24.—METHODS EMPLOYED AT CRAIG BROOK STATION IN REARING YOUNG SALMONOID FISHES.

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The station of the U. S. Fish Commission at Craig Brook was founded in 1889, on the same site where, in 1871, the first attempt at the artificial spawning of salmon in the United States was made. This site had been selected by the commissioners of fisheries of the States of Maine, Massachusetts, and Connecticut for that experiment because of its proximity to the salmon fisheries of the Penobscot River and the facilities presented for the maturing of the spawn that might be obtained The collection of spawn has been carried on in the vicinity annually from 1871 to the present time, with the exception of the three years 1876, 1877, and 1878, and since 1879 the development of the spawn has been conducted constantly at Craig Brook. No attempt was, however, made to rear the fry of any species until 1886. Two years later it was definitely determined to found a permanent station at Craig Brook, and in 1889 the purchase of the grounds was effected and permanent improvements begun.

The station is located in the town of Orland, Me., 7 miles east of Bucksport, a seaport on the Penobscot River. Its territory embraces a tract of land extending between Allamoosook Lake and Craig Pond and embracing within its limits the entire length of Craig Brook, which connects those two bodies of water. Its latitude is about 44° 42′ N. The mean annual temperature and precipitation are believed to approximate those of Orono, 25 miles distant, namely, 42·48° F. [5·8° C.] and 45·44 inches [116 cm.]. The range of air temperature observed at the station is from 18° F. below zero to 92·5° F. above [—27·7° C. to 33·6° C.]. Frosts not infrequently occur as late as the 1st of June and as early in autumn as the first week in September. The lakes in the vicinity are commonly covered with ice before the end of November, and they are not often released until near the end of April.

The water supply is derived from Craig Brook and from three large and several lesser springs. The source of the brook is Craig Pond, which affords a constant supply of exceedingly transparent water, warm in summer and cold in winter, moderated, however, in both extremes by the water from the springs, which mingles with the brook in its lower course, forming about a third of its volume. It is this mixed water which is mainly used in the rearing of fish. Its temperature ranges from 34° F. [1·1° C.] to 70° F. [21·1° C.]. The lowest monthly mean in 1893 was 35·8° F. [2·1° C.] in February. The highest was 64·6° F. [18·1° C.] in August. The total volume is variable, ranging from 875 to 3,000 gallons and averaging about 1,200 gallons per

minute. The difference of level between the source and mouth of the brook is about 190 feet. The sharpest descent is just above the hatchery and rearing troughs, which therefore receive well-aërated water. The conformation of the ground offers good facilities for the distribution and utilization of the water.

The leading motive in the foundation of this station was the desire to apply to the Atlantic salmon the system of rearing fish to the age of at least several months before liberating them. This motive has determined not only the principal subjects of the work, but also to a considerable extent the fixtures and methods. The scheme of work was determined in outline several years before the acquisition of full title to the premises, and, circumstances rendering it desirable to enter at once on its development, it became necessary to have recourse to movable apparatus, pending authority for permanent improvements. Hence the erection of a series of small troughs in the open air, which gave such excellent satisfaction that enlargement took the same direction; and it has thus come about that the rearing operations of the station down to the present time have been almost exclusively conducted in open-air troughs. A series of ponds has been constructed, but with the exception of a few small ones none of them have been as yet brought into use.

The troughs are for the most part such as are used in the hatchery for the maturing of spawn, and their form and size have been adapted to the hatching apparatus which has been in use at the Maine station for many years. The eggs are developed on wire-cloth trays measuring 12½ inches in width and length, and the troughs are therefore 12¾ inches wide. Their depth is 9 inches and their length is 10 feet 6 inches. Such short troughs were adopted for two reasons: (1) It was thought that a greater length might involve the exposure of the eggs near the lower end to the danger of a partial exhaustion of the air from the water by the eggs above them; (2) these short troughs are very convenient to cleanse and to move about for repairs or other purposes. They are made of pine boards seven-eighths inch thick. On the inside they are planed and varnished with asphaltum. When used for rearing fish each trough is fitted with a pair of thin wooden covers reaching its entire length, hinged to the sides and meeting each other, when closed, at a right angle, forming, as it were, a roof over the trough. When closed they protect from predatory birds and other vermin; when open they are fixed in an upright position, in effect adding to the height of the sides and preventing the fish jumping out. The time spent in opening and closing the troughs is by this arrangement reduced to a minimum.

Water is fed through wooden tubes, and the volume admitted is regulated by slides. The exit of the water is through another tube or hollow plug standing upright near the lower end of the trough, and by its height governing the depth of the water. The outlet tube is movable and is taken out in cleaning. A wire-cloth screen just above the outlet tube prevents the fish escaping.

In a trough of standard size 2,000 fry are generally placed, and to accommodate the large numbers of fish reared we bring into use sometimes nearly 200 troughs, which are of necessity placed in the open air. They are arranged in pairs with their heads against the feed troughs, supported by wooden horses at a convenient height from the ground. They are given an inclination of about 2 inches to facilitate cleaning.

The volume of water fed to each trough has varied from time to time, but is ordinarily about 5 gallons per minute, which renews the water every four minutes. The ordinary arrangement is to use the water but once in the troughs, letting it waste

into some small ponds in which yearling and older fish are kept; but there is one system of 52 troughs arranged in four series, which use in succession the same water. From these we have learned that young salmon thrive quite as well in the fourth series as in the first. Indeed, by an actual test, with fish of like origin and character in each series, the fish reared in the fourth series were found to grow faster, to an important degree, than those in the first. This phenomenon probably resulted from a somewhat higher temperature which the water acquired in passing through the several series. A like observation has been made on a few salmon maintained for a few weeks in the warmer water of a neighboring brook.

As already stated, the activity of the station has been mainly occupied with Atlantic salmon, but there have been reared each year a few landlocked salmon and brook trout, and occasional lots of other salmonoids, such as Loch Leven, Von Behr, Swiss-lake, rainbow, and Scotch sea trout. All these have received the same treatment. With the exception of the rainbow trout, they are all autumn-spawning fishes, and their eggs hatch early in the spring.

The embryos of salmon begin to burst the shell in the month of March, and the 1st of April may be stated as the mean date of hatching. If the open-air troughs are in order—and we aim to have them so—the eggs are counted out into lots of 2,000 or 4,000 each and placed before hatching in their summer quarters. The water is at that time very cold, the development of the alevins is slow, and it is not until the latter part of May that the yolk sack is fully absorbed. June 1 is, therefore, the date when feeding is ordinarily begun. The growth of the fish is at first slow, the water being still cool, but is accelerated as the summer passes away. In October and November, beginning commonly about the middle of October, most of the fish are counted out and liberated, but a small number, rarely more than 15,000, being carried through the winter at the station.

The reserved fish are sometimes left until midwinter in their summer quarters, and with a careful covering of the conduits and banking of the troughs themselves with coarse hay and evergreen boughs it is possible to keep them there the year round; but for ordinary winter storage there is provided a system of sunken tanks covered by a rough shed with a constant water supply. These tanks are molasses hogsheads, securely hooped with iron, sunk nearly their entire depth into the ground, each with an independent water supply and waste, the perforation for the latter being near the surface. They have a capacity of from 100 gallons of water upward, and will carry safely each 500 to 700 fish in their first winter, that is, just approaching the age of one year. This arrangement has answered its purpose fairly well, and in a very rigorous climate or where the water is very cold it is to be recommended; but since its construction it has been discovered that at Craig Brook it is not at all difficult to protect the ordinary troughs in such a way as to insure their safety from freezing, and their attendance through the winter is less troublesome than that of the sunken tanks.

A list of the articles employed for food at the station since its foundation, if designed to include those used on an experimental as well as a practical scale, would be a long one, and I will content myself with naming the following: On a practical scale we have used butcher's offal, flesh of horses and other domestic animals by the carcass, fresh fish, maggots; and on an experimental scale, pickled fish, fresh-water mussels, mosquito larvæ, miscellaneous aquatic animals of minute size. In the pro-

duction of maggots we have also made use of large quantities of stale meat from the markets and some barrels of fish pomace, in addition to the articles mentioned above.

The butcher's offal comprises the livers, hearts and lights of such animals as are slaughtered in Orland and Bucksport—mainly lambs and veals. These are collected from the slaughter-houses twice or thrice weekly, and preserved in refrigerators until used. The quantity of such material to be had in the vicinity has been inadequate to our needs and we have been compelled to look in other directions for food.

The flesh of horses has been used only during the season of 1893. Old and worn-out horses and those hopelessly crippled or dying suddenly have been bought when offered, and used in the same way as the butcher's offal; the parts that could be chopped readily have been fed direct to the fish so far as needed, and other parts have been used in the rearing of maggots. The season's experience has been so satisfactory that greater use will be made of horse flesh hereafter.

Next to the chopped meat, maggots have constituted the most important article of food, and their systematic production has received much attention. A rough wooden building has been erected for the accommodation of this branch of the work, and one man is constantly employed about it during the summer and early autumn months. The maggots thus far employed are exclusively flesh-eaters, mainly those of two undetermined species of flies—the first and most important being a small, smooth, shining green or bluish-green fly occurring at the beginning of summer and remaining in somewhat diminished numbers until October, and the other a large, rough, steel-blue fly that makes its appearance later and in autumn becomes the predominating species, having such hardiness as to continue the reproduction of its kind long after the occurrence of frosts sufficiently severe to freeze the ground.

In outline the procedure is to expose the flesh of animals in a sheltered location during the day, and when well stocked with the spawn of the flies to place it in boxes which are set away in the "fly house" to develop; when fully grown the maggots are taken out and fed at once to the fish. The materials used for the enticing of the flies and the nourishment of the maggots have been various. Stale meat from the markets has been perhaps the leading article, but we have also used such parts of the butcher's offal and of the horse carcasses as were not well adapted to chopping; fish, fresh, dried or pickled; fish pomace from herring-oil works, and any animal refuse that came to hand. Fresh or slightly tainted meat has been used to greater extent than any other material, and has proved itself equally good with any. Fresh fish is very attractive to the flies, and when in just the proper condition may be equally good with fresh meat, but some kinds of fish are too oily, for instance, alewives and herring, and all sorts thus far tried are apt to be too watery. A very limited trial of fish dried without salt or smoke indicates that it is, when free from oil, a very superior article; it has, of course, to be moistened before using. Its preparation presents some difficulties, but in winter it is easily effected by impaling the whole fish on sticks and hanging them up, (after the manner of alewives or herring in a smokehouse) under a roof where they will be protected from rain without hindering the circulation of air; in this way we have dried many flounders and other refuse fish from the smelt fisheries, which are conducted with bag nets in the vicinity of Bucksport. Doubtless a centrifugal drying machine might be successfully used for

this purpose in summer. Pickled alewives, freshened out in water, have been found to answer fairly well, when other materials are lacking, at least to give growth to maggots otherwise started. Fish pomace has not thus far given satisfaction, but seems worthy of further trial.

It is commonly necessary to expose meat but a single day to obtain sufficient fly spawn; the larvæ are hatched and active the next day, except in cool weather, and they attain their full growth in two or three days. To separate them from the remnants of food and other débris was at first a troublesome task. It is now effected as follows: the meat bearing the fly spawn is placed on a layer of loose hay or straw in a box, which has a wire-cloth bottom, and which stands inside a slightly larger box with a tight wooden bottom. When full grown the maggots work their way down through the hay into the lower box, where they are found nearly free from dirt. When young salmon or trout first begin to feed they are quite unable to swallow full-grown maggots. Small ones are obtained for them by putting a large quantity of fly spawn with a small quantity of meat, the result being that the maggots soon begin to crowd each other and the surplus is worked off into the lower box before attaining great size. No attempt is, however, made to induce the young fish to swallow even the smallest maggots until they have been fed a while on chopped liver.

In the above methods maggots are produced and used in considerable numbers, sometimes as many as a bushel in a day. Through September, 1893, although the weather and some other circumstances were not very favorable, the average daily production was a little over half a bushel. They are eagerly eaten by the fish, which appear to thrive on them better than on dead meat. Having great tenacity of life, if not snapped up immediately by the fish they remain alive for a day or two, and, as they wriggle about on the bottom, are almost certain to be finally eaten; whereas the particles of dead flesh that fall to the bottom are largely neglected by the fish and begin to putrefy in a few hours. In the fish troughs there are, therefore, certain gains in both cleanliness and economy from the use of maggots which may be set down as compensating the waste and filthiness of the fly-house.

As the growth of maggots can be controlled by regulation of the temperature, it is possible to keep them all winter in a pit or cellar, and advantage is taken of this to use them during winter as food for fish confined in deep tanks not easily cleaned.

The offensive odors of decaying flesh may be largely overcome by covering it, on putting it away in the boxes, after the visits of the flies, with pulverized earth, and it is not improbable that by this or some other method the business may be made almost wholly inoffensive, but in its present stage of development it is too malodorous to admit of practice in any place where there are human habitations or resorts within half a mile of the spot where the maggots are grown.

As remarked above, only flesh-eating maggots have yet been tried. It would be well worth while to experiment with the larvæ of other species, such as the house fly, the stable fly, etc. There is also a white maggot known to grow in heaps of seaweed. Should the rate of growth of either of these species be found to be satisfactory they might be substituted for the flesh maggots with advantage.

Occasional use has been made of fresh fish for direct feeding. When thrown into the water after chopping it breaks up into fibers to such an extent that it is not very satisfactory, and I do not suppose we shall use it in the future, unless in a coarsely

chopped form for the food of large fish. A few barrels of salted alewives have been used, and if well soaked out and chopped they are readily eaten by the larger fish and can be fed to fry, but are less satisfactory with the latter, and like fresh fish they break up to such an extent that they are only to be regarded as one of the last resorts.

Fresh-water mussels have been occasionally gathered in the lake close to the station when there has been a scarcity of food. Those employed belong almost wholly to a species of *Unio*, which abounds over a considerable area of soft bottom, under a depth of 2 to 10 feet of water. Many were taken with a boat dredge; more were scooped up with long-handled dip nets of special construction. Finally a wide, flat dredge was made, to be drawn by a windlass on the shore and manipulated by means of poles from a large boat. When needed for food the mussels were opened with knives—a great task—and chopped. The meat is readily eaten by all fishes, and appears to form an excellent diet. Being more buoyant than any other article tried, it sinks slower in the water and gives the fish more time to seize it before it reaches the bottom, a consideration of considerable practical importance. The labor involved in dredging and shelling is a serious drawback, but were the colonies of unios sufficiently extensive or their reproduction rapid enough to warrant expenditure of time in experimentation, improved methods might be devised, which would put this food-source on a practicable basis.

During the seasons of 1886 and 1888 some use was made of mosquito larvæ. Near the station is an extensive swamp where these insects breed in great numbers. From the pools of water the larvæ were daily collected by means of a set of strainers specially devised for this use. Barrels filled with water were also disposed in convenient places near the rearing troughs, and were soon swarming with larvæ from the eggs deposited by the mosquitoes on the surface of the water. When near the completion of their growth, which was only some ten days after the deposit of the eggs, the larvæ (or pupæ) were strained out and fed to the fish. No kind of food has been used at this station that has been more eagerly devoured, and so far as our observation has gone no other food has contributed more to the growth of the fish; indeed, I am inclined to put them at the head in both respects. It was found, however, that the time expended in collecting them was out of all proportion to the quantity of food secured, and pending opportunity for further experiment their use was discontinued. I think it quite possible that an arrangement might be devised whereby the greater part of the labor might be saved. Perhaps a series of breeding tanks arranged in proximity to the fish troughs, into which the water containing the larvæ might be drawn when desirable by the simple opening of faucet, would solve the problem.

Various methods of serving the food have been tried, but at present everything is given with a spoon. The attendant carries the food with the left hand—in a 2-quart dipper if chopped meat, in a larger vessel if maggots—and, dipping it out with a large spoon, strews it the whole length of the trough, being careful to put the greater portion at the head, where the fish nearly always congregate. Finely chopped food, for very young fish, is slightly thinned with water before feeding. At one time the finest food was fed through perforations in the bottom of a tin dish; the food was placed in the dish, which was dipped into the water a little and shaken till enough of the food had dropped out of the perforations; this practice was laid aside because it was thought that the food was too much diluted. In feeding maggots it was, at first,

the practice to place them on small "feeding boards" of special construction suspended over the water in the troughs and let them crawl off into the water; but whatever advantage this method may have had in furnishing the meal to the fish slowly was more than counterbalanced by the extra labor of caring for the boards and by the offensive odor, and it was abandoned. For use in feeding fish in a pond a box containing a series of shelves, adown which the maggots slowly crawl, was found sufficiently useful to be retained.

It is the common practice to feed all meat raw except the lights, which chop better if boiled first, except also occasional lots of meat that are on the point of becoming tainted and are boiled to save them. All meats fed direct to the fish are first passed through a chopping machine. The machine known as the "Enterprise" is the one now in use. It forces the meat through perforated steel plates. The plate used for the smaller fish has perforations $\frac{3}{32}$ inch in diameter, and for coarser work there are two plates $\frac{3}{16}$ inch and $\frac{3}{8}$ inch, respectively. It is operated by a crank turned by hand. Food is given to those fish just beginning to eat four times a day (in some cases even six times). As the season progresses the number of rations is gradually reduced to two daily. In winter such fish as are carried through are fed but once a day.

The cleaning of the troughs has been a troublesome matter, and the subject of much study and experiment, but nothing more satisfactory has been found than the following practice: The troughs are all to be cleaned daily—not all at one time, but as time is found for it in the intervals of other work. To facilitate cleaning, the troughs are inclined about 2 inches. The outlet is commanded, as already explained, by a hollow plug. When this is drawn the water rushes out rapidly and carries most of the débris against the screen. The fishes are excited, and, scurrying about, they loosen nearly all dirt from the bottom; what will not otherwise yield must be started with a brush, but after the first few weeks the brush has rarely to be used except to rub the débris through the outlet screen. Owing to the inclination of the trough the water recedes from the upper end until the fishes lying there are almost wholly out of water, but, although they are left in that position sometimes for 10 or 15 minutes, no harm has ever been known to result.

It has been the common rule at the station to count all the embryos devoted to the process of rearing, either before or after hatching; to keep an accurate record of losses during the season, and to check the record by a recount in the fall. When eggs are counted they are lifted in a teaspoon.

The counting of small fish is effected in this way: The fish are first gathered in a fine, soft bag-net, commonly one made of cheese-cloth, and from this, hanging meanwhile in the water, yet so that the fish cannot escape, they are dipped out a few at a time, in a small dipper or cup, counted, and placed in a pail of water or some other receptacle. This counting is generally preliminary to weighing, and in this case the fish, after counting, are placed in another bag-net, in which they are lowered, several hundred at a time, into a pail of water which has been previously weighed, and the increase noted. With care to avoid transferring to the weighing pail any surplus water, this is a correct method and very easy and safe for the fish.

In conclusion, I submit some estimates of cost. In September, 1893, we fed fry that were estimated at the close of the month to number 238,300. There were also a few hundred larger fish. From the known total outlay for food, attendance, and

superintendence a suitable allowance is made for the maintenance of the older fish, and the balance is charged to the fry. By this method we arrive at the following results:

Cost.	Total.	Per fish.
Food	$155.00	$0.00065
Attendance	99.79	.00042
Superintendence	205.96	.00086
Total	460.75	0.00193

Applied to the rearing operations of 1891, a similar calculation gives us this result: The fry that were carried through the season from June to October, inclusive, cost, for food, attendance, and superintendence, $0.0081 each; that is, about four-fifths of a cent each for the term of five months.