THE SALMONID FISHES OF PRAIRIE CREEK, HUMBOLDT COUNTY, CALIFORNIA

PROGRESS REPORT: SEASON OF 1948 - 1949 [1]

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INTRODUCTION

On November 1, 1948, the writer began a study of the salmonid fishes inhabiting the drainage basin of Prairie Creek, in Humboldt County, California. Particular emphasis was placed upon the relative efficiency of the natural reproduction of these fishes. The investigation was divided into the following principal parts:

I. Recording of observations during each spawning run.

Continual stream observations were maintained so that notes could be taken on the time of migrations, relative size of the runs, the details of redd construction and spawning behavior, amount of egg retention by females, and general ecological relationships.

II. Redd Sampling.

Spawning pairs of each species were located, the redd area marked, and the redds later sampled at various developmental stages.

III. Test section program.

Two sections of a small stream were appropriately screened off and used in the following manner:

A. Natural spawning section.

Utilized for the introduction of a mature spawning pair of each species so that the young fish could be captured and counted after emergence.

B. Eyed egg station.

Utilized for the planting of eyed eggs of each species so that the total emergent young could be counted. Similar number of eyed eggs were held in Prairie Creek Hatchery to allow a comparison of the two methods.

IV. Population Study.

An attempt to achieve an understanding of the continuous population fluctuations which occur in the small coastal streams.

A. Seining program.

Information on species, size, and numbers was collected at fairly regular intervals by seining in a selected section of Prairie Creek.

B. General observations.

Data regarding population interrelationships of adult and young fish. Occasional notes on predators and stomach contents.

The present report is submitted for the purpose of outlining the progress which has been achieved during the first season's work on the Prairie Creek project. No attempt has been made at this time to introduce comparative literature or reference material.

PART I. BIOLOGY OF THE SILVER SALMON

Time of Migrations

The first silver salmon appeared in upper Prairie Creek during the last week of October. However, the greatest numbers of fish did not arrive until the second week of November. The arrival of the main group of silvers coincided with the appearance of the main run of king salmon. The majority of the silvers kept moving until they had either reached the headwaters of Prairie Creek or until they had ascended the smaller tributaries of this stream. Many of them ran up as far as it was physically possible for them to go and stopped only when confronted by impassable barriers, such as fallen logs or waterfalls. They showed remarkable persistence in swimming up riffles where the water depth was as little as two inches and the flow down to one cubic foot per second (c.f.s.).

In most cases the fish did not attempt to enter these smaller tributaries until a heavy rainfall had served to increase the flow to some extent. Then they exhibited a tendency to ascend these streams in a "run" composed of at least several pairs of these fish. These runs occurred at non-related intervals in the various tributaries of Prairie Creek. For instance, in Brown Creek the first run appeared on November 22, in Godwin Creek on November 15, in East Creek on December 8, and in Elk Prairie Creek on December 3.

Silver salmon could be seen continuously in the watershed from the last week of October until the first part of January. Evidently the run was interrupted at this point by a prolonged period of dry, cold weather which persisted for the entire month. Whether the delay was caused by the low water or by the accompanying low temperature is hard to say. If the fish had wanted to migrate during this period they could have reached the spawning areas because there seemed to be enough flow for this purpose.

Temperature Effect

In connection with this question, an interesting occurrence took place on the Mad River. The Mad River is a coastal stream about 30 miles south of Prairie Creek. The runs of migratory fishes are counted as they pass through the fish ladder at Sweasey Dam, about 25 miles from the river mouth. During the past ten years the bulk of the large steelhead run had been passing over the dam during the four week period from January 15 to February 15.

This year, the steelhead appeared in the lower reaches of the river at about the usual time and good catches were taken by anglers all along this first 25 miles. During the cold weather of January there were no major increases in water flow and, as expected, only a very few fish came over the ladder. However, a large rise did occur as the result of mixed rain and snow on February 4, 5, and 6. The fish did not react to this situation

and the only obvious explanation was that it was not accompanied by the usual temperature increase because the precipitation was of this unusually cold type.

By February 8 only one trout had reacted to the water rise in spite of the fact that huge numbers of fish, perhaps two to four thousand, were quiescent in the river immediately below the dam. The temperature soon came up several degrees and the fish came up the ladder in great numbers.

These observations might constitute some evidence to support the theory that migrating salmonoids react more closely to temperature changes rather than to fluctuations in water volume. In the north coastal region the stream rises in the winter time seem to be almost always accompanied by sharp temperature increases. This fact has made it difficult, in the past, to separate the effects of these two environmental factors.

After the above described cessation of the silver run in January a few additional pairs of fish arrived on the spawning beds on February 6 and 7. Their arrival coincided with a period of increased stream flow and higher temperatures. By February 20 the watershed was again free of this species. Thus the total time of the silver salmon migrations extended over almost a four month period.

Once the fish entered the smaller streams they swam fairly rapidly to the headwaters and commenced spawning immediately.

These fish all seemed to be fairly ripe upon arrival in upper Prairie Creek. Both sexes had lost most of the silver coloration and the males were bright red on the sides. In addition, the males possessed a noticeable hooked modification of the upper jaw. There was no evidence of individuals undergoing an apparent waiting period in the deeper pools before becoming ripe enough to spawn.

In Elk Prairie Creek it was possible to time the progress of the run from the mouth of the stream to the spawning area two miles upstream. In this case they took approximately two days to travel these last two miles of their journey. However, it must be remembered that this last portion was the most difficult because of the smaller flow of water and the great number of obstacles to be surmounted. These include log jams, small waterfalls, and shallow water areas.

Size of Run

The total size of the silver run in numbers of fish cannot be given since no counting weir was maintained. However, from repeated observations of the spawning areas it is possible to give a close approximation of the size of the run compared to that of the king salmon which occurred at the same time. The silver run was about six times as large as that of the king salmon. (The steelhead and king salmon runs were about the same size.)

Redd Construction

When the fish approached the spawning area the females started digging in likely spots. Many times the fish appeared to become dissatisfied and moved on to some other place before depositing their eggs. This was proved through careful subsequent examination of such "false redds". In one such case a female (accompanied by a male) spent two days in digging up an area 12 feet in length without any liberation of eggs.

When a pair of fish were seen "working" a particular area of gravel over a period of several hours, this redd was marked as to the date and species. Later the gravel was dug up and thoroughly examined for eggs so that the natural mortality taking place in the gravel could be recorded. Approximately three-fourths of the redds so treated turned out to be the aforementioned false variety.

It was found later that still another type of false redd was usually constructed. After the eggs have been liberated and the male fish has departed, the female will usually still continue to dissipate her energy in the digging operation. This continued activity may or may not be carried out near where the eggs have been deposited. Many females have been observed digging at various places after they drift downstream from the area where the eggs lie. This instinct for turning up gravel seems to be so strong that most of these fish continued this activity until they were dead. Since most of the female silvers

remained alive from a week to two weeks after spawning, the net result was that large areas of gravel were disturbed by a relatively small number of fish. This would give the impression, to the casual observer, of a quite intensive use of some of the spawning area when only a few fish may be actually responsible.

The spawning activity itself was quite similar to that described for other salmonoid fishes. The female was responsible for the actual redd construction. At regular intervals, once every two to three minutes, she turned on her side and dug vigorously, displacing rocks and gravel through the lifting action of her tail. This action usually carried her forward from two to three feet. She would then rest before returning to repeat the process. During this time the male stayed in close attendance, lying to the side and slightly behind the female. He would attempt to stimulate her by a quivering motion of his body, and by swimming close to her, first on one side and then on the other. Ordinarily, the male exhibited but little activity compared to his mate. However, if any smaller males or grilse were present he would display great energy in chasing these rivals and keeping them away from the female. During all of the salmon spawning the only other fish in evidence were these smaller males or grilse. In no case was there any sign of other species of fish disturbing the spawning pair or attempting to steal eggs.

Only about one out of every eight females was noted to have two males in attendance. In these cases the larger of the two males seemed to be successful in keeping his competitor away from the egg pit. No more than two males were ever seen attending a single female. In two cases the female was accompanied only by a single grilse.

In general, pairs of this species demonstrated breeding activity for two to four days. After this, the male would lose interest and drift downstream to die within a short time. On the other hand, the female usually remained somewhere near the redd vicinity from several days to as long as two weeks before showing a tendency to drift with the current and finally die.

Several such females were taken alive just after the male had departed. These fish proved to be spawned out in spite of the fact that they still continued the digging operation. Most of these fish, whether taken dead or alive, displayed some tendency to retain a few eggs. However, the number of eggs retained was so small as to be almost insignificant when compared to the probable total that was placed in the gravel. Five spawned out females were examined. The number of eggs retained varied from 0 to 20, the average was 5.5 per female.

Redd Characteristics

When the nest was finished it usually consisted of a pit, oblong in shape with the long axis parallel with the flow of

water. The length averaged about three feet while the width was close to two feet. Depth measurements were taken of two of these pits before eggs had been placed in them. They were respectively eight and ten inches deep. However, in each of these cases the female did a little more digging before depositing eggs so that the actual depth may have been an inch or two more. In addition, when the eggs were dug up, the depths at which they were found varied from a maximum of 15 inches to a minimum of seven inches.

The size of the "gravel" didn't seem to be a decisive factor in the selection of a spawning site. A variation, from stones of 1-1/2 inches in diameter interspaced with much finer gravel and sand to stones averaging 5 inches in diameter interspaced with slightly smaller stones, was observed. However, it was noted that about 75 percent of the fish chose areas where the stones were close to three inches in diameter and interspaced with smaller stones and fine gravel. Fish were observed working areas where the stones were much larger (up to eight inches in diameter) but no eggs could be subsequently recovered from these places.

In most cases the depth of the water covering the gravel in which the fish choose to work, was fairly constant. Measurements ranged from depths of four to eight inches with the majority being close to five. The velocity of the water also seemed to be a fairly constant factor. This was roughly calculated through the use of the float and stop watch method. The slowest recorded was 1.5 feet per second, while the most rapid was 2.5 feet per second.

Most of them were very close to the two feet per second figure.

The fish demonstrated no particular preference as to whether they worked areas at the ends of pools or somewhere in a riffle stretch. The redds numbered about the same in each location.

The above observations seem to indicate that the fish is quite particular in selecting water of the correct velocity and depth. The other two factors of gravel size and location (pool or riffle) were not very constant. The depth at which the eggs were placed also varied considerably, ranging from seven to fifteen inches. However, in this connection it was noted that the fish dug deeper in the gravel that was the loosest and easiest to work.

Fish Characteristics

The size of the breeding adults were remarkably uniform. Actual measurements were made of ten typical fish, five males and five females. The males varied from 29.5 inches to 34.5 inches (total length), averaging 31.9 inches. The females varied from 27 to 28.5 inches, averaging 27.6 inches. All of the adult silvers which were observed, with the exception of a few small grilse, would probably have come within the above given size ranges.

Scale collections were made and the resultant data on the age and growth can eventually be added here.

The dimorphism between the sexes was extreme. The breeding male was larger and demonstrated marked modification in color and structure. The sides of this fish became suffused with red, often quite brilliant, and the upper jaw became prolonged and hooked. The female, on the other hand, exhibited no apparent structural modifications and the color change, if present, was much more slight than

in the case of the male. Both sexes, of course, lost the silver color which is typical of the fish taken from salt water. Some of the breeding females remained a dark greenish color, while others developed a distinct lateral red stripe and red on the opercles, very similar to the color pattern of the mature steelhead.

PART II. BIOLOGY OF THE KING SALMON

Time of Migrations

Most of the individuals comprising the first main run of king salmon all arrived within a few days of each other during the second week of November. These fish did not enter any of the small tributaries of Prairie Creek, as did the silver salmon, nor did they press far up the main stream. The second main run appeared on December 22. A considerable number of these fish entered Lost Man Creek, the lowest and largest Prairie Creek tributary. In periods of normal flow this stream contributes almost as much water as the main creek. With the exception of this one large tributary, this second run behaved in the same manner as the first. None of the smaller streams were entered and the fish appeared satisfied with the lower reaches of the main creek. A few fish put in an appearance as late as the first week of January but by the end of this month the waters were cleared.

It should be emphasized that, although these two species of salmon were occupying the same watershed at the same time of year, they were apparently quite compatable. Only a very few

silvers attempted to spawn in the general area which was preferred by the kings (Figure 2). This latter species was generally the larger and quite pugnacious. They usually chased the silvers and smaller kings quite viciously when they came near. However, this did not seem to prevent the pursued fish from getting past the danger area and on upstream.

Many of the king salmon arrived on the spawning area in a more or less immature state. A number of them still showed a large amount of silver on the back and sides. These fish could be seen lying in the deepest pools, where they waited until they were ripe enough to spawn.

Redd Construction

The selection of spawning beds and breeding activity followed the same general pattern set by the silver salmon. About the same number of false redds were constructed before the eggs were laid, and probably even more area was dug by the female after she had completed her spawning, since this fish generally remained alive for a longer time. The females remained upstream after spawning and some of them stayed alive for as long as four weeks. Their remains could usually be found well upstream near where the redds had been constructed. A number of these fish were captured after they had spawned and were then examined for egg retention, size, and scale data. A total of six spawned out female king salmon were examined for retained eggs. The numbers found varied from two to 74, the average being 20.

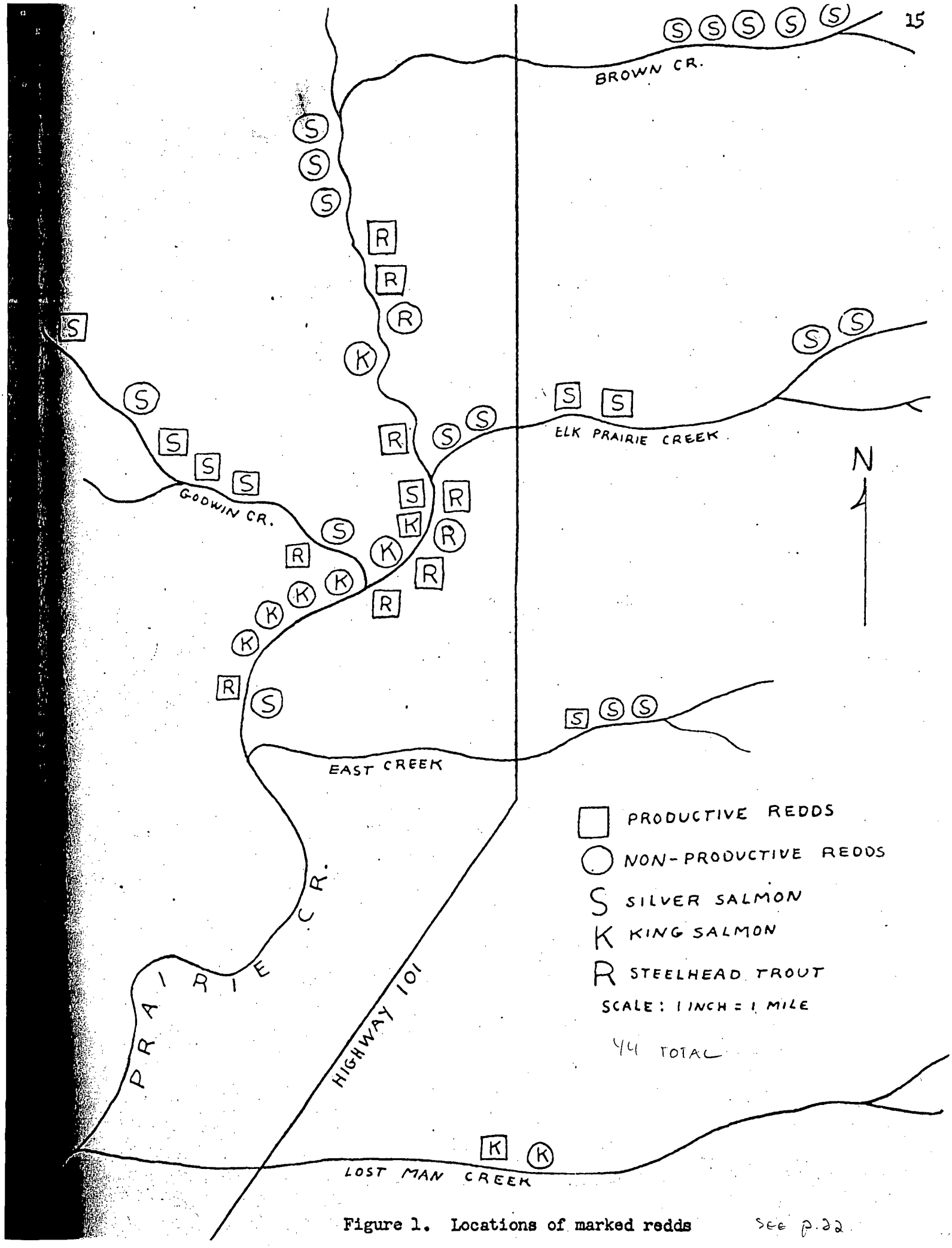

Figure 1. Locations of marked redds

See p.22

As in the case of the silver salmon, the males disappeared immediately after spawning, drifting downstream to die or even reentering the ocean while still alive. (A few males were seen doing this at the mouth of Redwood Creek, the stream into which Prairie Creek flows). No dead male fish could be found near the spawning area.

The spawning was carried on in a rather leisurely manner. The digging activity by the female occurred at five to eight minute intervals; and the entire breeding process extended sometimes to seven or eight days. No other species of fish was observed attempting to steal eggs.

With this species also, the male took no part in the actual redd construction. He exhibited little activity except when smaller males attempted to get too close to the female.

Redd Characteristics

The finished nest consisted of a pit about four feet long and three feet wide. Measurements taken of two of these pits when they were apparently excavated to their maximum depth gave 11 inches for one and 14 inches for the other. When the eggs were dug up they were found to lie from nine to 14 inches under the gravel.

The size of the gravel worked was rather uniformly large. This factor may or may not be significant because most of the suitable areas in the lower Prairie and Lost Man Creeks had much larger gravel than did the smaller tributaries utilized by the silver salmon.

The depth of water flowing over the redd locations ranged from ten to 24 inches. Generally, the deeper range of from 12 to 24 inches was preferred. The velocity of this water was fairly constant, varying from two to 2.5 feet per second. The locations at the ends of pools and in the riffle stretches were both about equally utilized.

Fish Characteristics

The size of the breeding adults was quite varied in this species. There was no noticeable difference in average size between the sexes. No spawned out males were measured because they disappeared so quickly after the redds were finished. A total of eight females were measured. The length (total) varied from 31.5 to 37 inches, with the average being 35.2 inches. Scale data from the above fish will be included later.

The sexual dimorphism was very slight with this fish. On a few of the males the upper jaw became slightly modified, but in no case to the extreme seen in the silver salmon. There was no color difference, and when the fish were in the water the sexes could not be distinguished except by the difference in activity.

Comparison between Salmon Species

When the habits of these two species of salmon are compared a number of rather striking differences become readily apparent. Perhaps the most interesting of these was the tendency of the king salmon to accept the deeper water spawning areas of lower Prairie and Lost Man Creeks, while the silver dalmon continued on past

these areas and up into the headwaters of the small tributary streams. Despite the fact that the two salmon were in the watershed at the same time there was very little overlap of spawning areas.

Significant differences were also apparent with such factors as water depth, gravel size, time of redd construction, pit size, pit depth, viability after spawning, sex dimorphism, and size of run.

PART III. BIOLOGY OF THE STEELHEAD TROUT

Time of Migrations

The first steelhead were seen on the spawning area on February 20. These fish continued to arrive in scattered numbers until March 30. The run was quite small and the total numbers would probably be close to the size of the king salmon run. With the exception of a single pair which spawned in Godwin Creek, the distribution of spawning fish was very similar to that demonstrated by the king salmon. The fish did not attempt to press up into the small tributaries although there was plenty of water available.

A good many of the fish arrived in a relatively immature state and remained in the deeper water areas until they were ready to deposit their eggs. It was noticed that one of the new arrivals in the early part of March had a characteristic scar on its back. It was possible to keep track of this particular fish until it took part in the spawning activities. In this case, the time interval between arrival at the redd area and the actual spawning was exactly two weeks.

Redd Construction

The breeding actions of the male and female fish were approximately the same as had been previously noted with the two salmon species. The female did all of the digging and accomplished it in a more graceful manner than did the female salmon. Her body seemed capable of being bent at a greater angle and she did not splash as much water around. The digging was quite rapid and somewhat erratic, the rest intervals being sometimes only about thrity seconds but varying to one and one half minutes in some cases.

In contrast to the salmon, the female trout was not inclined to waste energy in the construction of "false redds", either before or after the eggs were laid. Eggs were later found in all eight of the large redds that had been marked, and only two were non-productive. However, these were small areas that had evidently been abandoned soon after they were started, probably in favor of a more likely spot.

The adult trout were extremely shy, especially when the water was clear. They could be approached only with great caution, even when they were engrossed in the spawning process. In general, the period of greatest activity on the redds was the early morning and evening. During the middle of the day many of the fish discontinued redd construction and sought a hiding place in the vicinity, either in deeper water or under an overhanging bank.

Redd Characteristics

The shape of the egg pits was usually more circular than were those constructed by the salmon. The horizontal dimensions were about three feet by three feet. The depth measurement of one that looked

fairly complete was eight inches. When the redds were later examined all of the eggs were found to lie from seven to 11 inches under the gravel surface.

The depth of the water was quite consistent, around nine to 12 inches. The gravel size varied from three to five inches, and the velocity of the flow again showed but little variation, from 2.0 to 2.5 feet per second. The location at the ends of pools where the water began to pick up momentum seemed to be more attractive to the steelhead than a location along the riffle stretches. Only two redds were marked in this latter area.

When the spawning was completed most of the fish headed immediately down the creek. Some of them were seen swimming rapidly with their heads pointed downstream, instead of being satisfied merely to drift backwards with the current.

Fish Characteristics

The plan to capture some of the spawned out adults for examination to obtain size, egg retention, and scale data was not carried out because of the speed with which these fish left the redd areas after spawning. Judging from stream-side observations, the size of the adults appeared to be quite uniform with no apparent difference between the average size of the males and females. Most of the fish would probably measure 26 to 28 inches, total length. There was no sign of any smaller mature males comparable to the salmon grilse.

The difference between the sexes, while not marked, was still more apparent than with the king salmon. Both sexes, when ripe enough

to spawn, showed the characteristic rainbow stripe on the side extending well up on the opercles. However, most of the males showed additional red coloration in a second stripe, ventral and parallel to the main, mid-lateral one (see Figure 2). There was no visible modification of the upper jaw in the male.

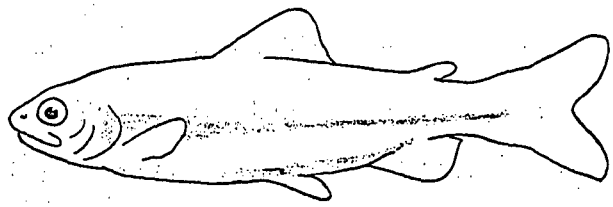

Figure 2. Breeding coloration, male steelhead.

It was most interesting to find that in some ways, the steelhead trout of Prairie Creek were quite similar in behavior to the king salmon. Both species had to undergo a waiting period in the upstream region before spawning, and they both indicated a perference for the deeper water of the main creek rather than venturing into the small tributaries. Both fish utilized faster water and larger gravel for spawning than did the silver salmon. In addition, the run appeared to be about the same size.

PART IV. REDD SAMPLING

Marking Procedure

The redd marking procedure consumed by far a greater amount of time than any other phase of the problem. This activity involved

covering, at frequent intervals, the twenty miles of apparently suitable spawning area in the upper Prairie Creek drainage. In many places the undergrowth was almost impenetrable and progress could be made only by wading the stream channel itself. It was also necessary to proceed with caution to avoid scaring the fish before they could be spotted. As the result, it took from four to five days to adequately cover this area once. Usually the numbers of actively spawning pairs were very small compared to the numbers of fish which could be seen in any one stretch of stream. Consequently, the number of marked redds probably represents only a small portion of the fish which actually spawned in this watershed.

In the case of the salmon it would have been a simple matter to locate and mark spots which looked as if they had been worked over by fish. However, this would not have resulted in a positive identification of the species because both king and silver salmon were present in the watershed at the same time. Therefore, it was decided to mark only those redds where spawning activity was actually witnessed.

Equipment

The equipment used in the operation was a sharp-pointed shovel and a net which was especially designed to collect the samples of eggs and larvae (Figure 3. The frame for the net was shaped from a rectangular piece of iron bar 1/2 inch wide, 1/4 inch thick, and 10 feet long. This piece was bent and the ends welded to give a rectangular frame four feet wide and one foot high. Four loops were

then welded on the front of it to accommodate two 18 inch iron bars which served to anchor the frame in place in the stream bed. Four panels of netting (similar to the standard bobinetting used in the hatcheries) were then sewn together and attached to the frame.

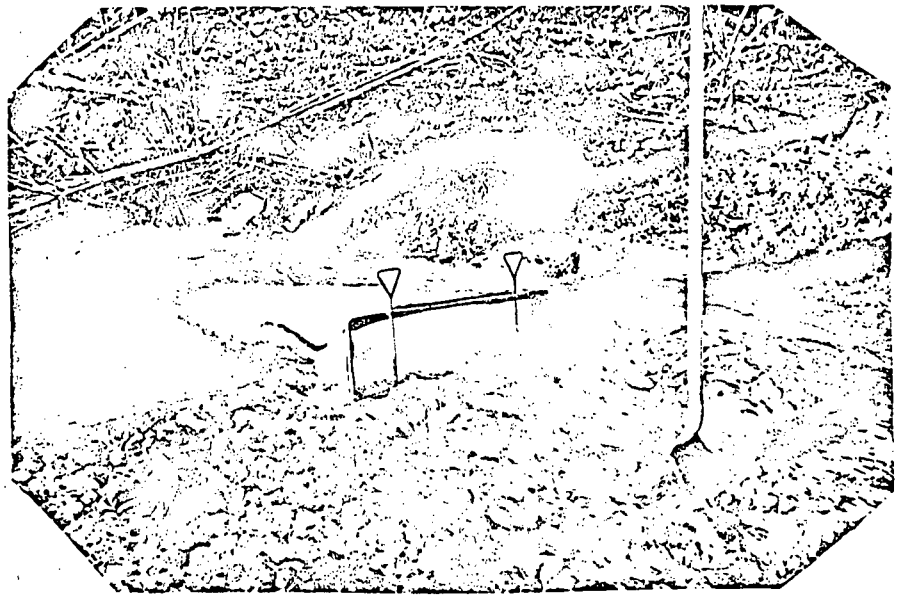

Figure 3. Net and shovel used for collecting samples of eggs and larvae.

The finished net proved to be quite practical for most of the places in which it was used. The strain on the netting would probably have proved too great in swift water much over a foot in depth. For this reason it was necessary to confine the sampling to the lowest water periods of the winter season. It was originally planned to sample all of the productive redds at least twice (at the eyed egg and larval stages). However, high flows present over the greater part of the rainy season was the factor which restricted a complete coverage of all the redds.

Sampling Procedure

The following general procedure was developed for the removal of samples from the redds: The collecting net was set about five feet below the downstream end of the redd. The first step of the digging operation consisted of shoveling across the width of the redd at the upstream end to a depth of about two feet. Then the gravel was slowly turned over down the length of the redd with the two foot depth being maintained until the eggs were contacted. This resulted in the eggs being freed of the gravel with a minimum amount of pressure and resultant damage (Figure 4). (The removal of gravel and eggs in this lateral direction instead of from directly above seemed to be much easier on them.)

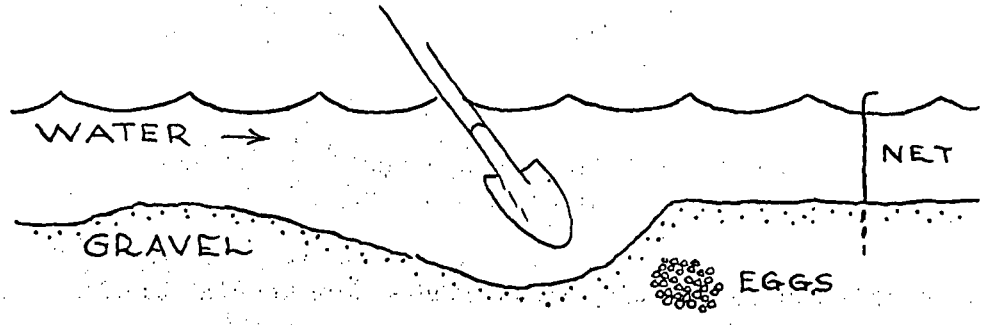

Figure 4. Method used for removing eggs from the gravel.

The date at which the eggs were deposited in these marked redds was of course recorded so that it was possible to guess quite accurately when they reached the various developmental stages. Eggs were being hatched in the Prairie Creek Hatchery at the same time, and the rate of their development closely paralleled those in the gravel, since they were exposed to almost the same temperatures.

The original intent was to sample at the three principal stages: pre-eyed, eyed, and larval. However, upon examination of two redds (one silver and one king salmon) which had been sampled in the pre-eyed stage it was found that evidently many eggs had been killed by the disturbance created with the removal of the first sample. Therefore, since the sampling at this stage seemed unnecessarily wasteful, it was discontinued. No such ill effects were discernible when samples were taken at the other two stages.

When it appeared as though about one hundred eggs or larvae had floated into the net, it was removed and the specimens were counted. The numbers of live and dead individuals were recorded and the live ones were placed back in the gravel and covered over.

Results

Silver Salmon: A total of eight redds out of 24 marked were productive. Table 1 gives the data for each productive sample taken.

TABLE 1

Results of Twelve Samples Taken from Silver Salmon Redds

Sample	Deposition date	Dead eggs	Live eggs	Dead larvae	Live larvae	Percent Mortality	Stage	Location
1	12/16/48	3	101			2.88	pre-eyed	East Cr.
2	12/15/48	15	192			7.25	eyed	Godwin Cr. 4
3	11/25/48	17	119		2	12.50	eyed	Godwin Cr. 3
4	12/25/48	18	129			12.24	eyed	Elk Prairie Cr.2
5	11/18/48	22	237	4	69	7.83	eyed and larval	Prairie Cr.
6	10/24/48	5		12	748	2.22	larval	Godwin Cr. 2
7*	11/25/48	15		25	361	9.98	larval	Godwin Cr. 3
8*	11/18/48	15		12	480	5.33	larval	Prairie Cr.
9*	12/15/48	1			25	3.85	larval	Godwin Cr. 4
10	2/6/49	32			31	50.79	larval	Elk Prairie Cr.1
11*	12/25/48	14		1	126	9.22	larval	Elk Prairie Cr.2
12	2/7/49	1			91	1.09	larval	Godwin Cr. 1

* Indicates sample taken from redd that had been sampled once before.

It would undoubtedly be a mistake to try to draw any definite conclusions from the above table at this time. When the data from another season's work is added, it can be carefully analyzed. It can be seen that the mortality in all of the samples is comparatively low except that of number ten. When this redd was examined it was found that apparently most of the eggs had not been fertilized. It had been noticed, when the redd was first being constructed, that the male fish disappeared very quickly. It is quite possible that he was captured, perhaps by some predator before all of the eggs had been fertilized.

King salmon: A total of only two redds out of nine marked were found to be productive, as shown in Table 2.

TABLE 2

Results of Three Samples Taken from King Salmon Redds

Sample	Deposition Date	Dead eggs	Live eggs	Dead larvae	Live larvae	Percent Mortality	Stage	Location
1	11/22/48	11	117			8.59	eyed	Prairie Cr.
2	12/22/48	14	138			9.21	pre-eyed	Lost Man Cr.
3*	11/22/48	3		2	19	12.50	larval	Prairie Cr.

* Indicates sample taken from redd that had been sampled once before.

Steelhead trout: A total of eight redds out of ten marked were found to be productive, as shown in Table 3.

TABLE 3

Results of Ten Samples Taken from Steelhead Trout Redds

Sample	Deposition Date	Dead eggs	Live eggs	Dead larvae	Live larvae	Percent Mortality	Stage	Location
1	2/21/49	12			187	6.03	larval	Godwin Cr.
2	3/30/49	2	211			.94	pre-eyed	Prairie Cr. 6
3	3/8/49	14	506			2.69	eyed	Prairie Cr. 5
4	3/1/49	15	50		160	6.67	eyed and larval	Prairie Cr. 2
5	3/10/49	51	50		3	49.04	eyed and larval	Prairie Cr. 7
6	3/10/49	22	233			8.63	eyed	Prairie Cr. 3
7	2/20/49	8			51	13.56	larval	Prairie Cr. 4
8	3/12/49	39	137			22.16	eyed	Prairie Cr. 1
9*	3/8/49	1			108	.92	larval	Prairie Cr. 5
10*	3/30/49	5			93	5.10	larval	Prairie Cr. 6

* Indicates sample taken from redd that had been sampled once before.

Note that samples five, seven, and eight show a comparatively high degree of mortality because of the large numbers of dead eggs. In these particular cases it was noticed that most of the eggs had reached the eyed stage before they died. In all of the other redds studied (including those of the two salmon species), the great majority of dead eggs showed no such development and apparently represented the non-fertilization loss. A possible cause may be the heavy infestation of a species of oligochaete worm. Large masses of these worms were found in the immediate vicinity of the eggs, the infestation being especially heavy in the redd which produced sample number five. There was no evidence that the worms were attacking the eggs directly, but they did exude copious quantities of mucus, which may have had the effect of upsetting the osmotic balance of the eggs or perhaps affecting the intake of dissolved oxygen.

It was mentioned previously that various types of data had been recorded at the time the redds were marked. A great number of these redds, upon examination, proved to be non-productive. It has since been decided to disregard all such data except that information upon redds in which eggs were found. Therefore, the various characteristics of the productive redds of all three species are given in Table 4.

TABLE 4

Characteristics of the Productive Redds of Trout and Salmon

Creek	Deposition date	Water depth	Water Velocity	Gravel Size	Depth of eggs	Location	Species
Lost Man	12/22/48	10"	2.5	6"	14"	riffle	KS
Prairie	11/22/48	16"	2.0	6"	9"	end pool	KS
Godwin 4	12/15/48	6"	2.0	3"	15"	riffle	SS
East	12/16/48	4"	2.0	2"	10"	riffle	SS
Godwin 3	11/25/48	5"	2.0	3"	11"	end pool	SS
Elk Prairie 2	12/25/48	6"	2.0	5"	11"	riffle	SS
Prairie	11/18/48	8"	2.0	4"	7"	end pool	SS
Godwin 2	10/24/48	5"	2.5	1.5"	10"	end pool	SS
Elk Prairie 1	2/6/49	5"	2.0	3"	12"	riffle	SS
Godwin 1	2/7/49	7"	1.5	2"	11"	end pool	SS
Godwin	2/21/49	10"	2.5	3"	10"	end pool	SH
Prairie 1	3/12/49	11"	2.0	3"	9"	end pool	SH
Prairie 2	3/1/49	12"	2.5	5"	10"	riffle	SH
Prairie 3	3/10/49	8"	2.5	3"	7"	riffle	SH
Prairie 4	2/20/49	8"	2.0	2"	11"	end pool	SH
Prairie 5	3/8/49	14"	2.5	4"	9"	end pool	SH
Prairie 6	3/30/49	13"	2.5	4"	11"	end pool	SH
Prairie 7	3/10/49	12"	2.0	5"	9"	end pool	SH

The average for the four characteristics of water depth, water velocity (feet per second), gravel size, and depth of eggs (under the gravel surface) have been calculated and are given below. These are, of course, subject to some change when additional information is

gathered in the final season's work.

A. King salmon: (two redds)

1. Water depth - 13"
2. Water velocity - 2.25
3. Gravel size - 6"
4. Depth of eggs - 11.5"

B. Silver salmon: (eight redds)

1. Water depth - 5.7"
2. Water velocity - 2.0
3. Gravel size - 3"
4. Depth of eggs - 10.9"

C. Steelhead trout: (eight redds)

1. Water depth - 11"
2. Water velocity - 2.3
3. Gravel size - 3.6"
4. Depth of eggs - 9.5"

PART V. THE TEST SECTION

It was decided to devise some method whereby the number of young fish which emerged from a redd could be counted and compared to the number of eggs which had originally been placed there. To do this it was first necessary to select a small stream which could be kept suitably screened off so that the young fish could be held and captured.

In the northern coastal area of California the annual rainfall is high, around 60 inches in the Prairie Creek drainage, and the

stream flows fluctuate widely during the rainy season. Streams which may ordinarily flow only a few cubic feet per second will sometimes increase their flow tenfold or more after one or two days of hard rain.

It was difficult to locate a stream in which fine screens could be kept. A little creek was finally located which was mainly spring-fed and had a very small drainage area. The normal winter flow was only about one-half a cubic foot per second, but there were ample numbers of deep spots capable of holding large fish.

Three screens were installed in order to create two protected sections, the upper one about 30 feet long and the lower about 20 feet. Additional gravel, consisting of stones about three inches in diameter, was hauled in so that there would be plenty to cover the eggs. The upper section, containing three deep holes plus riffle areas, was used to study the efficiency of natural spawning.

Natural Spawning

One mature pair of each of the three species of fish (silver salmon, king salmon, and steelhead trout) was placed in this upper section in the hope that they would spawn in a normal manner. These adults were netted in the fish ladder which extends over the Sweasey Dam on the Mad River. They were transported to the test section in a "live box" which was mounted on the bed of a pickup truck. A small electric pump supplied enough air so that the fish arrived at the destination in good condition.

All three species showed courtship activity and indicated the

desire to spawn. The silver salmon and trout females deposited virtually all of their eggs, (retaining four apiece). The king salmon female was apparently quite dissatisfied with the small flow and deposited few or none of her eggs. No eggs could be found in the gravel and close to four thousand were found in the coelomic cavity after she died.

In the case of the other two species it was noticed that the male apparently had trouble maintaining his position at the side of the female during the redd construction. The difficulty evidently was caused by the lack of the usual strong current to swim against. When the male attempted to stimulate the female he was carried on past her by his movements and was forced to turn around and swim back to regain his position. As the result, when the eggs were dug up later there was no sign of development in any of them, thus indicating that they had not been fertilized. They had been properly deposited by the female, however, and carefully covered over.

Because of this turn of events, the natural spawning part of the experiment gave but little information except to demonstrate that these species will probably not propagate successfully when the adults are transferred to such a small stream.

Eyed Egg Plants

The lower screened off section was used for the purpose of artificially placing eggs in the gravel after they had reached the eyed stage.

It was hoped that this part of the experiment would yield data which could supplement those obtained from the sampling of natural

redds. Information was needed particularly upon the condition of the young fish following emergence and the time required for the emergence process. Also it was hoped that useful figures on the mortality from the eyed stage on would be obtained.

The eggs utilized for this purpose were taken from fish which had been captured at the Sweasey Dam fish ladder. A live box, large enough to hold several pairs of fish, was constructed in one corner of the ladder. The adult fish were then held in this structure until they became ripe enough to be artifically spawned. The eggs were transported in cans to the Prairie Creek Fish Hatchery and held in the troughs until they reached the eyed stage. At this time the eggs were counted and divided into two groups. Approximately half the total for each species was kept in the hatchery while the other half was transported to the test section.

The eyed eggs were buried in pits in the gravel in an attempt to duplicate, as closely as possible, the conditions found in the natural redds. As soon as the young fish began to emerge they were collected and counted every day. Both species of young salmon tended to become concentrated against the lower screen. Virtually all of the king salmon and most of the silvers showed this desire to move downstream immediately.

The screens which bounded the section were constructed so that an ordinary trout egg basked composed the center section (see Figure 5).

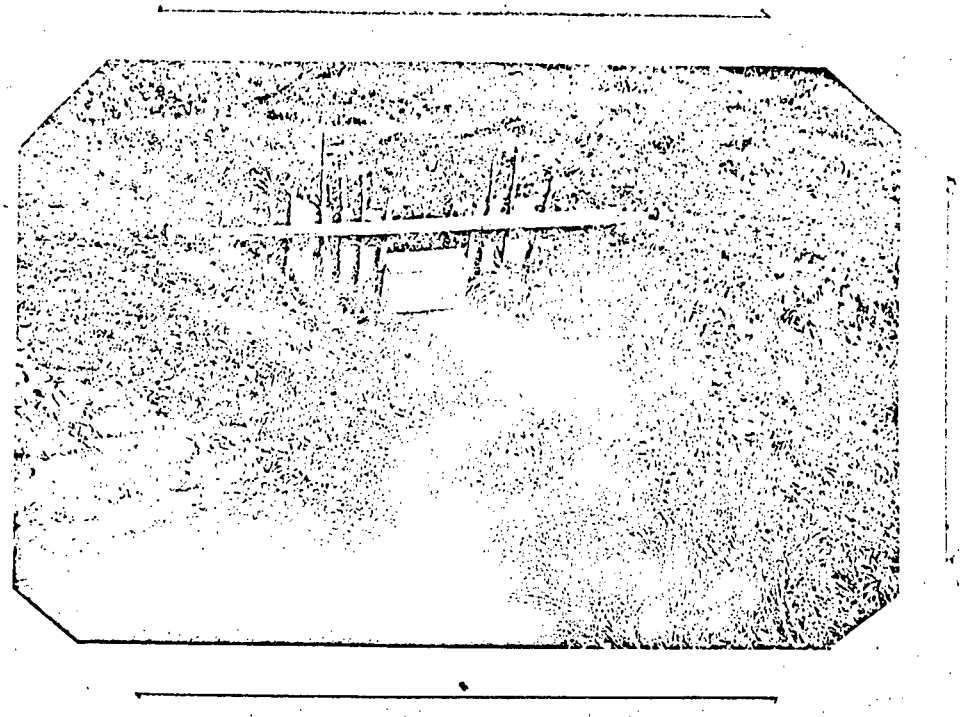

Figure 5. Screen at lower end of test station.

This basket was removable, making it easy to clean and replace in a few seconds. When the young fish drifted downstream they became trapped in the lower part of the basket. This made it easier to capture and count the fish but it also probably allowed the natural predation to increase. The basket was easily accessible to such animals as shrews, mice, racoons, and birds.

When the young trout began to emerge, the upstream side of the basket had to be covered with bobbinet material because these fish were small enough to pass through the wire mesh. Most individuals of this species didn't show a strong desire to move downstream as did the salmon. They moved in about equal numbers both above and below the emergence areas.

All of the fish, both trout and salmon, which made their way

out of the gravel seemed to be in good health. There was no sign of injuries which may have been inflicted during the emergence process. The majority of the individuals emerged at night. Although no accurate count was kept, it was noticed that about two-thirds of each daily total was usually picked up in the first collection in the morning.

Results

King salmon: 2,907 eyed eggs of this species were planted on January 11. 3,132 eggs were left to complete their development in the hatchery trough. Approximately 225 of the young fish were washed out of the gravel prematurely during a flood on February 24. This was probably the result of the eggs not having been buried as deeply as they would have been in a natural redd. The remainder proceeded to emerge naturally, beginning on March 9. The last fish were taken on April 21, giving a total emergence period of almost six weeks. The rate of emergence has been plotted on a graph with the other two species (see Figure 6).

A total of 1,049 young fish were counted. When this figure is compared to the original 2,907 eggs, it can be seen that a rather extensive loss took place, amounting to 1,858 individuals.

After all of the young fish had been captured the gravel was dug up and thoroughly examined in order that a check might be made of the mortality which occurred before the young fish left the redd. This resulted in a recovery of 54 eggs which had died before hatching. No dead larvae were found. It is believed that these 54 eggs, or 1.87 percent, represent the approximate total mortality which took place

in the gravel.

If 54 is subtracted from 1,858, there still remains a loss of 1,804 individuals. This number probably represents the loss from predator action. Of the 3,132 eggs which were held as a control group in the hatchery, 46 individuals died before the yolk sac was absorbed (nine as eggs and 37 as larvae). This number represents 1.47 percent of the total. It is interesting to note that from the eyed stage to the emergence time, the losses in both the hatchery trough and the gravel were quite similar and very small.

Silver salmon: 1,580 eyed eggs of this species were planted on February 27. 428 eggs were kept as a hatchery control. The first young fish were seen on April 13, and by May 2 the emergence was completed. This time, slightly less than three weeks, was shorter probably because of the slightly higher water temperatures which prevailed. See graph for data of emergence rate (Figure 6).

A total of 1,161 young fish were counted. This leaves a discrepancy of 419 when the counted total is compared to the original number. The examination of the gravel from the vacated redd yielded only three dead eggs and no dead larvae. This gives a loss in the gravel of only .19 percent and a probable predator loss of 416. The loss in the control group, covering the same period of time, amounted to 36 (33 larvae and three eggs) or 8.45 percent. In this case the loss in the hatchery was considerably higher than that discovered in the redd.

Steelhead trout: 1,416 eyed eggs of this species were planted on April 17. 2,060 were left for the hatchery control group. The first young trout were captured on May 14, and they continued to

emerge until May 26. This period of only 12 days is very short when compared to the time necessary in the case of the salmon species. The apparently faster developmental rate of the trout and the higher spring water temperatures are probably the principal reasons for such a rapid emergence. The rate is plotted on a graph (see Figure 6).

1,027 trout were captured and counted. This number subtracted from the original total leaves 389. Most of this number was accounted for when the gravel was examined and 225 dead eggs and one dead larvae were found. This left the comparatively small total of 163 which may be attributed to predator action. The trout did not tend to become concentrated in the lower basket but remained dispersed throughout the length of the section. This action evidently resulted in the predatory factor being greatly decreased.

The loss of 225 individuals in the gravel represents a 15.96 perdent mortality. This can be compared to a 429 or 20.82 percent loss in the hatchery, (13 eggs and 416 larvae). This hatchery loss is evidently due to some unknown disease that regularly affects trout at the Prairie Creek Hatchery.

When the results obtained in this part of the test section are considered as a whole it can be seen that the mortality varied quite widely between the three species, with the salmon doing much better than the trout. It is also evident that a slightly better survival was obtained in the test section rather than under hatchery conditions. It was interesting to note that most of the hatchery loss occurred during the larval stage while the main test section loss was in the eyed stage. It would probably be a good idea to repeat the experiment

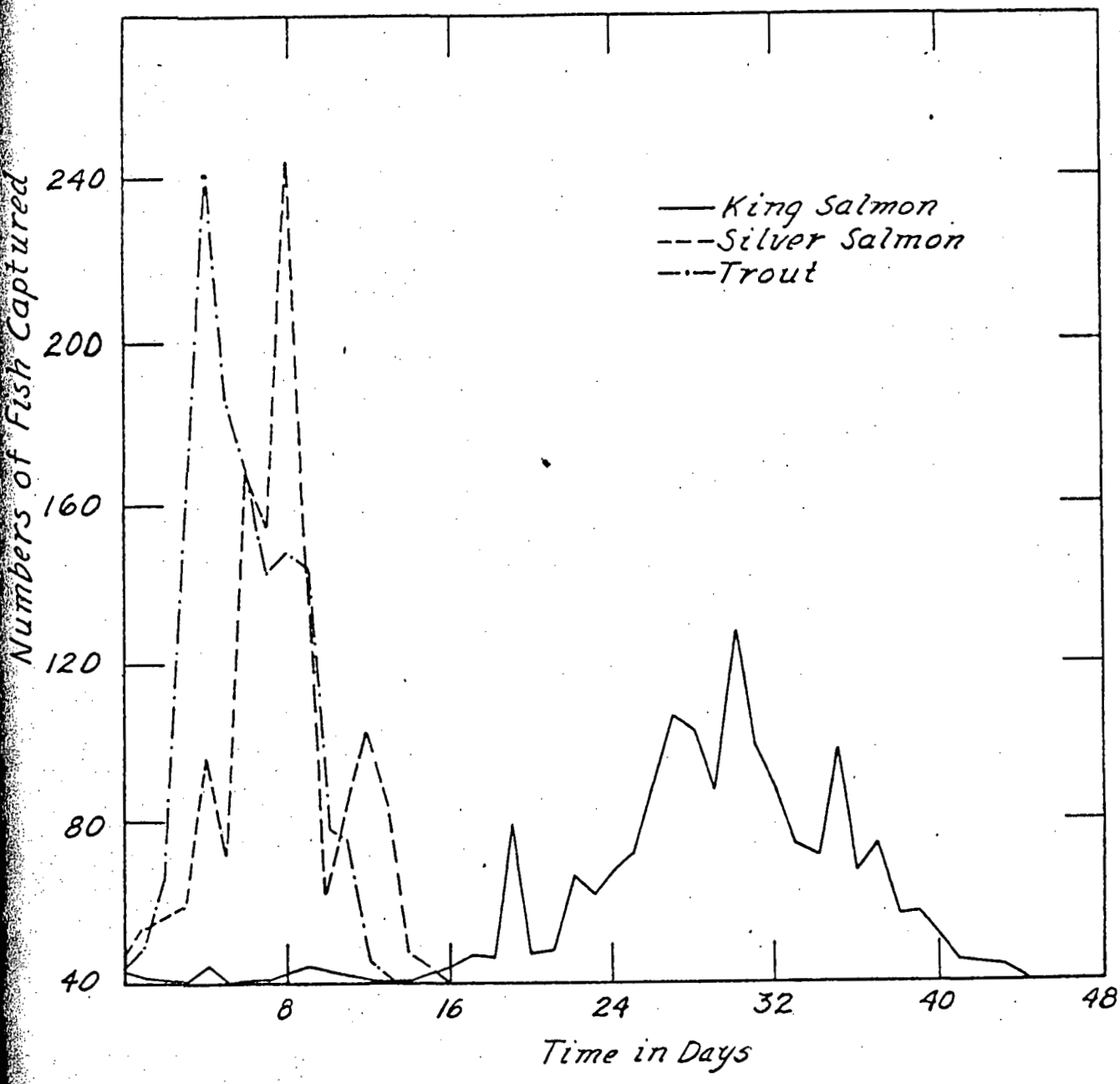

Figure 6. Comparison of the emergence rates in the test section.

once more in order to more definitely establish the reliability of this information.

PART VI. POPULATION MOVEMENTS

It was desirable to learn something about the movements and fluctuations of all of the fish native to the Prairie Creek drainage. The general movements of the large adult fish in this type of coastal stream are usually familiar to most observers because of the relative ease with which the spawning runs can be seen. On the other hand, there has been very little work done with the immature fish and those representing the smaller species.

Seining Program

In order to obtain a progressive picture of the changes which are continually occurring in the various species, it was decided to select a suitable area which could be sampled throughout the study period. Since it was necessary to use a seine for the procurement of the population samples, a stretch of Prairie Creek was selected that was comparatively free of logs, brush, and other debris. This section, approximately three hundred yards long, was located on upper Prairie Creek in the State Park just above the mouth of Godwin Creek. It was about equally divided into riffle and pool areas.

The seine, utilized for collecting in this area, measured about 15 feet long and 4.5 feet in depth. A quarter-inch square mesh was used, a size which allowed some escapement of very young

fish, but a finer mesh would have made the seine too difficult to handle. Other equipment used consisted of a small scalpel, a wood cutting block, a ruler, and a notebook for recording data.

It was originally planned to make a population estimate about once a month during the study period. However, it was found that if the flow was much above normal the seine became exceedingly difficult to handle and the efficiency of the sampling was consequently impaired. Therefore, only five estimates were made over the seven month period, and the time between each was somewhat varied.

Each population estimate was conducted in the following manner: the six pool areas within the selected section were carefully seined. All of the fish taken were placed on the smooth wooden block, measured, marked, and then returned to the same pool from which they came. The marking consisted of cutting off a small portion of the caudal fin so that the fish could readily be distinguished for a short time (Figure 7).

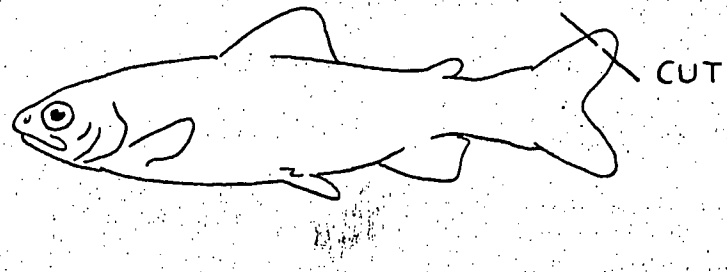

Figure 7. Location of cut to mark caudal fin

On the following day at approximately the same time, the six pools were again seined in exactly the same manner. The motions and

timing involved in each seine haul were carefully duplicated in this second day's work. The numbers of marked and unmarked fish could be recorded this time in addition to the measurements and identification as to species. With the above information at hand it was then possible to estimate the total numbers of fish (and of each species as well) which inhabited the section at this particular time.

The formula used in arriving at the estimated total was a simple proportion. If, for example, 20 fish were caught and marked the first day, and if 25 fish were caught the second day, (15 marked and 10 unmarked), the proportion can be set up in this manner:

let x equal total unmarked fish

$$\frac{15}{20} = \frac{10}{x}$$

$$x = 13.3$$

20 plus 13 equals 33 total population

I. First Estimate: November 20 and 21, 1948.

A. Seine haul first day

1. Steelhead - 4

2. Silver salmon - 20

B. Seine haul second day

1. Steelhead - 1 unmarked, 0 marked

2. Silver salmon - 5 unmarked, 2 marked

3. Cottid - 1

C. Calculated results:

1. Total fish in section - 73

2. Total by species - 11 steelhead
61 silver salmon
1 cottid

3. Size range (total length)

a. Steelhead - 2.5-2.9 inches

b. Silver salmon - 2.1-3.8 inches

c. Cottid - 3.9 inches

4. Size averages (total length)

a. Trout - 2.6 inches

b. Silver salmon - 3.1 inches

c. Cottid - 3.9 inches

II. Second Estimate: January 8, 1949.

No fish were taken on this attempt.

III. Third Estimate: February 26, 1949.

No fish taken.

IV. Fourth Estimate: April 23 and 24, 1949.

A. Seine haul first day

1. Steelhead - 1
2. Silver salmon - 39
3. King salmon - 9
4. Cutthroat trout - 0

B. Seine haul second day

1. Steelhead - 1 unmarked, 1 marked
2. Silver salmon - 47 unmarked, 14 marked
3. King salmon - 3 unmarked, 4 marked
4. Cutthroat - 1 unmarked

C. Calculated results:

1. Total fish in section - 83

2. Total by species

a. Silver salmon - 64

b. King salmon - 16

c. Steelhead - 2

d. Cutthroat - 1

3. Size range (total length)

a. Silver salmon (two age classes)

1. 1.5-2.2 inches

2. 3.0-5.0 inches

b. King salmon - 1.7-2.2 inches

c. Steelhead - 2.8-4.7 inches

d. Cutthroat - 10 inches

4. Size averages (total length)

a. Silver salmon (two age classes)

1. 1.8 inches

2. 4.1 inches

b. King salmon - 1.9 inches

c. Steelhead - 4.2 inches

d. Cutthroat - 10 inches

V. Fifth Estimate: May 21 and 22, 1949.

A. Seine haul first day

1. Steelhead - 0

2. Cutthroat - 0

3. King salmon - 6

4. Silver salmon - 85

5. Cottid - 1

6. Stickleback - 6

B. Seine haul second day

1. Steelhead - 1 unmarked

2. Cutthroat - 0

3. King salmon - 1 unmarked, 3 marked

4. Silver salmon - 34 unmarked, 32 marked

5. Cottid - 0

6. Stickleback - 1 unmarked, 1 marked

C. Calculated results:

1. Total fish in section - 193

2. Total by species

a. Steelhead - 1

b. Cutthroat - 0

c. King salmon - 8

d. Silver salmon - 171

e. Cottid - 1

f. Stickleback - 12

3. Size range (total length)

a. Silver salmon (two age classes)

1. 1.5-2.7 inches

2. 3.0-5.1 inches

b. King salmon - 1.5-2.5 inches

c. Steelhead - 4.5 inches

d. Cutthroat - 0

e. Cottid - 3.8 inches

f. Stickleback - 2.2-2.8 inches

4. Size average

   a. Silver salmon (two age classes)

      1. 2.1 inches

      2. 4.4 inches

   b. King salmon - 1.8 inches

   c. Steelhead - 4.5 inches

   d. Cutthroat - 0

   e. Cottid - 3.8 inches

   f. Stickleback - 2.4 inches

In order to obtain a more complete picture of these population changes it is planned to carry on this current study until the entire annual cycle is covered. Accordingly, at least two further estimates will be made, following the same established procedure. These will be accomplished probably in July and in September. With this additional information it will be possible to analyze the data more comprehensively than at this time.

Tentatively, it is planned to continue this part of the study for an additional year when the work is resumed on the rest of the problem. This would allow an interesting comparison to be made between two separate sets of information. It might also be possible to supplemant the seining program next time through the use of some small fyke nets or glass minnow traps.

GENERAL INFORMATION

It was possible to obtain further general information through the stream observations which were carried on during the study period. Such data as the time of spawning, location of redds, and relative

size of the run have already been given for the three most numerous salmonid species (silver salmon, king salmon, and steelhead trout). A fourth species of this same family is the cutthroat trout.

Although an occasional cutthroat was seen, the population seemed to be very small compared to the other three species. Only one spawning run was noted, when a group of six fish were seen swimming upstream in Prairie Creek on March 10. They appeared to be of a uniform size, apparently about 12 inches in length. Evidently these fish swam rapidly to the headwaters of Prairie Creek and its tributaries. Regretably there wasn't enough time available, during March, to maintain an extensive search for spawning pairs. Perhaps, during the final season's work, it will be possible to sample some redds of this species. Probably the actual size of the cutthroat run was larger than the observations indicate, since some spawned-out adults are taken throughout the Prairie Creek drainage during the first few days of trout season.

There was evidence of a striking degree of similarity in the selection of spawning area between the two species of trout and the two species of salmon. In the fall the king salmon confined themselves to the deeper water areas of the main Prairie Creek and lower Lost Man Creek, while, at the same time the silver salmon proceeded past these areas and on up to the headwaters and small tributaries.

In the spring, when the trout appeared, a repetition of the same process occurred. The steelhead remained in the lower areas while the cutthroat sought out the upper reaches. As the result, there was little or no competition between the adult members of these four species.

In regard to the young fish, there seemed to be a great deal of both food competition and predation during their existence in fresh water. The young salmon began to show up in the last week of February. The population peak probably was reached two months later in the latter part of April. They were consumed by the previous year's silver salmon and trout, and also the young salmon which hatched out earliest in the spring soon became large enough to prey upon the later hatching fry of the same year class. In addition, there ~~was~~ were a few cutthroat adults and cottids around at this time.

By the time the young trout began to appear, in the last part of April, all of these previously mentioned fish were waiting for them. The young trout seemed to be present in greatest numbers in the latter part of May. This population peak of the trout, as well as that of the salmon, was not immediately reflected in the data from the seining operations. The quarter-inch mesh of the net did not hold fish efficiently until they approached two inches in total length. Consequently, there were no small trout recorded in the seining data for May 21 and 22, although they could be seen in good numbers.

PART VII. SUMMARY

It was possible to make detailed observation on the activities of the adults of the four species of salmonids which are native to the Prairie Creek watershed, especially the silver salmon, king salmon, and steelhead trout. Significant differences in the habits of these species, not previously reported, were observed. Some of these most important differences were concerned with the lapse of time occurring between the arrival of the adults on the spawning area and the commencement of

breeding activities, variations in the part of the watershed utilized for spawning, and differences in the apparent size, deviation, and time of occurrence of the runs.

In addition, important variations were noted with respect to the actual spawning process. These include rapidity of digging, time required for spawning, creation of false redds, and length of life after egg deposition. The physical characteristics of the redd areas showed variation according to species, especially in regard to water depth and velocity, gravel size, and depth of egg placement. It was possible to compile a table showing the characteristics of the productive redds for the three principal species.

Samples were taken from productive redds during the various stages of development. The amount of information from this source was not as extensive as was originally hoped for, but with the results from another season's work it should be possible to obtain a close approximation of the natural mortality which can usually be expected to take place in the redd. It should then be possible roughly to compare this loss with that which takes place to a comparable developmental stage in artificial propagation.

The test section operation showed, first of all, that the adult fish will not successfully spawn where the water velocity is markedly less than in a normal habitat. Secondly, the planting of eyed eggs was most successful and the resultant mortality was quite low. The average loss from these plants was actually less than that which occurred in the hatchery controls.

Results from the seining program to date show that large variations can occur with respect to both the total numbers and the total by species. When the seining program is completed, in the fall of 1949, a separate paper will be submitted on the results of the population study over the one-year period.