DEPARTMENT OF FISHERIES

State of Washington

Report of the Preliminary Investigations Into the Possible Methods of Preserving the Columbia River Salmon and Steelhead at the Grand Coulee Dam

Prepared for

THE UNITED STATES BUREAU OF RECLAMATION

by

The State of Washington, Department of Fisheries, in cooperation with the Department of Game, and the United States Bureau of Fisheries

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

LIST OF SCIENTIFIC AND COMMON NAMES OF FISHES USED IN THIS REPORT

Scientific Name	Common Name
Oncorhynchus tschawytscha	Chinook salmon
Oncorhynchus nerka	Blueback or sockeye salmon or silver trout
Oncorhynchus kisutch	Silver salmon
Salmo gairdnerii	Steelhead or rainbow trout
Salmo clarkii	Cutthroat trout
Salvelinus malma	Dolly Varden trout
Salvelinus fontinalis	Eastern Brook trout
Prosopium williamsoni	Rocky Mountain whitefish
Prosopium oregonius	Oregon whitefish
Catostomus syncheilus	Small scaled sucker
Catostomus macrocheilus	Large scaled sucker
Pantosteus jordani	Rocky Mountain sucker
Ptychocheilus oregonensis	Squawfish
Mylocheilus caurinus	Columbia River chub
Acrocheilus aleutaceus	Chisel mouth chub
Richardsonius balteatus	Shiner
Rhinichthys cataractae dulcis	Long nosed dace
Cyprinus carpio	Carp
Cottus beldingii	Bullhead
Cottus rhotheus	Bullhead
Entosphenus tridentatus	Sea-run lamprey

REPORT OF THE PRELIMINARY INVESTIGATIONS INTO THE POSSIBLE METHODS OF PRESERVING THE COLUMBIA RIVER SALMON AND STEELHEAD AT THE GRAND COULEE DAM *

INTRODUCTION

The fishery in the Columbia River has been decreasing slowly since the turn of the century. The constant inroads of civilization have continually worked to the detriment of the fish populations. First irrigation diversions, then small hydroelectric dams on several tributaries, then more and larger irrigation diversions, over-fishing by the commercial interests, increase in sport fishing, gaffing of fish on the spawning grounds, and increasing industrial and domestic pollution bringing pressure constantly against the fish populations, have slowly decreased their former abundance. So many factors were at work in so many ways that the public's attention was never riveted for any length of time on the decreasing value of this enormous natural asset.

The initial reports on the development of the Columbia River for navigation, irrigation, power, and flood control purposes, which did not include adequate protection for the fisheries, brought sharply to the public's attention that this asset was in perilous danger of being completely extinguished by such developments. Public opinion was directed intensively on the problems of the preservation of the Columbia River fishery which was already greatly diminished by the development of power and irrigation projects in the tributary streams. The State of Washington restricted the commercial fishery on its side of the river by the passage of Initiative #77; the pressure of public opinion forced the construction of adequate protective devices for the fish at the Bonneville Dam; at a cost of some $220,000 an additional fish ladder was built by the Puget Sound Power and Light Company on the Rock Island Dam; the U. S. Bureau of Fisheries was allotted a sum of money for the investigation of the problems of the Columbia River watershed; the Washington Department of Fisheries was able to secure funds for their long proposed program of screening the more than 200 irrigation and power diversions in the Columbia watershed that for the past 35 years had been diminishing the fish populations by the destruction of vast numbers of the young seaward migrants annually. The future of the Columbia River fishery began to look up a little.

* Note: The biological work upon which this report is based was outlined in open conference by the Departments of Fisheries and of Game of the State of Washington, and the U. S. Bureau of Fisheries. This outlined program was placed in operation under the supervision of Dr. Wilbert M. Chapman, of the State Department of Fisheries, who gathered the data and prepared it for this report.

John M. Mayhall assisted in the compilation of hatchery data relative to the design and operation of the hatchery system and also assisted in the design and construction of the apparatus used in the biological work.

Acknowledgment is made of the advice and help given by Professor Lauren R. Donaldson, School of Fisheries, University of Washington, and Joseph A. Craig, Associate Biologist, U. S. Bureau of Fisheries, and also for the cooperation of the State Game Department in providing a truck for the purpose of hauling adult steelhead from Rock Island to Icicle Creek, and also for the cooperation of the State Game Department in providing equipment to aid the biological investigation.

At this point a new factor entered. For the past twenty years plans have been proposed for placing the semi-arid sections between Soap Lake and Pasco under irrigation. Soon after the present national administration took office, these plans crystallized, and the years' long plan of Eastern Washington citizens began to take on the aspects of reality. The plan settled upon was to build a dam across the Columbia and divert a portion of its run-off into Grand Coulee, from whence a gravity flow irrigation system would dispense the water to the great fertile plains below Ephrata, at the same time generating large quantities of electricity at the Columbia Dam. Before the ink on the final plans hardly had time to dry, construction on this dam was under way.

In the first burst of enthusiasm that the whole Northwest felt at the culmination of its plans, the fact that the construction of this dam would strike a serious blow to the Columbia River fishery was overlooked by the general public. When the plans for the high dam were finally approved, it became apparent (for reasons discussed below) that salmon could not be put over a dam of this height as they had been at the much lower Rock Island and Bonneville dams. The stock of salmon spawning in some 1,100 miles of river and tributaries was to be permanently destroyed. Further study revealed that the alternative methods for preserving these runs would be expensive, if they were possible. There was a feeling that the vast economic gains to be derived from this project should not be endangered by consideration of the fish. It was even felt in some quarters that the fish were not worth the money that it would take to preserve them.

That this last statement is erroneous is at once apparent from a glance at the facts. Although the Columbia River fishery is suffering from serious depletion, it still produces an annual yield to the commercial fishermen of from \$3,000,000 to \$5,000,000. Calculating this as a 6 per cent interest yield from a capital stock, it means that the fish populations of the Columbia River represent a capital investment of from \$50,000,000 to \$80,000,000. Each tributary stream is necessary for maintaining this annual production and each area represents a definite part of the capital investment. It is a matter of simple business prudence that, if the loss of a capital investment is threatened and a small portion of that investment reinvested would save the whole, the reinvestment should be made. The figures cited above do not include the large investments in boats, nets, canneries, processing plants, etc., which the industry has. Nor do they include the several millions of dollars already spent on fishways at Bonneville and Rock Island dams. No consideration is taken of the sociological costs which would be incurred by the decline of an industry upon which several thousand people depend for their livelihood. Furthermore, no consideration is taken of the sociological costs which would be incurred by the destruction of the inestimable recreational asset represented by the steelhead trout.

It is at once apparent that the expenditure of a sizeable sum of money to preserve the salmon runs of the upper Columbia is justified purely from a financial viewpoint. There is a further consideration from the national viewpoint; that is, that a necessary basic protein food resource should not be destroyed. While at present the country produces sufficient food for its inhabitants, the example shown by the teeming populations in more anciently settled portions of the world demonstrates that the human race on occasions can reproduce beyond the ability of the country to produce food. Food resources must be preserved for the future. There is no reason why agriculture and aquiculture cannot exist side by side.

Grand Coulee Dam will permanently isolate the spawning and rearing area of 1,100 miles of stream in the upper Columbia River. The promising programs which were afoot to rehabilitate these runs can never take place. The irrigation and power developments in connection with the Grand Coulee project are confiscating valuable prior rights to the river held by the fish and therefore by the commonwealth to which the fish belong. It is only just that these developments pay compensation for these confiscations; that is, the cost for the apparatus necessary to perpetuate these runs should be included as a part of the capital investment of the dam and irrigation system, and the operation of this apparatus should be included in the operating costs of the irrigation and power developments.

This the Reclamation Service, as the governing body of this project, has agreed upon. After this point was settled, there was left the question of what was the best way to take care of the fish. So little was known that a thoroughgoing investigation was essential. The State Department of Fisheries had no funds to use for such an investigation. Therefore, the Reclamation Service, upon request, provided $25,000 to be expended by the State Department of Fisheries over a one-year period for this study. By the time the money was received the early spring downstream migrations were nearly over and the upstream migrations of adults were well begun. Only six months of field work was possible. Therefore, the biological work was necessarily incomplete for lack of time. The following is a report on that investigation and recommendations, based upon its findings, for the perpetuation of the upper Columbia River salmon and steelhead runs.

PROBLEM

Grand Coulee Dam will stop the migration of salmon and steelhead to their spawning grounds in the upper Columbia River. It is the purpose of this report to present a method for the preservation of these runs of fish. The construction of this dam completely destroys the spawning grounds of the San Poil, Spokane, Kettle, Colville and Clark Fork rivers, and the numerous smaller creeks in the United States as well as the vast drainage system of the Columbia in southeastern British Columbia, including particularly Upper and Lower Arrow Lakes and Slocan Lake, by making them inaccessible to the adult fish. It eliminates 1,140 lineal miles of stream from the area available to the spawning fish.

The construction of the low dam, as originally planned, would have presented no insurmountable obstacles to caring for the fish. There would have been a spill over the dam during the time the young fish were migrating downstream; and the adult fish could have been put over the dam by ladders or lifts, as is done elsewhere successfully. The present plan of constructing a dam with 350 feet of head completely alters this picture. For several reasons it is impractical, if not impossible, to put fish over a dam of this height and maintain a run with the project under its ultimate development.

1. The tailrace, or the water on the downstream side of the dam, will be subject to maximum drops of as much as 25 to 40 feet vertically within a few minutes time with large variations, or a complete cutting off, of the load on the generators. The construction of fish ladders capable of allowing fish to go over a height of 350 feet and capable at the same time of working under such extreme and rapid fluctuations in tailrace levels, is, if not impossible, an extremely difficult problem.

2. At the time of the peak in the runs of blueback and chinook salmon (June, July and August) there will be a spill over the dam, most of the time of large volume. Hence, there will be all along the 1,800 foot spillway of the dam a violent current of agitated water to which the adult fish will be naturally attracted. The proportionally minute agitation produced by the water in the fish ladders would probably attract but a small proportion of the fish. The rest would continue beating themselves to pieces against the violent backlash along the face of the spill. The construction of a collecting apparatus along the face of the dam to lead the fish into the ladders would be very expensive. Furthermore, such devices would have to contend with the above noted sudden fluctuations in the level of the tailrace which would probably render them ineffective.

3. In the spring, when the river is rising, the pumping units will be pumping 18,000 second feet of water from behind the dam (for the irrigation part of the development), a stream about the size of the Skagit River. It will be a practical impossibility to screen these pump intakes with mesh fine enough to keep the young fish out. Unfortunately, this pumping period will coincide with the spring downstream migrations of the young salmon and steelhead. Large numbers of them would be pumped into the irrigation system to perish.

4. There will not be a spill over the crest of the dam the year around. The period of spill will vary widely from year to year with the fluctuating run-off period of the river and the power and irrigation load. In some years at least there will be no spill from September 1, to the latter part of April, or perhaps into May, coinciding with both the spring and fall downstream migrations of the young fish. In the spring this will hold up the young fish, concentrating them behind the dam so as to increase the number taken by the irrigation pumps. A large volume of water would flow over the 1,800 foot long crest of the dam in a thin sheet. When the spring spill started there would be a time at first when the sheet of water flowing over the crest would be so thin that the concentrated young fish population going over the dam would be all or mostly killed by the 400 foot slide down the concrete face of the dam. In the fall the young fish would be held over behind the dam till the next spring by the cessation of spill where there would be a minimum of food for their support.

5. Even with an abundant flow of water over the crest, so that the fish would not come into contact with the concrete, it is questionable how safely they could negotiate this 350 foot fall.

At the bottom of the spill of the dam there is to be constructed a device called a "bucket", which has the specific purpose of dissipating the vast energy of the water falling this distance. Experiments made by Mr. Milo Bell, Chief Engineer of the State Department of Fisheries, on the scale model of the dam at Fort Collins showed that small objects like young fish entering this violent backlash might not go right through and on down the river, but can go round and round in the current for a considerable length of time. How much of such punishment the young fish could stand is unknown. The other alternative the fish would have, of going through the turbines, would probably be more dangerous than the former because of the large difference in head.

Therefore, it is impractical to either put the adult fish over the dam so they could spawn, or to get the young fish safely back down over the dam on their seaward trip. Also, it should be noted that before the final decision to construct the high dam was made, construction on the foundation structure was nearing completion and all the plans for the dam were in their final shape. The construction of devices for handling the fish would have entailed costly alteration on that portion of the dam already constructed.

An alternative to passing the fish over the dam would be to construct a hatchery near the dam and take the spawn artificially. This would bring up the same difficulty mentioned above in collecting the fish in competition with the attraction of a large volume of agitated water along the 1,800 foot spillway. On the basis of the cost for similar structures at Bonneville, it is estimated that the cost of construction of a collection apparatus along the face of Grand Coulee Dam would not be less than one million dollars. It is very doubtful whether such structures when constructed would effectively collect the fish. Unlike the split channel found at both Rock Island and Bonneville dams, whereby the shore line of the river and island serves as leads for the fishways, the river leaves the base of Grand Coulee Dam in a straight channel.

If such contrivances were built and did operate successfully, the hatchery operations would not. When the fish arrive at the dam they are green. This would necessitate holding them until the sexual products ripened. In the rugged semi-arid country in the vicinity of the dam, there is neither space sufficient for the necessary holding and rearing ponds and hatchery, nor is there available a suitable water supply. Therefore, it is held that the construction of a hatchery near the dam, if it did not end in complete failure to propagate the runs of fish, would be in any event excessively costly and would likely prove to be very inefficient. For the same reasons noted above, there is no practical place between Grand Coulee Dam and the mouth of the Okanogan River to collect the green fish, hold them to maturity and successfully hatch the eggs. The nearest place downstream where the fish could be collected in a practical manner is the Rock Island Dam of the Puget Sound Power and Light Company, 14 miles below Wenatchee. The dam is high enough to prevent salmon from jumping over it. On this structure are three operating fish ladders, one on either side of the river and one in the middle through which all the salmon ascending to the upper Columbia must pass to reach their spawning grounds. At a proportionately small cost and without presenting any special construction difficulties, the fish could be trapped at this point.

Some difficulties in operating at Rock Island Dam are presented. The salmon and steelhead when they reach this dam are not ripe and will not spawn for several months. The blueback pass over the dam in July and August and do not spawn until the latter part of September. The first chinook reach Rock Island in April and do not begin spawning until the latter part of August. The fall run of steelhead pass Rock Island in September, October and November and do not spawn until the following late winter and spring. Thus, provisions must be made for the holding of these fish from the time they appear at Rock Island until they are ready to spawn. Also, if the fish are taken at Rock Island, it will be necessary to handle the smaller percentage of the fish naturally bound for the Wenatchee, Entiat, Methow and Okanogan rivers as well as the larger percentage naturally going to the tributaries of the Columbia above Grand Coulee Dam. As the fish reach Rock Island it is impossible to segregate the various races of fish.

The only possible exception to this might be the blueback. On other streams along the western coast of America and the eastern coast of Siberia it has been noted that fish of this species spawn naturally in places where the young can drop back into lakes to spend a year or more before descending the main stream to the sea. The number of blueback passing into Lake Wenatchee on the Wenatchee River and Lake Osoyoos on the Okanogan River was known from counts made on the fish ladders of the Tumwater and Oroville dams respectively. These were the only two of the four lower tributaries into which the blueback went to spawn. From these counts it was known that the combined runs into these two lakes formed only a small proportion of the total run passing Rock Island Dam. What was not known was where the rest of the blueback spawned. If they spawned in the river below Grand Coulee Dam it would not be necessary to handle them at Rock Island. They could be left free to spawn naturally and thus considerably reduce the cost of operations. If, however, these fish followed the habits of this species elsewhere and ascended to the lakes of the upper Columbia to spawn, Grand Coulee Dam would be an impassable barrier to their migration and they would have to be included in the Rock Island operations. This point was investigated as noted below.

In the vicinity of Rock Island Dam there was no hatchery site available for the same reasons as those given for Grand Coulee Dam. The summer water tempera--tures of the Columbia River are too high for hatchery and rearing pond use. Holding pond experiments at Rock Island in 1935, using Columbia River water, showed mortalities of 50 per cent for chinook and 52 per cent for bluebacks, indicating clearly that Columbia River water is unfit for holding adult salmon in concentrations. In the semi-arid country around Rock Island no other water supply is available. The only suitable site in the vicinity, which had sufficient space for hatchery operations of this size and an ample water supply that was free from pollution, was found to be at the confluence of Icicle Creek and the Wenatchee River near the town of Leavenworth. This site is approximately 42 miles by highway from Rock Island Dam.

Two possible alternatives as to how to get the fish from Rock Island Dam to Icicle Creek were presented. They could be hauled by truck to the hatchery site, or they could be hauled to the mouth of the Wenatchee River (cutting down the hauling distance to about 16 miles), liberated into the Wenatchee River and allowed to proceed up to Icicle Creek under their own power. They could be diverted into the holding ponds at Icicle Creek and left to ripen. Both methods were studied as noted below.

Since it was considered impractical to pass the fish over Grand Coulee Dam, and a hatchery site was available near Leavenworth, the following plan was proposed: To take the eggs at the Icicle Creek site. Establish rearing stations on the Entiat, Methow and Okanogan rivers as well as at the Icicle site on the Wenatchee. Distribute the resultant young fish to the Wenatchee, Entiat, Methow and Okanogan stations, and liberate them in these four tributaries.

This brought up the problem of attempting to produce from this 677 miles of lower tributaries all the fish that it would naturally support, and above this to also produce the amount of fish from these lower streams that the 1,100 miles of river above Grand Coulee should support. Obviously it is a manifest impossibility to do this by allowing the fish to spawn naturally because such factors as food, predators, and spatial requirements limit the natural productivity of any stream. Instead of a natural crop of young fish from these four tributaries, it becomes necessary to produce an intensified crop far in excess of that which could be expected naturally. It was also known that the practice of liberating hatched out fish in the fry stage could not compensate for this limitation because of the large natural losses in nature between the fry stage and the time of downstream migration. Therefore, it was proposed to rear the hatched out fish to a size optimum from both an economic and a conservation viewpoint before liberating. This point is discussed more fully in the section on Rearing.

It was also proposed to trap the fish at Rock Island and take all the spawn at the Icicle hatchery until the upper river runs would be transplanted to the lower tributaries, and then allow the fish to ascend these tributaries to four hatcheries without the intervention of the trapping and hauling at Rock Island Dam. The success of this portion of the plan depends upon the correctness of the following assumption: That salmon and steelhead that have migrated to sea will return to the river in which they were raised, not to the stream in which their immediate ancestors were raised; that is, that the home stream instinct is acquired rather than hereditary.

That salmon and steelhead can be transplanted from one watershed to another, even thousands of miles apart, and successfully establish marine runs, is an uncontestable fact. Steelhead (or rainbow trout) have been successfully transplanted from the Pacific states to many places over the temperate region of the earth. Chinook salmon have been successfully established in New Zealand and the St. Lawrence River watershed in Canada (Davidson and Hutchinson, the Progressive Fish Culturist, June, 1937). Similar transplantations from one hatchery to another on different watersheds up and down the Pacific Coast have been common practice for years. J. Kemmerich, of the U. S. Bureau of Fisheries, has successfully transplanted sockeye salmon from the Baker Lake run on the Skagit River to Lake Cavanaugh, Beaver Lake, Pleasant Lake and Lake Stevens where runs of sockeye never occurred naturally.

The point involved at Grand Coulee is not that of merely transplanting runs successfully from one watershed to another, but transplanting runs from one portion of a watershed to another part of the same watershed so successfully that none of the returning adults will attempt to return to the original part of the watershed from which their parents came. That is, will all the fish produced from eggs taken from blueback which normally spawn in the Arrow Lake country, but which were hatched and reared in Lake Osoyoos on the Okanogan River, return to Lake Osoyoos to spawn, or will part of them turn aside and go on up to Grand Coulee Dam in an attempt to return to Arrow Lakes? Upon this point depends whether the trapping and hauling of the fish from Rock Island to the central hatchery on the Wenatchee River must be a continuous process for as long as Grand Coulee Dam is in the river, or whether it can be dispensed with after the first cycle. Evidence to prove or disprove this point either one way or another is very scarce. Mr. Kemmerich transplanted marked sockeye fingerlings from Grandy Creek on the Skagit River to Bacon Creek on the same river. From this planting, he got returns of marked sockeye adults in Bacon Creek and none of the marked fish returned as adults to Grandy Creek. Mr. George Kelez, of the U. S. Bureau of Fisheries, has experimented extensively with the liberation of marked silver salmon fingerlings in the Puget Sound area. In a letter to the State Department of Fisheries, Mr. Kelez says in part:

> ".....At the time of the first Samish marking experiment in May, 1934, I moved 9,800 fingerlings, approximately 65 mm. in length, from the Skykomish Hatchery to the Samish, marked them by fin excision, and released them in Friday Creek. During the winter of 1936-1937, 11 of these fish were recovered in the Samish River and in Friday Creek. None were found in nearby streams and none returned to the Skykomish rack. This return was about four times as great in proportion as that from the first Samish lot of native fish, which averaged .45 mm. in length.

(The Samish experiments are described in the article in the 'Progressive Fish Culturist' for July, 1937, #41)

"In May - June, 1935, I moved 25,000 coho fingerlings from the Green River Hatchery to the Puyallup Hatchery, marked them by fin excision and released them in Voights Creek. At the same time, 50,000 native fish were marked at the Puyallup Hatchery with a different fin combination and also released in Voights Creek. Up to November 26 of this year (1937) 7 of the Green River fish had been recovered as adults at the Voights Creek rack and 28 of the native fish were also recovered. Thus far, no marked fish have been recovered at the Green River rack.

"From the data at hand, I think we may safely conclude that there is a very definite tendency for transplanted coho fingerlings to return, not only to the stream in which they were planted, but even into the very tributary of that stream in which they were first released.............."

Rich and Holmes (Bull. Bur. Fish. XLIV, 1928) found in their marking experiments with Columbia River chinook that there was no tendency for the transplanted fish to return to the stream from which the eggs were taken, and also that there was a tendency to return to the stream in which they were planted except when conditions were unfavorable to the migrations of the adults.

From these meager data, it is possible only to state that it is probable, but not positive, that after the first cycle the fish planted in the Wenatchee, Entiat, Methow and Okanogan rivers will return to those streams to spawn and will not try to return to the upper Columbia. To prove this point conclusively it will be necessary to haul adult fish from Rock Island for a few years past the first return cycle.

It should be borne in mind that the failure of this portion of the plan would not cast any reflection on the ability of the hatchery system to propagate these runs successfully. It means only that the hauling of fish from the Rock Island Dam would then have to be carried on year after year indefinitely.

COUNTS OF FISH AT ROCK ISLAND, TUMWATER AND OROVILLE DAMS.

Since 1933, counts of the fish going over Rock Island Dam have been made through the cooperation of the U. S. Bureau of Fisheries, the State Department of Game, the State Department of Fisheries and the Puget Sound Power and Light Company. In 1935 and 1936 counts were made by the Bureau of Fisheries at Tumwater Dam on the Wenatchee River and Oroville Dam on the Okanogan River. This year these counting operations were taken over by the Grand Coulee Salmon Investigation for several specific reasons:

1. To determine the average number of salmon and steelhead passing Rock Island, so that the number of eggs to be expected could be determined, and the size of the hatchery needed for the run ascertained.

2. To find out whether the phenomenal run of bluebacks counted in 1933 (40,727) would be repeated in 1937, and therefore could be expected cyclically in years to come.

3. To find, by elimination of the numbers of blueback entering Lake Wenatchee and Lake Osoyoos, the quantity of blueback spawning in the upper Columbia.

The implications of each of these points in relation to the proposed program are at once apparent.

The counts were made in the following manner: A counting weir was installed in the ladders at Rock Island so that all the fish passed through a restricted opening 4 feet wide. At this opening was a white board, about 2 feet wide, over which all the fish passed. There was a gate by which the opening could be closed. From 6 inches to a foot and a half of water was kept running over the white counting board. While the gate was raised, the fish went over the counting board and on up the stream. A man stood over the board and counted them. Counters were at each place 7 days a week. During the peak of the run at Rock Island (in the latter part of July and August) they were kept at the dam from 5 or 6 o'clock in the morning until dark. During the rest of the season counting did not start until 8 a.m., and usually ceased at 5 p.m. Counts were not made at night, since it had been ascertained by previous investigations that the fish did not move in the ladders during the period of darkness.

The resultant figures are probably quite accurate as to numbers of fish going over the dam, but the numbers per species are not so accurate. For instance, the "sucker" category consists of 3 species: _Catostomus syncheilus_ (fine scaled sucker), _Catostomus macrocheilus_ (large scaled sucker) and _Pantosteus jordani_ (Mountain sucker). The "chub" category includes _Mylocheilus caurinus_ (Columbia River chub), and _Acrocheilus aleutaceus_ (chisel mouth chub). The "whitefish" category includes _Prosopium williamsoni_ (Rocky Mountain whitefish) and _Prosopium oregonius_ (Oregon whitefish). The whitefish and chubs, being of approximately the same size and coloration, are easily confused. Fortunately, whitefish run predominately in the late fall, and the chubs in the middle of the summer. To a lesser extent chubs, squawfish and suckers can be mistaken for each other when they are coming across the board together in large numbers, or if one darts across rapidly. The counts of shiners and lampreys are not accurate as to numbers. Shiners are so small that numbers go between the rack bars. Lampreys are so slender and pliable that numbers of them also go between the rack bars.

Counting at Rock Island started this year on May 8 and ended October 27. In Table 1 the counts of this year are given by months, with the counts for former years for the same periods.

In 1933, 15,668 chinook, 40,727 blueback, and 1,055 steelhead were counted over Rock Island Dam from July 20 to September 30.

In addition to the fish listed in Table 1, 9 catfish and 2 bullheads were counted over the dam. One perch was noted going down the west ladder.

The counts by ladders for the various species for 1937 are given in Table 2.

Table 1. Counts of Fish Passing Rock Island Dam

Species	Chinook 21# Ave				Blueback -3#				Steelhead -9#			
Month	1934	1935	1936	1937	1934	1935	1936	1937	1934	1935	1936	1937
January	-	0	-	-	-	0	-	-	-	2	-	-
February	0	0	-	-	0	0	-	-	0	2	-	-
March	1	0	-	-	0	0	-	-	27	14	-	-
April	22	3	-	-	0	0	-	-	151	238	-	-
May	388	1473	767	58	0	23	0	0	11	729	823	316
June	87	940	1305	243	17	18	30	4	8	37	370	87
July	954	620	3248	2961	1526	5404	14975	13584	9	34	147	31
August	4776	8641	1070	1154	644	8482	1495	1397	9	792	266	251
September	309	3667	893	903	40	85	17	91	152	2104	727	838
October	560	816	-	203	0	0	-	15	147	1261	-	806
November	2	-	-	-	0	-	-	-	48	-	-	-
December	0	-	-	-	0	-	-	-	18	-	-	-
Total	7099	16160	7283	5522	2227	14012	16516	15091	580	5213	2333	2329

Species	Silver				Sucker -2#				Squawfish 3			
Month	1934	1935	1936	1937	1934	1935	1936	1937	1934	1935	1936	1937
January	-	0	-	-	-	0	-	-	-	0	-	-
February	0	0	-	-	0	0	-	-	0	0	-	-
March	0	0	-	-	23	4	-	-	0	0	-	-
April	0	0	-	-	126	400	-	-	0	58	-	-
May	0	0	-	0	258	1091	810	301	3	55	51	53
June	0	0	-	0	176	556	2731	757	170	172	1430	270
July	0	0	-	4	890	8866	13480	11190	1282	816	3696	3615
August	0	0	-	35	939	2574	3801	2391	1052	363	932	612
September	62	2	-	17	911	698	3910	1591	555	136	178	943
October	7	8	-	2	764	1798	-	448	30	148	-	29
November	0	-	-	-	35	0	-	-	0	-	-	-
December	0	-	-	-	0	0	-	-	0	-	-	-
Total	69	10	-	58	4122	15987	24732	16678	3089	1748	6287	5522

Species	Whitefish				Chub				Shiner			
Month	1934	1935	1936	1937	1934	1935	1936	1937	1934	1935	1936	1937
January	-	0	-	-	-	0	-	-	-	0	-	-
February	0	8	-	-	0	0	-	-	0	0	-	-
March	11	72	-	-	0	0	-	-	0	0	-	-
April	24	1376	-	-	1	60	-	-	0	0	-	-
May	6	81	0	0	0	238	162	169	0	0	0	0
June	2	7	0	0	130	353	5607	559	13	115	213	0
July	9	10	2	2	1630	3484	3419	2440	368	833	1414	332
August	176	42	4	2	2000	831	1311	886	825	571	219	77
September	177	122	6	42	1028	1252	2464	1587	584	750	143	59
October	1887	252	-	94	37	379	-	170	9	0	-	2
November	1546	-	-	-	0	-	-	-	0	-	-	-
December	310	-	-	-	0	-	-	-	0	-	-	-
Total	4148	1970	12	140	4826	6597	12963	5811	1799	2269	1989	468

Table 1 (Continued)

Species	Carp				Lamprey			
Month	1934	1935	1936	1937	1934	1935	1936	1937
January	-	0	-	-	-	0	-	-
February	0	0	-	-	0	0	-	-
March	0	0	-	-	2	0	-	-
April	5	0	-	-	0	81	-	-
May	84	0	0	10	60	17	0	0
June	57	0	1	2	801	73	95	17
July	243	12	103	156	4926	6664	660	125
August	239	22	15	7	2509	3343	100	343
September	63	1	8	23	940	833	48	71
October	3	4	-	1	132	24	-	0
November	0	-	-	-	0	-	-	-
December	0	-	-	-	0	-	-	-
Total	610	39	127	199	9368	11729	903	556

Table 2. Counts of Fish Passing Rock Island Dam from May 8, to October 27, 1937, by Ladders.

Species / Ladder	Chinook	Blue-back	Steel-head	Silver	Sucker	Squaw-fish	White-fish	Chub	Shiner	Carp	Lamprey
East	1072	5889	1168	25	6976	3629	2	1222	95	168	65
Middle	3015	3847	182	2	3024	337	0	168	0	1	1
West	1435	5355	979	31	6678	1556	138	4421	373	30	490
Total	5522	15091	2329	58	16678	5522	140	5811	468	199	556

The middle ladder was closed down from August 8 to September 15, and again from September 16 to September 22. The west ladder was closed from August 7 to August 14, and again from August 24 to August 30. The east ladder was closed August 8, 15, 22, 26, 29, September 1, 5, 6 and 19. From August 1 to September 9, all fish that were counted over the east ladder were hauled elsewhere, except for those which jumped over the trap. It will be seen from the above that the chinook, in spite of the closure period, show a distinct preference for the middle ladder, and that the blueback and steelhead (as do the scrap fish) show a preference for the side ladders. Also the chinook which use the middle ladder are the large ones. Those using the side ladders are smaller and predominantly males. This showed up strikingly at the Icicle holding pond. Of the 63 chinook hauled there from the east ladder, only 5 proved to be females. This whole circumstance is probably explained by the fact that the current through and at the sides of the middle ladder, is so much stronger than that at the sides of the river that the smaller fish have difficulty in ascending against it.

The time of day in which the salmon and steelhead ran in 1937 is shown in Table 3. It is interesting to note that the blueback, as a whole, showed a preference for running in the early morning, the numbers decreasing as the day progressed; but the blueback going through the middle ladder acted in a directly opposite manner, running predominately in the late afternoon. The time intervals below are somewhat misleading. Actual counting did not start until between 5 and 6 o'clock a.m. and ended at dark, during the peak of the run about 8:30 p.m.

Table 3. Time of Passage of Salmon and Steelhead Going Over Rock Island Dam From May 8 to October 27, 1937.

Species	Chinook				Blueback				Steelhead			
Ladder	East	Middle	West	Total	East	Middle	West	Total	East	Middle	West	Total
4 - 8 a.m.	202	510	407	1119	1815	425	2067	4307	155	29	221	405
8 - 12 Noon	398	865	531	1794	1741	888	1213	3842	344	52	293	689
12 - 4 p.m.	329	999	307	1635	1376	1063	1190	3629	515	70	220	805
4 - 8 p.m.	139	599	190	928	957	1339	885	3181	154	31	245	430
8 - 12 Mid-night	4	42	0	46		132		132				0
Totals	1072	3015	1435	5522	5889	3847	5355	15091	1168	182	979	2329

Counts at Tumwater

This year 4 chinook, 65 blueback, 1 steelhead, 6 eastern brook trout, 2 whitefish, 18 squawfish and 1 shiner were counted over the ladder at Tumwater Dam. In 1936, 5 chinook, 29 blueback, 44 "trout", 201 whitefish, 120 suckers, and 14 chub were counted over the dam. In 1935, 10 chinook, 889 blueback, 6 steelhead, 6 rainbow, 9 Dolly Varden trout, 1 eastern brook, 190 whitefish, 34 suckers, and 2 lamprey were counted there. This year there were 29 blueback and 2 chinook in August, 36 blueback and 2 chinook in September. The first blueback came over on August 4, and the first chinook on August 8. The last blueback came over on September 10, and the last chinook on September 11. As before stated, the efficiency of the ladder had a lot to do with this. As late as September 24, long after the last salmon had passed over the dam, 20 blueback and 13 chinook were seen around the mouth of the ladder and along the face of the dam.

It is very evident from the above figures that the chinook runs above Tumwater Dam are practically wiped out and the blueback run is not in much better shape.

Counts at Oroville Dam

The blueback entering the Okanogan proceed to Lake Osoyoos, where they lie until spawning time, and then run up into the Okanogan River beyond the lake to spawn. These fish, and such other fish as are headed for the upper part of the Okanogan, are counted at the mill dam at Oroville as they enter the lake. In 1935, 264 blueback and 6 chinook were counted there; in 1936, 895 blueback and 7 chinook were counted; and in 1937, 2,162 blueback and 5 chinook passed over the dam. The time of running is shown in the following table.

Table 4. Time of Peak of Blueback Run at Oroville and Rock Island Dams in 1937.

Oroville Dam		
Week ending	Blueback	Chinook
July 24	30	0
July 31	433	0
Aug. 7	1553	3
Aug. 14	133	2
Aug. 21	13	0
Total	2162	5

Rock Island Dam	
Week Ending	Blueback
July 3	4
July 10	7
July 17	4242
July 24	6274
July 31	3279
Aug. 7	556
Aug. 14	408
Aug. 21	207
Aug. 21 to Oct. 1	256

It is interesting to compare the time of running of blueback at Rock Island and at Oroville. The peak of the run at Oroville is about two weeks later than at Rock Island. As at Rock Island, the fish all come in a bunch, the great majority passing through in three weeks. Apparently the fish migrate from Rock Island to Oroville (about 150 miles) in about two weeks, and then lie in the lake for about a month and a half. They did not appear in the Okanogan River above the lake until after the first of October. They enter the lake as bright silvery and blue fish and leave it almost completely red.

SPAWNING PLACE OF THE BLUEBACK

Table 5. Number and Percentages of Blueback Going Over Rock Island, Tumwater, and Oroville Dams in 1937.

	Rock Island	Tumwater Dam		Oroville Dam		Percentage of blue-
Year	Number going over	Number	% of those going over Rock Island	Number	% of those going over Rock Island	back going over Rock Is. migrating to the upper river.
1935	14012	889	6.4	264	1.9	91.7
1936	16516	29	.2	895	5.4	94.4
1937	14523	65	.4	2162	14.2	85.4

As already mentioned, blueback are not known to spawn normally in any of the rivers between Rock Island Dam and Grand Coulee Dam, except in the Little Wenatchee above Lake Wenatchee and in the Okanogan River above Lake Osoyoos. It is certain that none go into the Entiat, and none have ever been seen in the Methow. Neither of these two river systems has the lakes apparently necessary for blueback reproduction. Therefore, those blueback that do not go into Lake Wenatchee or Lake Osoyoos must go into the upper Columbia. Farther up the Columbia, in British Columbia, is a series of large lakes (Upper and Lower Arrow, Whatshan and Slocan lakes besides numerous smaller ones) which would appear to be the logical source of the upper Columbia blueback run. However, no record of blueback this far up the Columbia had been found and repeated attempts to locate them in recent years had failed. This lake region is rugged and not much of it is accessible by road. As is shown in the above table, the combined runs into Lake Wenatchee and Osoyoos form a small percentage of the blueback that came over Rock Island Dam. More than 85 per cent of these went elsewhere. Where, nobody knew.

Our interest was primarily not in finding where these fish spawned but whether they went beyond the Grand Coulee Dam site or not. If they did not go beyond the dam, it would not be necessary to include them in the hatchery operations; if they did, it would. Since this run bulks so large in the total salmonoid run over Rock Island, the inclusion or exclusion of them in the hatchery operations would make a considerable difference in the cost of the program.

To determine where these fish went, 4 gill nets, 2 with $4\frac{1}{2}$" stretch mesh, and 2 with 3-5/8" stretch mesh, were used. It had been intended to start fishing at Grand Coulee Dam site and below Kettle Falls a few days after the run started over Rock Island Dam. An unfortunate mixup over the expenditure of funds delayed the work so that nets were not fished at Kettle Falls until the evening of July 29. Blueback supposedly had been seen by the Indians (who fish at Kettle Falls) jumping in the eddy for several nights before but none were seen on the evening of the 29th. Two blueback were caught, however, a male and a female. Evidently the bulk of the run had already passed over Kettle Falls. On July 30, a blueback jumped into a basket on Kettle Falls. (The Indians fish here by means of running wire baskets on a cable along the edge of the falls. When the fish jump up over the falls, those that hit the back of the baskets fall into the bottom and are captured. On August 5, a dead blueback drifted into the net below Kettle Falls. On this same day, a trip was made to Lower Arrow Lake as far up as Syringa Creek. Here a local inhabitant was found with a blueback which he had jigged in the Narrows on the previous day. On that day he had seen considerable numbers of them swimming through the Narrows. On the evening of August 5, numerous fish were seen flipping in the Narrows. One of these was identified as a blueback. The others were most likely of that species also but the character of the river at that point made gill netting impossible and, therefore, identification was not exact. There were upwards of 1,000 of the fish in the area. Evidently, from the stories of the local inhabitants, the greater part of the run had already passed this point.

On August 6, an old Indian was interviewed at Kettle Falls. Although he did not know the fish by the name blueback, he recognized them when confronted with the specimens which had been caught. He said that many years ago there used to be large runs of blueback over Kettle Falls, and the Indians used to congregate there to catch them, but in recent years the runs had been so small that the Indians had not fished for them. The habit the blueback have of swimming up through the eddies bordering the swift water instead of jumping like the chinook and steelhead makes them both hard to observe and to catch.

On the basis of this evidence, it is apparent that the blueback go above the Grand Coulee Dam to spawn and that a large share of them go into the Arrow Lakes. Therefore, it will be necessary to include them in the Rock Island operations.

FECUNDITY OF BLUEBACK, STEELHEAD, AND CHINOOK

In order to determine the size of the hatchery, it was necessary to know two things: 1. The number of fish of each species, and 2. The average number of eggs in each female. To determine the latter, the eggs from all females of these fish that were collected this summer were counted.

Blueback

From jumping out of the ladder, dying in the oxygen experiments and holding pond, and being caught at the Chelan power house, a total of 52 blueback females with eggs still tight in the skeins were collected and their eggs counted. The counts and lengths of the fish appear in the following table. Lengths are in inches and are from tip of snout to base of middle rays of caudal fin (standard).

Table 6. Lengths and Egg Counts of Blueback Taken at Rock Island Dam, 1937

Length in inches	No. of eggs	Length in inches	No. of eggs	Length in inches	No. of eggs
17.0	1895	19.9	3536	15.0	1840
18.0	2296	18.2	3240	18.0	2203
18.5	2758	18.5	2540	17.2	2070
17.5	2185	15.0	1636	18.2	2078
18.2	2645	17.8	3103	21.0	4864
17.5	2178	19.3	4152	18.1	2480
15.0	1656	19.6	3547	19.4	2921
18.3	2595	19.2	3922	18.0	2482
18.2	2830	15.3	1580	20.4	2555
19.3	2323	17.6	3336	17.6	2141
19.3	2558	14.8	1479	20.2	3339
20.1	3185	17.4	2905	21.4	6224
18.4	2830	18.2	2454	17.5	2408
20.5	3142	18.5	2314	16.0	1766
17.9	1928	17.4	1605	19.0	3134
17.8	2030	18.5	2314	17.7	2494
17.3	2585	18.2	1907	20.5	3507
				19.0	3050

The average number of eggs in each female blueback, calculated from the above data, is 2,667.

In calculating the percentage of dead eggs in the Icicle holding pond experiment, it was necessary to derive a formula for the length fecundity curve (see holding pond experiment). Lengths were taken from a total of 111 female bluebacks during the season. The average standard length of these 111 fish was 17.8 inches. The calculated fecundity of a fish of this length is 2,550 eggs. There are sources of error in both methods of which the largest three are probably: 1. personal error in counting eggs and measuring lengths, 2. lack of a sufficiently large sample of the total stock, and 3. lack of preciseness in the fit of the curve. Therefore, for purposes of calculating the total number of blueback eggs coming over Rock Island Dam a figure approximately halfway between these two calculations is taken, 2,600 eggs per female.

Steelhead

On September 6, 28 adult steelhead were trapped in a pothole below Rock Island Dam, by the fluctuations in the level of the river, and smothered. Twenty-one of these were females. Their lengths and egg counts appear in the following table.

Table 7. Lengths and Egg Counts of Steelhead Taken at Rock Island Dam, 1937.

Length in inches	No. of eggs	Length in inches	No. of eggs	Length in inches	No. of eggs
21.5	3750	21.0	3520	21.8	2780
28.0	8370	28.0	6780	22.0	4455
29.2	7650	23.0	6250	23.8	4160
19.0	3655	23.5	5930	21.0	3590
28.3	7540	29.7	6935	22.5	3745
29.0	7465	23.3	4180	21.8	3930
22.0	4165	27.2	6845	28.5	5325

Calculated from these data the average fecundity of a female steelhead in this area is 5,287 eggs. For purposes of calculating the number of steelhead eggs coming over Rock Island Dam each year, this figure is rounded off to an average fecundity of 5,300 eggs per steelhead female.

Chinook

A total of 11 chinook females were opened during the summer and their eggs counted. Their lengths (standard) and egg counts appear in the following table.

Table 8. Lengths and Egg Counts of Chinook from Rock Island and Kalama.

Rock Island Chinook				Kalama River Chinook	
Standard length in inches	No. of eggs	Length in inches	No. of eggs	Total Length in inches	No. of eggs
33.5	4841	35.5	4898	39.5	7528
37.5	6197	37.5	6037	39.0	6320
30.5	5221	28.7	4410	37.5	6273
37.7	5238	28.2	4189	40.0	6454
34.0	3927	27.6	3596	38.0	6801
31.0	5183				

A very limited amount of data are available for the determination of chinook fecundity. From the above data on the 11 Rock Island chinook, the fecundity of the average chinook female would appear to be 4,885 eggs. The hatchery division of the State Department of Fisheries use an average of 5,600 eggs per chinook female at two hatcheries on the lower Columbia River (Wind River and Kalama River). Actual counts at these localities are, however, not available except for the 5 listed above (furnished by Mr. R. T. Smith). In comparing the Kalama River and Rock Island chinook it should be noted that the former are in total lengths and the latter in standard length. That is, from 3 to 4 inches (for the caudal fin) should be subtracted from the lengths of the Kalama fish to make them comparable with the Rock Island. When this is done it will be noted that Kalama River fish of the same length as the Rock Island fish appear to have a considerably larger number of eggs. Unfortunately, insufficient data are at hand to define this difference, if actually present. Likewise, it is felt that the number of skeins of chinook eggs counted at Rock Island was too small to say that this smaller egg count is typical of the whole run over Rock Island Dam. For purposes of computing the number of chinook eggs coming over the dam annually an average fecundity of 5,600 eggs is used.

NUMBER OF EGGS TO BE EXPECTED

The following tabulation of the counts of eggs that have come from fish passing over Rock Island Dam is based on 3 assumptions: 1. That the Rock Island fish counts are approximately correct both as to numbers and species (for the salmonoids), 2. That on an average half the fish of each species that passed over the dam were females, and 3. That the average egg counts listed above are approximately correct.

Table 9. Number of Eggs Per Species Going Over Rock Island Dam, 1933-1937.

Species	1933	1934	1935	1936	1937
Blueback	52,946,400	2,896,400	18,215,600	21,470,800	19,619,600
Steelhead	2,792,100	1,537,000	13,817,100	6,185,100	6,174,500
Chinook	43,870,400	19,800,000	41,020,000	20,491,600	15,461,600
Totals, Salmon Only	96,816,800	22,696,400	59,235,600	41,962,400	35,081,200
Grand Totals	99,608,900	24,233,400	73,052,700	48,147,500	41,255,700

It will be seen from the above tabulation that the number of eggs available at Rock Island varies tremendously from year to year. Any attempt to predict closely the number to be expected in any future year would be futile. The figures in the above table need some clarification. In 1933 the counts were made only from July 20 to September 30. A comparison with the period of migration of salmon and steelhead in subsequent years shows that: 1. The greater portion of the 1933 steelhead were not counted, 2. A small part of the blueback run was not counted, and 3. A considerable part of the chinook run was not counted. Counts were then made continuously from February 1, 1934, to October 31, 1935. Therefore, all the fish were counted in 1934, which proved to be an exceptionally poor year for all three species. In 1935, a portion of the end of the steelhead run was not counted, and probably a few chinook went over after counting was discontinued. This happened to be the year in which the largest runs of steelhead and chinook occurred of the five years for which we have records, although the 1933 chinook run would probably have surpassed that of 1935, had it all been counted.

In 1936, the period of counting was from May 1 to September 30. It is probable that a considerable part of the spring run of steelhead got by without being counted. It is certain that a large part of the fall run passed by after counting ceased. The same is probably true of the fall chinook run. Only the blueback run was counted in toto. In 1937, the period of counting was from May 8 to October 27. Again the beginning of the spring run of steelhead, and perhaps a large part of the fall run were not counted. Also, the first part of the spring run of chinook was not counted. Only the blueback run was counted wholly.

RECOMMENDATIONS FOR TRAPPING FISH AT ROCK ISLAND

There are three factors to be considered in trapping the fish at Rock Island: 1. The advisability of getting the fish into the ladders and away from the face of the dam, 2. the probability of fish backing down out of the ladder if their way is blocked for a considerable length of time, and 3. the unpredictability of the running of the fish. If the fish remain below the dam for any length of time, they fight the counter attractions, thereby bruising and weakening themselves. To lessen this mortality, it is imperative that they be attracted into the fish ladders as soon as possible. The main fish run is roughly correlated with the fall of the river after the spring peak. It is possible to predict with some accuracy the week or weeks in which the peak of the run will enter the ladders, but the number of fish which will run on any one day or any few succeeding days is totally unpredictable from the data available. The fish will sometimes mill around at the foot of the ladder for several days and then, with no apparent change in the water conditions, may all come up the ladder in a bunch. Furthermore, the fish have a tendency not to stay in the ladder voluntarily if their route is blocked for a material length of time. Therefore, there should be provided in each of the ladders a trap pool large enough to hold a considerable number of fish so that when the fish are running up the ladders faster than the trucks can take them away, they can be safely retained where they are available until the trucks can haul them. (See section on recommendations for Hauling.) The increase in the size of the suggested trap pool over the actual size of the pools in the ladder itself is necessary to lessen the possibility of fish injuring themselves. It is an observed fact that a restricted area of confinement increases the activity of the fish causing a certain amount of injury.

It is recommended, therefore, that a trap pool about 20 feet wide, 20 feet long and 6 feet deep be made in each ladder (above the high water mark of the tailrace water and below the low water mark of the water behind the dam). This pool should be provided on the downstream side with suitable traps so that the fish can come into it readily. The upstream end of the pool should be closed off with grating so the fish cannot proceed on up the ladder. In the north ladder an additional collection pool is needed at the lower end of the ladder. This is to be accomplished by building suitable retention walls with an adjustable entrance and trap for tail water variation. An additional supply of water is needed for this pool and should be added by diffusion. No counter attraction should be created and the additional water should be introduced independent of the normal fish ladder flow. Such a pool will insure more efficient trapping and handling of fish in the north ladder where large numbers of blueback salmon concentrate.

It will be necessary that the attraction water (80 c.f.s.) be diffused into the trap pools located at the top of the ladders from the bottom in such a manner that no perceptible agitation is created. If the water is allowed to come down the ladder in the usual fashion and enter at the surface, the fish will fight the current and jump excessively, thus causing considerable damage to themselves. This happened to some of the large chinook this year before the water coming into the trap was regulated to enter mostly under the surface. With the rough methods of regulating the surface current this year, jumping in the trap was greatly reduced. If the current enters at the bottom, the fish nose down into it and do not jump so much at the surface.

From this large pool should lead a loading trap equipped with a tank which can be hoisted out and its contents (water and fish) dumped into the truck, a gate so that the entrance for fish can be closed, a trap so that the fish will not readily back out of it, constructed high enough to prevent fish jumping out over the top, and an individual water supply. Fish should not be held in such a small trap for any longer period of time than is absolutely essential for rapid loading. The fish should be held in the large pool. When it is wished to take a load of fish, the attraction water into the small trap can be turned on, (not less than 20 c.f.s.) the attraction water in the large pool diminished, and the entrance gate on the small trap raised. The fish can then pass into the small trap. When there is a load in the small trap, the gate will be closed, the tank containing the fish and water will be hoisted and the fish and water dumped into the waiting truck which will have already been partly filled with water from the Columbia River (a source of water should be provided at each trap for this purpose and for sluicing the tank). The tank can then be returned to the trap and the trap pool placed in normal operation again.

It is imperative that the dumping gate on the trap tank can be quickly opened (see recommendations for hauling) so that the fish will be in the water all the time and will not be rubbed on the walls of the tank. The fish will stand some handling so long as they are kept in water, but short exposures out of water weaken them rapidly. The same precautions will be necessary in unloading the fish from the truck. The unloading must be immediate so that the fish will go out with the rush of water.

The water carrying capacity of the lifting tanks should equal one-half the capacity of the largest tank truck and should be constructed with suitable adjustable drains to permit the same proportional capacity with the smallest tank trucks that may be designed. The lifting tank should be mounted within fixed guides and its position maintained by easily replaceable rubber mounted rollers to prevent shock and unnecessary vibrations. The capacity of the small loading trap in gallons should equal the total number of fish reduced to terms of blueback that may be expected to be hauled in a maximum load multiplied by seven and one-half.

The hoisting equipment must be of a type capable of high speed lifting once the tank is free from the water surface. If only one hoist and trap are provided at each ladder, the electrical equipment must be in duplicate and all other machinery capable of quick replacement by stocked parts.

During the time that the fish are straggling up the ladders by ones and twos, the concentration in the big pool will be so small that the fish will probably not come into the small loading traps of their own volition at the time when it is most convenient to transport them. The peculiarities of the fish may lead to a wait of hours, or even a day or two, before they would go into the small trap. The wastage of time and effort would be considerable each season. To guard against such eventualities, a mechanical device is needed to force them from the big pool into the small traps. This should be in the form of a grill which can be placed into one end of the big pool and drawn slowly to the end in which the small trap is located. The fish would thereby be restricted more and more until there is no place left for them to go except into the small trap. The apparatus can then be returned to its starting position and left until needed again. Such a device will expedite the loading of the fish. Provision must be made for the accurate counting of the fish entering the lift tank both as to species and number.

Scrapfish

A factor to be considered in the trapping, hauling and holding of the salmon and steelhead is that at the same time that they are running the so-called "scrapfish" are also ascending the river. Sea-run lamprey, large scaled suckers, small scaled suckers, mountain suckers, squawfish, shiners, chisel mouth chub, Columbia River chub, carp, and whitefish (classified as game fish but not considered a part of the problem), are present, some in considerable numbers. On the basis of the counts of the past four years from 28,000 to 50,000 of these scrapfish can be expected each year. Another factor is that the peak of the scrapfish run occurs at approximately the same time as does the peak of the blueback run.

If these fish were in the main predatory on young salmon and trout or if they competed with the young salmonoids for food, it would be an advantage to destroy them. This is not, however, the case. The squawfish are predatory and their elimination, or a diminution of their numbers, would probably be beneficial. Since they are roughly of similar size and swimming ability as the suckers and chubs, their separation from those fish would probably be economically unfeasible. The other scrapfish, from what data are at hand, are neither predatory on the young salmonoids, nor do they compete with them to any large extent for food. Furthermore, the young of these species furnish a valuable supply of food for the salmon and trout. Their elimination, therefore, would probably be harmful rather than beneficial to the salmon and steelhead. Moreover, the whitefish are a valued sports fish in Eastern Washington. It should also be noted that in the Eastern states suckers and chubs have become valued both for sport fishing and for food.

The water supplies should be so arranged that they can be regulated in the pool, in the small trap, or in the ladder independently. The upstream side of the pool should be provided with removable rack sections. The openings between the rack bars during the spring and the fall should be 1-3/4 inches so that steelhead and chinook will not be able to injure themselves, but will permit the scrapfish to go through. Since all the scrapfish except the largest squawfish are smaller than the chinook and steelhead, they can be allowed to pass on up the ladder by turning the water into the upper part of the ladder. Therefore, from September through till the latter part of the next June, few scrapfish need be handled. This will eliminate one kind, the whitefish, nearly entirely since they migrate in the fall and early winter.

The blueback reach the dam from June 25 to July 10, and continue running until about September 1. Since they are so much smaller than the chinook and steelhead, the rack bar sections of the upper side of the big pool will have to be replaced with sections having a one-inch opening. These latter rack bars will probably retain a large share of the suckers and squawfish and perhaps one-third of the chubs. The rest of these fish and all the shiners and lamprey will be able to continue on up the ladder through the rack bars to their normal spawning grounds. It will be possible to raise the rack bars from time to time and let a concentration of scrapfish through when there are no salmon in the big pool.

About two-thirds of the suckers and about one-third of the chubs, however, will have to be considered in the trapping and hauling of the salmon and steelhead.

The trap pools, grating bars, trap entrances, tanks and all other surfaces that are exposed to the fish in the collection system must be covered with rubber to prevent injury to the fish.

HAULING

Apparatus and Methods

All of the fish hauled for experimental purposes from July 28 to September 9, were taken from the east ladder of Rock Island Dam by means of a trap tank. This trap tank was six feet square and when it was in place, in one of the steps of the east ladder, the water in it was about 4 feet deep. The sides were constructed of wooden slats which allowed the water coming down the ladder to flow through the trap. The bottom was a water-tight steel tank in the shape of an inverted pyramid. At the center was an opening 20 inches square used for draining the tank. When in operation, this opening was covered by a steel door which could be tripped quickly to allow the water and fish to drain out. The water capacity of this trap tank was 240 gallons.

In front of the V-shaped tunnel opening of the trap was a white counting board over which water ran from 6 inches to a foot in depth. As the fish swam into the trap and over this board they were counted and classified by species.

When a load of fish was caught (a period of from one hour to eight hours), the entire trap tank was hoisted by means of a crane to the deck of the dam. Here the tank truck would be waiting with its tank about two-thirds full of water previously pumped out of the Columbia River. The tank would be dropped onto the top of the truck tank and when in place the bottom gate would be tripped and the contents of the tank, fish and water, spilled into the truck tank. The maximum drop was two feet. When empty the trap tank was lowered back into the ladder, the cover of the tank on the truck closed and the haul started.

The tank truck used for transporting fish was the one used by the Department of Fisheries at the Lewis River hatchery. It was designed and has been used successfully for several years for hauling adult salmon from the Ariel Dam on the Lewis River to the holding ponds of the hatchery on Colvin Creek, a haul of about three and three-fourths miles. The tank was rectangular in shape and constructed of steel. It had a capacity of about 800 gallons. It was painted with aluminum paint inside and ordinary black outside. A circular opening 15 inches in diameter at the back end of the tank at the bottom was opened by a sliding gate to allow the water and fish to spill out. The bottom of the tank was flat except for a rounded trough leading to the rear opening to insure all the fish and water draining out of the tank. The top of the tank had two interlocking steel doors which could be opened to expose most of the surface for loading and closed and securely locked to prevent fish from jumping out during transportation. The tank was equipped with a pump which circulated the water. The water entered the tank through a diffusion plate at the bottom near the rear of the tank. It left the tank at the front by an opening protected by heavy small meshed screening. This screen was rounded to lessen injury to the fish. Mounted on the intake line ahead of the circulating pump was a No. 2 Roper gear pump which forced a steady stream of air into the circulating water. The water when it emerged again into the tank released a constant stream of air bubbles which served to replenish the oxygen supply. These pumps were driven by a power take off from the engine of the truck. The gears driving the pumps could be engaged or disengaged by a lever in the cab of the truck. The air pump could be disconnected so that only the circulating pump was running. The walls, top and bottom of the tank were smooth without baffles or projections on the inside which lessened the possibility of injury to the fish while in transit.

While one load of fish was taken to the Okanogan, Methow, and Entiat each, the majority of the hauling was done to two places on the Wenatchee: Monitor, about 22 miles from Rock Island and 6 miles up the Wenatchee, and Icicle Creek about 42 miles from Rock Island, 25 miles from the mouth of the Wenatchee. Below the town of Monitor a rack was constructed across the Wenatchee River. It had one tunnel in it so that fish migrating up the river naturally could pass upstream but fish coming downstream were blocked. About a mile above this a road was constructed to the bank of the river so that the truck could be backed down to the edge of the river. Thus when the fish were dumped they fell a maximum of 3 feet into the river without the intervention of a trough of any kind. They landed in a quiet eddy 3 or 4 feet from the swift current of the river. Between the strong current adjacent to the dumping ground and the even swifter current at the rack there was a large deep pool just below the Monitor bridge which slowed the velocity of the stream down and afforded a good resting spot.

On Icicle Creek a section of the stream was closed off. A rack was put across the stream about two miles above its junction with the Wenatchee River in which the intervals between the rack bars were one inch so that none of the fish with which we were dealing could either pass up or downstream beyond it. About 3 miles upstream a falls made further passage impossible for salmon or steelhead at the stage of water existing during the time of this investigation. The 3 miles of creek thus fenced off was nearly equally divided between a rugged canyon and a flat lowland. Where the upper part of the enclosed section of the stream ran through the canyon the grade of the creek was precipitous, the bed was made up of large granite boulders, and in between the deep pools were swift running cascades with no gravel bars. The portion of the enclosed area below the canyon became a winding, more slowly moving stream with gravelly and sandy bottom, more scattered boulders and with gravel bars in between the spacious deep pools. It was this section of Icicle Creek in which chinook and steelhead spawned in former years.

Two unloading locations were used on Icicle Creek. Below the CCC camp at the mouth of the canyon a road was built to the creek's edge so that, as at Monitor, the fish dropped only about 3 feet in being unloaded from the tank. All the fish hauled to Icicle Creek from July 28 to August 23 were dumped here. By the latter date the level of the water in the creek had dropped until the dumping pool was so shallow that there was danger of fish being injured by striking bottom. At that time the unloading was shifted about 1/8 of a mile upstream to the deep pool at the CCC camp. Here a tin trough, 25 feet long, inclined at an angle of about 25° led the fish and water from the truck to the stream. From the end of the trough there was a two foot drop to the creek. All the edges of the trough which came in contact with the fish and water were covered with adhesive tape to prevent injuring the fish.

Hauling to Icicle

A total of 19 trips were made with fish from Rock Island to Icicle Creek between July 28 and September 9. During this time 858 fish were planted in the creek. Of these 93 were chinook, 57 steelhead, 351 blueback, 5 silver salmon, 59 chub, 46 squawfish, 245 suckers and 2 carp. The largest load hauled consisted of 194 fish of which 5 were chinook, 1 steelhead, 78 blueback, 36 chub, 7 squawfish and 67 suckers. The length of time normally consumed in the haul to Icicle varied from 1 hour 45 minutes to 2 hours 15 minutes. On one occasion it took 3 hours and on another, 3 hours 15 minutes. A list of hauls to Icicle with pertinent data is shown in Table 10. The following notes show all fish which appeared subnormal after

Table 10. Fish Transported to Icicle Creek.

Date	Haul	Chinook	Steelhead	Blueback	Silver	Chub	Squawfish	Sucker	Carp
7/28/37	1			26				1	
7/29/37	2	1		26					
7/30/37	3			50					
7/31/37	4			13				2	
8/5/37		1	(All dead except 1 chinook.)						
8/9/37	10	5	1	78		36	7	67	
8/10/37	12	7	4	38	1	3	7	40	
8/10/37	13	3	1	27	1	3	4	52	
8/11/37	14	6	7	30		3	6	54	
8/14/37	20	10		10	1	1	2	3	1
8/16/37	21	10	3	13				2	
8/20/37	23	7	2	8			7	12	
8/27/37	28	3	1	5	1		1	2	
8/28/37	30	1	3	3			1	2	1
8/31/37	31	19	4	15	1	2	2	3	
8/31/37	33	6	4	3			1	1	
9/8/37	40	7	10	2		2	2	2	
9/8/37	41	1	9			7	6	2	
9/9/37	43	6	8	4		2			
Totals		93	57	351	5	59	46	245	2

Table 11. Fish Transported to Monitor

Date	Haul	Chinook	Steelhead	Blueback	Silver	Chub	Squawfish	Sucker	Carp
8/2/37	6	1		20			1	2	
8/4/37	7	1		6			9	33	
8/6/37	9	5		60		1	4	40	
8/9/37	11	4	2	61		14	22	54	
8/11/37	15	2	4	17	1	1	4	24	
8/12/37	16	2	3	13	1		2	5	
8/12/37	17	1	4	9	1	3	4	30	
8/13/37	18	2	4	29	3	1		15	
8/13/37	19	11	5	14	1	3	6	25	
8/17/37	22	2	1	8					
8/21/37	24	10	2	6			9	5	
8/23/37	25	13	2	4			7	6	
8/24/37	26	7	2	6			5	4	1
8/27/37	29	2	6				4	3	
8/31/37	32	7	3	7		4	2	7	
8/31/37	34	3	2	5		2	4	2	
9/2/37	35	4	1	3					
9/2/37	36	3				1	3	3	
9/3/37	37	2	2	2		2	4	5	
9/4/37	38	1	1	4		1	3	6	
Totals		83	44	274	7	33	93	269	1

hauling. It should be noted that a considerable number of the blueback arriving at Rock Island Dam in the latter part of July and the first part of August bore heavy wounds and unhealed scars. In many cases chunks the size of a silver dollar had been gouged out of their sides exposing the muscles. In some cases portions of the operculum were gone, eyes were partially gouged out or the isthmus was badly bruised. Since all fish that came into the trap were hauled, these bruised and wounded fish figure in the hauling and holding mortalities. Some of the chinook were also bruised and nearly all of them bore gill net marks which showed either as streaks of lost scales or as cuts into the flesh.

Haul No. 1. Three blueback showed lack of air upon arrival, rising to the surface and gulping. Two of these righted themselves almost immediately and swam away. The third took about 3 minutes to return to normalcy. Within 10 minutes from the time they were dumped all the fish had disappeared upstream.

Haul No. 2. The big chinook was dead upon arrival. It had evidently been dead for some time. One blueback swam wildly about when dumped and then lay on its side. It was still alive after 15 minutes. On the return trip it was gone.

Haul No. 3. One blueback flopped on its side and was breathing only feebly. It was bruised heavily about the throat.

Haul No. 10. One blueback which had one eye partly gouged out of its socket and a bad wound on the side of the head, was in poor shape upon arrival but in a few minutes swam off in a normal manner.

Haul No. 12. One small blueback arrived in poor shape but recovered in a few minutes and swam off.

Haul No. 14. One small blueback 14 inches long was dead upon arrival. It was stiff and had probably been dead for some time. It had three deep wounds along the left side.

Haul No. 23. One large chinook was dead upon arrival. Another was in poor shape but recovered and swam away in a few minutes.

Thus, out of a total of 93 chinook, 57 steelhead and 351 blueback hauled to Icicle Creek, 3 chinook, 8 blueback and no steelhead showed immediate adverse effects. Of these 1 blueback and 2 chinook died. Even the badly wounded blueback swam away after a few minutes. The large chinook in Haul No. 2 was nearly dead when it was loaded into the truck. As explained in the section on the action of the fish in the trap, it had beat itself into a weakened condition in the trap. Its death cannot fairly be placed in the hauling mortalities. The large chinook that eventually recovered in Haul No. 23 was injured in the unloading, not in hauling. As explained above by August 20 the level of the water in Icicle had fallen until the dumping pool was shallow. This large chinook struck bottom on being unloaded and was apparently stunned by the impact. This was the last load dumped there. Thus only 1 chinook and 1 blueback died in the hauls to Icicle Creek. The blueback was badly wounded before it got into the trap and probably in a considerably weakened condition. It is interesting to note that none of the 57 steelhead handled was affected adversely in any way. They were, in fact, the liveliest of the fish upon being unloaded.

Hauling to Monitor

A total of 20 trips were made with fish from Rock Island to Monitor between August 2 and September 4. During this time a total of 804 fish were transported of which 83 were chinook, 44 steelhead, 274 blueback, 7 silver salmon, 33 chub, 93 squawfish, 269 suckers and 1 carp. This haul of 22 miles took from one hour to one hour 10 minutes. The largest single haul made was 157 fish including 4 chinook, 2 steelhead, 61 blueback, 14 chub, 22 squawfish and 54 suckers. The hauls with pertinent data are listed in Table 11. With the exception of the fish used in the oxygen experiments (to be explained below) none of the fish hauled to Monitor were killed or injured in any manner. All of them upon being dumped in the river swam off in a normal fashion. The steelhead and large chinook were particularly lively. On nearly every occasion upon hitting the water they would dart out into the current and swim off upstream almost as fast as the eye could follow them. From the observations that were made it was concluded that this short haul had no observed ill effects on the fish.

Hauling to Okanogan River

On August 25, a load of fish was taken from Rock Island to the town of Oroville on the Okanogan River near the Canadian Border. The distance covered was 154 miles. The haul was started at 9:45 a.m. and the fish were dumped at Oroville at 3:20 p.m., a total elapsed time of 5 hours 35 minutes. The load was composed of 1 large chinook, 8 blueback, 3 steelhead, 1 sucker and 1 squawfish. The temperature of the water in the tank at the start was 64.9° F.; the air, 76.1° F. At 12:1 the truck was stopped at Pateros for gasoline. The temperature of the water in the tank was 71.6° F.; the air was 84.2° F. The fish appeared to be normal. The fish were dumped into the mill pond at Oroville at 3:20 p.m. At that time they were all in good shape and particularly lively. The truck when unloading was parked at a slight angle so that the rear was a little higher than the front. Thus the current was not quite so strong as usual. Two of the steelhead and the chinook fought against it so strongly that they had to be frightened out of the tank. What fish could be seen for 15 or 20 minutes after being dumped into the pond were normal in their actions. At dumping the temperature of the water in the tank was 79.8° F., a rise of 14.8° F. during the haul. The temperature of the water in the mill pond was 68.5° F., a difference of 11.2° F. between the tank and the river. The air was 85.1° F.

Hauling to Methow River

On September 7, a load of fish was taken from Rock Island to the Twisp River, a tributary of the Methow River. The distance traveled was 111 miles. The time in transit was 4 hours 55 minutes. Eight chinook, 7 steelhead, 2 blueback and 1 sucker were included in the load. The trip was started at 11:15 p.m. The temperature of the water in the tank at the start was 64.8° F.; the air, 86.0° F. At Pateros at 2:30 p.m. the water in the tank was 72.0° F.; the air, 89.6° F. The fish were apparently in good condition. On arrival at the Twisp dumping spot at 4:10 p.m. the temperature of the water in the tank was 75.2° F., a rise of 10.4° F. during transit. The temperature of the Twisp was 59.0° F., a difference of 16.2° F. The air was 79.8° F.

The Twisp River at the first highway bridge above the town of Twisp widens out into a deep pool with only a moderate current. The fish were dipped out of the tank one at a time and dropped into the pool, a drop of about 15 feet. All of them appeared to be perfectly normal. They could be seen in the clear water easily and they were watched for about half an hour. At the end of this period, they were swimming about in a perfectly normal fashion. One of the large chinook had moved on upstream.

Hauling to Entiat River

On September 9, a load was taken to the Entiat River, a haul of about 32 miles. The haul took one hour and ten minutes. An accidental tripping of the trap gate during hoisting permitted all but 2 large chinook and 1 steelhead to escape. These 3 fish were taken to the Entiat River and dumped. The fish apparently showed no ill effects from the trip.

Effect of Temperature Changes

In the first few trips ice was used ro reduce the temperature and then this was discontinued. The precaution then taken was to leave the tank empty until time for loading and then to flush the tank well with water from the hose to remove the residual heat from the steel walls of the tank. If this were not done the hot tank would warm the tankful of water from 4° to 5° F. On the long trips to Orovill and Twisp no ice was used.

It will be noted by looking at Tables 1 and 2 that in the short haul from Rock Island to Monitor the water temperatures never rose more than 4° F. in the tank and the difference in temperature between the tank and the Wenatchee was at no time more than 2.7° F. Our observations indicated nothing that would show an immediate effect on fish by temperature change.

The difference in temperature between the water in the tank and Icicle Creek, however, varied from 4° F. to 13° F. Even at a difference of 13° F. no immediate effects could be noted on the fish. One would suppose that such a sudden shock would stimulate the fish in some manner. Some of the fish, especially the larger chinook and steelhead, would dart off upstream quick as a flash. Others would proceed more leisurely and others still would lie in the dumping pool for 10 or 15 minutes before showing any desire to proceed upstream. No immediate difference could be noted in the behavior of the fish dumped at Monitor under no temperature change and those dumped at Icicle Creek with considerable change of temperature.

In the hauls to Oroville and Twisp (above) there was a considerable rise in temperature during transportation and also large differences in the temperature of water in the tank and the rivers into which the fish were dumped. For instance, the rise during transportation to Oroville was 14.8° F. The temperature in the tank at arrival was 79.7° F. These fish were certainly as lively and appeared, outwardly at least, as healthy as any fish hauled. The difference in water temperatures between the tank and the Twisp River was 16.2° F. These fish were watched for half an hour and there was no outward indication of ill effects.

It might be possible that the effect of these sudden changes of temperature would not show up until later. On this point we have no data other than the fact that no rise in mortality was noted in the Icicle holding pond which was under close observation during the period. All data at hand would indicate that the changes in temperatures of a magnitude such as that encountered had no immediate deleterious effects on the fish. It should be pointed out, however, that these changes in temperature may have been a physiological shock of such magnitude that the viability of the eggs and sperm in the fish would be reduced. Such results would not be detected in our examinations. A study of the physiological effects of these changes could not be attempted this summer. Experiments carried on by the State of Washington Department of Game in planting trout fingerlings indicate that when the hauling water is not slowly tempered, no immediate effects are observed but that a high mortality usually results several days after the planting occurred.

Effects of a Decreased Oxygen Supply on the Fish

It took only one example to show that oxygen was a vital factor to be considered in hauling the fish. One trip was made to Icicle Creek (to be described below) with a load containing 2 chinook, 28 blueback, and numerous scrapfish without the air pump running. Upon arrival, 1 chinook was left alive and it was in a weakened condition. The other salmon were dead. It became desirable to find out the minimum requirements of oxygen for salmon and steelhead.

The oxygen, free carbon dioxide and pH tests in the following experiments were made in the field by Mr. R. T. Smith as the samples were taken, respectively, by the methods of Winkler as described in "Standard Methods of Water Analysis", the free carbon dioxide test given in the same book, and a Hellige Hydrogen Ion comparator.

On August 2, 8 blueback and 1 sucker were put in the tank at 1:25 p.m. Water had been in the tank since 11:00 a.m. with circulator and air pump running. Temperature of water in tank, 65.8° F.; air, 81.0° F. and oxygen, 8.1 parts per million. Circulator and air pump shut down at 1:30 p.m. and 150 pounds of ice added in two chunks. At 1:55 p.m. the oxygen was 7.4 p.p.m.; water temperature, 64.8° F. Fish appeared to be normal. At 2:25 p.m. the oxygen was 7.1 p.p.m.; water temperature, 64.8° F.; fish normal. At 3:10 p.m. the oxygen was 6.4 p.p.m.; water temperature, 66.2° F.; air, 87.8° F.; fish normal. At 4:10 p.m. the oxygen was 5.7 p.p.m.; water temperature, 67.6° F.; fish normal. At 4:15 all the fish appeared to be perfectly normal. Two blueback, 5 suckers and 5 squawfish more were added together with about 150 gallons of new water. The truck was moved to the laboratory at Wenatchee, a distance of about 16 miles. The air pump and circulator were left off. At 6:15 p.m. the oxygen was 4.1 p.p.m.; water temperature, 70.0° F.; air, 81.1° F. The blueback were gulping somewhat but swimming vigorously.

At 7:00 p.m. the oxygen was 3.35 p.p.m., water 70.0° F. The fish were breathing perhaps a little more rapidly than usual but otherwise no change in their condition was evident. At 7:25 p.m. the carbon dioxide was 2.3 parts per million. At 7:30 p.m. the oxygen was 2.7 parts per million, water 70.0° F. The fish were beginning to jump a little and gulp at the surface. At 8:00 p.m. the oxygen was 2.5 p.p.m. The fish by now appeared to have lost a large part of their senses of touch, sight and general sensitiveness. They swam about slowly, running into one another and into the walls of the tank. They seemed oblivious to outside interference. They would run into an outstretched hand held under the water, back up and run right into it again. This is in distinct contrast to their habits of even a few minutes before when they would dart out of reach at a slight disturbance.

At 8:15 p.m. the oxygen was 2.4 p.p.m., water 70.0° F. At this time 2 blueback and 1 sucker went over on their backs and ceased swimming. The circulator and air pump were started. In a minute or two several of the other salmon turned belly up. Evidently the current set up by the circulator was more than they could stand in their weakened condition. In a few minutes, however, they began to pick up and swim about part of the time right side up, part of the time on their backs.

At 8:30 p.m. the oxygen was 2.7 p.p.m. At 8:45 p.m. the oxygen was 3.1 p.p.m. At this time three of the most affected blueback were still stirring around part of the time right side up and part of the time on their backs. But the others were swimming quite well and apparently had recovered their sensitiveness. At 9:00 p.m. the oxygen was 3.0 p.p.m. At 9:15 p.m. the oxygen was

3.2 p.p.m. At 9:30 p.m. the oxygen was 3.2 p.p.m. At this time from what could be seen by means of a flashlight, all the fish had recovered. They were dumped and the experiment discontinued. One fish, a blueback, was found dead. All the others had recovered.

It was found out afterward that the air pump was operating improperly, thus accounting for the lack of rise of oxygen content after 8:45 p.m. when it presumably broke.

A confirmatory experiment was carried out on August 4. One chinook, 6 blueback, 33 suckers, 9 squawfish and 1 lamprey were placed in the tank at 11:15 a.m. The water had been in the tank since 9:30 without the circulator or air pump running. Three hundred pounds of ice were put in the tank at 9:30 to keep the temperature low. At the time of loading the oxygen content was 7.9 p.p.m., water temperature 62.9° F.; air 81.5° F. The haul was made to Monitor. At 1:00 p.m. at Monitor the oxygen was 5.8 p.p.m.; carbon dioxide, 1.3 p.p.m.; water, 65.6° F.; air, 86.9° F. Seventy-five pounds of ice added. All the fish were swimming about normally. At 1:30 p.m. the oxygen was 5.1 p.p.m.; water, 66.2° F. Fish normal. At 2:00 p.m. the oxygen was 4.45 p.p.m.; water, 66.9° F.; carbon dioxide, 1.5 p.p.m. Fish normal. At 2:30 p.m. the oxygen was 4.2 p.p.m.; water, 66.9° F.; carbon dioxide, 2.0 p.p.m. Fish normal. At 3:00 p.m. the oxygen was 3.8 p.p.m., water, 67.1° F.; carbon dioxide, 2.3 p.p.m. Fish normal. Air, 96.8° F.

At 3:30 p.m. the oxygen was 2.9 p.p.m.; carbon dioxide, 2.3 p.p.m. The blueback were beginning to show signs of distress, 4 of them swimming around the top of the tank. At 4:00 p.m. the oxygen was 2.6 p.p.m.; water, 66.5° F.; air, 94.1° F.; carbon dioxide, 2.5 p.p.m. Fish were milling around at top of tank. At 4:30 p.m. the oxygen was 2.6 p.p.m.; water 67.1° F.; air, 94.1° F.; carbon dioxide, 3.0 p.p.m. Last of ice melted. By this time the blueback had become groggy as they did in the first experiment at approximately the same oxygen content. There was a general loss in sensitiveness until some of the fish could be lifted out of the water by the dorsal fin with hardly a wiggle as they swam near the top.

At 5:00 p.m. the oxygen was 2.4 p.p.m.; water, 72.5° F.; air, 73.4° F. The first blueback keeled over at 5:00 p.m. as the oxygen sample was being taken. Another went over on its back at 5:25 p.m. This fish had its gills badly torn in the vicinity of the isthmus. At 5:30 p.m. the oxygen was 2.4 p.p.m.; carbon dioxide, 3.0 p.p.m.; water, 70.7° F.; air, 88.7° F. At 5:40 p.m. the chinook began to get groggy as had the blueback before. Another blueback keeled over at 5:40 p.m. Ten minutes later two more blueback went over on their backs. At 5:55 the chinook was swimming rapidly around the tank hitting the wall at every corner, apparently not able to see or feel its way around.

At 6:00 p.m. the oxygen was 2.3 p.p.m.; carbon dioxide, 3.0 p.p.m.; water, 70.0° F.; air, 86.4° F. At 6:10 the chinook finally keeled over and the air pump and circulator were started. At this point the suckers and squawfish were apparently as calm as ever and showed no distress. At 6:30 p.m. the oxygen had risen to 6.7 p.p.m.; carbon dioxide, 2.3 p.p.m.; water, 68.3° F.; air, 80.6° F. By this time the chinook had apparently fully recovered. It was dodging corners properly and swimming normally. At 7:00 p.m. the oxygen was 7.5 p.p.m.; carbon dioxide, 2.2 p.p.m. All of the fish were apparently in good shape and the experiment was closed.

The blueback as they keeled over had been taken from the tank by hand and placed in the eddy the dumping pool formed. All of them recovered, even the one with the badly torn gills. One of the fish had been left in the tank for several minutes after it had keeled over. When put in the river it was to all appearances dead. For some time not the slightest gill movement could be seen. However, at 7:00 p.m. it had recovered and was swimming around the eddy with a good strong gill movement. All the others had gone out into the current and moved upstream.

From the results of the successful haul to Monitor without using the air pump and the ability of the salmon to withstand low concentrations of oxygen, it was wondered whether or not it was possible to make the longer haul to Icicle Creek without the air pump running. On August 5 a load of 100 fish, including 3 chinook, 26 blueback, 61 suckers, 7 squawfish, 2 chub and 1 carp were hauled to Icicle Creek. At the start at 11:30 the oxygen was 8.4 p.p.m.; water in tank, 68.3° F.; air, 95.5° F.; pH, 8.0.

At 1:20 at Leavenworth the oxygen was 2.85 p.p.m., water, 71.6° F.; air, 95.0° F. Three of the blueback were swimming about sometimes on their back and sometimes right side up. At 2:00 p.m., on arrival, all of the blueback and two of the chinook were dead which certainly proved definitely the point being investigated. The third chinook, a small one, was keeling over. He was put in the creek and recovered. Oxygen, 2.7 p.p.m.; carbon dioxide, 2.5 p.p.m.

Since the oxygen content of the water was low it was determined to find out the least oxygen concentration the suckers, squawfish and carp could stand. At 2.30 p.m. the oxygen was 2.2 p.p.m., scrap fish apparently normal. At 3:00 p.m. the oxygen was 2.0 p.p.m.; carbon dioxide, 3.3 p.p.m.; water, 73.9° F.; air, 79.7° F. At 3:10 p.m. the suckers and squawfish were rising to the surface and gulping but they had not lost sensitiveness as the salmon did upon nearing the critical point. At 3:15 the pH was 6.9. At 3:30 p.m. the oxygen was 1.6 p.p.m.; carbon dioxide, 3.5 p.p.m.; water, 73.4° F; air, 77.9° F. Two suckers and 1 squawfish keeled over and were put in the creek. Most of these fish were coming to the top and gulping. At 3:45, 2 more suckers went over on their backs. All of the suckers and squawfish had now apparently lost sensitiveness and swam sluggishly. Between 3:45 and 4:00 p.m. 6 more suckers were thrown in the creek. All the rest appeared to be in bad shape.

At 4:00 p.m. the oxygen was 1.4 p.p.m.; carbon dioxide, 4.0 p.p.m.; water, 74.3° F.; air, 77.0° F.; pH, 6.7. At 4:15, 12 more suckers had passed out and were thrown in the creek. At 4:30 the oxygen was 1.35 p.p.m.; carbon dioxide, 4.3 p.p.m.; water, 73.4° F.; air, 77.0° F. Six more suckers were thrown out. The circulator and air pump were started. By 4:45 there were no fish coming to the top. All were swimming about on the bottom or near the inlet of the circulator. Three suckers were still on their backs but were breathing.

At 5:00 p.m. the oxygen was 4.5 p.p.m.; carbon dioxide, 3.0 p.p.m.; water, 75.2° F.; air, 77.0° F. The fish had apparently all recovered and were swimming normally. At 5:30 p.m. the oxygen was 6.2 p.p.m.; carbon dioxide, 2.4 p.p.m.; pH, 7.2; water, 75.2° F.; air, 76.1° F. Experiment discontinued.

It is interesting to note that the carp, even at the lowest oxygen concentration (1.35 p.p.m.), did not show the slightest distress and did not even come to the surface to gulp.

The above experiments apparently demonstrated the lower limits of oxygen concentrations that could be withstood by the salmon. There was the possibility, however, that the increased carbon dioxide concentration and the subsequent lowering of the pH had some part in the deleterious effects noted. If this were so it would be possible for the carbon dioxide concentration to rise, even though the oxygen content remained high, and cause damage to the fish. That is, the carbon dioxide given off by the respiration of the fish might accumulate in the water faster than it would be absorbed into the air and give rise to dangerous concentration. This would be especially pronounced under practical operating conditions when a greater poundage of fish would be hauled in one load than in the experiments. Therefore, an experiment was run with a tankful of fish with the air pump and the circulator left running to see whether the carbon dioxide would accumulate and whether or not it would harm the fish.

On August 6, 110 fish including 5 chinook, 60 blueback, 40 suckers, 4 squawfish and 1 chub were loaded in the tank. Four of the chinook were large, ranging in weight from about 20 pounds to 35 pounds apiece. This was, therefore, the largest poundage of fish hauled on any one trip. At the start at 1:50 p.m. the oxygen was 8.4 p.p.m.; carbon dioxide, .25 p.p.m.; water, 68.0° F.; air, 85.6° F.

On arrival at Monitor at 3:00 p.m. the oxygen was 5.3 p.p.m.; carbon dioxide, 2.5 p.p.m.; pH, 7.1; water, 70.1° F.; air, 83.3° F. Fish normal. At 3:30 p.m. the oxygen was 5.5 p.p.m.; carbon dioxide, 3.5 p.p.m.; pH, 7.1. The fish all appeared to be in fine condition, swimming about actively. One blueback jumped clear out of the tank into the river. The circulator and air pump were being run at approximately average road speed. At 4:00 p.m. the oxygen was 6.1 p.p.m.; carbon dioxide, 3.5 p.p.m.; pH, 7.0; water, 71.1° F.; air, 81.5° F. The fish appeared normal. Another blueback jumped out of the tank and swam upstream at 4:10. The lids of the tank had been left up so that the fish could be observed.

At 4:30 p.m. the oxygen was 7.0 p.p.m.; carbon dioxide, 4.0 p.p.m.; pH, 6.9; water, 71.9° F. Fish normal. At 5:00 p.m. the oxygen was 6.3 p.p.m.; carbon dioxide, 4.0 p.p.m.; pH, 6.9; water, 72.5° F. Fish normal. At 5:30 p.m. the oxygen was 6.6 p.p.m.; carbon dioxide, 4.0 p.p.m.; pH, 6.9; water, 72.5° F.; air, 77.0° F. Wenatchee River, 68.9° F.

The water was let down slowly until every fish could be clearly seen. All were in excellent shape. They were dumped into the river at 5:45 and all swam upstream in a perfectly normal fashion. Experiment closed.

It was evident that this quantity of fish, approximately one-half pound per gallon, was unable to raise the carbon dioxide content above 4.0 parts per million over a period of 4 hours which is twice the length of time necessary to make the trip from Rock Island dam to Icicle Creek. It was likewise evident that prolonged exposure to a carbon dioxide concentration 16 times that normally found in the Columbia River at Rock Island (.25 p.p.m.) was not harmful to the fish, at least to external observations. It is, therefore, concluded that an increase in free carbon dioxide and its attendant decrease in pH were not factors to be considered in the transportation of fish from Rock Island to Icicle Creek or on shorter hauls. The longer hauls to Oroville (154 miles) and Twisp (111 miles), although no chemical determinations were made, would further bear this out.

Conclusions regarding oxygen, carbon dioxide and pH limits of tolerations.

1. Any time during hauling that the oxygen content of the water becomes

less than 3.0 parts per million the salmon are in immediate danger.

2. When the oxygen content of the water reaches 2.5 parts per million or less, the salmon will die in a very few minutes.

3. An abundant supply of air introduced continuously into the water is an absolute essential for a haul as long as from Rock Island to Icicle Creek.

4. Because of the crowding of fish around the inlet of the oxygenated water from the circulating pump noted when the oxygen supply was getting low, it would be advisable to diffuse the inflowing water into the tank to avoid possible smothering.

5. The increase in the free carbon dioxide content of the water and the lowering of the pH to be encountered in a haul of this length with any moderate concentration of fish will not cause noticeable physical damage to the fish. Again, as with temperature changes, the physiological effects are unknown.

Results of Hauling to Monitor

As related above, fish were hauled to Monitor to ascertain whether or not it would be feasible to haul the fish from Rock Island to the mouth of the Wenatchee River and have them ascend to the hatchery site on Icicle Creek under their own power and to discover, if possible, the suitability of Wenatchee River water for holding and ripening mature fish. For this test a total of 83 chinook, 44 steelhead and 284 blueback (plus numerous scrap fish) were hauled and liberated above Monitor. Observation of these fish was possible at: 1. The rack built below Monitor, beyond which the fish could not retreat downstream, 2. The Tumwater dam of the Puget Sound Power and Light Company in Tumwater Canyon about 22 miles upstream from the Monitor rack, beyond which no fish could go upstream without being seen, 3. The rack on Icicle Creek, beyond which no fish could go up that stream, 4. Spawning beds of the chinook in the lower part of Tumwater Canyon, and 5. The Dryden dam of the Puget Sound Power and Light Company about 10 miles upstream from Monitor. On the rack at Monitor a man was kept constantly from August 7 to September 1 and daily visits were made from September 1 to October 2 at which time the rack was removed. A man was kept on the Tumwater dam from July 10 to the middle of November to count all fish going beyond that structure. Only scattered observations were made at locations 3, 4 and 5.

Of the fish planted at Monitor, only 43 blueback, 41 chinook and 28 steelhead were tagged so that they could be identified later. They were tagged as follows:

Table 12 - Dates of tagging fish liberated at Monitor.

August 21	7 blueback	5 chinook	1 steelhead
" 23	7 "	12 "	2 "
" 24	10 "	7 "	5 "
" 27	0 "	2 "	6 "
" 30	7 "	6 "	3 "
" 31	3 "	4 "	4 "
September 2	3 "	2 "	4 "
" 3	2 "	2 "	2 "
" 4	4 "	1 "	1 "

Recoveries from Monitor Rack

The fish recovered dead from the Monitor rack are listed in Table 14. The

Total recoveries were: 63 blueback, 7 chinook, 0 steelhead, 5,422 suckers, 18 Columbia River chubs, 34 chisel mouth chubs, 41 whitefish, 5 lamprey, 1 carp, 52 squawfish and 1 shiner. These fish were observed to be in a weakened condition and could not resist the current through the racks. As a result, they would be thrown up against the slats and perish. The suckers were observed to have just completed spawning. The blueback recovered in this manner were 22.2 per cent, or nearly one-fourth of those planted. Of the chinook planted, 8.4 per cent of the total planted were recovered from the rack. None of the steelhead planted were recovered.

Of the 43 tagged blueback 13, or 30 per cent, were recovered from the rack. Of the 41 chinook tagged 4, or 10 per cent, were recovered, and of the 28 steelhead tagged, none were recovered. The following list shows the spread between liberation and recovery of the salmon.

Table 13 - Dates of recovery of tagged fish from Monitor rack.

Tag No.	Species	Date liberated	Date recovered
5503	Blueback	August 21	August 25
5509	"	" 21	" 28
5511	"	" 21	" 24
5512	"	" 21	" 27
5517	"	" 21	" 26
5535	"	" 23	" 28
5959	"	" 24	" 30
5668	"	" 24	" 30
5669	"	" 24	" 28
5588	"	" 30	September 9
5903	"	" 31	" 9
5949	"	September 2	" 9
5919	"	" 4	" 14
5504	chinook	August 21	August 27
5547	"	" 23	September 1
5975	"	" 24	August 28
5996	"	" 24	" 29

None of the fish came back against the rack before 3 days after liberation. One blueback was recovered 10 days after liberation and 1 chinook was taken on the 9th day after liberation.

Fish accounted for at Tumwater Dam and down stream to confluence with Icicle Creek.

The greater share of the spawning area of the Wenatchee drainage is situated above the Puget Sound Power and Light Company's dam in Tumwater Canyon. Four large tributaries come in above this point: 1. The Little Wenatchee (the blueback spawning ground), 2. White River (both of these flowing into Lake Wenatchee), 3. Nason Creek, and 4. Chiwawa River. Yet only 4 chinook and 65 blueback were counted over the dam this year. The last salmon passed over the dam on September 11. After the date of the last salmon passing over Tumwater dam numbers of fish were noted spawning in the canyon below the dam. The largest number seen was on September 24. On that date 20 blueback and 13 chinook were seen at the foot of the dam; 14 blueback and 6 chinook were seen in a pool about a quarter of a mile below the dam; and scattered in various pools on down the stream in Tumwater Canyon 20 more chinook were seen. The various riffles between these pools have been noted in former years to be natural spawning grounds for salmon. A survey of Icicle Creek below the rack on the previous day had revealed 5 chinook. Thus counting the fish passed over the dam and the ones seen downstream, the total

Table 14 - Fish dying against Monitor rack Aug. 7 to Oct. 2, 1937

	Blue-back	Chinook	Sucker	Col.Riv. Chub	Chisel Mouth Chub	Squaw-fish	White-fish	Lam-prey	Carp	Shiner
Aug. 7	0	0	420	1	1	2	1	2		
8	0	0	142	1	0	3	1	0		
9	4	0	107	0	0	2	1	1		
10	5	0	114	0	0	0	0	0		
11	6	0	179	0	0	1	0	0		
12	3	0	140	0	0	2	1	0		
13	2	0	97	1	0	0	0	0		
14	0	0	117	0	0	4	0	1		
15	4	0	110	1	0	3	0	0		
16	3	0	69	0	0	4	0	1		
17	2	1	83	0	0	1	1	0		
18	5	0	119	0	0	1	0	0		
19	0	0	127	1	0	1	1	0		
20	0	0	84	0	0	2	1	0		
21	2	0	118	0	0	2	2	0		
22	1	0	74	0	0	0	0	0		
23	1	0	66	0	0	1	0	0		
24	1	0	70	0	0	1	1	0		
25	1	0	115	0	0	1	1	0		
26	2	0	137	0	0	0	0	0		
27	1	1	100	0	0	0	0	0		
28	4	1	115	0	0	0	0	0	1	
29	1	0	151	1	0	2	1	0	0	
30	2	1	87	0	0	0	0	0	0	
31	0	0	76	0	0	0	0	0	0	
Sept.1	0	1	103	0	0	0	0	0	0	
2			119	11	2					
3			138							
6	1	1	297	0	1	1	0	0	0	
7			279	1		2				
8			118		1		1			
9	3	1	100		1		5			
10			81		1		1			
11			69		3	1				
12	1		79							
13			64							
14	2		70		1					
15	2		103							1
16	1		87		3	2				
17	1		73		1	2	3			
18	0	0	61	0	2	1	0	0	0	
19	0	0	64	0	2	0	0	0	0	
20			97		3	1				
21	1		72		3	1	4			
22			46		1	2	1			
23			52		2	1	3			
24			39			1				
25			36		1		5			
26			26		1	1	2			
27			26		1					
28			31		2		1			
29			19				1			
30	1		18							
Oct. 1			16		1	3	1			
2			22				1			
Totals	63	7	5422	18	34	52	41	5	1	1

number of fish accounted for above the mouth of Icicle Creek in the Wenatchee were 48 chinook and 99 blueback. Subtracting the mortalities on the rack from the number of fish hauled to Monitor, the number of fish seen above the mouth of Icicle Creek were: blueback, 45 per cent of the total, and chinook, 63 per cent of the total. It is probable that all the fish in this area were not seen although a careful search was made.

The figures and percentages cited above are open to the serious criticism that because of the tunnel opening left in the Monitor rack the natural run of fish could come into the experimental area and thus be included in these figures. Any fish coming up naturally into the experimental area would raise the percentages of fish seen above the mouth of Icicle Creek since these percentages were calculated on the basis of the number of fish hauled to and dumped above the Monitor rack. Fish from the natural run seen in Tumwater Canyon (it is known from observations made in former years that there are always a few salmon that spawn there naturally) and included in those counts would raise those percentages. A subtraction of this unknown factor, no matter what its size, would make the percentages of fish seen above the mouth of Icicle Creek smaller than those given. It should be noted that the percentage of mortality against the Monitor rack of the tagged fish was for both chinook and blueback slightly larger than the percentages when calculated for total liberations and total recoveries. It is, therefore, felt that the additional unknown mortalities did not materially affect the figures given for the deaths against the Monitor rack.

Taking into consideration these various factors, it is concluded that on the basis of these experiments hauling fish from Rock Island Dam to the mouth of the Wenatchee and expecting them to ascend the rest of the way to Icicle Creek under their own power is not feasible for two reasons: 1. The percentage of fish which would finally reach Icicle Creek is too small (less than 45 per cent for blueback and less than 63 per cent for chinook), and 2. Mortalities for blueback and chinook were too high in the lower Wenatchee River (22 per cent for blueback and 8 per cent for chinook at the Monitor rack alone) indicating that the lower Wenatchee River is not adapted to the ripening of these fish which customarily spawn elsewhere.

Steelhead are not included in the above statements. They are in fine shape when they reach Rock Island Dam and this year proved to be much more hardy than the other two species dealt with. None died against the rack nor were seen in the vicinity of the rack. Only one was seen above the mouth of Icicle Creek (counted over Tumwater dam). This, however, was more or less to be expected for the steelhead do not spawn until the following late winter and spring. Therefore, they were probably lying in the many large deep holes in the river in the experimental area and would have appeared at their proper spawning time. The observations on the chinook and blueback extended through and beyond their spawning period. The hauling of the fish must be arranged to accommodate the least hardy of the three species, not the most hardy.

Results of hauling to Icicle Creek

The hauling to Icicle Creek was different in intention from that to Monitor in that besides finding out what the effect on the fish was from hauling and handling, we wished to determine whether or not it was advisable to hold the fish in Icicle Creek from the time they appeared at Rock Island (green) until spawning time. For this purpose a section of the stream was racked off (as described above) so that only the fish artificially retained could get into the experimental area.

For this purpose 93 chinook, 57 steelhead, 351 blueback and numerous scrap fish were hauled and placed in the holding pond between July 28 and September 9. During the first few days of hauling, the fish were checked on each day as the haul was made. From August 10 until after spawning was ended, a man made a daily search over the experimental area to locate the fish and pick out the dead ones. At no time until spawning started did more than 2 days elapse without a complete search being made of the area. The only part of the experimental area in which it is believed that fish might have died without being seen were several pools in the upper end in the canyon that were quite deep and bottomed with large boulders. A boat could not be taken in and conditions for observation were often very unsatisfactory. But few fish, however, penetrated that far up the canyon and it is felt that what undetected mortality there might have been there would not be large, especially since the known mortality where there were considerable concentrations of fish was so small. The mortality figures below include all the fish that died in this area up to the time when spawning started. Only one fish, a large female chinook which had not yet spawned any of her eggs, is included of those fish that died after spawning was under way.

Of the 351 blueback hauled to Icicle Creek, 12, or 3.5 per cent, were found dead before October 9, the date seining operations were started. Of the 93 chinook, 5, or 5.4 per cent, died. Two other chinook died that were not included in this total. One of these had flopped out high and dry on the rocks of a riffle that was left nearly dry during the lowest water levels in August. The other was the big chinook mentioned in the section on hauling that was dumped into the shallow dumping pool with such force that it was stunned. Next morning it was found dead, although it had apparently recovered the night before. It was believed that its death was chargeable neither to hauling nor holding, but rather to negligence on the part of the operators. The known mortality of the chinook was by no means alarming and the known mortality of the blueback was low.

An interesting point in regard to the blueback was the remarkable healing that took place during the holding period. As noted elsewhere, many of the fish when dumped in the creek had large pieces of flesh gouged out and numerous open cuts along the side. By spawning time these scars had all healed over. One with the dermis and underlying muscles scraped away over an area larger than a silver dollar had the area completely covered over with new skin which was pigmented as bright a red as the rest of the body. Another had a portion of the anterior gill on the left side injured. The injured portion had sloughed off and the wound had healed over leaving the rest of the gill in good working order. Many had cuts from gill nets. These healed over. No fungus was found on any of the fish until after they had spawned and became emaciated. The chinook reacted differently. Injured spots became fungused. One of the chinook that died was more than half covered with fungus, especially around the head.

Sixty-two out of the 93 chinook and 151 out of the 351 blueback hauled to Icicle Creek were accounted for before the fall floods took the lower rack out. How the remainder escaped observation is unknown to the observers. The following are some possible reasons: 1. Some fish may have died and not been observed before they disintegrated or were covered over with silt, or they may have died under the huge boulders which in some parts of the creek are common. It seems unlikely that the first two factors were large because the low temperatures of the creek retarded putrefaction, and during the period of the experiment the water in the ponds was exceptionally free from sediment. The ease with which the white bellies of the dead fish could be seen even at the bottom of deep pools would render it unlikely that any large number could have escaped observation.

That the small blueback could have gone under the large boulders to die is, however, possible. It should be noted that, if any number of the missing fish were lost by reason of the above possibilities, the mortality percentages listed above would have been materially increased. 2. Wild animals may have accounted for some of the loss. Three land otters frequented the lower pool. On one occasion an otter was seen swimming away with a live blueback. Bears were seen along the experimental area several times but were never seen catching fish. 3. People may have gaffed out some of the fish. Although there were rumors of people taking fish none were apprehended in the act nor could the rumors be traced. 4. Some fish may have been lost down the Cascade Orchard irrigation ditch which took off from the experimental area. Reports reached the observer late in August that such was the case. A close examination of the entire length of the ditch at that time revealed no fish. If there were any fish in the ditch they could have been easily removed by anyone. 5. A portion of the missing fish might be accounted for by the possibility of mixing in large suckers in the blueback counted into the trap at Rock Island. 6. Five blueback and four chinook were seen in the creek when the rack went out. It is possible that there might have been more.

RECOMMENDATIONS FOR HAULING FROM ROCK ISLAND TO ICICLE CREEK

In this section it is assumed that the oxygen and space requirements of fish are roughly proportional to their weight. The chinook average about 21 pounds, the steelhead about 9 pounds, the blueback about 3 pounds, the squawfish which will not go on up the river about 3 pounds, and the suckers that will have to be hauled will average about 2 pounds. The only salmon which were handled in any quantity in this summer's hauling experiments were blueback, and therefore our experience is based on handling fish of this size. For the purpose of estimating equipment that will be needed and the number of fish that could be hauled in one load, all fish are reduced to the common term blueback. It is assumed that the average chinook will take as much space and oxygen as 7 blueback, the average steelhead will equal 3 blueback, the squawfish and blueback will roughly average the same and the average sucker will equal two-thirds of a blueback.

The tank on the truck used this summer had a capacity of about 800 gallons of water. The most fish hauled to Icicle in any one load was 196, which reduced to terms of blueback was 185 fish. It was believed that no more than this could be hauled safely in one load, but since no larger loads could be taken, the point could not be definitely settled. This provided about 4 gallons of water per fish. It is recommended that 5 gallons of water, per average blueback, be provided for the Icicle Creek haul in order to permit a safety factor for minor delays and accidents.

The steelhead come in two fairly distinct runs, the spring and fall. The spring run starts in March and reaches a peak in April or the first part of May. The steelhead then slack off or may cease running entirely in June and July. The fall run starts in August or the first part of September and continues through until the latter part of November or the first of December. The chinook run is also more or less divided into two runs. The first begins in April and peaks in May. It then slacks off in June until sometimes well into July. The big run comes in the latter part of July, August and September and then tapers off until about the first of November. The blueback can be expected some time after the first of July and will be practically gone by the first of September. Thus it will be necessary to do some hauling from the first part of March until the latter part of November, and during July, August and the first part of September the greatest amount of hauling will be expected.

In the Tables 15, 16, 17 and 18 the number of fish appearing per day in the ladders for the past four years are shown. All species are reduced to terms of blueback as explained above. Two-thirds of the suckers and squawfish are included. The high day of the run in 1934 was 6,155 fish with a next high of 4,882; in 1935, 7,892 fish with a next high of 5,545; in 1936, the high day was 3,674 fish with the next high of 3,089; and in 1937, the high day was 3,785 fish with the next high 3,367.

The round trip from Icicle to Rock Island (approximately 84 miles) must not take more than 3 hours driving time. This summer the trip one way loaded took only 2 hours and the truck was old and of inadequate design. The unloading will probably take at least 15 minutes. Although the actual loading at Rock Island will take only a few minutes, the jockeying around to get into position and possible delays in getting the fish into the small traps will take up at least a half hour. Therefore, a round trip including time for miscellaneous items will take 4 hours. One truck can make 2 trips in 8 hours. Time out for meals, gassing up, etc., will probably limit the trips to 4 in 18 hours and 5 in 24. It is planned that the capacity of a 1,000 gallon tank will be 200 blueback, or the equivalent thereof in other fish, and a 2,000 gallon tank, 400 blueback. During the summer when the peak of the run occurs there are about 15 hours of daylight. If the loading at the dam is restricted to the daylight hours, each truck could make 4 trips a day. Two 2,000 gallon trucks and two 1,000 gallon trucks could haul 4,800 blueback, or equivalent, in an 18 hour day.

It is apparent from looking at Tables 15, 16, 17 and 18 that the size of the peak of the run is not necessarily correlated with the magnitude of the run. Thus in 1934, the year in which the runs of all species of fish were small, there was a period of 5 days at the peak of the run when the 4 trucks would not have been able to haul the fish away from the ladders as rapidly as they came into the traps. The rest of the season two, 1,000 gallon trucks could have handled the run. In 1936 and in 1937, when there were many more fish than in 1934, the peaks were spread out so that the 4 trucks would have been able to handle the whole run. In 1935, occurred the worst congestion with a sustained peak from August 17 to September 1. One night the surplus that the trucks could not have handled would have been more than 3,100 fish. In 1934, there would have been 1,363 left over one night, 1,442 left over the next night and 994 left over the third night. After that there would have been no surplus. In 1936 and 1937, there would have been no overnight surpluses left in the ladders.

The design of the large pools will leave each with about 2,400 cubic feet of water. It is recommended that no more than one fish for every 30 gallons of water be left in these trap pools overnight. This would allow 600 fish to remain in each trap pool overnight, or a total of 1,800 fish at the dam. It will be noted that one night in 1935 the surplus would have been nearly double this. There is always the possibility that a large run like that of 1935 might peak sharply and in the same proportion to the total number of fish as did that of 1936. Therefore, it will be necessary to make preparations for night hauling. Flood lights will have to be provided at each of the 3 loading places at Rock Island and at the unloading locations at Icicle Creek.

With these provisions the trucks could each make 5 trips in 24 hours. The 2 large and 2 small trucks could then handle 6,000 blueback, or their equivalent in 24 hours. The addition of a third 1,000 gallon tank truck, as is proposed for emergencies, would insure a daily haul of 7,000 fish. It is believed that the latter is a sufficient safety factor to safeguard against harmful congestion in the large pool traps and such things as highway construction, delays, etc. Therefore, it is recommended that 5 trucks, 2 with 2,000 gallon tanks and 3 with 1,000 gallon tanks be available for use in hauling adult fish from Rock Island Dam to Icicle Creek. Final design of the trucks may show that the 2,000 gallon tank trucks will exceed the weight limits of the State Highway Department. Regardless of this, it must be provided that 7,000 gallons of tank capacity be placed available on the road at one time in units of not more than 2,000 gallons nor less than 1,000 gallons.

It is further recommended that the unloading places at Icicle Creek be provided with concrete ramps extending into the pools so that the truck can be backed into the water at an incline to be unloaded. The unloading should be accomplished in such a manner that the fish will not drop more than two feet in coming out of the tank and the unloading incline should be at such an angle that no fish will remain in the truck after the outrush of water. The depth of water in the holding ponds at the foot of the unloading inclines must be not less than 6 feet.

Table 15. Number of fish, in terms of blueback, appearing at Rock Island during the peak of the 1934 run.

	NORTH	SOUTH	TOTALS
Aug. 12	264	285	549
13	3102	156	3258
14	5630	533	6163
15	4502	377	4879
16	2508	1844	4352
17	2331	964	3295
18	725	830	1555
19	623	250	873
20	476	311	787
21	997	63	1060
22	624	387	1011
23	138	39	177

The experiments this summer showed that a tank truck of the type used and in use at the Lewis River hatchery for the past several years, is satisfactory for the approximately 42 mile haul to Icicle Creek. The design must be modified considerably, however, for practical operation. The tank trucks used must have the following features:

Truck Specs 1158-D

1. The ability to make the round trip from Rock Island Dam to Icicle Creek in three hours' driving time.

2. A water circulating system capable of circulating the whole volume of water in the tank in from 8 to 10 minutes. If the water in the tank is not circulated it will stratify and the fish will suffer from oxygen depletion at the bottom of the tank. This circulation system must be in duplicate on each truck and operated by independent gas engines.

3. A means for introducing air into the circulating water and thoroughly mechanically mixing same in sufficient quantities that the water in the tank, with

a maximum load of fish, must at all times maintain the oxygen content at the saturation point.

4. Tight closing hatch on the top of the tank for loading the fish and to prevent loss of water during transportation. It is recommended that this hatch be of ample size to avoid fish striking the edges of the hatch opening when being loaded and be equipped with a mechanical opening and closing device.

5. An unloading gate located on rear end of truck in such a place as to be the lowest point in the tank's bottom so that draining will be complete and rapid. The gate must be capable of being opened suddenly and rising and remaining above the outflowing water. The gate must close in such a manner as to prevent leakage of water from the tank during transportation.

6. The inside of the tank must have all corners rounded, no inside braces, baffles or other obstructions, in order to reduce injury and wear to the fish in transit.

7. The incoming water (and air) from the circulating system must be diffused through several diffusion plates at the bottom of the tank and the outlet must be screened with easily replaced screens. In the truck used this season the circulating water all entered at one point. When the tank was crowded or the oxygen supply became low, the fish would bunch up at this outlet instead of spreading around the tank. The inlet port or ports to the pump line should be screened in a similar manner to the outlet ports. The velocity of approach to such port or ports should not exceed 1/4 foot per second. Air pressure release valve must be provided at each end of the tank.

8. The outside of the tank should reflect a maximum of the sun's rays. The heaviest part of the hauling will come at the time of year when air temperatures above 100° F. will not be unusual.

9. Temperature control. The experiments this summer did not show any deleterious physical effect to the fish from the temperatures encountered this summer during transportation, but this is no proof that the sexual products did not suffer from the physiological shock of the fish being dumped from warm water into cold water. Nor is it proof that higher temperatures than those encountered this summer, but which might be expected in other summers, would not be deleterious to the fish. Therefore, it is recommended that a cooling compartment be provided on the forward end of the tank through which the circulating water will pass. The temperatures of Icicle Creek in the summer are from 5° to 10° F. colder than those of the Columbia River at Rock Island. It is desired that the water in the tank shall be brought as nearly as practical to Icicle Creek temperatures during transportation so that the temperature differential at the time of dumping will be slight.

10. Instruments for indicating temperature and air and water flows should be located in the driver's cab of the tank trucks and placed in as convenient manner as is possible for constant observation.

11. All drainage water from the loading operations at the dam should be drained to some place other than in the fish ladders.

12. At Rock Island Dam the truck should be able to reach all the fish ladders with a minimum of interference from the present operation of the dam and should not conflict with any construction program which might disrupt the continuity of the fish hauling operations for a period of hours. Stops should be provided to lead the truck to fixed positions at all traps for loading purposes.

Table 16. Number of fish, in terms of blueback, appearing at Rock Island during the peak of the 1935 run.

Date	North	South	Totals
July 22	196	116	312
23	951	51	1002
24	510	104	614
25	231	34	265
26	954	61	1015
27	1249	122	1371
28	616	46	662
29	931	74	1005
30	828	56	884
31	831	94	925
Aug. 1	820	82	902
2	668	89	757
3	893	285	1178
4	359	873	1232
5	174	278	452
6	231	262	493
7	202	299	501
8	192	91	283
9	436	246	682
10	735	252	987
11	1186	273	1459
12	1202	144	1346
13	1498	875	2373
14	1350	158	1508
15	891	244	1135
16	504	269	773
17	479	655	1134
18	2737	334	3071
19	3054	625	3679
20	4648	897	5545
21	2556	860	3416
22	3546	777	4323
23	3103	494	3595
24	3529	1280	4809
25	848	1579	2427
26	1284	1597	2881
27	250	1633	1883
28	3960	806	3766
29	3503	4399	7902
30	507	313	820
31	332	767	1099
Sept. 1	550	1327	1877
2	1016	1619	2635
3	1350	228	1578
4	1582	62	1644
5	896	1777	2673
6	351	921	1272
7	329	94	423

Table 17. Number of fish, in terms of blueback appearing at Rock Island during the peak of the 1936 run.

Date	East Ladder	Middle Ladder	South Ladder	Total
May 31	994	227	468	1689
June 1	1194	119	814	2127
Recedes until July 13				
July 13	1334	98	214	1646
14	1164	616	86	1866
15	392	394	59	845
16	1161	289	73	1523
17	1333	1639	117	3089
18	840	1611	53	2504
19	916	1215	131	2250
20	732	1213	157	2102
21	1277	1423	723	3423
22	1557	1353	375	3285
23	1022	1135	196	2353
24	844	928	102	1874
25	973	375	176	1524
26	305	3027	342	3674
27	169	1827	315	2311
28	505	1544	287	2336
29	302	1610	284	2196
30	450	960	115	1525

Table 18. Number of fish, in terms of blueback, appearing at Rock Island during the peak of the 1937 run.

Date	East Ladder	Middle Ladder	South Ladder	Total
July 13	107	50	162	319
14	401	168	218	787
15	514	306	587	1407
16	677	943	333	1953
17	458	1093	384	1935
18	586	1225	426	2237
19	361	825	410	1596
20	597	415	472	1484
21	469	471	277	1217
22	537	1297	291	2125
23	184	1800	392	2376
24	1233	1559	575	3367
25	457	1357	489	2303
26	392	1940	363	2695
27	744	2489	552	3785
28	265	2300	332	2897
29	307	852	264	1423
30	227	1800	229	2256
31	219	946	344	1509
Aug. 1	230	1027	138	1395
2	19	772	146	937
3	34	462	201	697
4	24	287	201	512
5	42	144	278	464
6	95	0	111	206

MORTALITY OF BLUEBACK EGGS BEFORE SPAWNING

When the artificial spawning of the blueback in the Icicle holding pond was started on October 9, it was found that nearly all of the females had some eggs in their ovaries which were dead and some of the fish appeared to have more than half of their eggs dead. The numbers of dead eggs in 43 of these females, with other pertinent data, appear in the following table.

Table 19. Dead Eggs Found in Blueback at Icicle Creek at Spawning Time.

Standard Length in Inches	Calculated Total Eggs	No. of Dead Eggs	Per Cent of Dead Eggs	Standard Length in Inches	Calculated Total Eggs	No. of Dead Eggs	Per Cent of Dead Eggs
20.0	3581	14	0.4	18.4	2963	183	6.1
19.5	3350	36	1.1	19.0	3110	73	2.3
14.7	1565	0	0.0	18.5	2898	230	7.9
17.5	2495	95	3.8	17.8	2512	0	0.0
18.5	2898	173	6.0	20.0	3581	802	22.3
18.6	2900	577	19.6	17.5	2495	1982	79.4
15.0	1645	94	5.7	16.0	1925	1082	56.2
18.5	2898	104	3.6	18.0	2699	1318	48.9
18.0	2699	355	13.2	17.5	2495	64	2.6
15.0	1645	110	6.7	18.0	2699	253	9.4
15.5	1797	55	3.1	17.5	2495	1263	50.6
14.0	1308	121	9.3	17.0	2307	343	14.9
18.0	2699	39	1.5	18.5	2898	1192	41.1
17.5	2495	4	0.2	18.5	2898	351	12.1
16.0	1925	84	4.4	14.5	1460	87	5.9
18.0	2699	23	0.8	18.2	2794	58	2.1
20.5	3828	672	17.6	17.5	2495	91	3.7
18.3	2794	496	17.4	17.3	2400	59	2.5
18.0	2699	187	6.9	14.0	1308	94	7.2
18.2	2794	219	7.8	14.5	1460	14	.9
19.0	3110	79	0.2	18.7	2925	31	1.0
18.3	2794	137	4.9				

The formula of the curve of closest fit for length-fecundity of the blueback derived under the criterion of least squares on the assumption that the curve of closest fit was of the type $y= ax^b$, was calculated from the data on the length-weight relationship presented in Table 6. It was found to be y= 1.08 x 2.704 where y = the number of eggs in the fish and x = the standard length of that fish. Knowing the length of each female that had dead eggs in it, column two in the above table was calculated from this formula. Then dividing this total egg count (the egg count of the average female of this length) into the number of dead eggs found, column four was derived, giving the percentage of dead eggs of the total egg count. It will be seen that only 2 of the females examined were completely without dead eggs. In the other 34 females the percentage of dead eggs to total eggs varies from 0.2 per cent to 79.4 per cent. The average egg mortality in the 43 females was 11.9 per cent.

It was immediately wondered whether this mortality of eggs before spawning was a result of our operations in hauling the fish and holding them in Icicle Creek.

Unfortunately, all but 13 of the skeins of eggs taken from blueback at Rock Island during the summer had been counted and the eggs discarded, but four females were also on hand that had been netted from the tailrace of the Chelan power house, and another female was found in the west ladder on Rock Island Dam when it was drained down on October 11. A careful search of the Okanogan River above Lake Osoyoos revealed that the blueback in this area had nearly completed their spawning and no females were obtained. Thus there were the eggs from but 18 blueback females which had not been handled by us to compare with those that we had handled. These counts appear in the following table.

Table 20. Dead Eggs Found in Blueback Taken Elsewhere than at Icicle Creek.

Location	No. of Good Eggs	No. of Dead Eggs	No. of Doubtful Eggs	% of Dead Eggs	Location	No. of Good Eggs	No. of Dead Eggs	% of Dead Eggs
Rock Is.	2209	105	74	4.5	Rock Is.	2696	225	7.7
"	1534	71	29	4.4	"	2411	71	2.9
"	2248	120	14	5.1	"	2483	72	2.8
"	1843	64	6	3.4	"	2039	102	4.8
"	1769	71	30	3.9	"	3198	141	4.2
"	2155	8	25	0.4	"	1876	251	11.8
"	1825	245	26	11.1	Chelan	80	2328	95.7
"	1738	742		29.9	"	2929	205	6.5
					"	2376	128	5.1
					"	2858	192	6.3

In the skeins of eggs of some of the blueback from Rock Island, which had been preserved in formalin for 3 months before counting, were eggs which appeared doubtful as to whether they were dead before preservation or not. These are listed separately in the above table. Only the eggs which were definitely known to be dead in the live fish were used in computing the percentage of dead eggs. Of these fish taken under normal conditions, the percentage of dead eggs varied from 0.4 per cent to 95.7 per cent. The average egg mortality for these fish was 11.7 per cent. Thus the fish migrating under the natural stream conditions had only 0.2 per cent less dead eggs in their ovaries than did the fish which were hauled and held. Therefore, from the data available it is apparent that the hauling and holding the blueback did not result in death of ova in the ovaries.

What caused this mortality in blueback eggs cannot be determined from the data at hand. The appearance of the dead ova was striking and characteristic. The yolk was coagulated in one hard small kernel which was bright yellow in color. The albumen was liquified and was either colorless or with a darkish tinge. The yellow of the yolk kernel stood in distinct contrast to the pink color of the healthy eggs. Owing to the flabby nature of the dead ova accurate diameter measurements could not be made, but they appeared to be about the same size as the healthy ripe ova. They did not, however, break loose from the ovarian follicles when ripe, as did the healthy eggs. In the completely spawned out females the dead eggs still remained imbedded in the ovarian tissue and pressure in "stripping" would cause the eggs to break and the yolk kernel to pop out, but would not cause the dead eggs to loosen from the ovary. Microscopic observations and examination under the low power lense of a microscope revealed no evidence of parasites that might have killed the eggs.

In some ovaries there would be a band of dead eggs which appeared as if the fish had been struck with a hard object, but in other ovaries the dead eggs were scattered throughout the egg mass and in a few fish most of the eggs were dead. The fish taken from the west ladder at Rock Island Dam on October 11, which had 11.8 per cent of its eggs dead had the majority of the dead eggs in the anterior mesial portions of the ovaries where it would be presumed that the backbone, ribs, and the dorsal musculature would provide a maximum protection against mechanical injury. Careful examination of the body wall of all of these fish did not reveal a lesion or bruise in a single instance. Several of the fish, however, did have external scars on the sides of their bodies.

Evidently this phenomenon has not been observed before in the blueback of the upper Columbia. Other investigators in the area have not recorded it. If it is a natural condition, allowance for this percentage of mortality could be made in the size of the hatchery. But this is not known. It is possible that this mortality resulted from the unusual conditions at Bonneville Dam this year. During the first part of the blueback run the head of water there was such that the fish could not get over without difficulty. When these fish showed up at Rock Island Dam a considerable percentage of them were heavily bruised and scarred, especially around the head and on the sides. If this was the causative agent, it will probably be eliminated in the future by the proper operation of the fish ladders, lifts, etc., at Bonneville when these structures have been completed.

RECOMMENDATIONS FOR HOLDING THE ADULT FISH

The adult fish when they arrive at Rock Island Dam are not ready to spawn. They will have to be held from two weeks to six months to ripen. This holding period is perhaps the most crucial point in the proposed hatchery plan. The difficulty in designing holding ponds for the quantity of fish that must be handled is enhanced by the almost complete lack of knowledge of the actions of the fish in a natural state. It is known that the "spring" chinook and "fall" steelhead and the blueback reach Rock Island in excellent physical condition with considerable stored up energy in the form of fat. It is known that often the chinook and steelhead lie in deep pools in the rivers. It is known that blueback enter Lake Osoyoos soon after they pass Rock Island while they are still bright and in excellent condition, and that two months later they come out of the lake wasted away with their coloration changed from a shimmering blue and silver to red, ready to spawn and die. Little else is known. Perhaps it is necessary for the chinook and steelhead to have a certain strength of current to fight against to use up the stored up energy and complete the physiological process known as "ripening." Perhaps the blueback need the quiet water of a lake in which to do the same. On the matter of the physiological changes which take place during ripening and the causes necessary to bring these results we are in the dark. A knowledge of these factors is a fundamental necessity to designing a set of holding ponds which will bring the least possible mortality to the fish and the maximum viability to the eggs in the fish.

This same problem was faced on the Lewis River when a hydroelectric dam was placed across it stopping the spawning migrations of the fish. There a holding pond was constructed in a small creek adjacent to the hatchery. The canyon of the creek was dammed making a pool which was about 30 feet deep at one end and shelved up into a shallow artificial spawning bed at the other end. The creek itself flows not more than 300 gallons per minute when the maximum number of fish are in the pool. Three thousand gallons per minute is pumped from the Lewis River and runs through the pool. This is introduced both at one end and around the edges of the pool by means of jets. As a consequence there is very little current through the pond. At the time when there are the most fish in the pond there is about 1/3 of a gallon of water per minute per fish entering the pond. The pond is purely artificial and is not comparable to the natural habitat of these ripening fish in the river. The system is not eminently satisfactory. Considerable numbers of adult fish die before spawning. There is a large mortality among the eggs and alevins in the hatchery. The cause of these mortalities has not as yet been determined, but it may be that the holding in this artificial pond is a contributing cause to the death of the adults and the lessened viability of the eggs and young.

The holding experiments this year in Icicle Creek were satisfactory from the standpoint of low mortalities among the adult fish. The hatching of the blueback eggs (Table 19) was not so successful in that there was a high percentage of infertility. The cause of this was not determined. It might have been due to: 1. faulty technique in taking the sexual products, 2. using the remaining eggs of fish which were mostly spawned out naturally, 3. dead sperm in the same proportion as the dead eggs found in the fish before spawning, or possibly 4. lessened viability of the eggs due to the holding. Chinook or steelhead eggs were not taken.

Two plans have been proposed for holding the adult fish at Leavenworth. One entails the construction of purely artificial pools near the hatchery; the other considers using the bed of Icicle Creek. In view of the lack of knowledge of the physiological requirements of the fish during this period and the lack of complete success of the artificial pond at Lewis River, it is believed that the natural condition of the stream during the holding period should be duplicated as closely as possible. It is recommended that the natural bed of Icicle Creek be used for the holding ponds.

The experimental area used this summer was terminated at its upper end by a falls below the diversion dam of the Icicle ditch. In the next seven miles examined above this point the bed of the stream was uniformly rugged, scattered with large granite boulders and without either large pools or gravel riffles. No place in this section is suitable for holding large numbers of adult fish. In the section of the experimental area between the falls and the pool at the CCC camp the creek runs through a canyon and has the same general character as that noted for the section above the falls with the exception that there are some large pools. The ruggedness of the canyon renders this section of the creek inaccessible for trucking in or out without expensive road construction. Below the pool at the CCC camp the stream and the valley widen out. Between this pool and the lower rack of this year's experimental area there are four large pools from 600 to 1,000 feet long and from about 6 to 10 feet in maximum depth together with several smaller pools. The pools are separated by gravel bars. The bed of the stream is of gravel interspersed with large boulders in some of the pools and with small areas of sandy bottom. This is the section of the stream, according to available information, in which chinook and steelhead formerly spawned. All of this section is easily accessible to trucks on the hatchery side of the creek. Below the lower rack the gradient of the creek decreases slowly as it approaches the Wenatchee. There are no large deep pools suitable for the ripening of large numbers of adult fish.

The fish that were hauled to Icicle Creek this summer were dumped either in the CCC camp pool or on the riffle below it. All through August they remained concentrated in this pool. A few fish ventured on into the canyon above, some penetrating as far as the large pool below the falls. The most ever seen in this area at any one time were 8 fish, of which 7 were in the pool at the foot of the falls.

Table 19. List of Mortalities in Hatching Blueback at Icicle Creek, 1937

Date	A.M. Temp.	P.M. Temp.	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6
Total Eggs			3340	6054	3340	218	3426	854
Oct. 10	47.7 °F	47.7 °F	26					
11	46.0	48.2	61	64				
12	46.4	49.3	27	12	28			
13	47.1	49.1	2	1	257			
14	47.7	49.5	0	1	96			
15	49.1		0	0	13			
16	50.0	50.9	1	3	12			
17	46.9	48.2	0	11	39	0		
18	45.5	47.1	1	7	29	3		
19	44.8	46.8	0	6	31	0	2	
20	46.9	49.6	0	4	25	0	4	
21	46.4	50.4	0	4	14	0	0	
22	46.4	49.5	0	0	8	0	5	
23	46.8	48.9	1	1	3	1	0	0
24	47.1	50.0	0	0	5	0	0	0
25	46.0	49.1	0	1	1	0	2	0
26	45.5		1	2	2	0	1	0
27	48.7	50.4	0	1	2	0	1	0
28	49.3		0	1	7	0	1	0
29		48.7	2	2	14	0	0	0
30	45.7		0	4	5	1	0	0
31	42.8	46.0	2	0	4	1	1	0
Nov. 1	41.0	44.6	1	2	5	1	0	0
2	42.1	44.6	0	0	3	3	1	0
3	41.4	45.5	1	0	5	0	2	1
4	39.7	42.2	0	0	3	0	0	0
5	40.6	44.2	1	0	1	0	0	1
6	39.2	42.8	1	0	0	0	0	0
7	39.6	41.0	0	1	7	0	1	0
8	41.2	44.4	1	0	5	0	1	0
9	41.0	41.5	0	0	2	0	0	0
10	41.5	42.1	0	0	3	0	0	0
11	41.9	42.2	0	1	6	0	1	3
12	40.3	42.8	2	2	0	0	0	1
13	39.7	37.4	0	0	7	1	0	2
14	36.0	37.9	1	0	1	0	1	0
15	37.4	37.9	5	3	8	0	2	0
16	38.7	37.9	11	4	20	0	0	2

Table 19. (Continued)

Date	A.M. Temp.	P.M. Temp.	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6
Nov. 17	38.3 °F	40.1 °F	2	7	15	0	0	0
18	38.3	39.6	5	6	20	1	0	4
19	34.7	34.3	4	0	12	0	0	2
20	33.3	34.2	2	7	17	0	0	1
21	37.2	37.6	9	19	31	0	0	1
22	37.8	36.9	10	22	34	0	2	2
23	26.9	37.4	4	16	26	0	4	1
24	37.4	37.4	3	15	15	0	1	2
25	37.8	37.4	0	10	31	0	5	1
26	37.0	36.5	0	132	41	0	1	0
27	37.6	37.8	2	162	43	2	4	1
28	38.3	38.3	7	115	32	0	4	1
29	37.4	36.9	3	115	40	0	0	1
30	36.0	36.1	6	79	15	0	0	1
Dec. 1	35.1	35.3	5	47	26	0	1	0
2	35.3	35.6	6	80	28	1	9	1
Total mortalities to date			216	970	1097	15	57	29

(First three lots combined)

Date	A.M. Temp.	P.M. Temp.	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6
Transferred to Chelan Hatchery of State Game Department.								
Dec. 3				3710		82	972	69
Week ending Dec. 11	54°			172		2	23	37
Week ending Dec. 18	54°			41		4	11	2
Total mortalities to hatching				6206		88	1006	108

This condition existed until September 10, when the first fish were noted in the pools below the CCC pool. From this date onward no more fish were seen above the CCC pool and very soon there were but few in that pool. Also from this date the two pools in which the largest concentrations were noted were the ones directly above the lower rack. Until October 6, when the first blueback were seen on the spawning riffles the fish lay quietly in these various pools, mostly in the deeper parts. The steelhead showed a marked preference for the lowest pool, the one immediately above the rack. This pool differed from the rest in having most of its bottom of gravel, no large boulders, and a considerable amount of aquatic vegetation.

The preference by the fish of that section of the creek between the CCC pool and the lower rack was quite plain. It is believed that this section of the creek will provide ample space for the ripening of the 34,000 fish expected as a maximum at any one time. Therefore, it is recommended that that section of Icicle Creek between the site of the lower rack of this summer's experiment, and the riffle above the first pool below the pool at the CCC camp be reserved and developed for holding ponds for the adult fish.

An objection to the use of Icicle Creek for holding is the fact that it is subject to floods of such magnitude as would render it useless for holding during the spring and sometimes in the late fall. In the spring there will be chinook and steelhead in the holding area at the flood time; and in the fall there will be steelhead. To eliminate the difficulty created by these flood stages it is recommended that a by-pass be provided to divert these flood waters around the holding area defined above. It is recommended that this channel be of such a size that, excepting on the unusual floods occurring about once in 25 years, no more than 200 c.f.s. will have to be taken through the holding area. This by-pass must be provided with controls at the upper end so that the amount of water flowing down it can be regulated or completely shut off. It may be necessary to do some channel improvement work on the lower Icicle Creek to provide a quicker run-off for the flood waters carried by this diversion so that during extreme peaks the lower pool will not be flooded out by the backwater. This diversion will be in the neighborhood of 4,000 feet long and will need to carry about 5,000 c.f.s. of water.

The holding area should be provided with: 1. A control dam at the head end by which the amount of water going through the holding area can be regulated. 2. A dam at the lower end preceded by a rack so that the fish will not be able to escape downstream and so that the velocity of the water going through the rack will not be great enough to cause injury to the fish. This rack will need to be so constructed that at the extreme flood stages the backwater will not flood over its top. Provision must be made to allow fish to come up from downstream in order that if it becomes possible in later years to do away with the trapping at the Rock Island Dam the fish ascending the stream naturally can be accommodated at no extra cost. The low dam at this point should also be constructed with a view to taking fish over it in future years. 3. Certain racks, diffusion chambers, and, perhaps, low dams as will be needed to segregate the fish and facilitate their collection for ripening and spawning purposes. With the exception of the diffusion chambers which must pass only 200 c.f.s., these structures should be designed to permit the passage of 1,000 c.f.s. for a short period for the purposes of cleaning, etc. 4. Certain facilities for the spawn-taking operations such as roadways to the spawning grounds, seining grounds, sheds for tool storage and shelter from the sun, waste disposal facilities, piped water supply, egg hardening and washing troughs, fish bins, etc. The specific recommendations for these improvements in the holding area are dependent upon a knowledge of the contours of the creek and its banks and complete engineering data not available at present.

As nearly as could be estimated from watching the creek and fish this summer under flows varying from 20 c.f.s. to about 1,000 c.f.s., it is estimated that a flow of about 100 c.f.s. will be required as an absolute minimum to safely care for the quantity of fish expected. This will leave about 1-1/3 gallons of water per minute per fish, at maximum concentrations. Since this is only slightly under the normal flow of the creek at this time of year, there will be current velocities comparable with those found under normal conditions. The deviations from natural conditions will be small.

At present there is not 100 c.f.s. of water flowing in Icicle Creek during all of the irrigation season. In the canyon above the recommended holding area, two irrigation ditches, one diverting 110 c.f.s. and the other 15 c.f.s., take water from the stream. As a consequence, in the latter part of July, in August, September and October, the quantity of water flowing through the holding area will be much less than that required. This summer it went as low as 20 c.f.s. Therefore, it will be necessary to acquire more of the natural flow of the Icicle and, at times, all of the low flow.

The Wenatchee River in Tumwater Canyon, as shown in Table 19, reaches temperatures of as much as 70° F. and for a considerable period maintains a temperature of more than 60° F. This period of high temperatures comes at the time (in August and September) when there will be a maximum of fish in the holding area. The experiments at Monitor this summer and the 1935 experiments in holding fish at Rock Island strongly indicate that water of this temperature will induce excessive mortalities if used to hold the fish with which we are dealing until spawning time. Therefore, during the summer and fall it is recommended that Wenatchee River water not be used in the holding area.

The large Icicle irrigation ditch (carrying 110 c.f.s.) runs close to the head end of the recommended holding area, but on the hillside above. The contours of Tumwater Canyon and Icicle Flats are such that a gravity flow diversion can bring water from the Wenatchee River to the head end of the holding area. It is therefore recommended that an exchange of Wenatchee River water for Icicle Creek water (which has a lower summer temperature, see Table 19) be made with the ditch company with a view toward using the total natural flow of Icicle Creek, if necessary. At such times as the temperature of the Wenatchee River water is unsuitable for the holding area, it should be pumped into the irrigation ditch in exchange for an equal amount of Icicle Creek water. It is further recommended that the diversion from the Wenatchee River shall be of such a size that 100 c.f.s. of water over and above that required for exchange with the irrigation company can be provided in order that if it is found after experience that more water is needed in the holding area, or some contingency arises whereby more water is needed for a short period, it can be available without further development.

Table 22 Temperatures taken in Wenatchee drainage, 1937, in ^{o}F

	Wenatchee at Tumwater Canyon		Wenatchee at Mouth	Wenatchee at Monitor	Wen. at 2nd Dryden Bridge	Icicle Creek at Rack		Icicle Ditch Screen	Peshastin Creek
	high	low				high	low		
June 17	47.0	47.0							
18	47.0	46.0							
19	47.0	46.0							
20	46.5	46.0							
21	48.0	46.5	49.1	49.1				45.5	47.2
22	49.0	48.0							
23	47.5	46.0	48.2	47.6				44.6	45.5
24	51.0	45.0	49.1	48.2	47.6	46.0			47.2
25	52.0	47.0	49.1	48.6	47.6	46.4		46.4	47.2
26	54.0	49.0							
27	55.0	51.0	52.7	52.7	51.8	49.5		49.1	50.9
28	57.0	51.0							
29	53.0	51.5	53.6	52.7	51.3	50.0		50.0	51.3
30	54.0	49.5							
July 1	54.0	49.5	51.3	50.9	50.4	49.5		49.5	
2	54.0	51.0							
3	56.0	50.0	51.8	50.9	49.5	49.5		49.5	49.5
4	57.0	51.5							
5	56.0	51.5	54.0	52.7	51.8	51.3		50.9	51.8
6	56.0	50.0							
7	59.0	52.0	54.5	53.6	53.1	52.7		52.7	53.1
8	60.0	50.0	55.4	56.3	55.8				54.5
9	60.5	54.5	57.2	56.3	55.4	54.9		54.5	54.5
10	60.5	54.5							
11	61.5	55.0	57.6	57.2	56.3	55.4		54.9	54.9
12	62.0	56.0							
13	61.5	56.5	59.0	58.1	57.2			54.0	56.3
14	61.0	55.0							
15	61.5	54.5	59.0	58.1	56.7			52.5	59.0
16	64.0								
17	65.0							54.7	
18	66.5	59.5	64.4	63.9	61.7				65.3
19	65.0	57.5				59.0		59.7	
20		57.0	60.3	59.9	59.0				57.6
21	64.0					60.3	51.8	60.8	
22	65.0	57.5	64.8			60.3	52.7		
23	65.5	59.0				59.4	51.3		
24	69.0	61.5		67.1	67.5				69.3
25	70.0	65.0							
26	70.0	64.0				62.1			
27	67.5	63.0							66.2
28	67.0	63.5				63.0		61.5	
29	67.0	64.0				60.3	49.1		
30	65.0	61.0				61.2	52.2		
31	63.0	59.0				59.0	48.2		
Aug. 1	62.0	59.0				57.2	48.2		
2	64.0	58.0	67.1			57.2	47.2		
3	67.0	60.5				62.6	50.4		
4	67.5	62.0	67.1			63.9	51.8		
5	67.0	64.0				63.9	54.0		
6	67.0	63.5	69.8			63,5	63.6		
7	66.0	63.0				63.9	51.8		
8	65.0	63.0				62.1	53.1		
9	66.0	61.0				62.1	50.9		
10	66.0	64.5				61.7	54.9		

Table 22 (Continued)

	Wenatchee at Tumwater Canyon		Wenatchee at Monitor	Icicle Creek at Rack		Icicle Ditch Screen	Peshastin Creek
	high	low		high	low		
Aug. 11	68.0	63.0	71.2	66.2	54.0		
12	69.5	64.5		67.1	54.9		
13	66.0	65.0		66.6	54.5	54.0	
14	63.0	61.0		60.8	49.1		
15	61.5	59.0		59.0	46.8	52.5	
16	64.0	59.0		60.8	47.2		
17	67.0	62.0				54.7	
18	67.0	64.0		65.7	52.2		
19	67.0	64.0				59.9	
20	68.0	64.3		64.8	52.7		
21	68.0	65.0		65.7	52.7	60.8	
22	67.0	62.5		65.7	54.5		
23	62.0	60.5		58.5	51.3		
24	61.0	60.0	63.5				
25	63.0	60.0		61.2	48.6		
26	63.0	61.0		61.2	49.5		
27	62.0	60.0		60.8	48.6		
28	61.5	59.0		60.3	46.8	61.5	
29	63.0	59.0		61.2	50.0		
30	61.0	61.0		65.3	52.7	54.3	
31	60.0	59.5					
Sept. 1	63.0	58.0					
2	65.0	61.0					
3	64.0	61.0					
4	64.5	61.5					
5	64.5	63.0					62.6
6	64.5	63.0				56.3	
7	65.0	62.0					63.3
8	65.0	62.5				56.3	
9	64.0	62.5					64.0
10	66.0	63.0					
11	66.0	63.5				57.2	
12	63.4	61.3					65.1
13	62.0	60.0					
14	63.0	60.0					
15	64.0	61.0				58.1	
16	65.0	61.0		58.1		55.8	
17	65.2	63.1					
18	63.0	61.0				59.9	
19	63.0	61.0					61.2
20	63.0	61.0		59.0		55.4	
21	62.0	60.0					59.9
22	60.0	54.5		56.3		50.9	
23	60.0	55.0					59.4
24	54.2	53.0					
25	55.0	54.6		56.3		50.4	
26	57.0	56.0					54.5
27	57.0	56.0		54.5		51.0	
28	58.0	56.0					54.1
29	56.0	55.0		52.7		48.2	
30	55.0	54.0					48.2
Oct. 1	54.0	52.0					
2	55.0	54.0		50.9		47.2	
3	54.0	53.5					48.2

Table 22 (Continued)

	Wenatchee at Tumwater Canyon		Icicle Creek at Rack		Icicle Ditch Screen	Peshastin Creek
	high	low	high	low		
Oct. 4	54.0	51.7	49.6			
5	52.0	51.0				53.1
6	53.0	51.0	50.9		47.6	
7	54.0	51.0				53.2
8	53.0	51.0				
9	53.5	51.0	50.4		47.7	
10	52.8	52.0				
11	54.0	52.0	50.9			
12	.54.0	53.0				
13	55.0	52.5	51.8			
14	55.0	53.0				
15	55.5	53.0				
16	55.5	54.5	52.2			
17	53.0	51.0				
18	51.0	59.0	48.2			
19	51.0	49.0				
20	52.5	50.5	51.8			
21	53.0	52.5				
22	54.0	52.5				
23	54.0	53.5	50.4			
24	54.0	52.0				
25	52.0	51.0	49.1			
26	52.5	51.5				
27	54.0	52.0	50.9			
28	53.5	53.0				
29	52.5	51.5				
30	52.0	51.0				
31	51.0	49.0				
Nov. 1	50.0	48.5	45.5			
2	49.5	48.0				
3	49.0	48.0	46.4			
4	48.5	47.0				
5	47.5	47.0				
6	47.5	46.5	44.6			
7	47.0	46.0				
8	48.0	45.5	43.3			
9	48.0	45.0				
10	48.0	48.5	42.1			
11	48.3	48.0				
12	48.0	46.5				
13	48.0	44.0	39.2			
14	45.0	43.0				
15	45.0	44.0	39.2			
16	45.0	44.0				
17	45.0	44.7	40.1			
18	45.0	44.0				
19	44.0	42.0				
20	44.0	42.0	34.3			
21	44.0	43.5				
22	43.0	42.0	37.4			
23	44.2	43.0				
24	43.0	42.0	37.4			
25	43.0	42.0				
27			38.8			
29			36.9			
Dec. 1			35.8			

RECOMMENDATIONS FOR HATCHERY SYSTEM

There are two practical alternative programs for hatchery development: 1. the main hatchery at Leavenworth can be constructed large enough to hold all the fish up to the time the yolk sac has been absorbed and the fish can then be transported as fry to the sub-stations on the Entiat, Methow and Okanogan where subsequent rearing until liberation would take place. By this plan, the sub-stations would consist of rearing ponds only with no troughs. Or 2. The hatchery at Leavenworth could be constructed only on the basis of eyeing out the eggs. The eggs could then be shipped as eyed eggs to the sub-stations where hatching and subsequent rearing would take place. By this plan the sub-stations would have trough space to accommodate the eyed eggs and the alevins before the yolk sac was absorbed, as well as rearing ponds. They would be complete hatcheries.

The first plan has in its favor ease of supervision over the concentrated operations.

The second plan has several points in its favor: 1. It is an acknowledged fact that eyed out salmon eggs can be transported with less mortality and with considerable less expense than can the fish in any other stage of its life history. A classical example of this is the shipment of salmon eggs from this coast to London and thence to New Zealand where they arrived in good enough state to start a salmon run where there never had been one before. 2. The whole effort behind this program is to transplant the runs of the salmon and steelhead from the upper Columbia to these four lower tributaries. It is hoped that after one cycle the fish will return to the lower tributary in which it was reared instead of returning to the upper Columbia where its ancestors were reared. While it is believed that the evidence supporting such an assumption is strong, it is admittedly not infallible. If this should fail, the hauling of adults from Rock Island to Leavenworth will have to continue indefinitely. If, however, the above assumption does prove to be correct, the fish will return to the stream in which they were reared. By the second plan hatcheries will be ready for their return without additional construction and the costly trapping and hauling can be discontinued. 3. The Leavenworth hatchery site has been chosen because an adequate and suitable water supply is available. It is a well known fact of hatchery operation, however, that with the best of planning there will be times when something may go wrong with the water supply. It is even better known that disease of epidemic proportions may strike at the least expected and most inopportune time in the best of hatcheries. With the eyed eggs and subsequent developmental stages in four separate hatcheries the chances for accidentally high mortalities would be materially lessened.

As discussed in the section on the Problem, the hatching and rearing systems must be operated indefinitely, irrespective of the continuance of the trapping and hauling procedure.

In view of the above factors the second plan, transporting at the eyed egg stage, is recommended.

Insufficient data are at hand to give definite factual statements regarding ideal proportionate distribution of these three species in the four tributaries. There are only two of the tributaries that have lakes on them in which there are permanent runs of blueback, the Okanogan and Wenatchee. The Okanogan is favored over the Wenatchee because of the following facts:

1. Lake Osoyoos is larger than Lake Wenatchee by about half. There are also three other large lakes on this system in Canada (Telma, Skaha and Okanogan)

which might be brought into production in the future with the cooperation of the Canadian authorities.

2. Lake Osoyoos has a much more abundant plankton population than Lake Wenatchee. Since the young blueback are plankton feeders this is of extreme importance. Even the incomplete study of the food in these lakes this summer has demonstrated the superiority of Lake Osoyoos. A 5 minute haul with a plankton net with a 12 inch opening and made of No. 10 silk netting would yield from 15 to 25 c.c. of plankton containing thousands of organisms, whereas a haul of similar length in Lake Wenatchee would bring in only a few organisms. A study of the maps (figures 1 and 2) showing the depth contours readily explains the difference. The shallow margin of Lake Osoyoos is conducive to the growth of tremendous quantities of food. The steep slopes of Lake Wenatchee together with its cooler temperatures and, possibly also the lessened alkalinity, tend to inhibit the growth of planktonic food.

3. Lake Wenatchee is at present heavily stocked, perhaps overstocked, with silver trout, the landlocked variety of the blueback. Since the young of both varieties probably compete for the same food and the food is already scant, it is possible that this might be a limiting factor to the blueback productivity of this lake. It is interesting to note that the Wenatchee silver trout are dwarfed. Spawning adult individuals 5 inches in total length are common. On the other hand, the Lake Osoyoos silver trout average from 10 to 12 inches in length. This is probably also a result of the difference of available food and pressure of population in the two lakes.

In view of these facts, it is recommended that two-thirds of the blueback be planted in the Okanogan River system and one-third in Lake Wenatchee.

The Methow and Wenatchee rivers are comparable in size, the latter having only a little greater flow than the former. Both have a similar amount of spawning area and both have formerly maintained large runs of chinook and steelhead. The Entiat averages a little under half the flow of the Wenatchee and has much less spawning area.

Since all but two miles of the Similkameen River and the upper part of the Okanogan, except from Lake Osoyoos to a few miles above Oliver, B.C., is closed to salmon spawning, the available spawning area is reduced in the Okanogan watershed. A reconnaissance of these streams this summer disclosed no large proportional differences in the abundance of available food for the young fish. Therefore, it is recommended that one-half of the chinook and steelhead be planted in the Wenatchee, one-sixth, in the Entiat and one-third, in the Methow, with the exception that 1,000,000 chinook eggs and 500,000 steelhead eggs be transferred annually from the Wenatchee station to the Okanogan station.

The proposed hatchery system must, of course, be of sufficient size to handle the maximum number of eggs to be expected. The only basis we have for calculating this expectation is the past 5 years' counts at Rock Island. It is entirely likely that during the period of operation of this hatchery system there would be a particularly large run of chinook or of either of the other two species that would far exceed expectations. This appearance of exceptionally large runs, as well as exceptionally small runs, is by no means uncommon in other streams. A case in point is the large runs, especially of blueback, at Rock Island in 1933 and the likewise small runs in 1934. Upon these exceptionally large runs it is felt unwise to plan by reason of uncertainty and because of the great additional construction cost, capital outlay, which would lie unused in most years. The estimated 21.5 million blueback eggs in 1936 is only a little above the runs of 1935 and 1937, and it is taken as the maximum to be expected. The fact that the exceptional 1933 run was not repeated in 1937 adds some weight to this decision. The only years when all the steelhead were counted at Rock Island are 1934 and 1935 and it is questionable if all the run was counted in 1935. An exceptionally small run was produced in 1934. Therefore, the 1935 run estimated at a little under 14 million eggs is taken as the maximum year for steelhead. The largest chinook runs were produced in 1933 and 1935. Since all the chinook were not counted in 1933, that year probably exceeded the 1935 count, but the exact figure is not known. Consequently, the 1935 count of approximately 41.0 million eggs is taken. Therefore, the following recommendations are based upon a take of 21.5 million blueback eggs, 14 million steelhead eggs and 41.0 million chinook eggs or a total of 76.5 million eggs. (See Table 9.)

In designing a hatchery to handle runs of this size, the expected mortalities at different stages of growth will make a considerable difference in the size of the hatchery. Unfortunately, there are no data on hand to quote accurate mortality rates. The experiments of this summer indicate that the trapping and hauling of the fish to Icicle Creek will result in reasonably low mortalities. While this summer's experiments demonstrated the feasibility of holding fish in Icicle Creek to ripen, they did not indicate what the mortalities would be under conditions of concentration such as are expected under practical operating conditions. It is assumed that after holding there will be left about 16,340,000 blueback eggs, 34,400,000 chinook eggs, and 12,880,000 steelhead eggs. In the seining operations when taking spawn, females will be accidentally killed, eggs will be accidentally extruded or spilled, green females will be slit, and a certain number of fish will spawn or partially spawn naturally. It is estimated that the number of eggs that will finally reach the hatchery will be about 13,730,000 for blueback, 30,310,000 for chinook, and 10,820,000 for steelhead.

The limiting factor of a hatchery, however, is not the number of troughs needed to eye out the eggs but the number needed when the young larvae with yolk sac attached are hatched out. At this critical stage if too many of the young fish are placed in the trough, they will pile up on top of each other in the trough and the underneath ones will smother. About 25,000 young chinook or 35,000 young sockeye is the maximum number that can be accommodated safely in a standard 14 foot 10 inch trough. This crowding factor is accentuated in this hatchery system by the fact that the winter temperatures are so low in the area under consideration that those fish which heal first cannot be put out in the rearing ponds before March 15, because of the ice and snow conditions. Therefore, space must be provided to care for this congestion. It is assumed that from the time the eggs are fertilized until the time the young fish begin to swim, sufficient numbers of them will have been lost that there will be left to put in the rearing ponds approximately 11,670,000 blueback fry, 26,670,000 chinook fry and 8,220,000 steelhead fry. These mortalities are, of course, considerably above those experienced in standard hatchery procedure. The increase is allowed because of the extensive variations from the normal methods of artificial propagation.

Calculated Time of Hatching and Healing of the Yolk Sac Scar in Blueback, Chinook and Steelhead.

The time required by salmonoid fishes to eye out, to hatch and for the yolk sac to be absorbed is directly controlled by the temperature of the water they are in. That is, the rate of growth is proportional to the temperature. Blueback and chinook eggs will eye out with about 450 temperature units, hatch with about 900 temperature units and the yolk sac scar will be healed so that they can be placed in the ponds with about 1,800 temperature units from the date of fertilization of the eggs. Steelhead will eye out with about 300 temperature units, hatch with about 600 and the yolk sac will be absorbed and the scar healed with about 1,200 temperature units. The temperature unit is defined as the action of 1^{o} F. above 32^{o} F. for a 24 hour period. They are calculated by subtracting 32 from the average temperature of the water for each 24 hour period.

Unfortunately, temperatures are not available in the Wenatchee watershed except for those taken by us during this summer and fall. By courtesy of the Washington Water Power Company, however, we have the temperatures taken at their plant on the Similkameen River. Complete records of temperature taken 4 times daily are available for 1931, 1932, 1933 and 1934, also for the first 6 months of 1935. It is probable that the Similkameen temperatures are comparable to the Wenatchee River temperatures for the rivers have roughly the same flow and are both subjected to extremely cold temperatures during the winter. For lack of better data it is assumed in this study that the temperatures of the two streams are identical and the Similkameen temperatures have been used in computing the time of eyeing out, hatching and healing of the yolk sac scars of the blueback, chinook and steelhead at Leavenworth.

It was observed this year that the salmon began spawning in the Wenatchee in the latter part of September and had completed spawning in the first part of October. In Icicle Creek, where the water was colder than in the main Wenatchee, they did not begin spawning until October 6, and had completed spawning by October 26. The blueback and chinook spawned at the same time. Considering that they all spawned on October 1 and using the data noted above, the eggs would have eyed out on October 21 in 1931-32, on October 21 in 1932-33, on October 26 in 1933-34, and on October 20 in 1934-35. Eggs spawned on October 20 would have eyed out on December 15 in 1931-32, on November 13 in 1932-33, on December 9 in 1933-34, and on November 27 in 1934-35. Eggs spawned on October 20 would have hatched on April 4 in 1931-32, on December 12 in 1932-33, on February 23 in 1933-34 and on March 13 in 1934-35.

Eggs spawned on October 1 would have hatched on December 13 in 1931-32, on November 12 in 1932-33, on January 4 in 1933-34, and on November 27 in 1934-35. Eggs spawned on October 20 would have hatched on April 4 in 1931-32, on December 21 in 1932-33, on February 23 in 1933-34 and on March 13 in 1934-35.

Eggs spawned on October 1 would have had the yolk scars healed and the young fish could have been planted outside in the rearing ponds on April 28 in 1931-32, on April 24 in 1932-33, on April 23 in 1933-34, and on April 19 in 1934-35. Eggs spawned on October 20 would have been at this stage of development on May 24 in 1931-32, on May 20 in 1932-33, on May 16 in 1933-34 and on May 15 in 1934-35.

This year young steelhead with the yolk sac scar newly healed were seen at Rock Island Dam in the middle of June. By the 25th of July, steelhead at this stage of development were of widespread occurrence in the Wenatchee and its tributaries and in the tributaries of the Methow. To find the date of spawning of these adult steelhead the process of calculation noted above, based on temperature units, was reversed and the spawning date computed on the basis of 1,200 temperature units needed for the young steelhead to absorb their yolk sac and the scar to heal.

Young steelhead appearing in the stream with yolk sac scar healed on June 1 would have been the result of eggs fertilized on March 22 in 1931-32, on March 30 in 1932-33, on February 17 in 1933-34 and on February 15 in 1934-35. Young steelhead appearing in this stage of development on July 1 would have been the result of spawning on May 8 in 1931-32, on April 28 in 1932-33, on May 14 in 1933-34 and on May 4 in 1934-35.

From these calculations, it is apparent that the steelhead can be expected to spawn between the latter part of February and the middle of May. The latter date was further confirmed this spring by finding several freshly spawned out adult steelhead in the by-pass traps in Peshastin Creek and on the spill at the end of the Dryden Ditch (on the Wenatchee River) in the middle of May.

All of these data are based upon the rate of growth under natural conditions in the stream. In the hatchery the actual growth may be somewhat more repid than this because of the warming of the water as it passes through the hatchery building. The extent of this rise, if any, is not known. A small increase in temperature during the cold winter months would materially hasten development. It is assumed that a sufficient number of the salmon at the Icicle Creek hatchery will be put in the ponds by the time all the steelhead eggs are collected that the steelhead eggs can be accommodated in the troughs vacated by the young salmon. The steelhead will not affect the trough requirements of the 3 sub-hatcheries, either, because by the time the steelhead eggs are eyed out and ready to move, sufficient quantities of blueback and chinook will have been removed from the troughs to the rearing tanks and ponds to accommodate the steelhead eggs.

The steelhead eggs coming at the time they do will not enter into the calculations of the size of the hatchery since sufficient salmon will have been removed before they enter the hatchery to provide ample space for them. About three and a half million chinook eggs will be spawned in late August and early September and will develop rapidly enough that they can be put into the rearing ponds before the main part of the chinook and blueback will start swimming and therefore will decrease the hatchery space requirements by that much.

The feeding of the young blueback must start in the hatchery before they are put out into the rearing pond. Therefore, it is recommended that feeding tanks of permanent construction 5 feet wide, 15 feet long and 24 inches deep be provided in the Okanogan and Wenatchee hatcheries to make this preliminary feeding possible. Each of these tanks will have a capacity of about 70,000 blueback fry.

On the basis mentioned above of taking two-thirds of the blueback to the Okanogan station and leaving one-third of the blueback at the Wenatchee and the division of chinook and steelhead among the four tributaries as noted above, the following trough and feeding tank requirements must be met:

1. The Wenatchee station will need 432 troughs (each trough to be 14 feet 10 inches long, 8 inches deep and 12 inches wide, inside measurements) and 32 of the feeding tanks described above.

2. The Entiat station will require 192 troughs.

3. The Methow station will require 288 troughs.

4. The Okanogan station will need 192 troughs and 40 feeding tanks.

RECOMMENDATIONS FOR REARING FISH

Recent experiments have indicated that the terrific mortality which occurs among salmonoid fishes during their youth in fresh water (as much as 98 or 99 per cent in the sockeye according to Foerster, Bull. Biol. Bd. Canada LIII) can be markedly lessened by rearing the fish in sheltered ponds during the period of high natural mortality in the stream. Mr. George Kelez, of the U. S. Bureau of Fisheries, has demonstrated this in his experiments with silver salmon (Progr. Fish Cult., No. 32, July, 1937). Mr. Kelez liberated 26,150 silver fingerlings, marked by fin excision at the Samish Hatchery of the Washington State Department of Fisheries, which were of an average length of 1-7/8 inches and an average weight of .05 ounces. Another group of 26,150 fish was marked and reared to an average length of 4 inches and an average weight of .45 ounces before they were liberated. When the fish returned as adult specimens only 7 of the group liberated as small fingerlings were recovered, whereas 462 of the group reared to a length of 4 inches were recovered, a ratio of 66 to 1 in favor of the fish reared to a larger size. Regardless of the fact that unknown intervening factors, other than that being tested, might have had some effect in spreading this ratio, the very fact that 1.8 per cent of the larger fish returned to the Samish River to spawn after being subjected to the normal vicissitudes of a salmon's existence and an intense fishery is of such significance that the importance of this method to hatchery technique cannot be disregarded.

Dr. Foerster (Progr. Fish Cult., No. 26, January, 1937) found that sockeye fry liberated immediately after hatching in the lake showed a 5 per cent survival as seaward migrants (after 12 months in the lake); fry reared 3 months showed a 21.8 per cent survival; fry reared 5 months showed a 32.8 per cent survival; fry reared 7 months showed a 44.6 per cent survival; and fry reared 9 months showed a survival of 54.7 per cent.

The utility and practicability of rearing fish to larger than fry size before liberating have been recognized for several years in the artificial propagation of trout. Several of the eastern states rear their fish to a length of 6 inches before liberation. The Washington State Department of Game rear their fish in localities where planting by tank truck is possible to a length of from 4 to 6 inches.

It is, perhaps, this rearing of young fish that will lessen the threat of Grand Coulee Dam to the Columbia River fishery. As has been mentioned before, the State of Washington has taken steps in the past few years toward building up the runs of salmon and steelhead in the upper Columbia to their former magnitude. Protective devices on Rock Island and Bonneville dams were required at a cost of several million dollars. The intensity of the fishery on the Washington side was decreased drastically by the elimination of traps and beach seines. In particular, strong measures had been taken on the Wenatchee, Entiat, Methow and Okanogan rivers, as well as the Yakima River, to provide each water diversion with a screen so that the enormous destruction of the young seaward migrants would cease. There had been a systematic progression of improvements up the river with the idea in mind of bringing back every portion of the Columbia River watershed under the jurisdiction of the State of Washington into its former condition of productivity.

Grand Coulee Dam completely upset a large share of these plans and work. It not only will remove some 1,100 miles of stream from any possibility of improvement forever, but it will force the transplantation of the runs already frequenting that large section of the watershed into the four lower tributaries, the Wenatchee, Entiat, Methow and Okanogan. The only solution in sight at present for such a dilemma is the rearing of the young fish nearer to the size at which they normally migrate to the sea. Such a program may offset the damage done by Grand Coulee Dam; ordinary hatching and liberation in the young fry stage cannot.

As will be shown below, the young chinook move downstream either in the fall following hatching or in the next spring with only a very few spending a second winter in the stream. The steelhead apparently do the same (the results are confused by the movements of the landlocked "rainbow" form of this species). The blueback migrate to sea in the spring (according to this summer's work on the Wenatchee drainage approximately one-half after having spent one winter in the lake after hatching and one-half after having spent two winters in the lake). (See section on Migration of the Young.)

The extremely cold weather experienced in Eastern Washington in the winter would make it practically impossible to keep all the rearing ponds free from ice during the winter months. Unless the water were heated somewhat (an expensive process) there would be the constant danger of the water and fish freezing solid in the ponds. This unfortunate condition makes the rearing of all the fish for more than a few months impractical. To counteract this, all of the fish must be reared during the spring months and a good share must be reared during the summer and fall.

In any year it will be possible to keep the ponds open until well into October. By this time the steelhead and blueback will each have reached a length of about 3½ inches and weight of about 0.3 ounces and the chinook will average 4 inches in length and weigh about 0.4 ounces (see section on Migration of Young). Liberation at this time will coincide roughly with the time of the normal fall downstream movement so that those that wish can go downstream naturally, and the others can wait till spring.

For the rearing of the fish two types of ponds are recommended. The large pond shall be made of concrete, both sides and bottom. It shall be 100 feet long and 40 feet wide with a division down the center the length of the straight side wall, and with round ends. The depth of water shall be 4 feet. The minimum available water supply for each pond shall be 900 gallons per minute. The water shall be introduced by two methods: 1. by spray nozzles all around the circumference of the pond so that a current can be kept in the pond and a maximum of the sun's rays reflected, and 2. by diffusion along the center division near the bottom. The two systems should have separate controls. Both systems should be of such a size that they can handle all or any part of the 900 gallons per minute. The outlet should be so arranged and screened that the velocity of approach to the outlet screen be not more than ¼ foot per second and so that the level of the water in the pond can be regulated to any height up to 4 feet. The outlet screens shall be of a self-cleaning type. It is estimated that each of these ponds will have an initial capacity of 500,000 salmon or steelhead fry until June liberation. It is recommended that 30 of these ponds be constructed at the Wenatchee station, 16 at the Okanogan station, 16 at the Methow station, and 8 at the Entiat station.

The other type of pond recommended is identical in design of water supply, outlets, etc., as the large pond, except that it should be 80 feet long, 20 feet wide and carry water only 3 feet deep. It is recommended that 40 of these be provided at the Wenatchee station, 14 at the Okanogan station, 16 at the Methow station, and 8 at the Entiat station. Each of these ponds will have an initial capacity of about 100,000 fry and will need a minimum of 300 gallons of water per minute.

It is recommended that some over-winter rearing be done. Because of low winter temperatures (-20°F.) unsheltered ponds would be subject to freezing. Therefore, it will be necessary to house what ponds are to be used for winter rearing in buildings in which the minimum winter temperature will be not less than 33° F. It is recommended that 16 of the smaller ponds be so housed at the Wenatchee station, 4 of the large ponds at the Okanogan station, 8 of the small ponds at the Methow station, and 4 of the small ponds at the Entiat station.

The hot summer temperatures in this area can be just as deadly to the young fish as the cold winter temperatures. The small ponds have many advantages over the large ponds in some respects but their shallower depths render them more liable to heating during the summer than the deep pools. It is recommended that those of the smaller pools which are not housed for winter rearing (24 at the Wenatchee station, 14 at the Okanogan station, 8 at the Methow station, and 4 at the Entiat station) be covered by structures to provide a semi-shaded condition. These small ponds will be used as primary ponds for the first few weeks of feeding the small fish because of the great ease with which they can be attended during the critical period when the small fish are being taught to take artificial food. When the critical feeding period is over the fish will be moved on to the large ponds and the small ponds will be used for normal rearing.

FOOD FOR THE FISH TO BE REARED

By far the most economical and efficient method of feeding young fish for this proposed system is by concentrated dried food augmented by a portion of fresh beef liver and spleen. Numerous foods can be used (Lauren R. Donaldson, Am. Fish. Soc. Vol. 65, 1935, and manuscripts) with good results; dried salmon meal, scrap fish meal, horse meat, cereals, etc. With these concentrated foods is fed some such substance as fresh beef liver, spleen, pancreas, watercress, kelp meal, vitamin concentrates, etc., to provide the necessary vitamins to the diet.

An excellent, and perhaps the most economical diet yet disclosed for this region, is a combination of 40 per cent fresh beef liver or spleen with 60 per cent pre-cooked dried salmon carcasses or equivalent dried foods. It combines economy, accessibility of food, ease of feeding, and a lessened mortality among the fish. On such a diet one pound of food will produce about one pound of fish, with a minimum mortality.

The preparation of the dried salmon meal is accomplished at the Quilcene Hatchery of the U. S. Bureau of Fisheries in the following manner. The spawned out carcasses of the salmon are put through a cutting machine in the round (whole carcass). The resulting chunks of fish are placed in hot water for a few minutes to coagulate the proteins so that they will not be broken down during drying. The fish is then put through a meat grinder and goes from there into a chamber where it is dehydrated by a current of dry air at a temperature of about 170°. The dried product is then put through a hammer mill and the dried meal is sacked or put in a bin to await use.

It is recommended that a dried food plus fresh liver or spleen diet be provided for rearing the fish in this hatchery system. Figured on the basis of the maximum runs used in this report, a total of about 58 tons of dried salmon and scrap fish meal can be salvaged from the spawning operations on Icicle Creek. It is not advisable to buy commercial dried meals to feed to fish unless absolutely necessary because they are prepared at high temperatures and the resulting product is far less efficient fish food than the same product processed at lower temperatures.

It is recommended, therefore, that facilities be provided at the Icicle Creek Hatchery for the proper processing of dried meals for fish food, both from the carcasses of spawned-out fish and from such other products as can be procured and brought to that location for processing. It is possible to make only a very rough estimate of the food needs for this hatchery system. It will vary proportionately from year to year with the size of the egg take. On the basis of the maximum run used in this report, it is contemplated that 32.5 million young fish will be reared for about 3 months and planted in June and July. Until the latter part of October 10.9 million fish will be reared at which time they will be planted and 1,000,000 fish will be held over winter in the winter rearing ponds. The fish liberated in the first summer will have increased about 0.2 of an ounce in weight and will result in a total weight of about 406,300 pounds. The fish liberated in the fall will have increased about 0.4 of an ounce in weight since absorption of the yolk sac. They will weigh a total of about 272,500 pounds. The fish held over winter will increase about another 0.3 of an ounce during this period, or a gain of about 20,000 pounds. The total increment of weight during rearing so calculated will be about 350 tons. If it will be possible to get one pound of fish for one pound of the concentrated food, there will be about 350 tons of food needed for the rearing season. The mortalities expected during rearing will tend to reduce this figure and a probable increase in the growth rate over the natural growth rate will tend to increase it. Of this amount, about 140 tons will be liver or spleen and 210 tons will be dried meal.

The foregoing estimated requirements for fish food forms a basis for budgeting the fish food cost. It is not considered imperative nor expedient, however, that fish feeding operations be confined solely to the foods mentioned. Due to quantities available and price fluctuations it may be found necessary to substitute in part by using such other food materials as are procurable on the open markets at reasonable prices.

ADDITIONAL RECOMMENDATIONS FOR THE HATCHERY STATIONS

Wenatchee River Station

The Wenatchee River Station shall be located on Icicle Flats near the junction of Icicle Creek and the Wenatchee River in the general area proposed in the preliminary report. The hatchery shall have 432 standard 14'10"x12"x8" troughs and 32 feeding tanks 5'2"x15'0"x24". It shall have 30 40'x100'x4' rearing ponds and 40 20'x80'x3' rearing ponds. (All depth figures refer to water depth.) Sixteen of the latter shall be in a building constructed substantially enough that the winter temperature can be economically held at 33° F. or above. The remaining 24 small ponds shall be shaded.

The minimum water requirements for the station when in full operation shall be 42,400 gallons per minute or about 95 c.f.s. of which not less than 2,160 g.p.m.

will be needed for the hatchery troughs, 1,280 g.p.m. for the feeding tanks, 27,000 g.p.m. for the larger rearing ponds, 4,800 g.p.m. for the small winter rearing ponds, and 7,200 g.p.m. for the reamining small rearing ponds. The water supply shall be derived from three sources. The winter water supply shall come from Icicle Creek by gravity flow and from pumped underground water suitable for hatchery purposes. This winter water supply shall provide a minimum of 8,240 g.p.m. (for hatchery troughs, feeding tanks and winter rearing ponds). A 10 per cent additional flow shall be pumped underground water (for tempering the Icicle water). Pumping equipment should be provided. The winter water supply shall come from Icicle Creek. The conduit for this supply shall be covered and equipped at the headworks with heating facilities. If wood pipe is used for the conduit, it should be untreated on the inside. It must be so constructed that the above minimum water supply will be available all winter regardless of temperature. The water supply for the rest of the year shall be derived from the Wenatchee River. A diversion dam in Tumwater Canyon and a gravity flow diversion canal shall provide the hatchery with a minimum flow of 42,440 g.p.m. It must be remembered that this diversion shall also have to carry the exchange water for the Icicle ditch and the 100 c.f.s. standby water supply for the adult holding area. The diversion canal must therefore be large enough to carry a minimum of about 310 c.f.s. It should be provided with controls at the headworks so that all or any part of this supply can be put through the canal when in use. It is not normally intended that this Wenatchee River diversion should be used during the winter freeze-up period, but it should be available for emergencies at all times.

All of the water supply for the hatchery and rearing ponds shall be adequately screened. The water supply for the hatchery trough (minimum of 2,160 g.p.m.) must have facilities for sedimentation. The screens and sedimentation facilities for the winter water supply shall be so housed that it shall stand no chance of freezing in the coldest weather. The screens for all water supplies shall be of a self-cleaning type that will remove the debris from the water.

The hatchery building shall be of sufficient size to accommodate the number of troughs and feeding tanks noted above. The hatchery troughs will be arranged in sets, 4 wide and 2 long, so that the same water will flow through two troughs. Between each set of troughs will be an aisle sufficiently wide for a man to work in. Between each third set of troughs there shall be an aisle continuing clear through without the intervention of the supply trough which will be located through the center of the building. The runways extending the length of the building at the outlet end of the troughs shall be paved and wide enough to permit trucking. The hatchery building shall be of permanent type construction insulated for economic heating and shall be properly ventilated, lighted and heated. The minimum winter temperature in the main hatchery room shall be not less than 40° F. The building shall be so constructed as to have a minimum number of support posts in the main hatchery room. In addition to the main hatchery room the hatchery building shall contain: 1. Locker, dressing and lunch room for hatchery crew, 2. toilet and washing facilities for the crew, 3. small storage room for equipment in immediate use, 4. office for hatchery foreman, 5. reception room for the general public with proper toilet and lavatory facilities for both men and women adjoining the reception room, and 6. loft for storage of baskets and equipment.

The administration building shall contain offices for the general superintendent, clerk, and biologist; a biological laboratory; and proper toilet and lavatory facilities. It shall be properly heated, lighted and ventilated.

The food storage and preparation building should contain the following facilities: 1. Equipment for preparing and drying fish foods. The dryer and subsidiary equipment should be capable of processing 5 tons of fish meal in 24 hours. 2. Equipment for the cooking and processing of commercial meals (in case it is found necessary to use them for part of the diet). 3. Power equipment for the preparation and mixing of the food for feeding which will have maximum capacity of preparing 2 tons of food in 8 hours. 4. Refrigeration facilities which contain: a. ice-making machine capable of a maximum production of 2 tons of ice in 24 hours, b. storage space for a maximum of 10 tons of ice (additional ice needed in emergencies can be purchased from commercial plants in Wenatchee and elsewhere), c. sharp freezing room with a capacity of freezing about 40 tons of fresh produce in 24 hours, d. cold storage space for the storage of a maximum of 1 carload (40 tons) of liver and spleen and 2 carloads of other perishable foods, and e. cold storage space sufficient for cooling 1 ton of prepared food at a time. 5 Storage room (normal temperature) for 1 carload of such dried foods (cereals, kelp meal, etc.) as do not need cooling during the hot summer months. 6. Central heating plant for all buildings except residences, water supply intakes, etc. 7. Storage facilities for fuel for this heating plant. 8. Proper lockers, toilet, lavatory and dressing room facilities for the crew. The heating and refrigerating equipment should be so designed that the failure of any part of either facility will not shut down the operation of the whole while repairs are being made.

The building for the care of the mechanical equipment should have the following facilities: 1. Machine shop space, 2. carpenter quarters, 3. paint room, 4. blacksmith shop space, 5. pipe fitter's quarters, 6. wash rack, 7. grease pit, 8. grease storage room, 9. gasoline pump with gasoline storage tanks, 10, garage space for all motive equipment at the station, and 11. toilet and lavatory facilities for the crew. The building should be provided with proper heat, light, and ventilation. Storage facilities should be provided in this building for all spare mechanical parts and all materials pertaining to the mechanical equipment.

The general warehouse should have space for off-season storage of spawning equipment and miscellaneous ground work and maintenance equipment. Space will be needed for drying and treating nets. General storage space will be required for supplies for all hatcheries including the Wenatchee Station and the three sub-stations.

There should be provided at the Wenatchee Station two 6 room and two 5 room residences, one each for the General Superintendent, Biologist, Hatchery Foreman, and Chief Mechanic, which will be provided with individual heating equipment and garages.

Telephone communication should be available between the administration building, hatchery, general warehouse, garage building, food processing and heating plant, four residences, holding pond headworks and spawning ground, Icicle Creek water supply headworks, and Wenatchee River water supply headworks. A central switchboard should be provided in the clerk's office in the administration building.

STREAM FLOWS OF ICICLE CREEK DURING 1911, 1912, 1913, and 1914
IN CUBIC FEET PER SECOND TAKEN FROM THE U. S. GEOLOGICAL SURVEY
WATER SUPPLY PAPERS FOR THIS PERIOD.

DATE	1911	1912	1913	1914	DATE	1911	1912	1913	1914
January 1			176	176	February 19		224	345	176
2			210	186	20		224	320	176
3			320	214	21		224	296	200
4			420	476	22		224	345	200
5			420	738	23		224	370	200
6				1000	24		219	370	214
7				1160	25		219	395	224
8				835	26		214	345	210
9				645	27		214	370	320
10				570	28		209	345	272
11				520	29		205		
12				470	March 1		200	224	248
13				470	2		195	205	234
14				445	3		190	205	224
15				420	4		205	205	224
16				420	5		214	205	224
17				370	6		200	205	224
18				370	7		181	205	224
19				320	8		176	224	248
20				320	9		171	224	248
21				320	10		176	248	248
22				340	11		176	248	248
23				282	12		158	248	262
24				258	13		144	248	296
25				272	14		139	248	370
26				286	15		135	248	370
27				258	16		130	248	420
28				224	17		130	272	470
29				210	18		139	272	520
30				282	19		130	248	545
31				272	20		130	224	570
February 1			200	272	21		130	210	595
2			200	272	22		130	248	620
3			200	272	23		130	224	620
4			200	272	24		130	224	595
5			200	248	25		144	176	545
6		224	210	200	26		195	219	520
7		224	158	214	27		248	210	495
8		224	176	170	28		345	210	470
9		224	272	140	29		345	224	445
10		224	272	180	30		320	224	420
11		224	272	190	31		345	224	395
12		224	320	200	April 1		420	224	395
13		224	296	190	2		470	214	395
14		195	320	190	3		520	214	395
15		205	320	176	4		520	234	495
16		224	495	176	5		470	234	645
17		224	670	153	6		470	224	670
18		224	520	176	7		470	224	725

DATE	1911	1912	1913	1914	DATE	1911	1912	1913	1914
April 8		495	224	835	May 29		1930	2770	1160
9		545	229	890	30		1690	3010	1220
10		698	267	1000	31		1570	4050	1810
11		725	365	1000	June 1		1750	4180	2350
12		645	495	1000	2		1870	4640	2890
13		620	620	1110	3		1870	4640	2470
14		570	698	1160	4		1750	4440	1810
15		570	752	1450	5		2110	3660	1330
16		545	725	1220	6		2410	3270	1160
17		545	752	1060	7		2830	3460	1000
18		570	890	1000	8		3010	3920	890
19		520	1050	1810	9	1570	2770	3600	780
20		520	1050	1570	10	2050	2530	3140	780
21		520	1160	1280	11	3010	2470	3080	780
22		495	1000	1110	12	3660	2650	3270	1060
23		545	890	1060	13	3790	2470	3270	1450
24		520	808	1000	14	3200	1990	2770	1570
25		520	752	945	15	2710	1510	2170	2050
26		520	890	945	16	2410	1330	1990	2290
27		570	808	890	17	2050	1510	1930	2290
28		570	725	835	18	1690	1870	2110	2050
29		670	725	780	19	1450	2410	2890	1690
30		725	698	835	20	1330	2770	2770	1330
May 1		670	645	1110	21	1280	2230	2590	1110
2		620	620	1930	22	1630	1630	2650	945
3		670	620	2050	23	1390	1630	2770	835
4		725	620	1630	24	1110	2110	2530	1220
5		698	620	1450	25	1110	2170	2290	1110
6		780	780	1330	26	1330	2110	2110	1000
7		1000	1000	1330	27	1450	1870	2110	1000
8		1570	1570	1330	28	1220	1220	2290	1000
9		2290	2050	1280	29	1000	1060	2170	1110
10		1930	1810	1330	30	896	1000	2350	1220
11		1810	1570	1330	July 1	862	972	2350	1330
12		1930	1390	1570	2	890	862	1870	1330
13		2290	1330	1930	3	918	835	1690	1220
14		2770	1220	2590	4	890	862	1510	1220
15		3460	1160	2890	5	972	890	1690	1000
16		2710	1110	2530	6	1110	835	2050	890
17		2110	1110	2170	7	1060	780	2050	890
18		2110	1110	2050	8	808	725	1810	890
19		2410	1110	2050	9	698	725	1930	835
20		4120	1160	2170	10	645	780	1870	780
21		3530	1330	2350	11	645	780	1630	780
22		2530	1930	2350	12	645	808	1450	890
23		1990	2410	2590	13	698	808	1220	835
24		1930	2650	2410	14	752	725	1060	780
25		1930	2770	2050	15	780	725	1000	780
26		2470	3720	1630	16	890	752	1000	670
27		2350	3660	1450	17	862	725	1110	620
28		2530	3140	1220	18	725	698	1160	595

DATE	1911	1912	1913	1914
July 19	645	670	1450	620
20	620	645	1570	570
21	545	620	1810	520
22	495	570	1690	445
23	470	520	1690	445
24	470	495	1570	420
25	470	470	1390	420
26	470	420	1220	395
27	420	420	1000	395
28	395	395	945	345
29	370	370	890	345
30	370	370	752	320
31	350	345	725	320
August 1	345	345	698	320
2	320	370	752	345
3	320	345	698	320
4	320	345	670	296
5	320	320	670	296
6	320	320	620	296
7	296	296	595	272
8	272	296	670	272
9	272	296	595	258
10	272	296	495	248
11	248	296	470	248
12	224	272	470	258
13	224	248	445	238
14	219	248	370	238
15	210	272	370	224
16	205	320	320	224
17	200	345	320	210
18	195	272	320	200
19	195	272	320	200
20	195	248	296	200
21	195	248	272	200
22	186	248	272	186
23	176	248	296	176
24	171	224	296	176
25	167	224	296	176
26	158	210	272	176
27	153	214	248	167
28	148	200	248	153
29	139	200	272	153
30	148	200	272	153
31	167	224	248	130
September 1	171	420	248	130
2	171	320	224	130
3	171	320	248	130
4	176	272	890	130
5	176	248	670	122
6	190	224	495	122
7	248	272	445	122
September 8	214	248	370	130
9	224	224	345	122
10	224	214	320	122
11	200	210	296	110
12	181	214	272	110
13	224	214	248	110
14	224	224	248	110
15	320	195	248	176
16	395	176	248	176
17	320	167	248	176
18	296	153	224	224
19	248	153	214	296
20	224	144	214	224
21	224	135	224	224
22	224	130	320	200
23	224	130	272	176
24	205	130	248	176
25	186	130	214	176
26	176	130	210	272
27	176	110	200	296
28	162	110	205	248
29	144	110	200	224
30	139	110	200	214
October 1		110	176	200
2		118	176	214
3		114	167	214
4		126	153	200
5		130	153	200
6		130	176	176
7		118	176	176
8		118	176	153
9		153	176	130
10		130	200	224
11		122	670	248
12		114	570	248
13		110	670	296
14		110	520	320
15		110	445	272
16		106	395	272
17		130	370	420
18		214	370	420
19		210	445	470
20		181	470	420
21		176	470	370
22		176	420	345
23		176	420	320
24		153	570	320
25		176	495	296
26		176	420	296
27		167	370	296
28		148	370	296

DATE	1911	1912	1913	1914	DATE	1911	1912	1913	1914
October 29		167	345	296	December 19		176	214	
30		153	320	420	20		176	186	
31		153	296	445	21		171	186	
November 1		153	296		22		176	186	
2		148	296		23		153	200	
3		148	272		24		148	186	
4		153	272		25		176	186	
5		144	272		26		139	186	
6		144	296		27		130	176	
7		144	272		28		130	176	
8		176	262		29		130	176	
9		176	272		30		130	176	
10		176	272		31		130	176	
11		176	258						
12		176	224						
13		200	195						
14		224	219						
15		224	296						
16		205	1000						
17		210	835						
18		210	495						
19		205	445						
20		214	395						
21		224	395						
22		272	370						
23		282	370						
24		272	495						
25		262	445						
26		253	420						
27		243	420						
28		234	395						
29		224	395						
30		224	370						
December 1		214	345						
2		210	320						
3		272	296						
4		272	262						
5		248	272						
6		224	296						
7		214	296						
8		200	272						
9		181	248						
10		176	248						
11		181	248						
12		186	248						
13		190	248						
14		190	248						
15		190	224						
16		176	224						
17		176	224						
18		176	234						

Okanogan Sub-station

The temperatures of Lake Osoyoos even at the bottom in the American end of the lake can be expected to rise to at least 70° F. (see Table 23) during the month of August. This complicates the problem of rearing the fish through the summer at this station. While fish of the size that these will be can be reared in this temperature, it is at the upper limits for salmonoids. Whether or not late summer rearing can be done at this station without excessive mortalities can be determined only after actual operations. If it is found feasible, the fish will be reared the same as at the other stations. If it is found to be not feasible, the fish will be planted before the high summer temperatures begin. After the temperatures have gone down again (in September) fry will be hauled from the Wenatchee station for continued rearing. An alternative to this plan would be the placing of 5 rearing ponds at the Canadian end of Lake Osoyoos in Canadian territory where low sub-surface temperatures obtain throughout the summer.

The Okanogan station should be placed on the shore of Lake Osoyoos. The hatchery building will have 192 standard 14 foot 10 inch hatching troughs and 40 feeding tanks. The hatchery building will be of the same substantial type of construction as that at the Wenatchee station. The winter temperatures in the main hatchery room should be held at a minimum of 40° F. Besides the troughs and feeding tanks, the building will contain an office for the hatchery foreman, a combination lunch, locker, and dressing room for the crew, toilet and lavatory facilities, and a small storage room for hatchery equipment in immediate use.

A feed house should be provided to contain: 1. Equipment for the preparation and mixing of both the liver-dried salmon diet or the liver-commercial meal diet of about half the capacity of the same unit at the Wenatchee station; 2. Cold storage room for the preservation of frozen food and food needing protection from the hot summer weather which shall be large enough to accommodate 40 tons of food; 3. Pumps for the water supply (one electric pump and one diesel duplicate for standby); 4. Refrigerating unit for cold storage plant; 5. A two-truck garage with facilities for greasing and minor repairs; 6. A gasoline pump with fuel storage tank; 7. Heating plant with fuel storage facilities; and 8. Storage room for miscellaneous supplies and equipment not in immediate use.

The hatchery and rearing ponds when in full operation will need a minimum of 21,160 gallons per minute of which 960 g.p.m. will be needed for the hatchery troughs, 1,600 g.p.m. for the feeding tanks, 14,400 g.p.m. for the 16 big rearing ponds, and 4,200 g.p.m. for the 14 small rearing ponds. The necessary minimum winter water supply shall be 4,560 g.p.m. of which 960 g.p.m. shall be for the hatchery troughs and 3,600 for the 4 covered large rearing ponds. This water shall be derived from Lake Osoyoos and, in part for tempering, from underground water. As mentioned above (and shown in Table 23) the sub-surface waters may be at a minimum temperature of 70° F. in August. The water temperatures in the Okanogan River are even higher (Table 24). Lake Tuglnuit (Figure 4 and Table 25) proved to be shallow but cooler than Lake Osoyoos. It is in Canada near Oliver, B.C. Copper Lake (Figure 5 and Table 25), a small pothole lake tributary to Lake Osoyoos on the west side near the Canadian border, proved to have lower sub-surface temperatures (being spring fed), but the late summer flow diminishes to a mere trickle. The only cool water temperatures found in the valley during August (with the exception of the Canadian end of Lake Osoyoos and Lake Tuglnuit shown in Tables 23 and 25) were taken in several wells adjacent to the proposed hatchery site (Table 26). It is desired that at least an additional 10 per cent of the total water for the

Table 23. Temperatures in Lake Osoyoos - 1937.

South End of Lake (American side).

	June 26 1937		July 13 1937		July 21 1937	July 28 1937	Aug. 6 1937	Aug. 19 1937	Aug. 28 1937	Sept. 17 1937	Oct. 19 1937
Surface	75.2° F	Air	80.6° F	Air	81° F	89° F	81° F	78° F	71° F	65° F	52° F
15'	68.0	Surface	73.6	Surface	74	76	71	73	69	60	56
24'	65.3	10'	71.6	10'	74	76	71	72	69	58	55
36'	65.3	20'	71.6	20'	73	76	70.5	71	68	57	53
45' Bottom	64.4	30'	71.6	30'	73	75	70.5	71	68	56	53 (Bottom)
		40'	66.2	40'	72	73	70	71	66	54 (Bottom)	
		48' (Bottom)	64.4	50'	64	64	70	70	66		

North End of Lake (Canadian side).

	Aug. 20 1937		Aug. 24 1937		Aug. 28 1937		Oct. 29 1937
Surface	72° F	Air	66° F	Air	74° F	Air	50° F
60'	58	Surface	73	Surface	68	Surface	56
115'	50	30'	65	10'	68	10'	55
		60'	58	20'	66	20'	54
		90'	52	30'	66	30'	53
		115'	50	40'	64	40'	53
				60'	55		
				80'	54		
				100'	51		
				120'	49		
				130'	49		

hatchery can be derived from pumped underground water. Chemical analyses showed no known deleterious concentrations of dissolved gases (Table 27). How much underground water is available is not known at present. If a larger percentage than that given above is available and the water proves to be not deleterious to the young fish, the lower temperatures derived would assure the success of late summer rearing at the Okanogan station. The practicability of August rearing cannot be positively assured, however, from the present data.

All pumping equipment must be in duplicate; one set powered by electricity, the other by diesel engines. The water must be screened by the same methods as recommended for the Wenatchee station. No sedimentation facilities will be needed.

The Okanogan station should have 2 permanent residences with garages and sewage disposal of the same type as recommended at the Leavenworth Hatchery. Consideration should be given to maintaining Lake Osoyoos at a uniform level to lessen pumping costs.

Methow Sub-station

The site for the Methow sub-station has not yet been determined other than that it will probably be located on the Methow River above Twisp. The water temperatures in this drainage (Table 24) present no great difficulties for picking the station site, nor do the chemical analyses of the dissolved gases in the water (Table 28). The water supply will be derived from the main river by gravity and from either springs or wells. It will be necessary at this station, as well as at the others, to provide a certain amount of underground water for tempering the water for winter operations.

The hatchery shall contain 288 standard troughs and no feeding tanks. There will be 16 large rearing ponds and 16 small rearing ponds. Eight of the latter shall be sheltered for winter rearing and the 8 remaining will be semi-shaded. A minimum of 20,600 gallons per minute of water will be required for full hatchery and rearing operations of which not less than 1,400 g.p.m. will be for the hatchery troughs, 14,400 g.p.m. for the big rearing ponds, and 4,800 g.p.m. for the small rearing ponds. The necessary minimum winter water supply shall be 3,800 g.p.m. of which not less than 1,400 g.p.m. will be for the hatchery troughs and 2,400 g.p.m. for the 8 small winter rearing ponds.

The feed preparation and storage facilities, the general storage, garage, heating, residence, etc., facilities will be the same as for the Okanogan substation.

Entiat Sub-station

The Entiat sub-station shall be located on the main Entiat River. The hatchery shall contain 192 standard hatchery troughs and no feeding tanks. There shall be 8 of the big rearing ponds and 8 of the small rearing ponds. Four of the latter shall be sheltered for winter rearing and the remaining 4 shall be in semi-shade. The hatchery building shall be of the same type of construction as that recommended for the other stations.

A minimum of 10,560 gallons of water per minute will be required for the summer and fall operations of hatchery and rearing pond units of which not less than 960 g.p.m. shall be for the hatchery troughs, 2,400 g.p.m. for the 8 small rearing ponds, and 7,200 g.p.m. for the 8 large rearing ponds. The minimum winter water supply shall be 2,160 g.p.m. of which 960 g.p.m. shall be for the hatchery troughs, and 1,200 g.p.m. for the 4 winter rearing ponds. An additional 10 per cent of this total shall be available from underground water for increasing the natural stream temperatures. The main water supply shall be derived from the Entiat River by a gravity flow diversion. The screening and sedimentation facilities for the water supply will be the same at the Entiat, Methow and Wenatchee stations.

The feed preparation and storage facilities for the Entiat station will need to be half that of the Okanogan or Methow stations. The permanent residences, garage, general storage, etc., facilities shall be the same as at the Okanogan station. Because of the isolated position of the Entiat station, it will be necessary to provide living quarters for the temporary help.

All of the hatcheries including the Leavenworth station will require the usual standard operating equipment such as hatching baskets, riffle plates, perforated screens and pails, brushes, brooms, hose, rubber boots and aprons for personnel, allotted proportionately to each of the stations according to the size and capacity of same.

Drains from the rearing ponds at all stations should be located to afford the greatest efficiency in releasing fry directly from the ponds.

A pressure water supply should be provided at all hatchery stations for residential use, fire protection, sprinkling system and other miscellaneous purposes.

Adequate sewage disposal for all lavatory facilities should be provided. Water heating equipment should be provided at all intakes of the hatchery water supply division.

First and secondary road systems on the hatchery property should be provided. Primary roads should be oil construction (plant mixed type). All others should be gravelled. Fencing should be provided for the hatchery properties.

In addition to the principal buildings, water supplies and equipment heretofore designated, there shall be provided such other small buildings, equipment, fixtures, tools and general improvement of grounds as shall be shown in the development of the final plans to be essential and necessary.

Automatic alarm signals should be provided when practical for all pumping plants, water supplies, ground water pumping plants, central heating plants, and refrigerating plants. These signals should be duplicated in the hatchery office, in the hatchery building and in the hatchery foreman's residence.

Table 24. Daily Temperatures of Entiat, Methow and Okanogan River Drainage 1937

	Entiat		Twisp		South Fork of Methow		Chewack		Okanogan at Oroville	
	high	low	high	low	high	low	high	low	high	low
June 24							47.5	46.0		
25							51.5	44.5		
26							52.5	48.0		
27							56.0	48.5		
28							58.5	49.5		
29							56.0	52.0		
30							57.0	51.0		
July 1							56.5	50.0		
2							56.0	50.0		
3							59.0	49.0		
4							60.5	51.0		
5							58.5	50.5		
6							58.5	48.5		
7							60.0	49.0		
8			53.6				62.0	50.5		
9			53.0	47.7	53.0	47.2	62.0	51.0		
10			53.8	47.7	54.0	48.7	62.0	52.0		
11			54.5	48.6	55.0	49.1	62.5	53.0	73.4	71.6
12			53.8	49.1	52.5	49.6	59.5	54.4		
13			54.0	49.1	53.2	48.8	60.0	54.0	73.4	72.5
14			52.3	47.7	51.8	48.4	58.0	51.5	74.3	71.6
15	60.8		52.3	48.0	52.5	48.2	61.0	52.0	75.2	70.7
16	64.4	53.6	54.9	48.4	55.4	49.1	64.0	52.5	77.0	71.6
17	64.4	53.6	55.2	49.5	55.4	49.8	66.0	54.0	77.9	72.5
18	64.4	53.6	55.0	50.6	55.2	50.7	64.0	55.0	77.0	71.6
19	68.0	50.0	55.9	50.6	54.7	49.8	65.0	54.0	76.1	70.6
20	64.4	50.0	55.4	48.7	54.5	48.9	65.0	53.0	77.0	72.5
21	68.0	51.8	55.9	49.8	55.4	49.6	65.0	53.0	76.1	70.6
22	69.8	53.6	55.9	48.7	56.7	48.9	65.0	52.0	76.1	70.6
23	71.6	57.2	56.3	49.5	55.9	49.3	67.0	53.0	78.9	70.6
24	75.2	51.8	57.2	49.8	57.6	49.8	68.0	54.0	78.9	73.4
25	69.8	57.2	58.5	53.2	59.0	53.2	70.0	59.0	79.8	75.0
26	66.2	50.0	57.7	52.2	55.0	51.3	69.0	55.0	78.9	75.0
27	68.0	53.6	55.9	50.7	56.8	51.1	68.0	55.0	78.9	77.0
28	69.8	50.0	55.4	51.6	54.9	51.1	66.0	56.0	77.9	73.4
29	66.2	50.0	56.1	50.2	55.9	50.2	66.0	54.0	75.2	72.5
30	64.4	60.8	53.6	50.0	52.2	49.1	62.0	54.0	72.5	69.8
31		60.8	51.8	47.2	52.3	47.2	62.0	48.0		68.0
Aug. 1	64.4	60.8	51.8	46.4	52.5	48.0	56.0	50.5	71.6	68.9
2	66.2	50.0	54.3	47.1	55.0	48.2	61.0	48.0	72.5	69.8
3	68.0	51.8	55.4	48.2	56.1	48.2	64.0	50.0	73.4	69.8
4	68.0	51.8	56.1	48.9	57.4	49.3	65.0	51.5	73.4	69.8
5	64.4	48,2	54.5	51.4	54.7	51.6	61.0	55.0	71.6	68.9
6	66.2	50.0	54.5	50.6	54.1	49.6	62.0	54.0	71.6	68.0
7		48.2	54.7	49.3	56.3	48.7	64.0	56.5	71.6	68.0
8			53.2	50.0	53.4	50.2	60.0	52.0	71.6	68.0
9			54.5	48.7	55.9	49.1	63.0	51.0	73.4	68.9
10			54.1	50.6	55.0	50.4	60.0	53.0	73.4	69.8
11			57.0	50.7	58.6	50.5	68.0	54.0	73.4	69.8
12	64.4	48.2	57.2	50.9	59.5	50.7	67.0	54.0	74.3	73.4
13	62.6	48.2	53.6	51.3	54.1	50.6	67.0	56.0	73.4	71.6

Table 24 (Continued). Daily Temperatures of Entiat, Methow and Okanogan River Drainage 1937

	Entiat		Twisp		South Fork of Methow		Chewack		Okanogan at Oroville	
	high	low	high	low	high	low	high	low	high	low
Aug. 14	64.4	48.2	52.9	48.6	53.2	47.1	62.0	49.0	69.8	68.0
15	61.9	52.2	52.2	46.8	52.7	45.7	59.0	46.0	71.6	69.8
16	60.4	52.5	54.0	46.8	56.3	46.4	62.0	47.0	73.4	69.8
17	59.7	51.1	55.2	48.6	57.9	48.2	65.0	50.0	75.2	69.8
18	57.9	48.9	55.4	50.0	57.9	49.1	65.0	52.0	73.4	71.6
19	57.9	48.9	55.2	49.6	57.0	49.6	66.0	51.5	73.4	69.8
20	57.9	48.7	55.0	49.1	57.2	48.7	65.0	52.0	72.5	68.9
21	57.9	50.4	55.4	50.0	57.4	49.1	65.0	51.0		
22	54.0	48.9	51.6	49.8	52.0	48.2	55.0	52.0	68.0	67.1
23	54.7	48.4	52.3	48.0	53.6	47.6	61.0	50.5	67.1	65.3
24	54.3	48.2	51.4	46.8	53.2	47.6	57.0	46.0	67.1	66.2
25	55.8	48.7	53.2	47.2	56.1	48.2	60.0	48.0	67.1	64.4
26	54.0	49.1	52.7	47.1	54.3	47.1	61.0	47.0	66.2	64.4
27	53.2	47.1	51.8	47.7	52.5	46.0	60.0	46.5	66.2	64.4
28	53.2	46.0	52.2	45.9	54.5	46.4	56.0	45.0	66.2	64.4
29	53.4	46.2	52.5	46.0	54.5	52.5	59.0	44.5		
30	53.8	46.8	50.0	48.7	52.5	48.6	52.0	50.5		
31	54.7	47.4	50.4	48.2	52.3	47.7	57.0	50.0		
Sept. 1	55.0	49.6	53.4	48.6	58.6	47.4	62.0	50.0		
2	56.1	50.4	53.8	47.6	59.0	46.6	62.0	49.0		
3	57.9	48.9	54.0	48.2	60.1	47.4	63.0	50.0		
4	54.7	50.4	52.3	48.7	57.2	47.2	61.0	51.5		
5	55.8	48.6	50.7	50.6	57.2	53.1	60.0	55.0		
6	57.2	48.4	51.8	49.6	57.2	54.5	56.5	53.0		
7	57.6	49.3	52.7	47.7	56.1	47.1	59.0	49.0		
8	57.2	48.6	52.5	47.7	55.2	48.4	60.0	49.0		
9	55.8	46.8	52.7	47.4	53.8	47.7	60.0	49.0		
10	54.3	47.1	52.3	47.1	55.9	47.1	59.5	48.0		
11	55.8	48.9	52.7	47.1	56.8	47.4	60.0	48.0		
12	57.6	50.2	53.2	48.4	57.7	48.7	61.0	50.0		
13	54.0	48.4	52.7	47.7	59.0	52.2	60.5	49.5		
14	55.9	48.2	53.1	48.0	58.8	46.9	61.5	50.5		
15	57.2	50.2	53.4	48.0	59.0	47.1	61.0	50.5		
16	57.2	48.9	53.1	48.6	58.1	46.8	61.0	49.0		
17	50.6	50.0	51.4	48.2	54.7	51.1	57.0	52.0		
18	55.9	46.4	52.7	48.2	57.6	48.2	60.5	52.0		
19	56.1	47.4	52.3	48.0	57.2	48.4	60.5	50.0		
20	53.6	48.2	51.8	48.6	58.3	48.6	57.5	48.0		
21	52.5	47.4	50.9	47.6	57.4	48.0	57.0	48.5		
22	51.8	47.1	48.2	45.9	47.4	46.8	50.0	45.0		
23	48.2	42.8	45.2	44.2	50.0	40.3	47.5	41.0		
24	46.4	41.0	48.2	44.1	50.9	41.0	48.0	40.5		
25		41.0	48.9	45.9	50.2	45.1	52.0	44.5		
26	49.3	43.5	48.7	45.1	51.4	42.1	52.0	44.5		
27	48.2	42.8	48.9	45.0	53.6	41.5	52.5	44.0		
28	47.4	42.8	48.2	45.0	53.2	41.4				
29	46.4	41.0		45.1		41.0				
30	46.4	41.0								
Oct. 1	47.4	41.7								
2		41.0								

Table 25. Miscellaneous Temperatures in Okanogan Drainage, 1937.

Lake Tuglnuit

	July 14	Aug. 13	Aug. 28
Air temperature	82.4° F	87.0° F	74.0° F
Surface "	71.6	72.0	70.0
5 feet "	71.6	72.0	70.0
10 " "	71.6	71.0	70.0
15 " "		70.0	70.0
20 " "	66.2	67.0	68.0
25 " "	62.6	66.0	66.0
30 " "	62.6	65.0	66.0
35 " "		65.0	65.0

Copper Lake

	July 11
Air temperature	86.0° F
Surface "	71.6
5 feet "	69.8
9 " "	68.0
15 " "	68.0

Temperature in north end of lake at bottom	57.2° F

Table 26. Well Water Temperatures and pH on Southeast Side of Lake Osoyoos

August 27, 1937.

Property Owner	Depth	Temperature	pH
Corporon	15 ft.*	59° F	7.4
Puls	12 to 14 ft.*	57	7.3
Hill (house)	16 ft.	52	7.4
" (milk house)	12 ft.	53	7.3
" (by big tree)	15 ft.	54	7.4
Thrasher	14 ft.*	55	7.4
St. Hill	18 ft.*	59	7.4
Bartlow	20 ft.	55	7.4
Fisher	18 ft.*	59	7.6
Petry	30 ft.*	55	7.3
Irwin	27 ft.	53	7.4
Potter	10 ft.	60	7.2
Strikler	30 ft.	52	7.5
Conover	18 ft.	57*	7.35
Thompson[1]	5 ft.	60	7.3
Laramin[2]	5 ft.	61	7.2
Spencer	16 to 18 ft.	59*	7.3

[1] Thompson's well is located within 15 feet of the lake.

[2] This is also true of Laramin's well.

* Well sealed up: Temperature taken from water of pump: Depth according to report.

Table 27. Water Analyses of Well Water at Oroville and at Icicle Flats

Location	Date	Water Temp. °C	°F	Oxygen p.p.m.	CO_2 p.p.m.	Alkalinity p.p.m. of $CaCO_3$ M.O. (Methyl orange test)	phenol.	H_2S
Oroville Conover Well	10/19/37	13.2	55.7	2.3	5.0	277.0	0.0	0.0
Oroville Thompson Well	10/19/37	11.6	52.9	4.8	10.1	262.9	0.0	0.0
Oroville Fisher Well	10/19/37	12.8	55.0	8.5	4.5	399.4	0.0	0.0
Icicle Byron Well	10/20/37	12.5	54.5	6.2	14.6	53.7	0.0	0.0
Icicle Costello Well	10/20/37	12.3	54.1	8.2	9.7	50.3	0.0	0.0

Oxygen is undoubtedly somewhat high because the water is partially aerated in being pumped from the well.

Table 28. Chemical Analyses of Waters in Certain Portions of the Columbia River System, 1937.

Locations	Date August	Time	Water Temp. ° F.	pH	Oxygen p.p.m.	Carbon Dioxide p.p.m.	M. O. Alkalinity p.p.m.	$CaCO_3$ Phenol. Alkalinity (p.p.m.)	Air Temp. °F.	H_2S p.p.m.
Columbia River at Rock Island	3	10:20 a.m.	72.1	7.6	8.7	0.7	58.5	0.0	--	--
Methow at Bridge	7	2:00 p.m.	66.2	8.0	8.6	0.0	92.0	2.5	82.0	--
South Fork of Methow at Garman's Place	8	2:25 p.m.	59.0	7.7	8.7	0.25	45.0	0.0	--	--
Chewack Creek at Bridge	8	9:15 a.m.	52.3	7.6	9.3	0.5	29.0	0.0	60.8	--
Falls Creek at Road	8	10:05 a.m.	51.8	7.7	9.3	0.3	40.0	0.0	81.5	--
Twisp River at War Creek R.S.	7	5:15 p.m.	54.5	7.6	8.7	0.5	20.5	0.0	--	--
Okanogan River at Oroville below dam	15	3:15 p.m.	70.0	8.4	8.2	0.0	109.0	4.0	86.0	--
Okanogan R. about 3 mi. above L. Osoyoos	14	9:15 a.m.	64.9	8.0	7.8	0.2	111.5	0.0	59.9	--
Okanogan River about ½ mile above mouth	16	12:00 noon	68.0	8.2	8.1	0.0	109.5	3.8	77.0	--
Surface Lake Osoyoos	12	2:30 p.m.	71.1	8.4	7.7	0.1	107.5	0.0	--	--
Bottom (40 ft.) Lake Osoyoos	12	--		8.0	6.5	0.1	108.0	0.0	--	0.1
20 feet Lake Osoyoos	12	--	70.0	8.2	7.6	0.1	106.5	0.0	--	--
Lake Palmer--surface	14	3:00 p.m.	71.1	8.4	7.8	0.0	88.0	10.0	79.9	--
Lake Palmer--50 feet	14	--		7.4	2.7	2.0	90.0	0.0	--	0.0
Creek above Lake Palmer	14	5:30 p.m.	61.9	7.9	7.4	1.0	172.5	0.0	66.7	--
Creek below Lake Palmer at bridge	15	11:00 a.m.	68.0	8.5	7.4	0.0	91.5	7.5	68.0	--
Similkameen River below dam	12	10:00 a.m.	68.0	8.0	7.7	0.0	83.5	0.5	81.8	0.0
Similkameen River at Nighthawk	14	12:20 p.m.	65.8	8.2	7.9	0.1	82.5	0.0	72.7	0.0
Little Wenatchee River at Logging Bridge	17	6:20 p.m.	59.2	7.1	8.3	1.0	18.5	0.0	69.1	--
Lake Wenatchee shore near No. 1	17	10:30 a.m.	64.9	7.2	8.6	0.3	11.5	0.0	66.6	--
Lake Wenatchee Station No. 1--surface	17	11:00 a.m.	64.6	7.1	9.1	0.3	7.0	0.0	66.2	--
Lake Wenatchee Station No. 1--40 feet	17	--	58.5	7.1	8.2	0.5	10.5	0.0	--	--
Lake Wenatchee Station No. 1--100 feet	17	--	48.6	6.8	8.7	0.8	3.0	0.0	--	--
Wenatchee River ½ mile below L. Wenatchee	17	12:45 p.m.	65.5	7.1	8.3	0.4	9.5	0.0	69.4	0.0
Lake Wenatchee at Crescent B.	17	1:50 p.m.	70.0	7.1	7.8	0.5	11.0	0.0	65.8	--
Lake Wenatchee at Station No. 2--surface	17	2:30 p.m.	69.1	7.1	8.5	0.7	11.5	0.0	63.0	--
Lake Wenatchee at Station No. 2--100 ft.	17	--	53.2	6.8	8.9	1.0	10.0	0.0	--	0.0
Lake Wenatchee at Station No. 2--200 ft.	17	--	49.6	6.7	7.6	1.2	10.5	0.0	--	0.0
White River at second bridge	17	4:00 p.m.	55.9	6.9	8.7	1.0	11.0	0.0	69.4	--
Chiwawa Creek	17	7:30 p.m.	59.5	7.2	8.2	--	27.0	0.0	62.8	--
Nason Creek	17	9:15 a.m.	55.0	7.2	9.0	0.2	17.0	0.0	69.1	--
Wenatchee R. 100 ft. below suspension bridge	9	11:00 a.m.	--	7.5	8.9	0.3	15.5	0.0	--	--
Icicle Creek at Dude Brown's	9	12:20 p.m.	--	7.6	9.1	0.3	21.0	0.0	--	--
Wenatchee River at Enterprise	4	10:00 a.m.	67.1	7.6	9.0	0.2	[illegible]	0.0	--	--

Table 29. Miscellaneous Temperature Readings in Entiat & Methow Drainage in 1937

		Mouth of Entiat	Mouth of Methow	Methow at Bolinger Ditch	Mouth of Twisp	Methow above Winthrop	Chewack at Winthrop
June	24	50.0° F	52.7° F	50.9° F	49.6° F	52.3° F	50.9° F
	28	56.3					
July	1	52.3	56.3	54.5	51.8	55.4	57.2
	8	59.4	62.6	60.3	57.6	54.5	60.3
	9	59.0	63.5				
	15	60.8	63.5	60.8	55.9	57.4	59.9
	22	63.5	66.7	64.0	61.7	61.2	65.3
Aug.	1	58.8	61.2	58.8	57.0	55.8	58.6
	7		62.6	63.1	61.7	56.3	63.5
	22	61.3	63.5	58.8	63.0	54.5	59.0
	29	59.4	61.7	59.4	65.3	60.8	60.8
Sept.	5	60.8	61.7		56.3	53.6	56.7
	7				59.0		
	17		58.5		55.8	56.3	57.6
	22	57.7	57.2	55.4	55.8	53.1	53.6
	29	52.7	54.5	52.7	52.7	52.7	52.7
Oct.	2	48.6	49.1	49.1	48.2	50.9	47.2

Table 30. Temperatures in Lake Wenatchee, 1937

	August 29	September 6	September 9	November 23	December 4
Air Temperature	64° F	64° F	68° F	40° F	42° F
Surface "	61	61	62	46	46
5 feet "	61				
10 feet "	61	60	61		
15 feet "	60				
20 feet "	60	60	60		
25 feet "	60				
30 feet "	60	60	60		
35 feet "	60				
40 feet "	60	59	57		
60 feet "		58	57		
90 feet "		49	49	46	46
120 feet "		48	48		
180 feet " (bottom)		48	47		

MIGRATIONS OF YOUNG FISH

In order to find: 1. the age and size composition of the downstream migrants, 2. the natural rate of growth of the young salmon and steelhead, and 3. the period of downstream migration of the various species, numerous collections of young fish were made in the Wenatchee and Methow drainages. Unfortunately, the appropriation for biological investigations was not available until after the spring downstream migration was nearly over.

In the Wenatchee drainage the by-passes from the fish screens in the irrigation ditches were trapped. These traps, with the exception of a few days, were checked once daily throughout the season except during such periods (indicated in the tables) when the by-passes were closed down or the traps were flooded out by the spring high water. The number of fish, listed by species and weeks in which they were taken, are shown in Tables 31 to 39. The Icicle ditch is the large ditch from Icicle Creek referred to in the section on Recommendations for Holding Adult Fish. The Tandy, Union, Pioneer, Peshastin, and Gibbs ditches divert water from Peshastin Creek in that order, the Gibbs ditch being the one nearest the mouth. The Jones-Shotwell ditch diverts from the main Wenatchee a short distance above the town of Cashmere. The Gunn ditch also diverts from the main Wenatchee above the town of Monitor. The Icicle ditch diverts about 110 c.f.s., the Gibbs 10 to 20 c.f.s., Peshastin 40 to 55 c.f.s., Pioneer 5 to 8 c.f.s., Union 4 c.f.s., Tandy 20 to 25 c.f.s., Jones-Shotwell 25 c.f.s. and the Gunn ditch 40 c.f.s. It will be seen from the tables that a total of 5,424 fish were taken from these irrigation ditch by-passes alone during the season, of which 2,548 were steelhead and 333 chinook. It will be noted also that there was a definite downstream movement of chinook in the fall. The capture of this many fish from the irrigation ditches is remarkable because of the facts that the runs into the Wenatchee are in a serious state of depletion, the big ditch in the drainage (the Dryden ditch which diverts 1,350 c.f.s.) was not yet screened and so could not be trapped, and the large spring migration was well over before the work was started.

Collections were also made from the end of the Dryden Highline ditch near Rock Island. This was some 35 miles from the headworks of the ditch and of the 1,350 c.f.s. the ditch originally started with only about 10 c.f.s. were left, the rest having been used for power and irrigation. Only a very small portion of the fish that entered the ditch ever reached the collection place at Rock Island. Large numbers go into the numerous individual water boxes that divert from the main ditch. This was attested by finding fish in nearly every water box examined. The farmers depend somewhat upon the catches in their water boxes for fresh fish. One farmer questioned had removed 14 good-sized trout from his water box the previous morning.

Nevertheless, 991 salmonoid fish were taken from the screen at the end of this ditch, most of which were collected during the first two weeks. Of these, about one-half were blueback and one-quarter each chinook and steelhead. The measurements and ages of such as were collected fresh are shown in Tables 40 to 43.

Collections were also made in an irregular manner throughout August and September in irrigation ditches taking water from the Twisp and Methow rivers. The age, weight and lengths of these fish are shown in Tables 45 to 48. A fall downstream movement of salmon and steelhead is also shown in this drainage.

One collection of fish was made in the Yakima drainage on November 10, in the Selah-Naches irrigation ditch. The data on these fish are shown in Table 49.

Table 31. Catches of By-Passes on Various Ditches in the Wenatchee River Drainage from May 14 to October 2, 1937.

Ditch	White-fish	Steel-head	Chinook	Dolly Varden	Eastern Brook	Cut-throat	Sucker
Icicle		107	0	12	0	19	0
Gibbs		183	0	5	1	0	7
Peshastin		313	0	7	1	0	6
Pioneer		149	1	3	1	0	44
Union		261	0	5	0	0	1
Tandy		1431	0	11	0	0	0
Jones-Shotwell	35	48	37	0	0	1	294
Gunn	229	56	295	4	0	0	583
Season Totals	264	2548	333	47	3	20	935

Ditch	Sea-Run Lamprey	Cottus Beldingii	Cottus Rhotheus	Long-Nosed Dace	Shiner	Squawfish
Icicle	13	0	0	0	0	0
Gibbs	12	0	0	6	0	0
Peshastin	35	1	10	2	0	0
Pioneer	9	73	376	2	0	0
Union	4	1	6	0	0	0
Tandy	12	1	43	0	0	0
Jones-Shotwell	12	4	20	323	6	14
Gunn	16	1	6	66	87	113
Season Totals	113	81	461	399	93	127

Table 32. Catches of By-pass Trap on Icicle Ditch from May 15 to October 2, 1937

Week Ending		Steelhead	Dolly Varden	Lamprey	Cutthroat
May	15	1			
	22	By-pass closed			
	29	" "			
June	5	" "			
	12	" "			
	19	1			
	26	2	1		
July	3	5		3	
	10	9		7	
	17	5		3	1
	24	12			1
	31	5			5
Aug.	7	5	4		1
	14	2	2		7
	21	0	1		1
	28	9			2
Sept.	4	7	2		
	11	11	2		1
	18	3			
	25	10			
Oct.	2	21			
Season totals		107	12	13	19

Table 33. Catches of By-pass trap on the Tandy Ditch from May 22 to October 2, 1937

Week Ending		Steelhead	Dolly Varden	Sea-run Lamprey	Cottus rhotheus	Cottus beldingii
May	22	3	0	2	2	
	29	48	1	7	1	
June	5	0	0	0	0	
	12	6	0	0	0	
	19	10	0	0	36	
	26	3	0	1	0	1
July	3	4	0	0	0	0
	10	4	1	1	0	0
	17	21	0	0	2	0
	24	5	0	0	0	0
	31	2	0	0	0	0
Aug.	7	2		1		
	14	0	1			
	21	2	1			
	28	40				
Sept.	4	78				
	11	311	1		1	
	18	51			1	
	25	34				
Oct.	2	807	6			
Season totals		1431	11	12	43	1

Table 34. Catches of By-pass trap on Union Ditch from May 22 to September 18, 1937

Week Ending		Steelhead	Small scaled-sucker	Sea-run Lamprey	Cottus rhotheus	Cottus beldingii	Dolly Varden
May	22						
	29	1	0	1	0	0	0
June	5	0	0	0	0	0	0
	12	0	0	0	0	0	0
	19	5	0	0	2	0	1
	26	1	0	0	0	0	0
July	3	2	1	1	2	0	0
	10	2	0	1	2	0	0
	17	18	0	1	0	1	2
	24	1	0	0	0	0	1
	31	3	0	0	0	0	0
Aug.	7	Not visited					
	14	2	0	0	0	0	0
	21	8	0	0	0	0	1
	28	17	0	0	0		
Sept.	4	23	0	0	0		
	11	91	0	0	0		
	18	87	0	0	0		
Season totals		261	1	4	6	1	5

Table 35. Catches of By-pass Trap on Peshastin Ditch from May 15 to August 28, 1937

Week Ending		Steel-head	Dolly Varden	Eastern Brook	Suckers	Lamprey	Cottus rhotheus	Cottus beldingii	Longnosed dace
May	15	3	0	0	0	0	0	0	0
	22	9	0	1	0	0	0	0	0
	29	8	0	0	0	3	1	0	0
June	5	2	0	0	0	2	1	0	0
	12	11	0	0	0	2	0	0	0
	19	8	1	0	0	1	0	0	0
	26	3	0	0	0	0	1	0	0
July	3	10	0	0	1	0	0	0	2
	10	84	1	0	1	9	0	0	0
	17	80	1	0	4	8	2	0	0
	24	17	0	0	0	3	2	0	0
	31	15	0	0	0	1	0	1	0
Aug.	7	20	1	0	0	6	0	0	0
	14	2	0	0	0	0	0	0	0
	21	25	2	0	0	0	3	0	0
	28	16	0	0	0	0	0	0	0
Season totals		313	6	1	6	35	10	1	2

Table 36. Catches of By-pass Trap on Pioneer Ditch from May 22 to August 28,1937

Week Ending	Chi-nook	Steel-head	Dolly Varden	Eastern Brook	Small Scaled Suckers	Lamprey	Cottus rhoth-eus	Cottus beld-ingii	Large scaled suckers	Long-nosed dace
May 22		21	0	1	0	1	0	0		
29		6	0	0	1	4	0	0		
June 5		4	1	0	2	1	0	0	12	
12		5	0	0	4	0	0	0		
19		9	0	0	0	0	0	0		
26		2	0	0	0	0	0	0		
July 3		6	0	0	19	0	0	0		
10		31	0	0	6	0	0	1		
17		36	1	0	0	1	2	0		
24		3	1	0	0	1	11	9		
31		3	0	0	0	1	32	12		1
Aug. 7		6	0	0	0	0	224	31		1
14		12	0	0	0	0	93	17		
21	1	5	0	0	0	0	6	3		
28		0	0	0	0	0	8	0		
Season totals	1	149	3	1	32	9	376	73	12	2

Table 37. Catches of By-pass Trap on Gibbs Ditch from May 22 to July 24, 1937.

Week Ending	Steelhead	Dolly Varden	Lamprey	Longnosed Dace	Small scaled sucker	Eastern Brook
May 22	5					
29	12		1	2		
June 5	9	1	7		1	
12	12					
19	25	1				
26	4					
July 3	39			4		1
10	42		3		2	
17	33	1			2	
24	2	2	1		2	
Season totals	183	5	12	6	7	1

Table 38. Catches of By-pass Trap on the Jones-Shotwell Ditch from May 22 to October 2, 1937

Week Ending		Steel-head	Chi-nook	Cut-throat	White-fish	Small Scaled Sucker	Long-nosed Dace	Squaw-fish	Cottus rhoth-eus	Cottus beld-ingii	Sea-run lamprey	Shiner
May	22	3				8	2	1				
	29	1				16	2					
June	5	1				12	2		1		1	
	12	1				5	14		2		1	
	19	1				5	14		2	1		
	26	0				5	1				1	
July	3	12				18	10	1			4	
	10	7			1	6	16	1			4	
	17	5		1	1	5	0	4	2		1	
	24	3			0	1	1			1		1
	31	2			1	1	4		2	1		
Aug.	7	0	4		0	3	58					
	14	0	2		1	49	44		1			
	21	0	1		3	49	35					
	28	0	2		0	15	23		7	1		1
Sept.	4	11	26		18	73	18	4	3			1
	11	0	1		2	17	13					
	18	1	0		3	5	5					
	25	0	1		3	1	12					2
Oct.	2	0	0		2	0	49	3				1
Season totals		48	37	1	35	294	323	14	20	4	12	6

Table 39. Catches of By-pass Trap on Gunn Ditch from May 22 to October 2, 1937

Week Ending		Chi-nook	Steel-head	Dolly Varden	White-fish	Small Scaled Sucker	Large Scaled Sucker	Sea-run Lamprey	Long-nosed Dace	Squaw-fish	Cottus rhoth-eus	Chisel-mouth chub	Shiner
May	22	0	1	0	0	11	0	0	3	2	1		0
	29	0	8	1	2	88	0	0	5	1	0		6
June	5	0	0	0	1	14	2	3	0	1	1	3	3
	12	0	0	0	0	0	0	0	0	0	0		
	19	0	0	0	0	0	0	0	0	0	0		
	26	0	0	0	0	0	0	0	0	0	0		
July	3	0	2	1	1	50	3	0	0	0	0		
	10	0	0	0	0	21		6	1	1	0		
	17	1	1	1	2	13		7	1	12	1		7
	24	5	2	0	3	14		0	0	3	0		8
	31	15	5	0	13	77		0	11	1	2		3
Aug.	7	18	26	0	0	74		0	10	0	0		
	14	2	0	1	3	18		0	1	2	0		
	21	2	1		1	33		0	1	13	1		
	28	0	0		0	1		0	0	1	0		
Sept.	4	0	0		0	1		0	1	0	0		
	11	0	0		0	0		0	0	0	0		
	18	5	0		14	66		0	0	42	0	19	
	25	232	8		173	76		0	10	22	0	8	66
Oct.	2	15	2		16	21		0	16	12	0		
Season totals		295	56	4	229	578	5	16	60	113	6	30	93

Table 40. Wenatchee River Drainage - Dryden Ditch Blueback Downstream Migrants.

Date	"1" Year Class			
	Number of Specimens	Total Length Inches	Standard Length Inches	Weight in Ounces
June 10 - 20	13	4.4	4.0	
June 11 to July 7	57		4.0	
August 18	2	6.4	5.5	1.00
September 28	1	6.1	5.3	.60
October 4				
Weighted Average	73	4.7	4.0	.86
Percentage		59.4		

Date	"2" Year Class			
	Number of Specimens	Total Length Inches	Standard Length Inches	Weight in Ounces
June 10 - 20	11	6.7	5.7	
June 11 to July 7	28		5.8	
August 18	5	6.8	5.8	1.12
September 28	2	6.7	5.8	1.19
October 4	4	7.2	6.2	
Weighted Average	50	6.8	5.8	1.14
Percentage		40.6		

Table 41. Wenatchee River Drainage - Dryden Ditch <u>Chinook</u> Downstream Migrants.

Date	"0" Year Class Number of Spec.	Percent-age	Total Length Inches	Standard Length Inches	"1" Year Class Number of Spec.	Percent-age	Total Length Inches	Standard Length Inches
June 10-20					12	92	5.5	4.7
June 11 - July 17					40	98		5.0
October 4	6	60	4.5	3.7	4	40	6.1	5.3
Weighted Average	6	9	4.3	3.7	56	87	5.6	4.8
Percentage		9.4				87.5		

Date	"2" Year Class Number of Spec.	Percent-age	Total Length Inches	Standard Length Inches
June 10-20	1	8	7.1	6.0
June 11 - July 17	1	2		5.3
October 4				
Weighted Average	2	3	7.1	5.6
Percentage		3.1		

Table 42. Wenatchee River Drainage - Dryden Ditch Steelhead
Downstream Migrants

Date	"0" Year Class		"1" Year Class		
	Number of Specimens	Standard Length Inches	Number of Specimens	Total Length Inches	Standard Length Inches
June 11			5	7.3	6.4
June 11 - 16	1	6.1	12		6.3
June 17 - July 8	2	6.3	5		6.5
Weighted Average	3	6.2	22	7.3	6.3
Percentage	10		73.3		

Date	"2" Year Class		
	Number of Specimens	Total Length Inches	Standard Length Inches
June 11	2	8.5	7.5
June 11 - 16	2		7.6
June 17 - July 8	1		6.9
Weighted Average	5	8.5	7.4
Percentage	16.7		

Table 43. Wenatchee River <u>Chinook</u> Downstream Migrants Combined (Except Dryden Ditch).

Date and Ditch	"0" Year Class				
	Number of Specimens	Percentage	Total Length Inches	Standard Length Inches	Weight in Ounces
Rock Island - June 21	3	100	2.0	1.7	.05
Gunn - July 17 - 27	13	100	2.9	2.5	.16
Shotwell - July 29 - Aug. 6	3	100	2.7	2.3	.15
Shotwell - Aug. 3 - 6	14	100	2.9	2.5	.18
Gunn - Aug. 11 - 19	6	100	3.2	2.7	.21
Shotwell - Aug. 17 - 19	4	100	4.0	3.4	
Shotwell - Sept. 1 - 6	21	100	3.4	2.9	.26
Shotwell - Sept. 6	3	100	3.9	3.3	
Gunn - Sept. 20	27	100	4.0	3.4	.38
Gunn - Sept. 22	72	98.7	4.0	3.3	.33
Gunn - Sept. 23	28	100	4.0	3.4	.35
Gunn - Sept. 24	32	100	4.0	3.4	.34
Weighted Average	227	99.6	3.7	3.1	.33

Date and Ditch	"1" Year Class				
	Number of Specimens	Percentage	Total Length Inches	Standard Length Inches	Weight in Ounces
Rock Island - June 21					
Gunn - July 17 - 27					
Shotwell - July 29 - Aug. 6					
Shotwell - Aug. 3 - 6					
Gunn - Aug. 11 - 19					
Shotwell - Aug. 17 - 29					
Shotwell - Sept. 1 - 6					
Shotwell - Sept. 6					
Gunn - Sept. 20					
Gunn - Sept. 22	1	1.3	5.5	4.7	1.09
Gunn - Sept. 23					
Gunn - Sept. 24					
Weighted Average	1	.4	5.5	4.7	1.09

Table 44. Wenatchee River Steelhead Downstream Migrants (Except Dryden Ditch).

Date & Ditch	"1" Year Class Number of Spec.	Total Length Inches	Standard Length Inches	Weight in Ounces	"2" Year Class Number of Spec.	Total Length Inches	Standard Length Inches	Weight in Ounces
Gunn Ditch								
July 18	1	5.6	4.9	1.08				
July 20	1	5.1	4.6	.88				
August 19	1	5.1	4.4	.65	1	5.8	5.2	1.20
Weighted Average	3	5.2	4.6	.87	1	5.8	5.2	1.20
Shotwell Ditch								
June 15					1	5.5	4.9	1.10
July 15	2	5.4	4.8	.94				
July 17	1	4.5	4.0					
July 27	1	4.9	4.2	.69				
September 1	3	5.1	4.5	.87	3	5.9	5.2	1.34
Weighted Average	7	5.1	4.5	.87	4	5.8	5.1	1.27
Gunn and Shotwell Ditches Combined								
Weighted Average	10	5.1	4.5	.87	5	5.8	5.1	1.25
Percentage			62.5			30.8		

Date & Ditch	"3" Year Class Number of Spec.	Total Length Inches	Standard Length Inches	Weight in Ounces
Shotwell Ditch				
September 1	1	7.9	6.9	2.52
Weighted Average	1	7.9	6.9	2.52
Gunn and Shotwell Ditches Combined				
Weighted Average	1	7.9	6.9	2.52
Percentage		6.7		

Table 45. Methow River <u>Chinook</u> - Downstream Migrants

Date	"0" Year Class Number of Spec.	Percentage	Total Length Inches	Standard Length Inches	Weight in Ounces
Aug. 15	2	100	4.1	3.6	.38
Sept. 19	5	100	4.0	3.4	.33
Sept. 29	11	92	4.1	3.7	.44
Weighted Average	18	95	4.1	3.7	.41
		"1" Year Class			
Aug. 15					
Sept. 19					
Sept. 29	1	8	4.7	3.9	.61
Weighted Average	1	5	4.7	3.9	.61

Table 46. Twisp River <u>Chinook</u> - Downstream Migrants

Date	"0" Year Class Number of Spec.	Percentage	Total Length Inches	Standard Length Inches	Weight in Ounces
Aug. 7	5	100	2.7	2.3	.13
Aug. 15	18	90	3.9	3.3	.36
Aug. 23	8	84	4.0	3.4	.39
Sept. 5 - 19	5	76	4.0	3.4	.39
Weighted Average	36	88	3.8	3.2	.38
		"1" Year Class			
Aug. 7					
Aug. 15	2	10	4.7	4.1	.72
Aug. 23	1	16	5.3	4.5	.82
Sept. 5 - 19	2	24	4.8	4.1	.66
Weighted Average	5	12	4.9	4.2	.71
		Methow and Twisp Rivers Combined - "0" Year Class			
Weighted Average	54	90	3.9	3.4	.39
		"1" Year Class			
Weighted Average	6	10	4.8	4.1	.69

Table 47. Twisp River Steelhead - Downstream Migrants.

Date	Number of Spec.	Total Length Inches	Standard Length Inches	Weight in Ounces
		"0" Year Class		
Aug. 7	12	1.1	1	.08
Aug. 14				
Aug. 23				
Sept. 5				
Sept. 19				
Sept. 29				
Weighted Average	12	1.1	1	.08
Percentage		40		
		"1" Year Class		
Aug. 7				
Aug. 14				
Aug. 23	6	4.9	4.3	.72
Sept. 5	1	5.6	4.9	1.04
Sept. 19	7	6.1	5.2	1.40
Sept. 29	1	5.7	5.0	1.07
Weighted Average	15	5.6	4.8	1.07
Percentage		50		
		"2" Year Class		
Aug. 7				
Aug. 14	2	6.6	5.9	1.90
Aug. 23				
Sept. 5	1	6.3	5.6	1.51
Sept. 19				
Sept. 29				
Weighted Average	3	6.5	5.8	1.77
Percentage		10		

Table 48. Methow River Steelhead - Downstream Migrants.

Date	"0" Year Class			
	Number of Specimens	Total Length Inches	Standard Length Inches	Weight in Ounces
Aug. 7	7	1.4	1.2	.022
Aug. 8	13	1.3	1.1	.014
Sept. 15				
Sept. 19	63	3.3	2.9	.22
Sept. 29	50	3.7	3.1	.27
Weighted Average	133	3.1	2.7	.21
Percentage		96.5		
	"1" Year Class			
Aug. 7				
Aug. 8				
Sept. 15	1	7.4	6.7	2.32
Sept. 19	3	6.9	6.1	1.95
Sept. 29				
Weighted Average	4	7.1	6.2	2.07
Percentage		2.6		
	"2" Year Class			
Aug. 7				
Aug. 8				
Sept. 15	1	7.3	6.6	2.25
Sept. 19				
Sept. 29				
Weighted Average	1	7.3	6.6	2.25
Percentage		.9		
	Methow and Twisp Rivers Combined			
Weighted Average "0" Year Class	145	3.0	2.5	1.9
Percentage		86.3		
Weighted Average "1" Year Class	19	5.6	5.1	1.29
Percentage		11.3		
Weighted Average "2" Year Class	4	6.7	6.0	1.89
Percentage		2.4		

Table 49. Yakima Drainage Downstream Migrants - Selah-Naches Ditch, November 10, 1937.

	Number of Specimens	Total Length Inches	Standard Length Inches	Weight in Ounces
Chinook	282	4.4	3.8	.45
Steelhead	23	3.4	3.0	.26

RECOMMENDATIONS FOR PLANTING OF YOUNG FISH

The exact places and time for planting young fish shall be contingent upon the seasonal biological and physical conditions in the stream. It is proposed in general, however, that: 1. About 80 per cent of the blueback and chinook be planted in the early summer following hatching (June and the first part of July) before the high summer temperature is reached in the rivers and lakes. 2. The remaining 20 per cent of blueback and chinook shall be reared through the summer and of these about 90 per cent, or 5.3 million, will be planted in the fall after the fall of the high summer temperatures and before the winter freeze-up. 3. The remaining 10 per cent of the blueback and chinook of those reared until fall, about 660,000, shall be reared over winter and planted in the spring at a time to coincide with the normal spring migrations. 4. All the steelhead shall be reared through the first summer and about 90 per cent of them shall be planted at the time of the fall planting of blueback and chinook. 5. About 10 per cent of the steelhead shall be reared over the winter and planted at the time the held-over blueback and chinook are.

Both the two 2,000 gallon and the three 1,000 gallon tank trucks recommended for hauling adult fish shall be so designed as to be suitable for fry planting. In addition, another similar 1,000 gallon tank truck will be needed for the planting of the young fish.

MISCELLANEOUS RECOMMENDATIONS

It is recommended that the following motive equipment be provided:

Four light utility trucks for handling feed, ground work, etc., one to be placed at each station.

Two tank trucks, each of 2,000 gallon capacity, for transportation of adult fish from Rock Island to Icicle Creek.

Four tank trucks, each of 1,000 gallon capacity, for transportation of adult fish and fry planting.

Dump truck to be stationed at the Wenatchee station for general ground maintenance.

Two five-ton transport trucks for delivering supplies of fish food to the sub-stations, hauling of eyed eggs, and collection of food materials for processing. One of these should be equipped with detachable snow plow.

Pick-up truck for a shop service car at the Wenatchee station.

Light truck for stream rehabilitation work.

Two light panel delivery trucks, one for the general superintendent and one for the biologist.

Equipment for making minor road repairs.

The recommendations in this report have been based on a probable maximum number of fish coming up to Rock Island Dam. Within this limit the recommendations have been made as conservative as it is thought was practical. When the propagation plant is actually put into operation it will undoubtedly be found that minor changes may be necessary and that additions at some points will be called for. For instance, if after the passage of one cycle it becomes possible to abandon the trapping and hauling at Rock Island, it will be necessary to provide for spawn-taking facilities at each of the sub-stations. The change in operations at that time will very likely necessitate numerous minor changes which at this time cannot be foreseen. It is recommended, therefore, that a contingency capital outlay fund be made available for such changes as are found necessary after egg taking begins.

STREAM REHABILITATION OF THE LOWER TRIBUTARIES

The present plan of preserving the salmon and steelhead runs of the upper Columbia calls for the substitution of the relatively small spawning areas of the Okanogan, Methow, Entiat and Wenatchee river systems for the San Poil, Spokane, Kettle, Colville, Clark Fork rivers and numerous smaller creeks in the United States and the vast drainage system of the Columbia in southeastern British Columbia including particularly Upper and Lower Arrow Lakes and Slocan Lake. Through the courtesy of the U. S. Bureau of Fisheries, the following table of lineal miles of spawning streams is shown.

Table 50. Lineal Miles of Spawning Tributaries, Upper Columbia Watershed.

Name of Stream	Miles
Columbia River - Rock Island to Grand Coulee Dam	120.0
Wenatchee River and tributaries	241.0
Entiat River	66.6
Methow River	167.9
Okanogan River	81.1
	676.6
Grand Coulee Dam to British Columbia Boundary	
Tributaries - Grand Coulee to Boundary	137.0
Columbia River from Grand Coulee to Boundary	142.0
	279.0
British Columbia Boundary to Columbia Lake, B. C.	
Tributaries - Boundary to Columbia Lake	400.0
Columbia River from Boundary to Columbia Lake	461.0
	861.0

Thus it is proposed to transplant the fish runs frequenting 1,140 lineal miles of stream to tributary systems totaling only 677 lineal miles which already supported runs of these same species of fish. The successful operation of such a plan would demand that these four lower tributaries be in the best possible condition for the reproduction of salmon. Such is not the case at present.

Dams form hindrances and barriers, large diversions dry up sections of the rivers during the migration period, all blocking the migration of the fish to and from the spawning beds. Water diversions occur by the dozen on these streams, each diverting its share of the young downstream migrants as well as water. A total of 73 diversions on these systems divert 3,764 second feet of water. This does not include the diversions from the Similkameen in Canada, the power diversion on the Similkameen that takes the main flow of the river, the irrigation diversions from Sinlahekin Creek (tributary to Palmer Lake on the Similkameen), the complete diversion of Salmon Creek on the Okanogan, the diversions on the Okanogan above Lake Osoyoos, nor the numerous pumping diversions on many of the streams. It includes only the larger gravity diversions in the present area frequented by migrating fish which are in most immediate need of screening. Nevertheless, the amount of water diverted by them (circa 3,764 second feet) is nearly as great as the average mean flow of the Wenatchee, Entiat and Methow rivers (circa 3,847 second feet). The power diversions destroy fish life by diversion through turbines. There are three power developments on the Wenatchee that divert 1,675 second feet. The remaining 2,081 second feet of the above total is now used for irrigation. This creates a double hazard to the fish. The thousands of young fish diverted are practically all lost since those that do not go out onto the fields are killed when the ditch is dried up in the fall. Also, the diversion of this quantity of water actually renders some of the streams (particularly the tributaries of the Methow) unfit for the upstream migration of the adults in the fall, as well as strongly decreasing the feeding and shelter area for the young fish.

To the most casual observer it is an increasing source of wonder that any adult salmon are able to reach the spawning grounds and, once reached, that enough of the small salmon are able to return to the sea to maintain a run of any size. As a matter of fact, the salmon runs into these streams are at present in an extreme state of depletion. Irrigation and water power developments are the two principal causes. Mining and domestic pollution are not yet important factors, but are potentially so.

Okanogan Drainage

The Okanogan River from its junction with the Columbia River near Brewster, Washington, to its confluence with the Similkameen is a sluggish, slow-moving stream. As a consequence of this, there are no open ditch diversions for irrigation and no dams. The only water taken from the stream in this area is pumped for irrigation. The same characteristic, however, leaves but few spawning riffles. Salmon Creek, the only tributary along this stretch of the river that ever supported an important run of salmon, is so essential to the irrigation system of the valley that its rehabilitation for salmon reproduction is impossible.

At Oroville there is a small dam provided with inefficient fish ladders which retards the speed of migration of salmon and trout into Osoyoos Lake. Having passed this point, it would appear that the fish had access to a series of lakes (Osoyoos, Vaseaux, Skaha and Okanogan) extending far up into British Columbia. Such is not the case. Four miles upstream from Oliver, B.C., and about 23 miles from the border is a dam about six feet high provided with a long concrete apron which forms an impassable barrier to salmon. It is provided with a fish ladder, but the ladder is kept closed by the Provincial authorities to prevent the upstream migration of scrapfish. Thus, the salmon are restricted to this small sector of the river in which there is 20 miles of suitable spawning area for the blueback. In this section also are two unscreened water diversions. The above mentioned dam is for a large water diversion (maximum 180 second feet, average 145 second feet) which is unscreened.

Similkameen River

The Similkameen River, though listed as a triburary of the Okanogan, is considerably larger than the latter. Most of it lies in Canada. Six miles from the river's confluence with the Okanogan River is a power dam 65 feet high owned by the Washington Water Power Company that has never been equipped with a fishway. A few miles above this dam lies the unscreened intake to the Oroville-Tonasket Irrigation Company water diversion carrying a maximum capacity of 180 second feet. Above these points and extending a few miles beyond Keremeos, B.C., are mile after mile of good spawning riffles. Also in this area and lying within the borders of the State of Washington is Palmer Lake (Figure 3; Table 51) that is well adapted to the production of blueback. Thus, salmon and steelhead are restricted to the first six miles of this fine stream and because of the character of the stream in this section, nearly all the available spawning area is limited to the first two miles above its confluence with the Okanogan. The tributaries to Palmer Lake are utilized for irrigation and there are certain existing rights for irrigation storage in Palmer Lake itself.

A further factor of undetermined magnitude is the mining pollution. At and near Hedley, B.C., (about 40 miles from the border) are three large gold mines which employ the cyanide method in treating their ore. Since cyanide in very small concentrations is lethal to salmonoid fishes, and since there is at least a small amount of this deposited in the river by the mills, a thoroughgoing investigation of the extent of this pollution will be necessary before attempting to restock this stream.

Methow Drainage

The present condition of the runs into the Methow River probably still dates from a power dam which was placed near the mouth of the river at Pateros in 1915 and irrigation diversions developed years ago. The power dam has been long since removed (1929), but in its day it acted as a barrier to upstream migration of salmon and steelhead, a condition that was only partially compensated for by hatchery operations at that point. A good run of silver salmon, which was the species propagated by the hatchery formerly located at Twisp but since abandoned, has, from all information available, completely disappeared.

Table 51. Temperatures in Palmer Lake, 1937.

	June 28, 1937		July 29, 1937	Aug. 5 1937	Aug. 11 1937	Aug. 18 1937	Aug. 27, 1937
Air	82° F.	Air	80° F.	83° F.	87° F.	88° F.	68° F.
Surface	72	Surface	75	71	72	71	70
6'	61	10'	72	71	71	70	68
15'	61	20'	62	68	68	64	64
20'	61	30'	54	68	58	58	56
25'	59	40'	49	53	50	50	55
30'	58	50'	49	49	50	50	52
35'	57	60'	48	48	49	49	48
40'	52	70'	46	48	48	48	48
60'	48	80'	46	48	48	48	48
62'	47	90'	46	46	48	48	47
80'	46						
91'	46						

Since the removal of the dam near Pateros, the Methow drainage has been mainly featured by low dams for irrigation diversions. These do not interfere to any great extent with the migration of the steelhead and spring chinook since these fish migrate in the spring when there is an abundance of water in the river. The introduction of more fall migrating fish into this system will create additional difficulties in passing these upstream migrants over the low present dams and yearly created wing dams for irrigation diversions which become barriers at the low flow period.

There are 5 permanent dams in the system at present. All other diversions utilize seasonally constructed wing dams. The dam of the Parkinson Ditch, at the mouth of Libby Creek across the main Methow, is a serious barrier at most water stages. It raises the water level from 4 to 6 feet and is provided with a wooden apron from 10 to 12 feet long. Between Twisp and Winthrop is the newly built dam of the Barclay Ditch Company. On Chewack Creek, about 1 mile upstream from Winthrop, is a permanent irrigation diversion dam for the Fulton ditch.

The remaining permanent dams are on the South Fork, one 7 miles upstream from Winthrop which does not create as difficult a barrier except when the river is low and splashboards are put on. The upper Methow Valley Power and Light Company maintains a dam a short distance from the confluence of the South Fork with the Chewack Fork which is a barrier at low flows. The Chewack Fork is nearly dried by irrigation for a short distance below the Chewack ditch district diversion and is again depleted by the diversion of the Fulton ditch near Winthrop. This condition does not occur each year to the same degree and only for the latter part of the irrigation season. Such conditions would mainly affect the transplanted fall migrants.

The South Fork is seriously depleted of water by the power diversion mentioned above and would in dry years create a complete block to the fall upstream migrants by creating nearly a mile of dry stream bed. The main Methow between Winthrop and Twisp is almost depleted of water by the Methow Valley Irrigation District Canal diversion. A semi-permanent dam is maintained by the district at this point.

The Twisp River enters the Methow River at the town of Twisp. Besides four of the temporary dams, which are put clear across the river in the late summer and fall, the stream suffers in dry years from having all the water taken for irrigation so that the channel is dry at the mouth and below the Methow Irrigation Canal intake. In such years an upstream migration of adult salmon to the spawning grounds is, of course, impossible. Even in years of excess precipitation like 1937, there was a section of the river for about one-half mile below the temporary dam of the Methow Valley Irrigation Company's Twisp ditch so low that a chinook could not swim through it without being partly, and at some places mostly, out of water. Having negotiated this bare spot, the fish would then be under the necessity of jumping out of the shallow water over the above mentioned dam. Nevertheless, the results of the examination of the irrigation canals for small chinook, the finding of young chinook rather abundantly in the stream, and a record of finding adult chinook farther up the river show this stream to be still a definite producer of chinook and steelhead.

The Methow River system has a particularly large number of irrigation diversions. Of those diverting 4 second feet or more there are 46 having a total capacity of 840 second feet (more than 2/3 the 1,117 second feet average mean flow of the Methow). On the main river there are 12 ditches with a total capacity of 247 second feet located along the 46 miles between Winthrop and Pateros at the mouth. On the Chewack there are 8 ditches that divert 158 second feet. On the South Fork there are 11 ditches that divert 290 second feet. And on the Twisp 15 ditches divert 145 second feet. These figures do not include such smaller tributaries of the main river as Libby Creek which are entirely diverted for irrigation. The extension of wing dams clear across the river during the late summer and fall low period is particularly pernicious in that it not only hinders the upstream migration of the adults but also creates a perfect lead for diverting the downstream migrants into the ditches.

Entiat Drainage

The Entiat River is an excellent salmon stream. There is ample spawning area, irrigation does not dry the stream, the water does not become excessively warm in the summer, there is a minimum of pollution, and from the limited examination made, the food supply is adequate. Yet to the best of our knowledge there is no chinook or silver salmon run left in the river. If any fish came in this fall, they were very few in number and none were seen, although careful search was made.

The reason for the lack of salmon dates back a number of years to the construction of a power dam near the mouth which did not permit the passage of any fish to the spawning grounds. This dam is now removed. At present, there are three permanent dams operating in the stream. An old mill pond dam whose superstructure was removed some years ago is a partial barrier at extreme low water stages. The only other block to migration the year around is the fact that in the fall the power diversion at the lower end of the stream creates a partial dry area of approximately a mile in the stream bed. The Harris mill pond dam has a fish ladder built for passage of small fish. Because of the method of construction and the fact that this dam has been reconstructed twice and the methods of regulation changed, the fishway system is ineffective.

There are 8 water diversions on the Entiat which divert a total of 367 second feet of water.

Wenatchee Drainage

The Wenatchee River would appear to be potentially the most productive of the lower tributaries, especially since it has a blueback lake (Lake Wenatchee) (Figure 1, Table 30) and its numerous tributaries (Mission, Peshastin, Icicle, Chiwaukum, Chumstick, and Nason creeks, and the Little Wenatchee, White and Chiwawa rivers) all afford excellent spawning grounds. One reason why it does not produce the quantity of fish it is reported to have done in the past is evident from reference to the results of the trapping of the by-passes from screens in water diversions this season (see section on Migration of Young). In this drainage are 28 diversions taking a total of circa 2,300 second feet (more than the 2,225 second feet average mean flow of the Wenatchee at Plain). Of this total 1,675 second feet are taken for water power development and 625 for irrigation. From 30 to 35 years this widespread system of diversions has acted as a drain upon the fish stock. The figures collected this season should be considered in the light of having come from an already heavily depleted stream.

The most immediate problems regarding fish migrations on the Wenatchee River are the Dryden diversion and the Tumwater dam. The Dryden diversion takes water both for irrigation and the generation of electricity. The ditch has a maximum carrying capacity of 1,300 second feet; 200 second feet of this is reserved for irrigation. All the surplus above this figure is used for power. The Wenatchee River has reached a low of 250 second feet and quite commonly flows less than 500 second feet in August and September as well as in the winter months. The result is that from the latter part of August and September, when the blueback are running, a stretch of river about 2 miles long (from the Dryden Dam to the tailrace of the power plant) does not have sufficient water left in it to permit the adequate migration of fish. The only water coming down is that leaking through the dam and that coming through the two fish ladders. The river level drops so low that at times no water flows through one of the fish ladders. Consequently, the fish are sometimes delayed below the tailrace of the power house. This is, naturally, a condition which must be corrected if the Wenatchee River is to produce fall migrating chinook, blueback and steelhead, for practically all the spawning ground in the drainage is upstream from this point.

At the Tumwater Dam in Tumwater Canyon upstream from Leavenworth, somewhat similar conditions exist. The power house there is located about 1 mile below the dam. When the water level is low, not much of the river is left in its original bed between the dam and the tailrace of the power plant.

The reason why the fish must get over Tumwater Dam is easily seen in a glance at a map. Above it lie Lake Wenatchee, Chiwaukum Creek, Nason Creek, the Little Wenatchee, White and Chiwawa rivers, the bulk of the spawning grounds in the drainage and the only rearing area for the young blueback. Thus, the spawn of those blueback not getting up to Lake Wenatchee is apparently lost.

Conclusions

The introduction in the lower tributaries of the late summer adult migrating chinook, steelhead, and blueback in large numbers creates some conflict with the present use of water which is not serious as far as the spring adult migrants are concerned. As long as the fish are to be trapped at Rock Island, the problems of upstream migrants do not complicate the proposed present methods of preserving the upper Columbia River salmon and steelhead. However, when the trapping ceases so the fish may be free to ascend on their own power, the conflicts with dams and diversions become acute and must be taken care of. Unless these conflicts can be adjusted, the trapping at Rock Island would necessarily have to continue indefinitely.

The present plan of planting fingerling fish does create an immediate conflict in that all ditches must be screened at all times and sufficient water left at proper temperatures to permit a downstream movement at all times. In general, there is sufficient water in most tributary streams as well as the main channels to permit the passage of the downstream spring migrants. This does not hold true for the fall downstream movement in certain tributaries of the Methow and Wenatchee. Unless these conflicts can be adjusted, such tributaries could not be used. Except for Peshastin Creek and Mission Creek in the Wenatchee drainage and the Twisp River in the Methow drainage, adjustments for the downstream migrants in the fall should not be difficult.

Minor improvements in the river channels of the Wenatchee, Entiat and the main channel on the Chewack Fork of the Methow will solve the downstream problems, particularly if the upstream problems are satisfactorily adjusted as far as flow is concerned. Channel improvement work and certain flow right adjustments in the Peshastin Creek, Mission Creek and the Twisp River will be necessary if these 5 tributaries are to be used. The Twisp is an especially desirable chinook and steelhead stream and should be improved so that it can be used. To do this will require annual channel improvement work through the short area of practically dry stream bed and some adjustment as to flow rights at these two points.

The problems of flow in the Peshastin and Mission creeks may be alleviated by the exchange of water at the head of the Icicle ditch. If this should be found impractical, channel improvement with adjustment in flow rights must be made to utilize these streams.

The problems at the mouth of the South Fork of the Methow River can be overcome by the utilization of the slough by-pass at this point.

All the flow rights needed for downstream migrants are those used in the small by-pass channels of diversion screens. It will be necessary to continuously inspect and maintain the screen installations to insure that the by-passes are open at all times and screens in working order.

The greatest conflict with present flow rights is the need of adequate provision for the adult upstream migrants in the fall. Two such areas exist in the Wenatchee alone which lie below the principal spawning areas. Channel improvements and flow adjustments are necessary to overcome this. Fish could be transferred by mechanical means but this is not recommended as it will require extensive trapping and handling and the resulting difficulties and losses in fish life.

In the Entiat drainage flow adjustment will be needed to pass fish through the existing short semi-dry area.

No flow trouble is expected in the main channel of the Methow as far upstream as Twisp. Minor channel improvement will probably be needed between Twisp and Winthrop. In the South Fork channel improvement and flow changes are needed to overcome the present dry area at the mouth. The Chewack Fork may need some channel improvement and adjustments of flow in two places.

If the upstream channel problems are adjusted at the start of the stream rehabilitation program, the flow conflicts with downstream fish will be adjusted by such improvements.

All the fishway systems at the permanent dams must be rebuilt to successfully carry the increased number of upstream migrants; also, increased space room to take the increased size of adult migrants. In order to utilize the Similkameen River a fishway system will have to be installed at the power dam 7 miles upstream from its mouth. Channel improvements should also include the necessary by-passes through the annually created wing dams at points where such dams hamper the upstream movements of adult fish.

A screening program has been conducted by the State Department of Fisheries as a W.P.A. project which made possible the screening of all the diversions from the Wenatchee River system except the two power diversions in Tumwater Canyon and 14 small irrigation ditches on Mission Creek. Screens must be installed in these reamining diversions. Because of labor limitations it was not possible to complete the program in the Entiat or Methow river systems except for the large power intake on the Entiat. The diversions from these river systems must be screened. To utilize the upper Okanogan River and the Similkameen system, all diversions including those in Canada must be screened. The location of the hatchery in the Methow River system may eliminate certain of the problems of maintaining flows for the adult upstream migrants in this watershed. The solution of all flow problems must be met individually and will require the cooperation of all agencies administrating the water resources in the State of Washington.

RECOMMENDATIONS FOR FUTURE BIOLOGICAL WORK

It will have been noticed throughout this report that several points have been based on assumption. The reason for this has been that insufficient knowledge was available on certain points to make factual statements possible. The time allowed for the biological investigation was entirely too brief to collect all such data. For this reason it has been necessary to draw extensively from work done in adjoining fields and assume that the results would be comparable. Such methods were allowable only because of the emergency of the situation. (Grand Coulee Dam will close off the river late in 1938.) The administration of the hatchery program cannot be done on such a basis efficiently.

It will be necessary to keep a constant check on the efficiency of the trapping of adults, hauling of adults, holding of adults, artificial spawning, hatchery procedure, transportation of eyed eggs, feeding and rearing of young fish, and the planting of the young fish so that any abnormal mortalities which crop up can be quickly detected and attempts made to remedy them, and so that an attempt may be made to increase the efficiency and make more economical each step in the propagation program.

It shall be necessary to check accurately the home stream theory as it applies to this work so that it will be known when, or whether, the trapping and hauling of the adult fish at Rock Island can be abandoned in favor of natural migration to the four tributaries. To accomplish this it shall be necessary to conduct extensive and comprehensive marking experiments. From these experiments it will also be possible to determine the optimum size and time to which to rear and liberate the young fish, and to determine the intensity of the fishery upon these stocks of fish.

A factor which has had but brief mention in this report because of complete lack of knowledge on the subject, yet which is of fundamental importance to the whole program, is the reactions which will be met with in transplanting the fall runs of chinook and steelhead to tributaries naturally frequented by spring runs, and vice versa. This point requires careful investigation.

One striking hiatus in our knowledge is the data necessary to present an efficient planting program. The maximum number of fish any portion of these watersheds will efficiently support under this proposed rearing program is not known. To find this it will be necessary to know: 1. what is the natural food of the fish, 2. how much of this natural food is necessary to produce a given quantity of fish, and 3. how much of this natural food there is available to the fish at the seasons of the year at which it is needed. This is particularly evident in the case of the blueback. There is some reason to believe that the stock of silver trout (land-locked blueback) in Lake Wenatchee is of such a size that it will compete seriously with the young blueback in the matter of food. There is also reason to believe that the predatory fish in Lake Osoyoos may provide a limiting factor on the number of blueback that this lake can produce. Investigation must be made of the upper lakes of the Okanogan system to determine whether it is possible to bring them into blueback production.

An investigation should be started at once to determine the presence or absence, and seriousness, of the mining pollution in the Similkameen drainage and to determine methods of controlling it if present. This stream, larger than the Wenatchee, is at present barred to migratory fish by a dam near its mouth which could be made negotiable to the adult fish.

The best time of planting for the young fish will need to be determined each season.

The seasonal role that predatory fish play in the economy of the streams must be determined.

The rearing of so many fish will necessitate extensive food studies to determine the most economical diet for the fish and the optimum rate of growth under which these fish will thrive.

The hatchery has not yet been built that is not subject to disease. Equipment must be on hand to diagnose and treat these diseases promptly as they appear. Studies shall need to be conducted to determine and apply preventative measures.

The holding ponds for the adult fish present a physiological problem which is not as yet solved. Since this is such a vital cog in the proposed hatchery system, data must be gathered as to its efficiency, the sources of the mortalities, and to determine methods of improvement.

It is believed that few, if any, hatcheries have been given the careful forethought and planning this sytem has received. The gravity of the situation demanded such care. Yet it is almost certain that in so large and varied a system difficulties not anticipated will appear.

It is recommended, therefore, that the biological research at present in progress shall continue so that the data needed for the detailed design of the hatchery program can be acquired, and that in the permanent operations biological research shall be carried on hand in hand with the propagation program to study such factors as will increase the economic efficiency of the operations. To accomplish this work it is recommended: 1. that a trained biologist shall be permanently stationed at the Wenatchee hatchery, 2. that provision shall be made for such seasonal help as is needed, and 3. that proper laboratory and field facilities shall be provided.

Figure 1. Depth Contour Map of Lake Wenatchee.

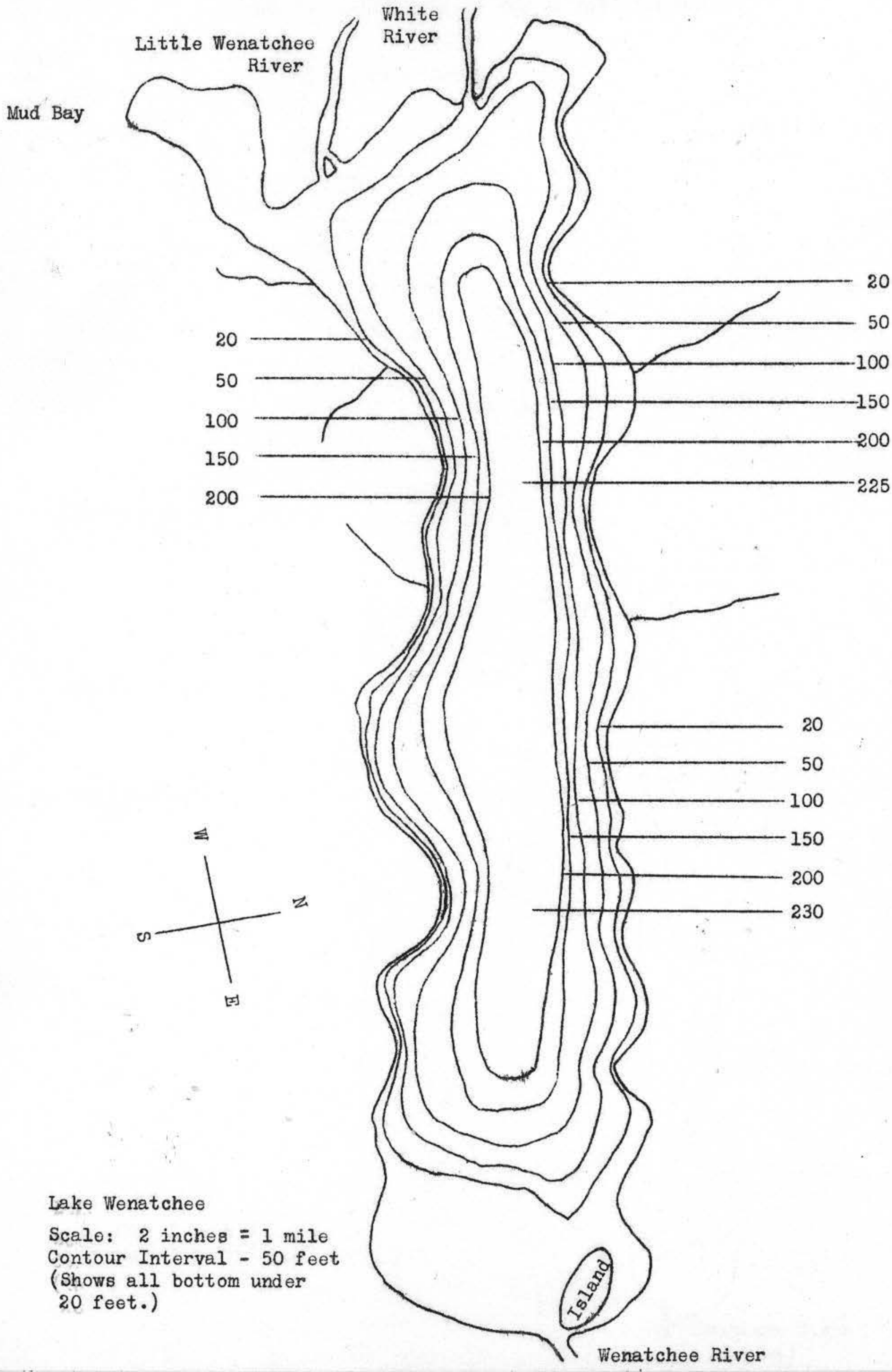


Figure 2. Depth Contour Map of Lake Osoyoos.

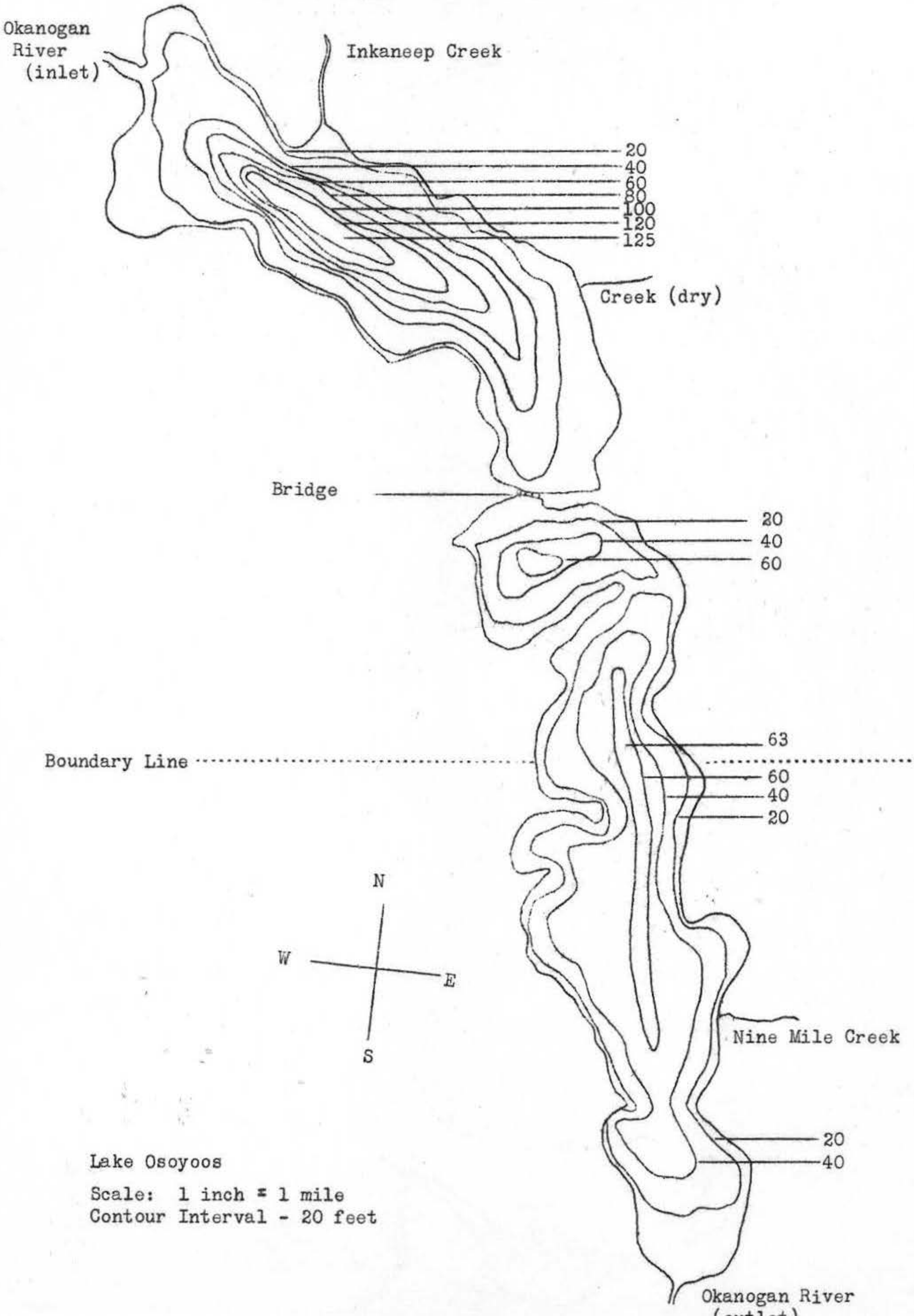


Figure 3. Depth Contour Map of Palmer Lake.

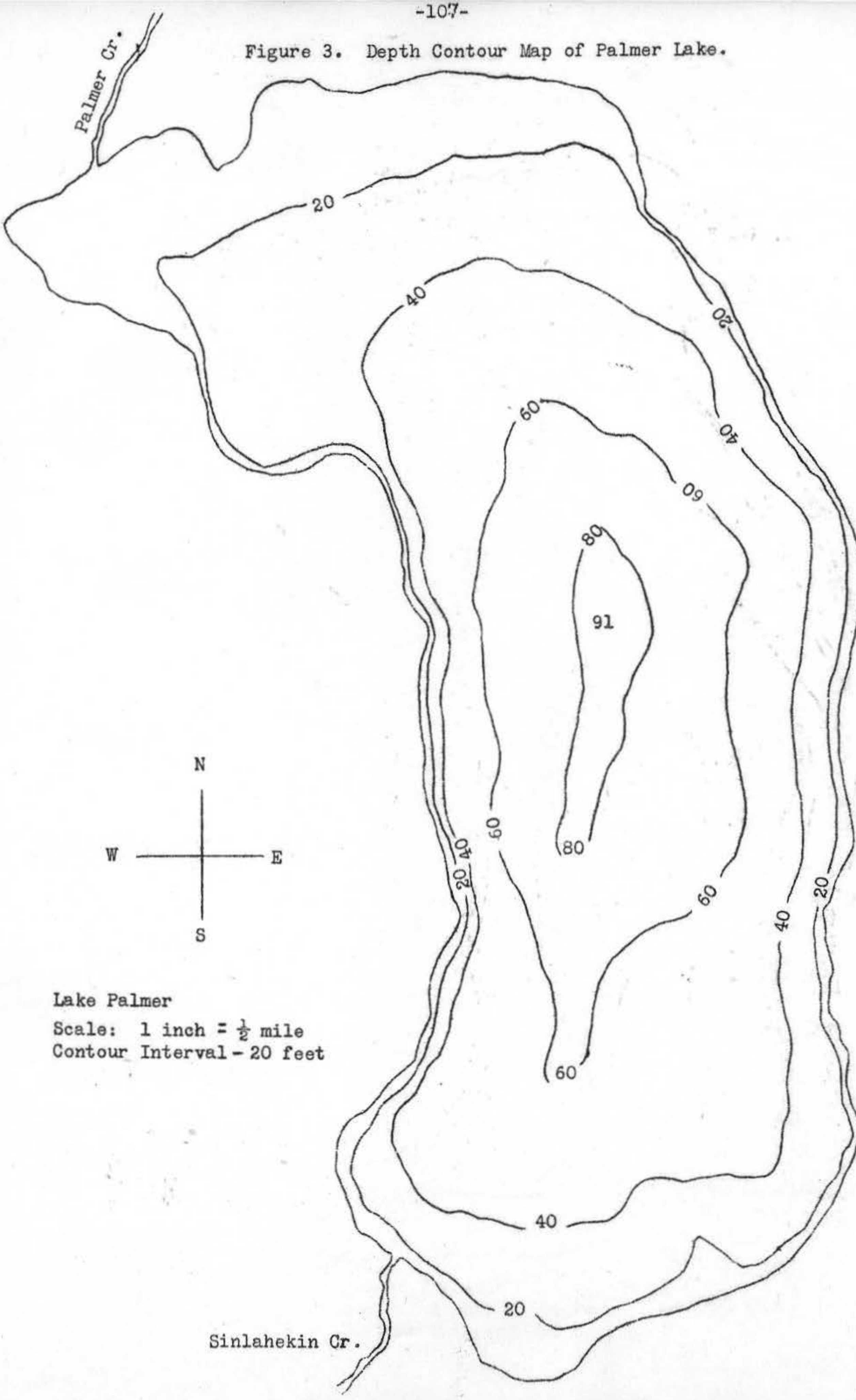
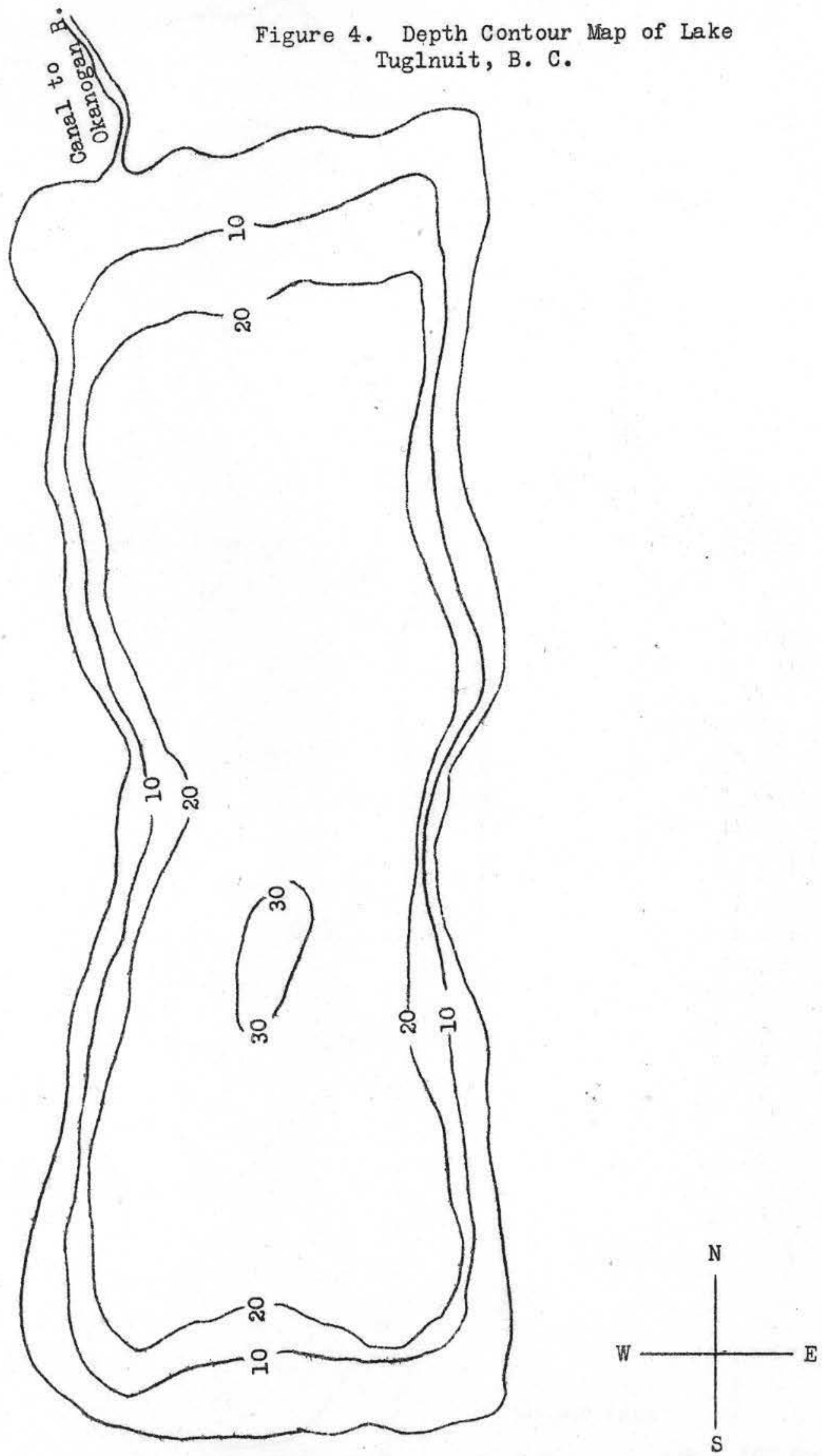
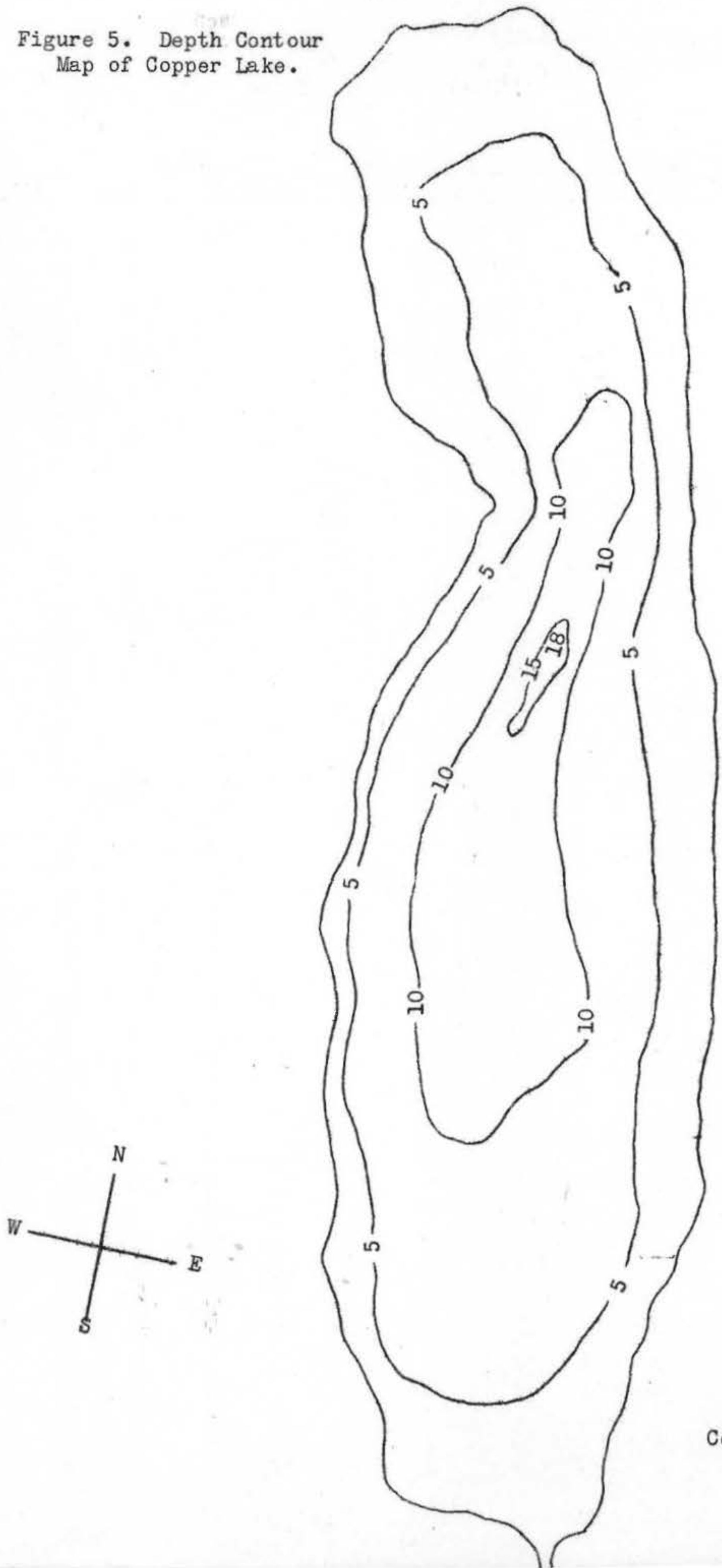


Figure 4. Depth Contour Map of Lake Tuglnuit, B. C.



Lake Tuglnuit
Scale: 1 inch = 500 feet
Contour Interval - 10 feet

Figure 5. Depth Contour Map of Copper Lake.



Copper Lake

Scale: 1 inch = 100 feet
Contour Interval - 5 feet

Appendix A - Counts of Fish Ascending the Ladders on Rock Island Dam, by Days, Species and Ladder for the Period from May 11 to Oct. 28, 1937

Date		Chinook			Steelhead			Blueback			Silver		
		East	Middle	West	East	Middle	West	East	Middle	West	East	Middle	West
May	11	0	0		0	0		0	0		0	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0
	13	0	0	0	0	1	3	0	0	0	0	0	0
	14	2	0	0	2	0	3	0	0	0	0	0	0
	15	2	0	0	2	1	4	0	0	0	0	0	0
	16	2	1	0	3	0	1	0	0	0	0	0	0
	17	0	0	0	1	0	3	0	0	0	0	0	0
	18	2	0	0	4	2	0	0	0	0	0	0	0
	19	0	0	0	2	0	0	0	0	0	0	0	0
	20	0	0	0	5	2	1	0	0	0	0	0	0
	21	0	0	0	16	5	3	0	0	0	0	0	0
	22	2	1	0	21	5	0	0	0	0	0	0	0
	23	2	0	0	19	11	2	0	0	0	0	0	0
	24	4	6	0	31	5	0	0	0	0	0	0	0
	25	3	3	0	22	8	3	0	0	0	0	0	0
	26	1	0	0	20	4	1	0	0	0	0	0	0
	27	3	2	0	19	7	0	0	0	0	0	0	0
	28	3	0	0	20	0	13	0	0	0	0	0	0
	29	1	0	0	20	0	6	0	0	0	0	0	0
	30	3	0	2	6	1	3	0	0	0	0	0	0
	31	11	1	1	2	2	1	0	0	0	0	0	0
June	1	7	1	4	4	0	2	0	0	0	0	0	0
	2	6	5	0	2	2	1	0	0	0	0	0	0
	3	4	2	2	8	0	2	0	0	0	0	0	0
	4	12	0	2	2	0	3	0	0	0	0	0	0
	5	7	1	1	2	0	1	0	0	0	0	0	0
	6	5	1	0	5	1	0	0	0	0	0	0	0
	7	1	0	0	0	0	0	0	0	0	0	0	0
	8	1	2	0	1	0	0	0	0	0	0	0	0
	9	1	0	0	1	0	0	0	0	0	0	0	0
	10	1	2	1	1	1	0	0	0	0	0	0	0
	11	0	0	1	1	1	0	0	0	0	0	0	0
	12	1	0	2	1	0	0	0	0	0	0	0	0
	13	3	3	2	1	0	1	0	0	0	0	0	0
	14	11	3	0	2	0	1	0	0	0	0	0	0
	15	3	1	0	2	0	0	0	0	0	0	0	0
	16	3	0	0	3	0	1	0	0	0	0	0	0
	17	0	0	1	0	0	3	0	0	0	0	0	0
	18	0	0	0	0	1	2	0	0	0	0	0	0
	19	0	1	1	0	0	2	0	0	0	0	0	0
	20	2	2	1	1	0	1	0	0	0	0	0	0
	21	1	0	1	2	0	2	0	0	0	0	0	0
	22	0	2	0	0	0	0	0	0	0	0	0	0
	23	0	3	0	0	0	0	0	0	0	0	0	0
	24	2	0	1	0	0	0	0	0	0	0	0	0
	25	0	2	0	0	0	1	0	0	0	0	0	0
	26	2	4	0	0	0	0	0	0	0	0	0	0
	27	7	2	0	0	1	0	1	1	0	0	0	0
	28	10	6	1	3	3	0	0	0	0	0	0	0

Appendix A - Continued.

Date		Chinook East	Chinook Middle	Chinook West	Steelhead East	Steelhead Middle	Steelhead West	Blueback East	Blueback Middle	Blueback West	Silver East	Silver Middle	Silver West
June	29	34	10	3	6	2	0	1	1	0	0	0	0
	30	32	4	5	0	3	1	0	0	0	0	0	0
July	1	20	4	2	0	3	1	0	0	0	0	0	0
	2	13	7	3	2	0	1	0	0	0	0	0	0
	3	21	19	2	6	1	0	0	0	0	0	0	0
	4	27	8	0	2	0	0	0	1	0	0	0	0
	5	19	4	0	0	0	0	1	0	0	0	0	0
	6	5	9	0	0	2	0	0	1	0	0	0	0
	7	3	13	5	1	1	0	0	1	0	0	0	0
	8	4	22	0	0	1	0	0	2	0	0	0	0
	9	3	21	3	0	0	0	1	0	0	0	0	0
	10	4	17	0	0	1	0	0	0	0	0	0	0
	11	3	6	1	1	0	0	6	2	0	0	0	0
	12	3	12	3	0	1	0	4	6	3	0	0	0
	13	6	6	3	5	0	0	24	5	127	0	0	0
	14	2	20	1	0	1	0	220	25	180	0	0	0
	15	3	25	1	1	0	0	291	131	540	0	0	0
	16	5	29	1	0	0	0	301	696	320	0	0	0
	17	8	56	4	0	0	0	316	505	350	0	0	0
	18	15	73	2	0	0	0	405	498	385	0	0	0
	19	7	62	4	0	0	0	287	292	350	0	0	0
	20	4	53	3	0	0	0	401	42	227	0	0	0
	21	6	41	2	0	0	0	362	239	137	0	0	0
	22	1	96	3	0	0	0	212	564	153	0	0	0
	23	0	163	8	0	0	0	41	289	265	0	0	0
	24	6	159	6	0	0	0	521	224	380	0	0	0
	25	11	165	10	0	0	0	304	121	331	0	0	0
	26	9	261	23	0	0	0	262	42	175	0	0	1
	27	15	344	16	0	0	0	276	71	275	0	0	0
	28	2	325	21	0	0	0	251	25	185	0	0	1
	29	6	121	24	0	0	0	265	5	96	0	0	1
	30	6	256	22	0	0	0	185	8	75	0	0	0
	31	9	116	29	0	0	0	156	2	141	0	0	1
Aug.	1	12	145	14	0	0	0	146	12	40	0	0	1
	2	0	110	15	0	0	0	19	2	41	0	0	0
	3	1	66	20	0	0	3	27	1	52	0	0	0
	4	1	40	17	0	0	2	17	7	76	0	0	1
	5	2	20	38	0	0	4	28	4	69	0	0	0
	6	5	-	11	0	-	3	60	-	19	0	-	0
	7	3	-	0	0	-	0	6	-	0	0	-	0
	8	0	-	0	0	-	0	0	-	0	0	-	0
	9	4	-	0	3	-	0	190	-	0	0	-	0
	10	11	-	0	5	-	0	48	-	0	1	-	0
	11	8	-	0	12	-	0	47	-	0	1	-	0
	12	3	-	0	7	-	0	21	-	0	2	-	0
	13	13	-	0	9	-	0	44	-	0	5	-	0
	14	10	-	60	0	-	18	10	-	43	1	-	1
	15	0	-	34	0	-	10	0	-	22	0	-	0
	16	10	-	35	4	-	7	22	-	22	2	-	2
	17	8	-	11	3	-	6	15	-	17	1	-	1
	18	10	-	30	3	-	14	9	-	29	1	-	2

Appendix A - Continued.

Date	Chinook East	Chinook Middle	Chinook West	Steelhead East	Steelhead Middle	Steelhead West	Blueback East	Blueback Middle	Blueback West	Silver East	Silver Middle	Silver West
Aug. 19	0	-	39	0	-	20	0	-	20	0	-	3
20	7	-	39	2	-	10	18	-	14	0	-	2
21	10	-	56	2	-	14	10	-	9	0	-	0
22	0	-	60	0	-	27	0	-	11	0	-	3
23	14	-	44	2	-	16	10	-	8	0	-	2
24	7	-	0	3	-	0	12	-	0	0	-	0
25	2	-	0	3	-	0	8	-	0	0	-	0
26	0	-	0	0	-	0	0	-	0	0	-	0
27	6	-	0	1	-	0	6	-	0	1	-	0
28	1	-	0	3	-	0	3	-	0	0	-	0
29	0	-	0	0	-	0	0	-	0	0	-	0
30	32	-	50	5	-	18	22	-	57	1	-	1
31	9	-	10	5	-	7	9	-	15	0	-	0
Sept. 1	0	-	4	0	-	4	0	-	8	0	-	0
2	3	-	6	4	-	8	4	-	3	0	-	1
3	3	-	5	1	-	5	3	-	4	0	-	0
4	0	-	30	1	-	4	3	-	5	0	-	3
5	0	-	8	0	-	6	0	-	5	0	-	0
6	0	-	0	0	-	0	0	-	0	0	-	0
7	5	-	5	10	-	4	1	-	10	0	-	0
8	4	-	3	25	-	1	2	-	4	0	-	0
9	8	-	5	18	-	7	5	-	5	0	-	0
10	5	-	2	7	-	6	1	-	4	0	-	0
11	1	-	5	8	-	4	0	-	1	0	-	0
12	0	-	4	1	-	3	1	-	0	0	-	0
13	9	-	11	16	-	5	3	-	1	0	-	0
14	8	-	5	12	-	7	1	-	0	0	-	0
15	9	1	10	13	0	3	0	0	0	0	0	0
16	3	-	7	15	-	7	0	-	0	0	-	0
17	4	-	8	8	-	7	0	-	0	0	-	1
18	16	-	23	29	-	11	1	-	0	0	-	2
19	0	-	0	0	-	0	0	-	0	0	-	0
20	13	-	18	47	-	8	3	-	3	0	-	0
21	96	-	77	20	-	38	2	-	0	0	-	1
22	15	7	53	8	9	25	1	0	1	0	0	0
23	21	13	53	15	19	36	0	0	0	0	0	0
24	10	5	37	6	17	24	1	0	0	0	0	0
25	5	4	33	4	7	21	0	0	0	1	0	0
26	11	14	34	5	16	11	0	0	0	0	2	0
27	6	2	16	15	7	11	0	0	0	0	0	0
28	18	0	30	22	5	45	1	0	0	1	0	0
29	14	1	24	31	0	47	0	0	0	5	0	0
30	14	0	39	24	1	34	0	0	4	0	0	0
Oct. 1	11	0	21	44	4	30	0	0	0	2	0	0
2	9	1	11	45	1	23	0	0	2	0	0	0
3	9	1	7	31	1	16	0	0	0	0	0	0
4	8	0	4	23	3	9	0	0	1	0	0	0
5	4	1	2	9	3	9	0	0	0	0	0	0
6	1	0	0	18	2	20	1	0	1	0	0	0
7	3	0	2	13	1	8	0	0	0	0	0	0
8	7	0	0	18	0	12	0	0	0	0	0	0

Appendix A - Continued

Date	Chinook			Steelhead			Blueback			Silver		
	East	Middle	West	East	Middle	West	East	Middle	West	East	Middle	West
Oct. 9	6	0	2	31	0	10	0	0	0	0	0	0
10	8	0	1	34	1	10	0	0	1	0	0	0
11	2	0	2	13	1	24	0	0	0	0	0	0
12	0	0	2	29	0	13	0	0	0	0	0	0
13	10	0	3	36	0	8	0	0	6	0	0	0
14	3	0	2	17	0	17	0	0	0	0	0	0
15	16	0	4	41	0	21	0	0	0	0	0	0
16	9	0	0	8	0	34	0	0	0	0	0	0
17	24	0	0	15	0	24	0	0	0	0	0	0
18	1	0	0	2	0	2	0	0	0	0	0	0
19	0	0	0	2	0	15	0	0	0	0	0	0
20	0	0	0	1	0	0	0	0	0	0	0	0
21	0	0	0	0	0	9	0	0	2	0	0	0
22	0	0	0	2	0	5	0	0	1	0	0	0
23	2	0	0	4	0	0	0	0	0	0	0	0
24	1	0	0	6	0	10	0	0	0	0	0	0
25	2	0	0	2	0	8	0	0	0	0	0	0
26	1	0	0	2	0	3	0	0	0	0	0	0
27	0	0	0	0	0	4	0	0	0	0	0	0

Date	Whitefish			Lamprey			Carp			Chub		
	East	Middle	West	East	Middle	West	East	Middle	West	East	Middle	West
May 11	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	1
13	0	0	0	0	0	0	0	0	0	0	0	1
14	0	0	0	0	0	0	0	0	0	0	0	1
15	0	0	0	0	0	0	0	0	0	0	0	1
16	0	0	0	0	0	0	0	0	0	3	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	2	0	0	0
20	0	0	0	0	0	0	0	0	2	0	0	0
21	0	0	0	0	0	0	0	0	2	0	0	0
22	0	0	0	0	0	0	0	0	2	1	0	0
23	0	0	0	0	0	0	0	0	1	4	1	0
24	0	0	0	0	0	0	0	0	1	2	0	0
25	0	0	0	0	0	0	0	0	0	4	1	48
26	0	0	0	0	0	0	0	0	0	3	0	43
27	0	0	0	0	0	0	0	0	0	1	0	39
28	0	0	0	0	0	0	0	0	0	1	0	10
29	0	0	0	0	0	0	0	0	0	1	0	1
30	0	0	0	0	0	0	0	0	0	1	0	0
31	0	0	0	0	0	0	0	0	0	1	0	0
June 1	0	0	0	0	0	0	0	0	0	3	0	1
2	0	0	0	0	0	0	0	0	0	140	0	38
3	0	0	0	0	0	0	0	0	0	111	0	14
4	0	0	0	0	0	0	0	0	0	4	0	3
5	0	0	0	0	0	0	0	0	0	1	0	4
6	0	0	0	0	0	1	0	0	0	1	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0

Appendix A - Continued

Date	White Fish East	White Fish Middle	White Fish West	Lamprey East	Lamprey Middle	Lamprey West	Carp East	Carp Middle	Carp West	Chub East	Chub Middle	Chub West
June 8	0	0	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	10	0	2
10	0	0	0	0	0	0	0	0	0	2	0	9
11	0	0	0	0	0	0	0	0	0	1	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	5	0	2
14	0	0	0	0	0	0	0	0	0	20	0	9
15	0	0	0	0	0	0	0	0	0	9	0	4
16	0	0	0	0	0	0	0	0	0	8	0	5
17	0	0	0	0	0	0	0	0	0	0	0	2
18	0	0	0	0	0	1	0	0	0	0	0	1
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	1	0	1
21	0	0	0	0	0	0	0	0	0	0	0	3
22	0	0	0	0	0	3	0	0	0	32	0	5
23	0	0	0	0	0	0	0	0	0	0	0	1
24	0	0	0	0	0	0	0	0	0	0	0	2
25	0	0	0	0	0	0	0	0	0	26	0	8
26	0	0	0	0	0	0	0	0	0	4	0	5
27	0	0	0	0	0	0	0	0	0	1	0	13
28	0	0	0	0	0	8	0	0	0	3	0	13
29	0	0	0	0	0	4	0	0	0	20	0	1
30	0	0	0	0	0	0	1	0	0	3	2	5
July 1	0	0	0	0	0	0	2	0	0	10	0	12
2	0	0	0	0	0	0	1	0	0	7	2	60
3	1	0	0	0	0	0	8	0	0	108	6	130
4	0	0	0	0	0	1	6	0	0	28	6	222
5	0	0	0	0	0	1	0	0	0	5	2	46
6	0	0	0	0	0	0	0	0	0	1	0	5
7	0	0	0	0	0	0	0	0	0	1	2	18
8	0	0	0	0	0	0	1	0	0	18	2	55
9	0	0	0	0	0	0	11	0	0	11	1	26
10	0	0	0	0	0	2	8	0	0	14	0	10
11	0	0	0	0	0	0	1	0	0	1	0	55
12	0	0	0	0	0	0	16	0	0	12	0	31
13	0	0	0	0	0	0	6	0	0	2	0	39
14	0	0	0	0	0	3	8	0	0	3	0	85
15	0	0	0	0	0	5	2	0	0	18	0	115
16	0	0	0	0	0	3	5	0	0	20	7	22
17	0	0	0	0	0	0	6	0	0	9	10	22
18	0	0	0	0	0	1	22	0	0	10	22	40
19	0	0	0	0	0	5	2	0	0	6	0	43
20	0	0	0	0	0	6	4	0	0	22	11	102
21	0	0	0	0	0	4	5	0	0	2	22	35
22	0	0	0	0	0	8	2	1	0	31	16	119
23	0	0	1	0	0	6	2	0	0	8	20	77
24	0	0	0	0	0	8	1	0	0	20	14	67
25	0	0	0	0	0	11	5	0	1	5	1	37
26	0	0	0	0	0	14	8	0	2	3	1	43
27	0	0	0	0	0	15	8	0	0	28	2	140
28	0	0	0	0	0	3	7	0	0	13	0	21

Appendix A - Continued.

Date	Whitefish			Lamprey			Carp			Chub		
	East	Middle	West	East	Middle	West	East	Middle	West	East	Middle	West
July 29	0	0	0	0	0	5	0	0	1	4	0	24
30	0	0	0	0	0	2	0	0	0	2	0	20
31	0	0	0	0	0	22	2	0	2	11	2	137
Aug. 1	0	0	0	0	0	20	0	0	0	2	1	34
2	0	0	0	0	0	45	0	0	0	0	0	19
3	0	0	0	0	0	68	0	0	0	0	5	20
4	0	0	0	4	1	32	0	0	0	0	9	34
5	0	0	0	0	0	33	1	0	0	2	0	15
6	0	-	0	1	-	18	0	-	0	1	-	0
7	0	-	0	1	-	0	0	-	0	0	-	0
8	0	-	0	0	-	0	0	-	0	0	-	0
9	0	-	0	0	-	0	0	-	0	49	-	0
10	0	-	0	4	-	0	0	-	0	6	-	0
11	0	-	0	0	-	0	1	-	0	3	-	0
12	0	-	0	14	-	0	0	-	0	3	-	0
13	0	-	0	4	-	0	0	-	0	4	-	0
14	0	-	0	8	-	0	1	-	0	1	-	101
15	0	-	0	0	-	3	0	-	0	0	-	23
16	0	-	0	0	-	9	0	-	0	3	-	27
17	0	-	0	0	-	25	1	-	0	0	-	51
18	0	-	0	0	-	12	0	-	0	1	-	67
19	0	-	0	0	-	14	0	-	0	0	-	122
20	0	-	0	0	-	8	0	-	0	0	-	44
21	0	-	0	0	-	7	0	-	1	0	-	65
22	0	-	0	0	-	8	0	-	0	0	-	56
23	0	-	0	4	-	4	0	-	0	0	-	47
24	0	-	0	0	-	0	1	-	0	0	-	0
25	0	-	0	0	-	0	0	-	0	0	-	0
26	0	-	0	0	-	0	0	-	0	0	-	0
27	0	-	0	0	-	0	0	-	0	0	-	0
28	0	-	0	4	-	0	1	-	0	0	-	0
29	0	-	0	0	-	0	0	-	0	0	-	0
30	0	-	0	0	-	0	0	-	0	6	-	13
31	0	-	2	0	-	0	0	-	0	3	-	49
Sept. 1	0	-	0	0	-	4	0	-	0	0	-	22
2	0	-	0	2	-	8	0	-	0	4	-	52
3	0	-	4	2	-	4	0	-	0	2	-	21
4	0	-	6	3	-	3	0	-	0	1	-	36
5	0	-	6	0	-	4	0	-	0	0	-	50
6	0	-	0	0	-	0	0	-	0	0	-	0
7	0	-	2	0	-	4	0	-	3	0	-	57
8	0	-	1	1	-	6	0	-	4	9	-	63
9	0	-	0	2	-	1	0	-	0	2	-	109
10	0	-	0	8	-	1	0	-	0	13	-	36
11	0	-	1	1	-	0	0	-	0	10	-	28
12	0	-	0	0	-	0	0	-	0	1	-	50
13	0	-	0	2	-	3	0	-	0	10	-	41
14	0	-	0	0	-	4	1	-	0	11	-	36
15	0	0	0	0	0	2	0	0	0	14	0	72
16	0	-	0	0	-	1	0	-	0	9	-	28
17	0	-	2	0	-	0	0	-	2	6	-	51

Appendix A - Continued

Date		Whitefish East	Whitefish Middle	Whitefish West	Lamprey East	Lamprey Middle	Lamprey West	Carp East	Carp Middle	Carp West	Chub East	Chub Middle	Chub West
Sept.	18	0	-	0	0	-	0	0	-	0	23	-	48
	19	0	-	0	0	-	0	0	-	0	0	-	0
	20	0	-	0	0	-	3	0	-	0	22	-	30
	21	0	-	4	0	-	0	3	-	3	29	-	138
	22	0	0	3	0	0	1	6	0	0	19	0	131
	23	0	0	5	0	0	0	0	0	0	9	0	92
	24	0	0	0	0	0	0	0	0	0	4	0	19
	25	0	0	1	0	0	0	0	0	0	7	0	28
	26	0	0	2	0	0	0	0	0	0	10	0	33
	27	0	0	0	0	0	0	0	0	0	3	0	16
	28	1	0	2	0	0	1	1	0	0	5	0	27
	29	0	0	2	0	0	0	0	0	0	8	0	22
	30	0	0	0	0	0	0	0	0	0	0	0	20
Oct.	1	0	0	0	0	0	0	1	0	0	6	0	14
	2	0	0	0	0	0	0	0	0	0	1	0	20
	3	0	0	1	0	0	0	0	0	0	1	0	8
	4	0	0	0	0	0	0	0	0	0	0	0	10
	5	0	0	0	0	0	0	0	0	0	0	0	8
	6	0	0	0	0	0	0	0	0	0	0	0	5
	7	0	0	0	0	0	0	0	0	0	1	0	6
	8	0	0	0	0	0	0	0	0	0	0	0	2
	9	0	0	3	0	0	0	0	0	0	0	0	6
	10	0	0	0	0	0	0	0	0	0	4	0	3
	11	0	0	1	0	0	0	0	0	0	0	0	2
	12	0	0	2	0	0	0	0	0	0	3	0	3
	13	0	0	4	0	0	0	0	0	0	7	0	9
	14	0	0	2	0	0	0	0	0	0	3	0	7
	15	0	0	2	0	0	0	0	0	0	4	0	7
	16	0	0	3	0	0	0	0	0	0	3	0	7
	17	0	0	3	0	0	0	0	0	0	0	0	0
	18	0	0	1	0	0	0	0	0	0	1	0	0
	19	0	0	0	0	0	0	0	0	0	1	0	0
	20	0	0	5	0	0	0	0	0	0	0	0	0
	21	0	0	10	0	0	0	0	0	0	0	0	0
	22	0	0	0	0	0	0	0	0	0	3	0	0
	23	0	0	2	0	0	0	0	0	0	3	0	0
	24	0	0	0	0	0	0	0	0	0	2	0	0
	25	0	0	16	0	0	0	0	0	0	0	0	2
	26	0	0	20	0	0	0	0	0	0	3	0	3
	27	0	0	19	0	0	0	0	0	0	0	0	2

Date		Squawfish East	Squawfish Middle	Squawfish West	Suckers East	Suckers Middle	Suckers West	Shiners East	Shiners Middle	Shiners West	Dolly Varden East	Dolly Varden Middle	Dolly Varden West
May	11	0	0	0	0	0	0	0	0	0	0	0	0
	12	0	0	0	0	0	3	0	0	0	0	0	0
	13	0	0	0	3	0	3	0	0	0	0	0	0
	14	0	0	0	2	0	4	0	0	0	0	0	0
	15	0	0	0	2	0	7	0	0	0	0	0	0
	16	0	0	0	0	0	4	0	0	0	0	0	0

Appendix A - Continued

	Squawfish			Suckers			Shiners			Dolly Varden		
DATE	East	Middle	West	East	Middle	West	East	Middle	West	East	Middle	West
May 17	1	0	0	0	0	20	0	0	0	0	0	0
18	0	0	0	0	0	20	0	0	0	0	0	0
19	0	0	0	0	0	20	0	0	0	0	0	0
20	1	0	0	0	0	20	0	0	0	0	0	0
21	0	0	0	0	0	14	0	0	0	0	0	0
22	7	0	0	7	0	10	0	0	0	0	0	0
23	9	1	0	5	2	14	0	0	0	0	0	0
24	10	0	0	11	0	23	0	0	0	0	0	0
25	7	0	0	5	0	18	0	0	0	0	0	0
26	7	0	0	3	3	14	0	0	0	0	0	0
27	1	0	0	4	3	39	0	0	0	0	0	0
28	4	0	0	3	0	8	0	0	0	0	0	0
29	4	0	0	3	0	1	0	0	0	0	0	0
30	0	0	0	0	0	1	0	0	0	0	0	0
31	1	0	0	1	0	1	0	0	0	0	0	0
June 1	2	0	0	0	0	2	0	0	0	0	0	0
2	75	1	0	53	0	57	0	0	0	0	0	0
3	108	0	0	219	0	53	0	0	0	2	0	0
4	3	0	0	19	1	6	0	0	0	0	0	0
5	1	0	0	5	0	7	0	0	0	0	0	0
6	0	0	0	2	0	1	0	0	0	0	0	0
7	0	0	0	0	0	6	0	0	0	0	0	0
8	0	0	0	0	1	3	0	0	0	0	0	0
9	2	0	0	5	0	6	0	0	0	0	0	0
10	0	0	0	1	1	4	0	0	0	0	0	0
11	0	0	0	1	0	1	0	0	0	0	0	0
12	0	0	0	1	0	0	0	0	0	0	0	0
13	0	0	0	0	0	6	0	0	0	0	0	0
14	5	0	0	24	0	18	0	0	0	0	0	0
15	2	0	0	15	0	17	0	0	0	0	0	0
16	3	0	0	15	1	6	0	0	0	0	0	0
17	0	0	0	0	2	3	0	0	0	0	0	0
18	0	0	0	0	0	1	0	0	0	0	0	0
19	0	0	0	3	0	1	0	0	0	0	0	0
20	0	0	1	1	0	2	0	0	0	0	0	0
21	0	0	0	0	0	3	0	0	0	0	0	0
22	13	0	1	12	0	3	0	0	0	0	0	0
23	0	0	0	0	0	1	0	0	0	0	0	0
24	0	0	1	0	0	0	0	0	0	0	0	0
25	2	0	0	8	0	4	0	0	0	0	0	0
26	3	0	2	1	0	7	0	0	0	0	0	0
27	2	0	0	1	0	7	0	0	0	0	0	0
28	14	1	5	9	2	31	0	0	0	1	0	0
29	11	0	3	49	16	13	0	0	0	0	0	0
30	6	3	0	11	0	9	0	0	0	0	0	0
July 1	5	1	1	12	2	5	0	0	0	0	0	0
2	6	0	1	5	3	43	0	0	0	0	0	0
3	79	1	2	101	5	29	0	0	0	1	0	0
4	176	0	11	593	4	291	7	0	0	0	0	0
5	14	3	6	19	0	10	0	0	0	0	0	0

Appendix A - Continued

Date		Squawfish			Suckers			Shiners			Dolly Varden		
		East	Middle	West	East	Middle	West	East	Middle	West	East	Middle	West
July	6	38	1	3	5	0	11	0	0	0	0	0	0
	7	3	0	9	31	0	2	0	0	0	0	0	0
	8	91	3	18	28	1	8	2	0	0	0	0	0
	9	159	2	10	167	0	26	7	0	0	0	0	0
	10	138	2	22	179	0	11	4	0	0	0	0	0
	11	37	1	85	15	0	46	4	0	1	0	0	0
	12	143	1	20	186	0	22	3	0	3	0	0	0
	13	34	5	19	4	0	8	1	0	9	0	0	0
	14	103	0	17	223	0	44	0	0	18	0	0	0
	15	32	1	37	402	2	35	0	0	22	0	0	0
	16	81	14	4	648	149	9	0	0	14	0	0	0
	17	75	17	4	76	414	5	3	0	9	0	0	0
	18	80	43	18	53	417	33	5	0	1	0	0	0
	19	40	10	35	11	200	19	0	0	0	0	0	0
	20	200	2	35	65	2	492	8	0	0	0	0	0
	21	82	6	10	16	49	260	0	0	1	0	0	0
	22	84	36	44	584	239	194	0	0	2	0	0	0
	23	29	67	63	276	737	68	0	0	6	0	0	0
	24	296	53	74	1063	420	235	0	0	6	0	0	0
	25	70	31	41	69	139	147	0	0	5	0	0	0
	26	85	6	29	18	153	16	0	0	64	0	0	0
	27	205	8	41	504	10	300	0	0	29	0	0	0
	28	88	4	8	52	2	13	3	0	45	0	0	0
	29	40	0	7	30	1	3	0	0	30	0	0	0
	30	12	1	8	97	0	4	0	0	2	0	0	0
	31	74	0	14	62	0	258	4	0	12	0	0	0
Aug.	1	21	2	4	25	2	20	0	0	5	0	0	0
	2	5	2	6	8	0	4	0	0	8	0	0	0
	3	7	0	11	15	1	25	0	0	6	0	0	0
	4	9	7	12	33	6	282	0	0	2	0	0	0
	5	7	1	5	61	34	51	0	0	2	0	0	1
	6	4	-	0	40	-	2	0	-	0	0	-	0
	7	2	-	0	7	-	0	0	-	0	0	-	0
	8	0	-	0	0	-	0	0	-	0	0	-	0
	9	29	-	0	121	-	0	3	-	0	0	-	0
	10	11	-	0	92	-	0	3	-	0	0	-	0
	11	10	-	0	78	-	0	1	-	0	0	-	0
	12	6	-	0	0	-	0	0	-	0	0	-	0
	13	11	-	0	40	-	0	0	-	0	0	-	0
	14	5	-	33	6	-	91	1	-	4	0	-	0
	15	0	-	14	0	-	82	0	-	1	0	-	0
	16	0	-	18	2	-	112	0	-	0	0	-	0
	17	3	-	22	1	-	51	0	-	11	0	-	0
	18	1	-	18	2	-	337	0	-	0	0	-	0
	19	0	-	45	0	-	275	0	-	4	0	-	0
	20	7	-	72	11	-	122	0	-	2	0	-	0
	21	10	-	60	8	-	109	0	-	1	0	-	0
	22	0	-	40	0	-	83	0	-	7	0	-	0
	23	14	-	26	7	-	33	0	-	6	0	-	0
	24	7	-	0	6	-	0	0	-	0	0	-	0
	25	1	-	0	1	-	0	0	-	0	0	-	0

Appendix A - Continued

Date		Squawfish East	Squawfish Middle	Squawfish West	Suckers East	Suckers Middle	Suckers West	Shiners East	Shiners Middle	Shiners West	Dolly Varden East	Dolly Varden Middle	Dolly Varden West
Aug.	26	0	-	0	0	-	0	0	-	0	0	-	0
	27	6	-	0	5	-	0	0	-	0	0	-	0
	28	2	-	0	3	-	0	0	-	0	0	-	0
	29	0	-	0	0	-	0	0	-	0	0	-	0
	30	9	-	4	10	-	29	6	-	0	0	-	0
	31	5	-	18	4	-	54	3	-	1	0	-	0
Sept.	1	0	-	3	0	-	9	0	-	0	0	-	0
	2	3	-	8	5	-	11	4	-	0	0	-	0
	3	4	-	11	5	-	7	2	-	3	0	-	0
	4	3	-	16	6	-	14	1	-	0	0	-	0
	5	0	-	7	0	-	11	0	-	0	0	-	0
	6	0	-	0	0	-	0	0	-	0	0	-	0
	7	0	-	24	2	-	170	0	-	2	0	-	0
	8	8	-	21	4	-	197	2	-	4	0	-	1
	9	3	-	44	4	-	179	0	-	3	0	-	0
	10	18	-	19	5	-	40	0	-	0	0	-	0
	11	14	-	6	3	-	28	0	-	2	0	-	0
	12	2	-	10	0	-	11	0	-	2	0	-	0
	13	28	-	9	11	-	27	1	-	0	0	-	0
	14	16	-	5	7	-	15	1	-	1	0	-	0
	15	16	0	22	5	0	23	0	0	1	0	0	0
	16	25	-	13	6	-	15	0	-	0	0	-	0
	17	6	-	13	2	-	17	3	-	2	0	-	0
	18	29	-	12	7	-	16	1	-	1	0	-	0
	19	0	-	0	0	-	0	0	-	0	0	-	0
	20	69	-	12	7	-	16	0	-	1	0	-	0
	21	100	-	61	23	-	90	4	-	2	0	-	0
	22	99	0	33	34	0	93	3	0	2	0	0	0
	23	45	0	30	14	0	92	4	0	2	0	0	0
	24	11	0	8	2	0	36	0	0	0	0	0	0
	25	12	0	7	17	0	59	0	0	1	0	0	0
	26	0	0	7	6	0	62	1	0	3	0	0	0
	27	0	0	5	10	0	18	0	0	0	0	0	0
	28	0	0	10	7	0	37	0	0	0	0	0	0
	29	6	0	4	9	0	57	0	0	0	0	0	0
	30	0	0	6	0	0	40	0	0	0	0	0	0
Oct.	1	5	0	3	6	0	40	0	0	0	0	0	0
	2	0	0	2	8	0	50	0	0	1	0	0	0
	3	0	0	2	4	0	26	0	0	0	0	0	0
	4	0	0	1	2	0	15	0	0	0	0	0	0
	5	0	0	0	2	0	11	0	0	0	0	0	0
	6	0	0	1	4	0	34	0	0	0	0	0	0
	7	0	0	0	0	0	26	0	0	0	0	0	0
	8	0	0	0	0	0	10	0	0	0	0	0	0
	9	0	0	1	0	0	17	0	0	0	0	0	0
	10	0	0	0	1	0	14	0	0	0	0	0	0
	11	0	0	0	2	0	16	0	0	0	0	0	0
	12	0	0	1	1	0	16	0	0	0	0	0	0
	13	0	0	1	3	0	32	0	0	1	0	0	0
	14	0	0	0	0	0	21	0	0	0	0	0	0
	15	2	0	0	8	0	11	0	0	0	0	0	0

Appendix A - Continued

Date	Squawfish			Suckers			Shiners			Dolly Varden		
	East	Middle	West	East	Middle	West	East	Middle	West	East	Middle	West
Oct. 16	0	0	0	0	0	4	0	0	0	0	0	0
17	1	0	0	8	0	2	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	2	0	0	2	0	1	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	2	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	3	0	0	17	0	1	0	0	0	0	0	0
24	3	0	0	17	0	1	0	0	0	0	0	0
25	0	0	0	1	0	5	0	0	0	0	0	0
26	1	0	0	5	0	2	0	0	0	0	0	0
27	0	0	2	0	0	0	0	0	0	0	0	0

Appendix B - Counts of Fish Going Over Tumwater Dam, by Days and Species for the Period from July 12 to September 11, 1937.

Date	Chinook	Blueback	Steelhead	Eastern Br.	Squawfish	Silver	White-fish
July 12	0	0	0	0	4	0	0
14	0	0	0	0	1	0	0
15	0	0	0	0	3	0	0
16	0	0	0	0	4	0	0
19	0	0	0	0	1	1	1
20	0	0	0	2	0	0	0
23	0	0	0	1	1	0	0
Aug. 4	0	4	0	0	1	0	0
5	0	0	0	0	1	0	0
6	0	8	0	0	0	0	0
8	1	1	0	0	0	0	0
10	0	0	0	3	2	0	1
11	0	2	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	1	0	0	0	0	0
14	1	0	0	0	0	0	0
20	0	9	0	0	0	0	0
22	0	1	0	0	0	0	0
28	0	1	0	0	0	0	0
29	0	0	1	0	0	0	0
Sept. 1	1	0	0	0	0	0	0
2	0	2	0	0	0	0	0
3	0	2	0	0	0	0	0
4	0	31	0	0	0	0	0
10	0	1	0	0	0	0	0
11	1	0	0	0	0	0	0
Totals	4	65	1	6	18	1	2

Appendix C.- Counts of Fish Going Over Oroville Dam, By Days and Species for the Period from July 20 to August 20,1937.

Date	Blueback	Chinook
July 20	1	0
21	1	0
22	10	0
23	15	0
24	3	0
25	23	0
26	8	0
27	3	0
28	3	0
29	3	0
30	0	0
31	393	0
Aug. 1	494	2
2	343	0
3	200	1
4	236	0
5	81	0
6	60	0
7	139	0
8	59	0
9	35	0
10	14	2
11	4	0
12	13	0
13	8	0
14	0	0
15	2	0
16	2	0
17	2	0
18	3	0
19	1	0
20	3	0
Total	2,162	5

m/

3/15/38 - Notes by Joseph Jacobs concerning the Grand Coulee Dam fisheries and fishway provisions as proposed by the State, and after reading the recent report by State Fish Commissioner Brennan (about June 1938).

1. The program impresses me as being too elaborate, too expensive, and entirely unfair and unjust to ask the U.S.B.R. to finance the program and particularly the annual operation and maintenance costs.

2. The program as outlined in the Brennan Report with its several large scale hatcheries, holding ponds, rearing ponds, dams, diversion channels, etc., and its provisions for artificial transfer of the upriver run of fish from Rock Island Dam to these several holding ponds, etc., must, necessarily, run into a high figure both as to initial installation and as to annual operating costs. Unfortunately the Brennan Report contains no cost data whatever and, of course, detailed estimates should be prepared and carefully considered before U.S.B.R. agrees to such a program. I conceive that these costs might run into possibly as much as $2,000,000 for installation and $200,000 for annual operation and maintenance costs.

3. The economic value of the fish run past Coulee Dam is relatively small--perhaps $20,000 per year as an outside figure. There is, of course, no fishing industry as such, no canneries or processing plants, only sport fishing and some food fishing by Indians. The count at Rock Island Dam indicates an annual run past that dam of 40,000 to 50,000 fish per year. Between Coulee Dam and Rock Island Dam the main Columbia River tributaries are the Wenatchee, Entiat, Methow, and Okanogan Rivers. The number of fish that reach Coulee Dam is probably less than 25,000 per year. Assuming an average weight of 10 pounds per fish and a $0.03-per-pound value for same, the resultant value of the run is only $7,500. Capitalize this at 3 percent and the indicated total value of the annual run of fish at Coulee Dam is only $250,000. Moreover, all of the fish are not caught; a considerable percentage reach the spawning grounds.

4. If U.S.B.R., to be liberal, paid the State outright double or treble the last named figure, as a settlement of its obligation to the State, it seems to me that that is the very limit of what the State could expect. Some will contend that the value of the upriver run, as above outlined, is not a full measure of the true value; that it is the downriver run to the ocean that maintains the industry below, etc. The total run of fish from the ocean into the Columbia is probably from 4,000,000 to 5,000,000 fish per year. The run at Rock Island Dam is about 1 percent of that and at Coulee Dam probably less than 1/2 percent. How much of the new stock of fish that this 1/2 percent may provide is not known. It may be more than 1/2 percent but probably not much more.

5. I think it ought to be recognized that the run of salmon past Coulee Dam is to be lost to the industry and a liberal compensation made therefor to the State, about as indicated in paragraph 3 above. The State could then, if it desired, build a hatchery somewhere above the dam and stock the upriver sections with nonmigratory fish species. Why should U.S.B.R. assume responsibilities entirely foreign to its purposes and at a cost far in excess of anything it destroys in building the dam?

6. The Brennan Report indicates an appreciable mortality of the fish in transporting them from Rock Island Dam to the proposed holding ponds and hatcheries upstream. It seems to me that a better immediate program would be not to provide such transportation but rather to permit the fish to move upstream on their own power, as they have always done, to the spawning grounds that their natural instinct may select, thus maintaining pristine conditions as nearly as is possible and practicable. If this involves a loss of all or a part of the Grand Coulee Dam portion of the run, concede that loss and let U.S.B.R. reimburse the State for that loss and for that loss only.

7. The Brennan program indicates the need of a considerable flowage of water (perhaps several hundred second feet) that, except by final pumpage from lower levels downstream, would be lost to irrigation and the water is altogether more valuable for irrigation than for fisheries--incomparably more.

8. The following program appeals to me as one U.S.B.R. might consider:

(1) Advise the State that U.S.B.R. does not approve the elaborate program outlined in the Brennan Report insofar as the U.S.B.R. is expected to finance the same.

(2) That U.S.B.R. will assume no obligations as permanent payment of annual operation and maintenance costs and will consider only a lump sum payment to the State that will properly compensate the State for the value of the normal fish run past Coulee Dam.

(3) That the State is requested to prepare an estimate of the capitalized value of this fish run and to submit same to U.S.B.R. for consideration. The U.S.B.R. will prepare like figures and, if negotiations between the State and U.S.B.R. do not then lead to agreements as to the lump sum to be paid to the State, that a disinterested commission be appointed to decide the matter, both sides agreeing to abide by the decision of such commission.

(4) That U.S.B.R. make a count of fish in the 1938 run at Coulee Dam and at Rock Island to establish the relationship of these runs and as an aid in arriving at the value of the upriver industry.

9. Fear has been expressed by some that failure of U.S.B.R. to accept Brennan's extravagant program, and pay for same, may result in a fight on further Congressional appropriations for completion of dam and for Columbia Basin project. I entertain no such fear. There may be idle threats of that character but State sentiment would not sanction it nor would political considerations permit it. If U.S.B.R. makes a liberal lump-sum offer for what damage it may do to fisheries all reasonable people will recognize the fairness of such an attitude.

3/29/38 - Dr. F. A. Davidson, U.S. Bureau of Fisheries, in a talk before Seattle Post, Soc. of Amer. Military Engineers, on the salmon fisheries of Alaska, said:

(a) That where U.S. can control they require fishermen to permit a 50 percent escapement of the fish in a salmon run, that is, a 50 percent catch and a 50 percent escapement for spawning.

(b) That fish require gravelly shorelines and cool water for successful spawning. The temperature range for successful spawning is 39° to 55° F. Outside that range there is a high mortality of eggs.

(c) The female, with her tail, whips out a nest in the gravel, spawns her eggs which are promptly fertilized by the male. The eggs being heavier than water, sink in the gravel and within a few months hatch out their "fry." If the stream carries fine sand or silt which covers up these nests the eggs smother or choke to death for lack of oxygen.

(d) The small fry (± 1 inch long) of the Chinook salmon go out to sea when only a month or two old but the young Sockeye remain in fresh water a year or more (± 2 to 3 inches long) before going to sea.

(e) There are 5 species of salmon in Pacific N.W. waters - King or Chinook salmon (the largest), the Sockeye, Chums, Pinks, and __________.

Mr. Hall said present Seattle price of Pinks was $1.10 per dozen cans (1 pound net of fish) = ± $0.09 per pound, and that reds (mostly Sockeye) were worth about double that price.

January issue of Pacific Fisherman gives statistics of the Alaska, Puget Sound, and Columbia River fisheries industries for the period 1897 to 1937, inclusive. For Columbia River I think maximum number of cases (case = 48 one-pound cans or equivalent in other size cans) was ± 1,200,000 cases of a value of ± $9,000,000.

4/26/38 - Mr. Paul L. Hislop (Mechanical Engineer, Bonneville project) in a lecture on Bonneville project before the Western Washington Section, Am. Soc. Mech. Engrs., stated that they attempted to count the fish run up the Columbia, past Bonneville dam, in 1937; that the spring run amounted to 150,000; that the maximum rate was 6,000 in one hour; that the figures represent the count of the fish actually seen and that there were some additional that were not seen. (He did not state what percent the spring run represented of the total annual run but, probably, it was less than one-half.)

The Columbia River fisheries should be divested of all of its sentimental aspects and be considered strictly on the basis of industrial economics. So far as game or sport fishing is concerned that can be amply provided by stocking the river above Grand Coulee Dam or other streams and tributaries of the Columbia River, when needed, with non-migratory game fish. U.S.B.R. is now, in a large way, providing the State of Washington, at no cost to the State, with two very important industries, irrigation and power, and in the single Grand Coulee and Columbia Basin project is scheduled to spend $400,000,000. The State of Washington is entirely unfair in asking U.S.B.R. to establish and maintain another industry with which it has no concern whatever, except to make good what it actually destroys. The State Fisheries Department is simply running wild in its excessive demands on U.S.B.R. If the State and Federal fisheries departments wish to expand the fisheries industry of the Columbia they should do so themselves and not ask U.S.B.R. to do it for them.

No statistical data are available but it is possible that the salmon runs above Rock Island Dam are less today than they were in former years. If such is the case the decrease has probably resulted, to some extent, from a reduced water supply in the headwater streams due to diversions for irrigation. To the extent that this has occurred it has been worth while for the use of water for irrigation is altogether more valuable than its use for fisheries on the upper Columbia. Also, to the extent that the upper Columbia fish runs have declined it has been due to operations of the State, not the Federal Government, for the only Federal irrigation project above Rock Island Dam is the little Okanogan project of 5,600 acres. The Federal Government is under no obligation to restore what it has not destroyed.

Expenditures at Bonneville Dam for fishways approximated $7,000,000; at Grand Coulee, if present State proposals prevail, the expenditures will also run to several million dollars; with 10 dams on the Columbia (7 yet to be built), if fishway expenditures continue at the same rate, the fishway expenditures in the aggregate might aggregate $50,000,000. It is time to consider very carefully just what is the economic limit of expenditures to protect the Columbia River salmon industry. It might prove cheaper for the U.S. to purchase outright all the canneries and retire the industry.

12/12/38 - Notes from Oregon State Planning Board Report of August 1938 on Columbia River fisheries.

<u>Commercial fisheries location:</u> These extend from the mouth to a point 5 miles below Bonneville Dam and from a point 15 miles above Bonneville Dam to the mouth of Deschutes River.

<u>Records of catch:</u> The total catch, expressed in pounds of fish caught, including that caught by trolling in the ocean just off the mouth of the river, and for both Oregon and Washington, is as follows:

Catch for 10-year period, 1928 to 1937, inclusive, in pounds

No.	Item	Pounds	Remarks
1	Total catch in lb.	257,908,825	*Made up thus: Chinook, 17,584,675 = 68.2%; Silvers, 3,737,201 = 14.5%;
2	Mean annual catch	25,790,883*	Steelheads, 2,460,280 = 9.5%; Chums, 1,641,372 = 6.4%; Bluebacks, 367,355 =
3	Max. year (1936)	28,886,670	1.4%.
			**The year by year figures are given in
4	Min. year (1936)	22,913,400	report but I (J.J.) did not have time to copy them as I had only about 1/2 hour to inspect the report at office of Washington State Fisheries Bureau office. Apparently, however, the mean annual catch for the later period is about 70% that of the earlier period.
	Catch for 29-year period, 1900 to 1928, inclusive, in pounds		
5	Total catch)**		***The ratio of the canned + mild cured
6	Mean annual)**		product (mostly canned) to that of the catch, by weight, was ± 74% for
7	Max. year (1911)	49,480,008)***	1911 and ± 81% for 1908.
8	Min. year (1908)	24,340,892)	

<u>Average weight of single fish:</u> Chinooks, 20-25 lb.; Silvers, 8-9 lb.; Steelheads, 9-10 lb.; Chums, 10 lb.; and Bluebacks, 2-4 lb. On basis of percents shown in note * above the mean weight for total catch was ± 18 pounds. This

would indicate an average catch for the period 1928 to 1937, of 25,790,883 ÷ 18 = 1,432,827 fish and the total run might have been double that or ± 2,865,000 fish. On same ratio basis (50 percent), the indicated run for the maximum year, 1908, was ± 5,500,000 fish. J.J.