UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF FISHERIES

ARTIFICAL PROPAGATION OF BROOK TROUT AND RAINBOW TROUT, WITH NOTES ON THREE OTHER SPECIES

By GLEN C. LEACH

Revised July 15, 1939

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UNITED STATES DEPARTMENT OF THE INTERIOR
HAROLD L. ICKES, Secretary

BUREAU OF FISHERIES
CHARLES E. JACKSON, Acting Commissioner

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Chief, Division of Fish Culture

APPENDIX VI TO THE REPORT OF THE U. S. COMMISSIONER OF FISHERIES FOR 1923

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ARTIFICIAL PROPAGATION OF BROOK TROUT AND RAINBOW TROUT, WITH NOTES ON THREE OTHER SPECIES.[1]

Revised and enlarged by GLEN C. LEACH, *Chief, Division of Fish Culture.*

CONTENTS.

[1] Appendix VI to the Report of the U. S. Commissioner of Fisheries for 1923. B. F. Doc. No. 955. This document represents a revision and enlargement of the chapters on "The brook trout," "The rainbow trout," and "Minor trouts" from A Manual of Fish Culture, Based on the Methods of the United States Commission of Fish and Fisheries, with Chapters on the Cultivation of Oysters and Frogs, revised edition, published in 1900.

BROOK TROUT.

The propagation of the brook trout is conducted under widely differing conditions throughout the natural and acclimated range of the fish. While the general principles on which the work is based are essentially the same everywhere, the details connected therewith must necessarily be modified to meet the varying conditions of climate, water supply, location, and the purposes in view. The aim of this article is to outline only those general principles, as it is manifestly impossible to enter minutely into all the details that would apply in any given section of the country. The material for the description of the methods outlined has been drawn from wide personal experience and observation.

DESCRIPTION.

The brook trout or speckled trout (*Salvelinus fontinalis*) is one of the most beautiful, active, and widely distributed of the American trouts. It prefers clear, cold, rapid streams, and belongs to that group of trouts known as charrs, characterized by the presence of round crimson spots on the sides of the body. Other members of this class are the saibling or charr (*S. alpinus*) of Europe and (*S. stagnalis*) of Greenland; the red charr (*S. Marstoni*) of eastern Canada; the Sunapee trout (*S. aureolus*) found in parts of New Hampshire, Maine, and Vermont; the blueback trout (*S. oquassa*) of the Rangeley Lakes in Maine, and Dolly Varden, red-spotted, or bull trout (*S. bairdii*) of the Pacific States and Alaska. The lake trout (*Cristivomer namaycush*) also belongs in this group.

The general form of the brook trout's body varies considerably, sometimes being elongated and sometimes rather short, but the usual depth is about one-fourth or one-fifth of the length. The head is large and blunt, and is contained four and one-half times in the body length. The large terminal mouth is provided with teeth on the jaws, tongue, and palate bones, and also with a small patch on the vomer. The eye is placed high in the head; its diameter is about one-sixth the length of head. The gillrakers on the first arch number about 17, of which 11 are on the lower arm. The scales are very small and numerous; about 230 are in the lengthwise series and 35 above and 35 below the lateral line. The dorsal and anal rays are 10 and 9, respectively. The tail is square or slightly lunate in the adult; forked in the young.

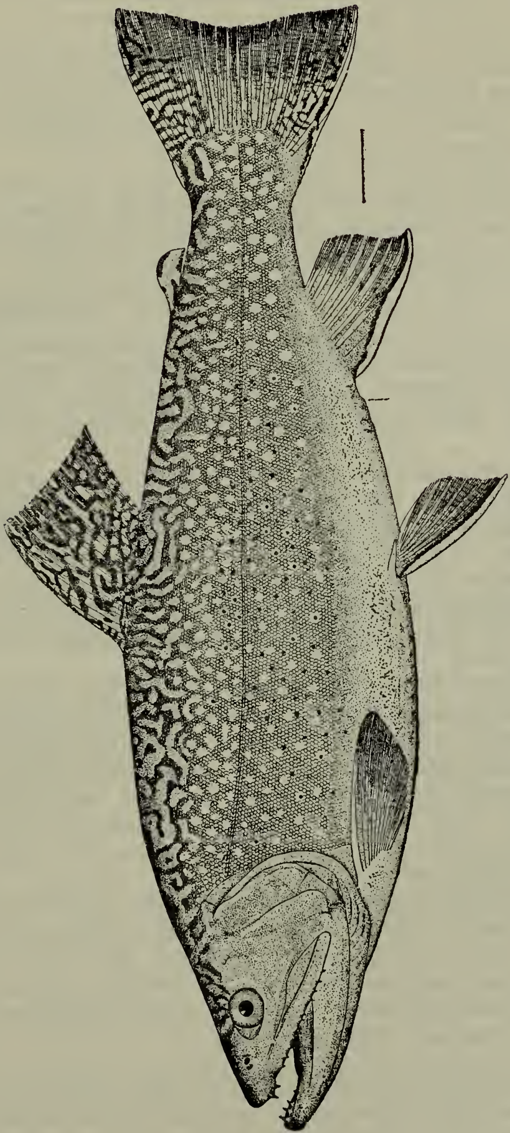

Fig. 1.—Brook trout (*Salvelinus fontinalis*).

There is considerable variation in the color of this trout, dependent on local conditions, sex, and age. The head, back, and sides of the body, dorsal and caudal fins are of a grayish or greenish color; the back, head, dorsal, and base of caudal are mottled with dark green or black. Along the middle of the side are numerous round, light-red spots surrounded by whitish or light-brownish circular areas. The lower fins are dusky, with a pale or cream-colored anterior border bounded by a black streak; remainder of fin often red in breeding males. The brook trout may be distinguished from the other charrs by the dark-brown or black marblings on the back and the general absence of spots on the back.

The parr marks, which are always present in young trouts and salmons, are often found in large brook trout. These marks, which in the brook trout are about eight in number, are large, dark, vertical blotches or bars extending along the sides.

The brook trout is closely related to the other charrs mentioned, but it has quite distinct color markings and is usually less slender in form. Individual brook trout, however, vary greatly in form and color; not only those of different waters, but often those of the same body of water or different parts of the same lake or stream. Modifications of both form and color also appear during the breeding season.

The brook trout exhibits such a variation in color under the varying conditions of sex, age, size, and locality, that it has been given many local names by fishermen under the impression that it was a distinct species. This variation is a protection provided by nature which permits the fish to change its color and markings rapidly when passing from one environment to another. The appearance of brook trout under various conditions of environment may be described, in general, as follows:

Slender, light-colored, and silvery in lakes, ponds, and swift streams that are clear and sandy, or in parts of other bodies of water where such conditions obtain. Stout and dark-colored in lakes or ponds or localities of lakes or ponds having muddy bottom and considerable vegetable growth and particularly water discolored by vegetable stain. The same may be said of streams, and it may be added that the swifter the flow of water where the trout occurs the slenderer it is likely to be.

As in external markings, there is likewise a great variation in the color of the flesh of brook trout. Although in most instances the flesh is white, trout with yellow or rich, red flesh are not rare. Several reasons have been assigned as the cause for this characteristic. W. C. Kendall, on page 543 of his paper on the Rangeley Lakes, Me.[2] gives the following as the probable cause:

> After taking everything into consideration it would seem that the character or quantity of food influences the color of the flesh only in its fattening effects, and it is only the intrinsic fat or oil in the fish which produces the red flesh and delicious flavor of the red-meated trout. The oil or fat is naturally red as that of some other animals is naturally white or some other color, and

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[2] The Rangeley Lakes, Me., with Special Reference to the Habits of the Fishes, Fish Culture, and Angling. By William Converse Kendall. Bulletin, U. S. Bureau of Fisheries, Vol. XXXV, 1915–16, pp. 485–594, Pls. XL–XLVI. Bureau of Fisheries Document No. 861, issued May 25, 1918. Washington.

it is the amount permeating the fish that gives the color its intensity. A well-fed, comparatively inactive adult trout will present a more intensive shade of the flesh than a fish of the same age living in running water, where its livelihood depends upon its activity, although it may be a well-conditioned, shapely fish. In the latter instance the food has been assimilated and utilized in the development of energy.

SIZE.

The size of the brook trout varies in different localities and probably is influenced by the abundance of natural food and the characteristics and range of the water in which it is found. A trout will not attain a very large size in a restricted environment no matter how much food it has. The average size, as taken from time to time in any given body of water, is remarkably uniform. It is generally true, and particularly as regards waters of small extent, that the size of the fish decreases in proportion to the numbers occupying a given body of water. Referring again to Kendall's Rangeley Lakes paper, we read on page 550:

> As previously stated, trout grow faster and larger in the larger bodies of water when food is plentiful than in smaller or more circumscribed places. Given plenty of room and plenty of food, it is a question to what size a trout might not attain. There are at least two natural conditions aside from those of environment just mentioned that probably affect trout. There is, doubtless, a natural size limit beyond which the trout could not go if it lived to be 200 years old; but even if there were no size limit, the species doubtless has a more or less definite life tenure that would in any case limit its growth.
>
> The comparatively recent development of the study of scales has shown that rarely, if ever, is a greater age than 10 years attained by European trout (*S. fario*), and probably not that; the lake trout of Scandinavia probably not over 12 years.
>
> Allowing, then, an average growth of 1 pound a year, as suggested by Mr. Page's experiment, the record fish would be only 12½ years old. It is quite probable that trout seldom live longer than 12 or 15 years.

The largest brook trout taken in American waters whose weight has been reliably authenticated was from Rangeley Lakes, Me., its weight being 12½ pounds, while from the Nepigon River, a Canadian tributary of Lake Superior, an example weighing 14½ pounds is recorded. From other streams brook trout weighing 10 and 11 pounds are recorded, but individuals of these sizes are by no means common.

The rate of growth also varies with the surrounding conditions, and is more rapid in water having a fairly uniform temperature throughout the year. The most favorable temperature for this fish is from 45 to 65° F. In the waters of the Rocky Mountain States where it has been successfully introduced, the brook trout grows rapidly and attains a large size. At present probably the largest examples are to be found in certain of the natural and artificial lakes of the lower altitudes of Colorado, though in the colder waters of the State, in altitudes ranging above 4,000 to 5,000 feet, it probably does not average more than 6 to 8 inches in length. Under favorable condititons the average growth is about as follows:

	Inches.
1 year old	4 to 5
2 years old	7 to 8
3 years old	10 to 12
4 years old	14 to 16

At 3 years the average weight should be about 1 pound. It is probable that fish under congenial artificial environment, receiving food regularly, will somewhat exceed this rate of growth. Because of the flavor and fine quality of its flesh the brook trout is highly esteemed as a table delicacy, and, as it is very game, it is much sought after by sportsmen. Those from clear, swift streams do not grow as large as those found in quiet and deeper waters but are superior in quality and appearance.

FOOD.

The brook trout has a voracious appetite and takes advantage of every opportunity to satisfy it. Some observers believe that brook trout do not feed during the spawning season. This may be true, in a measure, of wild fish, but fish that are kept under domestication and regularly cared for continue to feed throughout this period. In the wild state the species is no doubt largely carnivorous, its food consisting chiefly of Crustacea, Mollusca, and various forms of insects and worms. When pressed by hunger, it does not hesitate to devour its kind. Under domestication, however, it can readily be induced to eat mush made of various cereals. Kendall (loc. cit.) has the following to say regarding the feeding habits of the brook trout:

> The trout seems to avail itself of whatever animal life is available, and vegetable food is not always eschewed. A detailed list of what trout have been known to eat would be more astonishing than valuable. However, the general and principal food supply upon which the adult fish depends may be divided into two classes—fishes and insects.
>
> The trout of brooks subsist largely upon insects, particularly the aquatic larvæ of numerous species, such as caddis flies, Mayflies (*Chironomus*), and dragonflies, and also upon insects that fall upon the water or hover the water while depositing their eggs. The food of trout of larger streams, ponds, and lakes, of course, consists of the particular kinds that the waters afford, and these often differ materially from each other and seasonably in the same water. In all waters there is a seasonal supply of insects that varies with the season and locality; but where food in the form of fishes is available the insect food appears to be more or less neglected, particularly by the larger fish.
>
> The diet of the trout, however, varies not only with the season but with the age of the fish. The seasonal variation, however, may be one of convenience, but that of different stages of growth is influenced by suitability. The first food of trout fry consists largely of minute crustaceans and small insect larvæ, such as *Chironomus*, black fly, etc., and that of the fingerling of larger insect larvæ, worms, and small insects, which diet, however, is not exclusive and is controlled more or less by the habitat and environment.

COMMERCIAL IMPORTANCE.

While not to be compared in this respect with most of the fishes prominent in our market fisheries, there has been developed in recent years an important and apparently growing industry in connection with the brook trout. The comparative ease with which it may be brought under domestication, the constantly increasing demand in this country and elsewhere for the eyed eggs and fingerlings for the stocking of public and private waters, and the ready sale in many sections of the country for the adult fish at high prices as a table delicacy has induced a number of fish-culturists to undertake their artificial propagation on a commercial basis in New England, Pennsylvania, New York, and in many sections of the Western States. As the brook trout usually will spawn during the second year, many of the commercial breeders hold their fish through the first spawning period only and are able to dispose of both the eggs and parent fish at a profit.

RANGE AND SPAWNING SEASON.

The natural range of the brook trout in the United States is in the eastern section of the country. In Canada it occurs in many streams and tributary waters of the Great Lakes, the St. Lawrence River, and the Gulf of St. Lawrence, at least as far north as Hamilton Inlet on the Labrador coast. Its northern limit is not definitely known, but it extends southward in the Alleghenies to headwaters of streams in the mountains of Georgia and Alabama. It was also found naturally originally in the Great Lakes region of the United States as far west as Minnesota.

Owing to its hardy nature and ability to adapt itself to new surroundings, the species may be successfully transplanted into suitable streams, and it has become established in nonindigenous waters in Michigan, Wisconsin, Minnesota, many of the waters of the Rocky Mountains and the Pacific coast, in the Eastern States, and in creeks and rivers of the Allegheny Mountains. With the possible exception of the rainbow trout and steelhead it is the hardiest member of the salmon family and will make a brave struggle for existence even with adverse surroundings.

All streams can not be successfully stocked with this species. The flow must not be too sluggish nor the temperature of the water too high, although an unfavorable temperature, if not excessively high, is no serious obstacle where the current is swift enough to insure thorough aeration of the water or where the fish can run into spring-fed creeks flowing into the main stream. The ideal brook-trout stream receives numerous spring-fed tributaries throughout its course, so that its temperature does not exceed 65° F. in summer and by the same means is maintained at a relatively high temperature during the winter months. It has stretches of gravelly bottom, clear, shallow water, and a steady current. It should also contain large bowlders or projecting points of land at intervals for the formation of quiet eddies and deep pools.

Any stream having a summer temperature greater than 65° can hardly be considered suitable for brook trout unless it has large spring tributaries accessible to the fish during the heated period. Through the cutting away of the forests and the cultivation of the land many streams in the eastern part of the United States have become unsuited to brook trout. Wash from cultivated land during periods of heavy rainfall roils the streams and destroys much of the natural food contained in them. The rainfall on cultivated slopes drains rapidly into the adjacent streams, causing alternate periods of freshets, with turbid water, and drought. In wooded or uncultivated sections the rainfall is retained by the soil and returns to the streams in a uniform flow of cool, sparkling spring water, extending through periods of little rainfall. Streams flowing through open or cultivated areas are subject to high summer temperatures, influenced by the direct rays of the sun, and evaporation is increased proportionately. It may therefore be said that the best trout streams are to be found in wooded, hilly, or mountainous sections.

Remarkable results have been attained in introducing this fish into new waters in many sections of the country and in foreign lands, one of the most noteworthy instances being in connection with the Au Sable River in Michigan. This stream originally was the home of the grayling, a spring spawner. The utilization of the river by the lumber interests for the passage of logs at the time of the year when the grayling were spawning resulted in the destruction of the spawning beds and the consequent gradual disappearance of that species. The brook trout was suggested as the proper substitute because its spawning season is in the fall when the river is undisturbed. The work of stocking this river with brook trout was undertaken by the Michigan Fish Commission in 1885, during which year 20,000 fry were planted. This plant was followed from time to time by others, and the outcome of the attempt was so successful that during the spawning season of 1895 about 10,000 trout were captured on the spawning beds by means of a small seine and their eggs taken for artificial propagation. Many other Michigan streams where this fish was not indigenous have since been successfully stocked.

The most remarkable results of this work of acclimatization have been attained in the Black Hills and the Rocky Mountains. In these regions beautiful lakes and rivers hundreds of miles in extent, which formerly were either devoid of fish life or inhabited by coarse species of little value have been stocked so successfully with brook trout by the Bureau of Fisheries that they now constitute its chief source of supply for collections of wild eggs of that species.

In its native haunts, whether in lake or stream, the brook trout is always found in clear, cold spring water when it is accessible. When freshets occur, it pushes from lakes or rivers into the spring brooks of the upper waters, seeking out deep pools and eddies where it can lie concealed beneath the shelter of grassy banks or accumulations of drift and see without being seen. Throughout its range the brook trout spawns in autumn during the falling of the water temperature, the season beginning earlier in the north than in southern latitudes. In the Colorado region the first eggs are deposited in September and sometimes in August, while in New York and New England the season usually begins about the middle of October. Generally speaking, the spawning period does not last more than three or four weeks, though in some parts of the country, where the fish live in a copious flow of spring water subject to little change of temperature, it may cover three months or more.

As the spawning time approaches the fish seek suitable gravel beds for the deposition of their eggs. Those inhabiting lakes and ponds may find suitable nesting spots in those waters, or they may enter tributary streams, sometimes pushing long distances up to their headwaters. A favored nesting locality in a stream is at the head or the foot of a large pool, where the water ripples gently over gravel bars. The males usually precede the females, and they frequently have the beds well cleaned before the latter appear. The nests are formed by working out little depressions in the gravel and scrupulously clearing them of all sediment. In lakes or ponds such nests are made on gravelly shoals or bars where seeping water is present, either in the form of springs entering the pond or lakes or water seeping from the pond through a porous section of its bottom.

The fish usually pair on the nests, the males fighting viciously for the possession of the females. A few eggs are deposited at a time by a female and fertilized by the milt which the male simultaneously deposits. This process of spawning and impregnation by a pair of fishes is repeated many times until all the eggs have been deposited, and through the constant working of the fish on the beds the eggs become buried in the gravel. After a spawning bed is once occupied it is hard to drive the fish away, the female, especially, returning to it despite all hindrances. A female taken from her nest, marked, and placed in the water a mile downstream was found occupying the nest the following morning. The males remain on or near the beds for some time after the last females have spawned and left.

CHARACTER OF THE EGGS.

Brook trout eggs will average about one-sixth of an inch in diameter, but there is a great variation in the size of eggs taken from fish of different localities. Frequently lots are found of which little more than 300 eggs are required to make a fluid ounce, while other eggs are so small as to measure 700 to the ounce. Fish-culturists favor the larger eggs, as it is generally believed that they produce stronger and better fish than the smaller ones. The time necessary for developing the eggs is dependent on the temperature of the water, varying from about 125 days in water at 37° F. to about 50 days in water at 50° F.

PROPAGATION.

The first attempt to artificially propagate trout in America was made in Ohio in 1853 with marked success. Further satisfactory trials were made in 1855 and 1859 in Connecticut and New York, and in 1864 a hatchery was established in New York which carried on the work on a large scale. Somewhat later trout propagation was taken up by other State authorities and by the Federal Government, and it is now extensively conducted in many parts of the country.

WATER SUPPLY.

In selecting a location for a trout hatchery the first consideration is an ample supply of suitable water so situated with reference to the proposed hatchery that it can be brought completely under control. In this matter there is a rather wide range of choice. Perhaps the very best sources of water supply are deep-seated and well-protected springs, lakes of considerable depth, or spring-fed brooks.

In many instances spring water as it issues from the ground is quite unsuited to fish-cultural purposes, and before introducing it into the hatchery it should be exposed to the air for the correction of possible faults in aeration. Sometimes it may be possible to excavate a small, deep pool to form a reservoir, inclosing it to protect the water from sunlight, leaves, and débris of various kinds and to prevent small animals from entering it. Outside the spring house should be a ditch deep enough to convey all surface water away from the spring into a waste ditch. The inside of the reservoir should be protected by a foundation wall of loose masonry, the point above the water line being made substantial with mortar, building the house or cover above it, with a suitable overflow cut through the side of the masonry to provide an outlet for surplus water. The best results are obtained where the supply pipe leading from the spring to the hatchery is placed 2 feet or more below the surface of the spring and is continued underground at as great a depth as possible in order to insure a uniform temperature as it enters the hatchery. The most favorable temperature is 48° where the water leaves the ground, though no harm will result if it varies 3 or 4° either way. The entrance to the intake pipe should be covered with a wire screen inside the spring house.

If lake water is selected, the supply should be taken at a short distance below the outlet of the lake with rapids intervening if possible. The temperature of the water in lakes is influenced by the depth, and a deep lake, as a rule, affords water of more uniform temperature than a shallow one. Such water is generally quite even in volume and temperature. It is cold in winter and warms up slowly in the spring, assuring a slow normal development of the eggs, which is more conducive to the health and vigor of the resulting fry than rapid development.

A water supply obtained from a brook or stream is usually inferior to that from a spring or lake by reason of its susceptibility to floods, turbidity, and droughts, although a brook fed largely by springs may to some extent be free from these objections. In cold climates anchor ice at the intake is a serious cause of annoyance in connection with brook water. If the flow from a spring is not sufficient and lake water is not available, it would be advantageous, if possible, to have a combination of spring and river or brook water. Water from both sources should be brought to the hatchery in such a way as to permit of their use either separately or in combination, so that a temperature between the maximum of the spring and the minimum of exposed water may be maintained during cold weather. Under this arrangement the spring water may be utilized to force early hatching when desirable and the water from the exposed stream used for retarding development. This is a matter of importance in northern latitudes where the winters are long and cold and the waters locked with ice until late April or early May, conditions unfavorable for the distribution of fry. Farther south, where the waters remain open all or nearly all of the year, it is not such an essential factor.

Between these different sources of supply there is, of course, a great number of gradations. Water from boggy and stagnant ponds or marshes is objectionable, for although water of excellent quality, capable of bringing out the most vigorous of fish, may sometimes be had in such places, yet when not supplied by springs it is dependent for its freshness on rainfall, an unreliable source. Furthermore, bog water, particularly that from sphagnum bogs, is often excessively acid, and therefore deleterious to trout.

In some localities a meager flow of spring water may be successfully augmented by artesian wells. The suitability of such water for fish-cultural purposes should be determined in advance of extensive preparations, as water from such wells is frequently lacking in certain elements vital to fish life.

It is best to select a site for a hatching establishment in time of extreme drought, and if there is then an ample supply of pure sweet water the first requisite is fulfilled. It is also well to visit the place in time of flood, and during severe winter weather if in a cool climate, to learn what dangers must be guarded against. The volume of water necessary will depend upon its temperature, character as to aeration, the facilities existing for its aeration and repeated use, and the capacity of the proposed establishment. With water of the highest quality, low temperature, and adequate facilities for aeration, possibly 3 to 5 gallons per minute, or even less, will be sufficient for the incubation of 100,000 eggs. As the temperature rises or the facilities for aeration are curtailed a larger volume will be necessary. In the case of spring water having a temperature ranging between 48 and 52° F., aerated only by exposure in a pool and with no facilities in the hatching house for aeration, the amount necessary to incubate eggs in a trough of any given dimensions will be from 5 to 8 gallons per minute. As the number of eggs in a trough will vary from 40,000 to 50,000, or even more, no set rule can be applied. The proposition is different with relation to fry. A hatching trough 14 to 16 feet long and holding from 25,000 to 40,000 fry will require 6 to 8 gallons of water per minute. On the basis of 100,000 fish it may be figured that the following amounts of water will be required:

	Gallons.
Fry up to feeding stage	30
Fingerlings, 1 to 4 months old	50
Fingerlings, 4 to 6 months old	100
Fingerlings, 6 to 12 months old	200

These amounts are ample and probably even half as much would suffice if it were necessary to economize in the use of water.

If the water supply is drawn from a small brook or spring, it is necessary to measure the volume approximately, which is easily done. With a wide board 1 inch thick and having a smooth 1-inch hole bored through the middle, a tight dam is made across the stream so that all the water will have to flow through the hole in order to escape. If the water above the board rises just to the top of the hole, it indicates a volume of 2.3 gallons per minute. A rise of one half inch above the top of the hole indicates a volume of 3.5 gallons per minute; a rise of 2 inches, 5 gallons per minute; 13 inches, 12 gallons per minute. If two 1-inch holes are bored twice the volume will be indicated in each case, of course. The quantity of water flowing through holes of different sizes is in proportion to the squares of their diameters. Thus, a 2-inch hole permits the passage of four times as much water as a 1-inch hole. A tube whose length is three times its diameter will allow 29 per cent more water to pass than a hole of the same diameter through a thin plate or board.

THE HATCHERY SITE.

When a satisfactory supply of water has been found, a site that affords facilities for creating a head of water to provide the requisite fall into and through the troughs, security against inundation and severe freezing, and for general safety and accessibility must be selected for the hatchery. The extent of fall from the source of the water supply to the hatching house can hardly be too great. The minimum is as low as 3 inches, but only under circumstances in other respects extremely favorable will this answer the purpose, and then it is permissible only where there is an ample supply of aerated water, where the hatching troughs are less than standard in length, and where there is no danger of inundation. One disadvantage of a 3-inch fall is the impracticability of utilizing any form of aerating apparatus; another is the necessity of placing the troughs below the level of the hatchery floor. This makes the work of attending the fish and eggs very laborious. A fall of 1 foot will do fairly well if there is entire safety from inundation, as then the troughs may be placed on the floor, which is better than below it though still inconvenient, and some of the simpler aerating devices can be introduced. A fall of 3 feet is better, but a 10-foot fall is much better still as it permits the placing of the lowest hatching troughs 3 feet above the floor and leaves ample room for complete aeration. Everything depends upon the volume and character of the water, however, and upon its aeration before reaching the hatchery. In a small establishment there is no necessity for additional aeration in the building, and therefore a 3-foot fall is adequate.

Inspection of the site during flood season will suggest the safeguards necessary to provide against inundation. If located by the side of a brook, the building should not obtrude too much on the channel, and below it there should be ample outlet for everything that may come in the way of floods or freshets. Often much can be done to improve a poor site by clearing out and enlarging a natural watercourse. In a cold climate it is an excellent plan to have the building partly under ground for greater protection against cold. When spring water is used, there is rarely any trouble from the formation of ice in the troughs, even in a cold building, but in the latitude of the northern tier of States the water from lakes, rivers, or brooks is so cold in winter that if the air of the hatchery is allowed to remain much below the freezing point ice will form in the troughs and on the floor to such an extent as to be a serious annoyance. In very cold climates stoves are needed to warm the air sufficiently for the comfort of the attendants, but the building should be so located and constructed that it may be left without a fire for weeks without any dangerous accumulation of ice, and if the site does not permit of building the house partly under ground, the walls must be thoroughly constructed and well banked with earth, sawdust, or other material. In warmer climates no trouble will be experienced from that source. The type of building will, of course, be governed by the exigencies of each individual case. The location selected, extent and character of the fish-cultural work proposed, and the funds available, are all to be considered. The foregoing suggestions would apply to a small establishment in a more or less remote section and where strict economy in construction and operation are important.

DAMS.

The required head of water can often be obtained by throwing a dam across a stream and locating the hatchery near by. The dam will cause a small pond to form, serving the double purpose of aerating and settling the water. Unless the bed and the banks of the stream are of such character as to insure safety from undermining or washing out it is not wise to attempt more than a 2-foot head in this way. With any bottom except one of solid ledge there is always danger, and washouts are very troublesome and difficult to control. Methods of dam construction and the materials used must depend on local conditions. Other conditions being equal, a concrete dam offers advantages in permanency and low cost of upkeep. In any case a spillway to care for flood waters and avoidance of the danger from washouts mentioned above are important considerations.

If there is a scarcity of water, or if it be desirable for aerating or other purposes to secure a considerable fall, it will be advisable to construct the dam on higher ground, some distance above the building site, where a low dam will suffice to turn the water into a conduit in which it may be carried to the hatchery at the desired level. A square conduit made of planks, carefully jointed and nailed, in nearly all cases is satisfactory and a small one will suffice for an ordinary establishment. A thorough coating of hot tar inside and out previous to use acts as a preventative of leaks and decay. Pipe is generally more desirable than the conduit, and galvanized iron is preferable to black. Perhaps the most durable and otherwise satisfactory material for a water supply conduit for a permanent establishment is wood stave pipe. Such pipe properly installed and constantly carrying its full capacity gives satisfactory service for a long period of time. It deteriorates when exposed and not full of water.

WATER-SUPPLY INTAKE.

If the water supply is to be taken from a stream, and a dam has been constructed to create the required head, the extension of the conduit through the dam is an important point to be observed. Unless this is done and the intake end of the conduit is properly screened and protected there is bound to be serious trouble from clogged or damaged pipes, resulting in the cutting off of the hatchery water supply.

A very satisfactory intake for meeting the conditions mentioned consists of a rectangular box of concrete construction of any desired dimensions to meet the requirements of the case. The upstream face of the dam forms one end of the box, and the shoreward side extends upstream parallel with the bank for 15 to 20 feet, or any required distance. The upstream end of the box is projected into the stream, and the wall forming the remaining side is so placed as to present an angle of 20° to the flow of the stream. In this position it serves effectively to deflect ice or other drift from the screen guarding the entrance to the intake.

Between the downstream end of the outside wall of the box and the dam is a space sufficiently large to permit the free passage of water to the intake. This space is protected by a screen consisting of a frame of 2 by 4 material of the proper size, in which is inserted a grating of ¾-inch galvanized pipe spaced 2 inches apart. Inside the inclosure thus formed, and midway between the walls, a deflecting partition extends upstream from the dam to a point some 3 to 5 feet from the upstream end of the inclosure. This aperture is guarded by a second screen placed at an angle of about 45°, the bars being spaced about 1 inch apart.

In operation water enters the intake box through the screen in the outside wall adjacent to the dam, reverses its flow, passes through the inner screen, around the head of the deflecting wall, and thence into the supply pipe. An intake box constructed in this manner and provided with a cement top, with the necessary openings and covers for access to the inner screen and pipe, may be entirely submerged during flood periods without interrupting the flow of water. To insure the greatest efficiency from the pipe line, the section entering the intake box should be several sizes larger than the main line. Thus, if an 8-inch pipe is used the pipe entering the intake box should be 12 or 14 inches and taper to 8 inches in the course of the first 8 or 10 feet of its length. The end of the pipe in the intake box should be submerged to a depth of at least 18 inches.

CAPACITY OF WATER PIPES.

The amount of water conveyed by pipes of various sizes is dependent on the head of water, length, kind, and quality of pipe used, and the manner in which connecting joints are made and the pipe is laid. Unavoidable imperfections in the work of installation of the water supply in a hatchery make it advisable to allow liberal safety factors in applying hydraulic formulas to the work. The "head" or "total head," as applied to the flow of water through pipes or other conduits, means the vertical distance from the level surface of the water at the source of supply to the center of the opening through which the discharge takes place freely in the open air. Theoretically and in practice it makes no difference, as regards the quantity of water discharged, whether the pipe is inclined downward or upward, provided the total head and the length of pipe remain the same.

The following table indicates approximately the velocity in feet per second and the supply delivered in imperial gallons[3] per minute for long pipe lines flowing full:

TABLE 1.—*Velocity in feet per second and supply in gallons per minute, long cylindrical pipes flowing full.*[a]

Diameter of pipe.	Head of water divided by length of pipe.							
	$\frac{1}{1000}$		$\frac{3}{1000}$		$\frac{5}{1000}$		$\frac{9}{1000}$	
	Velocity per second.	Supply per minute.	Velocity per second.	Supply per minute.	Velocity per second.	Supply per minute.	Velocity per second.	Supply per minute.
	Feet.	*Gallons.*	*Feet.*	*Gallons.*	*Feet.*	*Gallons.*	*Feet.*	*Gallons.*
2 inches	0.522	4.26	1.02	8.29	1.37	11.17	1.92	15.65
2½ inches	.600	7.64	1.16	14.76	1.56	19.85	2.18	27.75
3 inches	.670	12.30	1.29	23.64	1.73	31.73	2.41	44.29
4 inches	.798	26.03	1.52	49.63	2.04	66.46	2.83	92.51
5 inches	.911	46.48	1.73	88.14	2.31	117.80	3.21	163.69
6 inches	1.02	74.64	1.92	140.83	2.56	187.95	3.55	260.81
7 inches	1.11	111.09	2.09	209.22	2.79	278.90	3.87	386.57
8 inches	1.20	156.92	2.26	294.70	3.01	392.46	4.16	543.49
9 inches	1.29	212.71	2.41	398.58	3.21	530.36	4.44	733.83
10 inches	1.37	279.16	2.56	522.08	3.40	694.24	4.71	959.88

[a] Pocket-Book of Useful Formulæ and Memoranda for Civil and Mechanical Engineers. By Sir Guilford L. Molesworth. 23d edition. Page 285. E. and F. N. Spon. London.

[3] Imperial British gallon, 277.274 cubic inches; American gallon, 231 cubic inches.

TABLE 1.—*Velocity in feet per second and supply in gallons per minute, long cylindrical pipes flowing full*—Continued.

Diameter of pipe.	Head of water divided by length of pipe.							
	1/100		3/100		5/100		9/100	
	Velocity per second.	Supply per minute.	Velocity per second.	Supply per minute.	Velocity per second.	Supply per minute.	Velocity per second.	Supply per minute.
	Feet.	*Gallons.*	*Feet.*	*Gallons.*	*Feet.*	*Gallons.*	*Feet.*	*Gallons.*
2 inches	2.04	16.61	3.76	30.72	4.99	40.67	6.86	56.01
2½ inches	2.31	29.45	4.26	54.35	5.63	71.79	7.74	98.73
3 inches	2.56	46.99	4.71	86.39	6.22	114.15	8.54	153.85
4 inches	3.01	98.60	5.51	179.73	7.27	237.17	9.97	325.41
5 inches	3.40	173.70	6.22	317.08	8.2	418.02	11.24	572.99
6 inches	3.76	277.10	6.86	504.05	9.04	663.96	12.38	909.42
7 inches	4.09	408.45	7.50	749.83	9.82	981.68	13.44	1,343.7
8 inches	4.41	575.83	8.02	1,046.8	10.55	1,377.3	14.43	1,884.3
9 inches	4.71	777.50	8.54	1,411.6	11.24	1,856.4	15.36	2,538.6
10 inches	4.99	1,016.9	9.04	1,844.3	11.89	2,424.5	16.25	3,314.2

Diameter of pipe.	Head of water divided by length of pipe.							
	1/10		3/10		5/10		9/10	
	Velocity per second.	Supply per minute.	Velocity per second.	Supply per minute.	Velocity per second.	Supply per minute.	Velocity per second.	Supply per minute.
	Feet.	*Gallons.*	*Feet.*	*Gallons.*	*Feet.*	*Gallons.*	*Feet.*	*Gallons.*
2 inches	7.27	59.29	13.10	106.64	17.18	140.18	23.43	191.16
2½ inches	8.20	104.50	14.75	188.42	19.33	246.46	26.34	335.86
3 inches	9.04	165.99	16.25	298.28	21.28	390.73	28.99	532.18
4 inches	10.55	344.23	18.92	617.47	24.76	808.21	33.70	1,099.9
5 inches	11.89	606.13	21.28	1,085.4	27.81	1,419.8	37.87	1,931.1
6 inches	13.10	959.72	23.43	1,720.4	30.63	2,248.9	41.65	3,058.2
7 inches	14.22	1,421.2	25.41	2,539.4	33.21	3,319.2	45.13	4,510.7
8 inches	15.26	1,992.7	27.25	3,557.6	35.60	4,647.9	48.38	6,315.4
9 inches	16.25	2,684.5	28.99	4,789.7	37.87	6,256.8	51.44	8,499.2
10 inches	17.18	3,504.5	30.63	6,246.9	40.01	8,161.0	54.33	11,081.3

In using these tables divide the head of water by the length of pipe. Example: Required the flow of water in a 5-inch pipe 200 feet long under a 10-foot head. 10÷200=.05. Referring to the table, under 5/100, it is seen that under these conditions a 5-inch pipe affords a velocity of 8.2 feet per second and supplies 418.02 gallons per minute.

A square conduit conveys approximately 25 per cent more water than a cylindrical pipe of the same diameter under similar conditions. Excepting in very unusual circumstances, a pipe less than 3 inches in diameter should not be used. Avoid sharp bends and the use of fittings as far as possible in laying the pipe line, as they tend by friction to reduce the flow of water. Forty-five-degree fittings are better than 90° fittings, but bending the pipe is most satisfactory. Pipes up to 6 inches in diameter and sometimes larger usually can be bent after heating. Abrupt bends in large pipe will require flanged joints.

If the water completely fills the conduit, air will be shut out entirely, while if the conduit is larger the quality of the water may be improved by aeration before it reaches the hatchery. If wood

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stave pipe is used, however, it should carry its full capacity of water, as otherwise it deteriorates rapidly.

In installing a long pipe line the expense involved in carrying it at an even grade over depressions or through high places is frequently excessive, and it is usually better to follow the general contour of the land over which the pipe is laid. This method, however, has the disadvantage of reducing the flow of water through increasing the length of the pipe. There is also danger of "air pockets" forming at the highest points in such a line, greatly reducing or even entirely cutting off the flow of water. To guard against such a contingency, vent cocks should be placed at all such high points.

AERATION.

Fishes, like all animals, require an abundant amount of air—oxygen—for their well-being. Unlike land animals, however, they do not obtain their supply of oxygen directly from the atmosphere, but it is absorbed from the water passing over their gills, organs performing a function similar to that of the lungs of land animals. It is obvious, therefore, that water suitable for the maintenance of fishes must carry in solution a sufficient amount of gaseous oxygen to meet the requirements of the fishes in this respect. Water from springs, wells, or sometimes deep lakes is quite deficient in this vital requirement, or such water may contain an excess amount of air or gases inimical to fish life. The remedy in either instance is the same—intimate contact with the atmosphere. Water readily absorbs oxygen whenever it comes in contact with the atmosphere, and by the same process it readily gives off any surplus oxygen or other gases that it may contain. The necessity for ample aeration of the water to be used in a hatching house has already been mentioned as a consideration of first importance, and some of the devices by which it is accomplished have been alluded to.

Water from a brook or stream that has been torn to frotn by dashing down a steep stream bed will be saturated with the life-giving oxygen, but such water, after supplying 16 to 48 feet of hatching trough space, will have lost a part of its oxygen and will need further aeration before it enters another series of troughs. As mentioned above, water from other sources may be entirely deficient in this respect, and it is therefore desirable to resort to all practicable means for the correction of such possible faults in the water supply.

If the hatchery site commands a fall of 5 feet or more, suitable aeration may be accomplished by a series of miniature riffles in the conduit outside the building. The broader and thinner the sheet of water provided the more thoroughly will it be exposed to the air. If it must fall through the air instead of flowing down the face of a perpendicular board, both surfaces of the sheet of water will be exposed to the air, thus doubling the effect. When circumstances permit, it is best to aerate in the conduit, which, as already suggested, should be made wide and open for that purpose.

If sufficient aeration can not be accomplished outside the building, much may still be done as the water enters. While an open water supply trough in the hatchery is somewhat unsightly perhaps, it has

FIG. 2.—Leetown (W. Va.) Hatchery.

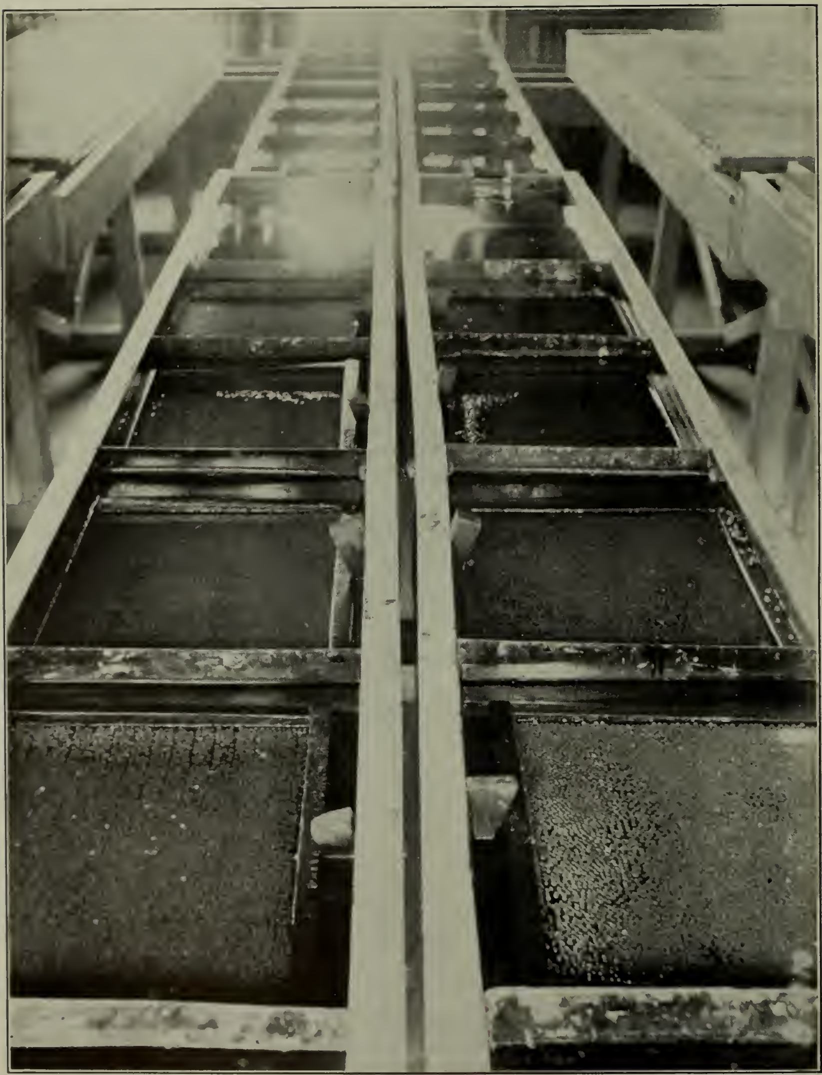

Fig. 3.—Hatching trough and trays of eggs.

advantages for aeration over a closed pipe. For a hatchery containing 20 hatching troughs a supply trough 10 inches wide by 10 inches deep, inside measurements, will carry sufficient water. As it enters this inside supply trough from the main conduit the water should have as great a fall as possible, and a number of riffles throughout its length will aid aeration further. The hatching troughs should, if possible, be set some 6 inches lower than and 3 to 4 inches distant from the supply trough. A satisfactory method of regulating the flow of water to the hatching troughs is by means of a 2-inch brass-faced molasses gate, set about 3 inches above the bottom of the supply trough. The horizontal screens and blocks on which the water falls as it leaves the supply trough, mentioned in connection with the propagation of rainbow trout, are recommended. The same results may be obtained by causing the water to pass through a pan (a 6-quart size is satisfactory) with a perforated bottom before entering the hatching trough or through a series of such pans in a rack one above the other, spaced a few inches apart. In cases where the water from a hatching trough is used again in troughs at a lower level one of these or a similar device is desirable.

In most instances, temperature and other conditions being equal, the more perfect the aeration the smaller the volume of water required, and, conversely, the greater the volume the less aeration is needed. In any event exposure to the atmosphere under the conditions mentioned can not result harmfully, and it may be very beneficial to water from any source intended for fish-cultural purposes. The use of all practicable means of aeration is recommended.

HATCHERY EQUIPMENT.

The troughs and other equipment used in the incubation of trout eggs vary considerably as to dimensions. All of the various kinds in general use have meritorious features, and in many instances they were designed to meet peculiar local requirements. The general principle in each case remains the same. The eggs are placed on trays or in baskets which are installed in the troughs and supplied with a free circulation of water.

The standard trough used at stations of the Bureau of Fisheries is 14 feet long, 14 inches wide, and 8 inches deep inside. It is constructed of white pine, cedar, or cypress, from 1 to 2 inches thick (usually 1⅝ inches) and is coated inside with asphaltum. Hatching troughs are usually arranged in pairs with aisles between, and, when desirable, the water may be passed through two or more series of troughs standing on different levels.

Each hatching trough is usually divided by galvanized iron dams into compartments large enough to accommodate the particular type of egg tray or basket in use. The dams are arranged in such a manner as to cause the water to flow over the dam at the head of the compartment, under the succeeding dam, then up through the trays or basket of eggs, and so on throughout the length of the trough. By placing the trays or baskets alternately, the first against the upper dam, the succeeding one close to the lower, and so on, all of the water is forced up through the eggs and utilized instead of passing around them.

The trays more generally used consist of frames 16 inches long by 14 inches wide, made of pine strips 1 inch by ¼ inch. To these frames galvanized wire cloth of an oblong mesh is fastened. The cloth is usually woven 8 threads to the inch, with a mesh seven-eighths inch long, galvanized after weaving, although it is gauged to retain the eggs and permit the newly hatched fry to fall through.

While the basket method was devised to meet adverse conditions at some of the Federal fish hatcheries and at such stations is considered to have meritorious features commending it for general adoption, many fish-culturists prefer the tray system, while still others use from choice the Clark hatching box, which insures a good water circulation. Perhaps the most compact and economical method is found in the Williamson trough, which has compartments divided by galvanized iron partitions as described in this article. From 8 to 14 trays are placed in each compartment, according to the depth of the trough. The flow of water is always up through the stack of eggs, which are held down in the compartment by a crossbar or binder. To facilitate their removal from the trough, a strap made of 28-gauge galvanized iron and having wooden handles on each end is placed around the stack of trays. This also serves to hold the trays together and prevents the escape of the fry, which would occur if the trays were lifted out singly. The troughs described in the section on rainbow trout, with trays 28 inches long, may be very successfully used in brook-trout culture. The eggs on such trays are always under the immediate observation of the fish-culturist, and dead eggs are easily discernible.[4]

FIELD OPERATIONS.[5]

While a very large percentage of the brook-trout eggs handled in fish culture is obtained from domesticated fish, the bureau still operates a number of profitable field stations where eggs are obtained from wild fish. Where natural spawning on a sufficiently large scale to make the gathering of wild eggs profitable occurs within reasonable distance of a hatchery, it is customary to establish temporary stations in the immediate vicinity of the spawning grounds. After taking and developing the eggs to a point where they will bear transportation they are shipped to the central station to be hatched. In certain instances green eggs may be shipped for a considerable distance without serious loss, though whenever practicable it is desirable to develop them to the eyed stage before subjecting them to a long journey. Brook trout work of this character is extensively conducted in Colorado, Utah, Wyoming, and Vermont.

If lakes or ponds constitute the spawning grounds, their bottoms must be cleared for seining operations. Where the lakes are artificial and retaining dams have been built, the water usually may be drawn and the fish collected easily. However, this process may involve the carrying away of most of the natural food contained in the

[4] Artificial Propagation of Whitefish, Lake Trout, and Grayling. By G. C. Leach, assistant in charge of fish culture. Appendix III to the Report of U. S. Commissioner of Fisheries for 1923. Bureau of Fisheries Document 949.

[5] Notes on the capture of wild brook trout and collection of their eggs were contributed by A. H. Dinsmore, superintendent of the St. Johnsbury (Vt.) station of the Bureau of Fisheries.

FIG. 4.—Racks and traps.

ponds, making artificial feeding necessary for the maintenance of the stock.

The capture of the brood fish is greatly facilitated where they enter tributary streams at or before the spawning season. Such migrations are very common in lakes and ponds having reasonably large inlets whose sources are at some distance, especially if they are subject to frequent increase in flow from rains. Such conditions often are met in the east and north. Here the fish may leave their common habitat as soon as high summer temperatures prevail or when the streams are affected by heavy showers or protracted rains. A larger movement usually will occur during periods of heavy rains in the fall, immediately before or a few weeks in advance of the spawning season. As it is not desirable to retain the brood fish in close quarters longer than is absolutely necessary, the tributary streams may be kept closed by racks during the early summer, thus preventing their ascent until near the approach of the spawning season. At that time traps are installed in the streams in which the fish are known to spawn.

TRAPS.

The general principles of trap construction for the capture of trout and salmon are identical, though the details, which are simpler in the case of trout because of the smaller sizes of the streams operated, must necessarily vary in each individual instance. The successful operation of a trap depends largely upon the ingenuity of the builder in so locating it that the fish will lead in rapidly and not escape easily through the entrance.

The simplest form of trap is built in the stream. It consists of a framework of poles or timbers supported by stakes driven in the bed or, if the foundation is of such coarse rocks as to preclude flood shifting, by means of three-legged horses weighted with stones. To these frames 1-inch square pickets are nailed sufficiently close together to prevent the passage of any fish it is desired to retain. Before nailing the pickets should be driven as deeply into the stream bed as its character will permit and must project 2 feet or more above high-water mark, so that the fish can not leap them. To form the entrance or lead, a rack is run from either bank diagonally upstream to a point in mid channel to form a V, with an opening at its apex large enough to permit the fish to enter. A rack of similar material crossing the stream in a straight line a short distance above the lead racks completes the pound. If the stream is large, however, the capture of the fish can be facilitated by running side racks from either lead rack at a point well above the apex of the V to the cross rack above, thus forming a pound in the shape of a reentering polygon. For greater convenience in sorting and handling the fish several retaining pens of similar material are frequently built above the rack.

A trout trap which has been successfully operated at stations of the Bureau of Fisheries for many years is built in the lower section of a retaining raceway through which the normal flow of the stream is diverted. From this raceway trap at the point where the water is returned to the stream the main channel is closed by a rack which extends to a point somewhat lower downstream on the opposite side to give greater rack surface. It is well to operate a somewhat coarser rack than that required to stop the small trout at a suitable point above where floating leaves and other débris may be stopped and removed, thus reducing the liability of the trap racks to dam up and undermine. The location selected for the trap is very important. Other conditions being favorable, it should be placed as near the mouth of the stream as the character of the banks will permit with the V-shaped entrance lead toward deepening water.

The fish run most freely on dark, rainy nights when the stream is rising, but during the spawning season ripe fish will enter night after night in times of normal stream flow. The majority of the fish are usually taken while one or two heavy rains are bringing the streams to flood stage. At such times it is necessary that the attendant have an assistant to keep the racks free from débris, as the fish often enter the trap as fast as one person can readily transfer them with a large dip net from trap to pens. Not infrequently as many as 1,000 to 3,000 fish are taken in a night. If ample rains are lacking at the height of the spawning season and the water is very low, only a few fish will ascend to the traps, and the egg collections will be relatively small unless the fish can be taken by seining the lower stretches of the stream. An abundance of rain late in the season will have little influence in bringing spawning fish to the traps.

A comfortable cabin in close proximity to the traps is a necessity, as the constant care of the racks and the work of guarding the fish against predacious animals and malicious persons often subject the attendants to great hardships during inclement weather.

TAKING THE SPAWN.

When the fish are running briskly, no attempt is made to separate them, but as soon as the run slackens they are carefully assorted and segregated in pens according to their degrees of ripeness. This saves much time and possible injury to the fish through constant handling for the purpose of ascertaining their spawning condition. A percentage is kept of the ripe fish taken from each pen so that the proper time for handling those in the various inclosures may be determined. It is sometimes necessary to examine every day or every other day the fish that appear to be nearly ripe and others from once to twice a week.

Eggs are not ripe enough to be taken until they flow readily under very slight pressure. In some instances a fish may by muscular contraction retain its eggs for a few seconds, deceiving the spawn taker for the moment, but if the eggs are ripe they will begin to flow as soon as the muscles relax.

The eggs are taken in pans or other metal vessels which have been thinly coated with asphaltum to prevent rust or in receptacles made of pressed fiber, the advantage of the latter being that they do not require painting and do not transmit cold as readily as the metal vessels. Just before the eggs are taken the vessel is dipped into cold water and drained.

The spawn taker holds the fish as firmly and gently as possible at such an angle as will cause the ripe eggs to flow naturally toward the vent. With the thumb and forefinger he then gently presses out the eggs, beginning the pressure just forward of the vent. The hand is then moved forward toward the head of the fish, and further gentle pressure is applied as necessary to assist the natural flow of eggs until all that will come freely from the fish are obtained. Pressure should never be applied forward of the ventral fins, as even slight pressure applied over the vital organs is very apt to result in injury to the fish. The above seems to be the logical and rational method of spawn taking, as the eggs nearest the vent are taken first, leaving a clear passage for those that follow.

As the eggs fall into the dampened vessel milt is immediately applied, being obtained by the manipulation of the male fish in a similar manner. The next step is to add enough water to cover the eggs and agitate the vessel sufficiently to thoroughly mix eggs and milt, or a feather may be used to effect the mixing prior to the introduction of water. The excess milt is then almost immediately discarded by adding and pouring off water until it becomes clear, when the vessel is half filled with clean water and is protected from temperature changes by placing it in running water or inside of a larger vessel of water. It is then left entirely unmolested until the adhering stage has passed and the eggs separate, the time required for separation being from 30 to 60 minutes, according to the temperature. Some spawn takers consider it advisable to delay washing the eggs until after separation occurs, while others use no water at all until that stage is reached. In general practice, however, the method herein described is most satisfactory. If the eggs remain in the vessel long after separation, the water must be changed frequently.

The work of spawn taking should be done only by thoroughly experienced persons. While the test of efficiency along this line is frequently based on the percentage of fertile eggs obtained, the numbers of fish stripped and not injured is a point of equal importance. Proper methods of spawn taking carefully applied will result in no injury to the adult fish, either females or males; but unless the spawn taker understands something of the anatomy of the fish and exercises the utmost care serious, if not fatal, injuries are very likely to be inflicted. Some of the more common mistakes made by spawn takers in handling fish during the egg-taking process are mentioned below:

Grasping the fish by the tail and holding it head downward while it struggles violently, or similar handling in a dip net. Such treatment is very apt to result in rupture of the delicate ova-containing membrane, causing the eggs to fall into the abdominal cavity, from which they can not be extruded. An injury of this nature may result in barrenness or even death. The proper method of removing a fish from the water is described under the section on rainbow trout.

After stripping a fish spawn takers sometimes throw it from a distance into the retaining inclosure or pond. This procedure is so obviously wrong that it should need no comment. Perhaps the most common cause of injury in spawntaking is the practice of certain spawntakers of squeezing the fish several times, beginning well forward near the gill opening, until blood and fecal matter are extruded, in order that every egg may be secured. This is sure to result in expressing some immature eggs that are incapable of more than imperfect fertilization, and it is very liable to injure the ovaries or other organs of the fish. The eggs in the ovaries of a trout do not all ripen at the same time. Those in the posterior end mature first, and it is good practice in all cases to take only such eggs as come freely from the fish by very gentle pressure, which should extend very little, if at all, forward of the ventral fins. In some instances it may be desirable to retain the fish for a second stripping a few days later.

Eggs taken in close proximity to a regularly established hatchery may, of course, be transferred there immediately for development, but when secured at distant field stations it is necessary to hold them at the point of collection until they reach the eyed stage, as green trout eggs are so tender that they rarely can be subjected with impunity to the rough treatment incidental to a long journey.

As a rule, an eyeing station consists of a small building equipped with a number of troughs patterned after the standard hatching trough described elsewhere. A gravity water supply should be provided and, where it is available, spring water of a volume not seriously affected by the falling temperature of late autumn is selected for this partial development work, as such a supply insures the rapid advancement of the eggs, making it possible to ship them to the main hatchery before the beginning of winter.

The troughs and equipment should be standard size. Trays 14 by 16 or 14 by 28 inches, as described, are satisfactory. In cases where the eggs are to be incubated and the fry held in a limited space until ready for planting, trays covered with wire cloth 14 to 16 meshes to the inch, as described on page 28, are useful.

As manv as eight trays may be stacked in a trough compartment, one compartment being reserved for the reception of trays from the other compartments when the eggs are picked over and cleaned. As the trays of eggs are picked over one by one they are transferred to the empty space in the trough, and each compartment emptied becomes in turn the depositing place for another stack of trays until all occupy new space. Four small blocks one-half inch in thickness are tacked to the rough bottom in the corners of each compartment on which the trays rest, thus permitting a flow of water underneath.

When the eggs are brought in from the stripping place, they are measured in a tin cup or glass graduate, the capacity of which has been established by count, and are then placed on the trays. As each tray is filled it is gently settled in place in one of the compartments. When there is an ample amount of water, as great a quantity is admitted into each trough as will flow through the eggs without disturbing them, but in case of a limited supply the eggs may be carried to the eyed stage in good condition with a flow of not over 2½ gallons per minute to a trough of 200,000.

During the early stages of incubation the eggs should be handled as little as possible, but in order to prevent the development of fungus it will be necessary to pick them over at intervals, removing all white eggs and those that are known to be dead. The lengths of these intervals can be determined only by close observation, as the necessity for frequent picking will be governed largely by the varying conditions of the water supply. However, they should be carefully gone over at least once a week. One attendant at a field station can care for a million eggs unless the percentage of fertilization is excessively low.

Trout eggs are extremely sensitive to shock during the period extending from two to four days after they have been laid down in the hatchery up to the time when the eyes of the developing embryo are discernible to the unaided eye, and any movement of the trays of eggs at this stage is liable to result in heavy loss. The exact length of this period is dependent on the water temperature. It is known to fish-culturists as the "tender stage," and until it is past it is advisable to leave the eggs undisturbed so far as possible. If it becomes necessary to remove dead eggs to prevent the spread of fungus, as indicated above, it should be done with the utmost care.

PACKING THE EGGS FOR SHIPMENT.

At the proper stage of development the eggs may be transported for long distances without material loss if skillfully packed. Cases of a great variety of shapes and sizes with an equal variation in the styles of trays and the methods of insulation have been used. The essential requirements for the successful transportation of trout eggs are, (1) a package so insulated that it will preserve a uniformly low temperature on the eggs; (2) protection from undue jars or shocks; (3) the maintenance to the end of the journey of a reasonable amount of moisture. Any package that will accomplish all of these things may be considered fairly satisfactory, although as such shipments are usually sent by express the weight of the package also becomes an important item. In this way the so-called bulk method of packing trout eggs is more economical than the use of trays, and for shipments involving not more than 48 hours' time it may be satisfactorily applied in most cases to the transfer of eyed eggs from the collecting fields to the main hatcheries. For journeys of longer duration the mode of packing described on page 25 is preferable.

As regards the bulk method, the size of the case will depend upon the number of eggs to be shipped. The case consists of one or more inner boxes for eggs and an outer box of sufficient size to hold them and allow 4 inches of space all around for packing. The inner boxes are made of one-half-inch lumber with the bottoms left partially open to permit the surplus water to drain off and to allow for swelling of the lumber when wet. An egg box 12 by 15 inches and 4 inches deep will carry from 80,000 to 100,000 eggs, the actual number depending on their size. Three of these boxes packed in a single case, containing approximately 300,000 eggs, will weigh about 125 pounds.

While a great variety of materials, including leaves, straw, sawdust, shavings, etc., have been used as an insulating medium in packing fish eggs for shipment, probably nothing superior to sphagnum moss for the purpose has been found. When saturated with water, it retains the moisture for a long time and is thus valuable for use on the egg trays or boxes. When dry, it packs closely around the egg trays and is a most excellent nonconductor of heat or cold. Further, it has not the tendency to "heat" that certain other materials possess.

Brook-trout eggs are in condition to bear transportation as soon as the eyes of the embryo are visible. Before packing the eggs for shipment they are thoroughly washed. This is accomplished by removing them from the trays to a tub of water and introducing a stream of water among them with sufficient force to slightly agitate them for several minutes. This treatment not only removes all sediment from the eggs, but it causes all infertile eggs to change color, thereby facilitating their removal. Unless this is done a considerable number of infertile eggs is likely to be included in the shipment, as such eggs will frequently retain the color and general appearance of good eggs for a long period. The same results may be attained by passing a feather brush among them. After washing, the eggs are again placed in a tub of water, the temperature of which is very gradually reduced several degrees.

The bottom of an egg box is covered to a depth of one-half inch with sphagnum moss freshly wrung from ice water. A mosquito netting large enough to fold in from the sides and ends, entirely covering the eggs, is laid over the moss. The water is drained from the eggs and the required number placed in the box. In folding the netting over them it is drawn in a little from the sides and ends of the box and a thin layer of moss is tucked around to prevent the eggs from coming in contact with the wood. The box is next filled with moss, so that when closed by the cover the eggs will be retained in place should the case receive rough handling en route. If more than one box is used they are stacked and cleated one above another and only one cover is used, the bottoms of the upper boxes forming the covers of the ones below. Dry moss to a depth of 4 inches is placed on the bottom of the outer case, the stack of egg boxes installed, and the remaining spaces tamped tightly with dry moss to keep the stack in place and to provide the necessary insulation against temperature changes. For short distances no ice is necessary, provided the eggs, moss, and netting used in the inner boxes are near the freezing point when the packing is done. If the weather will permit, the egg boxes may advantageously be left in a freezing temperature until the moss stiffens slightly before placing them in the outer case or a quantity of snow or grated ice may be sprinkled over them. In most instances an ice hopper is desirable, and this is made to occupy the 4-inch space immediately over the egg boxes, forming the cover of the upper box of eggs. Where ice in any form is used in the package ample drainage through the bottom of the box must be provided.

Brook-trout eggs have been shipped successfully to many foreign countries. For shipments of this nature, where the eggs will be in transit for an unusually long period and will require replenishing of the ice chambers and possibly the removal of dead eggs, a more elaborate case is necessary. A so-called refrigerator case has been used with good results in making foreign shipments.[6] A case similar to this in some respects but more compact and of less weight has recently been designed by G. C. Leach, assistant in charge of the division of fish culture, United States Bureau of Fisheries, and has been successfully used in European shipments. Figure 17, page 53.

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[6] Artificial Propagation of the Salmons of the Pacific Coast. By Henry O'Malley. Appendix II to the Report of the U. S. Commissioner of Fisheries for 1919. Bureau of Fisheries Document No. 879, pp. 26–28.

This case is 2 feet 4 inches square by 1 foot 7 inches deep, outside measure. It has double walls and bottom made of 1-inch lumber, and the 2-inch space between is filled with dry sphagnum moss or granulated cork, closely tamped. Two cleats are fastened to the bottom to give free vent to the iron drain tube, which extends through the insulation to the egg compartment as shown. The case has handles for convenience in moving and is closed by a hinged cover. The inside walls and bottom are lined with galvanized sheet iron to exclude moisture from the insulating medium as far as possible. After the lining is in place, two cleats 1 inch in thickness and 2½ inches wide are fastened to each inner wall of the case, eight in all, as shown in the cut. These cleats extend from the bottom to within 4 inches of the top and to them is fastened galvanized iron wire screen of ¼-inch mesh, thus forming a space about 2½ inches wide extending from the bottom of the case to within 4 inches of the top between the galvanized iron lining and the wire mesh, which is filled with chopped ice when the case is in use. Thin strips of wood are tacked over the wire mesh at the points of contact with the cleats. These serve to hold the wire mesh in place and facilitate the placing or the removal of the egg trays.

The remaining space in the center of the case is devoted to the egg trays. These are frames 14 inches square, made of five-eighth by three-eighth inch strips halved together at the corners and covered with linen scrim firmly stretched and securely tacked to the frames. The space provided will accommodate 15 such trays, leaving a space of 4 inches above for an ice tray. This is of galvanized iron 21 inches square by 4 meshes deep and occupies the entire space above the ice chambers and egg trays. The bottom of this tray has a double row of one-eighth inch perforations along each side, permitting drainage from melting ice down through the ice chambers and not over the egg trays. To the bottom of the egg tray compartment are fastened half-inch cleats, which hold the egg trays that distance from the bottom. The trays are intended to carry eggs in a double layer, and the case has a capacity for between 150,000 and 160,000 brook trout eggs, or more, according to their size.

TRANSPORTATION OF GREEN EGGS.

While the transportation of green trout eggs can not be recommended, it is sometimes necessary, and with great care it can be accomplished successfully provided the shipping destination is not more than 48 hours distant. The eggs should not be packed until they are thoroughly water-hardened, which will be within a few hours after stripping if they are maintained at a temperature of 48 to 55° F. Moderate success has been attained in shipping young eggs on trays, but ordinary fruit jars are probably best adapted to the purpose, and this is the form of container in general use. The jars are first filled with water and the eggs are poured in gently in sufficient quantity to replace about three-fourths of it. They are then sealed and packed in dry moss to guard against changes in temperature.

A satisfactory method of shipping green brook-trout eggs has been developed at the Rocky Mountain trout stations of the bureau. This method involves the use of a case of suitable size, with the usual provision for insulation and ice-hopper. The trays are divided into compartments or pockets 2 to 4 inches deep into which the eggs, wrapped in cheesecloth or mosquito bar, are placed. The dimensions of this type of case used at the Leadville (Colo.) station are $15\frac{1}{2}$ by 22 by $13\frac{3}{4}$ inches deep, outside measure. Each case contains four trays $8\frac{1}{4}$ by $19\frac{1}{2}$ inches and $2\frac{1}{2}$ inches deep. These are divided by cross partitions into three pockets 6 by $7\frac{5}{8}$ inches, with an ice hopper 11 by $19\frac{1}{2}$ inches and $2\frac{1}{2}$ inches deep. Such a case will carry from 100,000 to 150,000 eggs.

The superintendent of the Springville (Utah) station has described a method of packing the green eggs as follows:

> In putting the eggs on the hatching trays at the field station a 2-quart dipper is filled with water and over it is laid a piece of mosquito netting or cheesecloth about 18 inches square. Into this a measured lot of eggs—enough to fill one pocket in the shipping tray, between 20 and 30 ounces—is poured. The cloth is then lifted by the four corners and deposited, with the eggs, on the hatching tray. Here they remain until the time for shipment arrives. In shipping, wet moss is first placed on the bottom of each pocket, the shipping tray is submerged in water, and the eggs are lifted from the hatching tray as described and deposited thereon, a light layer of moss being placed on top. If desirable, the eggs may be shipped as soon as "water hardening" is completed.

INCUBATION OF THE EGGS.

When eggs are received from a collecting station or other source, their temperature is compared with that of the water in the hatchery, and before installing them in the troughs any wide difference is equalized by slowly adding and pouring off the hatchery water in small amounts. A quantity of the eggs, sufficient to register at the 32-ounce mark, is poured into a graduate full of water. The eggs are settled together by shaking the graduate, and enough are added to make up the deficiency thus caused. One such measure is placed on each tray, and any remainder is put into another tray to comprise a broken lot. As soon as it is convenient to count 32 fluid ounces of the eggs and ascertain the number contained in each tray, those in the broken lot are drawn upon and counted into the separate trays until the count of each is the even number decided upon for a tray unit. Owing to variation in the size of the eggs this may be any number from 10,000 to 15,000.

The incubation of the eggs beyond the eyed stage does not differ materially from the eying process. While the equipment at different stations varies somewhat to meet local conditions, the general principles of the work are the same. From this time on the care of the eggs consists in removing the dead ones and keeping the good ones free of silt, which is dislodged by raising the tray slightly and settling it back into place. In the event that the eggs become very dirty they may be removed from the trays or baskets, cleaned as described on page 24, and then returned to the trays. The fry are hatched in the troughs in which the eggs are incubated and are retained there until ready for distribution. The original number of eggs in each receptacle is maintained by the systematic daily addition of eggs from the broken lots to make up for any losses that may occur.

FIG. 5.—Interior of St. Johnsbury (Vt.) station.

CARE OF THE FRY.

With the approach of the hatching period great care must be taken to guard against the clogging of outlet screens by accumulations of eggshells. As the eggs hatch the fry drop through the trays to the bottom of the troughs and remain there during the sac stage, which varies in length from 25 days in water with a temperature of 50° to 50 days in a water temperature of 33° to 35°. As the young fish develop they will show a tendency to congregate near the head of the trough. To guard against suffocation of the fry, the troughs should be subdivided into compartments by the insertion of screens. The use of baskets for the retention of the fry also obviates this difficulty.

PLANTING THE FRY.

When the weight of the yolk sac has diminished sufficiently to permit the fish to rise in the water, they begin taking food, and under normal conditions are feeding freely by the time the sac has entirely disappeared. When very young fry are transferred to open waters, where there is natural food only, the planting should be done 8 or 10 days before the sac is entirely absorbed, for if delayed till after the sac disappears many will die before they become accustomed to finding food in their new environment. Very good results may be expected from the planting of fry if they are properly handled and carefully deposited in small spring-fed tributaries not frequented by larger fish.

Brook-trout fry are usually transported in ordinary round-shouldered milk cans of 10 gallons' capacity, the number of fish per can depending entirely upon the temperature of the water in which they have been held, the distance they are to be carried, and the facilities for taking care of them en route, such as opportunities for changing the water, supplying fresh ice, etc. From the fact that water absorbs air more rapidly at a low temperature it can readily be seen that more fish can be transported per can when the water is cold. However, trout may not be subjected to great and sudden changes with safety, and it is not wise to lower the temperature in the transportation cans more than 10° below that of the water in which they have been carried in the hatchery. In making trips of from 5 to 10 hours' duration between 2,500 and 3,000 fry may be carried in each can if the temperature of the water is not above 50°, but where they are to be on the road more than one day it is not safe to carry more than 1,500 per can.

The distribution work of the Bureau of Fisheries is accomplished mainly by means of cars especially built for the purpose and equipped with pumps for forcing air currents through the cans in which the fish are carried. Small shipments, however, are made by a special messenger in a baggage car, the railway companies usually offering every available opportunity for securing fresh supplies of water and ice. In the case of public plants, the fish upon arrival at the railway point nearest their destination are transported to the stream where they are to be planted and liberated in small lots in different places where there is shallow water and a good bottom or in small spring-fed tributaries when possible. Where deliveries of fish are to be made to individuals or organizations on formal application, the applicant is expected to meet the shipment at the railroad station and effect the necessary arrangements for their final planting. The demand for fingerling fish for stocking streams far exceeds the available supply.

The methods outlined on page 47 for handling fry may be applied advantageously to brook trout, and where it is necessary to economize, either in space or in the flow of water, the fry may be carried through the sac stage on trays stacked one above another in the trough compartments as is done with the eggs. In employing this method it is customary to transfer the eggs from the hatching trays to trays similar in size but covered with wire cloth 16 meshes to the inch just prior to the time of hatching. The more open mesh is desirable during the incubation period, as it gives a freer circulation of water, but the smaller mesh must be used to hold the fry successfully. This method of carrying fry is practiced extensively in fish-cultural operations addressed to such important commercial species as the Pacific-coast salmons and the lake trout of the Great Lakes.

REARING AND FEEDING.

If the fry are to be reared for breeding, one week before the food sac is absorbed they should be changed from the trays to a large pan and removed to the rearing troughs. Gravel may be used in these troughs, but in general practice it is undesirable, as the unconsumed food works down into it and, becoming fungussed there, causes a great spread of disease and increases the labor of caring for the fish.

Trout fry are ready to be fed regularly when they rise to minute particles of food thrown upon the water. The time and frequency of feeding young fish, the kind of food, and the manner of feeding them are of the utmost importance. A difference of opinion exists among fish-culturists as to how often young trout should be fed, but the majority is in favor of feeding them from five to six times a day until they are a few weeks old and after that giving them larger quantities of food at less frequent intervals. Only such an amount as the fish will eat readily at one time should be spread upon the surface of the water with a feather until they are accustomed to taking it.

While various foods have been fed more or less successfully, it is believed that beef heart and beef liver give better results than any artificial food, and their preparation is very simple. A less expensive and very satisfactory substitute is beef melts or spleen. The meat is first ground fine by running it through a meat chopper several times, using a plate with perforations five sixty-fourths of an inch in diameter, a little water is added, and the meat beaten to give it the proper consistency. An egg beater is used by some fish-culturists in preparing the food. The finely ground meat is placed in a deep pan, with sufficient water to bring it to the proper consistency, and then thoroughly mixed with the egg beater. This removes practically all the small particles of connective tissue and muscle which ordinarly pass through the finest plate of the meat chopper and cause trouble by clogging the screens and fouling the troughs.

The introduction of beef liver into the troughs causes a milky discoloration of the water. This may be overcome, however, by washing the prepared material before giving it to the fish. The washing process is accomplished by introducing a stream of water into the vessel containing the meat, which is screened to prevent loss of the food, and allowing the milky substance to escape with the overflow. This treatment does not in any way lessen the nutritive value of the food.

At this stage the young fish have such a precarious hold upon life that too much attention can not be given to their care. Not more than 20,000 can be held with success in a feeding or rearing trough, and a constant circulation of water through the troughs must be kept up to prevent disease, while the fish should be properly thinned out in order to prevent loss by suffocation when they increase in size. About 3 to 5 gallons of water per minute are sufficient for 20,000 fry, although this quantity must be increased as the fish grow stronger and are able to breast a heavier current.

In the spring when the water begins to grow warm the fish require more room than the feeding troughs afford and it is necessary to transfer them to other troughs or ponds. At some of the Federal hatcheries the young trout are held in troughs or nursery ponds until they attain a length of 3 or 4 inches before they are distributed. It has been demonstrated that raceways arranged as described on page 31 possess many advantages over troughs for the rearing of such fish. Among the most successful rearing ponds are those from 5 to 8 feet wide and not more than 100 feet in length, modeled after the ponds described on page 37. A water supply of about 200 gallons per minute and having a temperature of between 48 and 55° is desirable. Ponds of such shape and dimensions may be constructed with natural earth sides from the top of the bank to the water's edge and of cement from the water level to the bottom. The bottoms, with the exception of a feeding area of cement near the outlet, are of gravel. A rearing pond 5 by 20 feet, having a gravel bottom and a flow of not less than 50 gallons of water per minute, will accommodate from 10,000 to 20,000 fry till midsummer, when the number must be reduced to not more than 5,000. A raceway 4 feet wide and 100 feet long, with a strong current, will carry 100,000 fry, and as the fish develop the number can be reduced and the surplus distributed in other waters or shipped.

At this stage they are usually fed at regular intervals three times a day, and, as they do not take food readily during the first few days, a great deal of patience is necessary in their treatment and care must be taken to see that no unconsumed portions are allowed to remain at the bottom of the pond and pollute the water. At this time the food should be given in small amounts, and considerable time should be taken to see that it is properly administered. Three-fourths of an hour is not too long for feeding 5,000 fry. The time occupied in feeding should be diminished and the amount of food increased according to the judgment of the fish-culturist as the fish grow older, but their appetites should never be completely satisfied.

By early winter all fish reserved for brood stock should have attained a length of from 3 to 5 inches. If they have been held in troughs or small ponds, arrangements should be made for their transfer to more commodious quarters. A breeding pond 20 feet by 75 feet will accommodate 10,000 yearlings, 5,000 2-year-olds, and about 3,000 from 3 to 5 years old, though much better results will be attained with half this number. The water supply should be from 100 to 150 gallons per minute. For adult fish the pond may be any size from 1 acre up to 20 acres or more, provided it has a very large water supply entering at one end and flowing through its longest dimension to an outlet. A 20-acre pond should have a flow of 5,000 to 10,000 gallons of water per minute for best results. A raceway or channel should be arranged where the water enters the pond, with a trap to catch the spawning fish as they try to ascend the stream.

Less care is required in the preparation of food for adult trout. It may be given to them in pieces half an inch in diameter, may consist of almost any kind of raw meat or fish, and the flesh may be mixed with cooked mush made of a low grade of flour. Meat meal and fish meal in combination with meat and flour also have been used successfully.

DISTRIBUTION OF FINGERLINGS.

Fish which have attained a length of 1 inch are termed "fingerlings No. 1"; those which are 1½ inches long are designated as "fingerlings No. 1½", and so on. Small fingerlings are distributed from the eastern hatcheries in May and June and at a later period in the west. Larger fingerlings are sent out in the autumn. Assignments of fingerling fish are necessarily much smaller than assignments of fry. In shipping fingerlings No. 1 to No. 2 the number carried in a can ranges from 500 to 1,000, the actual number varying with weather conditions and the length of the trip to be made. Not over 200 No. 3 fingerlings can be safely carried in a 10-gallon can, even under the most favorable conditions.

EGGS FROM COMMERCIAL HATCHERIES

The collections of brook-trout spawn from wild fish, even when supplemented by eggs taken from brood fish under domestication, are totally inadequate to meet the present demand for eggs of that species, and but for the supply resulting from the raising of trout for the market by commercial fish-culturists the production of this fish would be curtailed considerably. The business of growing trout for the market was undertaken in this country more than half a century ago, but within the past 20 years it has developed so rapidly that it is now an industry of considerable importance.

The main object of the private hatchery usually is the production of adult trout. The eggs, which, as a rule, are stripped from the fish just prior to marketing, are a secondary consideration. As New York and Boston are the best markets for the fish, it is natural that the most successful commercial hatcheries in the east should be located within easy reach of those cities.

The methods followed by private plants in handling eggs and fry during the early stages of development do not differ materially from those employed at the Federal and State hatcheries. As the end in view is not the same, however, there is necessarily some variation in the treatment of the fish beyond the fry stage.

At some of the commercial establishments ponds more or less irregular in size and shape are used for rearing, but, as a rule, the growing fish are held in long narrow raceways, some of them half

FIG. 6.—Trout-rearing troughs, Pennsylvania.

a mile or more in length, though never more than 8 feet wide and with a water depth rarely exceeding 2 feet. Where there is an abundant supply of water a strong current flows through the raceways, sometimes broken at short intervals by partition boards extending half way from the surface of the water to the bottom, with openings somewhat narrower than the raceway. The refuse swept downstream by the current and the actions of the fish is deposited in the eddies formed above these riffles and may be removed easily. If the fish are uniform in size, no screens are placed between the compartments formed by the partitions, but if different sizes are carried in the same race screens form the partitions. Usually the upper sections of the raceways are screened for retaining the fry and the lower sections are used for holding the larger fish. As soon as the fry in the hatching troughs begin to take food freely they are transferred to the raceways and fed systematically.

While such packing-house products as the livers, hearts, melts, and lungs of cattle, hogs, or sheep form the principal food, quantities of small waste fish, especially small herrings, are utilized at hatcheries located in the vicinity of the New England coast fisheries.

The trout market demands fish known as "thirds," "quarters," and "fifths," designations for fish running, respectively, 3, 4, and 5 to the pound. Many of the fish attain these sizes by the time they are 20 months old, at which age they produce their first eggs. After taking the spawn the fish are again placed in the raceways or in special ponds or pools and fed all they will eat until they are in proper condition for marketing, when they command 50 to 60 cents per pound, net.

Some commercial fish culturists raise fish especially for an egg supply, holding them in ponds until they weigh from 2 to 3 pounds. Such fish yield eggs of better quality than are usually obtained from fish spawning for the first time, especially if a certain amount of natural food is available in the ponds in which they are kept.

The eggs produced in 1922 by commercial establishments were sold at from $1 to $1.50 per thousand, depending upon their quality and the number contracted for. As a rule, eggs are purchased subject to their condition upon receipt, and it is generally stipulated that they shall be shipped as soon as they have reached the stage when infertile eggs can be removed. Consignments of eggs that are very near the point of hatching upon arrival at their destination are likely to suffer heavy loss both in the egg and in the fry stage.

RAINBOW TROUT.[7]

The following discussion relates to the rainbow trout, which has received the attention of fish-culturists throughout the country. The earliest work along this line was concerned with the rainbow trout of the McCloud River and later was extended to include the trout of the Klamath River basin. Subsequently eggs of the steelhead from the Rogue River in Oregon and certain streams in Washington were shipped east, and in many instances the fish resulting therefrom have been distributed in public waters under the name of

[7] The notes for the section on Rainbow Trout were contributed almost entirely by George A. Seagle, superintendent of the Wytheville (Va.) station of the Bureau of Fisheries from 1880 to 1922, who has very ably described the methods employed at that station in the artificial propagation of this species.

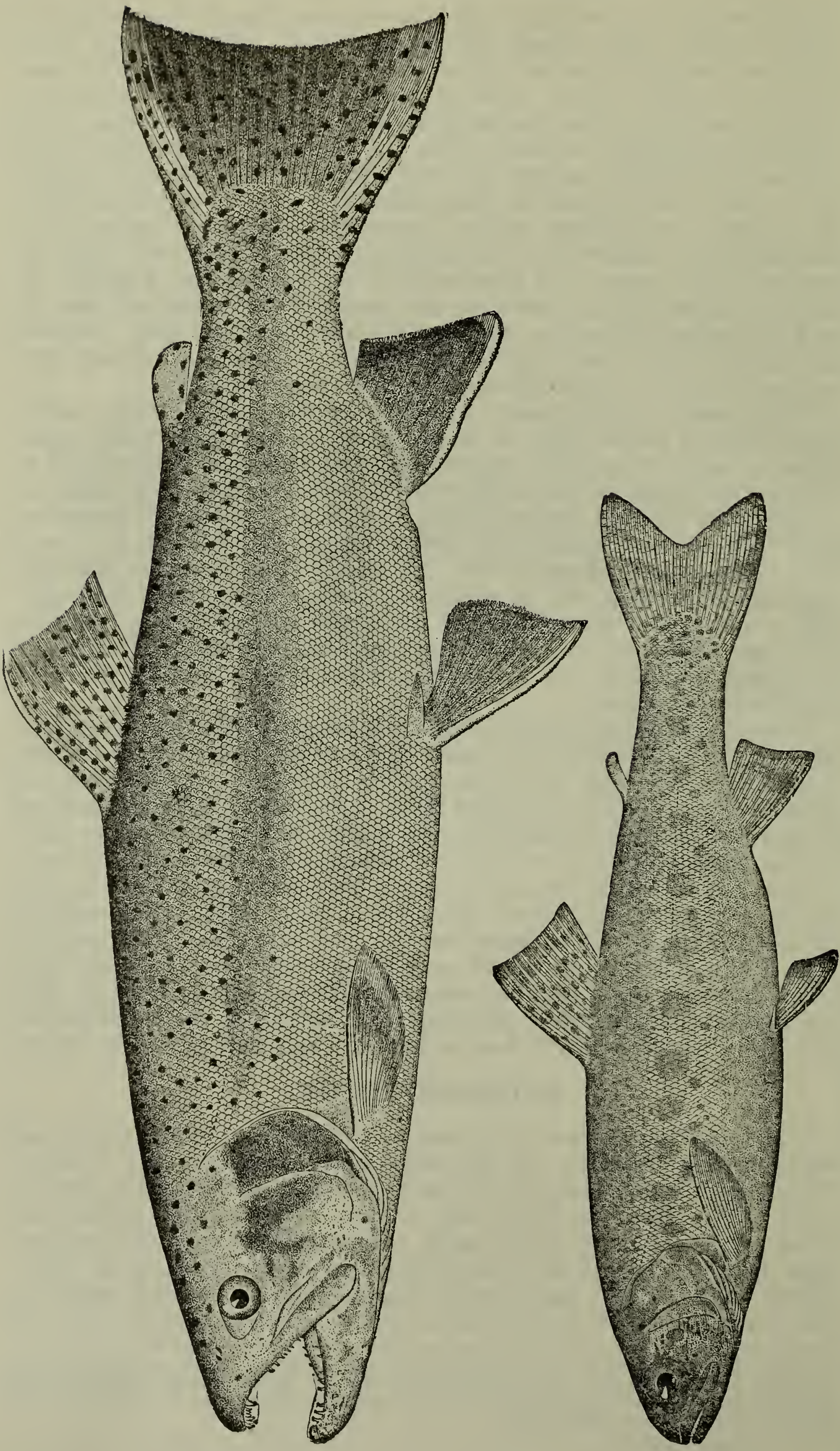

FIG. 7.—Rainbow trout (*Salmo irideus*). Upper figure, adult male; lower figure, immature fish.

rainbow or have been included in brood stocks at the various hatcheries, Federal, State, and commercial. The technical name, *Salmo shasta*, is used since it appears to be the name of the trout of the McCloud River, from which the original stocks were derived.

DESCRIPTION.

The body of the rainbow trout (*Salmo shasta*) is comparatively short and deep and is more elongate in males than in females. The average depth is contained about three and four-fifths times in the body length. The short head, which is obtusely ridged above, is about one-fourth the total length. The mouth is smaller than in other species of Salmo, the maxillary reaching scarcely beyond the eye, which is rather large and is contained five times in the side of the head. The caudal fin is distinctly but not strongly forked. On the vomer are two irregular series of teeth. The dorsal rays number 11 and the anal 10. In the typical species there are about 135 scales in the lateral series, with 20 rows above and 20 below the lateral line. In the several subspecies the number of rows of scales along the side is from 120 to 180. The color is variable, depending on sex, age, and character of water. Typical adult fish are bluish above, silvery on the sides, profusely and irregularly dark spotted on the back and sides, the spots extending to the vertical fins, with a red lateral band and blotches and a nearly plain belly. The sea-run fish are nearly plain silvery. The chief distinguishing color characteristics of the varieties are in the number and position of the spots.

RANGE AND VARIATION.

The rainbow trout is not indigenous to eastern waters. The natural home of *Salmo shasta* is in certain tributaries of the Sacramento River, and originally it was particularly abundant in the McCloud River, Calif. Other species of the rainbow trout (*S. gilberti*, etc.) occur in the upper San Joaquin River and its tributaries. *S. gilberti* appears to be very similar to *S. shasta*.

The rainbow trout is subject to considerable variation in form and color in different parts of its range. *Salmo shasta* has smaller scales than *S. irideus*, a species of steelhead trout inhabiting coastwise streams, and appears to be distinct from the Klamath River trout, which are probably either *S. irideus* or *S. newberri*. *S. shasta* has more than 145 scales in the lateral series, *S. irideus* has less than 135, while *S. newberri* has about the same number as the lowest count of *S. shasta*. The proper classification of the so-called rainbow and steelhead series has been the cause of much discussion among ichthyologists,[8] but it has no place here.

TRANSPLANTING.

The rainbow trout was introduced into eastern waters by the United States Fish Commission in 1880, but specimens of it, or its spawn, probably had been brought east by State commissions or private enterprise prior to that time. Previous to this date the State of New York had established a brood stock of trout from eggs taken in tributaries of the Sacramento River. They were known as California mountain trout (*Salmo irideus*). In certain streams of the East

[8] What are Rainbow Trout and Steelhead Trout? By W. C. Kendall. Transactions of the American Fisheries Society, 1920.

repeated plants of rainbow trout have failed to give results, the fish apparently seeking an outlet to the sea. Whether unsuitable conditions in the streams are responsible for this failure or whether it is due to some extent to a possible cross with the anadromous steelhead is a matter for conjecture.

The theory has been held that this species would serve for stocking streams formerly inhabited by the brook trout (*Salvelinus fontinalis*), in which the latter no longer thrives owing to the clearing of the land at the sources of the streams, which has changed conditions in and along the waters, so that they are not agreeable to the brook trout's wild nature. It has been believed generally that the rainbow trout is adapted to warmer and deeper waters and therefore is suited to many of the now depleted streams which flow from the mountains through the cultivated lands of the valleys. This theory is disputed by Meehan, Bean, and other fish-culturists, however.

Rainbow trout, particularly the smaller sizes, differ from brook trout and other predacious fishes in that they feed principally upon worms, larvæ, Crustacea, and the like, and do not take readily to minnows as food. They should be planted in spring or early summer, when their natural food is abundant, as they will then grow more rapidly and become accustomed to life in the stream, and when worms, larvæ, etc., are no longer to be found their experience and size will enable them to take a minnow or anything that may present itself in the shape of food.

SIZE AND GROWTH.

The size of the rainbow trout depends upon its surroundings, the volume and temperature of the water, and the amount of food it contains. The average weight of those caught from streams in the East is probably less than a pound, but some weighing 6¾ pounds have been taken. In the Ozark region of Missouri they are caught weighing 5 to 10 pounds. In some of the cold mountain streams of Colorado their average weight is not more than 6 or 8 ounces, but in lakes in the same State, where the water becomes moderately warm in summer and food is plentiful, they reach 12 or 13 pounds and a length of 25 to 28 inches. In the Au Sable River, in Michigan, they attain a weight of 5 to 7 pounds. In their native streams of California they are often caught ranging from 3 to 10 pounds, but average from 1 to 2 pounds. The largest specimen ever produced in the ponds at Wytheville and fed artificially weighed 6½ pounds, but many others in the same ponds weighed from 1 to 3 pounds. It is possible that *Salmo shasta* might be more successful in the southern range of the rainbow trouts, and that "steelhead" rainbows might thrive better in the northern range.

Under favorable artificial circumstances rainbow trout hatched January 1 should absorb the yolk sac in about 30 days in a mean water temperature of 55° F. At this time feeding begins, and if properly cared for and supplied with a sufficient amount of suitable food the young trout should attain the following sizes: 1 year old, 8 to 10 inches; 2 years old, 12 to 14 inches; 3 years old, 16 to 18 inches. In the open waters of natural lakes and streams their sizes probably would average about 2 inches less per year. They grow until they are 8 or 10 years old, the rate diminishing with age. Some grow much faster than others under the same circumstances, but the rate of growth is largely a question of food, temperature of water, and extent of the range. In water at 55°, with plenty of food, fish 1 or 2 years old will double their size several times in a single season, while in water at 40° with limited food the growth is scarcely perceptible.

The rainbow, like the brook trout, will live in water with a comparatively high temperature if it is plentiful and running with a strong current, but sluggish and shallow water, even with a temperature of 70° F., is dangerous for brook trout. Rainbow trout will live in warmer water than brook trout and are found in swift, rapid streams at 85° F., especially where there is some shade, but in ponds that temperature is dangerous even with shade and a good current. In its natural condition this trout is usually found in water varying from 38° F. in winter to 70° F in summer, and in selecting a site for a trout hatchery spring water with a temperature of 42° to 58° is required.

The rainbow trout is a superior game fish, a vigorous biter, and fights bravely for liberty, though in the east it is somewhat inferior to the brook trout in these respects.

PROPAGATION.

WATER SUPPLY.

The best water supply for a trout hatchery is that taken from a well-protected and deep-seated spring. The fall between the spring and the hatchery should be sufficient to permit the hatching troughs to be placed about 30 inches above the hatchery floor and to aerate the water as it enters the trough. Water obtained from a spring-fed stream or lake is apt to vary considerably in temperature and to carry much sediment and other foreign matter. While an open supply trough in the hatchery is somewhat unsightly and cumbersome, it seems to produce better results than a closed pipe. For a hatchery with 20 troughs a supply trough 10 inches wide and 10 inches deep, inside measurements, will carry sufficient water. A 2-inch molasses gate with a brass face set about 3 inches above the bottom of the supply trough is the best means of regulating the flow of water to the hatchery troughs. The water should have a drop of from 10 to 12 inches as it enters the hatchery supply trough from the main conduit, and it should be further aerated as it enters the hatching troughs. For this reason the supply trough should be set about 6 inches above the top of the hatching troughs with a space of 3 or 4 inches from the ends. When local conditions will not permit such means of aeration, the water supply must be aerated as thoroughly as possible by some other means.

The main water supply at the Wytheville (Va.) hatchery is obtained from a spring such as is described above. After heavy rains the water becomes very turbid and much discolored from the yellow clay soil characteristic of the locality. At times the water supply carries sufficient sediment to smother both eggs and newly hatched fry. While this condition is not permanent, it causes much labor and a considerable loss of eggs and fish.

As the water level from the spring is about 12 feet above the water level in the hatchery supply trough, it was a comparatively easy matter to construct a settling tank and filter. The settling tank was built near the spring. Water is conducted from the spring to the head of the tank through a 6-inch pipe controlled by a gate valve. It enters an end compartment in the tank 4 feet wide and 20 feet long, from which it flows into a second compartment 10 feet wide and 70 feet long, returning through a similar compartment and discharging into a compartment 5 feet wide and 70 feet long. Near the lower end of this compartment is a sand filter bed 20 feet long. The water passes down through the gravel and sand and is conducted to the discharge chamber through five lines of 3-inch tile. These drains are about 12 inches in length, with broken joints about $\frac{1}{8}$ inch apart, and they extend into bulkheads in either end of the compartment. The hatchery supply pipe is extended into this compartment and receives only water that has passed down through the filter bed, and since there is a fall of approximately 12 feet between the filter and the hatchery supply trough, this pipe carries a satisfactory head.

Arrangements are provided for cleaning the sand and gravel used as a filtering medium. To reach the filter bed, the water passes over a cement bulkhead built across the compartment. Near the bottom of this bulkhead is a 6-inch valve whereby the water is admitted for cleaning the filter. The water used for cleaning passes up through the sand bed and discharges through a gate valve in the lower end into the waste ditch. While the water is passing up through the filter bed a rake, made by driving spikes into a 2-inch plank, is moved back and forth, by means of a sprocket and chain, over the surface of the sand. This rake is manipulated easily by one man operating a crank on the outside. This action loosens the sediment contained in the sand and the flow of water carries it into the waste ditch. About 10 minutes' work is required, twice each day, to keep the filter in perfect working order.

To assist the percipitation of sediment and to relieve the sand filter an alum dropping device was installed between the spring and the settling tank. The alum solution is lifted by means of a hand pump to an elevated tank of 60 gallons' capacity; after remaining in this tank for 24 hours it is drawn off by means of a valve into a tank at a lower elevation. This gives a clear solution for use in the water supply. From the second tank the solution passes through a brass pipe to a copper-lined closet tank, in the bottom of which a $\frac{1}{2}$-inch sight-feed oil dropper is fitted. The float in the closet tank maintains a uniform level therein, and the solution is constantly discharged through the oil dropper into the water supply pipe. A constant rate of flow through the oil dropper is maintained—60 gallons per 24 hours—but the strength of the solution varies in proportion to the turbidity of the water. In extreme cases a mixture of 1 part of alum to 50,000 parts of water will supply the hatchery with practically clear water. From this mixture the solution is reduced to as low as 1 part of alum to 120,000 parts of water. As a rule, 4 pounds of sulphate of alumina per 24 hours, applied as described above, to each 20 gallons of water per minute used in the hatchery is sufficient to clarify the muddiest water. The untreated water carries in solution sufficient alkali to react completely with the small amount of sulphate of alumina used, leaving a sufficient amount of alkaline nitrate to prevent any "after coagulation" in the filtered water. It is doubtful if any of the alum is carried into the hatching troughs. Experiments conducted in Washington demonstrated that neither the eggs nor young

FIG. 8.—Wytheville (Va.) station hatchery.

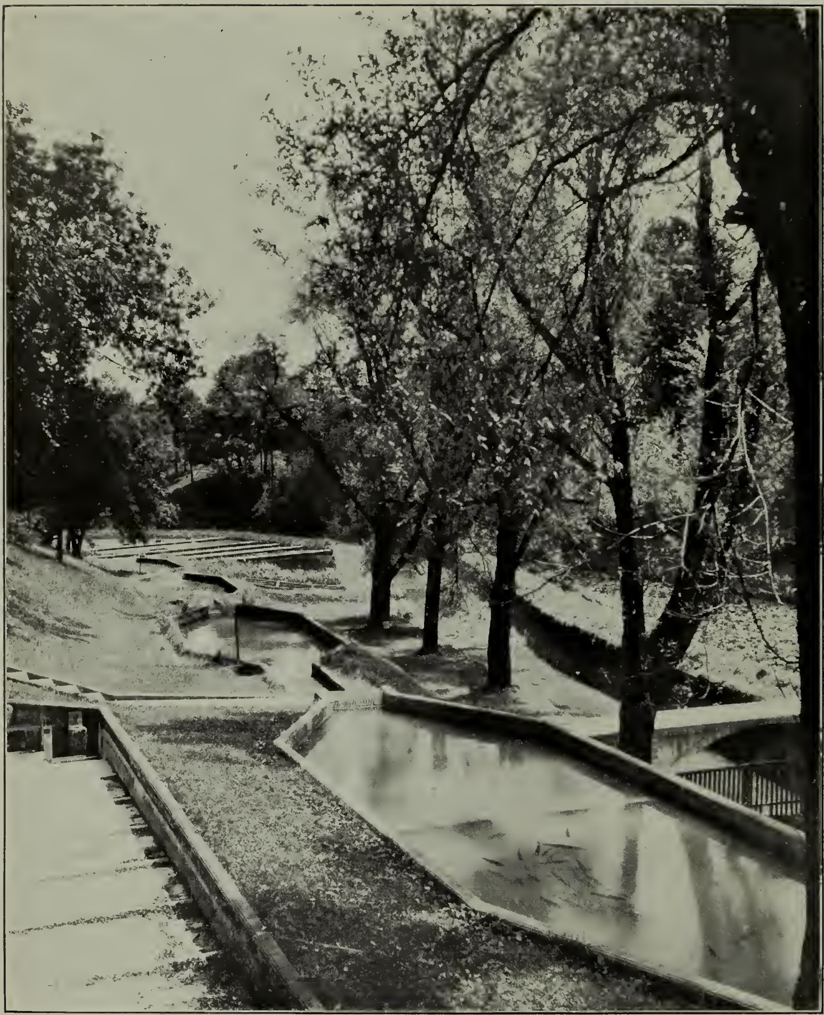

FIG. 9.—Spawning ponds, Wytheville (Va.) station.

fish of the rainbow trout were affected by an alum solution below a strength of 1 part of alum to 8,000 parts of water. Rainbow trout 2 inches long were held in a 1 to 20,000 solution for a period of two weeks without apparent harm.

SPAWNING PONDS.

In constructing ponds one of the first considerations is to place the fish absolutely under control, that they may be handled without delay or inconvenience. The ponds at Wytheville formerly were constructed of wood, but when they were rebuilt recently concrete was used. They are 15 by 50 feet and 3 feet 4 inches to 3 feet 6 inches deep, shaped as shown in Figure 10, page 38, and have proven very satisfactory. The length of the ponds may be increased up to 100 feet without impairing their efficiency, though the width should not exceed 12 to 15 feet. Much depends upon the volume of water available, but ponds more than 100 feet in length are difficult to clean and care for. Excellent water circulation is obtained in all parts, there being no corners in which refuse can lodge. From the outlet the bottom has a gradual rise of 6 inches in its entire length, making it practically self-cleaning. Most of the refuse will pass off, and any remaining can be disposed of readily by lowering the water level for a short period and then flushing the pond with fresh water. This method obviates the necessity of handling the fish, an important point, especially at the approach of the spawning season.

A guard rack made of thin narrow slats is arranged on an incline of about 45°, as shown at *A*, Figure 10. If the water is to be used again in ponds below, a "receiver" is built underneath the bottom of the pond, at the lower end, between the foot of the guard rack and the dam boards, and the floor of the pond immediately over the receiver is cut away and fitted with a grating. This allows all waste to fall through into the receiver. From there it is washed through the sluiceway by opening the gate valve. The sluiceway, *D*, is of 8-inch terra-cotta pipe and connects with a 12-inch drain of the same material.

The pond is provided with a spawning race about 14 inches deep, 4 feet wide, and 25 feet long, placed at the upper end of the pond, as shown in Figure 10. Three division boards (shown at *E*), about 12 feet long and of suitable width to come within 1 or 2 inches of the surface of the water when the pond is filled, are firmly fixed at the bottom. The object of these boards is to form four entrances to the raceway, so that one or two pugnacious fish can not command the approach and keep back spawning fish inclined to enter. There is a dam across the raceway about 4 inches high for the purpose of bringing the water to that depth in the lower end, so that when trout enter the raceway they will find sufficient water in which to swim freely and not be inclined through fear to return to the pond.

At the approach of the spawning season the water level of the pond is raised to within 6 inches of the top of the dam in the raceway, which will give the fish in entering the raceway a jump of 7 inches, allowing 1 inch for the depth of water on the dam in the raceway. This distance has been found the most satisfactory, as under such conditions only spawning fish will ascend. If a jump

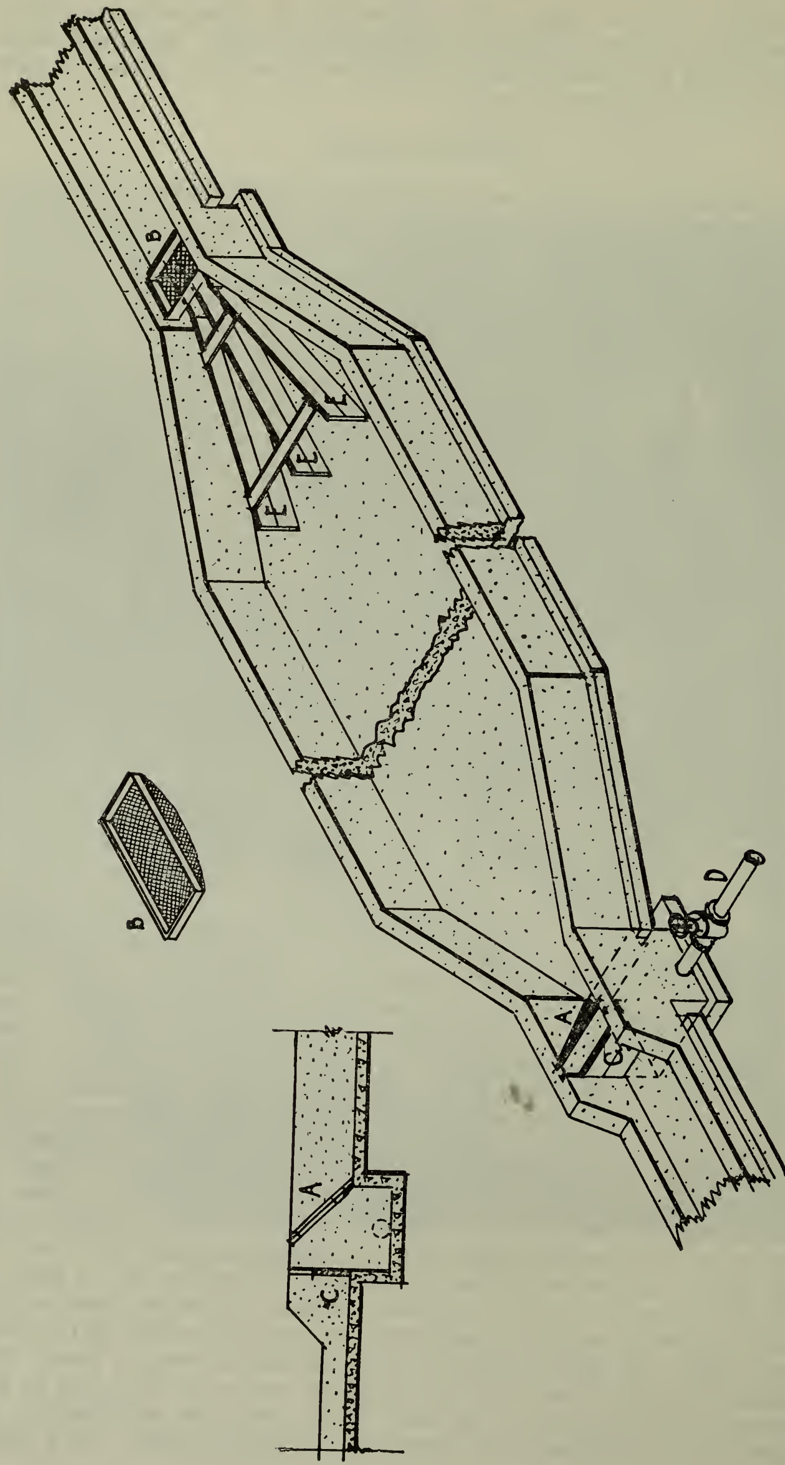

FIG. 10.—Spawning pond. *A*, retaining screen; *B*, catch screen; *C*, dam boards; *D*, drain; *E*, boards forming entrance to spawning race.

of less than 7 inches is provided, other fish can enter the raceway without much exertion and will ascend and disturb the breeding fish, which, when spawning, should be kept strictly by themselves.

There is no rule regarding the supply of water that applies to a spawning pond at all times and in all places. It is necessarily governed by the temperature of the water, size and shape of the pond, size of the fish to be supported, the amount of shade, and other factors. For a pond such as has been described, where water is plentiful, at least 200 gallons per minute should be provided, with not less than 75 gallons per minute as a minimum, even where the temperature is from 50 to 55° and all other conditions are favorable. While the former amount is not absolutely necessary for the support of the fish, it insures the pond being kept clean and the fish are more inclined to enter the raceway at spawning time. In order to maintain an even temperature of water, earth is banked against the sides and ends of the pond, the embankments being made broad enough on top to permit ample footway around the ponds. Such a pond can accommodate from 800 to 1,000 breeding fish. Fish must not be crowded, and in estimating the capacity of a pond several factors must be considered, such as the size of the fish, volume and temperature of water, and shade. In stocking the spawning pond a good proportion is two females to one male. The brood stock must be selected carefully each year, and only sound and perfect fish retained.

All pond bottoms should be cleaned frequently to prevent the accumulation of undesirable matter. A method recently devised permits the cleaning of ponds without subjecting the fish to the usual more or less protracted period of turbid water while the cleaning is in progress. About 10 feet from the intake end of the pond a cement bulkhead about 18 inches high extends into the pond from either side, leaving an opening in the center 4 feet wide. Each open end of this bulkhead is provided with slots in which boards may be inserted to complete the dam as required. In cleaning the water level is reduced and the section of the pond above the bulkhead thoroughly cleaned. The fish are then driven, by means of a seine, through the opening to the cleaned section and dam boards are inserted as described. The outlet valve is then opened and the remaining portion of the pond cleaned.

TAKING THE SPAWN.

The spawning season varies with the locality and the temperature of the water. It is usually from two to four weeks later in streams than in ponds where the fish are confined in spring water. At Wytheville the spawning fish may be found in the ponds any time after October 1; the season is well started by October 20, and generally closes about January 25, the height of the season being between November 1 and December 15. At the Neosho (Mo.) station the season usually begins about November 1 and extends to the 1st of March; at Manchester, Iowa, it occurs between November 15 and March 15. In California the season extends from February to May; in Montana from April 15 to June 1; and in Colorado from May to July.

The natural nests of these fish are made on gravelly bottoms and are round or elongated depressions about the size of a dinner plate.

The work of preparing the nest is performed chiefly by the male fish; upon completion the male and the female enter it together and by a rolling spasmodic tremor they deposit eggs and milt, which are brought together and mixed by agitation of the water. For a short period after they have been deposited the eggs are slightly adhesive, and during this time they absorb the impregnated water. When filled they fall apart and settle down between the gravel and stones of the nest, where they lie protected until hatched.

Under domestication the fish rarely will deposit their eggs of their own accord unless conditions are favorable. Swift, well-aerated water of suitable temperature, gravelly bottom, and a male consort seem to be necessary, although instances have been recorded where female rainbow trout have deposited their eggs on the cement bottom of the stock pond without a male fish in attendance. On the other hand, adult fish in an aquarium have been observed to make nests and apparently attempt to spawn, failing in the effort and later dying with the eggs still retained. Instances have been reported, also, where fish (rainbow trout and landlocked salmon) have been taken from native waters several months after the spawning season, apparently still retaining their full quota of eggs in the ovaries. In every case the eggs were hard and "glassy," though as far as could be observed the fish had suffered no ill-effects as a result of their unnatural condition. Under any circumstances, however, retention of the eggs beyond the spawning period is, of course, unnatural and undesirable. In practical fish-cultural operations easy access to a suitable spawning race will invariably permit the fish to spawn or to indicate that they are ready to spawn. Overlong retention of eggs undoubtedly results in "glassy" eggs, probably caused by their coming in contact with a serious ovarian exudation present in the fish under these conditions, and may also result in serious permanent injury or even death to the fish. Eggs that absorb this fluid become hard and incapable of fecundation. Similarly, freshly extruded eggs if immersed in water which lacks the male element of fecundation for even a short period become hard and "glassy."

When spawning ponds are provided with suitable raceways, the fish will ascend from the ponds into them in search of a place to nest and may then be taken out and stripped of their spawn. To remove the fish from the raceway, a square net (*B*, fig. 11) is dropped in on cleats bolted against the side walls in the approach, the dam in the mouth of the raceway is raised, and the fish driven back into the net. The net is then lifted out of the water, and if it contains too many fish to handle conveniently a landing net is used to take out part of them before the square net is moved. The ripe fish are then placed in tubs or other vessels provided for the purpose, but care should be taken not to put too many in the tub at one time, as they will become restless or sick before they can be stripped of their spawn. While being held in this way the water in the vessel should be renewed frequently.

There are two methods of taking and impregnating the spawn of fishes—the "wet" and the "dry" methods. By the wet method the eggs are taken in a pan containing sufficient water to cover them and allow them to mix freely with the milt, which is added immediately. After the contents of the pan has been stirred for a few

FIG. 11.—Taking the spawn.

seconds with the hand or a feather, the eggs are set aside and left undisturbed during fertilization. The dry or "Russian" method is now in general use; the eggs and milt are taken in a moist pan, and it makes little difference which is taken first, but one should immediately follow the other, and the contents of the pan is mixed thoroughly. In freezing weather it is advisable to use two pans, one set in the other, with water in the bottom pan to prevent the eggs from being chilled.

After the eggs and milt have had time for contact and before the eggs begin to adhere to the bottom of the pan, water is added to a depth of about an inch, the eggs being kept in gentle motion by turning the pan to prevent adhesion. After 2 or 3 minutes the milt is poured off and clear water is put in the pan, in which the eggs are allowed to remain until they separate, which will be in from 15 to 45 minutes. When eggs are held in a deep vessel capable of holding several layers of eggs, those at or near the top will harden in the time indicated above, but those in the lower layers will remain soft for a much longer period. Most fish-culturists consider the temperature of the water a factor in this connection and believe that the hardening process is hastened by higher temperatures. This theory is not held by others, and as far as is known no really authentic data on the subject have been recorded. A vessel was devised at the Wytheville (Va.) station especially for holding the eggs during this period of water hardening. It consists of a 6-quart tin bucket in which is fastened, about 1 inch above the bottom, a circular piece of perforated tin. A funnel-shaped spout, soldered to the outside of the pail, admits water between the bottom of the bucket and the perforated tin. About 4 quarts of eggs are placed in each bucket, and a small flow of water, about 1 gallon per minute, is supplied.

In taking spawn the manipulation of the fish without injury is a very delicate and exacting task, full knowledge of which can be acquired only by experience, as it is difficult to squeeze the spawn from the fish without injuring or even killing it. In taking hold of the fish in the spawning tub the operator catches it by the head with the right hand, the back of the hand being down and the nose of the fish well in the palm, with the fingers extending under and along each side of the fish in the direction of the tail. At the same time the fish is grasped between the dorsal and caudal fins with the left hand, the back of the hand being up. A fish caught in this way can be brought out of the water easily, and when held gently but firmly against the body will struggle only for a moment. The operator leans forward slightly, bringing the vent of the fish over the spawning pan and holding the head of the fish higher than the tail, its body at an angle of about 45°. The fish should be held well down in the pan, which is usually of 2-quart capacity, so that the eggs will not drop more than 2 inches. Some operators turn the abdomen of the fish upward with the tail bent backward. This method is not recommended, however, since the bending of the tail may cause serious injury and the eggs are subjected to a greater drop into the pan. A large fish may be held with its head under the right arm.

When the struggle is over, the hand is passed down the abdomen of the fish until a point midway between the pectoral and ventral fins is reached, then with the thumb and the index finger the abdomen is pressed gently, and at the same time the hand is slipped toward the vent. If the eggs are ready to be taken, they will come freely and easily. If they do not come freely after the first pressure, the hand is moved toward the head of the fish and a very gentle pressure is applied to assist the natural flow of eggs until all that will come readily are obtained. Pressure should never be applied forward of the ventral fin, as even slight pressure over the vital organs is very apt to result in injury.

By this method all of the eggs that have fallen from the ovaries and are ready to be expressed will fall into the abdomen near the vent, so that it will not be necessary to press the fish again over its vital parts, the eggs having left that portion of the body. An experienced operator can tell almost at a glance whether or not a fish is in spawning condition as soon as it is lifted from the water. By grasping the fish as described, holding the head highest, if ripe eggs are in the ovaries they may be observed to roll slightly toward the vent. If this movement can not be detected, the right hand may be passed lightly down the abdomen, and if the egg mass is soft and yielding to the light touch the eggs will flow freely from the vent with but slight pressure. Examination of a large number of specimens has proven beyond doubt that serious injury, resulting in barrenness or death, is very likely to result from improper handling of fish at spawning time.

Recent studies[9] tend to correct the long accepted belief that the mature eggs of trout and certain other salmonoid fishes fall loosely into the abdominal cavity and from there are extruded. As a matter of fact the ovaries of the Salmonidæ are inclosed in a delicate membrane, and the eggs are conveyed to the genital pore through an open membranous trough. The ova do not fall naturally into the abdominal cavity, and it seems probable that they can not be extruded if they are inadvertently displaced into it, and their presence there can not be advantageous to the fish.

Careless fish-cultural methods are responsible for displacing the eggs. Some of these are dipping the fish head first into a dip net, causing it to flop about, and grasping the fish by the tail and holding its head until its struggles cease. The dip net should always be large enough to permit the fish to lie extended. If the fish is ripe or partly ripe, the mass of eggs may be seen to sag toward the head, and inevitably any free eggs settle in the forward end of the abdominal cavity outside of the ova-containing membrane. It is after the stripping process has begun, however, that the danger of displacement is greatest, and particularly after some eggs have been expressed and the tenseness of the supporting abdominal wall is relaxed. Displacement is largely responsible for failure to secure all of the ripe eggs, and even though the fish may emit retained eggs later it is impossible for it to rid itself of displaced eggs.

Another disadvantage from which the fish may suffer is rupture of the membranes and injury to the ovaries from forcible pressure, so that the eggs falling into the abdominal cavity are not secured.

[9] Peritoneal Membranes, Ovaries, and Oviducts of Salmonoid Fishes and Their Significance in Fish-cultural Practices. By William Converse Kendall. Bulletin, U. S. Bureau of Fisheries, Vol. XXXVIII, 1919–20. Bureau of Fisheries Document No. 901. Some Previously Unrecognized Anatomical Facts and Their Relation to Fish-cultural Practices. By William Converse Kendall. Transactions, American Fisheries Society, 1920.

When injured in this way, the ovary may not recover its natural function and may become sterile. If, however, simple precautions are observed, no injury to the fish will result. As an illustration it may be mentioned that fish have been kept for 14 years and their full quota of eggs extracted each season during the egg-producing term, which is normally from 10 to 12 years. The male fish is to be treated very much in the same manner as the female, except that the milt must not be forced out, as only that which flows freely is of value.

After stripping, the fish are not returned to the spawning pond, but spent females are placed in one pond and males in another. The males are very pugnacious at this season and sometimes fight for an hour or more at a time until they are entirely exhausted; they run at each other with open mouths, lock their jaws together, and in that position sink to the bottom of the pond, where they lie for a short time, each holding the other in his grasp until rested, when they rise and resume the combat. As their teeth are abnormally long, they scar each other and even bite pieces of skin and flesh from the sides of their antagonists.

From 15 to 25 per cent of the females yield eggs the second year, about 60 per cent the third year, and from 80 to 90 per cent each season thereafter. From 10 to 15 per cent of the fully matured females are barren each season. At one time it was thought that the same individuals were barren each year, but experience has shown that such is not the case, as fish that were barren one season have been held over in a separate pond until the following year when a large proportion, if not all, produced eggs. The sterility may be the result of injuries received during the progress of spawning. The males are good breeders when 2 years old.

PRODUCTION OF EGGS.

The number of eggs produced by a fish depends upon its size and age. The maximum from one 2-year-old fish, weighing from 6 to 12 ounces, is from 500 to 800; from one 6-year-old, weighing from 2 to 4 pounds, it is 2,500 to 3,000. The average of fish from 3 to 6 years old is 1,200 to 1,500. The eggs vary in size from 4½ to 5 eggs to the linear inch, and from 300 to 360 per fluid ounce, according to the age of the fish, though in some localities larger eggs, averaging not more than 220 to 240 per fluid ounce, are not uncommon. They are of a rich cream color when first taken, changing to a pink or flesh tint before hatching. Eggs from wild fish are of a pink or salmon color, and as a rule average somewhat smaller than those from domesticated fish.

HATCHING TROUGHS AND TRAYS.

The eggs are incubated on trays placed in troughs of wood, metal, or concrete and of various shapes and sizes. Standard troughs are 14 feet long, 14 inches wide, and 8½ inches deep, inside measure. They are set in pairs, as shown in Figure 12, page 44. Six inches from the lower or outlet end inside is a guard screen of perforated zinc or wire mesh, fastened on a frame exactly fitted across the trough. Zinc with perforations one-sixteenth of an inch in diameter for very young fry, and larger ones as the fish increase in size, is preferable to wire cloth.

The screen is arranged to slide vertically between beveled cleats, so that it may be cleaned more readily. An iron standpipe of suitable length to give the desired water level in the trough is screwed into the discharge pipe from the inside of the trough. Each trough should be provided with two of these standpipes of different lengths, mak-

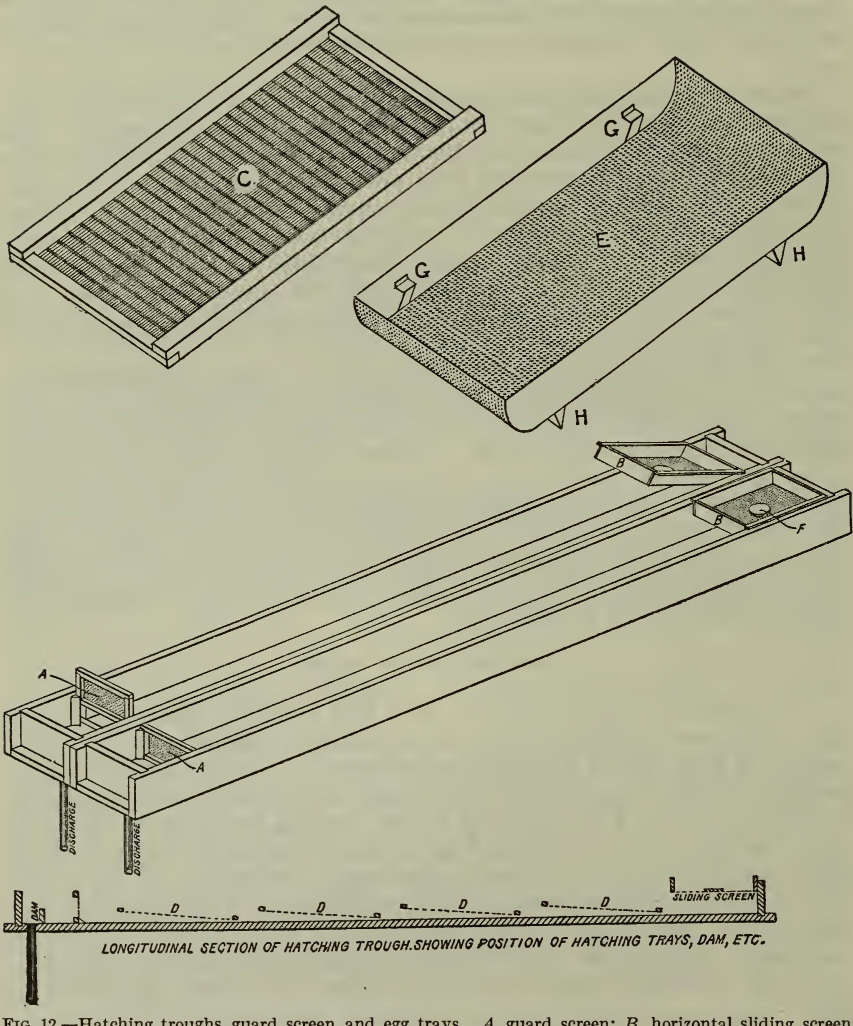

FIG. 12.—Hatching troughs, guard screen, and egg trays. *A*, guard screen; *B*, horizontal sliding screen; *C*, hatching tray; *D*, position of hatching trays; *E*, tin tray for use in muddy water; *F*, block for water to fall on; *G*, brackets; *H*, feet.

ing it possible to reduce the water level in the trough when desired for reasons which will be discussed in subsequent pages.

In the upper end of the trough a horizontal screen made of perforated tin, shown at *B* (fig. 12) is used. This is so constructed that it can be slipped forward or raised up (as shown in the illustration) when the fry are fed or the troughs cleaned. The water falling upon a small wooden block in the center of the screen is thoroughly aerated before entering the trough. This arrangement possesses many advantages over the old method, where the screens were vertical, or nearly so, as it permits fish to ascend to the head of the trough and receive the water as it falls from the screen, which is very beneficial. Its use not only keeps the fry clean even in muddy water, but also reduces the loss of fry from suffocation in the early stages, caused by their banking around the vertical screens, and obviates the necessity for trough covers to prevent jumping, as trout rarely jump where the horizontal screen has been adopted.

The horizontal screen and deflector are exceptionally valuable where the water supply is somewhat limited, and when used with the spreaders hereafter described the fish may be held under ideal conditions. The bureau's latest troughs have a pocket at the head, followed by a screen on a frame 6 inches from the upper end. Three-fourths of an inch below this is a dam board made of three-fourth-inch material extending from the top of the trough to within one-half inch of the bottom; a similar screen and dam board is placed in the middle of the trough. This system causes the current of water to pass close to the trough bottom, and a greater number of fish may be held in a trough divided in this way than otherwise. The tin spreaders, however, give the same effect; some fish-culturists are careless and do not use these until there has been a loss of fish. The young fish like to fight the current of water as it comes under the dam boards or spreaders, and it gives them exercise and good appetites.

The hatching trays, *C* (fig. 12), are convenient to handle and adjust in the troughs when made about twice as long as wide; that is, 28 by 13½ inches. The sides of the frame are made of good pine lumber, dressed, 1¼ by ⅞ inch. The ends are dressed ½ by 1 inch and are cut into the sides to form a smooth surface on the bottom for the wire cloth. The wire used on the trays is woven with eight threads to the inch, with a mesh seven-eighths inch long, and should be well galvanized after it is woven in order to prevent rusting at the laps. The inside of the troughs, the egg trays, and all other equipment used in the trough are given a coating of asphaltum, thinned with turpentine, prior to use and each successive season thereafter. This acts not only as a preventative of rust and decay, but aids materially in keeping the trough and fittings in a sanitary condition.

Four hatching trays are placed in each trough and secured by keys or wedges and should be from 1 to 2 inches lower at the end next to the head of the trough, as shown at *D*, *D*, *D*, *D* (fig. 12). When so placed, a tray will hold from 14,000 to 16,000 eggs of average size. Muddy water during the hatching season necessitates the use of a perforated tin tray 32 inches long and 13¾ inches wide, with perforations one-tenth of an inch in diameter in the bottom (shown at *E*, fig. 12). This rests on feet inside the trough, 1 inch above the bottom. The hatching tray containing the eggs is placed inside and rests on brackets shown at *G*. As they hatch the fish fall from the hatching tray upon the perforated bottom of the tin tray and by their movements work the sediment through so that they are left on a clean bottom and are in no danger of smothering. The tin trays are useful, also, in counting fish or for holding small lots of different species in the same trough. Where supplementary trays are not used the fry fall directly into the troughs.

A trough 14 feet long will carry 56,000 eggs safely on four hatching trays in a single row, 14,000 eggs to the tray, but if it is necessary to make more room a double row of trays may be put in, one tray resting on top of the other. Thus the trough could contain 112,000 eggs as its full capacity. By inclining the trays as described above a trough will carry this number up to the time of hatching.

When the hatching stage arrives, two trays of 14,000 eggs each are as many as should be left in one trough. With this number, by using the horizontal sliding screen in the upper end and several spreaders in the body of the trough at intervals of 2 or 3 feet, there is but little danger of the alevins congregating and smothering in any part of the trough. If it is necessary to hatch a much larger number of fry in one trough, the sliding screen should be so arranged that the water will fall well up toward or nearly against the end of the trough. This is done by raising the screen and turning it back against the supply trough. When danger from smothering has passed, the screen is again laid flat.

The spreaders are tin strips about 4 inches wide and 2 inches longer than the width of the trough, and when placed in the trough they are bowed toward the upper end, their excess length giving this effect. Three " feet " made of six penny finished nails are soldered to the bottom, giving the spreader a half-inch clearance above the bottom of the trough while the top extends just above the water level. The current created by this device near the bottom of the trough prevents the fry from congregating—a natural tendency—and serves to keep them well spread on the bottom.

The amount of water required for hatching and rearing depends upon its temperature and the manner in which it is applied. It should receive as much aeration as possible before entering the troughs or ponds containing eggs or fish. At the Wytheville (Va.) station each molasses gate in the supply trough furnishes water for two hatching troughs so placed that the water from the trough nearest the supply falls about 8 inches as it enters the trough below. In cleaning the higher troughs it is important that the plugs near the outlet end be removed in order that any refuse may pass directly into the drainage pipes. Under this arrangement eggs or fish in the lower troughs develop and thrive equally with those receiving water directly from the supply trough.

The volume of water at a mean temperature of 53° F. generally used in the troughs at this station, with their capacity for eggs and young fish of varying sizes, is indicated in the following statement. The figures given are for two troughs set end to end and supplied with water from one gate as described above:

Capacity of troughs:	Gallons per minute.
112,000 eggs	3½–4
56,000 fry, up to feeding stage	5
40,000 fingerlings, No. 1 to 1½	5
30,000 fingerlings, No. 1½ to 2	7
20,000 fingerlings, No. 2 to 2½	8
10,000 fingerlings, No. 2½ to 3	8
6,000 fingerlings, No. 3 to 4	8

The riffle ponds, 50 feet long by 5 feet wide (fig. 16, p. 48), carrying 40,000 No. 1 fingerling fish, receive from 20 to 40 gallons of water per minute. Yearlings and older fish in the brood or rearing ponds receive from 200 to 500 gallons of water per minute. A strong current of water is desirable in both the troughs and ponds, as it necessitates constant activity on the part of the fish, producing stronger fish than can be obtained in more sluggish water. The volume of water given here for fingerlings No. 1 and larger may be reduced without material disadvantage if the water temperature does not exceed 54°, but where water is plentiful and there is no need to economize in its use the amounts given can be used advantageously. In rearing ponds more water is required, as the circulation is not so good, and the outdoor exposure causes the temperature of the water to rise.

CARE OF EGGS AND FRY.

After the eggs are placed on the trays the only attention necessary until hatching begins is to keep them clean; dead eggs, which may be known by their turning white, must be picked out at least once each day. After the eyespot is plainly visible it is well to run a feather through the eggs for the purpose of changing their position on the trays and to disclose any dead eggs or foreign matter that may be hidden underneath. The greatest care should be exercised in handling the eggs at any time to avoid injuring them, especially from the first or second day after collection until the eyespots appear, and then only when absolutely necessary. During this period the eggs are very delicate and they should not be disturbed except to carefully remove the dead ones. This may be accomplished with wooden or metallic tweezers. A moderate amount of sediment has no harmful effect, since it covers one side of the eggs only. In cases where sediment is deposited on the eggs in sufficient quantity to solidify the mass and thus impair water circulation, the tray may be shaken gently, keeping the eggs well submerged during the operation.

In a water temperature of 53° the eyespots appear in about 13 days and at this time the eggs should be feathered carefully. In water of this temperature hatching occurs in from 35 to 38 days. A higher temperature shortens the incubation period, while a lower temperature lengthens it. As a rule, the best results are obtained in temperatures from 48 to 54°. A lower temperature prolongs the incubation period unduly, while higher temperature encourages the growth of fungus.

After the fry hatch they require but little attention until the umbilical sac is absorbed and the time for feeding arrives. They are examined daily and the dead fish and decayed matter removed from the troughs, which must be kept perfectly clean to keep the fish in healthy condition. As the fish grow they should be thinned out in the troughs from time to time as their size may require. When they first begin to feed, 20,000 to 25,000 fish per trough are not too many, but when they have attained a length of 1½ inches the number should be reduced to not more than 15,000, while from 3,000 to 4,000 three-inch fish are as many as one trough will accommodate advan-

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tageously. It is advisable to give them as much room as is practicable and to provide exercise for them several hours each day by lowering the water level in the troughs to a depth of about 1 inch. The extra overflow pipe previously mentioned is used for this purpose.

REARING PONDS.

Ponds for rearing trout from fry to fingerlings should be from 4 to 8 feet wide and of any desired length up to 60 feet, which, for convenience in drawing off the water and feeding the fish, is about the extreme limit. Between the advanced fry and No. 1½ fingerling stages it is of the utmost importance that the fish have several hours of exercise each day. This can be provided for best by having the bottom of the pond perfectly level across its width but with a slope of about three-fourths of an inch to each 5 or 6 feet from the head of the pond to the foot, with riffles 1 inch high at intervals. There should be a sufficient water supply to allow the riffles to work effectively, and this will be evident from the formation of water beads and air bubbles immediately beneath them. When the water is drawn down to exercise the fish, it should be about 1¼ inches deep above the riffle and one-half of an inch deep below the riffle. It is very important that the pond have ample screen surface, otherwise the water will dam and destroy the effectiveness of the riffles. The screen may be placed vertically or inclined, and where it is possible a horizontal screen from 10 to 12 inches wide should be placed level with the bottom of the pond in front of the vertical or inclined screen, with a pit underneath for the reception of excrement. This insures an even depth of water in the pond and affords an effective means of ridding it of waste matter, which must be flushed out of the pit every few days to guard against pollution. Under such an arrangement the water supply enters the pond at the shallow end and discharges at the opposite end at a point several inches below the bottom of the pond. A successful means of preventing the fish from entering the supply pipe is shown in Figure 16, page 48.

CIRCULAR TROUT-REARING POND.

Circular rearing ponds (fig. 15, p. 49) have become very popular for the purpose of rearing trout in the fingerling, and, in some instances, the adult stages. These ponds vary in size from 10 to 100 feet in diameter, depending upon individual taste, topography, water supply, etc. The Division of Fish Culture has adopted a circular pond 25 feet in diameter as its standard. It is believed that a pond of this diameter is preferable since it brings the fish within close observation. It is also much easier to clean the pond and to care for and feed the fish. The circular pond gives a better circulation of water, keeping the fish exercised and in good condition. It requires less flow of water than a rectangular pond of the same cubic content and it also requires less volume for the same number of fish carried per cubic foot of water. A 25-foot circular pond should be provided with from 30 to 40 gallons of water per minute, with a temperature of from 50° to 54° F. This volume of water is satisfactory for fish from 2 inches in length to the adult size. An increase in the volume of water to 50 or 60 gallons per minute will do no harm for fish over 3 inches in length. For small fingerlings from 1 to 1½ inches in length the volume of water should not be more than 20 or 25 gallons per minute. A 25-foot pond under the above circumstances will accommodate 25,000 three-inch trout. Figure 15 illustrates the 25-foot circular pond adopted by the Bureau of Fisheries. Blueprints and detailed specifications will be sent upon request to the Bureau.

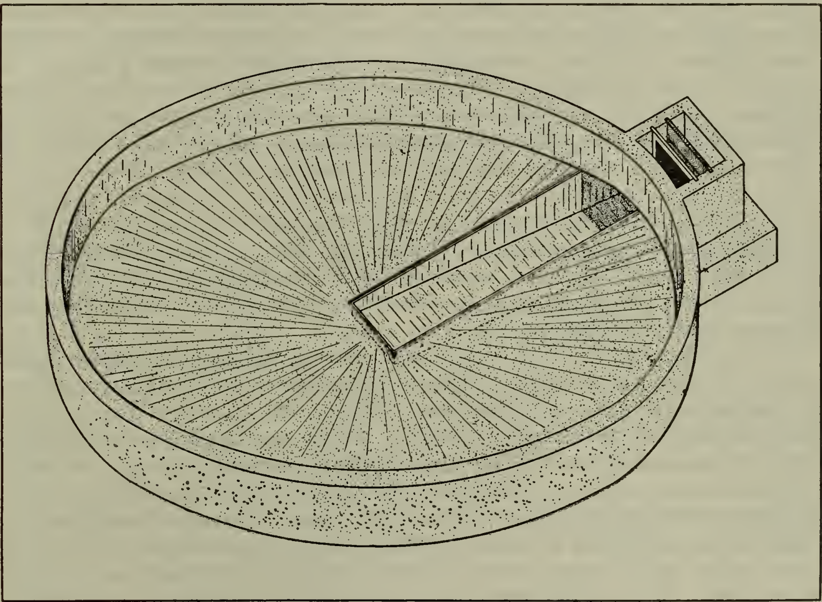

FIG. 15.—25-foot circular trout-rearing pond.

MATERIAL REQUIREMENTS: Reinforcing steel: ½-inch diameter, 1,500 lin. ft.; weight per foot, 0.668 lb. Concrete: 104 bags portland cement, 15 cu. yds. coarse aggregate, 7½ cu. yds. sand; total concrete in place 16.7 cu. yds. (1–2–4 mixture). Valves: may vary in accordance with the water head; a 1-inch gate valve is usually sufficient to meet the requirements for a bottom water supply as indicated in the blueprint. Outlet pipe: 4-inch galvanized iron, threaded on one end only; this pipe is to be surrounded with a galvanized sleeve of 18-gage iron approximately 2 inches greater in diameter than the outlet pipe.

FOOD.

Beef or sheep heart ground or chopped to a pulp seems to be the most satisfactory artificial food for young trout. Second to this in value is sheep liver, which is drier and more granular than beef liver, and it can be used to good advantage for the first two or three months or until the fish are large enough to thrive on a mixed diet. European fish-culturists have achieved at least partial success in producing a natural or living food, such as insect larvæ and small crustaceans, for artifically reared trout,[10] but nothing better than the meats mentioned has been found.

The proper method of feeding young fry should be understood thoroughly, as the losses resulting from improper feeding are frequently great. If there is undue haste, the water becomes polluted or the food is so distributed that some fish do not receive their share. Polluted water is very injurious to the young fish, sometimes causing inflammation of the gills and other ailments, which often result in heavy mortality. It may also produce undersized fish.

The fry are ready to take food as soon as the sac is absorbed, the time required for this depending upon the rate of growth, which is governed by the temperature of the water. In a uniform temperature of 53° they will take food in about 30 days after hatching, and the time to begin feeding may be closely estimated by observing the movements of the fish.

It is preferable to feed artificially reared rainbow trout on meat entirely if it is plentiful and cheap; otherwise a combination of liver and mush will give satisfaction. The mush is made by stirring wheat shorts or middlings in boiling water and cooking it until the mixture becomes thick. After the mush is thoroughly cool the finely ground heart or liver is added, the proportion usually being 20 to 25 per cent mush to 75 or 80 per cent meat. In some localities rye shorts are obtainable in better grades than wheat shorts and at a lower price, and the rye seems to be quite satisfactory as food for the young fish. Enough of the mush for several feedings may be made at one time, as it keeps well in a cool place, but the meat should not be added at one time, but only as needed.

Before the sac is entirely absorbed the school of fry at the bottom of the trough will begin to break up and scatter through the water, rising higher from the bottom each day until they can balance themselves gracefully in a horizontal position, all of them heading against the current and swimming well up in the water. By dropping small bits of cork or prepared food on the surface of the water it can be determined if they are ready for food. If they strike at the pieces as the current carries them down, it is evident that they are hungry.

The food is prepared by chopping it very fine and mixing it with water, in order that it may be distributed evenly. It should be given to the fish by dipping a feather into the food and gently

[10] Fresh-water Crustacea as Food for Young Fishes. By William C. Kendall. Appendix I, Report U. S. Commissioner of Fisheries, 1922. Bureau of Fisheries Document No. 914, 1921.

skimming it over the surface of the water. After the fish have grown to be 1¼ to 1½ inches long, they begin to take food that settles on the bottom of the trough, and it may then be given with a spoon. The young fry are fed five times a day, the food being given slowly and sparingly. After they learn to take their food from the bottom of the trough it is necessary to feed them only three times a day, but the amount given at each meal must be increased. Fish that are being fed artificially should not be carried in troughs that overflow into other troughs containing eggs or newly hatched fry, as particles of food will pass through the screen and cause trouble.

When the fish are first fed, the meat is prepared very carefully. The liver is usually "skinned" and all fat and connecting tissue removed from the heart. It is then passed through the finest plate of a meat chopper several times. These machines are provided with plates having holes from one-twelfth to one-half inch in diameter, so that the meat can be prepared fine or coarse, according to the size of the fish to be fed. At the bureau's stations the Enterprise food chopper No. 42, driven by a two or three horsepower gasoline engine, is employed.

The practice of throwing food into the pond by handfuls is entirely wrong, as it causes the fish to rush together violently, with open mouths, struggling to get a bite of food. They often hurt each other and injure one another's eyes, sometimes even plucking them from their sockets. This is probably one of the main causes of blindness among pond-fed fish.

The most approved method of feeding is to walk along the entire length of the pond to the upper end and then scatter a handful of food along the surface of the water so that it will fall to pieces. The fish quickly learn to follow and take up the food and then return to watch for the next handful. The operation is repeated until sufficient food has been given. This method of feeding induces all the fish to head in the same direction while eating, thus reducing the danger of injury.

The proper amount of food for a given number of trout depends upon their size, the temperature of the water, and to some extent on the kinds of food used. More food is required when the water temperature is comparatively high than when it is low. With water from 50 to 60° F. and food consisting of meat and wheat or rye mush, as described, the following daily ration for 1,000 fish will be found to be approximately right: Fingerlings, 3 to 5 inches long, 2 to 3 pounds per day; yearlings, 8 to 12 inches long, 4 to 8 pounds per day; adults, 8 pounds per day.

As the fish increase in size the amount of food should be increased proportionately and the number of feedings per day reduced until at the yearling stage they should receive food only in the morning and evening at regular hours. Some fish-culturists find one feeding per day satisfactory for year-old and older fish. In the table below are indicated the kind and amount of food per month per 1,000 rainbow trout of different sizes at some of the bureau's stations.

TABLE 2.—*Kind of food fed and amount required for 1,000 rainbow trout of various sizes.*

Station.	Size of fish.	Kinds of food.					Mean water temperature.
		Beef heart.	Beef liver.	Sheep liver.	Mush.	Fresh fish.	
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*°F.*
Wytheville, Va	Fingerlings No. 3		34		21		52
	Fingerlings No. 6	12	26		33		
	Adults	27	60		120		
Neosho, Mo	Fingerlings No. 3			105	157		58
	Adults			130	150		
Springville, Utah	Yearlings	31			25	26	53
	Adults	27			183	860	

PREPARING EGGS FOR SHIPMENT.

Trout eggs are in condition to bear transportation when they have developed sufficiently to show the eyespots but are not too old to reach their destination before the time for hatching. Allowance is made for changes in temperature on the road that would cause them to hatch too soon. Best results are obtained by selecting eggs after they have reached the "tender" stage, or when the eyespots are first discernible by holding the egg up to the light. Twenty-four hours in advance of shipment the eggs selected are transferred from the trays to pans or buckets. They are thoroughly washed with a stream of water of sufficient force to cause some agitation among them or by stirring them with a feather brush. This treatment not only removes all sediment from the eggs but causes all infertile eggs, which up to this time may have retained the color of good ones, to turn white and thus facilitates their removal. Unless this is done infertile eggs are very likely to get into the shipment. The eggs are then accurately weighed or measured (1 ounce may be weighed and counted or the eggs for one tray counted and then weighed), and the total number needed may be estimated from the result thus obtained.

To facilitate the work of packing the trays are sometimes placed in a trough in which there is no current of water and the eggs poured on them from the graduate or measure. The trays are then shaken gently to settle the eggs evenly into place. If trough room is not available, a tub of water may be used. All trays and moss should be soaked in cold water for several hours previous to use, and when dry moss is used it is well to expose it to frost. If this is not practicable, shaved ice may be sprinkled through it. It is also desirable that the packing be done in a room with a low temperature.

PACKING EGGS FOR SHIPMENT.

The method of packing trout eggs on deep trays with a cushion of wet sphagnum moss over each tray is no longer practiced to any great extent with rainbow trout. The egg tray now in use has a cheesecloth or linen scrim bottom, it is about three-sixteenths of an inch thick, has a depth varying with the diameter of the eggs to be shipped, and has such other dimensions as may be required. For shipping 50,000 eggs 25 trays are used; for 100,000 eggs 33 trays, and so on, each tray being proportioned to contain its quota of eggs, reckoning 25 eggs to a square inch of tray surface one layer deep in the shallow trays, as shown in Figure 16.

After the trays have been filled with eggs they are placed one on top of another in stacks of from five to eight trays, and in order to keep the eggs moist a tray of the same dimensions but three-fourths

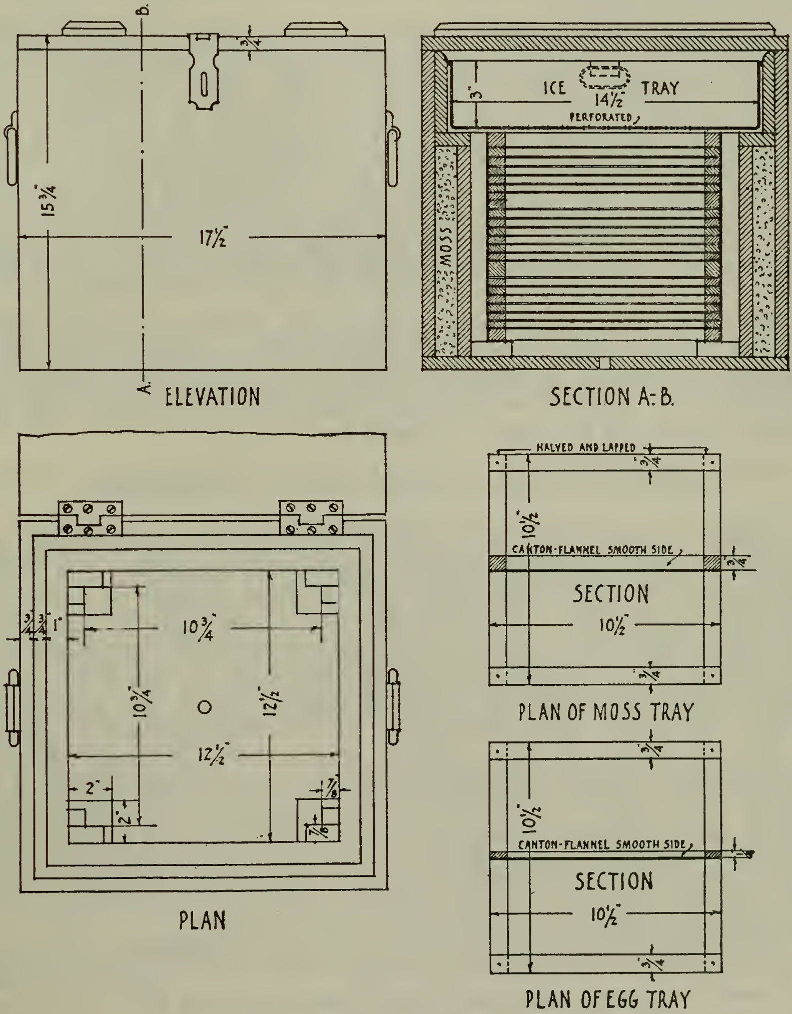

FIG. 16.—Plan of Seagle egg-shipping case.

of an inch deep is packed with wet moss and fastened on top of the stack with strong wrapping twine. First, a tray of moss is placed in the bottom of the shipping case, serving as a foundation for the trays containing eggs, then the stack of egg trays is placed on top of this and another tray of moss is set on top of the stack.

The outside shipping case has double side walls, with 1¼-inch compressed cork insulation between, extending up as far as the ice chamber, which occupies about 4 inches at the top of the case. Inside of the case, around the sides, and at the bottom of the stack of trays, is a one-half-inch air space, the air entering through four holes bored through the walls, one on either side near the bottom, one at the front, and one at the back under the ice pan. The case is provided with strong iron handles, and the lid is put on with four hinge hasps with drop fastenings, these being more satisfactory than common hinges.

The trays of eggs are held in place by V-shaped grooves formed by nailing cleats of suitable size in the corners of the case and are supported by four small blocks nailed to the bottom in the corners. Covering the bottom of the case and extending up 1 inch on all sides is a lining of tin, and through the center of the bottom is the drain tube. The ice pan, of galvanized iron and about 4 inches deep, fits the inside of the case. Its bottom is perforated to correspond with the inside dimensions of the egg trays, so that water from the melting ice contained in the pan must pass downward through the trays of eggs and escape through the tube at the bottom of the case.

After arranging the stacks of egg trays in the case the ice pan is set in position over them, filled with broken ice, and covered with a piece of oilcloth. A cushion or pillow of dry sphagnum moss is fitted into the space between the ice and the lid of the case; the lid is then closed and the eggs are ready for shipment.

DISTRIBUTING AND PLANTING FRY AND FINGERLINGS.

Rainbow trout from the bureau's hatcheries are distributed to applicants either as advanced fry immediately preceding the feeding stage or as fingerlings, after two or three months of artificial feeding. They may, however, be planted successfully at any time after the absorption of the yolk sac in waters where conditions are favorable. In the Southern States the best time for planting is the middle of March. In the more Northern States the springfed streams and open lakes are usually in condition to receive plants of fish in April. In any locality where the new green of the meadows and woods indicates the advent of spring the young fish may be safely planted. In their natural habitat the rainbows spawn during the early spring, and the young have absorbed the sac and are ready for food late in May or by June. Practically all of the fish hatched during the winter months at stations of the bureau are held and fed until weather conditions are favorable.

In making deliveries of fish to applicants, the ordinary 10-gallon milk can of the commercial dairyman is used. The number of fish that may be carried safely, per can, is dependent on the size of the fish, temperature of water, and the distance to be covered. In well-aerated water of a temperature ranging between 48 and 55°, the following numbers may be carried safely in a 10-gallon milk can:

Advanced fry, at feeding stage	2,500
Fingerlings No. 1	1,000
Fingerlings No. 1½	600
Fingerlings No. 2	300
Fingerlings No. 2½	150
Fingerlings No. 3	100

Too frequently plants of fish in public waters fail to give the best results because of careless and improper methods used in making the plants. The Bureau of Fisheries delivers fish to applicants free of charge at the railroad station designated in the application. It devolves on the applicant to see that the fish thus furnished are carefully and properly planted in the waters for which they are assigned. Many times the fish are taken to the place most easily accessible and the entire lot poured into water where there is but slight chance of their escaping large fish or finding congenial surroundings. The most suitable planting places in streams are to be found near the headwaters or in small tributaries. The fish should be scattered over as wide a stretch of stream as possible, in quiet, shaded, shallow backwaters and eddies. Deep pools where large fish are apt to be lurking should be avoided; also quick water, where the little fellows could not maintain themselves or find the food that is essential to their well-being. In stocking lakes or ponds the best places for planting are to be found in the small tributaries, as described above. Whenever possible avoid planting directly in the lake, but if it is impossible to do otherwise, select the shallow weedy margins or other places affording the greatest protection from enemies. Such places are the first to warm in the spring and they are sure to produce the greatest amount of natural food for young trout.

BLACK-SPOTTED, LOCH LEVEN, AND BROWN TROUT.

The methods employed in taking and fertilizing the eggs, the incubation thereof, and the care of the fry, fingerlings, and adult fish in the artificial propagation of the various trouts are practically interchangeable, and for this reason it is unnecessary to dwell again on the fish-cultural processes. In the following pages the three species of trout mentioned above are briefly described. Of these only the black-spotted trout (*Salmo lewisi*) of the Yellowstone National Park is artificially propagated to any extent by the Bureau of Fisheries.

The brown trout is not propagated by the bureau, and the Loch Leven trout is handled only incidentally at one or two of the Rocky Mountain trout stations. Propagation of the latter two species was discontinued because evidence was obtained from various sources to the effect that almost without exception these fishes offered nothing of advantage to the natural fish of the regions where they were introduced, and in many cases their introduction proved to be a serious detriment to the more valuable native species.

BLACK-SPOTTED TROUT (SALMO LEWISI).

Several varieties of the black-spotted trout have at various times been artificially propagated. In the past the more important operations were conducted at the Leadville (Colo.) station of the bureau and dealt with the black-spotted trout (probably *Salmo pleuriticus*) of the Grand Mesa Lakes, in Delta County, Colo. The Manual of Fish Culture[11] mentions the work of the Leadville station and that

[11] A Manual of Fish Culture, Based on the Methods of the U. S. Commission of Fish and Fisheries, revised edition, p. 181. Washington, 1900.

of the California Fish and Game Commission addressed to *S. henshawi* of Lake Tahoe. The same publication makes the following reference to the spawning season and incubation period of the eggs:

In the vicinity of Leadville the spawning season extends from May 1 to July 15. The eggs are hatched in the same troughs and under the same conditions as those of the brook and rainbow trouts. In water ranging from 42 to 60° and averaging about 52° F., the eyespots appear in 20 days and hatching ensues in 30 to 45 days.

At the present time artificial propagation of this trout is confined to the fish of the Yellowstone National Park (*Salmo lewisi*), and a limited amount of work is done at the Springville (Utah) station, where a small brood stock is maintained. Some information relative to the spawning season and incubation period of the eggs at these points is given in the following table:

TABLE 3.—*Spawning season of black-spotted trout (Salmo lewisi), showing egg production and period of incubation.*

Station.	Spawning season.	Average number of eggs per fish.	Number of eggs per ounce.	Minimum egg production.		Incubation period.		Fry.
				Weight of fish.	Number of eggs.	Eyespots appear.	Incubation completed.	Yolk sac absorbed.
Yellowstone Lake, Wyo.	June 10 to July 20.	950	350	2 pounds..	1,600	14 days at 47° F.	22 days at 47° F.	15 days at 47° F.
Springville, Utah.	May 27 to June 30.	2,000	320	....	....	....	23 days at 54° F.	

Smith and Kendall [12] have the following to say regarding the black-spotted trout in Yellowstone National Park waters:

In its numerous varietal, subspecific, or specific forms the redthroat, cutthroat, or black-spotted trout is of extensive distribution on the Pacific slope. In the park a form designated as *Salmo lewisi* is found naturally in both upper Snake and upper Missouri waters, having doubtless gained access to the latter from the Snake River by the way of Two Ocean Pass, and it is not unlikely that an interchange of individuals still takes place. Yellowstone Lake and Yellowstone River from its source to many miles beyond the park are inhabited by it. The abundance of trout above the falls is remarkable. At almost any time as one passes along fish are seen breaking water.

The size attained by trout in park waters, as elsewhere, varies much with locality and conditions. Fish of over 4 pounds have been reported.

In some waters this trout is highly esteemed as a game fish and can be taken in all sorts of ways—spoon, phantom, natural bait, artificial fly, etc. Mary Trowbridge Townsend (loc. cit.) writes of it in the Firehole River:

The father of the Pacific trout, the black-spotted "cutthroat," with the scarlet splotch on his lower jaw, was most in evidence, with long, symmetrical body, and graduated black spots on his burnished sides. He is a brave, dashing fighter, often leaping salmon-like many times from the water before he can be brought to creel. We found him feeding on the open riffs or rising on the clear surface of some sunlit pool.

[12] Fishes of the Yellowstone National Park, With Description of the Park Waters and Notes on Fishing. By Hugh M. Smith and William C. Kendall. Appendix III to the Report of the U. S. Commissioner of Fisheries for 1921. Bureau of Fisheries Document 940, p. 18.

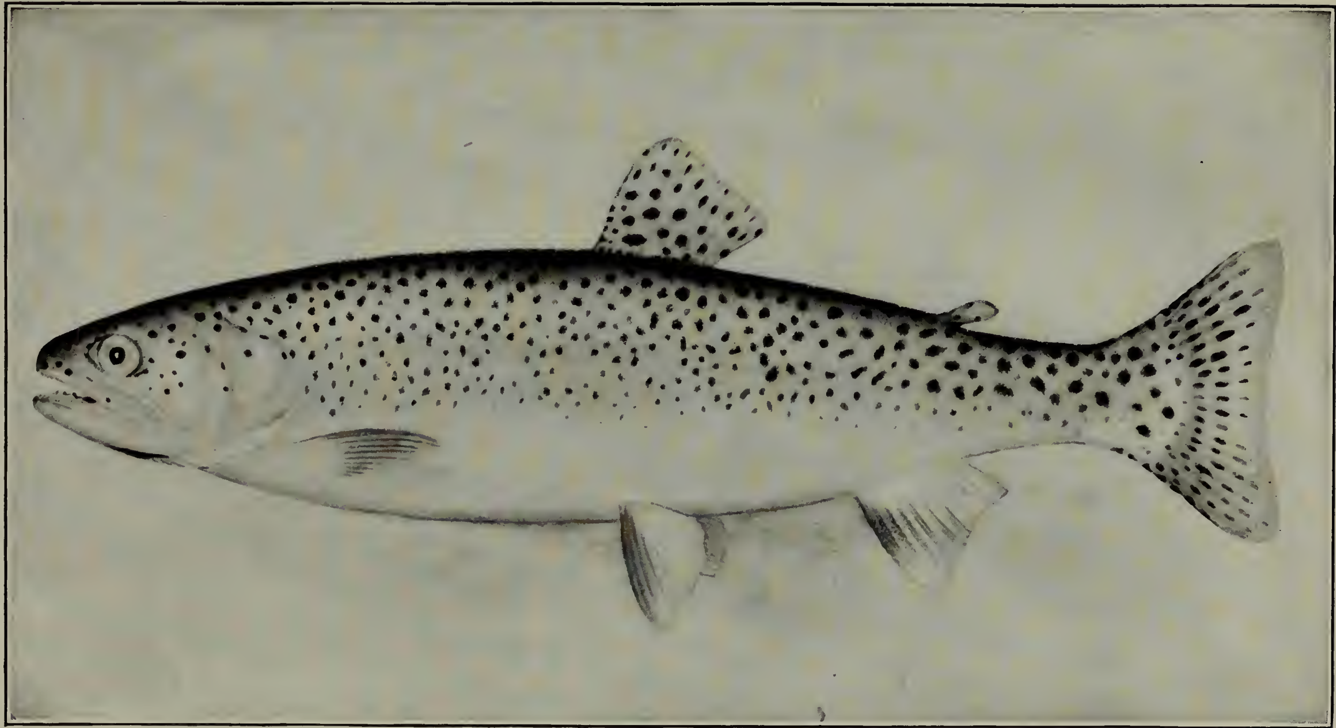

FIG. 17.—Black-spotted or cutthroat trout (*Salmo lewisi*).

FIG. 20.—Proper method of planting small fish.

Ralph E. Clark wrote (loc. cit.) that "the dark, silver-gray trout of the West seem to favor flies more in harmony with their own coloring," and mentioned the gray hackle, brown hackle, coachman, grizzly king, Seth Green, black gnat, and white moth:

> The junction of Yellowstone and Lamar Rivers is noted for fine fishing. If you find the waters high, swift, and roily, you will probably try your flies in vain. Put on a spinner or a little spoon and watch the fish rise to it, almost touch it, and then go away. They are after live bait and won't touch anything else. The grasshoppers are abundant. Catch a few, bait your hook carefully, and let it float down with the current. A large trout will rise to it, and if you are not very careful he will steal it away from you.

VARIETIES AND DESCRIPTION.

It has been said that there are two varieties of native trout in the park, the larger ones of the Yellowstone, with bright yellow bellies, and the smaller kind more silvery in appearance and exhibiting much greater activity and game qualities, of which Tower Creek fish are examples. Also trout of Yellowstone Lake seem to differ from those of Heart and Henry Lakes in having more distinct and rather less numerous black spots. However, in this respect very much individual variation is shown. It has also been suggested that the silvery color is a juvenile characteristic, while the "yellow bellies" are older fish. Who knows?

This is the principal fish artificially propagated by the Bureau of Fisheries at the hatcheries on Yellowstone Lake and Soda Butte Creek. From 3,000,000 to 20,000,000 eggs are taken annually. After the local park waters are liberally stocked the remaining young are supplied to suitable waters in the adjoining States. The park, however, should have and does have first claim on the hatchery output.

Jordan and Evermann[13] give the following description of the fish and other information concerning it:

> The Yellowstone or Lewis trout (*Salmo lewisi*) inhabits the Snake River Basin above Shoshone Falls and the headwaters of the Missouri. It is abundant throughout this whole region in all accessible waters and is particularly numerous in Yellowstone Lake. As already stated the trout of Yellowstone Lake certainly came into the Missouri Basin by way of Two-Ocean Pass from the upper Snake River Basin. One of the present writers has caught them in the very act of going over Two-Ocean Pass from Pacific into Atlantic drainage. The trout on the two sides of the pass can not be separated and constitute a single species.
>
> The cutthroat trout (*Salmo clarkii*) * * * is found in all the coastwise streams and lakes from northern California to British Columbia and possibly in southeastern Alaska. In the Columbia River Basin it is found as far up the Snake River as Shoshone Falls and in the headwaters of the Pend d'Oreille. In the waters about Puget Sound it is very abundant, as it is, in fact, throughout most of its range. It is known variously as cutthroat trout, black-spotted trout, Columbia River trout, and by many other local names.
>
> In the earlier books this species was identified with the Mykiss of Kamchatka and was called *Salmo mykiss* or *Salmo purpuratus*, but recent investigations have shown that it is not identical with the Kamchatkan species, and that there is a wide region between Kamchatka and southeast Alaska in which no trout are found.
>
> The cutthroat trout and all of this series spawn in the spring and early summer. Those in the streams seek the shallow waters of the smaller creeks, while those of the lakes come to the shallow waters near shore or upon the bars; in many cases they ascend tributary streams. * * *. The cut-

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[13] American Food and Game Fishes. Pp. 176 and 179. By David Starr Jordan and Barton Warren Evermann. Doubleday, Page & Co., New York, 1902.

throat trout and its different derived forms vary greatly in the sizes at which they reach maturity, the chief factors being, of course, the size of the body of water they inhabit and the amount of the food supply.

Those species or individuals dwelling in lakes of considerable size, where the water is of such temperature and depth as to insure an ample food supply, will reach a large size, while those in a restricted environment, where both the water and food are limited, will be small directly in proportion to these environing restrictions. The trout of the Klamath Lakes, for example, reach a weight of at least 17 pounds, while in Fish Lake in Idaho mature trout do not exceed 8 to 9½ inches in total length, or one-fourth pound in weight. In small creeks in the Sawtooth Mountains and elsewhere they reach maturity at a length of 5 or 6 inches and are often spoken of as brook trout under the impression that they are a species different from the larger ones found in the lakes and larger streams, but as all sorts of gradations between these extreme forms may be found in the intervening and connecting waters the differences have not even subspecific significance.

The various forms of cutthroat trout vary greatly in game qualities. Even the same species in different waters, in different parts of its habitat, or at different seasons will vary greatly in this regard. In general, however, it is perhaps a fair statement to say that the cutthroat trout are regarded by anglers as being inferior in gameness to the eastern brook trout. But while this is true it must not by any means be inferred that it is without game qualities, for it is really a fish which possesses those qualities in a very high degree. Its vigor and voraciousness are determined largely, of course, by the character of the stream or lake in which it lives. The individuals which dwell in cold streams about cascades and seething rapids will show marvellous strength and will make a fight which is rarely equalled by its eastern cousin, while in warmer waters and larger streams and lakes they may be very sluggish and show but little fight. Yet this is by no means always true. In the Klamath Lakes, where the trout grow very large and where they are often very loggy, one is occasionally hooked which tries to the utmost the skill of the angler to prevent his tackle from being smashed and at the same time save the fish. An instance is on record of a most enthusiastic and skilful angler who required one hour and three-quarters to bring to rest a 9¾-pound fish in Pelican Bay, Upper Klamath Lake. * * *. The typical cutthroat trout (*Salmo clarkii*) may be described as follows:

Head 4; depth 4; D 10; A 10; cœca 43; scales small, in 150 to 170 cross series. Body elongate, compressed; head rather short; mouth moderate, the maxillary not reaching far beyond the eye; vomerine teeth as usual set in an irregular zigzag series; teeth on the hyoid bone normally present, but often obsolete in old examples; dorsal fin rather low; caudal fin slightly forked (more so in the young). Color, silvery olivaceous, often dark steel color; back, upper part of side and caudal peduncle profusely covered with rounded black spots of varying sizes and shapes, these spots often on the head and sometimes extending on the belly; dorsal, adipose, and caudal fins covered with similar spots about as large as the nostril; inner edge of the mandible with a deep red blotch, which is a diagnostic mark; middle of side usually with a diffuse pale rosy wash, this sometimes quite bright and extending on to side of head; under parts silvery white. The red blotches or washing on the membrane joining the dentary bones of the lower jaw are usually constant, probably always present in the adult, and constitute a most important character. This species has been called *Salmo mykiss* in various publications by the writers and others, but the true *Salmo mykiss* is allied to *Salmo gairdnerii* and has never been taken outside of Kamchatka.

GROWTH AND EGG PRODUCTION.

The superintendent of the Bozeman (Mont.) hatchery gives the following information regarding the growth and egg-production of the black-spotted trout of the Yellowstone National Park waters:

Even with domesticated trout on the hatchery grounds, fed and reared in the same ponds and with the same opportunity for growth, there is a very wide range of development. In the case of wild fish we have reason to believe that this development presents even a greater range owing to food conditions, range, and number of fish in proportion to the previously named conditions. From observations in connection with the Yellowstone Park operations we believe that the following figures are approximately correct:

Age.	Length (inches).	Egg production.
Yearlings	3–5	....
Two-year-old	5–8	....
Three-year-old	8–12	500–800
Four-year-old	11–15	800–1,200
Thereafter	13–18	1,000–1,600

On several occasions when we kept count of the fish spawned the average production was found to run from 900 to 1,000 eggs per spawned fish. There are very few undersized spawning fish as compared with brook trout, where we find them producing spawn at 7 and 8 inches, and occasionally when even smaller. It is believed that very few females spawn under 3 years of age in the Yellowstone watershed. The season is short, due to both latitude and high altitude, hence the rate of growth is somewhat slower than in many sections more favored climatically.

PARASITES.

This is an excellent food fish when fresh from cool waters, but the trout from some parts of the Yellowstone Lake, Upper Yellowstone River, and Heart Lake are generally reputed to be infested with a parasitic worm. In his book pertaining to the fish of the park, General Chittenden says:

> The trout of Yellowstone Lake are to a slight degree infected with a parasitic disease that renders them unfit for eating. Many efforts have been made to discover the cause of this condition and a suitable remedy for it, but so far without success. An explanation sometimes advanced is that the excessive number of these fish and the absence of sufficient food reduce the vitality and they become easy prey to parasites which a more vigorous constitution would throw off. Later investigations have shown that reports of the prevalence of this condition were much exaggerated.

The parasite referred to is a tapeworm, of which only the larval or intermediate form occurs in the trout, the host of the adult being an entirely different animal, as is the case with all tapeworms of this kind. Briefly, its life cycle has been found to be as follows: Starting with the egg in the water it develops into a ciliated embryo. This passes into the fish, probably by way of the mouth, and becomes established and assumes the form usually observed. The fish is eaten by the pelican, and in the intestinal tract of that bird the parasite attains its adult and reproductive stage and its round of life is there completed. The eggs pass into the water and a new generation is begun.

General Chittenden's statement that the parasite renders the fish unfit for food involves a matter of prejudice rather than actual unfitness for food or danger to the consumer. Cooking destroys the vitality of the worm, and it may be said that this particular worm is not harmful to man. Probably no one would knowingly eat an infected fish, but if he should there would be absolutely no danger in doing so. Beyond doubt the presence of this parasite is greatly exaggerated, as General Crittenden says, and lean, cadaverous, unsightly trout, the condition of which is commonly attributed to parasitism, are often fish which are run down from breeding, although they may carry some parasites. There is scarcely a fish that swims that is not more or less infected by some sort of parasitic worm, and in this respect the Yellowstone fish do not appear to be worse than the fish of many other lakes in the country.

LOCH LEVEN TROUT (SALMO LEVENENSIS).

The Loch Leven trout[14] of Great Britain was introduced into the United States from Scotland in 1885 and subsequent years. It is somewhat closely related to the European brown trout (*Salmo fario*), and has been artificially crossed with that species in the United States, so that it is sometimes difficult to find the purebred Loch Levens in fish-cultural establishments at home.

DESCRIPTION.

The body of the Loch Leven is more slender and elongate than that of the brown trout, its greatest depth contained four and one-fourth to four and one-half times in the total length without caudal. Caudal

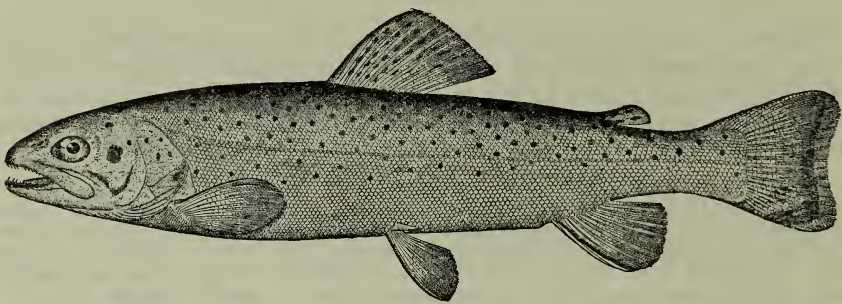

FIG. 21.—Loch Leven trout (*Salmo levenensis*).

peduncle slender, its least depth three-eighths of the greatest depth of the body and equal to length of snout and eye combined. The head is rather short and conical, its length two-ninths to one-fifth of the total length without caudal. The snout is one-fourth or slightly more than one-fourth as long as the head. The interorbital space is somewhat convex, its width equal to three-fifths of the length of postorbital part of head. The eye is of moderate size, its long diameter contained five and one-half to six times in the length of the head and equaling about twice the greatest width of the maxilla. The maxilla reaches to or slightly beyond the posterior margin of the eye. Teeth rather strong, those in the intermalillary and mandible the largest, triangular head of vomer with two or three in a transverse series at its base, teeth on the shaft of the vomer usually in a single, partially zigzag, persistent series. Mandable without a hook and but little produced even in breeding males.

Anterior end of dorsal base distant from tip of snout about as far as posterior end from base of caudal; the dorsal fin higher than long, its base one-eighth of total length without caudal, its longest ray equal to longest ray of anal fin. The anal fin is much higher

[14] Food and Game Fishes of New York. By Tarleton H. Bean. In the Seventh Report of the New York Forest, Fish, and Game Commission, 1901 (1902), p. 336. Albany.

than long, its distance from the base of the ventral equaling length of the head. The anterior end of the base of the ventral is nearly under the middle of the dorsal, the fin being as long as the postorbital part of the head. Pectoral equals length of head without the snout. Adipose fin very small, its width one-half its length, which is about equal to eye. The caudal when fully extended is square or truncate; in natural position it is somewhat emarginate. The outer rays are about one-seventh of the total length of the fish including the caudal.

Upper parts brownish or greenish olive, or sometimes with a reddish tinge; sides silvery with a varying number of X-shaped black spots, or sometimes rounded brown spots or rounded black spots which may be ocellated; occasionally red spots are seen on the sides, and the adipose fin may have several bright orange spots, or it may show a red edge and several dark spots; sides of the head with round black spots; dorsal and adiposed fins usually with numerous small brown spots; tip of pectoral blackish; anal and caudal fins unspotted, but the caudal sometimes has an orange margin and the anal a white edge with black at its base; a similar edge may sometimes be observed on the ventral.

RANGE, SIZE, AND FOOD.

The Loch Leven trout is a nonmigratory species, inhabiting Loch Leven and other lakes of southern Scotland and the north of England. Its range in Great Britain and on the continent of Europe has been greatly extended by fish-cultural operations, and the fish is now fairly well known in the United States, though mixed to some extent with the brown trout, as remarked above. Examples weighing 18 pounds have been recorded, but the average weight at 6 years of age is about 7 pounds, though some individuals of that age may reach 10 pounds. The natural food of this species includes fresh-water mollusks (snails, *Buccinum*, etc.), crustaceans, worms, and small fish. In captivity it is reared on liver, horse flesh, chopped clams, and various other meats.

As a food fish the Loch Leven is highly esteemed because of the red color and delicate flavor of its flesh when obtained from suitable waters. In some localities the flesh often becomes white from lack of proper food or from other causes.

The spawning season begins late in September or early in October and continues until December. In Michigan it corresponds with that of the brook trout. The egg varies from about one-fifth to one-fourth of an inch in diameter. A trout weighing 2 pounds contained 1,994 eggs, the weight of which was one-half pound.

The Loch Leven will take the artificial fly as readily as the brown trout and the brook trout. Its great size and strength add to its attractions for the angler.

Smith and Kendall[15] make the following comments on the Loch Leven trout as it occurs in waters of Yellowstone National Park:

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[15] Fishes of the Yellowstone National Park. With Description of the Park Waters and Notes on Fishing. By Hugh M. Smith and William C. Kendall. Appendix III to Report of U. S. Commissioner of Fisheries for 1921. Bureau of Fisheries Document 904, p. 22.

This trout originated in Loch Leven, the lake made famous by Scott's poem, "The Lady of the Lake." Typically it was peculiar to this loch, where it seldom, if ever, attained much over 1 pound in weight. The claim has been made that it is merely an ontogenetic development of the common brown trout, and that when transferred to other waters its progeny can not always be distinguished from the common brown trout. On the other hand, information derived from persons familiar with Loch Leven indicates that both this trout and the brown trout exist in the same lake, and that in that body of water they can always be distinguished.

It is not impossible that confusion has arisen by brown trout from that lake having been propagated under the supposition that they were Loch Leven trout. There are parallel instances of such mistaken identity in this country in respect to other species, and so-called Loch Leven trout have been propagated for a long time in this country. In the early years the progeny of Loch Leven eggs could easily be distinguished from brown trout hatched at the same time, especially when they had attained a few inches in length. Recently, however, there is reason to suspect that many of the so-called Loch Leven plants have been brown trout.

PROPAGATION.

The Bureau of Fisheries makes no special effort to artificially propagate the Loch Leven trout for reasons stated elsewhere. At two of the hatcheries—Leadville, Colo., and Spearfish, S. Dak.—very limited numbers of eggs are handled each year. At the former point the egg collections are obtained from the Arkansas River, and such work is incidental to the more important brook trout egg collections annually undertaken in the same region. At the latter station a small brood stock of the species is maintained, numbering 82 female fish sexually mature at the end of the fiscal year 1922. The distribution of the output in each case is limited to local waters.

The information regarding the spawning season, incubation period of the eggs, etc., contained in the following table, is taken from the reports of the superintendents of the stations:

TABLE 4.—*Spawning season of Loch Leven trout, egg production, and period of incubation.*

Station.	Spawning season.	Average number of eggs per fish.	Number of eggs per ounce.	Maximum egg production.		Incubation period.		Fry.
				Weight of fish.	Number of eggs.	Eyespots appear.	Incubation completed.	Yolk sac absorbed.
Spearfish, S. Dak.	Oct. 10 to Dec. 10.	920	300	....	....	25 days at 41° F.	112 days at 39° F.	35 days at 39° F.
Leadville, Colo.	Oct. 8 to Dec. 31.	1,500	260	6 pounds..	3,000	22 days at 43° F.	150 days at 33° F.	60 days at 34° F.

The superintendent at Spearfish (S. Dak.) station comments further on the Loch Leven trout, as follows:

The Loch Leven trout has proven to be the hardiest trout in the Black Hills, for, while the numbers planted each year have been small as compared with plants of brook and black-spotted trouts, the numbers taken by fishermen would seem to exceed those of both the other species. Very few black-spotted trout were ever taken in this section.

BROWN TROUT (SALMO FARIO).[16]

The fish better known in this country as brown trout was first introduced under the name of von Behr trout, after the man through whose instrumentality the eggs were obtained from Germany. It was later called German brown trout and finally just brown trout, also having many other local names. In Germany it is the Bachforelle (brook trout), but it is not exclusively a brook trout any more than the eastern brook trout of the United States (*Salvelinus fontinalis*) is such.

RANGE, SIZE, AND FOOD.

The brown trout also inhabits lakes, in some of which it reaches a large size, even 50 pounds, if the British *Salmo ferox* is the same species. Day, in his "British and Irish Salmonidae," 1887, gives the habitat of this trout as the colder and temperate portions of the Northern Hemisphere, descending into Asia as far south as the Hindu Kush, but not normally present in any portion of Hindustan.

This trout has been introduced into many United States waters, in some of which it has thrived. It is a good game fish, but Hen-

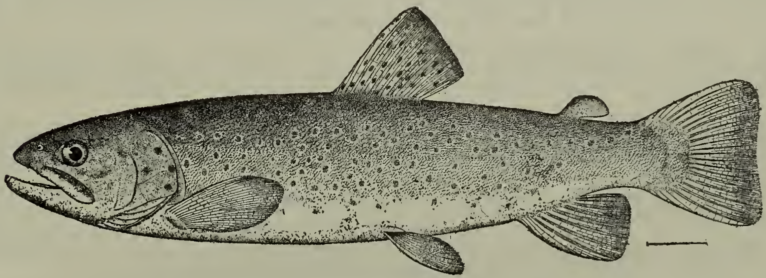

Fig. 22.—Brown trout or von Behr trout (*Salmo fario*).

shall says it is not as gamy in this country as the eastern trout (*Salmo fontinalis*). It will endure warmer water than *S. fontinalis* and may be suited to depleted trout streams which, owing to change of conditions, are unsuited to the brook trout. Day says:

> The food which trout consume is of various descriptions. One of about 1½ pounds weight, taken in June, 1882, in the Tweed, was found to contain 11 small trout and 1 minnow. They do not object to little fish, as the minnow, loach, sticklebacks, etc., water rats, young birds, frogs, snails, slugs, worms, leeches, maggots, flies, beetles, moths, water spiders, and even a lizard (Field, October, 1885). They will swallow one of their own kind two-thirds as large as themselves. In Mr. Buckland's museum was an example, the stomach of which was distended by 2,470 eggs of apparently the salmon.

BREEDING HABITS AND PROPAGATION.

Regarding their breeding habits, Day continues:

> Trout commence breeding in their second year or prior to their attaining 24 months of age, and often later in the season than their parents. The males are more forward than the females, but at this early period of their

[16] Fishes and Fishing in Sunapee Lake. By William Converse Kendall. Report of the Commissioner of Fisheries for 1912. Bureau of Fisheries Document 783, p. 45.

lives the probabilities of the ova being healthy and fertile are less than in somewhat older examples. At first the number of males appears to be in excess of the females, but the mortality among them is greater than those of the other sex, until at 3 or 4 years of age the proportion may be expected to be about the same, and subsequently the females predominate. The number of eggs produced by each female trout has been roughly estimated at 800 for every pound's weight of fish, which computation has been observed at the Howietoun breeding ponds to be fairly accurate. * * *. The period at which these fish breed varies in different rivers and districts, extending from October until February, and even, although rarely, to March. * * *. Although trout generally migrate into the smaller contiguous brooks to breed, large ones are more frequently found forming redds in the broader streams than are smaller fish; but it is by no means rare to find large examples having taken possession of pools in burns. The trout's redd or nest is a mound of gravel which would fill one or even two wheelbarrows, and when by probably causing a shallow may assist in aerating the water. The eggs themselves lie loose among the gravel at from 1 to 2 feet below the surface.

From the foregoing account of the brown trout it would not seem to be a very desirable acquisition in waters where the indigenous fish fauna is wholly satisfactory.

In connection with the foregoing comment on the probable undesirability of the brown trout in American waters the following extracts from opinions expressed by fish-culturists concerning the predacious habits of the fish are of interest:[17]

The largest trout caught in 1894 were (1) a German brown weighing 8½ pounds, (2) a rainbow weighing 3½ pounds, (3) a *fontinalis* weighing 2 pounds 9 ounces.

Some years ago the club planted as an experiment some German brown trout (*Salmo fario*) and a few of the rainbow variety (*Salmo irideus*). The former have proven to be very undesirable tenants of the stream. They grow to an enormous size, are very coarse, and are very destructive to the other fish. For the past two years a continuous effort has been made to rid the streams of these Germans. The rainbow trout are more beautiful and more desirable in every way, but they do not compare favorably with the *fontinalis*. In the future foreigners will not be encouraged in these waters.

Speaking before the American Fisheries Society at Grand Rapids, Mich., in 1906, Dr. Tarleton H. Bean, at that time fish-culturist for the State of New York, said:[18]

The State propagates the brown trout to a much less extent than formerly, and its present policy is that it should never be planted in any waters containing brook trout. An expert angler friend of mine told me he got 10 brown trout to 1 brook trout in the Beaverkill River. The cause of that is unquestionably (at least in the minds of the anglers, and it seems reasonable) that the brown trout destroy the brook trout. If they do not they at any rate destroy the food of the brook trout, which amounts to the same thing. There is now a continual desire on the part of the New York commissioner to refuse applications for brown trout, and he does refuse them for waters already containing brook trout. They are suitable for some waters, undoubtedly waters which contain no other trout, and they have done very well there.

The following is extracted from a letter written November 2, 1905, by State Fish Commissioner W. E. Meehan, of Pennsylvania.

We have had a great deal of trouble, and much disaster has followed the planting of brown trout in some of our brook-trout streams.

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[17] From a book of the Castalia Trout Club, Castalia, Ohio. By Frank C. Hubbard. Published in 1905.

[18] Transactions of the American Fisheries Society, 1906.

In a letter written January 7, 1921, John W. Titcomb, at that time fish-culturist of the New York Conservation Commission, stated:

I personally feel a pang of regret every time I see a German trout introduced into a new field to compete with the *fontinalis.*

DESCRIPTION.

The following description of the brown trout is taken from "Food and Game Fishes of New York," by Tarleton H. Bean, in the seventh report of the Forest, Fish, and Game Commission of the State of New York, 1901:

The body of this trout is comparatively short and stout, its greatest depth being contained about four times in the length without the caudal. The caudal peduncle is short and deep, its depth equal to two-fifths of the length of the head. The length of the head in adults is one-fourth of the total length without caudal or slightly less. The diameter of the eye is about one-fifth the length of the head, and less than length of snout. The dorsal fin is placed nearer to the tip of the snout than to the root of the tail; the longest ray of this fin equals the distance from eye to the end of the opercle. The ventral is under the posterior part of the dorsal; its length is about one-half that of the head. The adipose is placed over the end of the anal base; it is long and expanded at the end. The caudal is emarginate in young examples, but nearly truncate in specimens 10 inches long. The pectoral is nearly one-sixth of the length without the caudal. In the male the jaws are produced, and very old ones have a hook. The maxilla extends to the hind margin of the eye. The triangular head of the vomer has a transverse series of teeth, and the shaft of the bone bears two opposite or alternating series of strong persistent teeth. * * *.

On the head, body, and dorsal fin usually numerous red and black spots, the latter circular or X-shaped and some of them with a pale border; yellowish margin usually present on the front of the dorsal and anal and the outer part of the ventral. The dark spots are few in number below the lateral line. The ground color of the body is brownish or brownish-black, varying with food and locality.

Names.—In European countries in which this species is native it bears the name of trout or brook trout or the equivalents of these terms. In Germany it is *bachforelle;* in Italy, *trota;* in France, *truite.* In the United States it is known as the brown trout and von Behr trout, the latter in honor of Herr von Behr, president of the Deutscher Fischerie Verein, who has been very active in the acclimation of the fish in America.

Distribution.—The brown trout is widely distributed in continental Europe and inhabits lakes as well as streams, especially in Norway and Sweden. Tributaries of the White Sea, the Baltic, the Black Sea, and the Caspian contain this species. In Great Britain it lives in lakes and streams and has reached a high state of perfection; in Germany and Austria, however, the trout is a characteristic fish, and our supply has been drawn principally from the former country. Moreau found it at an elevation of 7,000 feet in the Pyrenees, and a color variety is native to northern Algeria in about 37° north latitude. In the United States the brown trout has been successfully reared in Colorado at an elevation of nearly 2 miles above sea level; it is now well established in New York, Pennsylvania, Maryland, Missouri, Michigan, Wisconsin, Nebraska, Colorado, and several other States. This trout has proved to be well adapted to the region east of the Rocky Mountains, which has no native black-spotted species, though the western streams and lakes contain many forms in a high state of development.

Size.—Under favorable conditions the brown trout has been credited with a weight of 22 pounds and a length of 35 inches. In New Zealand rivers, where it was introduced with unusual success, it now approximates equal size; but in most localities 10 pounds is about the limit of weight and 5 or 6 pounds is a good average, while in some regions the length seldom exceeds 1 foot, and the weight ranges from ½ pound to 1 pound. In the United States a wild specimen 7 years old weighed about 11 pounds. In a well in Scotland an individual aged 15 years measured only about 1 foot in length. These illustrations will serve to show how much the growth of a brown trout is affected by its surroundings and food supply. The species has been known to become sexually mature when 2 years old and 8 inches long.

Habits.—The brown trout thrives in clear, cold, rapid streams and at the mouths of streams tributary to lakes. In its movements it is swift, and it leaps over obstructions like the salmon. It feeds usually in the morning and evening, is more active during evening and night, and often lies quietly in deep pools or in the shadow of overhanging bushes and trees for hours at a time. It feeds on insects and their larvæ, worms, mollusks, and small fishes, and, like its relative, the rainbow trout, it is fond of the eggs of fishes. In Europe it is described as rising eagerly to the surface in pursuit of gnats, and it is said to grow most rapidly when fed on insects.

Reproduction.—Spawning begins in October and continues through December and sometimes into January. The eggs are from one-sixth to one-fifth of an inch in diameter and yellowish or reddish in color; they are deposited at intervals during a period of many days in crevices between stones, under projecting roots of trees, and sometimes in nests excavated by spawning fishes. The parents cover the eggs to some extent with gravel. The hatching period varies according to temperature from 40 to 70 days. Females aged 3 years furnish on the average about 350 eggs each, but individuals of this age have yielded as many as 700, and even at the age of 2 years some females produce from 400 to 500. When they are 4 to 5 years old, the number of eggs has reached 1,500 to 2,000. The young thrive in water with a temperature of about 50° F. Sterility in the females is common, and breeding females have been observed to cease reproduction when 8 years old.

Qualities.—The brown trout is in its prime from May to the last of September. Its flesh is very digestible and nutritious and deeper red than that of the salmon when suitable food is furnished. The flavor and color, however, vary with food and locality. Insect food produces the most rapid growth and best condition. This species has been so long known as one of the noblest of the game fishes, and its adaptability for capture with artificial flies because of its feeding habits is so well understood that I need not dwell on these familiar details.

DISEASES COMMON TO TROUT UNDER DOMESTICATION AND THEIR TREATMENT.

Trout in artificial environment are subject to various ailments, and little definite knowledge is available as to the causes or prevention of such ailments. The more simple and obvious preventive measures are (1) the utmost cleanliness in and about the hatchery, troughs, and ponds, and all equipment used in connection therewith; (2) careful handling of eggs, fry, fingerlings, and adult fish at all times; (3) a carefully selected diet of materials free from contamination of any kind; (4) an abundant flow of uncontaminated water through all ponds and troughs.

Most of the diseases to which trout fingerlings and adults are susceptible may be traced to some form of parasitic animal. Where these parasites attack the fish externally a number of methods of treatment, all more or less effective, have been prescribed. One of the most simple of these consists in immersing the affected fish in a solution of salt or cider vinegar. More recently certain chemicals, including copper sulphate and potassium of permanganate,[19] have been used with success. In certain instances bicarbonate of soda, applied with a brush to the affected parts of adult fish, has proven efficacious.

Parasites occurring in the intestines or other internal organs are less responsive to treatment, and internal medication of fish of any

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[19] A New Bacterial Disease of Fresh-Water Fishes. By H. S. Davis. Bulletin of the Bureau of Fisheries, Vol. XXXVIII, 1921–22. Bureau of Fisheries Document 924.

size or age is hardly practicable, and hope of eradication must lie along other lines. Sanitary conditions in and about the hatchery are undoubtedly important in this connection, and it has been suggested that some of these diseases may be carried in the eggs of fish that are "carriers" of disease. Eggs taken from such trout would seem almost certain to have mixed with them matter from the intestinal tract that would contain these organisms. It is possible that these might survive and develop in such a manner as to infect the fry.

The Twelfth Annual Report of the New York Conservation Commission for 1922 contains a description of some of the parasitic diseases common to trout under domestication, and the following notes on the subject are extracted therefrom:[20]

Hatchery diseases.—All fish hatcheries suffer annual losses of fish from disease. The combating of these maladies and the keeping of the losses from them within bounds presents one of the most serious problems of fish culture. There is wide variation between hatcheries as to trouble with disease. Some are practically free from epidemics, in others disease conditions are so severe as to restrict the kinds of fish which can be reared in them. The most obvious difference between hatcheries is the water supply, and it was decided to make a study of that feature as throwing valuable light on the water conditions most favorable to fish life. Such information is needed for the setting up of standards for the permissible pollution of streams.

Ground covered.—Recurrence of an epidemic of "whirling sickness" among the brook trout fry at Bath hatchery was reported early in the season, and the whole problem at that hatchery was given intensive study. Later the other hatcheries were examined for this and other diseases. Most diseases found were given some study, but special efforts were directed toward the particular disease above mentioned.

OCTOMITIASIS.

"Whirling sickness" or "gill trouble."—This disease is of long standing and practically universal. It attacks all kinds of trout and may cause heavy mortality. It is caused by a minute parasite of the intestine (*Octomitus salmonis*). The symptoms of what appears to be this disease have been described and the causative organism, or one closely allied to it, has been figured, but the two seem heretofore not to have been connected.

Symptoms of the disease.—Apparently this disease is confined to the intestines, and no external lesions have been thus far observed. Badly infected trout fingerlings have a characteristic behavior which aids in diagnosing the disease. Balance seems easily lost, and the fish turn over repeatedly with a "whirling" or "corkscrew" motion in the water. Too weak to make headway against the current, numbers of them are found in the corners at the foot of the trough or nosing along the sides near the surface. They lie on their backs with gills distended and in feverish action. The walls of the intestines themselves become translucent, whitish or yellowish in color. They are filled with a watery fluid, in which the active organisms swim about. * * *.

Distribution.—Probably this disease exists in wild fish, but under natural conditions causes little harm or inconvenience. In the crowded condition of a fish hatchery the disease seems to be aggravated and may assume the proportions of a deadly epidemic. It was found in all our trout-rearing hatcheries, but was not serious in all. Until more is known of the disease this difference can not be explained with certainty. Adverse conditions in the water supply may well contribute to the intensification of the malady. Thus, water low in dissolved oxygen, or high in deleterious substances, might lower the degree of resistance of the fish to the disease. Further study of this relation is needed.

Transmission.—*Octomitus salmonis* in ordinary form probably can not long exist outside of the intestinal tract of the fish. It can not readily be de-

[20] Diseases of Fish in State Hatcheries. By Emmeline Moore. Twelfth Annual Report of the New York Conservation Commission for 1922 (1923), p. 66. Albany.

tected in fish that have been dead for more than a few hours. It forms cysts and in this form may survive outside the fish for long periods. It seems probable that the disease is transmitted by such cysts in the excrement, which, if eaten by other fish, might become active and infect the new hosts. It is evident that hatchery water should be protected from infection by keeping it free from fish when this is possible. It was thought that it might be derived from frogs, but, though these animals are plentifully infested by a somewhat similar form, this particular one was not found in them.

COSTIASIS.

Occurrence.—Costiasis, a disease rapidly fatal under hatchery conditions to many species of fish and to which trout are particularly susceptible, appeared at one of our hatcheries early in June. Early recognition enabled remedial measures to be taken promptly and it was stamped out. Delay would have doubtless cost us hundreds of thousands of young trout. This disease was also found in other hatcheries.

Symptoms.—Fish die suddenly at any point in the trough. Loss of appetite and a frayed, slimy, and grayish appearance of the fins are the most readily recognized symptoms. Viewed against a piece of glass the attacked fin shows a clear area where the outer surface of the skin is sloughing away. Unfortunately, when these symptoms become evident to the unaided eye, the disease is far advanced.

Costia necatrix.—Costiasis is caused by a small protozoan parasite (*Costia necatrix*) which destroys the cells of the skin and other membranes. Once established it rapidly covers the entire body of the fish. In the final stage the gills are attacked and the fish dies of suffocation. *Costia* attach themselves under the edges of the epithelial cells and multiply with great rapidity. An exudation of slime issues from the diseased skin, marking the affected areas.

Transmission.—Costia appear to have a free swimming stage, during which they may pass from fish to fish. They also form resistant cysts, both on the fish and on the bottom of the troughs. It has been suggested that the use of fresh-water fish as food for hatchery trout may result in the introduction of the disease. Further study is necessary.

Remedy.—Remedial measures suggested in the literature on the subject have been tried out with success. The process consists in placing the fish in a 2½ per cent solution of salt in water (21 pounds of table salt to 100 gallons of water). Fish are left in this bath from 10 to 15 minutes, or a less time if distressed. This kills the attached and free-swimming forms. Four treatments at intervals of three days are required to kill the young as they emerge from the cysts. Best results are obtained by adding sufficient salt to the water in the trough in which the infected fish are. This treatment must be applied to both fish, infected troughs, and utensils. Additional work on these measures and the life history of the caustive organism is needed.

GYRODACTYLIASIS.

Fin disease.—Two of our hatcheries were infected with fin disease, or Gyrodactyliasis. This disease is probably widespread, frequently epidemic in hatcheries among fish of all species and all ages. Trout, particularly the brook trout, are especially susceptible. It is caused by a flatworm or fluke (*Gyrodactylus*), so called from its resemblance to a gyrating finger as it protrudes from the layer of slime over the affected skin. The animal itself is equipped with an anchor disk, by which it attaches itself to the fish, and a sucking organ for feeding.

Symptoms.—Affected surfaces are covered with a bluish gray slime, most conspicuous on the fins. This copious production of slime may cause confusion between this disease and Costiasis. Fins are apt to be most severely affected; in advanced stages they become frayed so that the rays project as spines, or may be reduced to mere stubs. The disease is not always fatal. At times open sores are produced at the bases of the fins, a condition which causes death in a short time. With a microscope diagnosis is simple and certain, as slime scraped from affected parts will contain adults, young, or both forms of the parasite. The worm itself is transparent and exceedingly active, moving backward or forward, looping along like an inch worm, or gyrating.

Remedial measures.—No cure for this disease has yet been found. External application of some solution is indicated. Salt solutions are not efficacious; thorough sanitation may be of assistance. Diseased fish should be isolated or destroyed; infected troughs and implements sterilized. Experiments with curative measures are in progress.

At the Neosho (Mo.) station of the bureau a 1 to 15 solution (approximately) of cider vinegar has been found effective in treating this trouble. The solution is prepared in a tub or any suitable vessel; the affected fish are removed from the trough with a dip net, immersed in the solution for a period not to exceed 8 to 10 seconds, and are returned immediately to fresh running water. The fish should be watched closely while in the solution and not retained in it beyond the point where they manifest undue distress by turning on their sides. Because of the variation in the strength of cider vinegar a 1 to 15 solution will not always give the best result. It would be well, therefore, for the practical fish-culturist to note the effect of his solution on a limited number of fish before treating the entire lot.

Trout eggs and fry, as well as fingerling and adult trout, are subject to disease. Perhaps the more common affections are the so-called "white spot disease" and the "blue sac," some notes on which are appended. The discussion pertaining to the white spot disease is quoted from a report on the subject by Dr. Franz Schrader, while the discussion of the blue sac is taken from a memorandum by Dr. Adrian Thomas.

WHITE SPOT DISEASE.

This trouble manifests itself by the appearance of an opaque or white area in some part of the embryo, very generally the yolk. There the gradually expanding milky white area is very noticeable in its semitransparent surroundings, and the affected eggs are easily recognized, even in the early stages of the disease. Any stage of development up to the complete absorption of the yolk sac may show the infection, and its appearance has come to be recognized as certain death to the affected specimen. Although by no means confined to the eggs, it is in the eggs of salmonoid fishes that it is most conspicuous and most easily observed.

The hypotheses of fish-culturists as to the cause or causes of white spot are more or less indefinite. Weakness of the parent fish, water temperatures, rough handling, holding of the adult fish under unfavorable conditions during the spawn-taking period, are some of the more common causes ascribed. In connection with the last one mentioned the belief is held by some experienced fish-culturists that the transfer of spawning fish from one pond to another just prior to the spawning period may be conducive to white spot, and that such contemplated transfers of adult fish should be made well in advance of spawning or not until after that function has been accomplished.

More serious attempts to clear up the nature of the white spot were made by Bataillon (1894) and Hofer (1892). The former was concerned with what was apparently an epidemic of the disease and obtained pure cultures of several bacteria from the dying eggs, one of which proved pathogenic from cold-blooded animals. Hofer also attributed the disease to bacterial agency, although he was unable to obtain pure cultures and found Bataillon's account too indefinite to render a comparison of the organisms concerned of much use. He was inclined, however, to believe that infection occurred through the agency of unclean packing material or the water from contaminated ice, since he observed disease only in eggs that had undergone shipment. Shipment might also weaken the eggs so that they would be more susceptible to bacterial invasion than untransported ova. According to him both single isolated eggs, as well as the entire contents of hatching troughs, may be affected.

It must be recognized at the outset that any disturbance that will cause a refraction of light at any location in the homogeneous transparant yolk will give rise to an opacity or white spot at that place. It is therefore entirely possible and even probable that the disease may have more than one cause, and that its progress is variable. Certainly the ordinary occurrence is not epidemic in character, differing thus from Bataillon's case and some encountered by Hofer.

General morphological features.—The yolk of trout fry that have just started the absorption of the sac presents a characteristic appearance under normal conditions. Beneath the enveloping layer of cells are located the embryonic blood vessels and what might be called an absorption area. The latter harbors periblast cells more or less irregularly distributed and surrounds the yolk, which is structureless and homogeneous under ordinary magnification, and takes a dense stain.

In yolk affected by white spot the diseased region showed uneven extent of the absorption area. Various stages of disintegration characterized such pictures, tracts of transformed yolk and yolk spheres of various sizes penetrating into the still unaffected material. Blood vessels follow the advancing disintegration, so that they are often found in the center of the yolk, whereas under normal conditions at such a stage of development they are entirely at the surface. Location of the white spot in the yolk sac is variable, but in a general way the following may give some idea of the distribution. The diseased specimens were Loch Leven fry from Saratoga, Wyo. (early stage of sac absorption), 42 being examined.

Diseased area close to liver	9
Touching or surrounding oil globule	8
Close to both liver and oil globule	12
Near heart	3
Posterior tip of yolk	10
	42

In no case was the spot located entirely in the interior of the yolk; that is, it always came in contact with the yolk enveloping cell layer at some point.

The question of bacterial agency.—In some cases bacteria are certainly involved. Examples were furnished by rainbow-trout eggs from Cape Vincent, N. Y. (stage shortly before hatching), which had been shipped there from Wytheville, Va., some weeks previously. Microscopic examination showed at least two kinds of bacteria present in the disintegrating yolk, and these were found side by side in the individual cases or also in seemingly pure cultures. The affected yolk had broken up as usual, and the bacteria were clustered most thickly around the yolk spheres. Similar conditions were observed in the few cases of the disease present in brook-trout eggs from a hatchery at Taunton, Mass.

But this serves to show only that bacteria may be involved in the progress of the disease—not that they are to be considered as causative agents. The random distribution of diseased eggs among healthy eggs is a fair proof in itself that the infection is not contagious or, better, that normal and healthy eggs are not attacked by the bacteria. There must, then, be a predisposition in some eggs that renders them liable to infection. It is of some note to observe that eggs with high mortality rates had generally (not always) undergone shipment from a more or less distant station. Naturally they had, therefore, undergone a certain amount of rough handling, and this made it very possible that the primary cause of the disease was to be found in some injury thus sustained by means of which the bacteria gained access to the yolk. To gain some data on this point, 200 brook trout in the fry stage (yolk sac at early stage of absorption; fry, 18 mm.) were isolated and the yolk sac of each pricked to a slight depth with a sharp needle. In a few cases the fishes were injured in the operation, and in still others the wound caused partial loss of the yolk. In what may be called successful operations the wound caused no loss of yolk and appeared only as a very small white area at the surface of the latter, the fishes showing no immediate ill-effects on liberation. One hundred uninjured fry were kept under similar conditions for control purposes. After 10 days a little more than 25 per cent of the operated fishes had entirely recovered and showed no signs of the injury, and somewhat less than 50 per cent showed a growth of the artificially produced white opaque area. A third of the latter died in the course of these 10 days. Development of fungus eliminated a greater part of the remaining 25 per cent. Of the control 2 per cent died during this period, neither they nor the survivors showing a definite development of white spot. Twelve of the fishes experimented upon that showed a growing white spot were examined and all showed severe bacterial infection. Several kinds of bacteria were involved, one of which seemed identical with one of the forms observed in natural infections. However, all of them were apparently effective in the destruction of the yolk. Similar infections were also observed in the eggs of landlocked salmon which had been subjected to the same treatment.

The difficulty of making exact bacteriological tests is apparent, since the injection of any pure cultures into healthy eggs will also cause the wound that opens a pathway for the general bacterial fauna in the water. The use of sterile water in the hatching operations of such experimental eggs would, of course, solve this difficulty, but practical difficulties in the use of such water have heretofore made these tests impossible.

Sufficient data is furnished by the observations and experiments set forth, however, to indicate that bacteria are not to be regarded as primary agents in the common form of white spot. That various bacteria are instrumental in the disintegration of the yolk is not to be doubted, but the yolk must be regarded only in the light of so much inert organic matter which, once deprived of its protective covering, is open to the attack of all saprophytic and holophytic bacteria. It is a rupture of the yoke envelope that furnishes the primary cause, and only the growth and spread of the spot is due to the bacteria.

Periblast activity.—The white spot cases involving bacteria furnish only one group, a group which, peculiarly enough, does not seem as large in numbers as that which is now to be discussed. In these cases the most careful microscopic scrutiny revealed no indication of bacteria, although the disintegration phenomena do not differ materially. The most remarkable feature is furnished by the periblastic cells. They are found throughout the disintegrating region, augmented in number as compared with normal eggs and embryos, but extremely active, judging from their lengthened form. It may be repeated that diseased eggs are generally found side by side with healthy ones. The affection is therefore not transmissible to normal eggs, and periblastic action just as much as bacterial infection must have the ground prepared for it by another factor, which is therefore the primary agent. Eggs showing such periblastic activity were obtained from Hartsville, Mass.; Saratoga, Wyo.; La Crosse, Wis.; and St. Johnsbury, Vt. Those from the two last-named points had undergone railroad transportation. The Saratoga occurrence was attributed by the superintendent of that hatchery to chilling of the freshly stripped eggs, something which might also have taken place in the case of the Hartsville eggs (the weather was cold at the time of egg taking), although no definite data was obtainable. It was of some significance that the eggs from La Crosse showed cases of bacterial infection, other cases wherein periblasts alone were active, and, finally, a few cases that showed bacteria and periblasts side by side in the disintegrating yolk. If mechanical disturbance was instrumental in introducing bacteria, and if it consisted in actual rupture of the yolk envelope, it could not have been responsible for the periblastic activity. In other words, since the bacteria involved were undoubtedly present at La Crosse, a rupture should give access to bacteria in one case as well as in another. Mechanical injury without rupture of the envelope—that is, shock or concussion—is then left as a possibility. An attempt was made to duplicate the conditions produced through concussion by dropping a wooden box containing 200 landlocked salmon eggs from a height of 3 feet. Two hundred normal eggs were kept for control. At the end of 10 days 10 of the former lot showed indications of white spot, while 6 showed it in the control, a difference of 2 per cent. This is certainly not significant enough to admit of any conclusions, save that eggs at that stage of development (immediately before hatching) are extremely resistant to concussion. A repetition of the experiment with younger eggs is therefore necessary, especially in view of the fact that experience has proved the early stages more susceptible to injury of any kind.

Unfortunately no experiments could be conducted in connection with the possible effect of chilling and freezing the eggs. The temperature factor is liable to be very important in clearing up the periblastic activity, and there should be little difficulty in the future in working out the relations.

The necessity of more experimental data is thus plainly apparent. Sufficient evidence is available, however, to point to physical injury of some kind as the causative agency of the common occurrence of white spot. It seems more or less of a truism to recommend more careful handling of fish eggs, but such a recommendation points only toward the greatest possible elimination of distance shipments at present. Although so crude at the first glance, the "bulk" method of shipping eggs may possibly be more safe than the careful tray method, simply because it confines scratching of the eggs to the outer layers, keeping the inner ones intact. On the trays, however, each egg is carefully placed on cloth, which, of course, exposes it to friction with rough places in the latter and also stray bits of packing material. Careful statistical scrutiny of shipping records should decide this, however, since no reliance can be placed on individual shipments, wherein the amount of rough handling is so exceedingly variable.

Summary.—(1) Both bacteria and periblastic activity are instrumental in the progress of white spot as it commonly occurs. (2) Neither of these features can be considered as the primary cause, however, since either can occur only in "predisposed" eggs. (3) "Predisposed" eggs are those which have been subject to physical injury of some kind.

BLUE SAC DISEASE.

This disease is otherwise known as *Hydrocele embryonalis* or yolk-sac dropsy. Dr. Bruno Hofer, in his "Handbuch der Fischkrankheiten," treats of this affection, and in doing so says that many breeders agree that it is probably due to shock or pressure to the eggs, though nothing appears to be certain concerning the etiology.

The disease appears sporadically, the first symptoms being an enlarged sac, which after a time becomes so weighty that the fry are unable to rise to the surface. After a few days the sac usually bursts, resulting in the death of the fry in a few hours.

The sac appears to contain a serous fluid, which surrounds the yolk and at times assumes a bluish tinge, hence the name blue sac. The disease seldom appears after the yolk sac has been nearly absorbed but usually attacks the fish during the first week after hatching.

Hofer seems to think that the disease is caused by rough handling of the eggs, whereby they receive shocks or jars or are injured by too much pressure during stripping. He also mentions the probability of the disease being caused by the taking of eggs from brood fish that are too young, and says that precaution should be taken against the taking of eggs from very young females; also that care should be exercised in handling and packing for transportation, and that eggs prepared for shipment should be packed in an abundance of soft insulating material, such as moss, etc.

It has been suggested that improper fertilization may be responsible for the disease. Improper fertilization may not be exactly the correct term, but it is well known that any injury to eggs or sperm will produce monstrosities or diseased offspring.

Up to this point no definite cause of or remedy for the disease is known, though several possible causes and their prevention have been mentioned.

L. von Betegh has made a study of the disease. Its sporadic occurrence led him to believe it infectious, and he attempted to isolate the specific organism causing the malady.

In the serous fluid of the yolk sac he found a diplobacillus in pure culture. This organism he proposed to name *Diplobacillus liquefaciens piscium*. Von Betegh concluded that the organism he found may be regarded as the specific cause of the disease. Though he states that further experiments will later be reported on, it does not seem that the mere presence of this diplobacillus is evidence that it causes the disease, yet it is not improbable that it does.

We must look for all diseases of young fish to arise from one of two causes, namely, infection or injury to the eggs. It is highly probable that this disease may be prevented in a hatchery if the hatching apparatus is kept perfectly clean, all fish suspected of disease are immediately removed and destroyed, and care is exercised in handling the eggs and fish. The stripping of eggs from very young brood stock should also be avoided.

George A. Seagle, former superintendent of the bureau's Wytheville (Va.) hatchery, speaks of the diseases occurring among the rainbow trout at that station, as follows:

The diseases most frequently occurring among rainbow-trout fry under domestication are an inflammation of the gills and a slimy skin affection. The causes of these diseases are not well known, but improper food, water pollution, or insanitary conditions of any kind are among the most probable. By closely watching the movements of the fish the symptoms can usually be detected before an alarming stage is reached.

When the gills are affected, the fish as a rule swim high in the water in an uneasy restless manner, as if gasping for breath. As soon as such a condition is detected the gills should be examined for inflammation or swelling. In the case of a skin disease the fish ordinarily indicate its presence by rubbing on the bottom of the trough or against any convenient surface. They dive with a quick twisting motion against the trough bottom. If the disease is not promptly checked it will soon reach a stage where nothing can be done.

One of the best remedies known for both these disorders is salt, which is sprinkled through the ponds or troughs after the water has been drawn low, about half a pint of salt being used to each gallon of water. In extreme cases the fish are always treated in the troughs, and in addition to the salt a half pint of apple vinegar is allowed to each gallon of water. These are the proportions for large fish; for lots which are small and weak the proportion of both salt and vinegar must be reduced. The fish are closely watched and allowed to remain in the solution only until they begin to turn on their sides, showing plainly that they have stood all they can endure. Fresh water is then turned on freely and distributed among the fish with the hand. As the fresh water fills the trough a slimy white scum rises and floats on the surface of the water.

Fungus, "blue-swelling," and other affections sometimes occur, but the most serious diseases of fry are those just described.

During the dry weather of summer fry and fingerling fish are frequently affected by external parasites, which usually make their appearance immediately after a rain following a drought. They first attack the tail and fins of the fish, sometimes forming a fringe around the outer fin edges, and after consuming the slimy coating within reach they move up toward the body of the fish, leaving nothing behind them apparently except the bony sinews of the fins. Under such conditions the fish soon weaken and die, when the parasites leave them for other victims.

Under the microscope the parasites appear to be small white worms, almost transparent, about 0.4 mm. or one-sixtieth-inch long and larger at one end than the other. The mouth is at the small end, and at the other are claw-like tentacles with which they fasten themselves to the fish. They appear to be continuously feeding upon the slimy coating of the fish, stretching themselves at full length and then drawing up until they resemble tiny rice grains. Their presence is indicated by the following symptoms: The color of the fish changes to a dark bluish-black; the fish swim high, dart around restlessly, and in the last stages turn their tails to the current or seek quiet corners and remain there until they die.

At some of the bureau's stations where it has been found necessary to treat fish for parasites from one to three times each season it is customary to turn the fish from two adjoining troughs into one. The empty trough is then thoroughly cleaned, wiped with a cloth or sponge saturated with vinegar, and allowed to fill with water. If proper care is exercised in making the solution and the fish are handled carefully, this remedy will be found to work perfectly. The salt treatment alone merely causes the parasites to abandon the fish for a short time; it does not kill them, and they will resume their attack when the water supply again becomes normal.

A very serious disease is sometimes encountered with adult rainbow trout. Very dark spots, ranging in number from 2 or 3 up to 20 or 30 and in size from one-fourth inch to 1 inch in diameter, appear on different parts of the body; a light spot about the size of a green pea forms on the head immediately over the brain. The fish refuse food and become restless; they jump and dart around as though frightened, settling back on their tails; they hide among the plants, seek shallow water in the corners of the pond, and finally sink to the bottom, dying within 24 hours after the appearance of the first symptom.

This disease was first encountered among a lot of von Behr (brown) trout that had been delivered at the bureau's Wytheville (Va.) station on November 29, 1895. The first symptom was noted six days after their arrival, and by December 12, one week later, 455 of them had died. During its first stages the fish were in the nursery, and the water in which they were being held passed through an empty pond into a second one containing about a thousand large rainbow trout that had spawned recently. On the morning of December 23 the disease was apparent among the rainbow trout, and by 4 o'clock of that day 56 had died. The water in the pond was drawn down promptly to about 300 gallons, and 150 pounds of common salt was sprinkled through it. After holding the fish in this brine for 15 minutes fresh water was turned on freely and good results were at once noticeable. The fish became quiet and improved steadily, making a second application unnecessary. The final outcome of the experiment was that the mortality among the rainbow trout amounted to only 30 per cent, whereas the death rate on the untreated von Behr fingerlings exceeded 71 per cent.

Foul ponds cause disease, and when fish become affected from that cause they must be removed at once to a clean pond and given a salt and clay bath, applying it in the following manner: While the salt bath previously described is being given, from 2 to 3 bushels of clay are placed in the reservior or supply trough, and when fresh water is turned on after the salting the pond is flushed for about 30 minutes with roily water from the clay, and after the clay water has passed an increased supply of water is maintained for 10 days or more.

Adult fish which have been bruised or scarred or have become emaciated are very liable to develop fungus. If the trouble originates from an injury, it can often be cured before it spreads to the sound flesh, but after the growth has spread like a slimy web over the entire body of the fish the case is hopeless. During the spawning season fish are especially susceptible to fungus, and they must be handled very carefully to avoid bruising or scarring in any way. If fungus makes its appearance, the affected fish should be caught and the diseased part treated with salt and with the vinegar solution. It should then be placed in a separate pond or tank with the view of giving it further treatment a day or two later. Any fish that are affected over the entire body should be removed from the pond at once and killed.

Thyroid tumor is not an uncommon ailment among artificially reared trout. It affects the gills and may be encouraged by a generally run-down condition of the fish or by insanitary conditions in and about the ponds and troughs. As preventives of disease, plenty of fresh water, scrupulous cleanliness, and the utmost care in handling eggs, fry, or adults are all-important factors. Many of the ailments to which the eggs under incubation and the fry in the early stages of development are subject—"white spot," "blue sac," etc.—may be traced, as a rule, to careless and improper methods of taking the spawn or handling the eggs during the incubation period. Sand sprinkled generously on trough or pond bottoms will facilitate the removal of the coating of slimy substance that frequently forms, and a small amount of salt occasionally mixed with the food is beneficial.

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