river.



STIZOSTEDION VITREUM. *Pike Perch or Wall-eyed Pike.*

THE PIKE PERCH OR WALL-EYED PIKE.

DESCRIPTION OF THE SPECIES.

The pike perch (*Stizostedion vitreum*) is the largest member of the perch family inhabiting American waters. The body is fusiform; its depth being contained about 4½ times in length. The head is long, pointed, and a little more than one-fourth the body length. The large mouth is provided with bands of villiform teeth, in addition to which there are long, formidable canine teeth on the jaws and roof of mouth. The eye is contained 4½ to 5 times in head. Serrations exist on the preopercular bone, and several spines on the preopercle. The high dorsal fins are well separated, and contain from 12 to 16 spines and 19 to 21 soft rays. The number of rows of scales in a lateral series is from 110 to 132, with about 10 rows above and 25 rows below the lateral line. The general body color varies from light yellowish to dark blue, with indistinct lines and mottlings, the under parts being white or pink. A large black spot involves the membrane of the last two or three dorsal spines, the fin being otherwise nearly plain; the second dorsal and the caudal are mottled with yellow and olive; the pectoral is dusky at its base, and the anal and ventrals are pinkish.

Three rather well-defined color varieties of the pike perch may be recognized, dependent on age and environmental conditions. These are the gray, yellow, and blue. The gray variety attains the largest size, 40 pounds being the maximum and 10 to 20 pounds being common. The yellow form reaches a weight of 20 pounds, and is often taken weighing 5 to 10 pounds. It has the widest range and is the most numerous. The blue pike occasionally may reach a weight of 5 pounds, but averages under 1 pound. The gray and yellow varieties are usually found in the larger streams, and in the Great Lakes seek water 10 to 40 feet deep, while the blue variety seems to prefer water 30 to 75 feet deep.

The pike perch in that part of Lake Erie adjacent to the islands of the western end are almost or entirely free from yellow, being a dark gray, almost black, on the back, shading on the sides to lighter grays, while the lower third and belly are silvery white; the body is less compressed and tapers less toward the tail than the yellow variety. In Sandusky Bay there is a uniformly yellow variety, of a fusiform shape. Although Sandusky is connected with the lake by a deep channel over a mile wide, it is reported that the yellow fish do not leave the bay and the gray fish rarely enter except during the spring, when small numbers resort to it to spawn.

From the sauger or sand pike (*S. canadense*), the wall-eyed pike is distinguished by its fewer pyloric cœca (3 instead of 5 to 7), fewer dorsal

rays, larger size, presence of black blotch on second dorsal, absence of similar blotch at base of pectorals, and some minor characters.

Various names are given to the pike perch in different parts of its habitat, and two or more names in some localities. Wall-eyed pike is the most widely used designation. Pike and pickerel are employed in the Great Lakes. As both of these names are also borne by the members of the genus *Lucius*, much confusion has arisen. In the Susquehanna and Delaware rivers and along the Ohio and its tributaries the fish is very inappropriately known as salmon. Dory or doré is a Canadian designation. Other names in use on the Great Lakes and elsewhere are yellow pike, blue pike, glass-eye, white-eye, and jack salmon. In order to avoid confusion and to indicate the family relationship, the U. S. Fish Commission has recommended the name pike perch, the fish being a perch of pike-like appearance and habits. This name corresponds with the generic term *Lucioperca*, applied to a similar European species. The sauger, however, is entitled to bear the same name, although its usual designation is distinctive.

GEOGRAPHICAL DISTRIBUTION.

The pike perch prefers clear water, with rock, gravel, sand, or hard-clay bottom. The center of its abundance is Lake Erie, but it is among the most widely distributed of our fresh-water fishes, its range extending along the Atlantic seaboard from New Brunswick, New Hampshire, Massachusetts, and Connecticut as far south as North Carolina; thence to the northern portions of Alabama, Georgia, Mississippi, and Arkansas on the south, with Kansas, Nebraska, the Dakotas, and Assiniboia its western limit and the Hudson Bay system its northern boundary. Over the greater part of this vast area it is fairly abundant, and in all of the waters of the Great Lakes region, the Mississippi basin, and the southern portion, at least, of the Hudson Bay system it is commercially important. In New Hampshire, Connecticut, New Jersey, and eastern Pennsylvania it is not indigenous. Its adaptability to suitable new waters is shown by its acclimatization in the Susquehanna and Delaware in Pennsylvania, in many small lakes in Michigan, and in the streams and lakes of Nebraska, where it has rapidly multiplied and is a great favorite with anglers and epicures.

The range of the sauger is less extensive than that of the wall-eyed pike. It embraces the Great Lakes region, west to the Upper Missouri, and south to Arkansas and Tennessee.

ECONOMIC VALUE, FOOD AND GAME QUALITIES.

The pike perch is one of the most valuable fresh-water fishes. In Lake Erie alone the annual catch is now upward of 6,000,000 pounds, valued at $225,000, besides which over 3,000,000 pounds of saugers, worth $75,000, are yearly taken in the same waters. Throughout its range it is caught nearly the year round, and, in spite of the zeal with which it is pursued on account of its fine table qualities and the ease

with which it is captured, it is holding its own well owing to its hardiness, its comparative freedom from disease, and the facility with which it is produced by fish-cultural methods.

As a table article it ranks high. The smaller fish are delicious fried, broiled, or boiled, while the larger ones, weighing from 5 to 15 pounds, are excellent when baked. The flesh is firm and well flavored, even in the warmest weather. Few fish stand shipment, holding, or freezing better than pike perch. It is not so well adapted to salting as some species, but this is not important, as the demand for it is so great that the supply is always disposed of fresh or frozen. The abdominal cavity is comparatively small and the head medium, so that little loss occurs in dressing. The bones are somewhat numerous, but they are generally large and easily separated. The gray and yellow varieties are considered superior to the blue for food, and are also better game fish.

The pike perch, although capricious, is readily caught with baited hook, artificial fly, spoon, etc., and deserves high rank as a game fish. About 100 tons are taken annually with hook and line through the ice about the Bass Islands, Lake Erie; large quantities are also thus caught near Buffalo, N. Y., in Saginaw Bay, Mich., and elsewhere. In ice fishing small minnows are generally used, the bait being taken near the bottom.

FEEDING HABITS.

Although the pike perch is predaceous, observations would seem to show that it devours fewer desirable species than any other predatory fish. Its main food in Lake Erie the year round is a small cyprinoid, usually called lake shiner, which abounds in these waters, with occasionally crawfish in the winter and the larvæ of insects and the insects themselves in the warmer months. A pike perch weighing 16½ pounds has been caught containing a bullhead which in its partly digested condition weighed 9 ounces. The stomachs of hundreds have been opened at all seasons of the year and under various conditions, and the examinations have as yet failed to disclose one containing a whitefish, black bass, or other valuable fish. Usually the stomach was empty so far as the unassisted eye could discover, except for a thick, tough, greenish-yellow slime.

The pike perch does not generally inhabit the depths of waters frequented by the black bass, preferring the deeper portions of the shallow parts of the lake. Excepting the blue pike variety, it is not found in deep water, which is the home of the whitefish during all the year except for a short period in the fall during its reproductive migrations. And even the blue pike does not inhabit the deep waters where the whitefish and cisco spend most of their lives.

SPAWNING AND SPAWN-TAKING.

The pike perch is not a nest-builder, as are the basses and sunfishes. The female discharges her spawn in shoal waters, the male following and emitting milt in proximity to the eggs. The spawning time varies

greatly in different localities, extending from the last of March with the yellow and gray varieties to the latter part of May. The blue pike has not been hatched by fish-culturists, and comparatively little is known of its spawning habits.

The work of collecting eggs for artificial propagation generally begins about the 10th of April and extends to the 25th of that month. The eggs are obtained from fish taken by commercial fishermen. Half or more of these are hatched into vigorous fry and deposited in public waters, and but for this work all the eggs thus saved would go to the market in the abdomens of the fish and be entirely lost.

The pike perch develops a greater number of eggs in proportion to its weight than the whitefish, and but a small percentage of them are fertilized under natural conditions. The eggs are 0.08 inch in diameter and average about 150,000 to a fluid quart. About 90,000 eggs would probably be a fair average per fish for Lake Erie, and as the spawning fish will average about 2 pounds each, 45,000 eggs to the pound weight of fish would approximate the true figures.

As the spawning time approaches spawn-takers are stationed at the various points on the lake where nets are to be fished. A spawn-taker accompanies the fisherman on his trips to the nets and examines the catch for ripe fish. His equipment is the same as that described in the chapter on whitefish, except that he takes a quantity of swamp muck for use in preventing adhesion of the eggs. After he has selected and stripped a fish, it is returned to the fisherman. The eggs after being fertilized are either shipped directly to the hatchery or through some central collecting station.

The inner membranes of the egg are delicate and easily ruptured, and the greatest care is necessary, from the taking of the spawn to the hatching of the fry, and especially until they are cushioned by the filling of the membranes with water.

The fish should be wiped so that slime will not drip into the spawning pan, as a very small portion will clog the micropile and prevent impregnation. The female is grasped firmly in the left hand just forward of the tail, with the back of the hand downward, the fingers outward and the thumb above and pointing upward, the head of the fish being held between the spawn-taker's right wrist and body, the right hand grasping the fish from below, just back of the pectoral fins, the fingers inward, the thumb outward. The anterior portion of the abdomen is thus firmly grasped and the pressure brought to bear on the eggs in the ovaries of the fish. A woolen mitten on the left hand allows a firmer grasp on the slippery body than is possible with the bare hand. The fish is now at an angle of 45°, the body forming a modified crescent, with the vent within 2 or 3 inches of the bottom of the pan. This position throws the pressure on the abdomen and facilitates the opening of the vent and the flow of the eggs. Gentle pressure is now maintained as long as the eggs come freely and in a

fluid stream, probably over half of them being procured before the hand is moved, but when the flow slackens, and not until then, the hand should be moved slowly toward the vent without releasing the pressure and only fast enough to keep the eggs flowing in a continuous stream. When this stops the hand should be replaced and the process repeated until all the good eggs are procured. If the eggs do not start readily they should not be taken.

As soon as one female is stripped the milt is added, care being taken all the time to allow no water in the pan until the lot is finished or until the pan is half or two-thirds full of eggs. If males are abundant one is stripped for each female, and one for every two or three females in any event. When the pan is about half full, and before any water is added, the eggs are very thoroughly and carefully stirred with the outstretched, spread fingers, and enough water is added to incorporate the egg mass and nicely cover the eggs, the whole being mixed again with the fingers and allowed to stand for 2 minutes. Next the milt of one or two more males and a little water are added, the mixture is stirred as before, and again allowed to stand for 5 minutes.

Impregnation can not take place unless the milt and eggs come into perfect contact, and as the milt dies 2 minutes after water is added, and as the eggs will not become impregnated after having been in water 6 minutes, it can readily be seen that the eggs and milt must be thoroughly and quickly mixed, both before and after the water is added. A tablespoonful of muck solution is now stirred into the mass and a pint of water added. The water is poured off after standing and this process is repeated every half hour, as described on pp. 174–175.

After the adhesion has subsided the eggs are placed in a keg nearly filled with water and stirred every half hour, with a change of water at least every hour from the time the eggs are taken until they are delivered at the station. The stirring is thoroughly, but gently, done with a dipper, care being taken that the dipper does not strike the sides or bottom of the keg.

The eggs should never be exposed to the sun, and the water surrounding newly taken eggs should preferably be kept between 40° and 50° F.; in fact, experience has shown that even 35° is not harmful. Of course, all sudden changes of temperature should be avoided.

DEVELOPMENT AND CARE OF EGGS.

When the eggs arrive at the station they are held in 15-gallon cans for about 24 hours, a gentle stream flowing into each can, this being considered better than to place them at once in the hatching-jars, where the motion is too violent for the green eggs. While thus held they are stirred every hour. Kegs or cans may be carried half full of eggs if properly cared for.

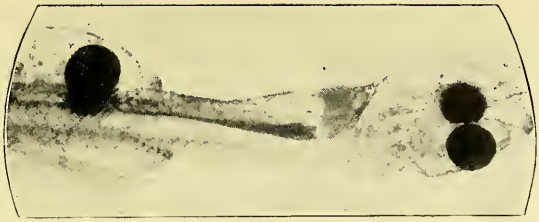
For the handling of all eggs at Put-in Bay, except those to be shipped by rail or wagon, 15-gallon pine kegs, painted outside, with iron hoops and iron drop-handles, are preferred to tin cans. They are cheaper,

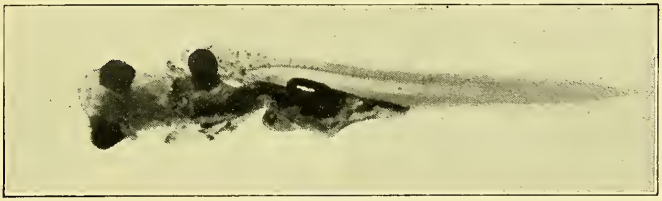
lighter, more durable and convenient. The eggs are in full view when being stirred and when water is poured off or added; the most important point, however, is that the kegs retain the water at a more even temperature, as they are less affected by heat and cold than the cans. All dishes and implements with which the eggs come in contact should be thoroughly scalded and cleaned at the beginning and close of each egg-taking season.

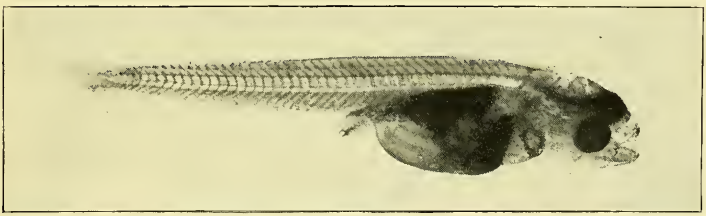
For hatching pike-perch eggs at Put-in Bay the same jars are used as for the whitefish eggs, and on pp. 115–119 will be found a description of the hatchery and its equipment, the arrangement of the jars in a "battery," the manner of operating them, etc. The pike-perch eggs are lighter than many others, and, being hatched in comparatively warm water, fungus quickly when dead. The water used in hatching them should therefore be practically clear, for if it contains any considerable portion of silt the fungused eggs will soon become so loaded as to possess the same specific gravity as the living ones, and sink in the egg mass, forming lumps which can be removed only by screening, which is always more or less injurious. Even the live eggs will become coated, interfering with the proper working of the jars. Where clear water is used the fungused eggs remain buoyant, keep on top of the egg mass, and are easily removed without loss or injury to the live ones.

Where water is only moderately turbid and a large number of eggs are being handled, if the water temperature runs up to 55° or 60° the eggs will fungus so rapidly that they can not be separated fast enough to prevent the live eggs from becoming mixed with them. As it is practically impossible to run "hospital jars" under such conditions, many eggs must be lost, or the small percentage of live ones contained in the mass of dead ones must be drawn off and distributed in the lake and thus given a chance there to hatch. Both of these conditions are to be deprecated and can be prevented by a filtering plant.

In order to insure perfect cleanliness, it is advisable to treat the whole system of troughs and pipes through which the water runs, once or twice a year, with a clear solution of chloride of lime, beginning with the supply tanks, which should be thoroughly washed inside, and following down until all have been reached, opening each faucet or cock during the procedure. In this way, at small expense, the system is freed from infusoria and other forms, which at times are very troublesome and more or less destructive to the eggs. This work should be done in the fall, just before whitefish eggs are to be placed in the jars, and again in the spring, as soon as the whitefish eggs and fry are all disposed of and before the pike-perch eggs are received. If these periods overlap, a battery at a time can be treated. After treatment, the tanks are thoroughly washed and the whole system is flushed for an hour or more. Chloride of lime is much more effective for this purpose than common lime. The preparation is made by dissolving 5 pounds of chloride of lime in 10 gallons of water, and after it has settled the clear solution is decanted off and added to many times its bulk.







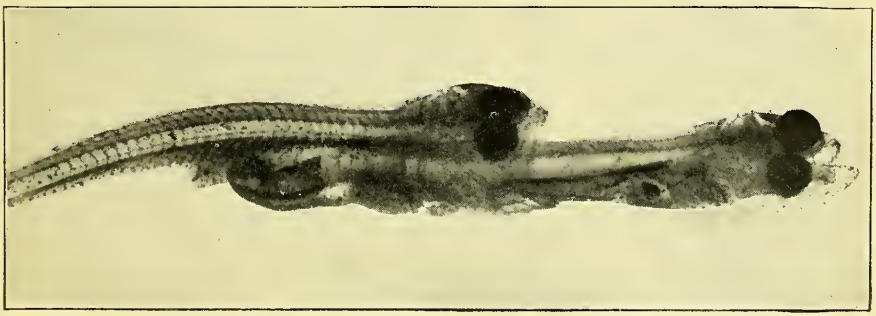


PHOTO-MICROGRAPHS SHOWING PHASES OF CANNIBALISM AMONG PIKE-PERCH FRY.

The fry of the pike-perch are only about as large round as ordinary sewing thread and about $\frac{3}{16}$ inch long; it therefore requires very fine brass-wire-cloth screens to hold them in the tanks, and it is exceedingly important that these screens be kept clear—preferably by the air jets described in the chapter on whitefish (p. 119). This apparatus gives perfect satisfaction and twice the number of whitefish or pike-perch fry can be successfully carried in a given amount of water with the air system than without its aid.

When the eggs are placed in the jars 24 hours after taking, allowance is made for some additional swelling, and accordingly 3½ quarts of eggs are placed in each jar on setting them up. These will swell to 4 or 4¼ quarts at the end of 3 days, and that number works best. The eggs are worked with the least possible amount of water that will keep them in motion throughout, and anything beyond this is harmful and will result in ruptured yolks. The jars are inspected daily, and one that is working too fast or is not working uniformly is carefully adjusted.

The eggs are semibuoyant and very adhesive. A single large, spherical oil-drop floats at the top of the yolk mass. The germinal disk is on the side of the yolk. The first cleavage of the disk ordinarily takes place in 5 to 6 hours in a water temperature of 45° to 50° F. Unequal division of the disk is rare, although it sometimes occurs, while with the whitefish and many other species inequality of cleavage is the almost universal rule.

In a water temperature of 45° to 50° the form of the embryo may be distinguished under a low-power glass in 4 days, and the eye-specks can be seen by the unassisted eye in about 6 days. By this time the pigment cells, or color stars, can also be seen with a microscope of moderate power, as well as the pulsations of the heart and the coursing of the blood through the vessels—the red corpuscles being distinguishable.

At this stage any monstrosities, malformations, and other blemishes may be easily discovered. They consist of embryos with double heads, the most common form, more than the normal number of eyes, curved spines, and various other deformities, some so slight as to be scarcely discernible. All these erratic forms perish before hatching or soon afterwards, and cause the loss of a large percentage of the eyed eggs, which die before hatching; insufficient food supply in the yolk causes the loss of the next greatest number, the two covering about 60 per cent of the whole loss of eyed eggs.

The eggs hatch in from 7 to 28 days, a mean temperature of about 57° producing the first result and about 40° the latter, neither extreme furnishing the best of fry. At a temperature of about 48° the eggs will hatch in 18 to 20 days and produce vigorous, healthy fry.

The absorption of the food-sac is governed by the period of incubation and in some measure by the water temperature, and a day or two after its complete absorption cannibalism will begin. If 28 days have been required the sac will be absorbed in from 5 to 6 days, while if a

shorter period—say of 14 days—has been required, it will likely take 10 days before the sac is fully absorbed and the fry begin to destroy each other.

TRANSPORTATION OF EGGS.

The best method of shipping eggs a considerable distance before hatching is a somewhat open question. The experiment of shipping them on trays rather than in water in kegs or cans, as described above, has been tried with varying success. If shipped on trays they should be accompanied by a watchful messenger, who will see that they are not subjected to sudden jars while in transit. They should be spread on the trays not over one-third of an inch deep, and should be sprinkled lightly every day. The cases containing the eggs should be packed in damp sawdust, so that all parts of them will be covered 6 or more inches. Ice should be used if the air temperature is higher than 45° or 50° F., as the nearer the eggs can be kept to 40° F. the better.

Eggs held from 2 to 5 days on trays at Toledo and then shipped 40 miles by steamer to Put-in Bay came out as well as the average of the eggs received near home and held in running water 24 hours. A lot shipped on trays from Put-in Bay to Cape Vincent, N. Y., about 400 miles, came out badly, while those from the same lot carried in water turned out well. This difference is probably accounted for from the fact that the eggs carried in water were not subjected to sudden jars, while in the other case they doubtless were. It is quite possible that failures in shipping pike-perch eggs on trays have been largely owing to concussions received during transit, such as must result in carrying them on railroad cars and wagons.

If the eggs are to be transported long distances, they should be covered with cheese or mosquito cloth and the remaining space to the top of the tray filled with damp sphagnum moss; but if only a distance of 75 miles or less is to be traversed, this is unnecessary, care being taken to keep the cases right side up.

Eggs that have been held on trays should be placed in running water, in kegs or cans, a few hours before they are put in the jars, or an allowance of about 12 per cent should be made for shrinkage of the eggs while on the trays. Otherwise too many eggs will be put into the jars to work well.

PLANTING THE FRY.

In order to prevent loss from the fry preying upon each other, whenever practicable they should be planted before the sac is fully absorbed, but not for 3 or 4 days after hatching, since if they are so held they gain strength, and if they are to be transported some distance, they become better fitted for withstanding the hardships of a long journey. But with large numbers, running into hundreds of millions, lack of space makes it necessary to liberate them almost as fast as hatched. Darkening the tanks prevents cannibalism, but owing to the absence of food and possibly to the darkness the fry become weak and light-colored in

a day or two and will not stand transportation. They must, therefore, be transported before the sac is fully absorbed or large numbers will be lost by either cannibalism or starvation.

During the season of 1899 the water pumped from the lake for the supply of the fry tanks at the Put-in Bay Station literally teemed with crustacea, such as *Cyclops*, *Diaptomus*, *Daphnia*, *Alonopsis*, etc., but at first, after the food-sac was absorbed, the fry refused to partake of these, their supposed natural food, and preyed on each other instead. Three or four days later, however, a few hundred fry held for experimental purposes devoured these crustacea greedily and throve upon them as long as the supply was kept up. When cannibalism was at its height 50 fry were placed in a tin pan, with myriads of crustacea. In 10 minutes there were 6 cases of cannibalism. In each case one of the fry seized the tail of another and swallowed all it could. Close watching failed to discover any of these fry attempting to seize one of the crustacea. It was also discovered that neither the fry of the whitefish nor of the pike perch, when later they began to feed on the crustacea, would touch a *Diaptomus*, although the most showy of all the *Entomostraca* present and resembling very strongly the *Cyclops*, with which it is closely related. When a hungry fry would, as if by accident, seize a *Diaptomus* it would at once reject it and go about showing unmistakable signs of discomfort. Contrary to the general belief, the fry do not always die from the effects of eating other fry. The swallowed portion may be digested and the head and attached tissues finally rejected.

It has been customary to employ the same method in planting pike-perch fry as in planting whitefish fry; that is, the fry are dipped from the fry tanks of the hatching battery into cans or kegs and transported on a steamer to the points selected, where the cans are carefully lowered into the water and the young fish allowed to swim out.

Toward the close of the season of 1899 an experiment was made of carrying fry to the planting-grounds in a tank on board the steamer. The tank held 400 gallons, and was therefore equal in capacity to forty 10-gallon cans, but it was found in practice that a half more fry could be carried in this way with a given amount of water than in cans, as there was a continual stream going in through hose connected with a deck pump and out through screened siphons, whereas with cans some must stand while the water in others is being changed. Moreover, it is impossible to get a maximum number of fry in each can, so that some cans are carried with fewer fry than they should contain, while experience soon taught how many could be safely handled in the tank.

The fry were drawn from the fry tanks in the house direct to the tank on the steamer through a 1-inch rubber hose, acting as a siphon, the suction end being held near the air supply, where fry collect in largest numbers. This required 10 to 15 minutes, while by the old method of dipping the fry into tubs and then distributing them into the kegs on board it would take more than an hour. This saving of time is very

important when fry are hatching rapidly. Another advantage is that by passing the hose about close to the bottom of the tank nearly all the shells are removed with the fry, thus keeping the tanks comparatively clean. Examinations showed that the fry were not injured by passing through the hose, which is also an advantage over dipping them out with scoops.

On arriving at the field of planting, the fry and water are discharged through a section of hose about 10 feet long, leading from the bottom of the tank. The steamer is kept at a slow speed at the time and the transfer of the fry to the water is accomplished as gently at least as would be the case in emptying them from kegs. Considerable time, as well as much hard work, is saved by this plan, and so far there appears to be no objectionable features in it.

USE OF SWAMP MUCK TO PREVENT ADHESION OF EGGS.

Many experiments have been made from time to time to determine the best means to prevent adhesion in the pike-perch eggs. This may be accomplished by constantly stirring the eggs from the time the water is added until it fills the egg and adhesion ceases; but this causes loss of time and a large percentage of yolks will inevitably be ruptured. Another method is to allow the eggs to agglutinate into a mass and stand thus until fully hardened, afterwards separating them by gently rubbing them between the hands, but this also sacrifices time. The date of the first use of foreign, inert substances to prevent adhesion is uncertain. Fine clay dust and clay in solution have been used with success and experiments with starch have given good results. By a series of experiments with eggs taken in the vicinity of the station from the boats of the fishermen, and from the penned fish as well, it was found that the proper use of swamp muck obviates the difficulty, with a great saving of time, labor, and eggs.

In the spring of 1895 finely divided, washed, and screened swamp muck was tried at Put-in Bay and has been used ever since, and recently with complete success, owing to a change in the method of application. The plan pursued up to 1899 was to add muck to the water in the kegs into which the eggs were poured after impregnation and to wash them quickly. The washing was done quickly in order to prevent adhesion. This was effective, but it involved the use of too much muck, which was removed from the water with some difficulty, and which smothered the eggs if left in too long in any quantity, and, furthermore, it was difficult to get exactly the right quantity of the mixture. Careful experiments were therefore made in using the muck in the pan immediately after impregnation had taken place and satisfactory results were obtained. The eggs are allowed to stand in the milt for about 10 minutes with sufficient water to barely cover them, being carefully stirred once or twice meanwhile. Then a tablespoonful of the muck mixture, of the consistency of thick cream, is added. Next the pan is nearly filled with water and stirred thoroughly, when

it is left half an hour, or while another pan is being filled. Without moving pan No. 1 more than is necessary the surplus water is poured off, the pan again filled, stirred, and left as before, while pan No. 2 is treated like the first. If the boat rocks so as to endanger the safety of the eggs it is better to pour them carefully into the keg and let them stand there, keeping only about an inch of water over them and pouring the water off and adding fresh water at intervals of not more than half an hour.

The important point in preventing adhesion is to leave the eggs alone until the particles of muck, or the spermatozoa, in case the eggs are held in the milt without the addition of muck, have settled, and then pour off the comparatively clear water, adding a fresh supply and then gently agitating the eggs. It will be observed that most of the muck particles will have settled in one minute, the water becoming measurably clear. If the eggs are held in the milt, the water being very milky from the mixture, the water will become comparatively clear in 3 or 4 minutes. This is because the spermatozoa are slightly heavier than the water and settle to the bottom. In either case it is important to retain the particles in the remaining water and eggs until adhesion has ceased, in order to keep the eggs separated from each other, for although the particles of muck or the spermatozoa, as the case may be, are adherent, sticking to the surface of the egg, they are easily washed off, thus permitting the eggs to come into contact and become fastened together. Aside from the washing off, the area of the egg membrane becomes constantly greater, removing the particles farther and farther from each other until finally the surfaces meet and adhesion takes place. This will not occur if the muck particles or the milt are left in the egg mass until adhesion has ceased or until the egg has become practically filled with water—that is, has finished swelling.

The first great loss of eggs is owing to lack of impregnation, and the second, shown by their turning white, is owing to the rupture of the sac. While the eggs are soft and not cushioned by the absorption of water, the greatest care possible will not prevent the rupture of a considerable percentage of the sacs where the old method is pursued of constant working to prevent adhesion. By holding the eggs in the milt—which is better than the old way and requires less labor, but is not to be compared with the muck process—or by using muck, with reasonable care in all other directions, the loss is very slight, as has been shown by careful experiments and counts.

Muck has proved far superior to starch or any other substance which has been tried at the Put-in Bay Station, starch being prone to settle into a hard mass among the eggs, requiring considerable work to again dissolve it, with more or less injury to the eggs.

The preparation of the muck solution is very simple, but should be carefully conducted, as follows:

At a suitable place in a swamp a depression is dug, which quickly fills with water. Muck is now suspended in this water by thorough

beating and stirring until most of the muck particles are freely divided. Care is taken not to get the mixture too thick, as the sand will not settle out nor can the mixture be screened freely. This is poured through a screen placed across a washtub until the tub is full, when the débris is knocked off the top of the screen and another tub is filled. The partially clear water is poured off of tub No. 1, it is again filled with muck, and this is continued until there are a few quarts of muck of the consistency of cream in the bottom of the tubs. The tubs are next filled with water, which is agitated thoroughly, and then allowed to stand a few seconds to give the particles of sand time to settle. The contents of the tubs are then emptied into kegs or cans, when the water may be poured off in an hour or more. This leaves quite a thick mixture of even consistency, as shown under the microscope. It should be free from sand, which would collect in patches in the bottom of the jars and interfere with the working of the eggs.

It is very necessary that the muck be now thoroughly cooked or scalded, otherwise infusoria will develop on the eggs, causing much inconvenience and some loss. Finally the muck is drained off, dried in any desired form, and held ready for use. It should be prepared before the egg-collecting season begins. The screen is about 20 inches by 30 inches and is made by tacking to a wooden frame a fine wire cloth of 40 meshes to an inch. The finest mesh that will let small particles of muck through is best. The cloth is bagged down somewhat, with the tack heads up, in order to present a smoother surface for the quick cleaning of the screen.

PENNING FISH.

The plan of holding in pens adult fish taken prior to the spawning season has been tried with pike perch as well as with whitefish. This is done to insure a sufficient and definite number of spawners, the collection of which during the spawning season is sometimes interfered with by stormy weather or other causes. Contrary to what would be naturally expected, the pike perch is much more difficult to handle in this way than the whitefish, probably owing to the higher temperature of the water at the time the work is carried on. Fewer can be transported in the tanks on board of steamers and fewer can be held in the pens. Where injuries have occurred fungus is apt to set in much earlier than with the whitefish, and on this account excessive care is necessary in handling pike perch, as well as to prevent injury to eggs in the ovaries. While the male whitefish can be held and used over for two or three days, the pike perch can be used but once, and when held for several days, especially late in the season, the milt comes from the fish thickened as if taken from a dead fish, and is far from being at its best. However, this is true to a great extent with the fish taken fresh from the nets late in the season. Females which do not "ripen" within two or three days are likely not to furnish eggs at all, and if held even two or three days late in the season are likely to yield eggs which will not hatch.

Pike perch are obtained in the same manner as the whitefish, from the pound nets of the fishermen. They are sometimes taken directly into the tanks on board the steamer from the pound when it is raised, but more often are dipped into supplemental nets by an employee of the Commission, who accompanies the fishermen when the pound is lifted, and are held until they can be picked up at leisure by the steamer. This permits the gathering of fish from many nets, while if they were taken directly from the pound only one lifting boat can be followed at a time and comparatively few fish collected. The supplemental nets are placed at each pound net where fish are expected. They are 3 feet in diameter and 7 feet in depth, and are held open at top and bottom by rings of half-inch iron, the bottoms being provided with puckering-strings to close them. The top ring is fastened to the outhaul stake and rim line of the pound, the lower one hanging free and acting as a weight to hold the end in place, and also serving to keep the net open so that the fish will have plenty of room and not be scaled by chafing against the meshes. When thus located, the supplemental net is in a convenient position for receiving the fish when the pound is lifted. Rowboats transfer the fish in tubs to the steamer, where they are placed in tanks and transported to the pens, where they are counted and assorted according to their ripeness.

The pens or live-boxes used in the pike-perch work are the same as those used for whitefish. Stationary live-boxes, supported by piling, have been used, but as the water at Put-in Bay becomes too warm for this, the boxes are now made so that they can be towed, like a raft, into open waters where the current is more vigorous and the temperature more uniform. Another advantage gained by this method is that an equal depth of water is maintained in the live-boxes, the rise and fall in this section varying from 4 to 5 feet in a single day, according to the direction and velocity of the wind and the atmospheric pressure. The boxes are 16 feet long, 8 feet wide, and 8 feet deep, divided into two equal compartments 8 feet square, provided with false bottoms controlled by standards running in guides at the ends. The standards are pierced by inch holes at intervals of 6 inches, so that the false bottoms may be held at any desired place.

The pens, in groups of five, are fastened end on between booms, and the whole thus forms a raft. The booms are made of 4 by 8 hemlock joists, 2 feet apart on the outside, trussed at frequent intervals by diagonal cross braces and ties, on top of which are placed two tiers of 1-foot wide hemlock planks, thus making the booms when completed 52 feet long, 2 feet wide, and 1 foot deep, and quite strong and rigid, capable of withstanding seas of considerable violence. At each end and between all the crates are placed 2-foot plank walks, giving ample room for working on all sides, which is a great convenience in handling fish and procuring eggs, especially in stormy weather. The pens are now made of boards 3 inches wide, nailed 1¼ inches apart, which gives sufficient space for free circulation of water. The lumber is dressed

on all sides and all inside corners are rounded, as the fish injure their noses on square corners in their attempts to escape. All parts of the pens are interchangeable and easily taken down for storage, being held in place by 4-inch log bolts. The pens are fastened to the booms by log bolts 6 inches long.

Much depends on the work of transporting either whitefish or pike perch from the nets to the pens, not only in moving the fish with the least possible injury, but in the saving of time, so that greater numbers may be penned and the risk of holding the fish in the supplemental nets may be minimized. Tow cars have been used, but they retard the speed of the steamer fully one-half, and tanks on the decks of the steamers have therefore been adopted. It is better to have several smaller tanks than one large one, as the fish can be dipped more readily from the small tanks and the water is not so violently agitated during rough weather. A convenient size is about 6 feet long, 4 feet wide, and 3 feet deep. The tank has two lids, submerged about an inch, arranged to open crosswise of the center and held by lugs below and by pins above. The lids are made of 3-inch boards nailed firmly upon cleats on the upper side, with about ¼-inch space intervening. This prevents slopping in any weather when fish should be handled. The tank is smooth and it has no obstructions inside. A 2-inch hole at the bottom at one end is provided for drawing off water, and one of the same size within 3 inches of the top for an overflow, when fresh water is being added. Fresh water must be furnished, varying as to the number of fish. This can be supplied with a "donkey-pump," the hose being carried from one tank to another as required. With three tanks of the dimensions given above, six or seven hundred pike perch of average size can be transported.

For coating these tanks inside, as well as all tanks and troughs about the hatchery, coal tar with about one-third its bulk of good spirits of turpentine, free from benzine, is applied as hot as it can be made. This forms a smooth, hard, strong, impervious coat which lasts well, and is cheaper than asphaltum varnish.

The use of a proper dip net in handling the fish is of great importance. The splitting of fins and removing of scales is to be avoided as far as possible where any species of fish is to be penned. The scales of the pike perch are not so easily abraded as those of the whitefish, but it suffers even more as the result of injuries, owing to the higher temperature of the water at the time it is penned. The ideal net would be made of cofferdam rubber of suitable thickness, perforated at frequent intervals so as to permit the free discharge of the water—that is, a rubber net—but where many are necessarily in use and subject to rough handling, especially in freezing weather, their expense would be considerable. The hoop of the net used at the Put-in Bay station is of ⅜-inch spring steel wire, that being the stiffest and strongest material obtainable of its weight. It is bent in the form of a parallelogram 22 inches long and 20 inches wide, with rounded corners. This is fastened

into an ash handle about 6 feet long. The bag is of cider-press cloth (which is made of large, soft twisted thread, loosely woven), with each alternate thread over a considerable space in the center of the net pulled out. The bag is fastened to the hoop with small copper wire, as twine is soon cut off in working around the nets and pens. The bag of the net is 8 or 10 inches, for if much more is given it will let the fish form a pocket against the wire and prevent an easy discharge.

Netting with a 1-inch mesh and large thread has proved to be a failure, the tails of many fish being split by it. It is believed that netting with a very small mesh and the largest thread that can be woven will do the work well, the greatest objection being the knots, which injure tender species.

A frame made like a stretcher, with gunny cloth tacked on in such a manner as to bag about 2 feet, is convenient for holding fish preparatory to spawn-taking. It should be about 6 feet long and 3 feet wide, making the bag 3 by 4 feet, with handles 1 foot long at each end.

A gate made of light stuff as long as the pens are wide (8 feet) and 2 feet deep, covered by ordinary netting drawn taut and fastened by small staples, is useful in sorting the fish in the pens. The false bottom is lifted and fastened in place with the pins. There will now be about a foot of water over the floor and 1 foot of the top of the pen will be out of water. Beginning at one side the gate is gently moved along until the fish are all confined in a sufficiently restricted space. They are sorted, the ripe fish placed in the "stretcher," preparatory to stripping them, the medium in a tub to be taken to the proper pen, and the hard, which it is assumed will be in the majority, are put back over the gate into the same pen they were taken from.

The pens are numbered and a careful memorandum kept of the fish, the number of males and females received from and turned back to the fishermen each day, the number stripped, and the number in each pen.

All unnecessary noise near the pens must be avoided, especially jars or discharge of firearms, and no one should go near them except in the performance of duty. The quieter fish are kept and the less and the more gently they are handled the greater the chances of procuring a large number of good eggs, while the opposite course will cause many "plugged" females and failure generally. In transferring the fish from one net or receptacle to another it is preferable to handle only one at a time, except when they are small.

Fish, particularly females, taken from a depth of from 30 to 35 feet, often come to the surface of the water in the pens and can not descend, owing to the expansion of air in the swimming bladder. The pressure may be relieved without injury by inserting a small-sized aspirating needle, at an angle of about 45°, through the flesh of the fish into the bladder, about halfway between the middle of the spinous dorsal and the lateral line. The air can be heard escaping and when the sound ceases the needle may be removed.

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