J. Bruce Kimsey

SALMON RESEARCH AT DEER CREEK, CALIF.

SPECIAL SCIENTIFIC REPORT: FISHERIES No. 67

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FISH AND WILDLIFE SERVICE

Explanatory Note

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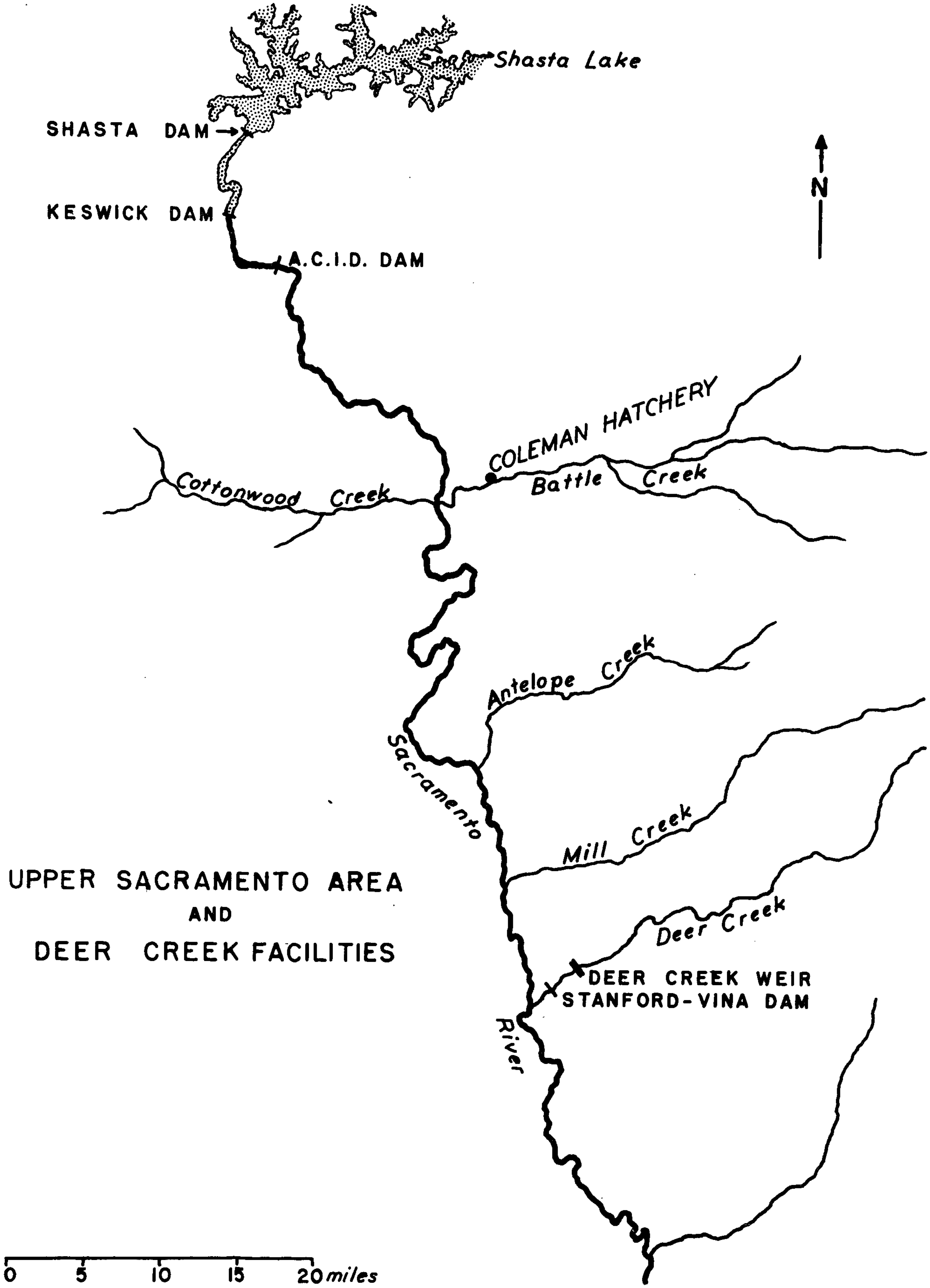

Location of places mentioned in the text.

United States Department of the Interior, Oscar L. Chapman, Secretary
Fish and Wildlife Service, Albert M. Day, Director

SALMON RESEARCH AT DEFR CREEK, CALIF.

By Frederick K. Cramer
and David F. Hammack

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ILLUSTRATIONS

The Shasta Salmon Maintenance Program, of which the Deer Creek research was a part, has been carried on successfully for several years and is adequately described elsewhere (Moffett, 1949; Hanson, Smith, and Needham, 1940). This report presents data and analysis not given in more general reports on the Program.

From the inception of preliminary surveys in 1938 until its termination in 1950, the entire program was under the supervision of the U. S. Fish and Wildlife Service and financed by the U. S. Bureau of Reclamation. Dr. Paul R. Needham directed the work from its beginning until 1944, and from then until 1950 Dr. James W. Moffett was in charge.

Field supervisor of the program until 1946 was Mr. Harry A. Hanson. From that time to 1950 this responsibility was that of the senior author.

Other employees, formerly or at present on the staff of the Fish and Wildlife Service, who have assisted greatly in various aspects of the Deer Creek program, are Dr. Osgood R. Smith, Leo F. Erkkila, Norman W. Mattoon, Verl L. House, Thomas J. Beland, Frank I. Barmettlor, Ralph H. Olson, J. Frank Massey, William H. Davenport, Thad M. Blake and Lewis P. Parker.

Engineering advice and aid in construction was supplied by the U. S. Bureau of Reclamation. Various types of useful information have been given by employees of the California Division of Fish and Game.

Description of Deer Creek

Deer Creek rises from a group of small springs in Child's Meadows, about 6 miles east of the town of Mineral, in Tohama County, Calif. It flows southeasterly for 6 miles to Deer Creek Meadows, thence southwesterly for about 50 miles to join the Sacramento River near the town of Vina. In common with many other streams draining the western slopes of the Sierras, Deer Creek begins in a mountain meadow and winds its way through miles of rugged canyon before reaching the Central Valley plain, where it flows through shallow gullies toward the river. Deer Creek Canyon is a deep cut in an ancient lava flow. At higher elevations its terrain is forested with conifers. In the lower regions the cover is the typical California valley oak-grassland association.

The first natural barrier to fish migration in the stream was a fall, 16 feet high, about 9 miles above Polk Springs and about 40 miles upstream from the mouth. A fish ladder around this barrier was completed in June 1943, and since then salmon have been able to utilize the stream area above it. About 6 miles above this first fall, a second fall drops sheer for about 20 feet. This upper fall is a barrier and limits utilization of Deer Creek by salmon to the stream area below it.

Two irrigation dams, one at the mouth of the canyon and one about 3 miles above the mouth of the stream, are located on Deer Creek. The lower dam, belonging to the Stanford-Vina Irrigation Company, is equipped with fish ladders on both north and south sides. The upper dam, property of the Deer Creek Irrigation Company, is a collapsible structure, and although no fish ladder is present, it is not a barrier to salmon migration.

The Deer Creek Fisheries Station is located about halfway between the mouth of Deer Creek Canyon and Sacramento River. It consists of a salmon-counting weir with supplementary towers, overhead cable, and hoist, living quarters, and a combination garage-office building. Not all of these units were available at the outset of this study but each was constructed as its need became apparent and as funds became available.

Deer Creek Program

In the original spawning-bed surveys of 1939 and 1940 (Hanson, Smith, and Needham, 1940), it was determined that Deer Creek, from its mouth to the lower falls, had gravel areas sufficient to accommodate 4,000 salmon nests, or ample space for a run of at least 8,000 fish. As a result of the original surveys, it was estimated that at least 1,000 additional salmon could be transferred to Deer Creek without causing crowded conditions among the native population. Since Deer Creek had enough spawning area to allow heavier utilization, and furthermore, since Deer Creek and Battle Creek were the only streams in the entire area into which spring-run salmon could be transferred successfully, it was decided that the early portion of the spring run in the Sacramento River would be transferred to Deer Creek.

It was necessary to determine, first of all, if transferred salmon would suffer any ill effects from the long haul in trucks, and whether transferred salmon would distribute themselves and spawn successfully throughout the length of Deer Creek. To answer these questions, experiments involving transfer of adult salmon into Deer Creek were conducted in 1941. These experiments are described in detail by Needham, Hanson, and Parker (1943) and Parker and Hanson (1944).

Observation of the utilization of spawning beds in the fall of 1941 showed that an estimated 7,000 spring-run salmon used only two-thirds of the available spawning gravel. Because the spawning area could be utilized more extensively and the fish ladder around the lower falls would be complete in 1943, thus opening up several additional miles of stream, it was decided that 10,000 salmon could be transferred from the Sacramento River without causing overcrowding. This figure was then set as the maximum allowable number of salmon to be transferred in any one year.

No salmon were transferred in 1942. Hauling continued in 1943, 1944, 1945, and 1946, although the number actually transferred each year never reached the allowable limit.

After the feasibility of transfers and the maximum numbers of salmon to be hauled each year had been determined, activity at Deer Creek was directed toward annual counts of native adult salmon, sampling of the downstream migration of young, studies of Deer Creek water temperatures, and observations of prespawning mortality, spawning, and utilization of available spawning grounds.

Transplanting of Salmon from Sacramento River to Deer Creek

The period of hauling varied from year to year. The beginning of transplanting operations depended upon the arrival of spring-run salmon at Keswick Dam and also upon the schedule of construction work under way. The termination of hauling each year was determined by the maximum water temperatures present in Deer Creek. When these became lethal to salmon, hauling, of course, was discontinued.

The number of salmon transferred to Deer Creek each year is shown in table 1, together with losses, periods of transfer, and numbers of successfully transferred salmon. Losses comprise fish lost in transit and those dying soon after release into Deer Creek.

Table 1. --- Salmon transfers to Deer Creek

Year	Total transfers	Losses	Successful transfers	Period
1940	None			
1941	920	284	636	June 3-30
1942	None			
1943	5,245	1,273	3,972	June 1-29
1944	7,867	1,263	6,604	Apr. 22-June 28
1945	1,604	100	1,504	Mar. 12-June 15
1946	167	20	147	May 6-June 14
1947	None			
1948	None			
Total	15,803	2,940 or 18%	12,863	

During the transfer operation, 15,803 spring-run salmon were introduced into Deer Creek. Of these, 2,940, or 18 percent, were lost. Presumably 12,863, or 82 percent, were successfully transferred. This percentage of successful transfers is considered a favorable one.

Transfer of the salmon to Deer Creek was made by means of specially built tank trucks, each of which had a capacity of 1,000 gallons. Total distance of the haul was about 60 miles and required from 2-1/2 to 3 hours to accomplish. The number of salmon per truck load ranged generally from 20 to 50, with an average load comprising 39 adults. The trucks were equipped with aerators and, while en route, the water in the truck tank was maintained at a temperature approximating 50 degrees Fahrenheit by circulating a portion of the water through a compartment filled with ice. When the trucks reached Deer Creek, the tank water was slowly tempered by pumping water from the creek into the tank. The fish were released when the water temperature in the tank was within 2 or 3 degrees of that in the creek.

Yearly Counts at Deer Creek Weir

Early in the investigations of the Shasta problem, the importance and necessity of knowing the size of the native salmon population was realized. With the advent of salmon transfers to Deer Creek, the value of such information was greatly increased. In 1940, a partial salmon count was obtained at the dam of the Deer Creek Irrigation Company at the mouth of the canyon. Since then, all counts have been made at the Deer Creek weir.

Periods of counting have not been uniform. Varying stream flows and run-off patterns determined the time of weir installation, and water temperatures regulated the termination of counting. It has often been necessary, because of floods, to remove the weir for varying periods of time during the counting season. The counts, therefore, are not complete.

End of the spring-run count in Deer Creek each year is always brought about by two conditions: (1) lack of sufficient water below irrigation diversions for the salmon to ascend readily, and (2) onset of high water temperatures which finally become lethal to salmon.

Counting of the fall-run salmon has not been attempted because of unpredictable stream flows which are either insufficient for migration or so high as to endanger the weir during this normally rainy season.

The yearly counts of salmon at Deer Creek, periods of counting, peak months or periods, and losses of salmon below the weir because of the onset of lethal temperatures are presented in table 2.

Table 2. --- Salmon counts at Deer Creek

Year	Period	Peak period	Number	Losses
1940	April 12-May 22	-	268	-
1941	May 20-July 6	June 4-15	635	-
1942	May 13-July 2	June	1,108	-
1943	Feb. 20-June 16	April	812	-
1944	Jan. 1-June 30	April	2,692	-
1945	April 13-June 23	May	3,363	283
1946	April 11-June 19	May	4,271	473
1947	April 11-May 15	May	2,669	108
1948	May 11-June 30	May	419	1
Total			16,237	865

From 1945 through 1947, a total of 10,303 salmon were counted through the weir. During these same years, 864 salmon were found dead between the weir and the mouth of the creek. This loss comprised nearly 9 percent of the number counted, and gives a conservative idea of the losses of adults in lower Deer Creek due to lethal water temperatures.

The total of transferred salmon, plus yearly counts at Deer Creek, is shown in table 3.

Table 3. --- Weir counts plus transferred salmon

Year	Successful transfers	Weir counts	Total
1940	-	268	268
1941	636	635	1,271
1942	-	1,108	1,108
1943	3,972	812	4,784
1944	6,604	2,692	9,296
1945	1,504	3,363	4,867
1946	147	4,271	4,418
1947	-	2,669	2,669
1948	-	419	419
Total	12,863	16,237	29,100

From hourly counts at Deer Creek, it has been found that there is no certain time during the day or night when a heavy migration can be expected. In general, however, the following statements concerning the movement of salmon in Deer Creek have been found to be true:

1. After a period of clear weather, a rain sufficient to cause a slight discoloration of the water will bring up a surge of fish.

2. At the close of a period in which the weather has been clear and the water relatively cool, sudden increases in water temperature to about 75° F. will cause an upsurge of fish.

3. After maximum water temperatures approaching 80° F. become common, the fish rest in deep pools throughout the day and move upstream only at night.

4. Water temperatures of 81° to 82° F. are lethal to adult king salmon.

5. Fingerling salmon in Deer Creek have remained alive in water of a temperature that is lethal to adults.

Distribution of Adult Salmon

Beginning in 1941, observations were made each year during the summer months along that portion of Deer Creek upstream from the mouth of the canyon to determine the distribution of adult spring-run salmon. Lethal water temperatures in the creek below the mouth of the canyon eliminate this lower section of the creek as a summer or prespawning-period holding area. Although the density of the population varied, it was always found that the salmon were well distributed throughout the stream section available to them. This distribution is important because it allows for the best possible use of the spawning gravels and prevents overcrowding on any particular area.

The distribution pattern of the fall-run salmon in Deer Creek is different from that of the spring-run, and is controlled primarily by water flows during October and November. With normal flows present, that is, enough water to enable the fall salmon to ascend the ladders over Stanford-Vina Dam, the bulk of the run spawns in the section of the creek between the canyon mouth and the Sacramento River. When lower-than-usual flows are present, the fall run is limited generally to that section of the stream below the Stanford-Vina Irrigation Dam. The fall-run salmon spawn soon after entering the creek from the Sacramento River and do not engage in any extensive holding or ripening period.

Spawning Observations

The most complete and thorough series of spawning observations was made in 1941 (Needham, Hanson, and Parker, 1943; Parker and Hanson, 1944), the year in which results of the experimental transfer of salmon to Deer Creek were obtained. Throughout the spawning season of the spring-run fish, the creek was examined daily.

The first prespawning activity was noted during the last week of August near the lower falls. Intensive nest-building activities were observed here the first week of September. In the Campbellville section, nest building began at the close of the first week in September. In the Apperson Ranch section, another week passed before any activity was noted, and below this section no nest building was observed until the first week of October. It was found that nest building activities commenced later the farther downstream the salmon were located, and that these activities did not commence until water temperatures had dropped sufficiently to equal those found in the upstream sections. The actual spawning season for the spring-run fish lasted from September 10 to October 25.

Subsequent observations in later years, while not as intensive, have shown that spawning periods of the spring-run fish closely followed those mentioned. In that portion of the creek above the lower falls now available to salmon because of a fish ladder, nest building activities and spawning usually begin the first week in September. By the end of the spawning season in 1941, a total of 1,463 dead salmon had been examined. The sex ratio in this sample was 1.65 males to 1 female. During this period of observation, the average area of 87 salmon nests measured in Deer Creek was 42 square feet.

Nest building activities and spawning of the fall-run salmon in Deer Creek occurs at a later date. Generally, this period for the fall fish is from the middle of October until the first of December.

Downstream Migration of Young Salmon

Sampling of the downstream migration of young salmon was started in 1941, but was not stabilized as to method, equipment, and site until the early spring of 1943. From that time on, sampling was uniform. The net was fished in the same location, over approximately the same season (January-June) and at the same time of day (night hours) each year. The last 6 years of fyke-netting at the Deer Creek Station have produced valuable information on the time of movements, peak periods, and size of migrants.

The type of fyke net used was rectangular in shape. It consisted of 1/4-inch bar mesh cotton webbing, 400 meshes deep, shaped to steel frames, the largest of which formed an 8-square-foot opening. The net tapered from the large opening to a point, and was tied off behind the fyke to form a bag in which the catch accumulated.

The hours fished each year, the total catch, the catch per hour, and and peak month of migration at Deer Creek Station during the years 1942 through 1948 are shown in table 4.

Table 4. --- Fyke-netting data, Deer Creek, 1942-48

Fished → January – June @ mid-[illegible] [illegible] (Valley)

Year	Hours fished	Total catch	Catch per hour	Peak month
1942	3,519	346	.098	March
1943	1,657	99	.060	March
1944	3,978	1,590	.400	April
1945	3,806	2,498	.656	March
1946	2,463	585	.238	April
1947	2,086	273	.131	March
1948	1,653	935	.566	March
Total	19,162	5,626	.307 (av.)	

A fyke net similar to the one used at Deer Creek Station was fished on Deer Creek at Polk Springs during the spring of 1946. At that location the peak month was March, and 1,482 fingerlings were captured in 1940 hours of fishing effort, or at a rate of 0.764 fish per hour. This is a higher rate of catch than any made at Deer Creek Station, approximately 30 miles farther downstream. At Polk Springs the peak catch occurred in early March, while at Deer Creek Station the peak was in April. The greater catch rate at Polk Springs may indicate a high mortality of young salmon, probably due to natural causes and to the irrigation diversion located between the two points.

It is interesting to note that there appears to be some correlation between the abundance of adult salmon moving upstream and the number of young salmon caught per hour of fishing effort on the crop produced by that spawning population. The comparison is given in Table 5, after the numbers involved have been reduced to comparable percentages. In this table, for purposes of easier comparison, the seaward migrant catch data are given on the same line as the numbers of adult fish, although actually the young from these adults are present in the stream in the early spring of the following year.

Table 5. --- Correlation between adult and young populations

Year	Adult fish transferred or counted less observed mortalities	Percent of total	Seaward migrant catch per hour	Percent of total
1941	1,271	4.48	.0983	4.57
1942	1,108	3.91	.0599	2.79
1943	4,784	16.73	.3996	18.53
1944	9,296	32.46	.6563	30.55
1945	4,867	17.01	.2375	11.06
1946	4,418	15.45	.1309	6.09
1947	2,669	9.96	.5656	26.33

In 1947, the anomaly from the correlation is probably due to the late rainfall during the downstream movement (spring of 1948 actually) which caused a greater-than-normal survival rate in these young fish. Irrigation did not start until well into May, a time at which the bulk of the migrants have passed into the Sacramento River. Hence, losses in irrigation diversions were substantially reduced. Also, the number of fall-run salmon in 1947 was greater than usual in Deer Creek because of early fall rains. This would also tend to increase the number of young migrants in the fyke-net catches.

The peak downstream movement of young salmon has always occurred in either March or April, usually in March. Lethal water temperatures are not normally present until the early part of June, and it is presumed that losses of young salmon from excessive temperatures are negligible.

Stream Temperatures

In April of 1947, a thermograph was installed on Deer Creek near the station and continuous daily recordings of water temperatures were made subsequently. Before that date, temperatures were taken by a hand thermometer at various times at the weir site, in the canyon, and on the upper reaches of the stream.

On July 3, 1941, a thermograph was installed at Campbellville. It remained there until October 22, 1941. Maximum temperatures were recorded each day about 4 p.m. They ranged from 48° F. to 70° F. In upper Deer Creek from the Lower Falls to Polk Springs during this time, the water temperature ranged from 43° F. to 67° F. In the area between Polk Springs and Campbellville, the range was 41° F. to 70° F., and below Campbellville to the Deer Creek Irrigation Company Dam at the mouth of the canyon, it was 48° F. to 77° F.

No water temperatures lethal to salmon have ever been recorded in Deer Creek from its headwaters to the mouth of its canyon. But, in the lower section of the stream from the canyon mouth to the Sacramento River, lethal temperatures occur every summer. The onset of these conditions varies with the weather, rainfall, and stream flow, but once these high temperatures are reached, the lethal conditions are usually maintained in the lower section of stream throughout the summer months.

The monthly maximum and minimum and the average daily maximum and minimum temperatures recorded for each month at Deer Creek Station are shown in table 6.

Table 6. --- Water temperatures at Deer Creek Station

	1947				1948			
Month	Average daily maximum	Monthly maximum	Average daily minimum	Monthly maximum	Average daily maximum	Monthly maximum	Average daily minimum	Monthly minimum
Jan.	-	-	-	-	46.7	52.0	40.2	34.0
Feb.	-	-	-	-	47.8	54.0	40.0	34.0
Mar.	-	-	-	-	51.4	55.0	42.5	40.0
Apr.	61.7	74.0	52.3	43.0	53.8	58.0*	46.1	43.0
May	75.5	84.0	62.3	55.0	60.0	69.0	51.4	45.0
June	76.0	82.0	64.8	57.0	71.7	85.0	60.2	53.0
July	80.8	84.0	69.0	67.0	-	-	-	-
Aug.	74.1	76.0	67.5	66.0	-	-	-	-
Sept.	73.0	77.0	65.8	63.0	-	-	-	-
Oct.	60.9	70.0	56.7	49.0	-	-	-	-
Nov.	50.4	55.0	40.6	46.0	-	-	-	-
Dec.	45.1	53.0	40.5	36.0	-	-	-	-

*Incomplete

Salmon in Deer Creek become lethargic and fail to migrate upstream when stream flows decline and water temperatures increase. This lethargy is overcome only when stream flows are increased and water temperatures greatly reduced. Coincident with low stream flows and rising water temperatures, great quantities of algae grow and are then separated from the stream bottom and disintegrate as they move downstream. Water analyses were undertaken in 1947 to learn if the disintegration of these algal masses reduced the dissolved oxygen content of the water materially or caused a marked change in the hydrogen-ion concentration.

Results showed that, apparently, little change in the chemical characteristics of Deer Creek results from algal decomposition. Dissolved oxygen decreases in amount as summer progresses, but this change is a function of water temperature. As temperature increases, the saturation point for oxygen in water decreases.

Deer Creek water becomes increasingly alkaline as the season progresses. This change is probably due to changes in run-off. Large quantities of snow water entering the stream from surface sources tend to reduce the alkalinity. After the snow run-off is completed, the stream is fed chiefly from springs and these springs contribute more alkalinity because of the dissolved salts they usually contain.

Diurnal changes in pH are evidenced by analyses made at different times on any one day. The pH appears to be lower during darkness and early morning when stream temperatures and oxygen content are lowest.

The amount of dissolved oxygen in the water of Deer Creek varied from a low of 7.92 p.p.m. at 5 p.m. on May 19, with a water temperature of 80° F. to a high of 11.85 p.p.m. at 11 a.m. on November 18, with a water temperature of 47° F. The pH varied from 7.4 to 8.5.

Hazards Encountered by Adult and Young Salmon

A substantial part of the seaward-migrant salmon produced in Deer Creek are lost in irrigation diversions which take nearly all of the stream by the end of May each year. Results of periodic fishing in the diversion located at the mouth of the canyon during the 1945 season are presented in table 7. They give a good example of the potential loss of young fish in such diversions.

Table 7. --- Losses in Deer Creek Irrigation Company Canal, 1945

Date	Number of salmon	Hours fished	Catch per hour
Jan. 25-31	4	119	0.03
Feb. 1-28	41	360	0.11
Mar. 1-31	45	570	0.079
Total	93	1,427	0.065 (av.)

In 1946, a fyke net was fished for a brief period (nights of May 31 and June 3 and 11) in the south canal of the Stanford-Vina Irrigation Company. A total of 32 young salmon was captured at a point below the fish screens. This catch exceeded that in the creek for the similar period.

The Board of Consultants recommended that the need for additional water in Deer Creek be investigated. If the need became apparent, a method was to be devised whereby water could be supplied to irrigation interests from the Sacramento River, and an ample, continuous flow maintained in Deer Creek for perpetuation of the salmon.

Before operations began and each year since, adult salmon have had difficulty negotiating the Stanford-Vina Dam. An inadequate fish ladder at this dam operated only occasionally. Usually the fish battered themselves to death or sustained major injuries on the shallow apron of the dam. The State of California remedied this condition in part when it built a functional ladder over the south end of the dam. Even with this new ladder, however, low flows in the stream make it extremely difficult for salmon to pass this dam.

When the stream flow diminishes and irrigation demands increase, the creek becomes so warm that often late arrivals are killed before they reach the dam. In 1945, close inspection of Deer Creek below the Station, immediately after the onset of lethal water temperatures, revealed 283 dead adult salmon. In 1946, despite rescue efforts, 473 salmon died on June 24. By May 20, 1947, water temperatures were high enough to kill 108 salmon in this section.

The downstream migration of young salmon and steelhead trout, as mentioned before, is reduced seriously by irrigation diversions at the mouth of Deer Creek Canyon and at Stanford-Vina Dam, despite operation of so-called screens in all ditches. Losses of young fish in diversions are aggravated in years of low precipitation because irrigation demands begin earlier than usual and nearly all of the stream flow is taken while the migrants are still moving downstream in large numbers. However, California State Fish and Game officials have condemned these screens and have designed new and adequate ones. A new rotary screen, together with a by-pass back to the creek, has recently been installed on the south canal of the Stanford-Vina Irrigation Company by the California Division of Fish and Game. Elimination of fish losses in the diversions from Deer Creek would go far to improve the contribution of that stream to the fishery resources of California.

Effect of Transplanting Program

Losses of both adult and young salmon in Deer Creek cast doubt on the ultimate success of the transfer activities carried on from 1941 through 1946. That these losses are not the result of lack of space is indicated by surveys of spawning grounds and natural holding areas, which show that space is available for more than 15,000 nests. This includes 5 miles of new spawning stream made available by construction of a fishway over Lower Falls which was first used in 1944. Water temperatures (except for those in the lowermost section of the stream) are suitable for holding of adult salmon and for egg incubation.

Stream-flow patterns are also favorable; floods do not occur until the hatching period is nearly over, and stream runoff, even in dry years, is enough to maintain a large run of spring salmon and many fall salmon.

The real causes for lack of complete success in the transplantation program lie in the low flows due to diversion of irrigation water, high water temperatures in the lower portion of the stream, poorly screened irrigation ditches and at least partial blockage by the Stanford-Vina Irrigation Company Dam. These conditions were present before salmon were transferred from the Sacramento River, and the addition of salmon similar in species and habits to the native population has resulted in only partial success.

The Deer Creek investigations led to the conclusion that certain improvements are necessary if efforts to maintain in it a segment of the Sacramento River spring-run salmon are to prove successful. These improvements are (1) development of an irrigation water supply from the Sacramento River for farms in the drainage which would permit the natural flow of Deer Creek to reach the river, (2) channelization of Deer Creek from the mouth of the canyon to the Sacramento River, and (3) removal of all dams and obstructions now impeding the movement of fish upstream and downstream. Channelization was done by the U. S. Army Corps of Engineers in 1949, but was carried out in such a way that the stream was widened instead of being deepened as would be favorable for salmon spawning. The anticipated benefit thus was not realized.

Summary

1. The construction of Shasta Dam created the problem of salvaging and maintaining the salmon run in the river, normally present above this structure. The plan of salvage and maintenance finally adopted, included, among other features, the transfer of an important segment of the spring-run from the Sacramento River to Deer Creek.

2. Surveys of available spawning areas and observations of spawning activities revealed that space in Deer Creek was available for over 15,000 salmon nests. The native population of salmon was small enough so that a total of 10,000 adult salmon could be transferred to Deer Creek each year without causing overcrowded conditions.

3. Experimental transfers of salmon from the Sacramento River to Deer Creek in 1941 determined that such transfers were feasible. The salvage plan, as essentially approved by the Board of Consultants in 1940, was put into operation on June 1, 1943.

4. From 1941 through 1946, a total of 15,803 spring-run salmon from the Sacramento River was hauled to Deer Creek. Of this number, 82 percent, or 12,863, were successful transfers. The other 18 percent died either in transit or soon after being released into the creek.

5. Beginning in 1940 and extending through 1948, a count of the spring run in Deer Creek has been maintained. High water, causing delays in weir installation or necessitating its removal, has resulted in incomplete counts each year. From 1940 through 1948, 16,237 adult salmon were counted. Because of low water flows and occasional flood hazards in the fall, no attempt has been made to count the fall-run segment of the population.

6. Salmon transferred and counted at Deer Creek since the beginning of operations total 29,100. The number each year was as follows: 1940, 268; 1941, 1271; 1942, 1108; 1943, 4784; 1944, 9296; 1945, 4867; 1946, 4418; 1947, 2669; and 1948, 419.

7. It has been found that the spring-run salmon in Deer Creek distribute themselves well throughout the length of the stream, thus allowing for the best possible utilization of available spawning areas. Fall-run salmon usually use only the lower section of the stream and spawn soon after their entrance from the Sacramento River.

8. Spawning of the spring run in Deer Creek begins the first of September and lasts until the latter part of October. Spawning usually begins earlier in the upper reaches of the stream and progresses downstream as water temperatures decrease. In 1941, intensive observation during the spawning season and recovery of spent adults revealed that the sex ratio was 1.65 males to 1 female. The average area of 87 salmon nests was 42 square feet.

9. Sampling the downstream migration of young salmon to determine time of movement, peak periods, size of individuals, and magnitude of the movement was begun in 1941. Method, equipment, and site fished were stabilized in 1943. From 1942 through 1948, a total of 5,626 young migrants was captured in 19,162 hours of fishing effort. The peak period of downstream movement in Deer Creek occurs in February or March, most frequently in March. The bulk of the young fish move out of the creek into the Sacramento River before water temperatures become lethal. A fairly close correlation exists in all years, except 1948, between the number of adult fish counted or successfully transferred each year and the rate of catch of the progeny of these fish the following spring.

10. Each year during the summer months, water temperatures in the section of Deer Creek below the mouth of the canyon become lethal to salmon. The onset of these high water temperatures is one of the factors which stop the upstream movement of spring-run salmon and cause a loss of fish. From 1945 through 1947, lethal water temperatures killed at least 864 salmon in the lower section of the creek. No lethal temperatures have ever been recorded in Deer Creek above the mouth of the canyon. Water analysis of Deer Creek showed that algal decomposition, as a result of low water conditions and high temperatures, caused little change in the chemical characteristics of the water.

11. By the end of May, nearly all of the flow in Deer Creek is diverted into irrigation ditches. Resultant low flows, together with high water temperatures, force an end to the upstream migration of spring-run salmon. The presence of sub-standard rotary screens on the ditches causes a large loss of young salmon. The California Division of Fish and Game has planned to screen adequately all ditches and one such screen and by-pass has been completed.

Low flows, high water temperatures, poorly screened irrigation ditches, and the extreme difficulty salmon have in passing over the Stanford-Vina Irrigation Company Dam during low water periods are the factors which prevent Deer Creek from expressing its full potential as a salmon producing stream. These conditions were present before salmon were transferred from the Sacramento River, and since these limiting factors have not been corrected, the addition into the stream of salmon similar in species and habits to the native population has resulted in only partial success.

12. The progeny of the transplanted salmon are doomed to a gradual or rapid extinction unless the conditions under which both populations are forced to live are changed enough to accommodate them. Improvements necessary are (1) development of an irrigation water supply from the Sacramento River for farms in the drainage which would permit the natural flow of Deer Creek to reach the river, and (2) removal of all dams and obstructions now impeding movement of fish upstream and downstream.

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