NOTES ON THE PLANTING OF

SALMON AND TROUT FRY

By N. B. SCHOFIELD
Of the California Fish Commission.

A REPORT ON THE PLANTING OF QUINNAT SALMON FRY IN THE SHORT COAST STREAMS OF MARIN COUNTY, CALIFORNIA,

WITH RESULTS OF OBSERVATIONS MADE UPON THEIR MOVEMENTS, FOOD, RATE OF GROWTH, ENEMIES, ETC.

By N. B. Schofield, of California Fish Commission.

DESCRIPTION OF PLATES. The three accompanying plates are to illustrate the rate of growth of Quinnat salmon fry from the streams of Marin County, California.

In Plate I are four outline figures of the fry at progressive ages. Fig. 1 represents the young salmon with yolk sac just absorbed; Fig. 2, 25 days after absorption of yolk sac; Fig. 3, 46 days after absorption of yolk sac; Fig. 4, 62 days after absorption of yolk sac. Figures 1, 2, 3, and 4 are from specimens 1.35, 1.7, 2.51, and 2.98 inches, respectively.

Plate II represents a young Quinnat salmon taken in brackish water, 107 days after absorption of yolk sac—showing loss of markings below lateral line and the faded out parr marks, caused by the brackish water. Drawn from an average specimen 3.2 inches long. This drawing should be compared with Plate III, which figures a young salmon from fresh water.

Plate III shows a young Quinnat salmon taken in fresh water 162 days after absorption of yolk sac. Drawn from an average specimen 3.55 inches long.

The planting of Quinnat salmon fry in the short coast streams of Marin County was primarily an experiment. The Quinnat salmon has never been known to spawn in these streams, probably due to their proximity to the Sacramento River, which is the popular spawning ground for the salmon of this region. (North of the Russian River, the Quinnat spawns in the small streams as well as in the larger rivers of the coast.)

Paper Mill Creek and its tributaries are exceptionally rich in aquatic insect life, affording an abundance of food for the fry; and the absence of predaceous fishes, excepting the trout and blob, make them apparently better streams for the rearing of young salmon than the Sacramento. It was thought that if the fry could thrive in these streams and pass successfully into salt water, it would be of advantage to utilize coast hatcheries and plant in the smaller streams where the young salmon would not be subjected to their enemies like they are during the long journey from the upper Sacramento to the sea.

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later, they were fed for a few days on curds of milk, and then, in the second week of March, were turned into Paper Mill Creek and its tributaries—Nicasio, Olema, and Hatchery creeks. The fry were strong and healthy, and as the streams were near the hatchery, and the fish were in no case over two hours in transportation, they were turned into the streams in the best of condition.

The young salmon were watched day after day and systematic observations made upon their movements, habits, etc. The work was first begun by the United States Fish Commission, and carried on until the middle of May. After a break here of three weeks, the California State Commission carried it on to completion.

The thing to be feared in this experiment was that the streams would prove too short and that the young salmon would arrive at salt water before they were ready to conform to the kind of life they would have to lead there.

The observations carried on in connection with the fate of these young salmon fully demonstrate the success of the experiment and prove that the fry can be as safely planted in these streams as in the Sacramento. They grew more rapidly than the same fry in the Sacramento, had fewer enemies, and passed successfully into salt water and thrived there.

By far the most interesting part of the experiment was the knowledge gained as to the habits, enemies, and growth of the fry after being turned loose. The streams being free from any young salmon but those planted from the hatchery, an excellent opportunity to observe the rate of growth was afforded. Any knowledge in this line is of great economic importance, as it enables us to more intelligently choose the right time and place to plant the fry, and proves that they do not require two or even three years to reach salt water.

DESCRIPTION OF STREAMS.

Paper Mill Creek, the largest stream in Marin County, rises in the high land just north of Golden Gate, and runs northwest for about twenty-five miles, where it empties into Tomales Bay after passing through a three-mile stretch of tide water. The bay continues a very narrow stretch of water in the same northwesterly direction for thirty miles before the open sea is reached. Paper Mill Creek is formed by the junction of the San Geronimo and Lagunitas, each of which is quite small, the water cold and swift, running over a rough rocky bottom, and everywhere overhung with trees and bushes. After uniting to form the main stream, the water frequently runs over quiet stretches of gravelly bottom, but for the most part the bed is rough and rocky and there are many cascades and deep rocky pools. The stream for nearly its entire length is well shaded with overhanging trees. The width of the stream in its normal state is about fifty feet, and its depth averages about two

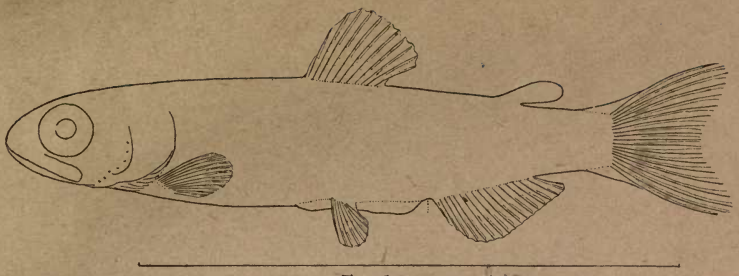

FIG. 1.

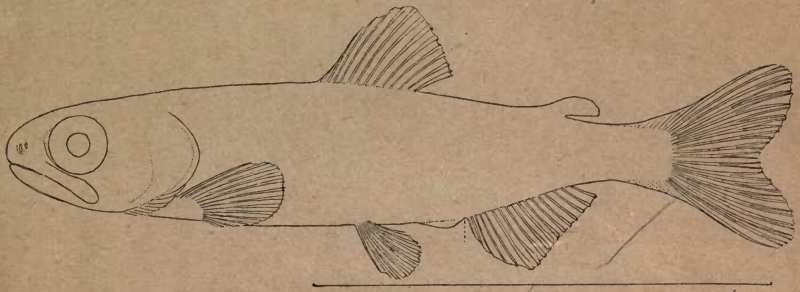

FIG. 2.

FIG. 3.

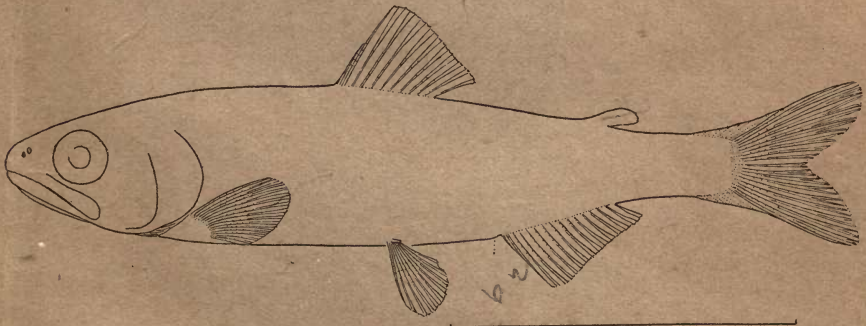

FIG. 4.

PLATE I—SALMON FRY.

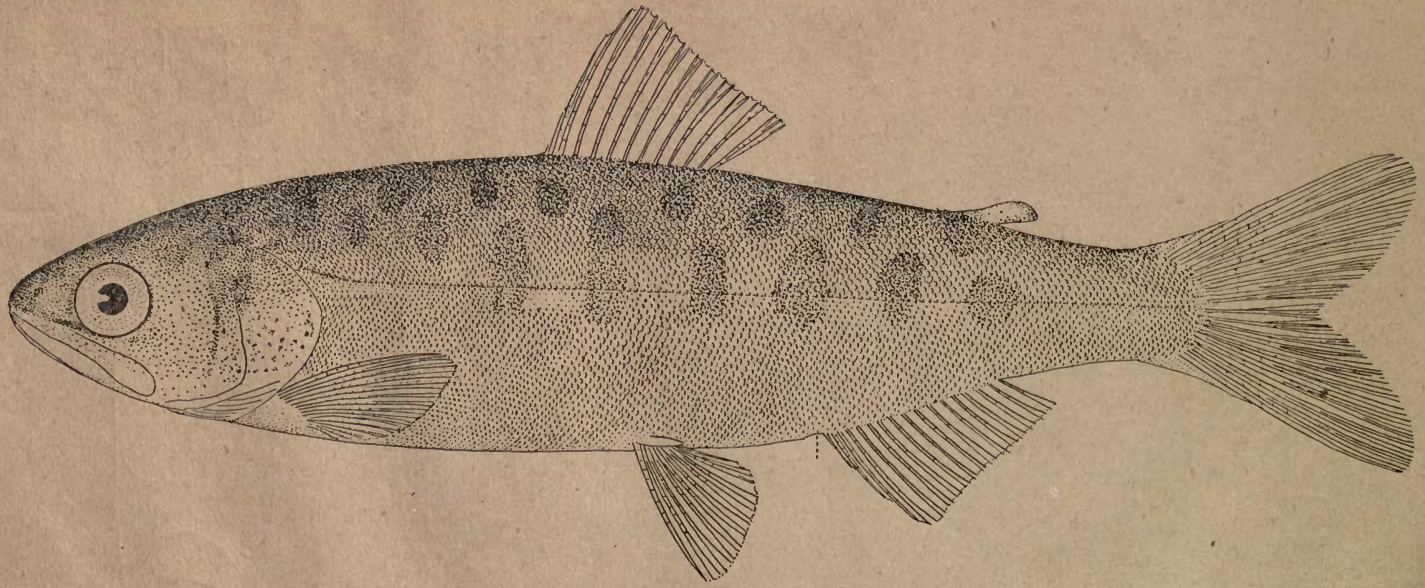

PLATE II.—SALMON FRY.

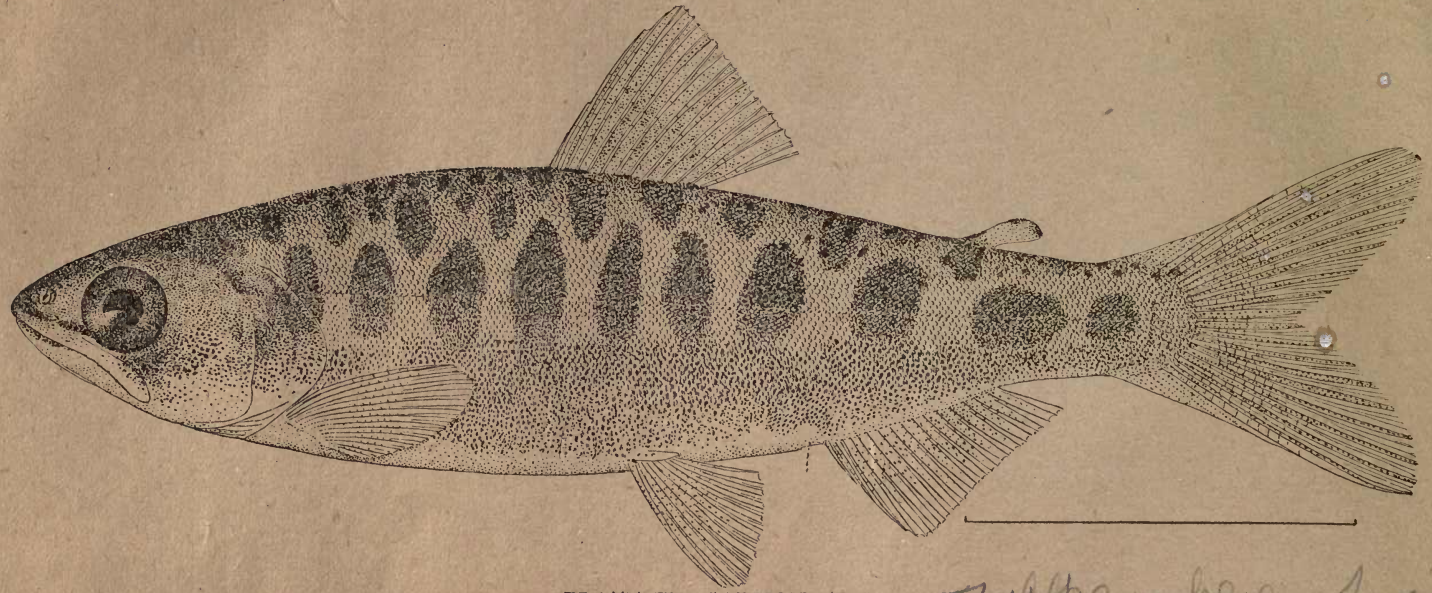

PLATE III—SALMON FRY.

feet, but its size is increased enormously after each heavy rain. The water in the upper end of Paper Mill Creek during the six months after planting the fry had an average maximum temperature of 64°, while at the lower end in tide water the average was 71°.

Nicasio Creek rises to the east of Paper Mill Creek, and flows into it about five miles above tide water. Nicasio Creek is very much smaller than the Paper Mill, being only about twenty feet wide, with an average depth of six inches. Throughout its length it flows over flat, gravelly beds, with few trees or bushes to shade the water. The sun has full sweep at it and heats the water each day during the summer to a temperature of 75° or 80°.

Olema and Hatchery creeks rise to the west of the main Paper Mill, and flow almost parallel to it, emptying into it near together about one mile below upper tide-water mark. Olema Creek is about the size of Nicasio, but carries more water during the dry season. The water, too, is much cooler, and the upper stream has more of the character of the upper Paper Mill. The banks are thickly grown with brush and trees. The last two miles of the creek runs through low swampy land, with its banks most of the way heavily lined with willows. The average maximum temperature for lower Olema was 63°, and the upper stream averaged but one degree colder.

Hatchery Creek is very much smaller than Olema Creek, and is not nearly so long. At first fed by springs and running through cool, shady woods, the water is quite cold, but on gaining the open valley and running through two miles of marshy lowlands, with but little shade, it becomes, on reaching Paper Mill Creek, even warmer than the water in Olema Creek. The average maximum temperature of the upper Hatchery Creek was 54°, while at the lower end the average was 64°.

The species of fish found in these streams are limited to four. The most important is the steelhead (*Salmo gairdneri*), which runs in from salt water each winter and spawns in the streams, keeping them well stocked with young trout. About the most abundant fish is the "chub" (*Rutilus symmetricus*). The "stickle-back" (*Gasterosteus cataphractus*) and "blob" (*Cottus gulosas*) are fairly abundant. Occasionally the dog salmon (*Oncorhynchus keta*) enters these streams and spawns.

Tomales Bay, nowhere deep, grows very shallow at its upper end, where it receives Paper Mill Creek. No bar ever forms across the mouth of the creek, as is the case in most of the small coast streams, but is always open for fish to run either in or out. Temperature of Tomales Bay at its upper end averaged 70°.

THE PLANTING OF THE FRY.

The young salmon at the time they were turned loose had an average length of 1.35 inches. On being liberated from the cans they scattered in all directions, the swift current at first carrying them some distance down stream. But they soon recovered, and turned their heads against the strong current, and found their way immediately to the quieter waters along the shallow edges, in eddies, quiet pools, or among the stones at the bottom of the stream. Some few would even move a few yards up stream, and demonstrated that they were able to hold their own even against a very swift current. On gaining quieter waters they rested themselves, moving only enough to keep from drifting down stream. As soon as they gained a position of this kind they immediately began feeding on any particles of food that floated within their sight; often snapping viciously at flies half as large as themselves. Each individual acts for himself. They do not run in schools, and no more than two or three are found together unless the nature of the stream compels it. In eddies and pools they are thrown together, but in a long, shallow, quiet stretch of water they scatter out—each one taking a position in the eddy of a small stone, or other object, where they have to barely move a fin to keep their position, while the water above them is moving swiftly. Lying in such places they watch for insects or any particles of food that may be floating past. They feed principally upon objects floating on the surface, but often they are seen to strike at objects beneath. After striking at an object they almost invariably return to their old position. Frequently one would be seen to move a few yards down stream and take up another similar position. The young salmon undoubtedly move down stream in this manner: moving down individually and by dropping a few feet at a time.

After two weeks in the stream but very few of them were to be found in the shallow water; nearly all had moved into the deeper holes. Here they would be nearer the center of the current, where there is more floating food and where they could also hide, for by this time they are very shy, and dart into the deeper water or under a rock at one's approach. The young steelheads which hatched out shortly after this time were not nearly so shy at the same age.

Four weeks after planting, practically all had moved into the deeper holes, and as long as they remained in the streams they occupied these places. In the deep water of the lower Paper Mill, where the water was four and five feet deep, they would hang stationary in the center of the current a foot or two below the surface, darting now and then at objects on the surface.

MOVEMENT DOWN STREAM.

As before stated, the only noticeable movement down stream was the occasional movement of individuals dropping from one resting place to another. During the first three weeks after planting, the water in the streams was high and muddy, and, except in Hatchery Creek, good observations could not be made. It was only a matter of a couple of days until most of the salmon had dropped down out of the upper Hatchery Creek. If there was a similar movement of the young salmon in the other streams during the first few days I do not know; but when the first seining was done, a month after planting, the fry were found more abundant in tide water than in the upper streams where they were liberated. There can be no doubt that there was a decided movement down stream during the first month, which probably began immediately after planting.

Forty-five days after planting, the fry were found in considerable numbers in brackish water. As this was the first time seining was done in brackish water, we do not know how much sooner they reached this point. We subsequently learned that the fishermen near Marshall, fifteen miles down the bay, caught the young salmon in considerable numbers as early as the last of April, or fifty days after they were liberated. At this time for about a week they caught fifteen or twenty at a haul in their 300-foot nets. After a week they caught only two or three in a haul, and then, as the fish grew scarcer, they caught only two or three in a day's seining. After the middle of June, three months after planting, they caught no more.

It is unfortunate that we have to rely solely on the fishermen for information as to when the salmon reached salt water. Information obtained in this way cannot usually be relied upon, but the young salmon was a new fish in the bay and the fishermen could not help noticing it. The stories of the different fishermen agree so well that in this case it is safe to rely on them.

The first seining in the bay was on April 29th, fifty days after planting, on which day we caught one of the young salmon. This was at a place about two miles from the mouth of Paper Mill Creek. The seining was done with a thirty-foot net, and although we seined almost daily in the bay after this and with a fifty-foot net, not another salmon was caught.

The young salmon were found in brackish water, near the mouth of Paper Mill Creek, up to the 11th of May, two months from the time of planting. This date probably marks the end of the run. Those that remained, continued to go out a few at a time, until by the sixth month but very few were left in the streams. After the sixth month no seining was done until the eleventh month, which was after the winter rains. After the most thorough seining at this time only three of the fry could be found, showing that practically all had run out before the end of the year.

By the middle of the second month, when the water had become clear enough to watch the young salmon from the bank, it was found that they retained their positions in the current for hours without moving down stream even for a few feet. In one instance an albino (one without color) kept one position for three days, after which it could not be found either above or below its old position. These facts all tend to show that there was a decided movement of the salmon down stream during the first month, and after that time they moved out much slower. It probably took the rains of the next winter to drive them all out.

We tried another experiment. By stretching a net across a narrow place near the mouth of Paper Mill Creek as the tide was coming in, it was demonstrated that the salmon play back and forth with the tide before passing into salt water, as they repeatedly ran into the net ahead of the tide when it was fixed in this way.

MOVEMENT UP STREAM.

In all of the streams except Hatchery Creek the fry were planted where they could easily move up stream two or three miles if they so desired. The streams were carefully seined above the planting places to determine to what extent they moved up stream. In Nicasio Creek only a very few had moved up, and they had gone but a fourth of a mile above where they were liberated. We found a few in Olema Creek a fourth of a mile above where they were planted. In Paper Mill Creek I found that none had moved up stream. All of the side streams were seined to see if the fry had entered any of them, but it was found that they had entered only one—a very small stream fed by springs flowing into lower Hatchery Creek. The water in this small stream was much colder than the water in the creek and was grown full of water cress. Nearly a hundred of the fry had entered this and were found as far up as they could get. Some had even found their way through a perfect mat of grass and drifted rubbish. The current in this stream was very slow, and it entered the creek at such an angle that it was a sort of trap, and I have no doubt the fry got in there in trying to get down stream. Although some of the fry do work up stream for a short distance, they are the exception. Why they move down stream we do not know, and we will have to credit it to instinct. A young steelhead or other trout when frightened prefers to dart up stream rather than down, and if one wades down stream and attempts to drive them before him he will find that they will not drive, but will dart between his legs or around him in their frantic efforts to get up stream. Knowing this trait of the fish, in seining for them the net is always hauled down stream. With the salmon fry it is different—when frightened they will run even more readily down than up stream. By walking along a small stream they can be driven either up or down. In seining for them they are caught as readily by seining against the current as with it.

GROWTH. The most important part of the work was finding the rate of growth of the young salmon while remaining in the stream. This was determined by capturing series of the fry at intervals and making careful measurements of their length.

The young salmon were put in the stream on or about the 10th of March, thirty days after hatching, at which time their yolk sacs were absorbed. At this time their average length was 1.35 inches, and the rate of growth is figured from this time. Although the rate of growth could have been determined more accurately had larger series of fry been saved, it is accurate enough to demonstrate a remarkable growth and to enable us to make comparisons between the different streams and different parts of the same stream. It also gives us some idea what to expect in larger rivers.

The most rapid growth was during the first month, at the end of which time they had, in the lower stream, reached an average length of 2.28 inches; a gain for the month of .93 of an inch. A few individuals reached a length of 2.40 inches.

Through the second month the growth was not quite so great, and during the third and fourth months correspondingly less. At the end of the second month the salmon in the lower end of the creeks averaged 2.98 inches in length, and a few had reached a length of 3.1 inches.

During these first two months the fish in the lower streams averaged considerably larger than those above. At the end of the first month those above averaged 1.71 inches, against 2.28 inches for those below. At the end of the second month those above averaged 2.75 inches against 2.98 below.

After two months there was no marked difference between the salmon in the lower streams and those above, except in Hatchery Creek, where those above remained very small.

At the end of four months the average length of the salmon was 3.35 inches. The rate of growth during the four months, taken from an average of all the salmon retained, was .52 of an inch per month. After four months this rate of growth fell off very considerably, and at the end of the fifth month they had reached an average length of only 3.46 inches. After the middle of the sixth month no more seining was done in the streams until the following February, or eleventh month, when one salmon was found in Olema Creek measuring 3.64 inches. On April 14th, thirteen months after planting, another was found in Olema Creek 4.45 inches long. One other was found in Olema Creek, of which I have no measurements.

Nearly all the salmon had run out of the streams by the end of the fourth month, and those remaining after this time were evidently stunted individuals, as is shown by their very slow growth. An instance proving this is shown in the following: In March, 5,000 of the

fry were put in Bear Valley Creek, which is dammed at its lowest end and fixed with a screen so that the fish cannot get out. Here, eleven months after planting, two salmon were caught, each measuring 5.5 inches. At the same place, fifteen months after planting, two specimens were caught, one 6 inches, the other 7.5 inches long. This remarkable growth in a stream where they were confined is another point that leads to the belief that the salmon which preferred to remain, after four months, in the streams where they were not confined were individuals stunted or the physical inferiors of those running out during the first four months.

The growth of the salmon was the same in Paper Mill, Nicasio, and Olema creeks, but in Hatchery Creek the growth was not so rapid. The salmon in the lower end of the creek grew rapidly enough, but those above grew very slowly, gaining on an average the first three months only .15 of an inch per month. At the end of the fourth month they had all descended to the lower stream. The reason of this slow growth in the upper stream was due to the scarcity of food. Although the temperature of the water there is much lower than it is below or in the other streams, we cannot, knowing what we do of their growth in other cold streams, attribute their slow growth to the temperature of the water.

Owing to this difference in growth in the same stream, the variation in the size of the individuals is great. Out of thirteen specimens taken from lower Hatchery Creek at the end of three and one-half months, the largest was 3.53, the smallest 2.26 inches, a difference of a little over 1.25 inches; or, expressed in the amount gained by each since planting, the largest 2.18 inches, the smallest 0.91 of an inch. The variation in Olema Creek, where no difference was found between the upper and lower stream, after the second month was nearly as great. From seventeen specimens taken at the mouth at the end of three months the largest was 3.42, the smallest 2.58 inches.

The important points learned in connection with the rate of growth of the young salmon were: *First*, that during the first four months their growth averaged 0.52 of an inch per month; *Second*, that the few salmon remaining in the stream after four months were stunted, and grew very slowly in comparison with those confined in Bear Valley Creek.

An important fact to be noted in connection with the salmon confined in Bear Valley Creek is, that of the two salmon taken in February, 1898, both were males; one with the generative organs fully developed. It is not uncommon to find young 4 to 4½ inch male salmon remaining in the streams with the testes fully developed, but it was never before found in a salmon whose age was known. This individual found in Bear Valley Creek was 5.5 inches in length, and was just twelve months

old. It should also be noted that it was no smaller than the other male salmon taken at the same time. Evidently the development of the sexual organs did not retard its growth.

Although these young male salmon are occasionally found with the generative organs prematurely developed, no females, to the best of my knowledge, have ever shown such development. This premature development peculiar to the males, accounts for the undersized males, or "grilse," accompanying each run of salmon up the rivers, and it tends to prove that such "grilse" are not stunted individuals, but simply that they have matured at an earlier age and are younger than the salmon which they accompany.

THE AGE OF THE "GRILSE."

The following is a mere speculation in regard to the age of the above mentioned "grilse": We have already seen that one out of the two males taken in Bear Valley Creek at the age of one year was sexually mature. In the headwaters of the Sacramento we have in November found among the young salmon remaining in the streams several sexually mature males, which at that time were under ten months of age. These few examples which have come to my notice represent a very small percentage of the number that must mature within ten months or a year in the large body of salmon that leave the stream immediately after hatching. Reaching maturity they would naturally follow the next run of salmon up the river. There are two runs of salmon up the Sacramento each year; the fall run starting up the river about the end of July and reaching the spawning beds at Battle Creek in October. The eggs spawned by this run hatch in January and February. Ten months after hatching, at which time the "grilse" would have matured, would be too late for them to catch the next fall run up the river, but they could catch the next spring run, which starts up the river in April, and reaches the spawning grounds in the McCloud River in June and July, the eggs hatching in October and November. The salmon hatching from this spring run get out of the river in time for the "grilse" to catch the fall run ten months later.

If this is true the "grilse" running in the spring are about sixteen months of age on reaching the spawning beds in June. Those arriving on the spawning beds in the fall are about twelve months of age. If this actually happens, the "grilse" of the spring run should average larger than those of the fall run. The age of these "grilse" can be determined by better and more extended observations, and such knowledge would be a long step toward determining the important question of how old the full-grown salmon are when they run.

FOOD. The young salmon, from the time they first begin to feed, eat almost anything they can get, but they show a preference for insects and insect larvæ, and they prefer to capture food that is floating on the surface of the water. An examination of the contents of the stomachs of the young salmon taken from Paper Mill Creek and its tributaries, from the time they were planted to the time they reached salt water, shows that their food was almost exclusively flying insects which had dropped upon the surface of the water.

These streams abound in caddice worms of three or four species, small periwinkles, the larvæ of stone-flies, may-flies, and other insects; but they were all neglected for the flies, bees, beetles, caterpillars, etc., that fall into the stream. No caddice worms or periwinkles were found in their stomachs, and but very few of the larvæ of aquatic insects. This same thing was observed in the younger trout; and although the larger trout eat large quantities of caddice worms, the insect larvæ in the water do not furnish the amount of food to these fish that is popularly supposed.

Although these salmon live almost exclusively on insects that drop upon the water, we have found in their stomachs pieces of leaves and buds, small feathers, shells of salmon eggs, and the helpless young of their own species. (See notes on planting of salmon fry before yolk sacs were absorbed, at Sisson, November, 1897.)

In the salmon taken in brackish water I found they had been eating small salt-water crustaceans, and one three-inch salmon taken in salt water had eaten six of the young of the "silver smelt" (*Atherinops affinis*) and one small leaf-hopper of the kind that is found among the pebbles along the shore of the bay.

In almost every case the stomachs were filled to their utmost with food. Tomales Bay abounds in small crustaceans and the young of the "silver smelt," and the young salmon would have no trouble in finding an abundance of food on reaching salt water.

Scarcely any vegetable matter was found in their stomachs, and what little was found no doubt was taken by accident.

If these young salmon live almost exclusively on flying insects, the way to choose a good stream for planting would be to select one with plenty of trees, bushes, and grass along its banks, for such vegetation is a harbor for insects.

ENEMIES. The principal source of danger to young fish in a stream is from predaceous fishes, or even from older fish of their own kind. Of the four species of fish in these Marin County streams—chub (*Rutilus symmetricus*), stickle-back (*Gasterosteus cataphractus*), blob (*Cottus gulosas*), and trout (*Salmo gairdneri*)—the last two only are predaceous.

After planting the young salmon, a number of these two species were caught daily, and the contents of their stomachs carefully examined. Altogether only about twenty-five specimens of *Cottus gulosas*, of size large enough to prey upon the young salmon, were caught. Out of these twenty-five, not one had eaten a fish of any kind. Thirty or forty specimens of *Salmo gairdneri* were examined daily for three weeks after planting, and in not one instance had a salmon been eaten. The only fish eaten by them was *Rutilus symmetricus*, and no more than ten of these were found in about seven hundred examined.

The other enemies to young fish observed were water snakes, kingfishers, herons, and divers. Although none of these were killed to find out what they were eating, it is safe to say that the loss of young salmon due to them was slight.

PLANTING OF QUINNAT SALMON FRY IN MARIN COUNTY STREAMS IN 1898.

In February, 1898, 2,000,000 Quinnat salmon fry were planted in Paper Mill Creek and its tributaries by the United States Fish Commission. On account of limited hatchery space and lack of funds, the fry were all planted before the yolk sacs were absorbed. The fry hatched at the same time as those liberated in these streams last year, but they were planted about three weeks earlier. The height of the water in the streams at the time of planting and during the next month was lower in 1898 than in 1897. Notwithstanding this, the salmon ran out earlier than the year before. In April there were not as many salmon left in the streams as in June of the year before. In June no salmon whatever could be found in Paper Mill Creek. Only a very few were found in Olema Creek, and they were not much more plentiful in Hatchery Creek—the same condition that existed two months later in 1897. The only reason I can give for this difference in time of running out is that they were planted at different ages. Apparently, planting before the yolk sacs are absorbed causes them to run out earlier. This brings up an important question: Does the holding of the fry until after the yolk sacs are absorbed keep them from running out as soon as they would under natural conditions?

From a series of specimens taken in April and June, it was found that their average growth was .52 of an inch per month. It should be noticed that this rate of growth during the first four months is almost exactly the same as that found for the same period in 1897—differing only .05 of an inch.

NOTES ON THE MOVEMENTS OF THE YOUNG OF THE STEELHEAD TROUT (*Salmo gairdneri*, Richardson) IN MARIN COUNTY STREAMS.

By N. B. Schofield, of California Fish Commission.

The steelheads ascend Paper Mill Creek and its tributaries regularly each year for the purpose of spawning. Late in October and early in November they appear in tide water, where they remain until the first good rains. They then ascend the creeks, and spawn on the gravel bars in December and January, reaching their height in early January.

After spawning the steelheads drop back down the stream, and remain for some time in the holes in tide water before running into salt water. Unlike the salmon, they do not die after spawning, but drop back into salt water and return to spawn again. Steelheads from the lower Paper Mill Creek examined in April after spawning showed the ovaries with the eggs forming, which would probably have matured by the next winter run.

The first young steelheads appear in shallow water along the edges of the stream after absorbing their yolk sacs late in March, but they do not appear in any great number until late in April. In 1897 they began to show themselves in considerable numbers by the 15th of April, and by the 25th the edges of the stream in places were fairly black with them. At this time they are not very shy and are not frightened when one comes near them, unless his shadow chances to fall on them. By being cautious one can with his hand scoop them out onto the bank. This cannot be done with the young salmon of the same age, as they are much more shy. These young steelheads as they lie in the shallow water kept their heads against the current, and were entirely absorbed with the task of catching something to eat—feeding in the same way as has been described in the case of the young Quinnat salmon. In a very few days they left the shallow water and moved more into the center of the stream, where there is more floating particles of food for them to catch.

By the middle of May nearly all the small steelheads had moved from the shallow, quiet water along the edges into the swift water near the center of the stream or into the deeper holes.

On the 12th of June the average length of the young steelheads was taken from thirty-three fish measured, and was found to be 2.6 inches. The age of these fish we can estimate very accurately to be fifty days, counting from the time their yolk sacs were absorbed. At the time of

such absorption their length would average less than 1.15 inches. Thus, in fifty days their actual gain in length was 1.45 inches, or considerably over three-fourths of an inch per month. This is even a more remarkable growth than that found in the young Quinnat salmon.

To get at some idea of their abundance I will copy from my notes of June 16, 1897, on seining with a thirty-foot net in upper Olema Creek: "The first haul was through a hole thirty feet wide, fifty feet long, and three feet deep in the deepest place; caught 61 young steelheads, 27 large stickle-backs, and 3 blobs. The second haul was over a riffle with pebbly bottom; hauling about thirty feet we caught 25 steelheads and 10 stickle-backs. The third haul was made through a small hole ten feet across and two feet deep, with roots of an old stump at the edge, under which they could hide. Here we caught 165 steelheads, 7 stickle-backs, and 10 blobs. The fourth haul was through a hole ten feet wide, fifty feet long, and three feet deep in deepest place; caught 152 steelheads. The fifth haul caught 100 steelheads; the sixth, 75; the seventh, 28; the eighth, 58; and the ninth, 127 steelheads. In one-fourth mile seined we caught 578 steelheads, all under three inches in length. I have estimated that we took two thirds of the steelheads in that distance. There are twelve miles of the stream in which they are just as plentiful, which would make about 37,000 young steelheads for the stream. The number in Paper Mill Creek would be from five to seven times this amount, and the number in Nicasio and Hatchery creeks would, for each, be about one fourth the number in the Olema."

"Very few, if any, of the young steelheads have moved down stream, and nearly every one to be found in Olema Creek now has been hatched this year."

A thorough seining of the streams at that time showed that there was scarcely a steelhead over three inches in length. During the summer, when the water is low and warm, the steelheads, except those hatched the same spring, nearly all run into salt water. During June, while seining for young salmon in brackish water near the mouth of Paper Mill Creek, young steelheads were caught in considerable numbers, ranging from 5½ to 6½ inches in length. In all the red colors were not lost and the dark bars on the sides were bright and distinct, showing that they had just come from the upper stream—for the bars on the sides, and especially the red markings, are quickly lost in brackish or salt water.

After the first good rain in the fall, when the streams begin to rise, the young steelheads from 6 to 10 inches long appear in large numbers in tide water, with their sides bright and silvery and the dark bar marks almost lost. They gradually work up the streams and soon their color gets darker and the dark markings more distinct. After each heavy rain there is a fresh run of these steelheads, and as the water subsides again they drop back into salt water.

There is the best of evidence that these fish do not enter the streams for the purpose of spawning. In all the seining done from January to September, not one steelhead under three pounds was found sexually mature, and none were found that showed any sign of becoming so. By questioning people resident here and familiar with the fish in these streams I find that small steelheads under two pounds are very rarely if ever found with spawn.

Rainbow trout (*Salmo irideus*) are nearly every year liberated in Paper Mill Creek, but if they live they have gone back to the habit of running back to salt water and cannot, in habits, general appearance, or structure, be distinguished from the steelhead.

Although seining was done in tide water from the time young steelheads begin to hatch until the 14th of June, none of them were caught. Up to this time they had not begun to run out, but they did run out before the next January. They probably run out when the stream is at its lowest, late in August and early in September.

NOTES ON AN INVESTIGATION OF THE MOVEMENT AND RATE OF GROWTH OF THE QUINNAT SALMON FRY IN THE SACRAMENTO RIVER.

By N. B. Schofield, of California Fish Commission.

Aided by the knowledge gained in the study of the habits, movements, and rate of growth of the young salmon in Marin County, we were better enabled to carry on the more difficult work of finding out the movements and rate of growth of the salmon fry in the Sacramento River.

The work was begun in the headwaters of the Sacramento in the neighborhood of Sisson in August, 1897, and has been continued at intervals to the present time. During the present spring the United States Fish Commission has taken up the same work in the Sacramento, and in the following report I have made free use of some of the results of their work, especially of their work in the brackish and salt water of Suisun and San Pablo bays.

To make clear what is to follow I will explain that although a few salmon may spawn in some of the tributaries of the Sacramento in almost any month of the year, the vast majority of them spawn at two separate and distinct times. Eggs deposited by the spring run hatch in October, and the eggs from the fall run hatch the following February. After hatching it is another month before they begin to swim around and feed.

The adult Quinnat salmon, in its journey up the Sacramento for the purpose of spawning, never reaches Sulloway Creek, and it very rarely reaches a point as far up the Sacramento as the mouth of the Sulloway. The young Quinnat salmon found in the Sulloway and this part of the Sacramento are from the State hatchery at Sisson, and, knowing the age of the fry liberated, it is possible to estimate very accurately their rate of growth.

On August 28, 1897, I seined Sulloway Creek, and found the salmon fry quite plentiful. To better illustrate their number, in one haul, through a hole three feet deep, ten feet wide, and fifteen feet long, I caught twenty-seven young salmon. In other parts of the creek they were just as plentiful. None were found above the point where they had been liberated. These fry had been planted in February, and at the time their yolk sacs were absorbed—about March 10th—their average length was 1.35 inches. On August 28th, five months and twenty

days later, they had grown to an average length of 3.26 inches, or an actual gain in length of 1.91 inches; an average gain per month of .33 inch. The specimens from which this average was taken contained the smallest and largest salmon found, or 2.83 and 4.08 inches, between which two lengths there was a perfect intergradation.

On November 2, 1897, a little over two months later, Sulloway Creek was again seined, and only about one half as many young salmon were found, and from a representative series ranging from 3.30 to 4.18 inches in length, the average was found to be 3.5 inches, or a gain of .24 of an inch in the two months.

Early in November, salmon fry hatched from eggs taken at Baird, on the McCloud River, were planted in Sulloway Creek, and by November 22d they had absorbed their yolk sacs. In the February following, salmon fry hatched from eggs taken at Battle Creek were again planted. These absorbed their yolk sacs about March 10th. No seining was done between these two plants, and none after, until the 15th of May, 1898. On this date young salmon were caught, and, after measuring a larger series, it was found that they were of three well-developed sizes. Those making up the smallest size exceeded all of the others 8 to 1, and they had grown from a length of 1.35 inches on March 10th, to 2.18 inches, or a gain of .83 of an inch, a rate of .38 of an inch per month. The smallest salmon found belonging to this group was 1.64 inches, the largest 2.8 inches. The next size ranged from 3.58 to 3.9 inches, and averaged 3.73 inches. These had remained in the stream since the November preceding, and there were very few of them as compared with the smaller size. They had been in the stream nearly six months, and showed an average gain of .39 of an inch per month. Only two specimens were found larger than this size, and they each measured 4.6 inches. These had undoubtedly remained in the stream at least since March of the year before.

Although it had been only a little over two months since several millions of salmon fry were planted in this small stream, there were—compared with the immense number planted—scarcely any left. These observations seem to warrant us in drawing the following conclusions: That the great bulk of the fry planted in February and March leave the stream, on their way down the river to salt water, within two months; a few of them remain until the rains of the following winter, and a few individuals may even remain through the winter up to the beginning of the rains the next fall. Of the fry planted in November, nearly all leave the stream during the winter, and it is probable that they do the same as the others—leave the streams within two months. I should add that the observations of the young salmon in Marin County, which are to be found in a separate report, and the subsequent observations carried on in the Sacramento, all demonstrate the correctness of these conclusions.

On August 29, 1897, I seined in the Sacramento near Sisson, and found salmon ranging from 2.63 to 4.37 inches in length, with an average length of 3.25 inches. On November 3, 1897, I seined again in the same place, and found the salmon ranging from 3.25 to 4.50 inches, with an average length of 3.92 inches. They had gained .67 of an inch in the two months since the stream was seined before; or, for the eight months which they had remained in the stream, an average gain of .32 of an inch per month. In the two months their number had diminished about one-half, which was the same falling off as found in Sulloway Creek.

On November 6, 1897, I seined the upper Sacramento at Sims, and found the average length of the salmon there to be 4 inches, although they ran from 3.5 to 4.5 inches.

On May 17th of the following year, a little over six months later, the stream was again seined at the same place. The average length of the young salmon at this time was 2.67 inches, although they ran from 1.52 to 3.76 inches. In this series the fry were hatched from eggs spawned by two different runs, which accounts for the great difference between the largest and the smallest of the series. Those in the upper end of the series, and which average about 3.5 inches, had absorbed their yolk sacs and begun to feed six months before, while the lower end of the series represents those which had begun to feed only two months before. If two hatches of salmon as young as these and with such a difference between their ages had been found in a small tributary of the Sacramento we could expect to easily separate the two sizes, but in the main stream, as at Sims, where the young salmon are from several different tributaries, a large variation in the size of the individuals occurs and it is not strange that the two sizes cannot be readily distinguished. Out of a very great number of small salmon caught here the largest was scarcely larger than the smallest taken at the same place six months before, which is the best evidence that none of those in the stream six months before remained through the high waters of winter. If they had remained until this time they would have been fifteen months old.

In Hazel Creek, a tributary of the Sacramento near Sims, I found, on November 6, 1897, two sizes of young salmon. The smaller size varied from 2.65 to 2.95 inches, with an average length of 2.87 inches; the larger size ran from 3.93 to 4.42 inches, with an average of 4.19 inches. The larger size greatly outnumbered those of the smaller size, and agreed well with the size of the salmon in the Sacramento at Sisson and at Sims. Of the smaller size only four were taken. Assuming that they had grown at the same rate as the others, they must have hatched from the egg early in August, and allowing three months for hatching, they were spawned early in May. There is nothing remarkable in the fact that salmon spawned here in few numbers at that time of year. The first salmon of the spring run have been observed passing

Baird on the McCloud in April, and they have been observed spawning in considerable numbers in the river above Baird early in May. Although the spring run does not reach its height at Baird until late in July, a good many salmon arrive earlier, and move farther up the river. The number of these irregular salmon is so small in comparison with those of the regular spring and fall runs that the fry resulting should not materially affect the two sizes of fry hatched by the spring and fall runs.

On May 17th of the following year, after the winter rains, Hazel Creek was again seined, and the largest salmon found was 2.82 inches, the smallest 1.53 inches, with an average length of 1.79 inches. It will be seen by comparing these figures with those of fish taken six months before that none of the salmon of the two sizes then found remained in the stream, and that the smaller size found on May 17th were hatched since that time from eggs deposited by the salmon of the fall run.

In the first week of September, 1897, I seined the lower end of Battle Creek thoroughly, and found young salmon in considerable numbers running from 3.08 to 4.58 inches, with an average length of 3.58 inches. The next time this part of the stream was seined, on December 5th, it was found that none of the salmon found three months before had remained in the stream, but that their places were taken by a new lot, averaging 2.39 inches. These salmon were spawned in the upper creek by the spring run, had absorbed their yolk sacs only two months before, and were already dropping down the river on their way to salt water.

At the United States and State hatchery on Battle Creek practically all of the fall run of salmon entering the stream were caught and their eggs taken. Five million of the fry hatched from these eggs were liberated in Battle Creek in February, 1898. They were liberated before they had begun to feed, but it was estimated that their yolk sacs would have been absorbed by the 10th or 15th of March. Mr. Cloud Rutter, of the United States Fish Commission, seined the lower Battle Creek on April 30th and found large numbers of salmon ranging from 1.40 to 3.45 inches, with an average length of 2.13 inches. This shows a gain of .45 of an inch per month in length. Although a large number of salmon were found in Battle Creek, they were not found nearly as abundant as they should have been had all the immense number liberated remained in the stream. A very large part of them had unquestionably drifted into and down the main river, and this within a month and a half of the time they began to swim about and feed after absorbing their yolk sacs.

On April 28th Mr. Rutter found young salmon in the main river at Red Bluff more abundant than he found them in Battle Creek two days later. These salmon ran from 1.51 to 3.09 inches, and had an average length of 2.16 inches. As they were found below the mouth of

Battle Creek, and their size coincided within .06 of an inch of those in Battle Creek, and in view of the fact that a larger number of the salmon in Battle Creek had moved out, we are justified in saying that they came out of Battle Creek.

On May 4th he found salmon abundant at Redding, ranging from 1.8 to 3.65 inches and averaging 2.38 inches. On May 5th at Tehama he found salmon ranging from 2.14 to 2.91 inches and averaging 2.53 inches.

Beginning with the second week in May the United States Commission carried their investigations into the lower Sacramento River and into Suisun and San Pablo bays. In the second week of May young salmon were found at Collinsville and at Benicia, but I have no record of their number, and of their size I only know that it corresponded with those found in the same place later in the same month.

On May 17th, six were found at Pinole, San Pablo Bay, ranging from 2.4 to 3 inches and with an average length of 2.6 inches. On the same day one was caught at Point Richmond, San Pablo Bay, 3.31 inches long. On May 18th, one was taken at Rodeo, San Pablo Bay, 2.4 inches long. On the 20th, 23d, and 24th, five were taken at Benicia, in the strait between Suisun and San Pablo bays, running from 2.06 to 2.56 and averaging 2.29 inches in length. On the 30th, three were taken at Rio Vista, in the lower Sacramento, running from 2.03 to 2.18 inches and averaging 2.08 inches. On June 10th, two were taken at Marshall's Landing, near Antioch, the largest being 3.3 and the smallest 2.12 inches in length.

If this small number of salmon taken in salt water represents, as it unquestionably does, the first big movement of young salmon out of the river, it at first appears that more of them should have been found, but when we consider the vast expanse of territory the lower Sacramento covers with its many channels and bayous, to say nothing of San Pablo and Suisun bays, it is not so strange that so few were found—in fact, the strange part of it is that so many were found—and we can realize the vast number that must have distributed themselves in these waters.

During the last two weeks of May I accompanied Mr. Rutter on a trip down the Sacramento in a row boat. Our object was to stop and seine the river at every available place, and learn the abundance, size, and movements of the young salmon. At Redding, on May 18th, we found the young salmon abundant, with an average length of 2.43 inches. At this place, two weeks before, their average length was 2.38 inches. At Red Bluff, on the 20th, we found no salmon whatever, although two weeks before they were very numerous. Just below Red Bluff we found a good many, their average length being 2.16 inches. From here to a point opposite Chico we found the salmon not so abundant. In a haul with our fifty-foot fine-meshed net we usually caught from twenty to

thirty. Below Chico this number fell off, and we caught only four or five in a haul. At a point two miles below Knights Landing the last salmon was caught, although we seined thoroughly between this point and Sacramento.

Below Red Bluff the salmon were very uniform in size, averaging 2.4 inches. It should be remembered that while we were making this trip small salmon of this same size were being caught in salt water. They were all hatched from the fall run of salmon, and it had been but a little over two months since they were old enough to feed. Their rate of growth after the absorption of the yolk sac was almost .5 of an inch per month.

Early in July Mr. Rutter again made the trip down the Sacramento, but was unable to find any salmon whatever below Battle Creek. The run of small salmon out of the river had ceased.

The conclusions to be drawn from these observations are: That immediately or very shortly after the salmon are old enough to feed and begin to swim about they begin to drift down the river, and within two months of this time they reach salt water. By the end of the fourth month the run is over, and those remaining in the headwaters of the river stay until the high waters of the following winter. The number of these thus remaining is small compared with the number running out immediately.

The rate of growth of the salmon during the first two months after absorbing the yolk sac, taken from an average of all the salmon taken on the Sacramento, was .42 of an inch per month. Those remaining after two months do not grow so fast. Salmon from four to eight months old show an average gain per month of a little over .30 of an inch.