DEPARTMENT OF FISHERIES OF CANADA

PROGRESS REPORT

FISH CULTURE DEVELOPMENT BRANCH
PACIFIC AREA

1962

SUMMARIES OF CURRENT PROJECTS

VANCOUVER , B.C.
MAY , 1963

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PROGRESS REPORT

of the

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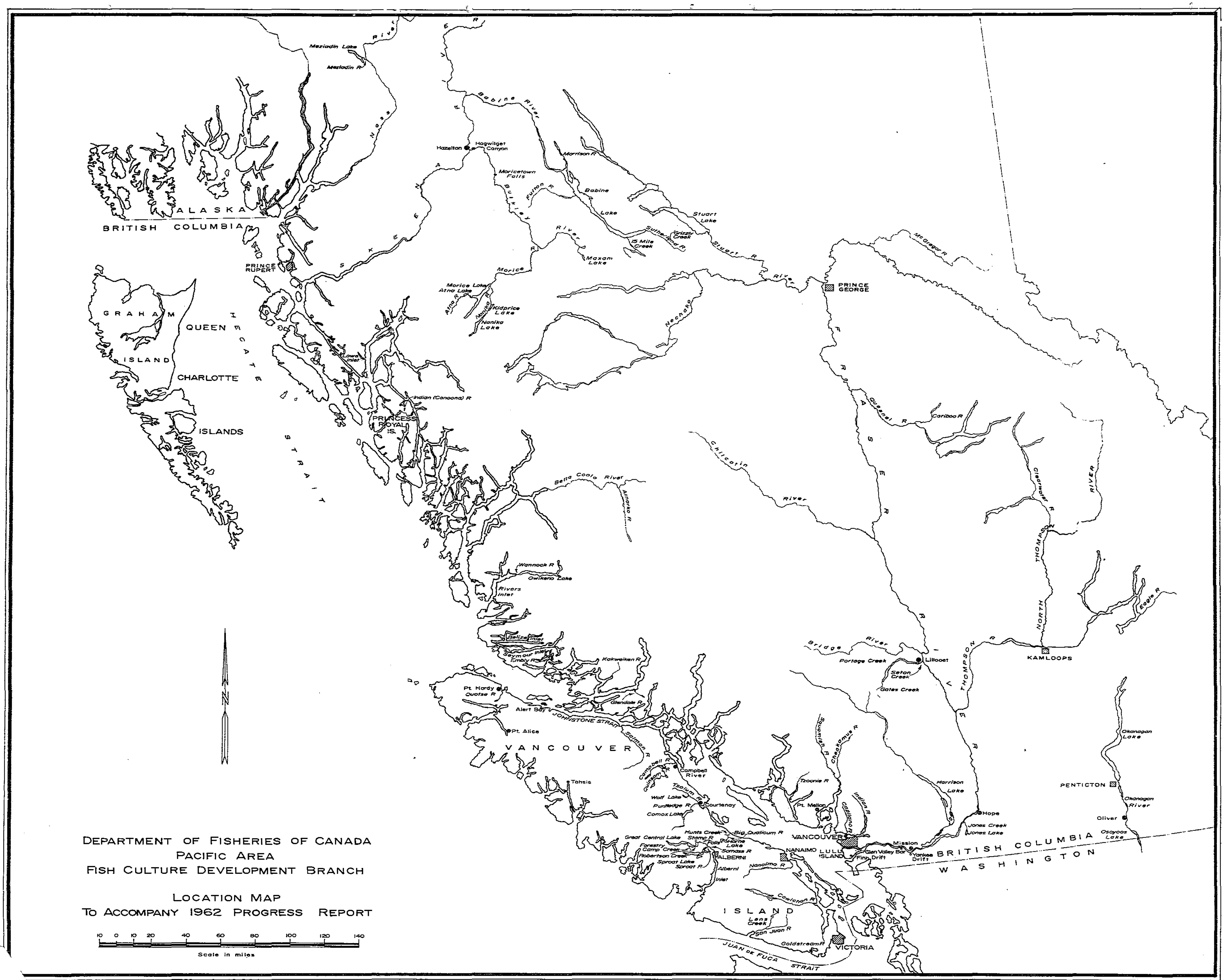

DEPARTMENT OF FISHERIES OF CANADA
PACIFIC AREA
FISH CULTURE DEVELOPMENT BRANCH

LOCATION MAP
TO ACCOMPANY 1962 PROGRESS REPORT

DEPARTMENT OF FISHERIES OF CANADA

FISH CULTURE DEVELOPMENT BRANCH

PACIFIC AREA

1962 PROGRESS REPORT

INTRODUCTION

The Pacific Area staff of the Fish Culture Development Branch, comprising twelve engineers, thirteen biologists and twenty-five supporting personnel, direct a great deal of attention to the study of pollution, hydroelectric, and other industrial projects affecting the fishery. The Branch has also been engaged since its reorganization and expansion in 1949 in a program which entailed the construction of projects designed for the maintenance and improvement of the fisheries resource. Initially this program was directed towards the removal of obstructions and the construction of fishways at natural obstructions which were limiting the spawning and rearing capabilities of the various streams. More recently, however, this program has been expanded to include stream improvement projects which have been constructed for the purpose of controlling the salmon's environment. The program reached a new high in 1959 when authority was granted to proceed with the Big Qualicum River Project which will provide controlled flow and temperature conditions throughout the year as well as improved spawning areas. Other significant development projects undertaken in recent years include the construction of a new-type salmon incubation hatchery for the purpose of rehabilitating a sockeye salmon run and a massive transplantation of pink salmon eggs to a foreign area in an effort to establish a new run of this species.

As the work of the Branch expanded to keep pace with industrial developments and as the need for the application of scientific principles to maintain and improve the salmon stocks became more evident, some divisionalization was inevitable, but this has been held to a minimum in order that staff can be readily transferred within the divisions in accordance with current demands. Since 1957 the Branch has been operating within the following three divisions.

1. SPECIAL PROJECTS - These consist principally of industrial projects, existing and proposed, which through their operations constitute a threat to the fisheries if remedial measures are not applied. Developments such as hydroelectric projects, flood control programs, industrial and domestic water supplies, waste disposal systems, pollution control, etc. fall within this category.

2. SALMON DEVELOPMENT - This division is concerned primarily with the implementation of appropriate measures with a view to increasing the present stocks of salmon. The work initially consisted mainly of the alleviation of obstructions by means of fishways or other devices. To-day, however, the Division has much more scope and it now deals with artificial spawning channels, hatcheries, flow

improvement, temperature control, stream bed improvement, and any other means by which the freshwater production of salmon can be improved.

3. APPLIED RESEARCH - This division has been established for the express purpose of undertaking research assignments looking to the development of solutions to specific problems encountered by the special projects and salmon development divisions. In this capacity the division is associated with problems for which there is no known solution, or problems which require investigation through the development and application of new principles and techniques. Recent or continuing projects in this field are: refinement of louver designs for the safe passage of seaward migrants around a proposed power development; evolution of an electronic fish counter for the enumeration of fish passing through a fishway; investigation of the source of attraction for beach-spawning sockeye salmon at a lake; various hydraulic model studies to develop the best possible designs of fishways and other fish facilities; investigations to determine the optimum and minimum flow requirements of rearing coho, etc.

In 1960, for the first time, a biologist from the Branch was assigned full-time to assist the Area Director and the Protection Branch in the formulation of fishing regulations and to conduct scientific studies which might form a basis for future salmon management policies. Since that time the responsibilities of the Branch in this field have been substantially increased, and in 1962 two biologists and one technician from the Branch were assigned to salmon management on a full-time basis.

To date the Branch has dealt with hundreds of special projects and fewer, but nevertheless substantial numbers of projects in the other fields, and it has been felt for some time that a concise review of the Branch's activities, issued on a periodic basis as deemed necessary, would be a worthwhile undertaking. While the details of the Branch's major projects are described in the Department's Annual Report, these necessarily receive only very brief coverage, and others of only slightly lesser importance receive no mention whatever. This Progress Report has been prepared therefore with a view to fulfilling this deficiency. It should not be regarded as an annual publication, however, as revisions and updating will be undertaken only when sufficient data has been collected to warrant the considerable effort involved in so doing.

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1. SPECIAL PROJECTS

1.1 POWER DEVELOPMENT

1.1.1 Cheakamus River

The Cheakamus River Hydroelectric Development, which is owned and operated by the B. C. Hydro and Power Authority, is located approximately 40 miles due north of the city of Vancouver. The development consists of a 90-foot-high diversion dam on the Cheakamus River, approximately 15 miles upstream from its mouth, and a 7.1-mile tunnel by means of which flows of up to 2000 cfs are diverted to a powerhouse on the banks of the Squamish River.

The Cheakamus River supports important runs of all species of Pacific Salmon except sockeye, and when it was announced in 1954 that the power development would be constructed, the Department was concerned with its possible detrimental effects on these stocks of fish. Detailed engineering and biological investigations were therefore initiated immediately by this Branch. The results of these studies were presented in a technical report which described the salmon populations; their migrations, timing, and distribution; the possible effects which the power development might have on them; and several alternative schemes by means of which the fisheries could be protected.

While the dam and diversion tunnel were located some six miles upstream from the upper limit of spawning migration it was foreseen that the development could seriously affect the salmon runs if adequate residual flows were not maintained in the lower river. Accordingly, this Branch recommended that a minimum flow of 500 cfs be maintained in the river throughout the year. It was suggested, however, that the runs might be maintained by a lesser flow if an artificial spawning channel of an appropriate capacity were constructed. By the time the power development came into service in September, 1957 negotiations with the Owner had resulted in an agreement whereby flows of at least 500 cfs would be maintained on the spawning grounds.

Since 1957, this Branch has conducted biological surveys on the Cheakamus River each year as a means of assessing the effects of the diversion. The tag-and-recovery method has been employed for the enumeration of adult pink and chum salmon and visual estimation only has been used for the other species. The chum and pink salmon fry output has been measured by sampling programs employing fyke nets and inclined-plane traps. The table at the top of page 3 sets forth the estimated adult escapements and fry output for the period 1954-62.

Inspection of the table reveals that with the exception of pink salmon the magnitude of the spawning escapements to the Cheakamus River have not changed appreciably since the power plant came into operation in 1957. The substantial increase in production of pink salmon could be associated with a closure of the Howe Sound fishery which was imposed in 1956.

	ADULT ESCAPEMENTS				FRY OUTPUT	
Year	Pinks	Chums	Coho	Chinook	Pinks	Chums
1954	-	12,300	1-2,000*	500-1,000*		
1955	12,800	9,800	1-2,000*	500-1,000*		
1956	-	2,600	2,350	300- 500*		
1957	34,000	45,000	1,000	1,000		
1958	-	52,000	4,500	2,000	3,900,000	4,000,000
1959	57,000	64,000	4,000	1-2,000*		4,300,000
1960	-	12,000	1-2,000*	300- 500*	18,500,000	20,400,000
1961	300,000	9,300	5,000	2-5,000*		3,600,000
1962	-	28,200			58,300,000	2,500,000

*As reported by the local Fishery Officer.

It is significant to report also that few, if any, salmon have been attracted to the powerhouse tailrace located on the Squamish River.

1.1.2 Jones Creek

The Jones Creek Spawning Channel was constructed in 1954 as a solution to the salmon problems created when the B. C. Electric Company constructed a dam at the outlet of Jones Lake, diverting the outflow through a tunnel to a powerhouse located adjacent to the Fraser River eight miles downstream from the mouth of Jones Creek. This diversion substantially reduced the normal flows in the lower reaches of Jones Creek, where a well-established run in the order of 5,000-6,000 pink salmon spawned every odd-numbered year, and small numbers of chum salmon and coho salmon spawned each year.

The channel, 2,000 feet long with a bottom width of ten feet, was designed to provide a spawning area equivalent to that lost in the stream. By use of a controlled intake, and baffles throughout the channel, a depth range of 1-2 feet and a velocity range of 1-2½ feet per second was provided with an inflow of 20 cubic feet per second. Gravel ranging in size from 1/4" to 1-1/2" was laid in the channel to a depth of from 12" to 18". A fish-diversion structure was constructed to prevent fish from entering the original stream bed which now serves as a flood channel for flows in excess of the channel requirements.

Four generations of pink salmon have spawned in the channel since its construction. As a result of consistently good egg-to-fry survival (four to six times the average of natural streams) this native run has increased progressively from the 400 fish that survived construction of the power project to 5,000. The following table shows the fry survivals and the history of this run.

Year	Total Number of Spawners	Number Spawning Above Counting Fence	Eggs Deposited Above Counting Fence	Fry Output	Percent Survival
1955	400	400	428,000	158,436	37.0
1957	1,456	1,056	947,000	363,000	38.4
1959	2,604	2,119	1,519,000	959,000	63.0
1961	5,000	4,388	3,789,300	1,100,000	29.0

The small runs of chum and coho have spawned successfully in the channel each year. These species are not followed closely enough to determine whether or not they are increasing in number, but the one year of adult and fry counts of chums show that egg-to-fry survival is of the same order as that for pinks.

The capital cost of the channel was $60,800.00, over half of which was spent on the diversion structure and the acquisition of land. Operating costs covering inspection, silt removal, and miscellaneous repairs and maintenance averaged $1,750 per year.

The eight-year history of the spawning channel showed it to be a successful solution to the hydroelectric problem at Jones Creek. In addition, it revealed the potential value of spawning channels as a fisheries development technique.

1.1.3 Bulkley-Morice River System (See also Section 2.3.1)

In January, 1961 the B. C. Power Commission announced plans to develop hydroelectric power on the Bulkley-Morice River system, tributary to the Skeena River. The initial stage of the development included construction of a 75-foot power dam on the Bulkley River at Moricetown; this to be followed in a second stage by construction of a storage dam on the Morice River near the outlet of Morice Lake which would raise the lake level approximately 20 feet.

In 1961 and 1962, biological studies carried out on the Bulkley River system defined the fisheries problems associated with the proposed hydroelectric development. In 1961, a tagging program conducted at Moricetown Falls, and a survey of the spawning grounds, provided details in connection with the magnitude and timing of the salmon migrations, and their distribution within the system. A similar survey in 1962 was restricted to sockeye salmon. The 1961 and 1962 sockeye smolt migration from Morice Lake and the 1962 sockeye fry migration from the Nanika River were studied to provide details on their magnitude and timing.

The following table sets forth the pertinent details with respect to the results obtained from the tagging program and fishway counts at Moricetown.

Species	Number tagged		Tags recovered in fishways		Fishway counts		Peak migration period (1961)
	1961	1962	1961	1962	1961	1962	
Sockeye	1,132	242	324	19	5,423	946	July 27-Aug. 5
Pinks	1,343	-	472	-	8,531	88	August 4-21
Coho	288	51	78	12	7,226	4,037	August 10-24
Springs	417	148	20	10	916	1,169	July 25-Aug. 4
Steelhead	150	17	9	-	792	207	August 17-31
Total	3,330	458	903	41	22,888	6,847	

On the basis of fishway counts and recovery of tags the calculations reveal that the following numbers of adults reached Moricetown.

Species	Calculated number of fish 1961	1962
Sockeye	18,043	9,908
Pinks	23,964	-
Coho	26,310	-

Although the 1962 sockeye escapement to Moricetown was calculated on the basis of only limited recovery data from the fishways, it is considered to represent a good measure of the sockeye population level at that point inasmuch as the Indian fishery records and spawning ground surveys were also considered.

The catch of the important Moricetown Falls Indian food fishery, as recorded in the weekly reports submitted by the local Fishery Guardian, is presented by species for the years 1956-62 in the following table.

Year	Sockeye	Chinook	Coho	Pink	Chum	Steelhead	Total
1956	1429	3200	1617	-	-	296	6542
1957	175	2440	461	-	-	52	3128
1958	165	2874	244	4	-	112	3399
1959	624	2508	1258	1021	-	343	5754
1960	Data not available						
1961	2092	2498	1157	1178	-	614	7539
1962	645	2163	1362	500	40	405	5115

Observations at Moricetown Falls confirm that the native fishermen, employing gaffs, seriously injure large numbers of sockeye salmon. It is estimated conservatively that there are at least as many fish injured and lost as there are actually caught. That the majority of these estimated losses represent an actual loss to the stock is borne out by the fact that virtually no injured sockeye salmon have been observed on the spawning grounds, and that very few even pass through the fishways.

The estimate of escapement above Moricetown Falls, as determined by making allowances for the catch of the Indian fishery and the estimated minimum losses from injuries, is set forth in the following table.

Species	Escapement above Moricetown 1961	1962
Sockeye	14,000	8,500
Pink	21,500	-
Coho	24,000	-

When it was found that there were too few fish available for a tagging-and-recovery program on the Nanika River, live and dead counts were made on the spawning grounds during September and October. On the basis of these counts the Nanika River sockeye escapement has been estimated at 5,000 in 1961 and 3,500 in 1962. In the light of the calculated 1962 output of 8.5 million fry the 1961 adult estimate appears to be low (See Section 2.3.1, Page 95). The 1962 adult estimate which was made under better observation conditions, is considered to be more accurate.

The existence of a significant sockeye salmon spawning population in Morice Lake was confirmed in 1961 and re-confirmed in 1962 when mature sockeye salmon were caught in gill-nets at 17 sites along the lakeshore. While sockeye were caught throughout the lake the greatest concentrations were found over an area of alluvial fans situated along ten miles of shoreline near its south end.

The discovery of juvenile salmon in the Atna River during the summer of 1961 prompted an examination of that system during the spawning season. The fact that mature sockeye were captured by gill-nets in Atna Lake in both 1961 and 1962 proved that a falls below the lake was not totally impassable, as had previously been reported.

In 1961, the water levels of the upper Bulkley River were too low to permit the entry of salmon during the sockeye migration period. In 1962, however, the local Fishery Officer reported an escapement of 400 sockeye salmon to Maxan Lake, which is situated in the headwaters.

Although no major concentrations of spawning pink salmon were located in 1961, scattered groups were observed throughout the lower Morice River and in the Bulkley River near the Morice confluence. A few were reported to have ascended the Morice River for as far as 20 miles. No spawning ground surveys were conducted in this area in 1962.

On the basis of visual observation made from fixed-wing aircraft and helicopter, it is estimated that 2,000-5,000 chinook salmon spawned in the upper ten miles of the Morice River in 1961. This area was not examined in 1962. A small number of chinook salmon have been observed in the upper Bulkley River and several specimens have been taken from sampling-gill-nets in Morice Lake.

While the surveys terminated before the start of coho spawning, migrants of this species were observed in the Bulkley, Morice, and Nanika Rivers, and some were captured in nets at several sites near the shore of Morice Lake. It is probable that this species utilizes all of the accessible streams in the Bulkley-Morice watershed.

Steelhead trout have been observed throughout the Morice River and several which were tagged at Moricetown Falls have been recovered by anglers in the Morice River.

A continuing study of the Morice River sockeye fry and smolts is being carried out and this work is discussed in the section dealing with the Nanika rehabilitation program (See Section 2.3.1, Page 95).

Temperature records were obtained at Moricetown Falls and from the Morice, Nanika, and Atna Rivers in both 1961 and 1962. In addition, vertical temperature series were recorded at four stations on Morice Lake during both years. These data are not available for presentation at this time.

1.1.4 Seton Creek

About May 1, 1962 an unusually large number of dead and injured sockeye salmon smolts were observed in the tailrace channel of the Seton Creek powerhouse, near Lillooet, B. C. Subsequent observations and investigations by the technical personnel of this Branch and the International Pacific Salmon Fisheries Commission attributed this mortality and injury to the part-load operation of the generating unit.

The Seton Creek hydroelectric development, which was completed in 1956, utilizes almost the entire flow of the Seton-Cayoosh watershed and that portion of the Bridge River flow which is diverted into Seton Lake via the Bridge River power development. The single turbine at Seton Creek has a rated capacity of 58,500 hp under a head of 147 feet, and discharges a maximum of 4,500 cfs at full load. A 12,500-foot canal, extending from a diversion dam at the outlet of Seton Lake, conveys the flow to the powerhouse which is located on the right bank of the Fraser River 4,500 feet downstream from the Seton-Fraser confluence. A minimum residual flow ranging from 200-400 cfs is released into Seton Creek below the diversion dam to meet requirements for migration, spawning, incubation and rearing of salmon.

Sockeye salmon migrate through Seton Creek, ascend the fishway at the diversion dam, and spawn in Portage and Gates Creeks, tributaries to Seton and Anderson Lakes respectively. Annual escapements to these spawning grounds range from approximately 1,000 to 9,000 fish. The Portage Creek escapements in the cycle years of 1954-58-62 averaged about 5,000 sockeye, while those at Gates Creek in the cycle years of 1952-56-60 ranged from 5,000-9,000. Estimates based on the fact that the 1962 smolt migrants were the progeny of 5,450 sockeye which spawned in Gates Creek in 1960 determined that the number of smolts passing through the Seton powerhouse in the spring of 1962 was in the order of 200,000.

The mortality rate for sockeye smolts passing through the Seton Creek turbine was determined as 9.2 per cent in experiments conducted in 1957 by the International Pacific Salmon Fisheries Commission, which employed, as test specimens, Chilko sockeye fingerlings with an average length of 3.38 inches. Plant conditions during the 1957 tests were: full load, 142 feet gross head, tailwater level 16 feet above the centerline of the runner distributor, and pressure in the draft tube near the underside of the runner of 1.5 psi above atmospheric.

In early May, 1962 when dead and dying sockeye smolts were observed in the tailrace, the Seton plant was operating under varying load conditions ranging from $\frac{1}{4}$ to full load. The gross head was 154 feet, and the tailwater level was 5 to 6 feet above the distributor centerline, with the probable result that sub-atmospheric pressures existed in the draft tube beneath the runner. The average length of the Gates Creek sockeye smolts examined was 4.75 inches. Dead and dying fish netted from the tailrace had gas bubbles in the fins, gills, and eyes; haemorrhages in the eyes and at the base of the fins were evident. Many fish also had injured opercula and haemorrhage of the isthmus, which were attributed to hydraulic shear forces from vortices, etc.

While no precise estimate can be made of the mortality experienced at the Seton Creek plant in 1962, observations of the tailrace during part-load operations indicated that mortality was much higher than that at full-load operation. Extrapolation of the results of experiments undertaken by the U. S. Army Corps of Engineers at Cushman No. 2 plant, and by the Washington State Department of Fisheries at the Big Cliff plant, indicates that the mortality rate at Seton Creek at ¼ load (0.28 gate) could be as high as 40 percent. The efficiency of the Seton Creek turbine at various loads is as follows:
42 MW (Full gate) = 92.5%; 30 MW (0.6 gate) = 90%; 20 MW (0.43 gate) = 81.6%; 10 MW (0.29 gate) = 65%. During the period April 15 to May 15, 1962, the Seton plant was operated at 30 MW or less for 46% of the time, and at 10 MW or less for 30% of the time. The plant operated at 10 MW for 2/3 of the peak day of sockeye migration.

It has been concluded that the part-load operation of the Seton Creek plant during the downstream migration of sockeye smolts leads to a very serious mortality at the power plant. The facts have been put before the B. C. Hydro and Power Authority, which owns and operates the power plant, with the recommendation that in future the Seton Creek plant be operated either at full-load (best gate), or no load, during the period of downstream sockeye migration from Seton Lake.

1.1.5 Somass River System

The Somass River discharges into the head of Alberni Inlet on the west coast of Vancouver Island. Two major headwater lakes, Sproat and Great Central, are drained by the Sproat and Stamp Rivers respectively, which unite to form the Somass River some four miles from the sea.

Historically, the system has supported substantial populations of sockeye, coho, chinook, chum salmon and steelhead trout. Maximum, minimum, and average spawning escapement by species, based on counts and estimates since 1940, are listed below.

	Minimum	Maximum	Average
Sockeye	6,000	180,000	51,000
Coho	7,000	100,000	31,000
Chinook	3,000	15,000	8,000
Chum	1,000	15,000	4,000

The commercial sockeye salmon fishery, which is mainly local, operates in Alberni Inlet and the adjacent waters of Barkley Sound. Sockeye catches in this fishery since 1940 have ranged from a low of 7,000 to a high of 77,000 pieces with an average annual catch of about 29,000. These catches include an unknown but probably relatively small contribution from the Henderson Lake stock. The commercial catch of coho, chinook, and chum salmon destined for the Somass River system is difficult to assess because of an intermingling of many stocks.

In 1955, the B. C. Power Commission announced plans for the construction of three hydroelectric developments on the Somass system - the first would entail the construction of a diversion dam on the Ash River, a major tributary of the Stamp, and diversion of a large portion of its flow to a powerhouse on Great Central Lake; the second development called for a new dam at the outlet of Great Central Lake and the diversion of a major portion of the Stamp River flow, along with the diverted portion of the Ash River, to a powerhouse on Sproat Lake; and finally, the construction of a dam and integral powerhouse on the Sproat River which would utilize the diverted flows and the normal Sproat River runoff. In recognition of the fisheries problems posed by these developments this Branch, since 1956, has conducted detailed annual surveys with a view to obtaining additional data with regard to the timing, distribution, and magnitude of the spawning populations and their progeny.

Estimates of the coho populations spawning in the Ash, Stamp, and Sproat systems, and of the chinook and chum escapements to spawning areas in the Stamp and Sproat Rivers were obtained in the fall of 1956. In 1957, these spawning ground surveys were continued and the sockeye escapements to spawning grounds in the headwaters of the Stamp and Sproat Rivers were enumerated; the former as they passed through a fishway at the outlet of Great Central Lake, the latter as they ascended a weir at the outlet of Sproat Lake. In 1958 and 1959, periodic spawning ground checks from boat and helicopter were made throughout the system. Daily counts of sockeye entering Great Central Lake (Stamp River) were continued annually until 1961. Following the 1957 counts, the Sproat Lake sockeye escapement was not assessed again until 1961. The increased reliability of spawning ground counts and estimates obtained in larger streams by personnel using skin-diving equipment prompted a reassessment of the Somass, Sproat, and Stamp River coho, chinook, and chum spawning in 1960 and 1961.

While complete presentation of the data resulting from these surveys is not within the scope of this report, an indication of the timing of the coho migration may be gained from the records obtained at the outlet of Great Central Lake which show that the average migration commences in late August, peaks in mid-September, and continues through to mid-October. Similarly, a four-year summary of the timing of chinook spawning in the three major spawning rivers shows that the modal peaks occur in the Stamp River in the last week of October; in the Sproat River in the first week of November; and in the Somass River just a few days after the Sproat. The annual variability in the timing of the sockeye migration is evidenced in the counts made at the Stamp Falls fishway, the Great Central Lake outlet, and the Sproat River weir from 1956 to 1961, which show that the migration usually commences about mid-June and extends through to the first week in October, with the peak normally occurring about mid-July, although the 1958 and 1961 peaks did not occur until the first week in September. The calculated estimates of escapements based on spawning ground and migration route counts are presented in the table on page 18.

Initially, downstream surveys established the timing and relative magnitude of the seaward migrations from the major spawning areas. A summary of the data collected throughout the system since 1957 reveals that active migration commences before mid-April, peaks from late April until mid-May, and virtually ceases by early June. Recently, emphasis has been placed on the need for obtaining reliable estimates of sockeye smolt production in Great Central Lake from which the downstream migrants can

Species	Location	1957	1958	1959	1960	1961
Sockeye	Stamp River at Great Central Lake	90,000	20,000	25,000	14,000	35,000
	Sproat River	*27,000	-	-	-	9,600
Coho	Stamp River at Great Central Lake	x 9,800	7,000	13,700	5,200	4,400
	Sproat River	x 3,300	-	-	-	5,900
Chinook (Spawning ground estimates)	Somass River	-	-	-	1,300	2,100
	Stamp River	x 1,900	-	-	1,300	8,500
	Sproat River	9,700	-	-	3,000	8,500
Chum (Spawning ground estimates)	Somass River	-	-	-	1,300	1,600
	Stamp River	-	-	-	0	100
	Sproat River	-	-	-	100	900

*Sproat River fishway and weir counts.

xStamp Falls fishway counts.

leave via alternate routes - Stamp River or Robertson Creek. The Stamp River portion of the migration was sampled with a 4' x 4' inclined-plane trap, the efficiency of which was determined from the recovery of marked smolts released upstream from the trap. A total count of the Robertson Creek migrants was facilitated by the installation of a Wolfe-type trap. Using these methods the smolt production of Great Central Lake was calculated to be 1.9 million in 1960 and 500,000 in 1961. Age analysis of scale samples taken from smolts and adults in 1957 and 1961 indicates that over 90 percent of the sockeye population migrate to sea in their second year and return to spawn in their fourth year. On the basis of a four-year cycle, the 1960 smolt production resulted from 20,000 spawners in 1958 while that of 1961 stemmed from 25,000 spawners in 1959. These represent an adult-to-smolt production ratio of 1:98 and 1:20 respectively.

In 1962, the sockeye smolt migration from Great Central Lake had commenced by March 27, when the trap was installed, and was virtually completed by June 14. A well-defined peak was not evident but the major migration occurred between April 20 and May 20. A preliminary estimate places the total population at 180,000 smolts, and assuming that these are the progeny of the 1960 escapement of 14,000 adults, this represents an adult-to-smolt production ratio of 1:13.

Approximately 15,000 sockeye were taken by the commercial fishery from May 29 to August 7.

The 1962 sockeye-counting program undertaken at the outlets of Sproat and Great Central Lakes determined that the migration commenced in the first week of June, increased to a broad peak during July, and continued at a relatively low level throughout August, September, and early October. In contrast to previous years, however, counts were made only on alternate days during the hours of maximum migration, and the counts for the intervening days were assumed to be the mean of the actual counts obtained on the preceding and following days. Periodically, 24-hour counts were made to establish the diurnal migration pattern. The results of nine 24-hour counts revealed that 88 percent of the sockeye migration occurred during daylight hours at the Sproat Lake counting site and 70 percent at the Great Central Lake counting site.

The 1962 sockeye escapement to the Somass River system was calculated to be 31,000, 17,000 of which entered Sproat Lake, while the remaining 14,000 entered Great Central Lake. The Great Central escapement plus that portion of the catch destined therefor (estimated to be 6,000 sockeye) is the return from the 1960 smolt emigration and represents a smolt-to-adult survival of 1.1 percent. Spawning ground counts of coho, chinook, and chum were not undertaken during the year.

As an adjunct to the annual sockeye counts obtained at the Great Central fishway and the Sproat weir, records of the visible injuries to migrants have been maintained since 1959. The average annual incidence of injuries at the Sproat River site has not exceeded two percent while that at Great Central (Stamp River) has ranged between five and eleven percent. In recent years, Departmental personnel have expressed dissatisfaction with the attractive qualities of the upper fishway at Stamp Falls at some river levels. On the assumption that this condition might contribute to delays and encourage attempts to surmount the series of falls which the fishway bypasses, a biological assessment of the fishway operation was undertaken in 1962. During the period July 20th to July 24th, when observers were stationed at the fishway and at the lowermost falls, the maximum hourly count of sockeye passing through the fishway was 72, while the maximum hourly count of attempts to surmount the falls was 1,236. Through the co-operation of MacMillan, Bloedel and Powell River Company, which controls the outflow from Great Central Lake, the river discharge was increased from 1,170 cfs to 1,740 cfs during a 24-hour period on July 25th and simultaneous counts during this period revealed that the hourly fishway counts had increased to a maximum of 306 while the number of attempts at the falls had decreased to a maximum hourly rate of 146. In the 24-hour period following resumption of "normal" discharge, the hourly fishway counts did not exceed eight while the attempts at the falls reached an hourly maximum of 898.

In addition to counting the total number of attempts to ascend the lower falls, the observers also kept a record of the number of apparent successes and the possible injuries. At "normal" discharge, it was found that less than six percent of the attempts were apparently successful, and more than ten percent were assumed to have sustained injury due to forcible contact with the canyon walls. With increased discharge, over seven percent of the attempts were judged successful and potential injuries rose to nearly twelve percent.

No change in weather conditions or stream temperature occurred during the assessment period, and recruitment to the population holding below the falls was observed to be negligible. It appears therefore that the improved attractive qualities at the fishway entrance, coupled with the increased velocities and turbulence at the falls resulting from the increased discharge, significantly increased the efficiency of the fishway and greatly reduced the potential losses attributable to damage and delay.

In the light of these and previous observations remedial measures to improve the attractive qualities of the Stamp Falls fishway will be undertaken in the summer of 1963 (See Section 2.1.5, page 87).

1.1.6 Puntledge River

The fisheries problems on the Puntledge River arose in 1954 when the B. C. Power Commission took over the original water licence held by Canadian Collieries (Dunsmuir) Ltd., and rebuilt the hydroelectric installation to increase its capacity from 7,000 kw to 35,000 kw. This increase was accomplished by the construction of a new powerhouse, a new impounding dam, and a new intake, which could divert up to three times as much water as that which had been utilized by the original development in a period of over 30 years.

The fisheries problems created by this redevelopment are associated, primarily, with a population of approximately 3,000 early-run chinook salmon which spawn upstream from the powerhouse. The main problems are:

A. Safe Passage of Downstream Migrants -

As a result of a study which showed that 30-40 per cent of young salmon passing through the powerhouse turbines are killed, temporary salvage measures have been employed each year to trap and remove a substantial portion of these fish from the intake. This program reduced the numbers of young fish entering the turbine by 35 percent but it was never considered to be more than a temporary means of alleviating this problem.

B. Passage of Adult Salmon Upstream Beyond the Powerhouse -

Adult salmon are delayed at the tailrace pool of the powerhouse where they are attracted to the large volume of cool water emanating from the turbines. During this delay considerable injury, fatigue, and mortality are sustained as a result of these fish moving into the draft tubes, fighting the strong currents, and being thrown back against the structure. The installation of a weir upstream from the powerhouse provided the means of assessing these injuries and of obtaining an indication of the immediate mortality. Observations on the spawning ground revealed the extent of the latent mortality which occurred when high temperature accelerated fungus intrusion of the minor injuries, causing a large percentage of the recorded mortality. The Power Commission carried out a series of water releases each year and these achieved some success in moving the fish away from the influence of the tailrace and upstream toward the spawning ground. They also installed a guard rack to prevent fish from swimming into the draft tubes. These temporary measures only slightly reduced the incidence of injury and mortality.

C. Passage of Upstream Migrants Over the New Impounding Dam - Reconstruction of the impounding dam rendered the existing fishway inoperable so the Power Commission constructed an entirely new fishway, based on the design prepared by this Branch, to allow fish to continue to enter Comox Lake.

D. Maintenance of Minimum Flows for Migration, Spawning, Incubation, and Rearing -

The threefold increase in the rate of water usage at the new power development could result in inadequate flows for fisheries purposes at certain times of year. Accordingly, a schedule of minimum flow requirements was prescribed to ensure that adequate flows are maintained in the following river reaches.

- downstream from the powerhouse, for spawning and incubation of chums, pinks, and the late-run chinooks.

- between the powerhouse and the chinook spawning grounds, located upstream from the diversion dam, to facilitate the upstream and downstream migrations. Determination of these requirements relates primarily to the provision of adequate flows for the adult migrations at Stotan and Nib Falls, the transportation requirements of the downstream migrants, the requirements of trout and salmon rearing in this reach, and the need to provide suitable water conditions for anglers.
- between the impounding dam, and the diversion dam and plant intake, to provide for spawning and incubation of the upriver chinook run. Fulfillment of this requirement has not proved to be a problem inasmuch as the powerhouse flows are conducted over this reach.

The investigations into these problems were completed in 1958 and the covering report recommended that:

- a louver screening system be installed at the intake to prevent the entry of downstream migrants.
- a barrier dam, fish collection works, and a trucking system be employed to facilitate the transportation of upstream migrants from below the powerhouse to the head pond of the diversion dam.
- a fishway be built at the new Comox Lake impounding dam (now built).

- a revised schedule of minimum flows be adopted in order to allow for reduced flows in the reach between the spawning grounds and the powerhouse.

The Power Commission estimated that the proposed fish facilities would cost $720,000, and on the grounds that these costs could not be justified economically, or that the Department should, at least, underwrite a substantial portion of their costs, it took no action to implement the recommendations laid down in the Report.

In December, 1961 the Government of British Columbia appointed Dr. Henry F. Angus as sole Commissioner to inquire into the problems on the Puntledge, including the economics of the proposals. At the hearings which were convened in March, 1962 in Vancouver and Courtenay, major briefs were presented by the Power Commission and this Department. An additional 15 submissions supporting the fisheries case were presented by the Provincial Fish and Game Branch, the fishing industry, the fishermen's union, various commercial and tourist interests, and several Fish and Game Clubs. Two additional submissions gave a small measure of support to the B. C. Power Commission's case.

Upon completion of the Inquiry, Dr. Angus submitted a 33-page, two-part report to the Government of British Columbia and this was released to the press in September, 1962. The first part dealt with the immediate issues in line with his terms of reference. His analysis and discussion of all aspects of this case led him to the following recommendations.

> "That the works suggested by the Department of Fisheries be constructed as expeditiously and economically as possible; and that the entire cost of these works be paid by the Power Commission (or its successor)".

The second part of the report dealt with wider issues and pointed to the Puntledge as an example of the difficulties associated with multiple-resource development. Dr. Angus expects that conflicts of interests, such as that which arose on the Puntledge, will recur and he suggests that political and legislative action are required in order that future multiple-interest resource developments may be undertaken without encountering such obstacles.

No action has been taken to date to implement the recommendations of the Inquiry, nor has the Department been given any information concerning the future course planned by the Provincial Government or the Power Commission's successor, the B. C. Hydro and Power Authority.

1.1.7 <u>Whitehorse Rapids</u>

The Whitehorse Rapids hydroelectric development of the Northern Canada Power Commission is situated on the Yukon River approximately two miles south of the city of Whitehorse, Yukon Territory. Its main features include a 60-foot-high earth-fill dam with integral concrete spillway;

a power canal by means of which flows are conducted to the plant intake; and a powerhouse, located some 2,000 feet downstream from the dam, which houses two 7,500 hp propellor-type turbines. Construction of this development was initiated in the spring of 1957 and the plant was brought into service in November, 1958.

The Yukon River, in the vicinity of Whitehorse, supports important populations of resident species, such as Arctic Grayling, Lake Trout, Least Cisco, and others, and it serves also as the migration route for an important run of chinook salmon destined, primarily, for the M'Clintock River, tributary to Marsh Lake. While precise population estimates were not available until after the power development came into being they were known to be substantial enough to warrant the construction of suitable fish-protective facilities at the dam and powerhouse. In this connection, the local resident species were important from the recreational viewpoint whereas the chinook salmon contribute to substantial native subsistence fisheries not only on the local level but also along the lower reaches of the Yukon River throughout the Yukon Territory and the State of Alaska.

In 1957, construction of the dam had not progressed to the point where the structure interfered in any way with the normal migration patterns. By 1958, however, all river flow was being diverted through the incomplete concrete spillway where the velocity was so swift that it created a total barrier to all upstream migrants. Emergency salvage operations, consisting of a temporary timber fishway leading to a holding pool from whence the fish could be trucked around the obstruction, were therefore employed, but when this proved to be ineffective (reasons unknown), fish were netted below the dam, placed in a tank truck and returned to the river upstream. By 1959, the permanent fish facilities had been constructed and these have been in service ever since.

The permanent fish facilities consist of a powerhouse collection system and bypass channel by means of which fish attracted to the flows issuing from the powerhouse are led back to the river several hundred feet upstream from the tailrace; a barrier dam, located between the powerhouse and the power dam, which constitutes a total barrier to all upstream migration and serves to lead fish to the right (east) bank location of an integral fishway entrance; and a weir-type fishway, approximately 1,200 feet long, by means of which fish can ascend to the forebay of the power dam from whence they can continue upstream unimpeded. No facilities have been provided for downstream migrants as it was considered that losses, if any, would be light.

A counting trap which was incorporated into the fishway near the exit has been operated each year since the facilities came into service. While it was hoped that it would be possible to count all fish passing through the structure excessive debris and turbidity in the spring have made it impossible to do so for species other than salmon. Reliable counts have been obtained, however, for the latter species, which migrate upstream past the site in August. The actual counts of chinook salmon have been:

1959 - 1,054
1960 - 660*
1961 - 1,061

In 1962, it was not possible to assign an individual to this project on a full-time basis and a complete count therefore was not obtained. However, the local Fishery Officer, in co-operation with the operating personnel of the power station, obtained some daily counts and these in conjunction with visual observations of numbers of fish in the river below the fishway entrance led to the conclusion that an estimated 1,500 chinook salmon migrated through the fishway in 1962.

1.1.8 Fulton River

Early in 1961, the B. C. Power Commission announced plans for a hydroelectric development on the Fulton River, which would consist of a dam at the outlet of Fulton Lake, a powerhouse located some distance downstream at the base of the falls, and an interconnecting tunnel and penstock. Although the entire development would be located

*Estimated 400 additional chinook salmon taken in native fishery which was operated downstream this year only.

above the upstream limit of salmon migration, its possible effects on the lower reaches of the river required that all relevant factors be assessed to ensure that the fisheries interests could be adequately protected.

The Fulton River constitutes the most valuable sockeye salmon spawning area tributary to the main basin of Babine Lake. During the years 1953-60 the sockeye salmon escapement to this river, as estimated by the local Fishery Officers, have ranged from 17,000 to 140,000, with an annual average of 90,000.

In August of 1961, a study was initiated to determine the magnitude, timing, and distribution of the sockeye salmon spawning escapement. This study included a tagging program located near the mouth of the river and an extensive dead-recovery program on the spawning grounds. The spawning population was also sampled for size, composition, egg content, and success of spawning.

A downstream-sampling program, employing equipment which permitted vertical and horizontal sampling within a cross-section of the stream, was conducted on the Fulton River during May and June of 1962, to measure the fry output from the 1961 spawning, and to define the period of downstream migration.

Temperature records were taken during the months of salmon migration at stations located at Fulton River and Fulton Lake.

A summary of the tagging-and-recovery data, and the calculated adult escapement, fry output, and egg-to-fry survival are presented hereunder.

Adult	Number tagged	7,185
	Number of tags recovered	3,590
	Number of dead recovered	98,527
	Calculated number of fish	189,049
	Calculated egg deposition	237,705,770
Fry	Calculated number of fry	25,323,613
	Percent egg-to-fry survival	10.7

The sex ratio of the 1961 adult escapement has been calculated at 45.2 percent females, 44.6 percent large males, and 10.2 percent jacks.

A few adult sockeye were present on the spawning grounds when the study was initiated on August 11, but no significant numbers appeared until August 24. The peak period of entry to the river was August 30 to September 15 and spawning reached a peak during the last two weeks of September.

The sockeye fry migration which had just begun when the downstream studies were initiated on May 2, was still in progress when sampling was terminated on June 21, but the bulk of the migration had occurred between May 15 and June 15, with May 29 being the calculated peak night.

Fry migration at the sampling site was restricted almost entirely to the hours of darkness, with the nightly peak consistently occurring between 11:00 p.m. and 1:00 a.m., P.S.T.

An impassable falls, approximately four miles from the mouth of the Fulton River, constitutes the upstream limit of salmon migration. With the exception of a few salmon which utilized the area immediately below the falls, spawning was confined, primarily, to those reaches lying between the lower one-third mile and the upper one-half mile of the river.

In 1961, water temperatures were recorded at two sites: one near the outlet of Fulton Lake and the other at the downstream end of the spawning grounds. In 1962, temperatures were recorded at the lower site only. While temperatures in excess of 70°F were recorded at the beginning of adult migration the daily mean temperatures at the downstream site, during the peak period of migration and spawning, ranged between 47.5° and 61.0°F. During the 1962 fry migration the daily mean temperatures recorded at the lower site ranged from 39.3° to 54.5°F.

During July and August of 1961, temperatures above the falls were consistently lower than those at the downstream site, with the maximum recorded increase of daily mean temperature between the two sites being 4.7°F which occurred on August 14. During September and October the situation was reversed.

Vertical temperatures were recorded at Fulton Lake during the period June to October of 1961. A thermocline which was first noted on July 23 at a depth of 12 feet, was situated at approximately the same depth on August 22, but by September 18 it had descended to 39 feet. By October 16 the lake had approached an isothermal condition.

A comparison of temperatures in the lake and river on July 23 and on August 22, indicate that the river was drawing, in part, from within the thermocline; and it was concluded from this that a surface spill over the proposed dam at the lake outlet could cause dangerous temperature increases on the spawning grounds.

1.1.9 Campbell Diversions

In the mid-1950's the B. C. Power Commission (now the B. C. Hydro and Power Authority) proposed to divert part of the flows of the Salmon, Quinsam, and Heber Rivers from their normal courses to the Campbell River watershed in order to increase the hydroelectric output from the existing generating stations on that system. The Salmon and Quinsam Rivers support valuable runs of coho and pink salmon in addition to a few chinook salmon and steelhead trout, while the Heber River is noted primarily for its steelhead trout.

While the proposed point of diversion, in each instance, was located above the normal upstream limit of salmon and trout migration, it was foreseen that there was a need to specify minimum flow requirements for fisheries purposes in the lower reaches of each of these rivers. Otherwise, unprecedented low flows might occur and these could be expected to result in fisheries losses. However, available information was not such that these minimum flow requirements could be readily determined at that time. Accordingly, arrangements were made with the power agency whereby construction of the diversion works was allowed to proceed immediately on the understanding that their operation would be subject to providing minimum flows as soon as they could be defined. Comprehensive stream-gauging programs were therefore initiated immediately with a view to collecting these data as soon as possible. In this connection, a complete schedule of flow requirements was not developed until 1962, and these have now been accepted by all parties. These are:

A. Salmon River

(a) a minimum flow of 100 cfs at the head of the spawning grounds during the migration and spawning periods (August 20 - November 15).

(b) a minimum flow of 83 cfs throughout the balance of the year.

(c) if natural flows are less than those prescribed in (a) and (b) all diversion shall cease and the entire flow will be released to the lower river.

B. Quinsam River

(a) a minimum flow of 60 cfs at the head of the spawning grounds during the spawning and migration periods (September 1 - November 15).

(b) two feet of storage in the Upper Quinsam Lake reservoir to be reserved exclusively for fisheries purposes in augmenting releases below the point of diversion at those times when inflow is not sufficient to meet the fisheries requirements.

(c) the rate of diversion may be restricted during the balance of the year if necessary in the fisheries interests.

C. Heber River

The rate of diversion may be restricted at any time of year if necessary in the fisheries interests.

While it was originally intended that the agreements reached in the case of the Quinsam and Heber diversions should be as well-defined as those on the Salmon, the complex runoff patterns of the former and the relative isolation of the latter have proven to be such that the cost of obtaining the necessary basic data is out of all proportion to the benefits gained thereby. Under the circumstances the conditions outlined in the foregoing seem to be a reasonable compromise, and, in fact, they appear to be working out well in practice.

1.1.10 Rampart Canyon

During the last several years the U. S. Corps of Engineers has been conducting preliminary feasibility studies in connection with a proposed gigantic power development on the Yukon River at Rampart Canyon, approximately 75 miles from Fairbanks, Alaska. The development under study contemplates the construction of a 440-foot-head dam on the Yukon main stem which would alienate all salmon runs to the upper Yukon River in the Yukon Territory, if suitable fish passage facilities are not incorporated therein. Since these runs contribute to an important native subsistence fishery in the Yukon Territory this Branch has been concerned with the proposed development.

Preliminary engineering and economic studies related to this development reportedly have been favourable. More detailed studies are now in progress and in this connection the sum of $300,000 has been allotted to U. S. Fish and Wildlife agencies to determine the presence and relative abundance of fish and game which might be affected by the proposed hydro development. While the report on the outcome of these studies will not be completed until June 30, 1963 an excellent liaison has already been established between this Branch and the responsible U. S. fisheries agencies in order that the Department can keep abreast of not only the results of the Rampart fisheries surveys, but also the progress being made on the entire project. To this end, representatives of this Branch met with senior officials of the U. S. fisheries agencies in Juneau, Alaska in April, 1962 in order to impress upon them the importance which Canada attaches to the Yukon salmon runs (See Section 1.1.7, page 27)

and to be briefed on the progress of the U. S. fisheries studies, particularly as they may relate to the Canadian interests. A further meeting is contemplated for the spring of 1963 at which time the results of the 1962 surveys will be reviewed.

1.2 WATER SUPPLY

1.2.1 Capilano River

The Cleveland Dam, constructed on the Capilano River in 1954 by the Greater Vancouver Water District to improve its domestic water supply system, is over 300 feet high, and the accompanying reservoir is three and one-quarter miles long. Small populations of pink and chum salmon spawn in the reaches below the dam and coho salmon and steelhead trout utilize spawning and rearing areas located above the reservoir.

Joint investigations undertaken by this Branch and the Provincial Fish and Game Branch, and negotiations with the Water District, resulted in the construction of the following fish protective works: a diversion weir, fishway, holding pool, brailing pool, hopper pool, hopper, and tank truck. These facilities have operated efficiently and no insurmountable problems have been encountered to date.

The annual numbers of fish transported above the dam since trapping and trucking operations were initiated in July, 1954 are listed below.

Date	Coho	Steelhead
1954	2915	47
1955	4999	137
1956	1841	82
1957	5062	25
1958	3789	95
1959	2785	214
1960	3663	161
1961	2119	39
1962	2636	87

A ski-jump-type spillway was incorporated into the dam to minimize the losses of downstream migrants. In 1955 and 1956, joint studies conducted at the spillway indicated that the mortalities of coho and steelhead smolts, over a widely varied range of discharges, averaged 57 percent and 69 percent respectively. These mortality rates were confirmed by further tests conducted in 1958 and 1959.

In conjunction with the spillway tests, additional studies, involving the enumeration of coho smolts entering and leaving the reservoir, were conducted during the period of downstream migration. These studies indicated that some residualism is occurring within the reservoir where smolts are rearing to both the sub-2 and sub-3 stages.

While detailed studies have not been undertaken on the Capilano River since 1959 this Branch has maintained an accurate record of the numbers of coho and steelhead transported around the dam.

1.2.2 Alberni Pulp Mill (Sproat Lake)

The water supply to the MacMillan, Bloedel and Powell River Limited pulp mill at Alberni is drawn by pumps from the head of Stirling Arm of Sproat Lake from whence it is transported approximately five miles by pipeline to the mill.

Important stocks of sockeye and coho salmon are found in the Sproat system, and Sproat Lake serves as their rearing area. To protect these species the intakes to the pump well were fitted originally with acceptable-type stationary screens, but successive boosts in the mill water demand in the interim were accompanied by increases in the approach velocity to the screens. By 1958 salmon fry and smolts were first noticed in numbers impinged on the screens and it was concluded that the velocity of approach was too high to ensure the escape of juvenile fish from the screen. The Company's cooperation was enlisted and plans to remedy the problem were prepared. These involved the construction of a new intake structure, fitted with two self-cleaning travelling screens and a double row of timber sheet piling which formed a channel through which water was drawn from the intake to the existing pumphouse. At that time the maximum expected mill demand was 39,300 US gpm (87 cfs) and the intake was so designed that the maximum velocity of approach at minimum submergence would not exceed the accepted standard velocity of approach of 0.40 fps for this type of installation. These works were constructed in 1959 and there has been no evidence since then to indicate that young salmon are being killed at this site.

In 1962, however, the mill was undergoing another major expansion which envisaged an immediate increase in demand to 52,300 US gpm (116 cfs) with provision for an ultimate demand of 65,300 US gpm (145 cfs). To facilitate these plans the Company has constructed a new pumphouse adjacent to the original one, and as a result of Company liaison with the Department, the two intake bays have been fitted with self-cleaning travelling screens similar to those at the existing pumphouse. The excavation for two additional intake bays and a future expansion of the new pumphouse have been completed but construction will not be initiated until the need becomes apparent (probably in several years).

Neither of the pumphouses are equipped with fish bypasses and this deficiency has been becoming a matter of increasing concern as the mill continues to expand. In this connection, the pumphouses are located at the head of Stirling Arm, and when migrants are blocked at the intake screens they must reverse their direction of migration for approximately 1½ miles in order to obtain egress from the

Lake via the only outlet, Sproat River. When the original pumphouse was constructed it was concluded that the amount of water to be diverted was so small in comparison with normal lake outflows that only a relatively small proportion of the downstream migrants would be attracted to the diversion; and that those fish that were so attracted would easily find their way to the natural outlet when they found their path blocked by the intake screens. This theory proved to be correct inasmuch as there have been no reports of unusually large concentrations of migrants in the vicinity of the pumphouse at any time.

Preliminary studies have indicated that construction of a suitable bypass, if feasible, would be an extremely costly undertaking but the Company has been advised that any future expansions, beyond those already announced, will be subjected to a more critical review than those in the past. In the meantime the two pumphouses now in service will be watched very carefully in order to determine whether or not the problem outlined above is likely to materialize.

1.2.3 Elk Falls Pulp Mill (Campbell River)

The water supply for the Crown Zellerbach (Canada) Limited, pulp mill at Duncan Bay, near the town of Campbell River, is drawn from the Campbell River by means of a diversion canal and pumphouse, from whence it is conveyed through a pipeline some two miles to the mill. The main spawning grounds for a valuable stock of chinook salmon are situated between the point of diversion and the John Hart powerhouse, approximately one mile upstream.

When the diversion was first contemplated in the early 1950's the Department contacted the Company, and as a result of technical discussions the Company agreed to install stationary screens to exclude fry and smolts from the pumphouse. These screens subsequently proved to be effective but it was found that because they were located at the end of a 100-foot-long intake channel from the river there was a need to provide a suitable bypass to return fish from the face of the screens to the river. Accordingly an 8-inch bypass pipe, approximately 150 feet long, was installed for this purpose. It proved to be rather ineffective because of the low head available but no large accumulations of fish have been recorded at the face of the screens.

In 1962, when the Company announced plans for increasing this diversion, this Branch met with its representatives to review the plans in order to define the possible effects on the local fish stocks. As a result of subsequent negotiations it was agreed that the existing pumphouse and a new one to be constructed alongside would be fitted with self-cleaning travelling screens which would provide for a maximum approach velocity of 0.40 feet per second at minimum submergence and the maximum expected demand of 40,000 US gpm (89 cfs). Furthermore, it was agreed that the bypass should be abandoned as it had been largely ineffective for its intended purpose. In its place the Company agreed to excavate the new intake channel in such a way that its downstream (referring to the direction of river flow) bank would be flared out at an angle of 45 degrees to the upstream bank, which would be perpendicular to the river. In this way the pumphouse, in effect, was moved to the edge of the river and instead of being confronted with a dead-end channel, as previously existed, fish which are attracted to the intake are expected to continue downstream readily when they approach the screens. The quantity of water diverted is small in comparison with the regulated minimum flows emanating from the powerhouse upstream so it has not been necessary to date to establish a minimum flow for fisheries purposes in the lower river.

Work on this project was underway in 1962 and the situation will be watched closely when the installation comes into service in order to be certain that it is fulfilling the intended purpose.

1.2.4 Nanaimo Pulp Mill (Nanaimo River)

In 1949, MacMillan, Bloedel and Powell River Ltd., as it is known to-day, was constructing a pulp mill at a site on tidewater approximately five miles south of the city of Nanaimo. At the same time it was constructing along the banks of the Nanaimo River, some seven miles away, a number of Ranney wells which were expected to draw a clear, filtered water from an "underground lake" for use in fulfilling the mill's water demands.

Nanaimo River supports important runs of chinook, coho, and chum salmon, and steelhead trout and while it was recognized that the Company would not be drawing water directly from the Nanaimo River, this Branch considered that the latter probably was at least partly responsible for recharging the "underground lake", and there was a need to specify a minimum flow in the lower river for fisheries protection. As a result of subsequent studies the Department recommended to the Company that a minimum flow of 39 cfs (minimum daily flow recorded in the river up to that time) be provided in the lower river at all times.

When the mill came into production it was reported that the Ranney wells were proving to be incapable of fulfilling the mill's demands. In any event, the Company began construction, almost immediately, of a pumphouse, near the sites of the Ranney wells, which would draw water directly from the Nanaimo River. The Company subsequently agreed to install stationary screens at the intake to the pumphouse, but because the structure was to be located at the river edge there was no need for a bypass. Furthermore, the Company agreed to maintain the 39 cfs minimum flow requirement for fisheries purposes in the river below the point of diversion.

By 1953, the Company had constructed a storage reservoir at Fourth Lake, in the headwaters of the Nanaimo

River, for use in augmenting normal low flows in the lower reaches of the river. At this time the Company was authorized by the Comptroller of Water Rights to divert from the system at a maximum rate of 100 cfs, and the addition of 30,000 acre-feet of live storage ensured that the Company would be able to fulfill its mill demands and the recommended minimum flow for fisheries at all times.

In 1962, however, the Company applied to the Comptroller of Water Rights for a license to divert an additional 25 cfs (an aggregate of 125 cfs) from the Nanaimo River. To facilitate this diversion the Company proposed to construct a second pumphouse on the Nanaimo River alongside the existing structure. This Branch objected to the application pending approval of fisheries protection at the new pumphouse and assurance that adequate flows would be maintained in the river below the point of diversion.

No problems were encountered in convincing the Company that the intakes to the new pumphouse should be adequately screened to prevent entry of small fish, and it has agreed to install self-cleaning travelling screens in the intakes to both pumphouses. Since there is no need for a bypass at either intake the fisheries problems associated with the pumphouses have been resolved satisfactorily.

With regard to minimum flows in the lower river the Company has been approached with a view to providing, at least in some years, a larger minimum flow than that which has been required in the past (39 cfs). Evidence which has come to light since the initial minimum flow recommendation was advanced clearly indicates that this should have been more in the order of 75 cfs, based on the mean of the minimum mean monthly flows over the period of record, rather than 39 cfs, which was the minimum daily flow recorded up to that time. Furthermore, periodic reports from the Department's local field officers suggest that 39 cfs is definitely too low for fisheries purposes. Accordingly, this Branch initiated studies to determine whether or not it would be possible to boost the minimum flow requirement without impairing the output of the mill.

These studies disclosed that in the driest of the 13 years studied it would not be possible to provide more than 39 cfs, as even this amount would require almost full drawdown of the reservoir. However, these studies also disclosed that in most years a minimum flow requirement of 39 cfs will result in only moderate drawdowns of the reservoir and that it therefore would be possible to provide more than 39 cfs most of the time. In the light of this development a rule curve for operation of the Fourth Lake reservoir was submitted to the Company. This curve contemplated a minimum flow of 75 cfs at those times when there was not a water shortage, but allowed for a reduction to 39 cfs in extreme drought periods. Computations which assumed that the rule curve was employed during the 13 years of discharge records disclosed that the extreme drawdowns would have been no more severe than those required for a continuous minimum flow of 39 cfs, although an average minimum flow in the order of 60 cfs would have been maintained. As this seemed to be a reasonable solution to this matter the rule curve was discussed with representatives of the Company. To date, however, no final agreement has been reached and negotiations will be continued in 1963.

1.3 MULTI-PURPOSE DEVELOPMENTS

1.3.1 Fraser River Board

Recognition of the growing need for an advisory board to recommend a resources development program for the Fraser River basin resulted in 1949, in the formation of the Dominion-Provincial Board, Fraser River Basin, which consisted of five members each from the Federal and Provincial governments. During its term in office this Board collected a wealth of basic data in connection with the resource potential of the basin but it was superseded in 1955 by the Fraser River Board, which was charged with more specific terms of reference.

The Fraser River Board consists of four members - the Director, Pacific Area, of the Department of Fisheries, and the Director of the Water Resources Branch of the Department of Northern Affairs and National Resources, representing the Federal Government; and the Comptroller of Water Rights, and the Surveyor-General, of the Department of Lands and Forests, representing the Provincial Government. This Board fulfilled its specific terms of reference with its submission of an Interim Report on Flood Control in June, 1956, which was followed, in June, 1958, by the Preliminary Report on Flood Control and Power - the latter, for the most part, superseding the earlier report.

The Preliminary Report discusses three alternative schemes for the optimum development of the hydroelectric potential of the system, each of which would be capable of providing over 5,000,000 kw of power while affording the desired degree of flood control.

These studies were not restricted to a complete plan of development of the basin because the Board felt that the urgent need for flood control, as demonstrated by the flood of 1948, was of more immediate importance than the production of power, and because of the serious fisheries problems associated with full development. Studies of alternative systems of partial development were carried out therefore to determine whether or not they could meet the following four requirements.

- To provide the desired degree of flood control.
- To be compatible with the fisheries interests.
- To be economically self-supporting through the production of power.
- To form an integral part of full development.

Although it was found that none of the partial, or minimum systems could fulfill these four requirements, System "A", as it is known, was considered to be the most suitable as it came closest to achieving this objective. This system, which would have a peak capacity in the order of 1,000,000 kw, consists of 11 sites: five on the Clearwater River, three on the Cariboo River, one on the Fraser above Prince George at Ollson Creek, one on the McGregor River, and one at Stuart Lake.

The Preliminary Report stressed the fact that the planning to date had consisted only of academic studies, and it recommended that a program of site surveys, beginning with System "A", be initiated to determine whether or not the projects were feasible. It recommended also that surveys be initiated to study the fisheries problems associated with the development of this System. The Report suggested that a sum of $1,845,000, to be spent over a period of three years, would be adequate for these additional studies, and it recommended that $200,000 of this amount be allotted to the requisite fisheries investigations.

The Governments' acceptance of these recommendations resulted in the re-establishment of the Board in the summer of 1959 under terms of reference which, in effect, authorized the studies recommended in the Preliminary Report. The Board was directed also to submit a final report on or before September 30, 1963.

Early in 1960, the Board engaged a biologist and two technicians to carry out the recommended fisheries studies under the direction of the Department of Fisheries.

During the period 1960-1962 fisheries studies included extensive air and ground surveys to obtain information on the numbers, timing, and distribution of the runs which might be affected by the System "A" dams. Good counts of adults were obtained on the Clearwater River but results of a similar order were difficult to obtain on the McGregor and Fraser Rivers because of turbid water conditions. Two fishwheels were installed on the Upper Fraser to sample adult runs to that area.

Inclined-plane traps, which were installed near the mouth of the Clearwater River and on the Fraser River upstream from Prince George, in order to obtain details with respect to the downstream migrations, resulted in good catches at the Clearwater site while those at the Fraser site were quite low.

Thermographs, installed at a number of sites to obtain water temperature data, were serviced and maintained in collaboration with the International Pacific Salmon Fisheries Commission.

The initial System "A" has been altered substantially as a result of information obtained from the drilling programs and other detailed studies. While the five sites on the Clearwater River have not been changed appreciably, two of the three sites on the Cariboo River have been eliminated on the basis of their geological conditions. It has been necessary therefore to increase the proposed height of the dam at the third site in order to create additional storage capacity to offset these losses.

The Ollson Creek site, which was probably the key project in the entire System, had to be discarded when it was found that foundation conditions were very poor. It was replaced by the Grand Canyon site, which is on the Fraser River upstream from its confluence with the Bowron River.

A special report on the fisheries problems associated with the proposed Stuart Lake dam was prepared jointly by this Branch and the Salmon Commission, for submission to the Board in August, 1962. This Report recommended that the Stuart Lake site be withdrawn from the System on the grounds that:

(1) the development is not compatible with the fisheries interests.

(2) it represents only a minor contribution to the overall flood control requirements.

(3) equivalent flood protection can be obtained more economically by other means.

The site was subsequently deleted from the System.

The McGregor damsite was not changed but consideration is now being given to a proposal whereby the McGregor River would be diverted into the Peace River.

This revised system, which is known as System "E", includes five dams on the Clearwater River, one on the Cariboo River, one on the Fraser River at Grand Canyon, and one on the McGregor River.

Engineering surveys were carried out during the summer and fall of 1962 on the Clearwater, Upper Fraser, and McGregor Rivers to obtain data necessary for the design of suitable fish facilities. Following the completion of the drilling program and the biological and engineering surveys in the fall of 1962, detailed office studies were initiated to determine the fisheries requirements at each of the proposed dams.

In general, all of the Board's studies are progressing satisfactorily and it is expected that they will be completed in time to report to the two governments by September, 1963, as contemplated by the terms of reference.

1.3.2 Okanagan River Flood Control Project

The Okanagan River is one of the two remaining tributaries of the Columbia River which supports sockeye salmon. While these fish are exploited by the United States commercial fishery in the lower Columbia, their spawning grounds are situated entirely in Canada, primarily in a four-mile reach of the river upstream from Oliver, B. C.

Historical records show that the Okanagan River has supported sockeye spawning over the past 50 years, but by 1939 this run was at a low level, and this decline has been attributed to the numerous irrigation and other water-use projects on the stream. In 1939, when the construction of Grand Coulee Dam alienated the spawning grounds of the upper Columbia River, the Okanagan River was one of the streams selected to receive transplants in a program implemented by the U. S. Government to transfer the upper Columbia sockeye to other parts of the Columbia basin. Large numbers of adult and fingerling sockeye were planted in the Okanagan in the period 1939 to 1943, and it has since become a major contributor to sockeye production in the Columbia River.

In 1946, a Board of engineers which had been commissioned to study the flood problems of the Okanagan valley, submitted a report which recommended that new storage dams be constructed on the major headwaters; that the existing diversion dam, employed for irrigation purposes, be replaced; and that a new straight channel, with a greater discharge capacity than the river bed, be constructed in the reach designated as "Section C", which lies between the town of Oliver and Osoyoos Lake, 15 miles downstream. The diversion dam constitutes the upstream limit of salmon migration and the Board's recommendation that this structure be replaced would not alter this situation. The new channel, however, would be less than half the length of the natural river, and the Board recommended that a steep two-mile section be paved with heavy rock and that the remaining 13 miles be equipped with 13 drop structures, each three feet high, to re-distribute the natural stream gradient. This work involved the entire 15-mile length of river in which sockeye salmon are known to have spawned.

While construction of the flood control works proceeded upstream of the upper limit of salmon migration, a joint assessment of the possible effects of the Section "C" flood-control works on the fishery was conducted during the period 1952 to 1954 by the U. S. Fish and Wildlife Service, the Washington State Department of Fisheries, and the Department. This assessment defined two critical problems: paving of the channel would destroy the most productive spawning areas, and the drop structures would obstruct access to the spawning areas. These problems were satisfactorily resolved when the flood control authorities accepted the fisheries agencies' recommendations that the major spawning areas be left intact by substituting rock-fill dykes for channelization and paving; and that a drop structure design, passable to upstream migrant fish, which had been developed from hydraulic laboratory tests conducted by this Branch, be used in Section "C" of the project. Construction of Section "C" was completed in 1957, and assessment of the project during sockeye migration, spawning, and incubation periods since that time has determined that the fisheries protection measures are fulfilling their intended functions.

The total 1962 sockeye run to the Columbia River was 40,000 fish, consisting of a catch of 11,000 and an escapement of 29,000. This is only 18 percent of the previous ten-year average of 218,000 and it is the smallest run recorded since 1949. The total escapement counted at

Bonneville Dam surmounted the seven main-stem dams as far as Rock Island Dam, above which 12,420 fish were accounted for in the Wenatchee River system. The 13,200 sockeye which migrated through Rocky Reach Dam, which is upstream from the Rock Island Dam and the Wenatchee River, were presumably en route to the Okanagan. Four spawning ground surveys conducted in October, 1962 accounted for 6,400 sockeye on the Okanagan spawning grounds, which represents a substantial decline from the previous 10-year average escapement of 27,000 fish.

The annual engineering inspection, conducted in early September, disclosed that six of the 13 drop structures were obstructed by planks placed by local farmers to raise water levels in the river. This is an annual occurrence, and steps were taken to have the obstructions removed before the sockeye migration arrived. The flows of the Okanagan River were abnormally low for spawning, but because low flows were expected to continue throughout the winter on account of low storage levels in upriver reservoirs, the spawning flows were not artificially increased.

Biological surveys led by the U. S. Bureau of Commercial Fisheries established that the Okanagan spawning escapement was composed of 59 percent 3_2 fish and 41 percent 4_2 fish. Estimated total egg deposition was 6,333,246. Spawning success was 90 percent for 3_2 females and 80 percent for 4_2 fish.

1.4 POLLUTION

The fisheries problems resulting from the wide variety of pollution problems which arose during the current year can be grouped under the following headings:

A. Pulp Mill Effluent

B. Mine and Miscellaneous Industrial Wastes

C. Domestic Sewage

D. Pesticides

This report outlines the salient features of the most important problems in the first two categories, and lists the problems in the last two categories. It also summarizes the results of the following three field studies.

(a) a baffle experiment to remove insecticides from stream water

(b) distribution of kraft mill pollution in Alberni harbour

(c) surveys related to a proposal that toxaphene be employed to eradicate coarse fish from lakes of the Eagle River system.

A. Pulp Mill Effluent

Several existing pulp mills have been completed, or were contemplating expansion in 1962, and in each case the adequacy of the effluent disposal facilities was assessed. At the Port Mellon mill of Canadian Forest Products, where a new bleach plant and accompanying submerged sewer line were installed, the studies indicated that the wastes from this plant will continue to be adequately diluted in Thornbrough Channel. Similarly, the wastes from expanded production at Crown Zellerbach's Elk Falls Mill are expected to continue to be rapidly diluted by strong tides in Discovery Passage. Reports of large numbers of dead and dying fish were received from Alice Arm, near the Port Alice pulp mill, in late July, 1962 when temperatures were high and freshwater inflow was low. Dissolved oxygen values in the order of 1 ppm or less were found in surface waters (0-10 feet depth) at stations 6 miles from the mill and these depletions persisted to the mouth of Alice Arm.

An interim report was prepared jointly with the technical staffs of the International Pacific Salmon Fisheries Commission and the Provincial Department of Recreation and Conservation to describe solutions to the fisheries problems which might otherwise be expected if the effluents from proposed bleached-kraft pulp mills are discharged into the Fraser River. Mills at Springfield, Oregon, and Longview, Washington were visited, where in-plant practices presently being used to reduce the quantity and toxicity of the pulp mill effluents were discussed with plant technical personnel. Moreover, biological problems and pollution-abatement facilities at some mills in Oregon and Washington which discharge effluent into rivers were discussed with staff members of Oregon State University and the Oregon State Pollution Control Board. Meetings were held in 1962 with representatives of Canadian Forest Products Company, Cooper-Widman Company, and Noranda Mining and Exploration Company, all of whom expressed interest in building pulp mills in the Prince George area. Only Canadian Forest Products definitely plans at this time to build a mill in this area, and negotiations relating to effluent disposal are underway. Discussions were held also with representatives of Kamloops Pulp and Timber Company, with regard to a proposal to build a bleached-kraft mill at Kamloops, and these negotiations are continuing.

B. Mine and Miscellaneous Industrial Wastes

Negotiations were initiated with Hooker Chemical Company concerning the disposal of effluent from a proposed chlorine manufacturing plant into Northumberland Channel, near Nanaimo, and these negotiations are continuing satisfactorily. In order to alleviate the considerable difficulty Lafarge Cement Company experiences in precipitating and recovering flue dust from their cement kilns at their Lulu Island plant modifications were effected in the system of jet exhausters and provisions were made for recirculating the effluent in the jet exhauster circuit. These measures proved successful as the amount of calcium and the volume of the effluent has been substantially reduced, and extreme fluctuations in pH of the effluent have been overcome. Difficulties with clogging of the diffuser which discharges the effluent into the Fraser River are being experienced and remedial measures are being taken by the Company.

Discussions concerning the provision of tailings disposal facilities were initiated during the year with the managements of Mount Washington Copper Company (Tsolum River), Granduc Mines (Unuk River) and Jordan River Mines (Jordan River). At Britannia Mine (Howe Sound) studies have commenced to determine the sources, and the effects on fish and invertebrates inhabiting the intertidal zone, of copper- and iron-sulfate-bearing waters originating from the bacterial oxidation of sulfide ores in slag piles and old mine workings.

Disposal of wastes from several small plants was studied. Panco Poultry Company, Surrey, provided an oxidation deck and lagoon for aerobic biological oxidation of viscera, blood, and offal from poultry. At the same plant a turbine aerator has been installed to augment the air supply and to prevent anaerobic decomposition of solids accumulating on the bottom of the lagoon. Effluent disposal facilities were provided by B. C. Chipsteak Company, Richmond, B. C. Negotiations for the provision of screening followed by either an enlarged oxidation lagoon or a sprinkler field disposal system were initiated with Berryland Canning Company Limited, Haney, B. C. and are continuing. Fruit and vegetable wastes from this plant are presently discharged into an overloaded pond which has become anaerobic, resulting in the pollution of a small tributary of the Alouette River.

C. Domestic Sewage

The following sewage treatment facilities have been studied and approved in 1962.

1. Mamquam Sewerage District - Oxidation ditch - Squamish River
2. Village of Squamish - Oxidation ditch - Stawamus River
3. Crown Zellerbach Company - Septic tank - Fraser River

4. Village of Ashcroft - Activated sludge - Thompson River
5. Village of Parksville - Submarine pipeline - Gulf of Georgia
6. Canada Rice Mills - Enlarged septic tank - Fraser River
7. Village of Merritt - Activated sludge - Nicola River
8. Town of North Kamloops - Enlarged stabilization pond - Thompson River
9. City of Quesnel - Activated sludge - Fraser River

D. Pesticides

The following pesticide applications were carried out under surveillance of this Branch and the local Protection staff.

1. Copper salts for swimmer's itch control - Cultus Lake
2. Sodium arsenite for control of marine borers
   - Teakerne Arm
   - Crofton
   - Call Creek
   - Tyee Plaza Marina
   - Horseshoe Bay
   - Earl Cove
   - Wesport Export

- Norwood Lumber
- Burrard Drydock
- Moore-Whittington

3. Benzene hexachloride for ambrosia beetle control
   - Cowichan Lake
   - Comox Lake
   - Nanaimo Lake
   - Tahsis Inlet

4. 2-4-D for brush control
   - Cowichan Lake
   - Nanaimo Lake
   - Tsolum River

Special Studies

(a) A Baffle Experiment to Remove Toxic Insecticides from Stream Water

Two plots of logging slash adjacent to two forks of Lens Creek were selected by the Federal Department of Forestry as areas in which to apply benzene hexachloride and thiodan, in order to assess their relative value in controlling the ambrosia beetles' attacks on felled and bucked logs. This experiment presented an opportunity to determine whether or not baffles placed in a stream would remove these low-density toxic materials and thereby prevent mortality of fish downstream from the spraying area.

The baffles, made of 1" by 6" fir planks nailed butt-to-butt, were positioned on the water surface of both branches of Lens Creek below the areas to be sprayed. Slots were cut into the leading edges of the baffles just below the level at which they floated. In position, the baffle spanned the creek width forming a "V" with its apex pointing in a downstream direction. A plywood box was placed at the apex to collect the deleterious material. Liveboxes containing 50 coho salmon fry were placed upstream and downstream of the baffles, and a "control" livebox containing the same number of coho salmon fry was located well upstream of both spray areas.

Area "A" was sprayed with thiodan and benzene hexachloride, while only thiodan was applied to Area "B". A light but noticeable oil-slick, observed on the water surface, was collected by the "A" baffle, but there was no fry mortality in any of the liveboxes after a period of two days. At "B" there was no immediate fry mortality after spraying, although a noticeable oil-slick was picked up by the baffle. Fourteen hours later fish in both "B" liveboxes were in severe distress, and all were dead after sixteen hours. All "controls" survived. Small resident rainbow trout were observed upstream of the baffle at "B" prior to spraying, and after all fish had died in the liveboxes, the stream was examined to determine whether or not any rainbow trout had survived. Most of them were dead, the remainder moribund. A dye, Williams Oil Red, had been added to the thiodan-oil mixture, and streamers of coagulated red material were seen adhering to aquatic plants, stones, and debris on the bottom of the stream.

From this experiment, it has been concluded that baffles are unlikely to be effective in preventing mortality of fish in waters downstream of areas treated with insecticides, although they may recover some floating materials.

(b) Distribution of Bleached Kraft Pulp Mill Pollution in Alberni Inlet

Studies of current patterns in Alberni Inlet were undertaken during the year in an attempt to determine the distribution of the local pulp mill effluent. These were based not only on the actual effluent itself but also on the distribution of the freshwater inflow from the Somass River.

A thirty-percent rhodamine B - ethyl alcohol mixture was introduced into the Somass River four feet below its surface by means of a pre-diluting- and diffusing-apparatus mounted on a 14-foot scow.

Dye releases, perpendicular to the direction of river flow, which were calculated to give a final dye concentration of 0.12 ppm were made twice during periods of high-slack, low-slack, flood, and ebb tides. The dye fronts produced by each release were observed from a helicopter and subsequently plotted on a map.

While releases of even larger concentrations of rhodamine into the dark, turbid effluent from the Alberni pulp mill failed to produce a color which was discernible from the helicopter, it was noted that the pulp mill effluent imparts a distinct brown color to the normally-white propeller wash from a boat. By plotting the point at which the propeller wash was most highly discolored, it was possible to detect the main path followed by the effluent for considerable distances from the outfall, and to establish the regions of high, intermediate, and low effluent concentration in Alberni Harbour. These observations were made during tidal phases similar to those at which dye releases were made in the Somass River, and ten stations were selected at which vertical series of measurements of temperature, salinity, and dissolved oxygen were taken. Windless conditions prevailed while these studies were being carried out.

The results of the studies indicated that during the period of observation (August), there was no direct entry of the effluent into the Somass River, nor was there any evidence of the effluent backing up into the river during any tidal phase. There was no line of distinction between the effluent and the river flow off the mouth of the river as mixing appeared to take place over a broad front between the river flow and the effluent as it left Pulp Mill Bay. During the ebb and low-slack tidal phases, movement of effluent from Pulp Mill Bay seemed more pronounced but at no time was flushing complete. Consequently, high concentations of effluent persisted in Pulp Mill Bay. Low salinity values measured in Pulp Mill Bay confirmed the visual indications of stagnation and low oxygen values. Examination of the results of a sampling program indicated that dissolved oxygen concentrations in Pulp Mill Bay were appreciably depressed. Dissolved oxygen concentrations at the surface ranged between 0.74 to 2.63 ppm at the head of Pulp Mill Bay, while those obtained at three stations beyond the immediate outfall region remained below 5 ppm. At all stations dissolved oxygen concentrations at the bottom were low, generally below the 5 ppm level. Temperature measurements taken at four stations on the effluent path indicated that surface temperatures were raised by at least 7°F in the outfall area. Water samples obtained at the same stations during the third week of September gave similar results, although dissolved oxygen concentrations were not quite so low as they were in August. Additional measurements are planned in the winter as well as in the spring of 1963, when the downstream migration of salmon smolts is underway in the Somass River system. Further dye releases are planned during periods when up-inlet winds tend to drive the effluent toward the river mouth.

(c) Studies Relating to a Proposal to Eradicate Coarse Fish from Lakes in the Eagle River System

The Sicamous Fish and Game Club erected a barrier between Griffin and Three Valley Lakes on the Eagle River system as a means to prevent coarse fish from entering Three Valley, Victor, and Summit Lakes, which they planned to poison with toxaphene and re-stock with trout. While the barrier had to be removed because it blocked the passage of coho salmon, which spawn as far upstream as the outlet of Victor Lake, the proposal to poison the lakes was deferred until further studies had been completed.

It was therefore necessary for this Branch to conduct a survey to determine the numbers of coho and sockeye salmon which might be exposed to the toxaphene. It was also necessary to estimate the river discharge in order to determine the dilution capacity available between key points in the system.

Separate surveys were made in early October and mid-November, 1962. From Three Valley Lake downstream to Malakwa Bridge a total of 643 sockeye salmon were counted, while 1,182 coho salmon were counted in the reach between Summit Lake and Perry River. On the assumption that Summit, Victor, and Three Valley Lakes would be poisoned, it was estimated that a dilution factor of only 1.6:1 would be available, and that 90.5 percent of the coho population might therefore be endangered. On the assumption that Victor and Summit Lakes only would be poisoned, it was estimated that a dilution ratio of 7.5:1 was available between Victor Lake and Perry River, and that an estimated 21 percent of the coho salmon population might be endangered.

1.5 MISCELLANEOUS

1.5.1 Seismic Surveys

Considerable interest in oil exploration along the Continental shelf of the Pacific Coast of Canada has developed in recent years. Several companies have obtained exploration permits, and occasional surveys have been carried out in specific areas such as off the east coast of Graham Island, in the Queen Charlotte group, and off Roberts Bank in the southwest corner of British Columbia. In addition the Royal Canadian Navy and the Department of Mines and Technical Surveys have carried out non-commercial surveys using heavy explosives.

Seismic surveys using the gas-exploder and electric sparker technique have proved to be innocuous to fish life. This technique is being used for rapid preliminary surveys, but in most cases high-velocity explosives with deeper penetration are required for accurate definition of potential oil-bearing formations. These explosives are lethal within a certain radius of the explosion point; this radius being a function of the size of the charge and the velocity of its shock wave. Since large charges of high-velocity explosives also provide the best seismic records, any marine seismic program represents a potentially serious threat to fish life.

To guard against these hazards the Department studies each proposed exploration program and outlines certain fish-protective requirements. Upon receipt of the company's assurance that it will comply with these conditions the Department withdraws its objection to the program. The main requirement is that the survey carry a Departmental observer who is vested with the power to stop, delay, or modify the program if fish are being killed or endangered. Other imposed requirements relate to the size of charges, the type of explosive, the area of operation, the timing of operations, and the provision of equipment for fish detection and communications.

In 1962, this Branch was involved with the planning of fish-protective measures for a major survey of approximately 11 million acres of Continental shelf off the west coast of Vancouver Island, Queen Charlotte Sound, and Hecate Strait, which will be undertaken in 1963.

1.5.2 Logging

As a result of negotiations with the B. C. Forest Service in 1959, a liaison was established whereby this Department is afforded an opportunity to insert fish-protection clauses, as required, into Timber Sale Licenses and annual cutting permits for sustained-yield Tree Farm Licenses in the Vancouver Forest District. These protection clauses, which are enforced by the B. C. Forest Service, relate only to those aspects associated directly with the logging practice and they do not provide protection against activities such as log-booming or log-driving which take place within the stream channel.

A comparable system to that described in the foregoing has been in operation for several years in the Prince Rupert Forest District, where all processing is conducted by the district staffs of this Department and the B. C. Forest Service. The combined protection offered in these two major forest districts covers the entire coastal area of the Province.

During 1961, the B. C. Forest Service announced plans for the development of a "Public Working Circle" in the Owikeno Lake watershed. This, in effect, means that the logging operations in that area will be subject to a sustained yield basis but that the harvestable timber will be sold in relatively small packages. Since the Owikeno watershed supports substantial populations of all five species of Pacific Salmon, the most important being the sockeye salmon which provides the commercial fishery with an average annual catch of one million, all possible precautions have been taken to ensure that the salmon resource is protected against damage resulting from the logging operations. To this end a report which describes the value of the system to the fishery, the distribution and life history of the various species, and the problems associated with logging has been prepared and forwarded to the B. C. Forest Service to serve as a guide in the development of the system as a "Public Working Circle". Furthermore, a series of meetings with individual operators has been conducted, and further discussions with both the Forest Service and the individual operators are contemplated before the logging plans are finalized. A matter of immediate concern, however, is a proposal which contemplates the use of the Wannock River to convey logs from Owikeno Lake to tidewater.

In 1962, a series of meetings were held with Rayonier (Canada) Ltd. which resulted in the development of a mutually acceptable solution to a conflict of interests stemming from log-driving operations on the Homathko River. During the year, also, there was a considerable exchange of correspondence with a number of logging companies looking to the development of solutions to specific problems on a number of systems including the Nass, Nadina, Naden, and Chuckwalla Rivers.

1.5.3 Water Licence Applications

All water-use projects in British Columbia, from the largest hydroelectric development to the smallest domestic water supply, must be authorized by a water licence issued by the Provincial Comptroller of Water Rights. Having regard to the fisheries problems posed by some of these types of projects this Branch has established a liaison with the Provincial authorities whereby it is given the opportunity to review all water licence applications before the licences are issued, and in this way it is possible to forestall many of the fisheries problems which might otherwise be expected to develop.

During 1962, approximately 1,000 of these applications were examined for possible harmful effects to the fisheries, and while most of these were approved outright, some were made subject to certain provisos which were inserted to protect the fisheries interests, and a few were opposed unconditionally on the grounds that they would not, under any circumstances, be compatible with the fisheries interests. These provisional clauses usually required that the water intakes be adequately screened to prevent entry of small fish, but in a few instances, notably in connection with placer-mining or gravel removal from stream beds, they restricted the operations to those periods when fisheries losses would be minimal or non-existent.

Several applications, involving large-scale diversions of water, resulted in detailed studies and negotiations with the owners looking to the development of suitable screening installations. The more important of these were the water supply intakes for the Village of North Kamloops on the North Thompson River, the Noranda Mines Development on the Toquart River, and three pulp mill expansions involving the Sproat, Campbell, and Nanaimo river systems.

Many of the applications involved small diversions for domestic and irrigation purposes. In these cases, the applicants were provided with the Branch's standard screening specifications, from which they could develop a design to suit their particular intakes.

An inspection of water diversions in the Kamloops area was made with a view to collecting information on which the development of a standard screen design, adaptable to all small pump intakes, could be based.

At the request of the Provincial Water Rights Branch, which was preparing a report on flood control measures for the Coquitlam River, this Branch prepared and submitted a brief outlining relevant details with respect to protection of the salmon stocks utilizing this river system.

1.5.4 <u>Placer-Mining Leases</u>

All placer-mining operations in British Columbia must be authorized by a permit issued by the Chief Gold Commissioner for the Province, who, through a liaison which has been established, advises this Branch of all such applications in order that recommendations for fisheries protection can be defined before the licences are issued. Recommendations in this regard have been subsequently incorporated into the Provincial permit.

In 1962, approximately 80 such applications were reviewed by this Branch and while most were of the routine type, one, involving an application for 26 leases on the Bridge River system, is worthy of particular note. On the basis of results from an investigation by this Branch, the Protection Branch, and the International Pacific Salmon Fisheries Commission, the Department objected to the issuance of the requested licences on the grounds that the proposed operations would destroy the spawning grounds of important stocks of chinook and pink salmon, and steelhead trout. When this objection was upheld by the Chief Gold Commissioner, the applicants appealed to the Minister of Mines and Petroleum Resources, who convened a hearing into the entire matter.

This Branch and the Salmon Commission collaborated in the preparation of a joint brief outlining the basis for their objections, and this subsequently was presented to the Minister at the Hearing. While there is no doubt that this brief was a factor in the Minister's ultimate denial of the applicants' appeal, his decision apparently stemmed primarily from the contention of the local Indian band and the Indian Affairs Branch that the bed of the Bridge River in the area in question was part of the Indian Reserve, and was therefore not available to the applicants.

Regardless of the basis for this decision, the Department and the Salmon Commission were extremely pleased with the decision itself, as it was foreseen that issuance of the requested licences in this instance would have resulted in a much greater threat to the fisheries interests elsewhere as a result of placer-lease applications being filed in future for rights on river beds which had previously been regarded as Indian reserves.

2. FISHERIES DEVELOPMENT

2.1 STREAM IMPROVEMENT

2.1.1 Big Qualicum River (See also Section 2.4.11, Page 142).

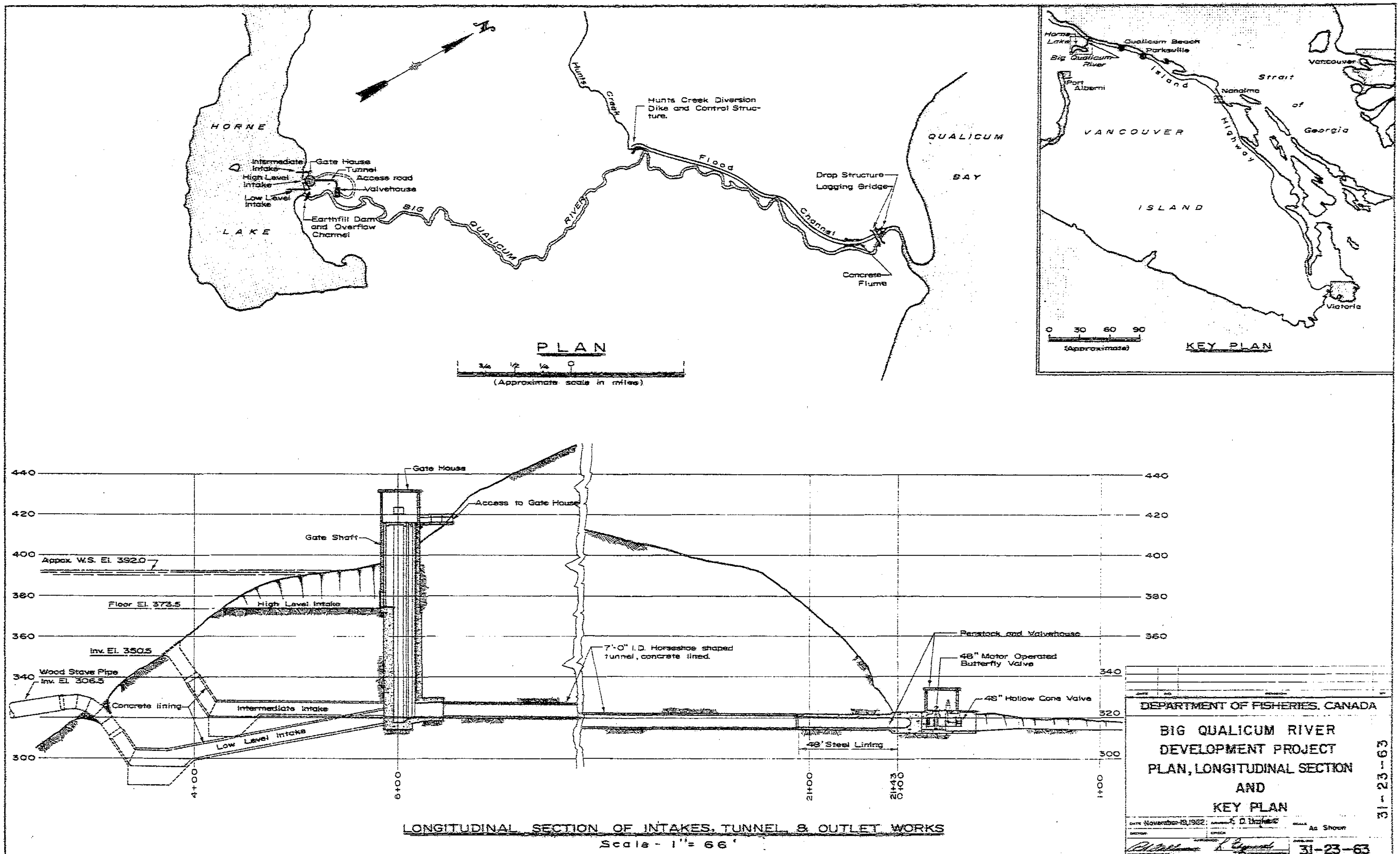
Research undertaken in recent years at Jones Creek and elsewhere has provided evidence that elimination of floods, with their attendant shifting of gravel beds, and the grading of spawning gravel to achieve greater porosity, will result in a substantial increase in the egg-to-fry survival rate of salmon. On the basis of these results, it was concluded that employment of these principles on an entire river system could be justified by the increased salmon production which would be reflected in the catch of the fishery. After a careful study of several alternatives the Big Qualicum River on the east coast of Vancouver Island was selected in 1958 as the most suitable site. With the Department's concurrence, detailed studies, looking to the preparation of the development plans, were initiated immediately.

The lower Big Qualicum River (see accompanying plan) originates in Horne Lake from whence it falls approximately 190 feet in the first 3/4 of a mile before establishing its normal gradient which is maintained for the remaining seven miles to its mouth on the Strait of Georgia, 39 miles north of the city of Nanaimo. Hunt's Creek, which flows into the Qualicum about halfway between the lake and the sea is its only major tributary in this lower reach.

Twelve years of available records reveal that the mean annual discharge of the Big Qualicum River is 286 cfs, with a maximum of 7,080 cfs and a minimum of 15 cfs. Hunt's Creek records show that its discharge has varied from 5 cfs to an estimated 2,500 cfs.

The detailed studies undertaken by this Branch revealed that it would be physically and economically feasible to regulate the flows in the lower seven miles of available spawning area by providing 200 cfs from August 1 to December 15, and 200-500 cfs during the balance of the year. It was foreseen, however, that the flow in the period after December 15 might have to be raised to 750 cfs for short periods during an extreme flood, and, conversely, that it might be necessary to reduce this flow to as low as 150 cfs in order to replenish storage during a drought.

Plans and specifications for the project were completed in 1960 and tenders were called in March, 1961. The contract was subsequently awarded to General Construction Co. Ltd., of Vancouver, whose tender of approximately $900,000 was the lowest of eight which were received. The Department supplied the valves, sheet piling, electrical equipment, etc. at a cost of about $125,000, and property acquisition and engineering costs amounted to approximately $200,000, so the total cost of the project will be in the order of $1,250,000.


HORNE
LAKE
Intermediate Intake
Gate House
Tunnel
High Level Intake
Access road
Valvehouse
Low Level Intake
Earthfill Dam and Overflow Channel
BIG QUALICUM RIVER
Hunts Creek
Hunts Creek Diversion Dike and Control Structure.
Flood Channel
Drop Structure
Logging Bridge
Concrete Flume
QUALICUM BAY
PLAN
3/4 1/2 1/4 0
(Approximate scale in miles)
Horne Lake
Big Qualicum River
Qualicum Beach
Parksville
Island Highway
Port Alberni
Nanaimo
Vancouver
Strait of Georgia
VANCOUVER ISLAND
Victoria
0 30 60 90
(Approximate)
KEY PLAN
Gate House
Access to Gate House
Gate Shaft
Appox. W.S. El. 392.0
Floor El. 373.5
High Level Intake
Inv. El. 350.5
Wood Stave Pipe Inv. El. 306.5
Concrete lining
Intermediate Intake
Low Level Intake
7'-0" I.D. Horseshoe shaped tunnel, concrete lined.
48' Steel Lining
Penstock and Valvehouse
48" Motor Operated Butterfly Valve
48" Hollow Cone Valve
440 420 400 380 360 340 320 300
4+00 6+00 21+00 21+43 0+00 1+00
LONGITUDINAL SECTION OF INTAKES, TUNNEL & OUTLET WORKS
Scale - 1" = 66'
DEPARTMENT OF FISHERIES, CANADA
BIG QUALICUM RIVER
DEVELOPMENT PROJECT
PLAN, LONGITUDINAL SECTION
AND
KEY PLAN
November 19, 1962
As Shown
31-23-63

The contractor commenced work in May, 1961, and with the exception of the dam at the outlet of Horne Lake and the high-level intake channel to the gate shaft, the contract was completed on December 15, 1962. These structures had to be deferred in September when an unforeseeable problem developed in connection with the B. C. Hydro and Power Authority transmission line at the upper end of Horne Lake. These incompleted works are scheduled for completion next summer when it is expected that the problems associated with the transmission line will have been resolved.

The outlet control works (see accompanying plan) for regulating Horne Lake outflows consist of a concrete-lined vertical gate shaft, 98 feet deep, which has three separate intakes from the lake; a gate house on top of the shaft for the manipulation of the three intake gates and the main tunnel headgate; a seven-foot inside diameter concrete-lined horseshoe-shaped tunnel, approximately 1,700 feet long, extending from the base of the gate shaft, about 75 feet below the normal level of the lake, downstream to near the head of the spawning grounds; a control works at the tunnel outlet; and an earth-fill dam and concrete spillway near the outlet of Horne Lake (not yet complete).

The high-level intake, when completed, will be an open-cut channel while the low- and intermediate-level intakes are seven-foot diameter concrete-lined tunnels.

The low-level intake is fitted with a seven-foot diameter woodstave pipe, which extends downward along the lake bottom for a distance of 90 feet, in order that water can be drawn from about 20 feet below the actual low-level invert, some 85 feet below the normal lake level. The high-level intake will draw water from near the surface. A multi-level intake is essential for the maintenance of the desired degree of temperature control in the river.

The earth-fill dam, with a crest elevation 28 feet above the normal water surface of Horne Lake, allows for increased lake levels as a means to provide sufficient storage for flood control. A spillway channel with a concrete control weir approximately 20 feet above the normal lake level has been constructed near the left abutment of the dam for emergency use in the event that an extremely heavy runoff threatens to overtop the dam. It is extremely unlikely, however, that an spillage over the crest will ever occur.

With these works, a total storage capacity of 142,000 acre-feet is available, of which 75 percent will be obtained from below the natural lake level. About one-third of the total storage will be used to augment normal low flows, while the remainder will be employed for flood control. Furthermore, employment of the low-level intake during the critical late summer and early fall, when natural water temperatures often rise to 68°F and endanger spawning, can lower these temperatures.

A low dam has been constructed on Hunt's Creek approximately one-third of a mile upstream from the Big Qualicum confluence in order to divert flash floods which otherwise could interfere with the controlled flows from Horne Lake. This dam is equipped with a 36-inch diameter culvert and a regulating gate through which water may be passed as required to the spawning area in Hunt's Creek below the dam. The culvert normally will be set to pass all flows of less than 20 cfs, but it can be adjusted to pass as much as 50 cfs. All flows in excess of those noted above will be diverted from the creek into a specially constructed flood channel, approximately 2½ miles long, which parallels the Big Qualicum along its north bank to a point near tidewater where it joins the main river. To prevent fish from entering the flood channel, a concrete drop structure and barrier dam, about five feet high, was constructed in the flood channel at its confluence with the Big Qualicum River. The flood channel has a trapezoidal cross-section, 20 feet wide at the base with 2.25:1 side slopes, a minimum depth of 12 feet and an overall vertical drop of 92 feet throughout its length. A low earth-fill dyke, 15 feet wide at the top, separates the flood channel from the Big Qualicum River and doubles as an access road for maintenance and for future development work on the river.

The first, or flow-control phase of the project will be functional when the dam and high-level intake channel are completed. Preparations are now underway for the second phase, which relates to the improvement of the spawning gravel in the stream and the construction of artificial spawning channels. This phase will be continuing over a period of years in the future.

2.1.2 Embley River

Embley River which flows into Embley Lagoon in Grappler Sound approximately 32 miles northeast of Port Hardy, is one of two streams that drain Huaskin Lake. It supports an even-year run of 5,000-10,000 pink salmon, but in recent years the coho population has been estimated at less than 500 fish.

In 1952, it was first reported that two falls near the mouth of the stream constituted an obstruction to salmon migration. These reports indicated that the more serious obstruction was that at the lower falls where the stream is confined to a narrow chute which forms a velocity barrier at high discharges. The hazards associated with this obstruction were evident in 1952 when it was estimated that 30 percent of the pink salmon spawned in the tidal waters below the falls, and again in 1960 when it was reported that a major portion of the estimated 5,000-10,000 pink salmon were lost because they were unable to surmount the falls.

As a result of a preliminary engineering survey undertaken in 1958, it was recommended that remedial work be initiated to assist the migration of salmon at these falls. Planning along this line was deferred, however, pending the outcome of a biological survey of the river above the obstruction. This survey which was conducted in 1961, indicated that there was sufficient spawning grounds above the falls to warrant some improvement measures and studies were therefore initiated to determine the most economical means by which this could be done.

These studies resulted in the preparation of a preliminary layout for an 18-baffle (Ice Harbour-type) fishway, the cost of which was estimated to be in the order of $50,000. As this structure could not be placed in service in time to assist the 1962 pink salmon migration, some marginal rock work was undertaken that year at both falls. As it was reported that this work appeared to have eased the obstruction, construction of a fishway has been deferred pending a full assessment of the effectiveness of this marginal rock work.

2.1.3 Quatse River

Quatse River, from its source in Quatse Lake, flows a distance of approximately seven miles before discharging into Hardy Bay, near the town of Port Hardy, on the east coast of Vancouver Island. Two natural falls, which are known as Four-mile and Six-mile Falls because of their respective distances from the river mouth, constitute an obstruction to migrating salmon.

Historically, Four-mile Falls has been an obstruction to sockeye and pink salmon during only those periods when flows were at low or medium levels, and it was not considered serious. In the 1940's, however, this watershed was subjected to extensive logging operations and the resultant denuding of the terrain so altered the runoff patterns of the river that the periods of low- to medium flow were extended substantially with the result that salmon were blocked at the falls more frequently. In 1960, a five-baffle (Ice Harbour-type) fishway was constructed by this Branch on the left bank in order to ease this situation.

When salmon experienced difficulty in ascending through a culvert constructed by the Highways Department below Six-mile Falls, the Province, at the request of this Branch, constructed a concrete baffle below the culvert to facilitate passage at low-to-average flows. This work was undertaken in 1960, but it has not proven to be as effective as was expected because of serious maintenance problems.

In 1962, marginal rock work was undertaken at Six-mile Falls to facilitate salmon migration during the low and medium water levels. This work apparently has proved successful as pink salmon were observed spawning in the river above the falls.

2.1.4 Meziadin River

Meziadin River, which discharges into the Nass River approximately 115 miles above tidewater, is an important contributor to the valuable Nass River sockeye fishery. Two falls on the Meziadin River, immediately upstream from the Nass confluence, have long been known as obstructions to salmon migration, and in 1913 this Department constructed a weir-type fishway at the upper falls. This structure was composed almost entirely of local materials because of the relative isolation of the site, which made access extremely difficult. Even to-day, the Meziadin area is considered remote although a new Provincial highway, now under construction, will pass within a few miles of the obstruction.

Commencing in 1956, this Branch undertook detailed biological and engineering surveys of the Meziadin obstruction looking to the determination of the spawning escapement, the duration of the delays, the magnitude of the losses, and to obtain basic data from which detailed plans of remedial measures could be developed.

The biological surveys determined that the Meziadin sockeye escapement represented 39 percent of the Nass River total in 1957, and 31 percent in 1958. Furthermore, it was found that an average delay of seven days and losses of 38 percent occurred at the falls in 1957 when water levels were low; while in 1958, when water levels were relatively high, the average period of delay was four days and the losses represented four percent of the total migration.

On the basis of data obtained by the engineering surveys undertaken in the period 1958-61, preliminary plans for a new fishway at this site have now been prepared. This structure, which has been designed as a vertical-slot type, will consist of 17 pools eight feet wide by 10 feet long at the lower falls, 13 pools of the same dimension at the upper falls, and the two sections will be made continuous by five interconnecting pools, each approximately 75 feet long. It is intended that the fishway will be equipped with an auxiliary exit to facilitate tagging, recovery, enumeration, etc. A barrier dam, consisting of a reinforced concrete weir will be erected at the lower falls to direct fish to the fishway entrance on the left bank.

The cost of constructing these facilities would be prohibitive if it were not for the fact that the Province is constructing a new highway which will be located near enough to the site to justify the construction of an access road. A suitable route has been located and it has been determined that a single-lane access road, ten miles long with turnouts at half-mile intervals will be economic. It is also intended that a section of the road near the fishway site will be constructed as a landing strip for light aircraft.

While definite dates for construction of these facilities have not yet been established, it is expected that they will be completed within a few years. The most favourable schedule requires that the access road be constructed in the spring and summer, with the fishway construction in the fall and winter when water levels are lowest and interference with fish migrations can be held to a minimum.

2.1.5 Stamp Falls Fishways

The Stamp Falls fishways, which were completed in 1955 at an approximate cost of $125,000, facilitate passage of valuable stocks of sockeye, coho, and spring salmon and steelhead trout at Stamp Falls, a natural cataract on the Stamp River some nine miles northwest of the city of Alberni. More recently, these structures have been used also by the adults returning to Robertson Creek from the pink salmon transplants.

Shortly after the fishways came into operation, it became evident that the upper fishway had some hydraulic shortcomings in that the attractive qualities at its entrance at moderately high and high river discharges were not as good as expected. This fishway is of the vertical-slot type with 25 baffles, each of which provides for a maximum drop of one foot. At minimum river discharge all baffles are in full service but as the river discharge increases, the water level at the fishway entrance rises at 2-3 times the rate of that at the fishway exit, producing the net effect of reducing the total fall through the structure. As a result, the lower baffles are "drowned out" at the higher river discharges and the flows issuing therefrom are sometimes barely noticeable, providing little attraction for fish to enter.

While water levels to date have not been such that serious delays have been encountered as a result of this deficiency, it is possible that such might occur at any time. As a result, this Branch undertook a study of the situation in 1962 and this has resulted in the advancement of a proposal whereby auxiliary water would be diverted from the river by means of a channel from whence it would be introduced through floor-type diffusers into the area of the fishway entrance. As it is believed that this will be the cheapest and most effective of the several alternatives considered, funds to cover the costs of constructing same in the 1963-64 fiscal year have been requested.

2.2 THE ROBERTSON CREEK SPAWNING CHANNEL & APPURTENANT FACILITIES

Great Central Lake, which is located near the city of Alberni on the west coast of Vancouver Island, has two outlets - the primary one being the Stamp River, which flows into the Somass River and thence into Alberni Inlet; and Robertson Creek, a secondary outlet which discharges into the Stamp River approximately one mile downstream from the lake.

The purpose of the Robertson Creek project is twofold: firstly, it provides suitable facilities for the investigation of fish culture techniques aimed at increasing the production of pink, coho, and chinook salmon during the freshwater stage of their life cycle and secondly, it is intended to increase the production of salmon species in Robertson Creek. The project will also provide the locale for the study of fisheries problems posed by hydroelectric power developments, particularly those associated with the rearing requirements of coho and chinook salmon, and the successful relocation of these same species to artificial spawning areas.

While the major portion of the Robertson Creek construction took place during 1959 and 1960, the work was sufficiently advanced in the fall of 1959 to allow the commencement of a biological program. The official opening of the project by the Hon. J. Angus MacLean, Minister of Fisheries, on November 4, 1960 marked the completion of the major facilities, although the experimental rearing channels were not finished until 1961, and minor improvements have since been made to the overall facilities.

A brief description of the individual facilities which had been constructed up to the end of 1961 is set out hereunder.

(1) A spawning channel, consisting of three discrete sections of varying lengths and uniform cross-section, creates 10,000 square yards of spawning area in a total length of 2,550 feet. The spawning gravel, which is laid to a depth of 15-20 inches, is

of a designed composition ranging in size between 3/4 inch and four inches.

(2) Four drop structures, which create water surface drops ranging from 3 to 8½ feet, have been constructed at intervals along the channel in order to localize the excess drop in the natural creek gradient. These structures also separate the three sections of the spawning channel and allow for some individual hydraulic control in each.

(3) Control works installed by this Branch in MacMillan, Bloedel, and Powell River Limited's dam at the Robertson Creek outlet from Great Central Lake are capable of regulating the channel discharge to any desired magnitude up to 250 cfs.

(4) A screening system installed at the upstream end of the channel diverts fish entering from Great Central Lake into a 30-inch diameter woodstave flume which provides the means for them to continue downstream without disrupting channel studies.

(5) The fishway in drop structure no. 4, at the downstream end of the facilities, connects with a holding-brailling pool from which fish can be readily transferred to special holding pools, or to an electrically-operated loading hopper. A 700-gallon tank truck is available to transport trapped fish to discrete areas within the channel.

(6) A 150- by 240-foot plot adjacent to the spawning channel has been set aside for studies of the rearing requirements of juvenile coho in their pre-migratory stage. This area was designed to have eight parallel sub-channels, each 10 feet wide by 210 feet long, having individual discharges of 5 cfs. Isolation screens are provided at each end of the channels.

(7) A fishway viewing room, built into drop structure no. 4, is equipped with windows through which it is possible to observe fish passage at all depths in two pools of the fishway. This installation provides an excellent opportunity for assessing the effectiveness of various baffle types.

(8) A reinforced-concrete test flume, measuring 20 feet by 150 feet with a minimum depth of 6'-6", was erected in the lower reaches of Robertson Creek to provide a suitable facility for studies associated with the diversion of downstream migrant salmon and trout from power intakes. It is also readily adaptable to numerous other research projects undertaken by this Branch and the Fisheries Research Board of Canada.

(9) An office-residence has been constructed at the entrance to the project for the use of the resident technician, and a field camp at the downstream end

of the channel provides living quarters for seasonal crews of up to 10 men. A utility building which has been constructed as a warehouse-workshop in the area adjacent to the field camp also houses a well-equipped biological field laboratory.

1962 Additions

Capital expenditures at Robertson Creek during the 1962-63 fiscal year amounted to $68,000.

The single temporary experimental screen at the downstream migrant diversion structure was replaced by two permanent inclined-plane screens equipped with an automatically-controlled chain-driven cleaning device which sweeps debris from the screens into trash collection bins. This installation is designed to handle 300 cfs.

A second utility building was constructed next to the present warehouse, as it had been found that the existing building was required exclusively for a workshop and biological laboratory. The new building is equipped with a monorail and hoist, which also serve an adjacent storage area to facilitate the storage of heavy equipment, machines, materials, etc.

Fish barrier screens, fabricated of aluminum, were installed at all drop structures so that adult salmon could be retained in discrete channel areas. An A-frame fish barrier was erected in the #3 (lowermost) spawning channel for the same purpose.

An overhead water-spray system was installed at the holding and brailing pool at drop structure no. 4 as a means to discourage captive fish from sustaining injuries as a result of jumping. Protective netting was also installed to prevent fish from jumping over the walls of the structure.

Other improvements constructed in the channel and adjacent areas are: a new holding pool in the uppermost channel, several timber-crib ramps for tank truck access into discrete areas, an additional 600 feet of 6-ft high fencing to shield fish in the channel from traffic on the access road, and the paving of the first 1,400 feet of access road.

In mid-1962, the Robertson Creek experimental flume was converted into a temporary egg-incubation station to facilitate the pink salmon transplant from the Atnarko River. Troughs and baskets with a capacity of over 10 million eggs were fabricated and erected within the confines of the dewatered flume. All structures, including the roof, were designed for prefabrication in sections so that the facilities could be installed, removed, and stored, as required. Employment of the experimental flume structure as an eyeing station brings it into service on a year-round basis through its three widely divergent uses.

The total capital outlay for the Robertson Creek spawning channel and appurtenant works was $370,000.

1962 Operations

With the completion of the additions undertaken in 1962, the construction phase of the Robertson Creek project, as now envisaged, is virtually complete, and the biological program is now filling out to make full use of the available facilities.

Most of the facilities have been in operation for more than three years and during this time they have experienced extremely varied flow conditions as a result of a number of independent research and fish cultural projects which required that particular hydraulic conditions be maintained. The works have proven to be extremely adaptable for their many uses. Ease of operation and maintenance of the facilities have also been up to expectations.

With the exception of the routine operation of the facilities to satisfy the requirements of the biological program, the only annual engineering requirements are those related to the regrading of the channel bottom prior to the arrival of adult fish in late summer, and the annual changeover of physical conditions in the experimental rearing channels.

Biological studies undertaken to date at Robertson Creek are described elsewhere in this report. While engineering research studies have not yet been initiated investigation of the surface- and subsurface hydraulics of the channel, various methods of gravel cleaning, and related engineering research will commence in 1963.

2.3 SALMON TRANSPLANTS

2.3.1 Nanika River Rehabilitation Program (See also Section 1.1.3)

The Nanika River rises in Kidprice Lake, approximately 120 miles east of Prince Rupert, from whence it flows in a northerly direction for some 16 miles to its mouth at Morice Lake. The upper three miles of the river constitute an excellent spawning ground for sockeye salmon, and in fact, the Nanika River, historically, has contributed about 10 per cent of the total sockeye catch in the valuable Skeena River fishery.

The route of the spawning migration to the Nanika follows the Skeena River to its confluence with the Bulkley; then up the Bulkley to the Morice River, which it ascends to Morice Lake, from whence it finally enters the Nanika River itself. Two major obstructions located on this migration route have been alleviated by this Branch. In 1951 fishways were constructed at Moricetown Falls, and in 1959 a rock obstruction was removed at Hagwilget Canyon, both of these being located on the Bulkley River.

During the period 1945-53 the annual sockeye escapement to the Nanika River varied between 24,000 and 70,000, with an average of 49,500 for the period. Commencing in 1954, however, this run underwent a serious decline and the annual escapements recorded since then have been in the range of 1,000-6,000.

Rehabilitation by protective regulation in the commercial fishery, with a view to increasing the spawning escapements to the Nanika, proved to be impractical inasmuch as the Nanika sockeye migrate through the Skeena River fishery at the same time as the early- and middle Babine runs. It was concluded therefore that the adult escapement could be increased only by improving the production of juveniles; and a study of the various alternatives culminated with the recommendation that the run be rehabilitated through the implementation of artificial propagation measures utilizing a hatchery.

The Nanika River rehabilitation program was initiated in 1960 when a new hatchery, constructed on the right bank of the Nanika one mile upstream from Morice Lake, was brought into partial operation. This hatchery, which embodies many of the latest fish cultural techniques, was brought into full service for the first time in 1962. A brief description of its most significant features is set out hereunder.

(1) Electrical power to fulfill all hatchery requirements is provided by two 15 kw diesel-driven generators, only one of which is operating at a time, the other being for standby in the event of a mechanical breakdown of the operating unit.

(2) The water demands of the hatchery are fulfilled by a conventional pump-and-tank arrangement.

Water is drawn directly from the Nanika River by an electrically-driven pump (max. capacity of one cfs), which feeds a 10,000-gallon elevated storage tank. Water is delivered from this tank, as required, by gravity flow. The pumps and water lines have been duplicated in an attempt to virtually eliminate the threat of losses occurring as a result of mechanical, or other failures.

(3) The hatchery employs the vertical-stack incubation principle in which a series of 20 incubation baskets, each containing from 10,000-15,000 sockeye eggs, are stacked one above the other so that water delivered at the top of the stack must circulate through each tray before passing to the one underneath. The advantages of the vertical-stack incubators are clearly evident in the economies they effect in water-usage and floor space, as each stack requires only four feet of floor space and a flow of only 3-6 gpm to incubate up to 300,000 sockeye eggs to the late alevin stage The hatchery has been designed for 50 stacks of incubator trays, and full utilization of these gives it a capacity between 10- and 15 million eggs.

Eggs for the hatchery are flown in from Fifteen-Mile Creek, a tributary of Babine Lake, where they are obtained by seining and stripping sockeye on the spawning grounds. The entire transfer operation, from egg-taking to unloading at the hatchery, is effected in less than 10 hours.

Fungus growth during the incubation stage is controlled in the hatchery by the twice-weekly application of Malachite green at a concentration of 1:200,000 for a period of one hour. This treatment is discontinued when hatching commences. Each tray of eggs is "picked" at least once during the eyed-stage.

Before yolk absorption is complete the alevins are transferred from the incubation trays to a "fry release tank", which consists of a 14-ft diameter, 10,000-gallon woodstave tank, where they are placed in 12 individual pie-shaped pens. These pens, which are four feet deep, are suspended so that their screen floors are approximately 3'-6" below the water surface in the tank. Water delivered at the base of the tank wells up gently to the surface and is discharged via 12 surface outlets which also serve as the fry exits from the pens. Water discharging from these outlets passes into a common trough, which rings the outside of the tank, before emptying into a pipe leading to the river. As the fry reach the migrant stage they are permitted to leave the tank from whence they are conveyed to the river by the trough-and-pipe arrangement. Although fry release is restricted to the night hours the tank is completely enclosed in order to provide continual darkness.

The 1960-61 hatchery operation was restricted to a small-scale "pilot plant" in order to test the equipment and operating conditions during the severe winters. Several defects and deficiencies detected thereby were immediately corrected, and the hatchery was then operated at half-capacity in 1961-62. Full capacity was achieved for the first time in 1962. The following table summarizes the pertinent details with respect to the hatchery operation to date.

Year	Number of Eggs Received	Number of Fry Released	Percent Survival Egg to Fry
1960-61	315,000	74,000	23.5
1961-62	5,200,000	3,800,000 (preliminary estimate)	73
1962-63	11,400,000		

In order to assess the effectiveness of the hatchery operation a long-range program involving comprehensive studies of the juvenile and adult migrations was initiated in 1961.

In 1961 and 1962 the sockeye escapement to the Bulkley system was enumerated at Moricetown Falls, and that portion which migrated to the Nanika was estimated on the basis of live- and dead counts on the spawning grounds. Substantial numbers of mature- and spawned-out sockeye were also observed on a series of alluvial fans along ten miles of the shoreline near the south end of Morice Lake, and mature sockeye were taken by nets in the Atna River system; but when it proved to be extremely difficult to obtain accurate estimates of these populations by direct means, an indirect approach, which assigned all of the unaccounted-for escapement to the Morice and Atna system, was employed to develop the following estimate of the spawning distribution.

Year	Total Escapement Moricetown	Nanika	Upper Bulkley	Morice & Atna
1961	14,000	5,000	-	9,000
1962	8,500	3,500	400	4,600

The sockeye migration at Moricetown Falls continues through the months of July and August with the peak occurring about the end of July. The peak of spawning activity in the Nanika River occurs in late September, approximately 10-15 days later than that in 15-Mile Creek, the hatchery donor stream.

The mean fork lengths of female and large male sockeye sampled at Moricetown Falls measured 57.3 cm and 60.7 cm respectively in 1961, and 58.2 cm and 62.1 cm in 1962. These fall within the range of the mean lengths recorded in the period 1949-61 at the Babine counting fence, through which the 15-Mile Creek spawning population would have passed.

Studies to determine the age composition of the

Bulkley-Morice sockeye stocks were undertaken at Moricetown Falls in 1961 and 1962 with the following results, which are expressed as percentages.

Year	No. Samples	Age						
		3_2	4_2	5_2	4_3	5_3	6_3	6_4
1961	211	-	5.2	1.9	0.5	74.4	17.1	1.0
1962	219	0.5	6.4	11.0	1.8	48.4	31.1	0.9

A downstream-sampling program employing equipment which permitted sampling at any point in the river cross-section was conducted on the Nanika River in the spring of 1962 in order to measure the fry output from the 1961 spawning. Fry migration continued throughout the sampling period May 31 to July 16 with the peak occurring on June 25. In this connection it is interesting to note that the fry emigration from the hatchery release tank coincided closely with that from the natural spawning. The mean length of the fry from the hatchery was only 23.0 mm and 26.1 mm in 1961 and 1962 respectively, while those of the natural fry were 27.7 mm and 30.8 mm.

The total natural output of sockeye fry from the Nanika River in 1962 has been computed at 8.5 million, and an additional 3.8 million were contributed from the hatchery. While the native fry were the product of the largest spawning escapement since 1956 the calculated egg-to-fry survival rate is sufficiently high to give rise to the suspicion that the

1961 escapement was greater than previously estimated.

The Nanika River sockeye fry rear in Morice Lake for one or more years before migrating to sea as smolts. In the years 1961 and 1962, the smolt migration from the lake has therefore been sampled with a view to determining its magnitude and timing. The migration was in progress throughout the period April 28 - June 24 in each year with the peak occurring between May 10 and June 3 in both years. Computations based on the smolt-sampling program revealed that the 1961 migration was composed of 59.5 percent Age 1 (Sub 2) fish and 40.5 percent Age 2 (Sub 3) fish, while the corresponding results in 1962 were 31.7 and 68.3 percent, respectively. The mean weights and lengths of the samples taken in both years are set forth in the following table.

	Mean Length in mm.		Mean Weight in Grams	
Year	Age 1	Age 2	Age 1	Age 2
1961	76.2	98.6	3.43	7.39
1962	75.0	98.4	3.72	8.10

A tow-netting program was initiated in 1961 to measure the relative abundance and distribution of juvenile sockeye in Morice Lake; and during the same year a limnological study, embracing the collection of temperature data, secchi-disc records, and the relative densities of zooplankton, was also initiated.

2.3.2 Pink Salmon Transplants to Robertson Creek (See also Section 2.2, page 88)

Small indigenous populations of pink salmon, which have a biennial cycle, spawn in the lower reaches of the Somass River system, near Alberni, in the odd-numbered years only. While this species has rarely been observed in the upper reaches of the system recent developments such as the alleviation of an obstruction at Stamp Falls and the construction of a suitable spawning ground at the Robertson Creek spawning channel created conditions which were deemed suitable for the introduction of pink salmon into the upper watershed with a view to establishing a substantial run in all years.

Transplants of eyed pink salmon eggs to the Robertson Creek spawning channel, which is situated in the upper Somass system, commenced in 1959, and these have been continued annually since that time on a varying scale depending upon the availability of eggs in the donor streams. Collections from the Tsolum River and Indian River (Burrard Inlet) in 1959 resulted in a transplant of 1.6 million eggs, while the Tsolum escapement in 1960 permitted a transplant of 850,000. The full-scale transplants of 1961 (4.8 million) and 1962 (5.4 million) were secured from the Indian and Atnarko Rivers respectively.

In the years 1959 to 1961 inclusive, the green (newly-fertilized) eggs were transported by vehicle or aircraft to a hatchery near Courtenay, where incubation was permitted to proceed to about 650 Fahrenheit units. At this stage they were transported to, and planted in the spawning channel. Incubation losses were held to a range of 5-8 percent.

In the spring of 1960, the entire downstream migration resulting from the 1959 transplant was captured and enumerated, and egg-to-fry survival was found to be approximately 95 percent. Coincident with the regular planting procedure a number of survival-assessment basket plants were made. These consisted of 100-300 eyed eggs and assorted gravels in wire-mesh baskets, fabricated in the shape of 5-inch cubes, which were buried at selected locations between the planted rows. A number of these baskets were removed and examined periodically throughout the incubation period, and the rate of survival calculated by this means corresponded closely to that obtained by the total enumeration. The trapping and handling associated with complete enumeration imposes unnatural physical stresses which in all probability reduces the survival rate. Consequently complete enumeration has not been undertaken since 1960 although downstream migrations have been sampled in order to establish the diurnal and seasonal timing; and basket plants have been employed to determine the egg-to-fry survival rate. By these methods it has been found that about 85 percent of the fry emerge from the gravel to commence their downstream migration when 2,000-2,150 Fahrenheit units have been accumulated. Average survival rates have been 89 and 93 percent in 1960 and 1961 respectively.

Eggs for the 1962 transplant were taken from the escapement to the Atnarko River (Bella Coola system), and in contrast to previous years, pre-planting incubation was undertaken at both donor and recipient streams. One million eggs were placed in a temporary floating "hatchery" in the Atnarko River while six million were shipped directly by vehicle and aircraft to temporary incubation facilities at Robertson Creek. Pre-planting mortalities at both stations were inordinately high (over 17 percent at Robertson Creek and 31 percent at Atnarko). Preliminary histological examinations indicated that a high proportion of these losses were caused by unfertilized eggs. In addition, an estimated five percent of the Atnarko-incubated eggs were characterized by reduced vascularization and retarded or arrested development. It is considered that incomplete circulation and mechanical injury probably contributed substantially to the severe losses at the Atnarko, while high temperatures during the initial incubation period may have been instrumental in the Robertson Creek losses.

A total of 5.45 million eggs drawn from both sources were planted between October 12 and November 5, and a preliminary estimate based on the inspection of 11 of the 45 survival-assessment baskets indicates that average egg-to-alevin survivals will be in the order of 76 and 86 percent respectively for the Atnarko- and Robertson Creek-incubated eggs.

In 1961, 131 adult pink salmon, which were the product from the 1959 transplant, returned to Robertson Creek, and an additional 30 spawners were observed during periodic inspections of the remainder of the Somass system. In 1962, the adult return to Robertson Creek from the 1960 transplant totalled 240. Surveys of the upper Stamp River during the peak of spawning activity in the channel revealed only two spawning fish, and in both years, losses to the Alberni Inlet-Barkley Sound gillnet fishery were negligible.

Experience obtained to date in connection with this program supports the following generalizations: Redds were mostly confined to the channel margins except in those instances where an earlier planting produced a riffle effect. Egg retentions in 1961 averaged 0.1 percent with a maximum of 1.5 percent. Total egg deposition was approximately 70,000. In 1962, pre-spawning mortality and an increased period of retention reduced the potential egg deposition of 110,000 by 30 percent. Water temperatures in the channel during the holding and spawning period ranged between 65° and 58°F in 1961, and 64° to 60°F in 1962. Post-spawning velocities at redd sites ranged from 2.1 to 4.4 feet per second, and dissolved oxygen in the sub-gravel ranged between 9.6 and 13.2 parts per million.

2.3.3 Transplants of Adult Coho and Chinook Salmon to Robertson Creek (See also Section 2.2, page 88).

In 1961, 653 coho and 220 chinook salmon, captured at the mouth of Robertson Creek and at Stamp Falls, were transported by tank truck to discrete sections of the Robertson Creek spawning channel.

The section reserved for coho is approximately 40 feet wide by 785 feet long, which, with due allowance for three 30-foot holding pools situated at the two extremities and the mid-point, provides approximately 2,600 square yards of spawning area. Chinook transplants were introduced into a 630-foot section, with pools at the downstream and upstream ends, which provides a potential spawning area of about 2,000 square yards.

Eighty percent of the spawning of both species occurred within 100 feet of the holding pools, with water temperatures during spawning ranging downward from 55° to 48°F for the chinooks, and from 55° to 38°F for the coho. The average individual spawning duration was six days for chinooks and nine days for coho. Chinooks averaged 4,500 eggs per female, coho 2,700. Twenty percent of the 80 chinook females spawned completely, 30 percent partially, and the remainder died unspawned. Of the 270 coho females, 41 percent spawned completely and 6 percent partially. Incidence of fungus (saprolygnia sp.) infection was in excess of 80 percent for both species.

The average area of 15 chinook redds was 4.6 square yards while that of 12 coho redds was 2.7 square yards. At the imposed densities, utilization of the spawning areas available to each species was only seven percent for the chinooks and 16 percent for the coho. Dissolved oxygen concentrations in the sub-gravel at redd sites ranged from 9.6 to 12.2 ppm. The total calculated egg deposition was 326,000 and 150,000 for the coho and chinooks respectively.

In the spring of 1962, traps were installed in the experimental test flume, which is situated downstream from the transplant areas, in order to facilitate a complete enumeration of all downstream migrants. From April 16 until May 24, a total of 81,000 chinook and 85,000 coho fry were captured. The former, which represents a 54 percent egg-to-fry survival rate, is considered to be a relatively accurate minimum assessment whereas the latter must be adjusted to include approximately 15,000 coho fry captured upstream of the trapping site for use in the rearing experiments. Furthermore, it has been estimated that upwards of 10,000 coho fry took up residence, at least temporarily, in the channel. With allowances for these factors the coho egg-to-fry survival has been estimated at 33 percent. Water temperatures during the period of fry migration ranged between 48° and 55°F.

The 1962 adult transplants were limited to 493 coho which were captured in the lower extremities of

Robertson Creek and at the Stamp River outlet from Great Central Lake. These were liberated in the spawning section used for the 1961 transplants. The high pre-spawning mortality incurred in 1961 prompted examination of all captives so that only the damage-free individuals would be introduced into the channel. By the end of the year over 80 percent of the transplanted population had been accounted for, with 42 percent of the females having spawned out completely, 14 percent partially, and the remainder dying unspawned. Post-mortem examination of all females revealed that the incidence of fungus infection approached 100 per cent. The relative seriousness of the individual infections was measured by recording the percent of head or body areas which were visibly infected; whether or not the gills were infected; and the nature of the infection - whether superficial, or deep. Furunculosis lesions, fin rot, gill damage, and internal damage were also recorded. The results of the preliminary analysis based on these records are presented in the accompanying table, which refers only to those conditions which were most commonly encountered and/or those where lethal potential could reasonably be inferred.

It will be noted in the table that the extent of fungus infection in the head region and the incidence of damage and infection in the gills are significantly higher in the unspawned and partially-spawned dead; that damaged gills and furunculosis lesions are common only to the unspawned dead; and that the extent of fungus on the body does not appear to be correlated with spawning success.

Dead Condition (Females only)	Spawning Success		
	Unspawned	Partially Spawned	Completely Spawned
Average % of head area infected by fungus (Superficial and deep)	90	80	65
Percent incidence of deep fungus infection (head area)	90	85	55
Percent incidence fungus infected gills	90	100	75
Percent incidence gill damage	25	0	0
Percent incidence furunculosis lesions	20	0	0
Average % of body area infected by fungus (Superficial and deep)	23	10	22

Redd distribution in 1962 varied somewhat from that which was recorded in 1961, with 44 percent of the established redds having been classed as marginal (centres not more than five feet from the channel margin), 27 percent pool-influenced (not more than 40 feet upstream or downstream from holding pools), seven percent central (not associated with pools, and their centres lying in the middle-third of the channel), and the remaining 22 percent being grouped in a general "submarginal" classification. Floating cover set out in mid-stream and along the margins of the channel did not appear to be of significance insofar as redd distribution was concerned, although it was utilized extensively in the holding pools. The effect of riffle areas on the selection of spawning sites was tested by means of a simulated, channel-width riffle, 50 feet long, which was well-removed from the possible influences of the pools. While the riffle constituted less than eight percent of the total available spawning area, over 20 percent of the recorded redds were concentrated in this area, with over 60 percent being marginal, and the remainder submarginal. In spite of the relatively-low imposed population density, up to 30 percent of the redds suffered to some degree from overspawning. The average area of 18 randomly-selected redds was 6.3 square yards. Spawning temperatures ranged between 50° and 38°F, and channel discharge, which ranged between 130 and 150 cfs, maintained the depth of flow at approximately 20 inches, with velocities in the range of 1.9 to 2.2 fps.

2.4 INVESTIGATIONS AND ASSESSMENTS

2.4.1 Indian River

Indian (Canoona) River, which is situated on Princess Royal Island approximately 120 miles southeast of Prince Rupert, drains a two-lake system into Princess Royal Channel, near Butedale. The one-mile length between the lower (Canoona) lake and the river mouth is relatively steep with three significant reaches of localized drops, one of which is located near the mouth immediately above the flood-tide influence, another immediately downstream from the lake, and the third midway between these two. Throughout the normal range of discharge, one or more of these drops constitutes an obstruction to migrating pink salmon which spawn in the river, and in some years, they have caused this species to be either partly excluded from the watershed or their distribution has been restricted. Only under rare, and exceptionally favorable conditions, have small numbers of pink salmon been able to ascend the uppermost falls and proceed to Canoona Lake and the extensive spawning grounds upstream. While coho salmon have been more successful in gaining access to the upper watershed, they frequently have been observed to experience mortality at the third falls. Recent salmon escapements to the Indian River have been estimated at 20,000-50,000 pinks (odd-numbered years only), 1,000-5,000 coho, 500 chums, and less than 50 sockeye. As the bed of the Indian River consists only of scattered pockets of gravel in a bedrock base the total spawning area available is restricted to less than 10,000 square yards; and it would appear that the spawning escapement to this system is substantially greater than that which would normally be considered as the optimum capacity.

The Anchor River, which drains the upper (Anchor) lake into Canoona Lake, contains extensive gravel beds which are virtually unused because of the access difficulties outlined in the foregoing. With a view to achieving full utilization of this upstream potential, this Branch has constructed three vertical-slot fishways, one at each obstruction in the lower river.

A biological program was initiated in 1961 to assess the effectiveness of the newly-constructed fishways. In that year a pink salmon population estimated at 50,000-100,000 entered the system during August and September, and it was observed that these fish utilized all three structures without apparent delay or injury. While spawning occurred throughout the watershed it was especially significant that an estimated 20,000 pink salmon ascended the lower river to Canoona Lake where they resided for a short period of time before continuing on to spawn in the Anchor River. A study of carcass samples obtained from the Anchor River spawning grounds indicated that the fish had spawned successfully. The total egg deposition was calculated to be 18.0 million.

The unprecedented utilization of the Anchor River as a pink salmon spawning ground logically raised questions as to the egg-to-fry survival rate and the relative success of the fry in migrating through the system to the sea. Morevoer, the relative ease with which the pink salmon ascended to Canoona Lake ensures that the coho, and possibly some chums and sockeye, will utilize the upper watershed to a greater extent than formerly; and since these stocks might therefore be expected to increase it was important that their abundance be accurately measured. To answer these questions a downstream-sampling program was conducted in Anchor River, Canoona Lake, and Indian River in 1961.

The egg-to-fry survival rate was estimated from data obtained at inclined-plane traps installed in the Anchor River, and in the Indian River at two locations - the outlet of Canoona Lake and immediately above tidal influence. Small-mesh beach seines and gillnets, which were operated throughout the season at several locations in Canoona Lake, provided the basis for estimating fry abundance. The traps were useful also for the collection of samples for determination of sex, length, and stomach contents.

The trapping operation conducted in the Anchor River from April 8 to May 18 resulted in a catch of 46,000 fry. Only slightly less than one percent of the total cross-section was fished, however, and it has been estimated that the total fry population originating in the Anchor River was in the order of 4.5 million, which indicates an egg-to-fry survival of approximately 25 percent.

The seaward migrations from Canoona Lake and Indian River were sampled from April 4 to May 19, and while no attempt has been made to calculate the total migrations there was some evidence that the traps were not consistently sampling the emigration. Nevertheless, it is known definitely that pink salmon fry migrated out of Canoona Lake.

The data obtained at the Anchor and Indian Rivers showed that the fry at the time of emergence ranged from 32 to 37 millimetres in length, with the average being 34.5 millimetres (tip of snout to fork of tail). The fry captured at the outlet of Canoona Lake, however, had a range of 33 to 40 millimetres with the average being 38 millimetres, and it was possible therefore to identify the Anchor River fry in the Indian River sampling trap.

The 15 beach-seine sets made in Canoona Lake resulted in an aggregate catch of 39 adult trout, five coho fry, 46 pink fry, 316 stickleback, and 143 sculpin, while 15 gillnet sets caught a total of 213 cutthroat trout, 51 kokanee salmon, 29 dolly varden char, and 13 sculpin. The presence of kokanee is of interest in view of the few adult sockeye observed in the system.

Examination of the stomach contents of trout taken in the gillnets revealed that those which were sexually mature had not been taking food whereas the immature trout had been feeding on bottom material and pink salmon fry. While in most instances an accurate analysis of the stomach contents was not possible because of the advanced stage of digestion, it was estimated that some samples contained as many as 100 fish. Fry were found in the stomachs of the other species, although schools of fish, believed to be kokanee, were observed on the lake surface when fry were present. The limited data indicates that predation may be an important factor in future evaluation studies.

As a result of the data obtained from the biological programs undertaken in 1961 and 1962 it has been concluded that the Indian River fishways are fulfilling their intended function.

2.4.2 Seymour-Belize Inlets

Several years ago this Branch was requested to cooperate with the Fisheries Research Board in a joint study to determine whether or not it might be feasible to convert Seymour-Belize Inlet from a tidal basin into a freshwater lake into which sockeye salmon could be introduced with a view to establishing a valuable self-perpetuating run. This investigation, which was of a very preliminary order, involving only office studies and a research of available literature, was completed in 1962.

Seymour-Belize Inlet, located on the mainland coast of British Columbia opposite the northern tip of Vancouver Island, is a tidal basin with approximately 100 square miles of water surface which is completely land-locked except for its narrow outlet to the sea. Tributary streams are known to support small runs of coho and chum salmon but the area has never been regarded as a good producer of these species, nor has it ever been known to support sockeye. Nevertheless, the geographical, physical, and other similarities between this basin and Owikeno Lake immediately to the north, led to the conjecture that if Seymour-Belize were converted into a freshwater lake, it should be able to support a population of sockeye which would be comparable to that of the Owikeno system (Rivers Inlet fishery).

Preliminary studies of this proposal revealed the following:

(a) In order to prevent saltwater intrusion into the proposed lake, it would be necessary to construct a dam at the outlet which would be at least 1,600 feet long with an average height of 90 feet minimum. While available data was not such that even a very preliminary cost estimate could be prepared, it was concluded that a suitable structure at this site probably would cost upwards of $10,000,000 and might even run as high as $50,000,000. Furthermore, the structure would have to be equipped with suitable spillways, fishways, and a navigation lock, and these undoubtedly would cost an additional several million dollars.

(b) While no predictions have been made with respect to the time required before the basin could be "freshened" to permit the introduction of sockeye salmon, there is evidence to indicate that this would require tens of years and if this is so, there is little doubt that the construction costs and the accumulated interest accruing over the transition period would not be offset within a reasonable period of time by the fisheries returns.

(d) Available spawning areas within the basin's watershed are not extensive enough to support a large sockeye population and there is doubt that spawning channels or hatcheries would be suitable for a project on so large a scale.

(e) Available knowledge is not such that the requirements for a successful large-scale transplant of this type can be defined.

The joint conclusion reached in this study was that while the project might, perhaps, have some merit, its relatively colossal scale and attendant uncertainties are such that it would not be a reasonable undertaking at this time. In this connection, it has been noted that there are many known sockeye-supporting lakes in British Columbia which are considered to be capable of supporting much larger populations, and it is suggested that since improvements aimed at native runs will have the best chance for success, the fisheries development program should continue to be directed toward these projects before consideration is given to the possible establishment of runs in areas to which they are now foreign.

2.4.3 Owikeno Lake

Owikeno Lake, which is situated approximately 250 miles northwest of Vancouver, serves as the freshwater rearing area for the valuable Rivers Inlet salmon stock, which over the last 60 years has contributed to the commercial fishery an average annual catch of one million pieces.

As part of an overall investigation, which included an assessment of the adult escapement, this Branch, in the early spring of 1960, initiated a program on Owikeno Lake to measure its basic limnological features as they pertain to juvenile sockeye production. These studies have been continued each year since then, so there are now three years' data on hand.

Owikeno Lake (see accompanying map) is composed of a chain of four separate basins interconnected by relatively shallow narrows. Basins 1 and 2 (the lowermost basins) are characterized by extreme depths, exposure to strong winds, and high turbidity. In contrast, the upper two basins (basins 3 and 4) are shallower, sheltered from the prevailing winds and are considerably less turbid.

The data presented in the following review represent twice-monthly observations collected from five juvenile sampling stations and eight limnology stations which were evenly distributed throughout the lake. While the full significance of these data is lost by combining them into yearly averages, a more detailed analysis is beyond the scope of this report. The "All Basin" data has been weighted, however, for the relative area represented by each basin.

Since sockeye smolt production is directly dependent upon the basic nutrients → phytoplankton → zooplankton → sockeye fry food chain, the present study is primarily concerned with the measurement, in a quantitative manner, of each of these trophic levels.

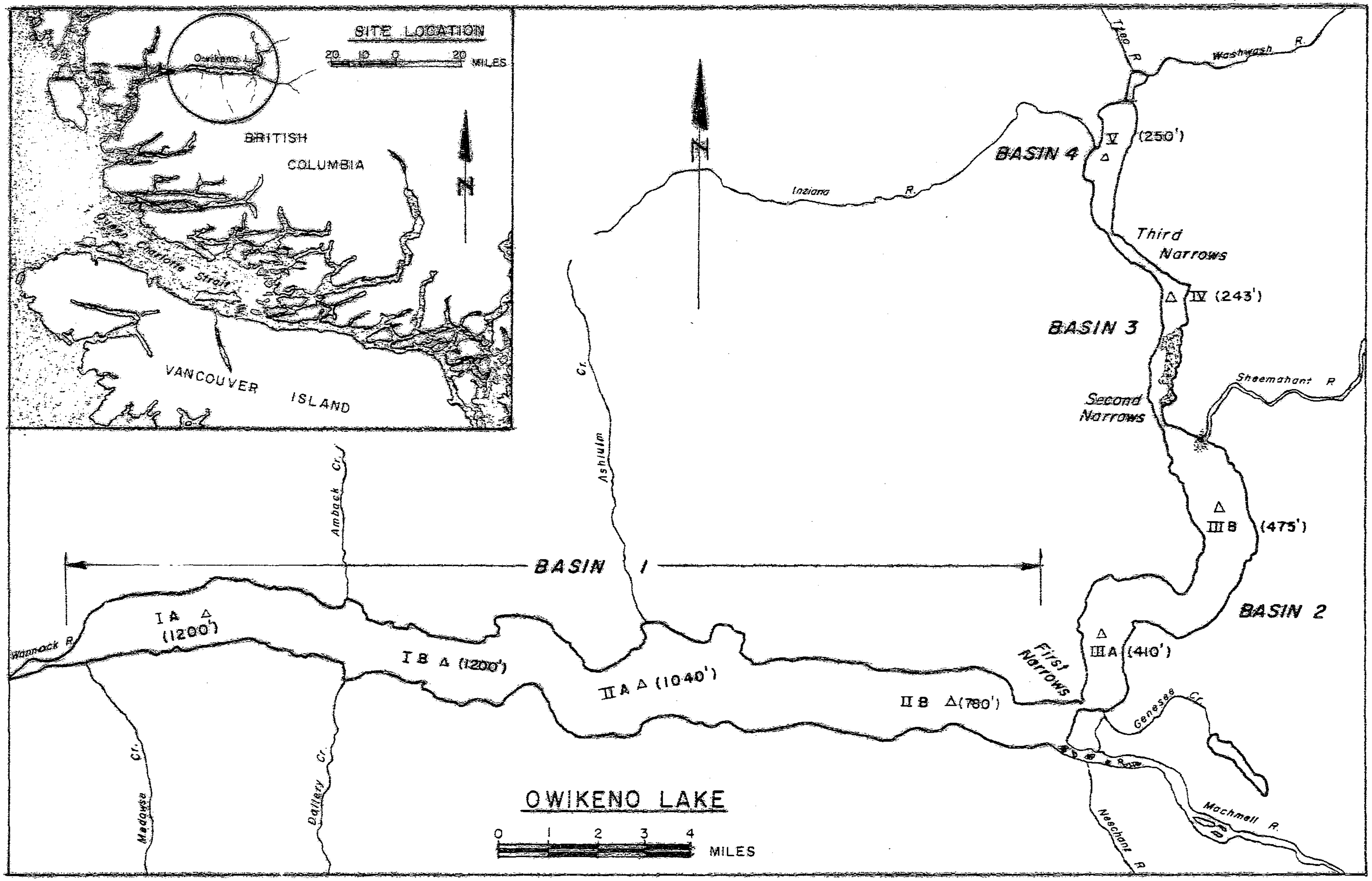
Basic Nutrients

Since a deficiency of phosphorus, more than that of any other basic nutrient material, is apt to limit basic productivity, it was chosen as a measure of basic nutrient value. While the method employed for the determination of soluble inorganic phosphate content had a sensitivity as low as 0.01 ppm, it did not prove to be suitable for the extremely low concentrations present in Owikeno Lake.

Phytoplankton

The "light and dark" bottle technique was chosen to measure the rate of photosynthesis and hence the rate at which basic nutrient materials are incorporated into phytoplankton cells. This technique also proved to be too insensitive for use at Owikeno Lake, and consideration is now being given to the feasibility of using the hypersensitive radioactive carbon technique.

Measurements of the lowermost steps in the food chain have been attempted but these have not been completely



SITE LOCATION
20 10 0 20 MILES
Owikeno L.
BRITISH
COLUMBIA
Queen Charlotte Strait
VANCOUVER
ISLAND
N
Tzeo R.
Washwash R.
BASIN 4
V (250')
Inziana R.
Third
Narrows
IV (243')
BASIN 3
Sheemahant R.
Second
Narrows
Ashlulm Cr.
Amback Cr.
III B (475')
BASIN 1
BASIN 2
Wannock R.
I A (1200')
I B (1200')
II A (1040')
II B (780')
First
Narrows
III A (410')
Genesee Cr.
Madowse Cr.
Dallery Cr.
Neechanz R.
Machmell R.
OWIKENO LAKE
0 1 2 3 4
MILES

satisfactory, although they do provide some indication of the very low primary production which occurs in Owikeno Lake. On the other hand, the zooplankton- and sockeye fry sampling techniques are apparently providing an adequate measure of the distribution, growth-rate, and relative abundance of the sockeye juveniles in the lake, and of the abundance and distribution of their main food supply.

Zooplankton

A No. 10-mesh plankton net, raised vertically at representative stations on the lake, provided the means by which zooplankton was collected. The mean April-to-October results, expressed as dry weight of organic matter in pounds per acre, is presented hereunder.

Year	Basin 1	Basin 2	Basin 3	Basin 4	All Basins
1960	4.5	6.0	3.1	6.7	5.0
1961	3.5	3.7	2.0	6.1	3.7
1962	7.5	7.4	7.7	12.3	8.2

The wide variations in the zooplankton standing crop which have occurred during the three-year period appear to be directly related to lake transparency, and inversely correlated to the population density of the juvenile sockeye. In all years Basin 4 exhibited the highest standing crop, while in two of the three years, Basin 3 had the lowest. From year to year, the quantity of zooplankton in all basins varied similarly.

Juvenile Sockeye

The abundance of juvenile sockeye in the various basins of Owikeno Lake was estimated by means of a method, developed by the Fisheries Research Board of Canada, which converts tow-net catches per unit of effort into population densities per acre on the basis of catches obtained in a lake for which the approximate population is known. The following table sets forth, in fish per acre, the juvenile abundance in the various basins of Owikeno Lake, as estimated from the tow-netting results obtained in July-October of the years 1960-62 inclusive, and the total abundance in 1959, as estimated from the tow-netting conducted in the spring of 1960.

Year	Basin 1	Basin 2	Basin 3	Basin 4	All Basins
1959	-	-	-	-	9,675
1960	6,690	8,880	8,290	6,180	7,620
1961	3,640	2,880	970	1,990	3,553
1962	4,105	2,210	4,510	2,970	3,924

It will be noted that disproportionately-low populations existed in Basins 2, 3, and 4 in 1961, and while the situation improved somewhat in Basins 3 and 4 in 1962, the juvenile population in Basin 2 still remained disproportionately reduced from the 1960 levels. It is of interest to note that this uneven distribution of juveniles is comparable to the distribution of parent spawners in the tributaries to the respective lake basins.

Fingerling sockeye in Owikeno Lake exhibit an extremely slow growth rate as is evidence by the fact that in April and May the mean weight of an individual approximates 0.2 grams and by mid-October its weight has increased to only about 1.0 grams. The following table shows the mean October weight of fry, in grams, recorded in the various basins of Owikeno Lake during the three years of study.

Year	Basin 1	Basin 2	Basin 3	Basin 4	All Basins
1960	0.8	0.7	0.6	0.6	0.8
1961	1.2	1.1	0.9	1.2	1.1
1962	1.0	1.2	0.8	1.0	1.0

Analysis of the mean weight fluctuations from year to year in the various basins indicates that the growth rate of juveniles is inversely related to the existing population density.

The product of the mean weight and the number of juveniles present in an area, is a measure of the amount or biomass of sockeye in that area. In view of the inverse relationship between numbers and size, the biomass of a population of juveniles in a lake does not fluctuate as widely from time to time as do the numbers of fry. From the tropho-dynamic standpoint, the biomass is a good measure of sockeye production as it is indicative of the amount of material that ends up as fish flesh. The following table sets forth the mean October biomass, in pounds per acre, of sockeye juveniles in the various basins of the lake in 1960-62 inclusive.

Year	Basin 1	Basin 2	Basin 3	Basin 4	All Basins
1960	11.8	13.1	10.0	8.2	12.6
1961	9.0	7.1	2.0	5.2	8.7
1962	9.8	5.9	7.9	6.4	8.9

A series of regressions, based on the logarithm of the catch in relation to the elapsed time over a 100-day period, have been computed as a means of assessing the survival rate. The regression lines so computed generally tended to be straight, and it was assumed, therefore, that the mortality rate was constant throughout the 100-day period. It was also assumed, with one exception which is discussed below, that the availability of the fry remained constant during this period. A summary of these survival rates, expressed as percentages over a 100-day period from July to October, is presented in the following table.

Year	Basin 1	Basin 2	Basin 3	Basin 4	Mean
1960	30	17	6	25	20
1961	40	32	9	79	40
1962	29	66	2	39	33

The low survival rates in Basin 3 are suspect, and it is thought that they might be due to emigration from the sampling area. A plot of the survival rate against the numbers of juvenile sockeye present indicates that these two factors are inversely related, with survival gradually increasing as the population density declines from 9,000 juveniles per acre to 4,000 per acre, after which further reductions produce an even greater effect on survival.

The abundance of zooplankton can also affect the survival of resident sockeye juveniles in the lake, as evidenced by the plots for each basin of the mean April to October zooplankton standing crop against the 100-day survival figures. These indicate that a positive relationship exists between the amount of zooplankton available and the rate of survival of juvenile sockeye, although the correlation, as might be expected, is not high since survival is dependent upon factors other than those related to food supply.

2.4.4 <u>Stream Inventory Program</u>

In 1961, this Branch initiated a long-range program to assess all existing and potential salmon-bearing watersheds in British Columbia with a view to delineating the individual factors which limit salmon production in each; and having done so, to consider, on a priority basis, the remedial measures which might be implemented to improve salmon production for some, or all, of these watersheds. This assessment will result in the compilation of a catalogue or inventory which will record each stream by means of a description, map, a classification, and a tabulation of its spawning populations.

Queen Charlotte Islands

The Queen Charlotte Islands were selected as the first area for study because their present stocks of salmon are substantially lower than their long-term averages. The watershed surveys, which were conducted during the late spring and in the summer months, had as their objective the following program: to measure the quantity and quality of gravel in the areas which were readily accessible to fish, as a basis for estimating the total available spawning area; to record instances of logging and mining operations (past and present) in close proximity to the streams, in order to determine whether or not these operations have influenced salmon production; to obtain basic data with respect to points of difficult passage, and to collect information regarding stream characteristics above these points, having reference to their potential salmon production; to record for future reference, the type and scope of fisheries development work which might be implemented with a view to substantially increasing production; and to obtain samples of chum salmon spawning populations looking to determining the size and age composition.

These surveys were facilitated greatly through the cooperation extended by the Protection Branch, which supplied transportation, accommodation, and general advice and assistance.

The data on hand indicate that the watersheds of the Queen Charlotte Islands have an estimated 3.0 million square yards of readily-available spawning gravel, and that these are being exploited only lightly by the present salmon populations. Some minor streams in the southeastern sector of the area have lost their productive capacity as a result of altered runoff patterns which have developed from the denudation of the watershed by the logging interests; although loss of suitable spawning substrata as a result of gravel-removal by the logging, and other industries, is also a factor. A number of other minor streams appear to have rehabilitated themselves after being logged-off and these may have regained their initial productivity. While industrial operations appear to have adversely influenced salmon production in some local areas of the Queen Charlotte Islands, the affected regions are not of such a scope as to be responsible for the present condition of the salmon stocks. This view is strengthened by the fact that the relative declines in the salmon stocks of the unlogged watersheds have been in the same order as those of the logged-off watersheds.

Points of difficult passage have been located on six streams, and while preliminary engineering surveys have been recommended, it is considered that implementation of remedial measures would not greatly enhance their present production.

Stream-flow metering stations were established during the year on five major streams which are considered to be potential sites for fisheries development projects. The results obtained from these installations will prove invaluable to the future assessment surveys inasmuch as there are no existing records of discharge for the streams on the Queen Charlotte Islands.

Scale and length samples taken from chum salmon in 17 streams in 1961 revealed that these fish were three- and four-year olds.

2.4.5 Babine Lake

Approximately 90 percent of the sockeye salmon taken in the Skeena River fishery originate in the Babine system, which discharges into the Skeena 150 miles northeast of Prince Rupert. Babine Lake, with a surface area of 186 square miles, and Nilkitkwa Lake, a small expansion of the Babine River immediately downstream from Babine Lake, serve as the rearing areas for this sockeye run.

Studies undertaken by the Fisheries Research Board of Canada have shown that the smolt production from Babine Lake currently represents only 1/3 of the lake's estimated productive potential; and in view of these findings it would seem that the lake could sustain a fry input some 300 percent greater than that which now occurs.

Accordingly, this Branch and the Fisheries Research Board, with the guidance of the Skeena River Management Committee, have initiated studies looking to determining the most suitable means by which the full potential of the Babine system might be realized.

Sixteen streams tributary to Babine Lake currently provide spawning grounds for 300,000-500,000 sockeye, but one-third of this area is of only sporadic value from the production viewpoint because of unstable flow regimens. Furthermore the commercial fishing operations at the mouth of the Skeena River are regulated in accordance with the recommendations of the Skeena River Management Committee to ensure that the spawning escapements are of a magnitude which will fully utilize these available spawning areas. In view of these considerations preliminary assessments determined that improvement and extension of the existing spawning grounds, looking to increasing the fry input to the lake, constituted the most reasonable approach to developing the full potential of the Babine Lake rearing area. Engineering and biological surveys have therefore been initiated with a view to formulating a program of development which would achieve this objective.

Surveys undertaken to date have revealed that three spawning streams (Morrison River, Fulton River and 15-Mile, or Pinkut Creek), by virtue of their lake-fed water supplies and relatively stable conditions, warrant serious consideration for intensive development. These streams accommodate the largest existing spawning runs to the system and their geographical locations are such that each contributes its fry output to one of the three major rearing basins in Babine Lake. Grizzly Creek, a tributary of Sutherland River at the south end of Babine Lake, is also receiving consideration for possible development because of its strategic location and its lake-fed water supply. Its priority, however, would be lower than the other three in view of its relative isolation and its smaller potential.

The Morrison River, which serves as a spawning ground and as a waterway to spawning grounds upstream, is frequently obstructed by beaver dams. The stream bed, which is composed of boulders, bedrock, and some gravel, can accommodate an estimated maximum of 30,000 spawning sockeye. Preliminary results of the surveys indicate that development of this stream should be directed first to the access problem, after which attention should be centred on improvement of the spawning grounds, and possibly to the implementation of flow regulation measures.

The Fulton River which is accessible for a distance of four miles, one-quarter of which is canyon, is currently undergoing a special productivity study. The 1961 spawning run of 189,000 sockeye, which is considered to be its current capacity, represented a potential deposition of 237.7 million eggs. Fry output in 1962 was

25.74 million for a computed egg-to-fry survival of 10.8 per cent. The 1962 spawning run which consisted of 86,000 sockeye represented a potential egg deposition of 137 million. Fry output and the egg-to-fry survival rate will be determined in 1963. Some spawning ground improvements could be effected in parts of the presently used areas.

A float survey, conducted in 1962, determined that there were 159,400 square yards of suitable spawning gravel in a 16-mile reach of the river upstream from a falls which now constitutes the upstream limit of salmon migration. As this upper area constitutes an area as extensive as that now being utilized, engineering surveys are being considered to determine the physical and economic feasibility of implementing measures to allow fish to surmount the 60-foot falls.

Fifteen-Mile Creek, which is accessible to salmon for a distance of less than one mile, constitutes a productive spawning area with an estimated capacity for 20,000 sockeye. While it may be that the spawning potential of this stream in the upper areas is not large the extensive flats located near the river mouth suggest that it might be a practical undertaking to construct a spawning channel or hatchery for purposes of supplementing the natural production.

While these investigations will be continued in more detail preliminary results indicate that it might be possible to improve fry production by a program of intensive development of three, and possibly four, strategically-located spawning areas.

2.4.6 Goldstream River

Sport-fishing interests in the Victoria area have strongly recommended that a fisheries development program be implemented on the Goldstream River, some 15 miles from the city, with a view to increasing its production of coho salmon, and, possibly, to introduce chinook salmon into the system.

The population levels of the coho and chum salmon stocks which now utilize the lower reaches of the river for spawning purposes are being restricted by low prevailing flows. These result, in part, from the upstream operations of the Greater Victoria Water District which maintains several reservoirs from which water is diverted to the Greater Victoria area for domestic purposes. The proposal advanced by the sport fishermen stemmed from reports to the effect that completion of a tunnel now under construction to divert water from the adjacent Sooke River watershed into the Goldstream would so improve the available water supply in the Goldstream that it would be possible to provide increased flows in the lower river for purposes of improving salmon production. In the light of this report the recommendation was deemed worthy of further study, and investigations were therefore initiated by this Branch in

1962.

Chum salmon, with a maximum population estimated at 20,000-50,000 in 1952, and more recently (1959-60) in the 2,000-5,000 range, are the more prevalent species of salmon utilizing the Goldstream system. While the coho salmon escapement was recorded as being in the 2,000-5,000 range in 1934 and 1940, this stock, in recent years, has been estimated to range from 50 to 500 fish. A steelhead trout population of 1 to 50 fish has been recorded in some years. Spring and pink salmon have also been recorded in some years, but no pinks have been seen since 1939 and only one spring salmon was recorded in 1962. Twenty thousand spring salmon fry were planted in the stream in 1930 and 20,000 spring salmon eggs were planted in 1931. The adult spring salmon observed during the 1930's may have resulted from those plantings.

A preliminary study was carried out to determine the physical make-up of the accessible area, the quantitative and qualitative measures of the stream bed material, and the amount of wetted area available under varying flows. In addition an inquiry was directed to the Greater Victoria Water District to ascertain the magnitude of the minimum spill which the District would be able to provide following completion of the new scheme.

The Goldstream River is accessible to fish for a distance of only 2½ miles from the mouth, further progress being prevented by an impassable falls. The stream is relatively small, with a base width of approximately 12 yards, and a summer flow of not more than 15 cfs. The stream bed is composed largely of boulders and bedrock with only the lowermost one-fifth containing gravel.

On the basis of the bottom composition and the full wetted area which would be provided by additional flows, it was calculated that the total spawning capacity of the Goldstream River would be in the order of 8,000 chum salmon. This capacity is approximately double the recent escapements. Under existing flows, however, only part of the stream bed is wetted and it appears that the productive capacity of the Goldstream may well be that of the present population level.

A principal factor affecting the production of coho salmon and steelhead trout is the amount of available rearing area, which, in turn, is dependent upon stream contour, wetted areas, and pool-riffle relationships, for which only estimates are available. Based on the relationship that one coho salmon requires five square yards of rearing area, it is considered that 3,000 coho smolts could be sustained by the Goldstream under existing average flow conditions. This may represent a return to the stream of 300 adults, which is the level of the present population.

The absence of chinook salmon in the Goldstream River is not surprising in view of the fact that this species normally returns to the smaller streams of Vancouver Island in the months of September and October, where they reside in pool areas for approximately one month before moving onto adjacent spawning gravel. This behaviour pattern would not be possible in the Goldstream River, however, because of the shallow depth of flow, the absence of suitable pools, and a lack of suitable spawning gravel in other than the lower reaches.

The many vagaries and intangibles associated with the operation of a domestic water supply are such that the Greater Victoria Water District is not in a position to promise water releases in excess of those which have been maintained in recent years. While it is true that the tunnel from Sooke Lake will provide for an increased diversion to the Goldstream, this work will not be completed until 1970, and it is estimated that the domestic demand will have increased in the interim to more than offset the apparent advantage of the new diversion capacity.

In view of the fact that additional flow releases to the lower Goldstream River are not compatible with the interests of the Greater Victoria Water District it has been concluded that a fisheries development program, under existing conditions, would not be likely to produce results which would be commensurate with the cost. A close liaison will be maintained in future, however, with the Water District to ensure that the flows in the lower Goldstream are maintained at the maximum possible in order that its full capacity for fisheries production is fully utilized.

2.4.7 Cold Creek

Cold Creek, located between the Campbell Lakes and the Quinsam River, is a relatively small stream approximately three miles long and five yards wide. It rises in a 'pothole' lake which is fed by springs and, reportedly, by infiltration from the McIvor Lake extension of the Campbell Lake reservoir. The stream's discharge and temperature characteristics are very stable; the maximum average discharge is approximately $2\frac{1}{2}$ times the minimum, and the annual temperature range is from slightly over 40°F to 53°F. While it has been reported that Cold Creek in the years prior to 1930 supported several thousand pink and coho salmon only a few of the latter species have been observed in recent years.

In 1961, private interests in the Campbell River area urged that the Department undertake a fisheries development program at Cold Creek looking to the rehabilitation of its depleted stocks of salmon. In line with this request this Branch has conducted site investigations extending over the years 1961 and 1962, with the following results.

(1) Two rock falls and a number of beaver dams in the lower one-third of the stream restrict access at some flow conditions.

(2) Less than five percent of the stream bed, which is composed largely of silt and sand, appears suitable for spawning purposes.

(3) The upper two-thirds of the creek plus some limited areas in the lower one mile have a favorable combination of pools and riffles for rearing purposes but the maximum water temperature is below that considered favorable to growth of Pacific salmon. Bottom insects appeared scarce at all observations, probably as a result of the combination of cold temperature and relatively unproductive silt-sand bottom.

Lacking details of the spawning history, and the physical and other changes which may have been wrought in the drainage area, it can only be speculated that the stream bed and water quality have been altered drastically since the 1930's when sizeable runs of coho and pink salmon occurred with regularity. The raising of the water level in Campbell Lakes has possibly altered the balance between spring inflow and surface runoff. The removal of forest cover by fires and logging probably created conditions responsible for the heavy silt load. These combined effects have apparently made the creek unsuitable at this time for a development project.

2.4.8 Kakweiken River

The Kakweiken River, which rises in Kakweiken Lake, flows in a southeasterly direction for about seven miles before discharging into Thompson Sound, approximately 40 miles east of the town of Alert Bay. For most of its length the river has a gentle slope, but two falls, located about two miles from the mouth, form an obstruction to salmon endeavouring to reach the excellent spawning areas upstream. In this connection it has been reported that only a small portion of the spawning escapements of up to 100,000 pink and chum salmon have been able to surmount the falls, with the result that spawning has been confined primarily to the gravel-poor lower reaches of the river. Furthermore, it was reported that sockeye, coho, and chinook salmon, bound for their natural spawning grounds in the upper reaches, were being injured as a result of the difficulties they experienced at the falls at certain discharges. Some years ago, a channel was excavated around the left bank of the upper falls as a means to facilitate fish passage at this point but it did not achieve the desired degree of success.

On the basis of these reports a preliminary engineering and biological survey was undertaken by this Branch in 1961. This was followed by a detailed survey in 1962. These surveys confirmed the earlier reports when it was found that salmon were being obstructed and seriously injured at both falls. Observations at the upper falls disclosed that there was only one success for every fifteen attempts to surmount the falls.

In the light of these conclusions it has been recommended that the existing channel which has been cut in the left bank at the upper falls be deepened and converted into an orifice-weir-type fishway as a temporary means of relieving the situation, pending the completion of more detailed biological surveys of the river system.

2.4.9 Tsolum River

For the past several years this Branch has conducted surveys of the Tsolum River system, near Courtenay, B. C., with a view to measuring the quality and quantity of the available spawning gravel, and to develop a means by which the normal low flows during the pink salmon migration could be augmented. These surveys have indicated that it might be feasible to develop a storage reservoir in the headwaters of the system at Wolf Lake, from which controlled discharges could be released during the critical low-flow periods to augment the natural flow, and thereby improve conditions for spawning and migration.

Additional studies, which are now in progress, will determine the storage capability of a reservoir at Wolf Lake, and whether or not the temperature of the water impounded in the reservoir could be maintained at a desirable level.

On the basis of available information it is believed that it might be feasible to increase the flows in the river by at least 50 cfs, and coupled with stream improvement there would be a marked improvement of conditions for pink salmon migration, spawning and incubation.

2.4.10 Tzoonie River

The Tzoonie River, tributary to Sechelt Inlet, approximately 40 miles northwest of Vancouver, was examined with respect to an access problem existing in a slide area, some 3/4 of a mile in length, which is located approximately 2½ miles from its mouth. While sockeye, coho, and chinook salmon and steelhead trout have been reported to be delayed and blocked at some flow conditions, chum and pink salmon have been restricted at all stages, to the river below the slide.

Recent population estimates range as follows: pinks 2,000-5,000; sockeye 2,000-5,000; chums 10,000-50,000; coho 2,000-5,000; and chinook salmon 50-100; and steelhead trout 50-100.

The area of difficult access has been under observation since before 1923, and remedial work in the form of blasting was done, without apparent success, in 1947. The results of a preliminary engineering survey undertaken in 1960 suggest that a major fishway would be required to solve the access problems for all conditions of flow.

A further survey was conducted in 1962 to re-assess the problems at the slide area and to estimate the potential production above and below. This study involved spot observations at a number of points in order to assess the ability of fish to ascend the obstruction. In addition measurements of the quantity and quality of stream bed material were taken over several miles of watershed.

At the prevailing water levels, migrating salmon were found to be holding at three sites in the slide area. Some were observed upstream of the slide, however, and it therefore appeared that the blockage had not existed throughout the entire duration of the salmon run.

The lower reaches of the river, which are used extensively for spawning purposes by chum and pink salmon only, were found to be largely rock and sand with the suitable gravel concentrated in the upper mile. The capacity of the total spawning area below the slide was calculated to accommodate 47,000 fish, which approaches the chum salmon populations recorded in some recent years. Development work in the form of stream bed improvement may more than double the present capacity of this area.

Upstream of the obstruction the streambed contains several miles of suitable spawning area plus favorable conditions for rearing coho juveniles. It would appear therefore that the productive potential is far in excess of the present populations.

On the basis of the foregoing preliminary findings it has been recommended that a comprehensive biological-engineering survey be undertaken with a view to assessing the access problem in detail and to develop a practical and economic solution.

2.4.11 Big Qualicum River (See also Section 2.1.1, page 77)

The Big Qualicum River, situated on the east coast of Vancouver Island some 39 miles north of Nanaimo, supports important stocks of chum, coho, and chinook salmon and steelhead trout, the populations of which have varied widely from year to year as a result of the extreme fluctuations in discharge and the high summer temperatures which are common to most coastal streams. In an attempt to maintain the annual salmon production at the maximum recorded levels, or higher, this Branch has constructed temperature- and flow-control works which are scheduled to commence operation in 1963 (see plan, page 77). The environmental control afforded by these works, together with the future improvement of the existing spawning grounds and the creation of artificial spawning areas, provide reasonable assurance that the productive potential of the stream will be so increased that it will more than offset the cost of the project.

With a view to assessing the effectiveness of the project, this Branch, in 1959, initiated a comprehensive program of investigations to obtain detailed basic information under natural conditions for later comparison with that resulting from the controlled conditions. These investigations, the results obtained to date, and the plans for the future are set forth hereunder.

Since 1959 adult salmon have been enumerated at a counting fence located 2,300 feet above tidal influence, and the abundance of seaward migrants has been measured at the same site. It is to be noted, however, that since a varying portion of the chum salmon population spawns downstream of the counting fence not all of this species is enumerated, and some reliance must be placed on estimates. Four years' estimates of the adult salmon escapements are given in the following table, with the figures in brackets being the numbers of chum salmon enumerated through the counting fence.

	1959	1960	1961	1962
Chinook	2,411	1,569	1,111	787
Coho	3,624	2,522	2,886	4,615
Chum	98,500 (83,500)	60,000 (57,501)	15,000 (10,421)	40,000 (35,033)
TOTAL	104,535	64,091	18,997	45,402

The yearly fluctuations in the reproductive potential of a given number of spawners has been due, in the main, to variations in the sex ratios and size compositions of the populations. The positive relationship between length and fecundity has remained virtually constant although yearly variations have been noted in the actual egg deposition as a result of the varying abilities of the females to complete the spawning act. For the three years in which the studies have been continuing the following estimates have been made with respect to spawning and survival of chum salmon in the Big Qualicum River.

	1959-60	1960-61	1961-62
Number of females above fence	42,300	23,750	6,000
Percent females in population	50.7	50.0	57.5
Potential egg deposition (x 10^6)	123.2	74.1	19.4
Success of spawning (%)	75.5	95.0	96.0
Net egg deposition (x 10^6)	93.0	70.4	18.7
Fry output (x 10^6)	17.7	3.7	3.4
Percent survival (from net deposition)	19.0	5.3	18.2
Percent survival (from potential deposition)	14.4	4.9	17.5

The poor survival in 1960-61 has been attributed to unusually high discharges which occurred in December, 1960, while the low level of spawning success in 1959 has been attributed to delays in the estuary as a result of low discharges which prevailed in November.

In addition to the quantitative measurements of the downstream migrants, attempts have been made to measure their quality with regard to length and weight inasmuch as the production of fry and smolts at higher population densities may result in a smaller average size at the time of migration, which, in turn, could result indirectly in a lower rate of survival during the early marine stage.

The salinities and temperatures of the waters off the mouth of the Big Qualicum River have been recorded by the Pacific Oceanographic Group of the Nanaimo Biological Station since the spring of 1961, so that these factors can be assessed in future studies of early marine survival.

A tagging program conducted in 1961 for the purpose of defining the time of arrival of chum salmon at the river mouth, and the varying times spent there, employed a drum seiner which operated within one-half mile of the river mouth. While the program commenced on October 23, only seven fish had been tagged by November 11; but the catch rose from zero on November 5 to 213 on November 11, the next fishing day, indicating an abrupt buildup in the chum salmon population. A total of 1,353 tags was applied from November 11 to December 6, of which 335 (24.8%) were recovered on the spawning grounds. The use of six tag-baffle combinations, which afforded the means by which the time of passage from the tagging site to the fence could be assessed, revealed that the average time between tagging and recovery on the spawning grounds was 21 days - 12 in the river, nine off the river mouth. It was also noted that the usual tendency for late arrivals to spend less-than-average time in migration and on the spawning ground was applicable to the Big Qualicum chum salmon.

Preliminary analysis of the results of a tagging program (See also Section 2.4.13, Page 150) conducted in 1962 in Johnstone Strait indicates that there was a peak abundance of Big Qualicum chum salmon in the lower straits during the first week of November, as approximately 50 percent of the spawning ground recoveries were fish which had been tagged during the period October 31 to November 7. The average time between tagging and passage through the counting fence, for the bulk of tagged individuals, was 21-23 days, and it was again found that the late arrivals took less time. If the movement of fish into the estuary followed the 1961 pattern, the major portion of the tagged fish spent approximately 14 days between tagging and arrival off the mouth, with the early segments taking 3-4 weeks. Results of previous chum salmon tagging programs in Johnstone Strait during 1945 and 1950 showed an average time lag of 7 and 12 days, respectively, between lower Johnstone Strait and recovery in the fishery off Qualicum. The apparently slow rate at which the Big Qualicum chum salmon migrate through the local fishing area (Area 14) is such that this stock (particularly the early segment) is extremely vulnerable to the fishery. This could have resulted in heavy exploitation in the past.

The efficient use of controlled flows to improve the freshwater survival of salmon in the Big Qualicum River requires that the effects of discharge and temperature on survival and behaviour be clearly understood. To this end discharge and temperature have been recorded continuously, since the fall of 1959, at the outlet of Horne Lake and 1/4 mile from the river mouth. Furthermore the thermal structure of Horne Lake has been determined at 1-2 week intervals during this period.

The studies which have been undertaken to provide the basis for future development of the river with a view to increasing its spawning capacity could result in the improvement of existing spawning areas by various artificial methods and/or the construction of artificial spawning channels adjacent to the river. In line with these principles a general approach has been taken to determine the spawning requirements of each species. To this end the distribution of spawners has been plotted by area over the entire stream length with notations as to the general characteristics of the preferred spawning areas and the location of non-productive areas. Depth and velocity measurements and gravel samples for size composition have also been obtained from some of the preferred areas.

The wetted areas corresponding to discharges of 33, 110, and 230 cfs have been classified under several categories in an attempt to develop a workable relationship between discharge and the optimum rearing conditions for juvenile coho salmon and steelhead trout. Five sampling stations located at intervals along the river, provide information on growth rate and abundance of rearing species, and a basis for comparing the productivity of the different sections of the river.

The biological investigations outlined briefly in the foregoing will be continued in future in order that the information so obtained can be applied with confidence to realize the ultimate goal of the Big Qualicum project; which is to increase its annual salmon production to the level where it is comparable in size to the largest recorded under natural conditions. It is also expected that these investigations will contribute incidental information which will be most useful in the field of research.

2.4.12 Lowe Inlet

Lowe Inlet, a small indentation in the shoreline of Grenville Channel some 65 miles south of Prince Rupert, receives the outflow from a small multi-lake system which supports an important stock of sockeye salmon. Lowe Lake, the lowermost in the system, is fed from the northwest by Simpson Creek which drains Simpson Lake; and from the east by Weare Creek, which drains Weare Lake, which, in turn, drains Gamble Lake via Kumowdah River. Obstructions to salmon migration have been reported at the entrance to the system and on each of the streams which interconnect the various lakes; the former being passable at some water stages, whereas all of the latter are considered to be virtually impassable at all stages.

During the period 1955-61 this Branch has undertaken engineering and biological studies of the system looking to determining whether or not it would be economically feasible to alleviate fish passage at some, or all, of these obstructions. At present, only Lowe Lake is utilized by sockeye for rearing purposes, and its average adult return since 1934 has been in the order of 6,000 sockeye. The studies to date have indicated, however, that this represents only 30 percent of the lake's productive capacity and that the estimated full potential of 21,000 adults could be realized by an expenditure of approximately $250,000 to alleviate the access problem. Furthermore it has been estimated that an expenditure of $1,000 to improve access to Simpson Lake would provide accommodation for an additional 46,000 sockeye; while removal of the obstructions to Weare and Gamble Lakes at estimated costs of $250,000 each would provide accommodation for 21,000 and 75,000 sockeye salmon, respectively.

No firm recommendations have yet been advanced in connection with the results of these studies but it would appear that development work to create improved access to Lowe and Simpson Lakes might be a worthwhile undertaking in view of their more favourable cost-benefit ratios. It would however be contingent upon the establishment of an anadromous race of sockeye by artificial methods.

2.4.13 Johnstone Strait Chum Salmon Tagging Program

A chum salmon tagging program was conducted in southern Johnstone Strait in 1962, for the purpose of further defining the time of passage of the individual stocks destined to streams located in and south of Area 13. Knowledge of their time of passage and their rate of exploitation in the fishery was necessary for an assessment of the fisheries development program now underway on the Big Qualicum River. Furthermore this information provides valuable background for management of the stocks migrating through this area. The tagging operation, which employed a chartered drum seiner, extended throughout the period of September 20 to November 16, with a cessation of operations on the day before and the day after the Johnstone Strait commercial net fishery. The Petersen disc tag, employing various combinations of colours and shapes of baffles, was used in order that records of approximate tagging dates could be obtained without recapturing the fish. Tag recovery from the commercial fishery was facilitated through the use of tag return envelopes distributed by the Protection Branch and by personal contact with the fishermen. Tag recovery from streams was accomplished by Departmental field crews located in the Big Qualicum, Cheakamus, and Fraser Rivers, supplemented by additional special crews from this Branch and the field officers of the Protection Branch. In 34 major and minor chum salmon streams a "pitch" of the dead was made in order to obtain tagged-to-untagged ratios for population enumeration.

During the season, 3,413 chum salmon were tagged and to date 494 have been recovered in the commercial fisheries, 314 in stream waters, and 12 in test-fishing operations, for a total of 820. This represents a 24 per cent recovery.

Preliminary analysis of the 1962 results shows that there was an intermingling of chum salmon stocks in lower Johnstone Strait. This is evidenced by the fact that tags applied during the latter part of September and the first half of October were recovered in the Fraser River tributaries, and in non-lake and small-lake systems such as Bonell Creek, Chemainus River, and Nanaimo River on Vancouver Island; while those applied during the period from mid-October to November 15 were recovered in the Fraser River tributaries, in the Puntledge, Big Qualicum, Cowichan and other lake-fed rivers on Vancouver Island, and in the Cheakamus and Squamish Rivers on the mainland. The majority of recoveries from the Big Qualicum stemmed from the early November tagging.

An analysis of the data is being made in an effort to obtain an indication of the size of the chum salmon populations and the rates of exploitation by the fishery.

3. APPLIED RESEARCH

3.1 COHO FRY REARING EXPERIMENTS

The lack of information on the freshwater rearing requirements of coho salmon is a serious disadvantage when assessing residual flows and other fisheries problems associated with hydroelectric projects. In addition, a knowledge of the dynamics of coho smolt production is desirable if development work designed to maintain and increase stocks of this species is contemplated. With the completion of the Robertson Creek experimental channels in 1961, this Branch initiated an applied research program designed to provide some of the ecological information required for understanding the dynamics of coho smolt production.

Information of this kind is usually obtained from a long series of observations of a natural stream according to some definite plan. Changes which occur can then be explained on the basis of correlations among the quantities measured and on known principles of biology, physics and chemistry. Since so many factors very together in the natural environment, it is often difficult to collect enough data to permit the thorough statistical analysis that is needed for separating the effects of the factors. However, the experimental control offered by the rearing channels at Robertson Creek provide a means by which the effects of environmental changes on coho smolt production can be more accurately evaluated.

In 1961, the physical facilities of the rearing channels were tested and information was gathered on the practical problems involved in utilizing the channels for long-term rearing experiments. In the spring of 1962, formal testing began on the effects of three depth-velocity situations on coho smolt production. Final results are not yet available since the main part of these experiments are still in progress, hence the following report provides a description of the methods used and the pertinent information available from observations to date.

The experimental rearing area consists of four parallel channels 200 feet long and 20 feet wide, each with individual inlet and outlet works enabling independent hydraulic control for each channel. Channel No. 1 is designed to provide shallow depth, in the range of 4-12 inches; channel Nos. 2 and 3 are designed to carry a normal depth of 18 inches; while channel No. 4 has a normal water depth of 3'-9".

Each of the four channels is divided longitudinally by a centre wall, forming two sub-channels 200 feet long by 10 feet wide. Each sub-channel is screened at the upstream end to prevent extraneous fish from entering the channel and inclined screens at the downstream ends allow for the enumeration of emigrants. The substrate in all channels is composed of the standard spawning gravel used in the Robertson

Creek channel which is between 3/4 and 4 inches in diameter.

Both long-term and short-term experiments were initiated in 1962 to assess some of the physical factors affecting coho rearing. The long-term experiment, which is designed to show which of three depth-velocity situations is most conducive to coho smolt production, will not be concluded until the smolts have left the channels in the spring of 1963. The short-term experiments, carried out in one of the channels set aside for this purpose, provided information on the practical stocking densities for the long-term experiments and examined some of the factors regulating the initial holding capacity of the channels.

A. Long-term Experiment

Equal inflows of 10 cfs to each of three experimental channels created the following depth-velocity conditions.

(1) A riffle condition

- depth, 0.5 feet
- velocity, 1.2 feet per second

(2) An intermediate condition

- depth, 1.3 feet
- velocity, 0.5 feet per second

(3) A pool condition

- depth, 3.9 feet
- velocity, less than 0.1 feet per second

Each channel was divided into two parallel sub-channels enabling duplicate tests to be made on each depth-velocity condition. The shallow swift channel was designated as channel 1, the intermediate channel as channel 3 and the deep slow channel as channel 4. Channel 2 was utilized for short-term tests. The resulting sub-channels due to partitioning were designated as left or right when looking downstream.

The channels were stocked on three occasions with coho fry obtained from Robertson Creek. These releases were made in the middle portion of each sub-channel, and considerable effort was made to keep stocking procedures identical for all six sub-channels. Fish emigrating from the channels within 24 hours after their introduction were returned to their respective channels. After this initial adjustment period, all emigrants were trapped and counted at the downstream screens and then held in liveboxes for future experiments. All fish while being held in the liveboxes were fed a dry commercial fish-food about four times per day. Each channel was stocked with numbers of fry considered to be in excess of the holding capacity of the channel. Since identical numbers were placed in each channel, emigration would reflect the holding capacity of the three depth-velocity conditions under study.

The first release of experimental fish into the rearing channels was made on May 24 and 25. On May 24, 1,000 coho fry were released into sub-channels 1-left, 3-left, and 4-left. The next day, the procedure was repeated with the right sub-channels. The one-day delay served as a check on the "fish-tightness" of the centre walls. These fish (6,000 in total) averaged 34 mm in length and 0.68 grams in weight.

The second release was made on June 1, when 250 marked coho fry were introduced into each sub-channel. These fish (1,500 in total) had a mean length and weight of 39 mm and 0.55 grams respectively.

The third and final release of 2,850 coho fry was made on June 6; 475 into each sub-channel. These fish had a mean length of 40 mm and a mean weight of 0.79 grams.

After release into their respective channels the coho fry exhibited a definite and almost immediate upstream migration. Upon reaching the upstream screens (100 feet from the release point) the fry held in the immediate area for a period of from 20 to 30 minutes, after which they moved downstream in groups, sometimes all the way to the lower end where they stopped and held position.

Most of the emigration from the channels occurred within the first day or two after stocking and after this initial exodus, the emigration rate decreased to only one or two fish per channel per day. The channel with the greatest depth and least velocity held the most fish, and the channel with the least depth and greatest velocity held the least.

The following table is a summary of the emigration from each channel for a six-day period immediately following the three introductions. The numbers in the table represent the total emigration over the six-day period and the percentages are the percent that these numbers represent of each release. Results from the two sub-channels have been averaged.

	Channel 1	Channel 3	Channel 4
Release of 1,000 fry May 24 and 25	706 71%	515 52%	361 36%
Release of 250 fry June 1	162 65%	88 35%	33 13%
Release of 475 fry June 6	359 71%	322 68%	332 70%

The first two releases showed that channels 3 and 4 were holding a larger percentage of additional fish than channel 1, but in the third release all channels showed about the same emigration rate and this was interpreted to mean that the approximate holding capacity of the various channels had been reached. For this reason no more introductions of fry into the long-term channels will be made for the duration of the experiment.

These data represent the numbers of fry remaining in the channels after emigration, but do not take into account the natural mortality occurring within the rearing channels. The initial holding capacity of channel Nos. 1, 3 and 4 was approximately 500, 800 and 1,000 fry, respectively. After the initial emigration surge during the first two weeks all channels showed a rapid decline in the population level during the latter part of July and most of August. This has been associated with rising water temperatures. By December, the holding capacity of channel Nos. 1, 3 and 4 was 100, 250 and 600 fry, respectively.

Preliminary results from studies of bottom fauna suggest that although the fry prefer lower velocity and greater depth, food production is higher in the shallow channel, as the fry in the shallow channel grow faster than those in the other two channels. It would appear that some combination of pools and riffles would be the ideal situation. Smolt production will not be known until the spring of 1963 and final analysis of the data collected over the course of the experiment cannot be made until then.

B. Short-term Experiment

One of the rearing channels designated as channel No. 2 was utilized for short-term experiments. The depth and velocity conditions in this channel are approximately the same as those in channel 3. An inflow of 10 cfs into channel No. 2 produces a mean velocity of 0.6 feet per second at an average depth of 1.3 feet.

Initial stocking of this channel was carried out on May 18, to establish the approximate stocking density for the long-term experimental channels. Further experimental stocking was done to examine the behaviour of the fry upon release under high and low population densities. A comparison of the initial holding capacity of shaded and unshaded channels was made. Estimates of the mortality rate at both high and low population densities were derived from data obtained in short-term experiments. This was done by comparing the estimated number present in the channel, based on emigration and stocking records, with the actual number present determined from poisoning and counting the entire population. Results so far from these short-term experiments suggest the following:

(1) The higher the population density, the greater the relative number of emigrants.

(2) Certain individual fry have a tendency to migrate downstream irrespective of the population density.

(3) The addition of overhead shade, in the form of a 4-foot overhang supported from the centre wall 22 inches above the water surface and extending the full length of the channel did not appear to have an appreciable effect on the initial holding capacity.

(4) When emigration was allowed to reduce the population level in the channel to its natural holding capacity, the mortality rate over the period June to September of those fish remaining in the channel, was about 15 percent per month.

(5) When the population pressure was increased by large introductions and re-introductions into the channel, the mortality rate rose to 31 per cent per month over the period July to September.

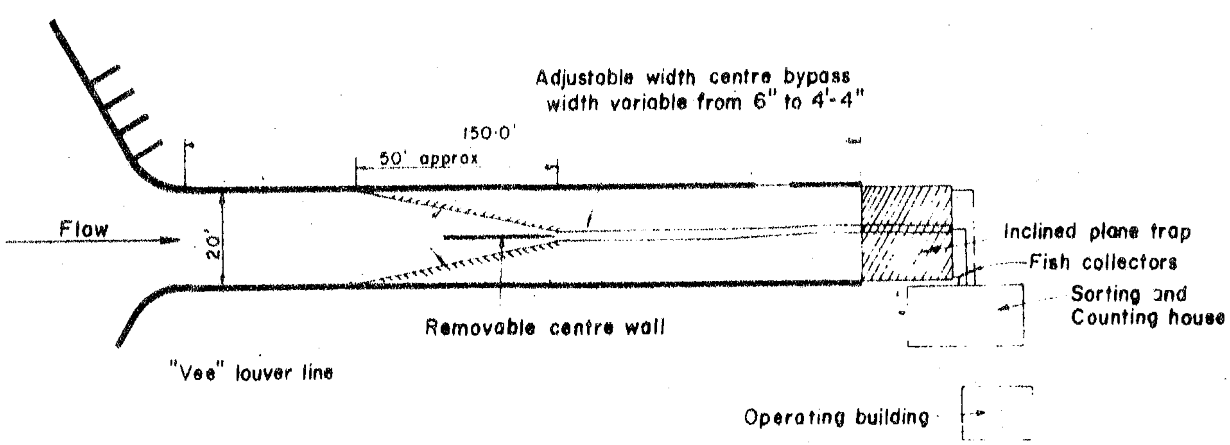
3.2 LOUVER GUIDING TESTS

The 1962 louver guiding tests were the latest and probably the last of a series conducted since 1960 to establish if the louver principle would offer a satisfactory means of screening the intake of the proposed Stamp River power development on Vancouver Island near Alberni, B. C.

Among the several difficult fisheries protection problems posed by the Stamp River development, which was proposed in 1956 by B. C. Hydro, was the screening of the 2,200 cfs power intake to prevent the entry of downstream migrant sockeye and coho salmon smolts emigrating from Great Central Lake. Experience in testing the louver deflector at the Puntledge River near Courtenay, Vancouver Island from 1957 to 1959 indicated the need to test louvers under the physical conditions and with the species of fish which would occur at the site for which they are proposed. Hence, a large experimental test flume was constructed on Robertson Creek, a secondary outlet of Great Central Lake where natural migrant sockeye and coho smolts would be available for testing. The flume was built during 1959 and early 1960 at a cost of $75,000, and preliminary tests were conducted during the spring of 1960.

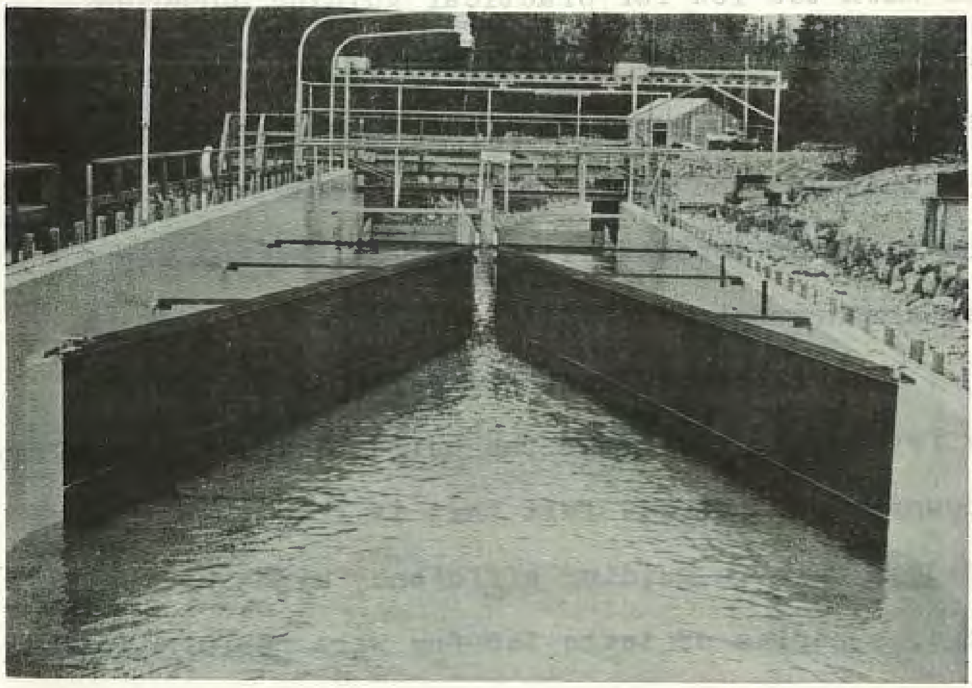
The results of the preliminary 1960 tests served as a basis for the design of a thorough testing program during the 1961 smolt migration. The results of the 1961 tests showed that the louver principle was successful in guiding up to 99 percent of the sockeye smolts, and better than 96 percent of the coho smolts, at Robertson Creek. The data clearly pointed out that the full guiding potential could be realized only by providing an adequate bypass. Under the conditions tested in 1961, a bypass width of at least 18 inches was indicated.

The main objective of the 1962 tests was to determine the feasibility of the V-type centre bypass shared by two lines of louvers. This type of bypass, if successful, would greatly reduce the quantity of bypass water required by a prototype louver installation. The apparatus was designed and constructed to test the following variables: bypass width, bypass acceleration, approach velocity and centre wall position. The accompanying figures show a diagrammatic plan of the test setup and a photograph of a test of a V-louver without a centre dividing wall.



Diagrammatic plan of 1962 louver test arrangement.

The 1962 louver studies were conducted in the test flume from April 16 to June 3. A total of 91,600 sockeye smolts, 20,100 coho smolts, 86,200 coho fry, and 76,000 chinook fry migrated naturally through the test flume over the 44-day test period. Sockeye and coho smolts reacted well to the V-louver array. With a 12-inch wide bypass shared by two louver lines, 92 percent of the sockeye smolts and 85 to 89 percent of the coho smolts were successfully deflected into the bypass at approach velocities ranging from 2.5 to 3.4 feet per second.



Test of V-louvers with 12-inch bypass and no centre divider wall.

During these tests, the velocity of the water entering the bypass was maintained at 1.34 times the average approach velocity. The behaviour of the sockeye and coho smolts exposed to a single louver line only was observed to be similar to that of previous years. It was found that a centre dividing wall was not required for sockeye and coho smolts.

Chinook and coho fry migrants, progeny of the natural spawning of adults transplanted to the Robertson Creek spawning channel in the fall of 1961, provided data on the guiding success of louvers with these two species. The efficiencies for coho fry ranged from 15 to 36 percent, which is much too low for practical guiding purposes. Chinook fry efficiencies ranged from 52 to 77 percent and in general tended to substantiate the results of the 1957-59 Puntledge louver tests. The necessity of providing a centre wall for successful guiding of chinook fry with a V-louver arrangement was indicated.

Visual observations suggested that coho and chinook fry tended to favour the walls of the flume as they moved downstream. It was felt that if this tendency was exploited, a gain in guiding efficiency might be realized. Therefore, a series of tests for fry were performed using a single line louver arrangement guiding to a bypass along one wall. This arrangement also provided information on the guiding success of a 100-foot louver line on chinook fry. Up to this time, only a 50-foot array had been tested. Below is a gross summary of the range of guiding efficiencies obtained with the two different louver arrangements.

	50-foot V-louvers	100-foot Single Line
Coho fry	15 to 36%	17 to 51%
Chinook fry	52 to 79%	53 to 88%

The 1962 tests with chinook fry were useful in confirming the earlier results with this species at the Puntledge River test flume. There is still considerable room for improvement in the guiding efficiencies for chinook fry, and further work in the future appears desirable.

The passive behavioural response of downstream displaced coho fry to louvers leads one to suspect that a louver is most effective with fish having an active downstream migratory urge. However, further work on coho fry is indicated, particularly with much higher bypass accelerations, before the possibility of guiding this species with louvers is discarded.

The louver investigations have now advanced to the point where sufficient information exists to enable a louver system to be designed to screen sockeye and coho smolts at the proposed Stamp River Development intake. If and when these facilities are designed, there may be need for further tests to assess any special design modifications. It appears that no more than one further testing season would be required for these special tests if plans for the development proceed.

In general, it appears that future research with louver guiding should be concerned mainly with testing of improvements to the bypass. Work of this type would be especially practical since the bypass problem is common to all types of guiding and screening devices.

3.3 GREAT CENTRAL LAKE SOCKEYE BEACH SPAWNING STUDIES

Great Central Lake is situated at the headwaters of the Stamp River, a tributary of the Somass River which discharges into the head of Alberni Inlet on the southwest coast of Vancouver Island, British Columbia. The lake is 24 miles long with a maximum width of approximately 1.5 miles.

In November, 1955 the British Columbia Power Commission presented the Department with a brief outlining a proposed development of the hydroelectric potential of the Somass River system. Among the complex of fisheries problems associated with this proposal were the possible effects of considerably increased storage levels in Great Central Lake on the spawning success of the sockeye which spawn predominantly in the lake. Initial surveys were directed toward determining the timing, distribution and relative density of spawning populations. Subsequently, observations of behaviour together with measurements of the physical environment were undertaken.

Since 1956, the sockeye escapement into Great Central Lake has been established by fishway counts at the lake outlet.

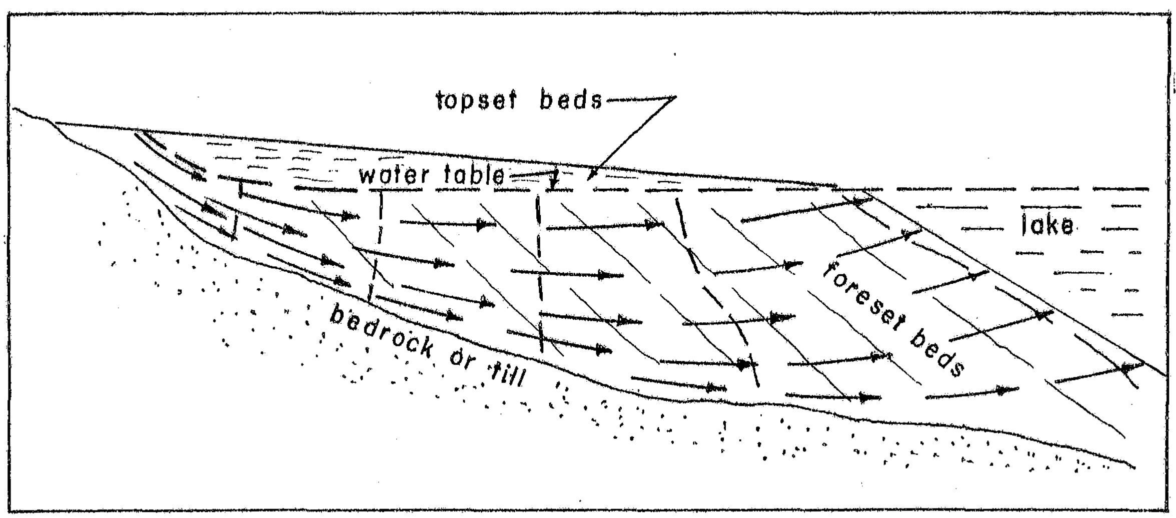
In 1956, the sockeye escapement to Great Central Lake was the lowest on record. Despite considerable effort spent in patrolling the lakeshore and tributary streams, no clear indication of the spawning distribution was forthcoming.

In 1957, approximately 90,000 sockeye entered the lake through the fishway at the lake exit. One percent of this number was observed spawning in streams tributary to the lake, the remainder were found to be utilizing portions of the lake periphery. The water is clear and, weather permitting, visibility is good to a depth of 20 feet. Less than ten percent of the lake spawning population could be accounted for, despite repeated visual observations from boats, helicopter and beach towers.

Accordingly, professional SCUBA divers were engaged to examine selected areas where the incidence of jumping indicated the presence of numbers of fish beyond the limit of surface observation. Limited examination revealed the presence of large numbers of spawning sockeye utilizing the gravels of submerged alluvial fans. Evidence of redd digging was recorded at depths in excess of seventy feet.

As a result of these observations, a consulting geologist was commissioned to undertake a geological survey of the beach spawning areas in August, 1958. His report presented the following physical description of the alluvial fans together with a brief outline of the mechanics of groundwater flow.

"The deltas are typical in all respects (See accompanying diagram). All have been built on an irregular surface of bedrock and/or glacial till since the last glaciation about 10,000 years ago, by relatively small streams which flow across them from drainage basins a few square miles in extent. Surface gradients and particle sizes in the fans built above lake level have been influenced not only by the size and gradients of the streams, but also by the availability of the various sizes of detritus. Forestry Camp Creek (the beach subsequently chosen for study), has the highest stream gradient and the steepest, coarsest, most actively-built fan.



Diagrammatic section of alluvial fan showing ground water percolation in homogeneous saturated fans.

Movement of stream water beneath the surface of the fans is self-evident. All the streams examined, with the exception of Lowry Creek, disappeared beneath the gravel shortly after reaching their fans, thereby discharging (at this date) something in the order of one to four cubic feet per second into the deltas. The rate of subsurface flow is dependent upon two factors, viz., the permeability of the gravel and the slope of the water table. Gravel permeability although doubtless highly variable within any given alluvial fan, should maintain a near constant value for the fan as a whole. Thus, the rate of ground water discharge from the face of the fan is directly dependent upon the slope of the water table, which varies directly with the degree of saturation of the fan. Fan saturation, in turn, is dependent upon the volume contribution of the associated surface stream and precipitation. It is therefore possible that seasonal fluctuations in runoff and precipitation will be reflected by changes in rate of fan discharge and thus the rate of water exchange available to incubating eggs buried in the gravel of the fan face."

In the fall of 1958, a more intensive study of the physical characteristics of the spawning beaches and the behaviour of spawning populations was undertaken. The results of the initial surveys indicated that the proposed sampling and observations would be confined to depths accessible only to SCUBA-equipped divers and that the distribution and size of the major spawning beaches predisposed the selection of a single beach for study.

Since the alluvial fans are geologically similar, the choice of a "study" beach was predicated by secondary considerations. Forestry Camp Beach was chosen because it supports a sizeable spawning population, and it is readily accessible and relatively close to densely populated Lindsey Beach and the rarely utilized (atypical) delta of Lowry Creek.

The subaqueous portion of the Forestry Camp alluvial fan was found, in 1957, to extend 1,300 feet east and 800 feet west of the creek mouth. To provide for the possibility of spawning fish beyond the 70-foot depth limit reported in 1957, it was decided that observations should be extended to 100 feet. The average distance from shoreline to this depth is 225 feet. These dimensions represent a total area of 535,000 square feet or about 12.3 acres. A grid of permanent underwater markers proved indispensable in guiding the underwater observer and facilitated recording and plotting information.

In 1958 and 1959, the majority of the underwater sampling and observations were made by professional divers. Since 1960, the underwater work has been assumed by Departmental employees.

It is generally accepted that sockeye salmon return to their parent stream to spawn. There is some evidence to indicate that their ability to recognize a specific freshwater source by means of its chemical constituents (olfactory perception) plays a significant role in guiding or attracting them to their home stream. Initial surveys established that Great Central sockeye "home" to several discrete beach spawning areas. Assuming that olfactory perception enables them to do so, it is reasonable to further assume that choice of individual spawning location may be determined by the presence of groundwater emissions and that in a given area spawning intensity is in direct proportion to the volume of outflow. To permit assessment of a possible correlation between volume of outflow and spawning intensity, in addition to recording the timing and estimating the size of the spawning population, periodic underwater examination of the study area was undertaken. The number of fish seen, and their location, behaviour and position in relation to the lake bottom were recorded. Suspected redd sites were examined and distinctively marked when eggs were found in the gravel.

The survival of salmon eggs developing in hatchery troughs or buried in the gravel is contingent upon their receiving a near-continuously renewed water supply. The establishment of a sizeable sockeye beach spawning population in Great Central Lake indicates that incubation conditions in the spawning areas are generally satisfactory. Sampling procedures were directed toward detecting the presence of groundwater flow in the areas where spawning took place and determining some of its physical characteristics. The apparent origin of Great Central Lake alluvial fan groundwater suggests that it may be characterized by a lower dissolved oxygen and a higher dissolved salt content than surrounding lake water and that it may exhibit slight seasonal variation in temperature compared with that involved in the summer stratification within the lake. It was thus evident that consistent temperature or water quality differentials between overlying lake water and suspected groundwater would confirm the presence of the latter. Accordingly, paired intragravel and above-gravel water samples and temperature readings were taken at redd and non-redd sites throughout the spawning and incubation period. The latter were compared with identical measurements taken at a "non-seepage" control station consisting of a 5 x 5 x 3-foot open topped box, buried to a depth of 1.5 feet in the spawning area and filled to lake bottom contour with "beach run" gravel. Lake water temperatures recorded at two-foot intervals to a depth of 100 feet were secured regularly. Gravel samples were taken at a number of redd and non-redd locations. Measurements of pressure differentials due to outflowing groundwater were undertaken using a modified

Wickett-Trehune Mark VII (lake) standpipe.

A measure of spawning success (egg retention) was obtained through examination of spawned-out dead. Survival of eggs naturally deposited in the spawning areas was assessed by means of retrievable green or eyed-egg "basket" plants, at redd, non-redd and control locations. At various stages of development the baskets were removed from the gravel. The method of analysis consisted of a count of dead eggs, live eggs, dead alevins, live alevins and associated macrofauna. Evidence of predation and scavenging was also recorded. "Standard" eyed-egg plants were planted, removed and analyzed as described above.

In the event that the natural spawning beaches would be rendered unsuitable by the proposed increase in lake storage, perpetuation of the existing beach spawning populations would be contingent upon providing suitable artificial spawning areas. Accordingly an artificial spawning beach was installed on the study beach prior to the 1960 spawning season. The beach, extending from five to 50 feet in depth, was located in an area reportedly utilized by spawning fish. Essentially it consisted of a 50 x 100-foot grid of perforated plastic pipe overlain by 12 to 18 inches of graded river gravel. Intragravel water was supplied at a rate of 55 gallons per minute (0.01 gal/sq. ft/min) by pipeline from the stream servicing the alluvial fan.

In order to assess the effect of elimination of groundwater flow on the behaviour and spawning success of the sockeye population utilizing the study beach and provide additional information on the effectiveness of the artificial beach in terms of attraction and spawning success, a dam was constructed at the apex of the alluvial fan in 1961. It incorporated outlet works connected to a pipeline which assured passage of all but peak stream flows directly to the lake shore. Once in operation, the dam and pipeline effectively eliminated the major source of groundwater servicing the natural beach spawning area. The area is thereafter referred to as the "modified" natural beach.

Coincidental with dam construction, a number of holes were drilled in the alluvial fan between the lake shore and the fan apex. They extended to a depth well beyond the existing water table. Fitted with perforated two-inch diameter pipe they provided stations at which water table height could be measured, groundwater temperatures recorded and, pending development of suitable instrumentation, samples of subsurface water could be secured for analysis. Precipitation and lake level recorders were also installed.

To provide a relatively small area devoid of groundwater flow in which the physical characteristics could be effectively measured and upon which spawning behaviour could be readily observed, a larger non-seepage control "box" (hereafter referred to as a "false beach") was installed in a high intensity spawning area on the nearby Lindsey Creek alluvial fan in 1962. It consists of a 20 x 20 x 2.5-foot open-topped PVC plastic "box" buried to a depth of approximately two feet in the selected area and filled to lake bottom contour with "on site" gravel.

The bulk of the Great Central Lake sockeye spawning migration commonly enters the lake between late June and early August. Periodic diving observations in the beach areas during the summer months have established their presence in considerable numbers as early as July 14th. Spawning commences in late September, peaks between mid-October and early November and is nearing completion by month's end.

Observations have established that a chronological succession of five behaviour activities occurs, dating from the first appearance of numbers of spawners in the beach area to completion of spawning and death. The fish are first observed traversing the spawning area in schools (cruising). Their movement is directed parallel to the beach front and a vertical distance above lake bottom in excess of 20 feet is usually maintained. By early September smaller groups are observed somewhat aimlessly (milling) in relatively confined areas, five to ten feet above lake bottom. When approached they disperse readily as a group or school. Prior to the appearance of spawning behaviour, the fish move to within a few feet of bottom, reduce the scope of random movements, are more readily approached and are less disposed to school when dispersed. Their activity at this time has been designated as holding. Spawning behaviour is evidenced by courtship and territorial activity together with evidence and observation of redd construction. Post-spawning activity, apart from redd defense, occasionally involves more or less directed, non-localized movement (wandering) by individuals and small groups (predominantly males).

Under natural conditions relative spawning intensity (number of spawners per unit of area) in any locality did not fluctuate widely from year to year. In a single instance a preferred area in the vicinity of the creek mouth was apparently rendered unsuitable by an extraordinary deposition of silt and detritus occasioned by winter freshets. Lake water temperature and depth do not appear to influence redd distribution. Spawning has been observed to commence simultaneously at temperatures ranging from 43° to 58°F and at depths ranging from less than 20 feet to more than 70 feet. Although there are reliable indications that heavily silted and/or highly mobile gravel is avoided by spawning fish, sampling indicates that gravel composition, within the range available, has little influence upon the choice of redd site. The limits of gravel size variability are exemplified by two redd site samples; the first containing 11 percent by weight smaller than 1/4 inch and the second 54 percent by weight smaller than 1/4 inch.

Following installation of the artificial beach in 1960, there was a notable increase in spawning intensity in the artificial beach area despite a 30 percent reduction in total escapement.

Construction of the dam at the fan apex prior to the 1961 spawning season, coupled with an extended rainless period, resulted in a pronounced reduction in water table level as indicated by drill hole measurements. The resultant reduction (or elimination) of groundwater flow in the natural spawning area was apparently reflected by a notable departure from previously observed holding and spawning distribution. Despite a twofold increase in spawning escapement, compared with 1960, periodic counts in 1961 indicate a 60 percent reduction in the spawning population on the "modified" natural beach. This contrasts sharply with an indicated fivefold increase in the spawning population utilizing the artificial beach.

Although numbers of holding and milling fish had been consistently observed in the false beach area, no observations of spawning behaviour were reported. However, post-spawning examination of the false beach revealed the presence of at least five definitive redds containing living eggs.

Temperature differences between subgravel and above-gravel water at natural redd sites varied between zero and 20°F. Positive differentials (groundwater cooler than lake water) recorded during spawning and early incubation diminished as the overlying lake water progressively cooled and groundwater temperatures remained relatively constant. Less pronounced <u>negative</u> differentials (groundwater warmer than lake water) were recorded on several inshore redds throughout the late spawning and incubation period and occasionally at redd sites in the intermediate depth zone (20 to 40 feet). There was no apparent correlation between groundwater temperature at redd sites and those recorded simultaneously at nearby drill holes. Subgravel-above gravel temperature differentials at the non-seepage control box rarely exceeded one degree.

Following spawning in 1961 subgravel oxygen levels ranged between 9.7 and 10.2 ppm at redd sites located on the natural control beach at Lindsey Creek, compared with a range of 4.1 to 11.2 ppm at redd sites on the "modified" study beach. The average above-gravel (lake water) dissolved oxygen concentration was 10.8 ppm. Periodic sampling at redd sites on the modified beach throughout the remainder of the incubation period indicated a progressive increase in oxygen values to a low of 9.6 and a high of 13.3 ppm. Subgravel oxygen values in the non-seepage control box ranged between 1.8 and 0.6 ppm.

During the 1962 spawning and early incubation period a general increase in subgravel oxygen values at redd sites on the "modified" beach was again evident. Ranging from 1.3 to 8.2 ppm in the early incubation period they rose to a range of from 2.7 to 11.4 ppm by mid-incubation.

There is some indication that choice of redd site is influenced to some extent by subgravel oxygen values. In both 1960 and 1961, areas which exhibited low subgravel oxygen levels prior, or subsequent to spawning, were characterized by light and/or delayed spawning together with positive indications of protracted digging activity unaccompanied by egg deposition.

Subgravel oxygen levels in the artificial beach remained consistently high (10-11 ppm) from the time of installation until late 1962 at which time flow was reduced by 40 percent due to obstructions in the distribution system. As a result, available oxygen decreased to 6.4 ppm.

Periodic subgravel water samples from the false beach revealed relatively high oxygen levels (7.9 to 9.8 ppm) throughout the three-month spawning and early incubation period. Subsequently they diminished rapidly to a low of less than one part per million.

Preliminary analysis of the data indicates that a positive correlation between drill hole measurements indicating water table height, and amount of groundwater movement as indicated by subgravel oxygen levels at redd sites is not attainable at the sampling and monitoring intensity applied.

The spawning gravel composition as determined from averaging the results of 41 redd and non-redd samples may be generally described by the following statistics.

Redds	- Mean value by weight passing	0.187-inch mesh	- 7%
		0.75 -inch mesh	- 41%
		2.0 -inch mesh	- 80%
Non-Redds	- Mean value by weight passing	0.187-inch mesh	- 22%
		0.75 -inch mesh	- 48%
		2.0 -inch mesh	- 97%

Subgravel-above gravel water quality differentials as indicated by dissolved solids content were found to be of equal magnitude at control box and redd sites.

To date standpipe measurements in areas of suspected outflow have failed to yield consistent results.

Examination of carcasses found on the beach and retrieved from the lake bottom revealed that 98 percent of the total egg potential was successfully deposited.

Survival of both green and eyed eggs at redd sites in the study area prior to groundwater diversion, and at the natural beach at Lindsey Creek ranged between 81 and 100 per cent. There was no apparent correlation between survival and gravel composition or degree of siltation. Eggs planted at redd sites in the study area following diversion of the groundwater source have exhibited survivals ranging from six to 100 percent. The survival of both green and eyed eggs annually planted in the artificial beach was consistently in excess of 95 percent prior to 1962 when the flow became reduced. The indicated survival resulting from a single green egg plant in 1962 was 60 percent. Green and eyed egg plants in the false beach resulted in an average survival of three percent; those placed in the control box suffered complete mortality. Preliminary analysis indicates that a reliable correlation exists between subgravel dissolved oxygen concentration and survival. In addition, the lower limits of oxygen tolerances at several stages of development are indicated.

The role of invertebrate predators in decreasing the potential survival of eggs buried in the gravel is difficult to assess. Careful examination of basket plant contents has provided considerable evidence of dead egg consumption (scavenging), and a single record of active predation, by free living flatworms. Insect larvae are much less numerous; no evidence of predation and few indications of scavenging are on record.

3.4 ELECTRONIC FISH-COUNTER

In 1962, the Department's Maritimes Area enlisted the services of this Branch in the design and installation of an electronic fish-counter for the enumeration of the Atlantic Salmon, Shad, Gaspereau and Speckled Trout which utilize the upstream-migrant facilities at the Beechwood hydroelectric development on the Saint John River in New Brunswick. The development of a suitable device was severely hindered by the excessive turbidity of the river and the fact that only the four least numerous of the more than 20 species of fish utilizing the system were to be counted; but these problems were largely overcome by an arrangement consisting of a camera unit and an electronic counter which was capable of photographing every fish, or every "nth" fish, passing through a counting tunnel.

The Department had not previously employed an electronic counter for the purposes of a biological investigation and when it was found that suitable instruments were not available on the commercial market, two model "Y" counters, which formed the nucleus of the ultimate installation at Beechwood, were borrowed from the Seattle office of the U. S. Bureau of Commercial Fisheries. A Vancouver consulting engineering firm was commissioned to design and construct two camera-control units each of which is designed to trigger a camera and electronic flash each time a fish ascends through the counting tunnel. Two submersible photo-counting units, employing 35 mm Shackman MK3 Auto cameras, were designed to photograph a side view of the entire fish as it cleared the upper end of the counting tunnel. The cameras were located at a distance of approximately four feet from the tunnel, and because the turbidity of the river was such that good-quality photography was not possible at this range, a water-tight funnel, filled with clear water, was installed between the camera and the exit from the counting tunnel.

Under the supervision of an engineer from this Branch these counting units were installed at the Beechwood site in mid-June. Screened leads, erected in the six-foot wide fishway, guided the upstream migrants to the counting tunnels, which were located along with the camera units, at a depth of 12 feet when in operating position.

Each camera had a 300-frame film magazine, which provided adequate capacity for an entire day's operation. It was arranged therefore that the complete counting unit would be hoisted out of the fishway each day in order to recharge the film magazines and perform any other necessary servicing of the equipment. After processing, the exposed films were projected onto a screen for identification and enumeration of the individual fish ascending through the structure. After the gear had been thoroughly tested an operational procedure was developed before the Maritimes Area staff assumed responsibility for the operation of the counters.

As with all new devices, several unforeseeable problems arose in connection with the operation of the Beechwood counters in 1962. The most noteworthy of these were:

(1) The lamprey tend to rest in the tunnel for long periods of time, thereby rendering the counter inoperative. In the light of further study, however, it is now considered that this problem can be solved by a shock relay system which would be activated at predetermined intervals by an imbalance of the tunnel bridge.

(2) The large numbers of elvers migrating upstream had a tendency to travel close to the sides of the tunnel where the electrical field is stronger, and it was difficult to tune them out without lowering the mid-tunnel sensitivity to an undesirable level. It is now thought that this problem can be overcome in future by the creation of a transverse field in place of the longitudinal field employed in 1962.

(3) Certain of the electrical components, particularly cable connections, proved to be unsuitable for the continuous submergence. Efforts are being made to develop suitable replacements for these.

While the principles of the photographic technique employed in the Beechwood counter operation have been known for a number of years, it consistutes the first known application of these principles. Operation of this counter in 1962 has clearly shown that it can be employed as a useful tool in biological investigations, and there is no doubt that the wealth of experience so gained will result in the development of more refined devices in future.

3.5 FISH PASSAGE THROUGH HYDRAULIC TURBINES

The subject of fish passage through hydraulic turbines was thoroughly reviewed by the Branch during 1962. While there is no pressing need for solutions to the problem of fish mortality in turbines, the long-term outlook dictates the propriety of obtaining further knowledge of the problem and of keeping abreast of similar research being conducted elsewhere in the world.

There are three types of situations where further knowledge of the problem of fish passage through hydraulic turbines has application. First is the case where the fish mortality at an existing hydroelectric plant may be minimized by modifying turbine operating practices (e.g. Seton Creek, Whitehorse Rapids, Puntledge River, Tobique and Beechwood). Second is where total screening of a large power intake is economically and technically infeasible, and if the project went ahead despite the fisheries problem, a turbine design to minimize fish losses could be used (e.g. Grand Canyon site on upper Fraser, Moricetown Falls on the Bulkley, proposed Saint John River sites). The third situation is where screening at a proposed power intake is possible, but it may be far more economical to install a turbine especially designed to safeguard fish at least as effectively as a screen (e.g. proposed Stamp River plant).

The need for a report to review the field of fish passage through turbines has been felt for some time. In early 1962, Engineer K. C. Lucas of this Branch prepared a paper entitled <u>The mortality to fish passing through hydraulic turbines as related to cavitation and performance characteristics, pressure change, negative pressure and other factors.</u> This report was written to conform to the form and size stipulated by the International Association for Hydraulic Research who were sponsors of a Symposium on Cavitation and Hydraulic Machinery to be held in Sendai, Japan in September, 1962. A synopsis of the report follows:

> "The importance of providing for safe passage of young downstream migrant fish past proposed hydro-electric power installations, particularly in the case of salmon in North America, is emphasized. The rate of mortality for various species and sizes of salmon at hydro-electric plants in North America on which fish mortality test information is available is presented, along with pertinent observations. The physical characteristics of the plants and hydraulic turbines (both Francis and Kaplan) which have been subject to fish mortality tests have been tabulated and include data on most of the factors which are believed to influence fish mortality such as cavitation (as indicated by plant sigma, specific speed and speed ratio), minimum blade clearances, pressure differentials, etc. Results of studies of the effect of pressure change, sub-atmospheric pressure, cavitation, impact and abrasion on fish are reviewed. Results of model hydraulic turbine tests, which indicate cavitation, speed and clearances as important factors governing fish survival, are also reviewed. The possibility of the design of turbines to reduce fish mortality is discussed, particularly with reference to cavitation elimination. In evaluating the economics of a change in the design of turbines to provide for safe fish passage, the importance of including the cost of alternative fish screening works is stressed."

The Sendai Symposium was the 2nd biennial meeting of the IAHR's Committee on Hydraulic Machinery, Equipment and Cavitation. This committee represents most of the organizations and laboratories throughout the world which are engaged in the field of hydraulic research related to turbo-machinery. Thus the Sendai meeting was an ideal place to present a review of the problem of fish passage through turbines and to suggest the consideration of a program of hydraulic research aimed at establishing design criteria for turbines which would provide optimum fish passage.

The paper was accepted by the IAHR and the Department sent the author to Japan to participate in the Symposium. The presentation was well received and generated considerable discussion. The paper, together with the discussion and author's closure will be published in the Proceedings of the Sendai Symposium, presumably early in 1963.

Liaison was continued during the year with the U. S. Army Corps of Engineers' program of study on fish passage through turbines. Field tests conducted by the Corps at Shasta Dam in November, 1962 were inspected by a senior engineer of this Branch and a detailed report was produced (unpublished mimeographed report).

It is likely that the applied research section of this Branch will in the near future implement a program to study certain factors affecting fish mortality in hydraulic turbines. This work would be designed to complement studies taking place elsewhere and at the same time would be aimed at future problems which might arise within the Pacific Area.

4. SALMON MANAGEMENT

In the fall of 1960, this Branch was given a specific assignment in the field of salmon management when it was requested to conduct a study of the chum salmon stocks of the Fraser River to determine the factors responsible for their apparent decline, and to provide information pertinent to management of the stocks through regulation of the fishery. This investigation, which was initiated in 1960, is still in progress.

The activities of the Branch in the management field were expanded in the spring of 1961, when a Salmon Management Committee, consisting of several senior Departmental staff members, including the Chief Biologist, was formed by the Director, Pacific Area. Under the general direction of this committee one biologist from the Branch was assigned to conduct studies relating to salmon management; the first specific assignment being that of analyzing the available data concerning the chum salmon catch and escapement for the Johnstone Strait - Gulf of Georgia - Fraser River area, where the total stock had declined by 1960 to only a fraction of the pre-1955 level despite the imposition of severe restrictions on the commercial fishery. The contribution of the Branch in 1961 to the Johnstone

Strait area included an analysis of available chum salmon catch and escapement data and subsequent preparation of a report describing that initial analysis. Moreover, in 1961 this Branch, for the first time participated in the regular Departmental field meetings which are held throughout the season to discuss the current status of the salmon stocks passing through the Johnstone Strait area.

In 1962, the analysis of chum salmon data was continued, and comparable studies were initiated in connection with the pink salmon stocks indigenous to the area.

Prior to the commencement of the commercial fishing season in 1962 the salmon management group of the Branch established an operations centre in the headquarters office which was maintained throughout the season to present an accurate day-by-day picture of the commercial salmon catches in every fishery operating on the British Columbia coast. This centre is now known officially as the "Operations Room".

In addition to the direct salmon management activities outlined above, other investigations being undertaken by the Branch are contributing to this field indirectly. For example, the studies currently in progress at Owikeno Lake (See Section 2.4.3, Page 119), contribute the type of data which is of material assistance in the management of the stock. The most finite measure being recorded at this time is the relative annual size of sockeye smolt production but the long-term aim of the investigation is one of obtaining a better understanding of the general dynamics of sockeye production of the system. In its present phase, the investigation is being directed toward juvenile sockeye and limnological studies and has yet to be expanded to include a full-scale adult assessment.

4.1 FRASER RIVER CHUM SALMON INVESTIGATION

A. Methods

The 1960 adult program consisted of:

(1) a purse-seine operation in the estuary to capture chums for tagging. Subsequent recapture of these tags would indicate the time of passage through the fishery area and would provide evidence of delay and concentration in the estuary.

(2) a beach-seine operation in the vicinity of Glen Valley Bar located near the upstream limit of the commercial fishery. Recovery of tags applied at this location would (a) in conjunction with dead recovery on the spawning grounds provide the basis for the calculation of a total Fraser River system escapement; (b) define more closely the time of passage of individual races through the fishing area; (c) indicate rate of movement from the tagging site to arrival on the various

spawning grounds; and (d) perhaps indicate the relative daily abundance of chum salmon throughout the season.

(3) tagging and recovery programs on the known major spawning areas. Tagging and recovery programs were conducted on the Chehalis, Harrison, and Vedder Rivers to provide the basis for calculation of escapements to each of the individual streams.

With the exception of the estuarial purse-seining which proved impractical, the basic program was repeated in 1961 and again in 1962. In 1961, test-fishing by gillnet was introduced at two locations, (a) Finn Drift near Steveston, to provide an early indication of the magnitude of the run entering the river, and (b) Yankee Drift near Mission to corroborate the value of the Glen Valley seine catches as a daily index of abundance.

In 1962, the Yankee Drift test-fishing was discontinued and gillnet test-fishing was conducted in the estuary area as well as at Finn Drift. The remainder of the program was conducted as originally established in 1960.

In the spring of 1961, a program was designed in conjunction with the International Pacific Salmon Fisheries Commission to develop equipment suitable for sampling downstream migrant fry at Mission. A mobile 4' x 4' inclined-plane trap and a vertical sampler, capable of fishing to a depth of twelve feet, were designed and the sampling results were compared with those of stationary equipment of a similar nature operated during 1961.

In 1962, the mobile gear was operated throughout the migration period, and catches so obtained were used for the calculation of an index of the total fry output.

B. Results

(1) Magnitude and distribution of the adult escapements.

The following table summarizes the calculated escapements to the total Fraser River system and to the individual spawning areas for the years 1960 and 1961. Figures given for 1962 are preliminary only, and as such are subject to adjustment after complete analysis.

Year	Total System Escapement	Chehalis River	Harrison River	Vedder River	Minor Trib. Streams	Fraser R. Mainstem
1960	253,780	17,685	51,805	72,249	18,280	93,711
1961	164,155	18,159	20,702	46,593	22,239	56,462
1962	215,000	15,000	55,000	50,000	20,000	75,000

The total system escapements were calculated on the basis of dead counts conducted on all spawning grounds and the recovery of Glen Valley tags; the escapements to the Chehalis, Harrison, and Vedder Rivers were calculated from tagging and recovery programs conducted in each area; the minor tributary streams total was the sum of escapements to all other streams as estimated by visual live and dead counts; and the Fraser River mainstem escapements were calculated by subtracting the sum of all tributary escapements from the total system escapement.

It is apparent from the calculated escapements listed in the above table that the Fraser River mainstem escapement, the magnitude of which had not been reported upon until 1960, has during the study years been the largest single stock in the system.

(2) Timing of Migration

The time of passage of the individual spawning escapements of Glen Valley in 1960 was established by tag recovery and dead counts. The escapements were grouped into three arbitrary categories: (a) early run, consisting mainly of Chehalis River, Weaver Creek, Jones Creek fish. This segment demonstrates a migration peak at Glen Valley in late September; (b) middle run, consisting primarily of mainstem fish, some Vedder and Harrison River fish, and most of the fish bound for minor tributary streams. The migration of these runs peaks at Glen Valley in late October; (c) late run, consisting primarily of the Harrison and Vedder River escapements which peak at Glen Valley in early December.

A comparison of the timing of these three groups in 1960 and 1961 is presented in Figure 1. It is apparent that some variation in timing existed at Glen Valley, but the chronology of the runs on the spawning grounds remained identical in all three study years.

(3) The Condition of the Stock

The Fraser River chum salmon stock is of primary importance not only to the Area 29 commercial fishery but also to the fisheries located in Johnstone Strait and in the Strait of Georgia. The total stock entering the Johnstone Strait area and proceeding southward to include the Fraser River, has declined from the 1954 high of 4,300,000 to a low of 900,000 in 1961.

From the information on distribution, timing and magnitude of escapement obtained by the 1960 Fraser River study, and in conjunction with extensive analyses conducted on past catch, escapement and timing data in both Area 29 and in

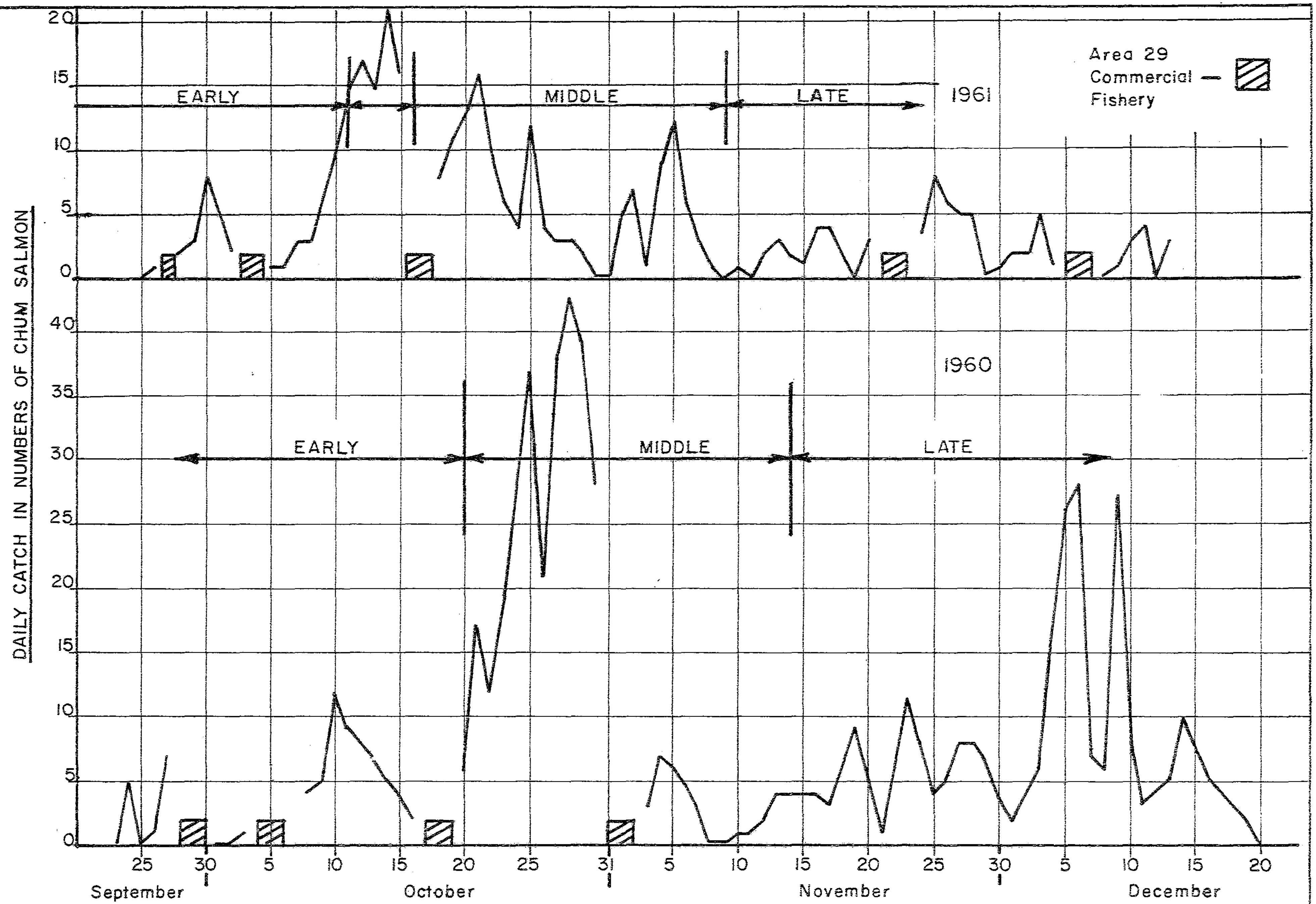


Figure 1. A comparison of the 1961 Glen Valley catches with the 1960 catches to show the relative timing of the early, middle, and late segments of the escapement.

the Johnstone Strait area, the following major hypothesis was developed: that a previously unrecorded mainstem Fraser River chum salmon population has formed, until recently, the main foundation for both the Johnstone Strait and Fraser River chum salmon fisheries and that this stock has been reduced to an extremely low level by commercial exploitation.

The hypothesis was developed on the following points:

(a) The Fraser River commercial catch of chum salmon has ranged between 46,137 and 551,509 pieces during the period 1951 to 1961 and as late as 1959 the catch totalled 233,290. According to the tagging conducted by the Fisheries Research Board in 1953, a total of 667,000 chum salmon, or 44 percent of the entire stock entering the Johnstone Strait area, consisted of Fraser River-bound fish. In addition, 376,000 chum were caught that year in Area 29, for a total contribution to the fishery in 1953 of 993,000 chum salmon. The highest recorded Fraser River escapement for the period 1942-61 inclusive occurred in 1950 and totalled 201,660. The reported chum salmon escapement, consisting of tributary spawning only, could not solely have provided the contribution to the fishery that was attributed to the Fraser River stock.

(b) The major commercial catches of chums in the Fraser River are made during the latter part of October and in the early part of November. The timing of the known major tributary stocks through the Fraser River fishing area, as determined by the tagging conducted at Glen Valley in 1960 tends to be earlier (Chehalis) or later (Vedder-Chilliwack and Harrison) than the period of maximum catches.

(c) The peak catches made in Johnstone Strait during the pre-1955 period occurred in late September and early October. The timing information available at this time indicated that the only major stocks present in strength during that period were those of Area 17 and of the Fraser River. Once again, the timing of the known major Fraser River stocks in Johnstone Strait should be earlier or later than this and the size of the catches would require a contribution greater than that possible from Area 17 and the early segments of the other stocks.

(d) Following 1954, fishing time was reduced in Area 29 to compensate for lower stock size, but the reduction tended to favour stocks migrating in late November and early December. The escapement level of minor tributary stocks which exhibit timing similar to that calculated for the mainstem population (i.e., the last three weeks of October and first week of November) has been differentially reduced; by association it could be assumed that the mainstem stock has also been similarly affected.

As a result of these combined studies, it was concluded that the mainstem stock of the Fraser River has been the foundation of the Johnstone Strait-Area 29 chum salmon fishery and that rehabilitation of this particular stock is the major key to the rehabilitation of the entire fishery.

In order to initiate this rehabilitation, the 1961 fishing pattern for Area 29 was designed to provide full protection during the migration time of the mainstem stock, and to permit exploitation of the relatively strong later-migrating stocks. In addition, the over-all exploitation of chums in the Johnstone Strait area was reduced to one of the lowest levels recorded in the last decade.

The results obtained by adjusting the Area 29 fishing pattern in the above-described manner are listed in the following table. In terms of percentage, the exploitation of the mainstem stock was reduced in 1961 by almost half from that of 1960. The total return of chum salmon to the Johnstone Strait-Fraser River area in 1961, however, was lower than that of 1960, and in terms of actual numbers the escapements to all major Fraser River spawning areas were again reduced; this in spite of the severe restrictions imposed not only on the Area 29 fishery but also on the Johnstone Strait fishery.

Run	Commercial Open period	1961 Catch	1961 Escapement	1961 Percent Exploitation	1960 Percent Exploitation
Early	Sept. Total) Oct. 3-4)	9,704	18,159	34.8	37.8
Middle	Oct. 16-17	14,077	78,701	17.9	30.5
Late	Nov. 21-23) Dec. 5-7)	22,356	67,295	24.9	6.1
Total		46,137	164,155	21.9	21.1

The general fishing pattern established in 1961 was repeated in 1962. Restrictions more stringent than those of 1961 were imposed on the Johnstone Strait fishery in late September when it became evident that the early and middle segments of the stock were returning at an extremely low level, and fishing was not permitted in Area 29 during the period that the peak of the middle run migrated through the fishery area. Preliminary analysis of the results of the 1962 study indicates that the 1962 regulation of the fishery was successful in increasing the mainstem escapement over that of 1961 despite the small total return. Escapements to the late areas (Harrison and Vedder) also appeared adequate.

(4) Downstream Migrant Enumeration

Mobile sampling equipment developed in 1961 by the Fish Culture Development Branch in conjunction with the International Pacific Salmon Fisheries Commission was used in 1962 at Mission Bridge to sample downstream migrants. Mobile equipment was necessary as the tidal effect at Mission was sufficient to render the standard stationary sampling gear inefficient.

The 1961 program established the peak period of daily chum fry migration as occurring between 0500 and 1300 hours. In 1962 this period was considered as the standard daily shift during which the mobile 4' x 4' inclined-plane trap was fished. In addition, two 24-hour periods of fishing per week incorporating a mobile vertical sampling unit were introduced to assess seasonal changes in diurnal periodicity and vertical distribution.

The results of the 1962 program were as follows:

(a) During the early part of the season's migration, eight percent of the chum fry travelled past the sampling site during the eight-hour period 0500 to 1300. By the end of the migration, this had increased to 85 percent.

(b) During the early part of the migration 95 percent of the chum fry travelling in the top twelve feet of water travelled in the surface to three-foot depth; by the end of the season, this percentage had decreased to 75 percent. The majority of the fry travelled in the top twelve feet of water, as evidenced by the distribution by station shown in Figure 2. It seems valid to assume from the vertical distribution in the surface twelve feet of water (Figure 2) that the percentage of fish travelling beneath the vertical sampling unit was small.

(c) The calculated number of seaward migrant chum fry in 1962 as measured at Mission Bridge totalled 32,650,000, which represented an egg-to-fry survival of approximately 12 percent.

C. Summary

The most important result of the studies to

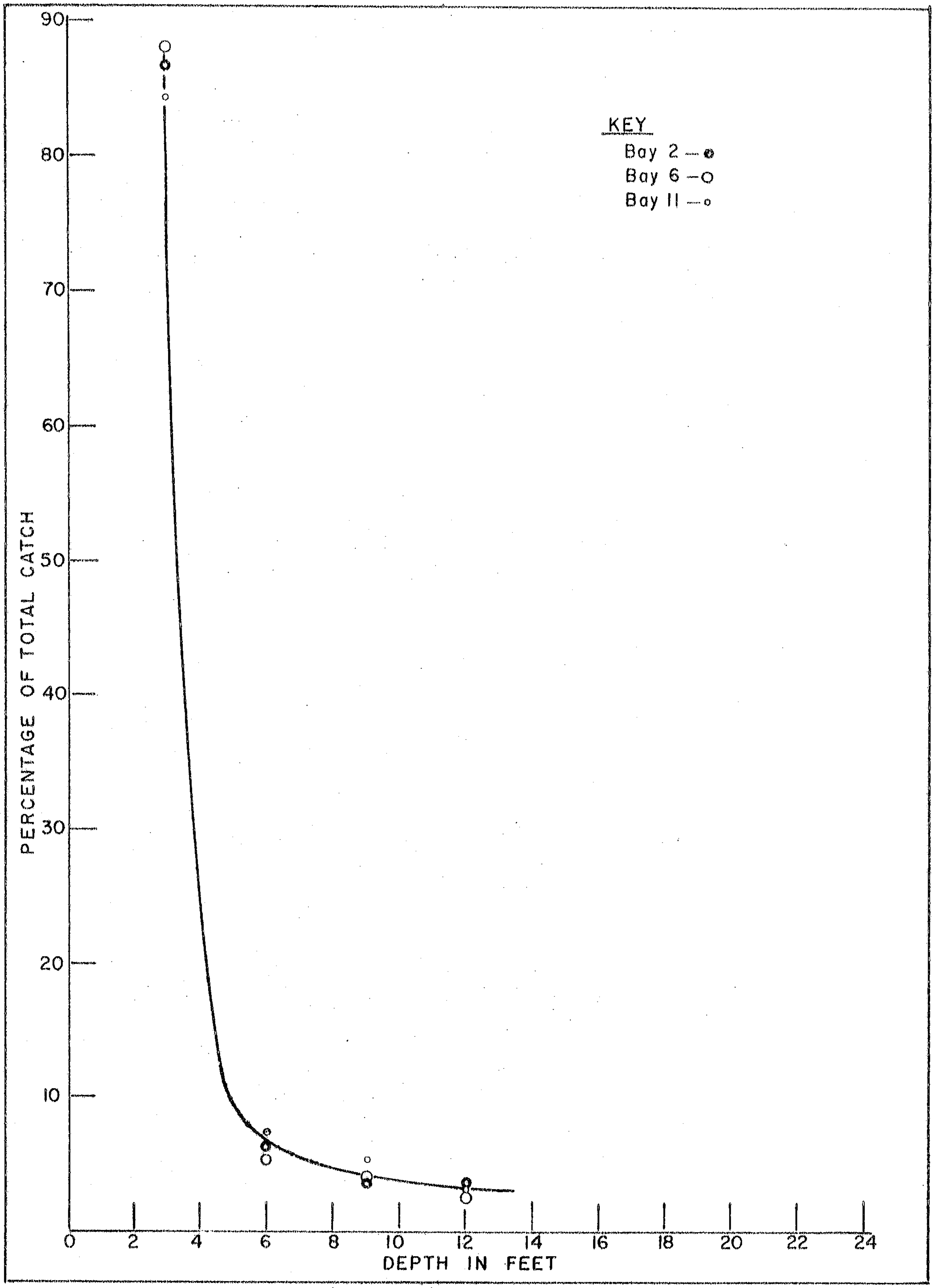


Figure 2. The seasonal average vertical distribution of chum fry at the three fishing locations.

date is the conclusion that the Fraser River mainstem spawning population is the major contributor to the Johnstone Strait-Area 29 commercial fishery, and that this stock has been reduced to an extremely low level in recent years. The escapement range of 50-100,000 calculated in the three years of study must be greatly increased if full rehabilitation of stock is to be achieved.

4.2 JOHNSTONE STRAIT

Following 1954 and continuing until the present time, the total chum salmon stock returning to the Johnstone Strait-Georgia Strait-Fraser River region has been declining. Prior to the 1961 season, an analysis of available catch and escapement data on the chum salmon stocks entering and passing through Johnstone Strait was conducted in an attempt to assess from the existing data, the condition of the stocks which originate south of the northern tip of Vancouver Island (comprising commercial fishing Areas 12-18 and 28 and 29, Figure 3), and also to determine the effect of present exploitation on those stocks. On completion of this first-year analysis, a report was prepared in which a number of factors affecting the status of the stocks were described and in which recommendations regarding the 1961 fishing pattern were proposed.

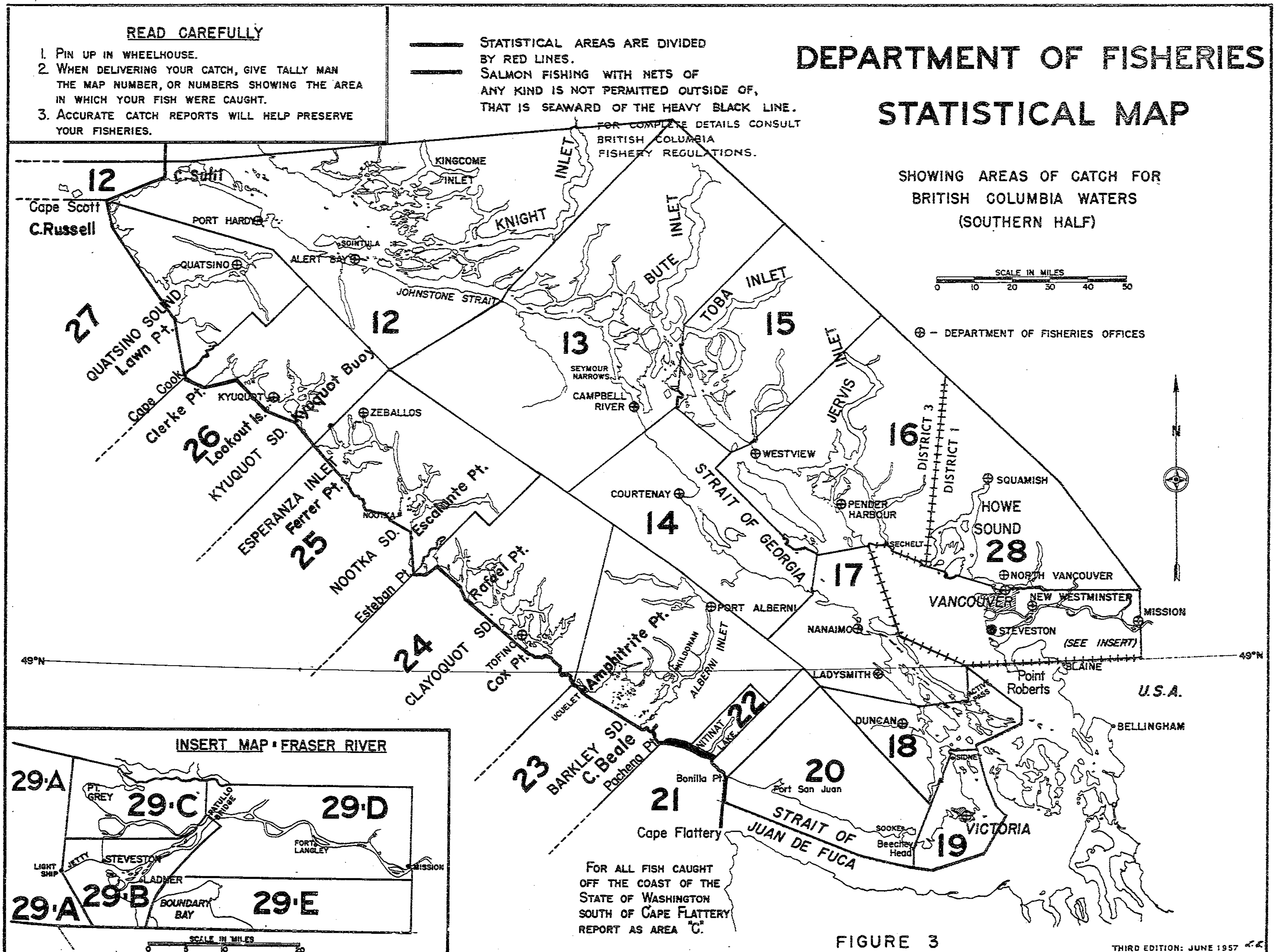
Prior to the 1962 season, analysis of the catch and escapement data of this study area was continued in order to further describe the status of the chum salmon stocks; to analyze additionally, the status of pink salmon stocks returning to the study area; to summarize the effects of recent regulations on those stocks and to present calculations on the anticipated size of the pink and chum stocks returning to the area in 1962.

A description of the results obtained from the analyses conducted to date is presented in the following summary. For the purpose of analysis, the nine commercial fishing areas referred to above have been grouped into a single unit for calculation of total stock, total exploitation and age composition. The catch figures used are those prepared by the Economics Branch of this Department; the escapement figures have been obtained by summing the median of the range submitted for each stream in the annual spawning ground reports of the officers of the Protection Branch. The latter figures, based on visual surveys, have recognized limits of accuracy but are considered a relative measure of annual escapement.

CHUM SALMON

Status of Stocks

Catch and escapement data for this study area are fairly limited in that the present system of catch statistic collection was only initiated in 1951 and



READ CAREFULLY
1. Pin up in wheelhouse.
2. When delivering your catch, give tally man the map number, or numbers showing the area in which your fish were caught.
3. Accurate catch reports will help preserve your fisheries.
Statistical areas are divided by red lines.
Salmon fishing with nets of any kind is not permitted outside of, that is seaward of the heavy black line.
For complete details consult British Columbia Fishery Regulations.
DEPARTMENT OF FISHERIES
STATISTICAL MAP
SHOWING AREAS OF CATCH FOR BRITISH COLUMBIA WATERS (SOUTHERN HALF)
SCALE IN MILES
0 10 20 30 40 50
⊕ – DEPARTMENT OF FISHERIES OFFICES
N
12
Cape Scott
C.Russell
C. Sutil
PORT HARDY
SOINTULA
ALERT BAY
QUATSINO
KINGCOME INLET
KNIGHT INLET
JOHNSTONE STRAIT
12
BUTE INLET
TOBA INLET
15
13
SEYMOUR NARROWS
CAMPBELL RIVER
27
QUATSINO SOUND
Lawn Pt.
Cape Cook
Clerke Pt.
KYUQUOT
Kyuquot Buoy
26
Lookout Is.
KYUQUOT SD.
ZEBALLOS
ESPERANZA INLET
Ferrer Pt.
25
NOOTKA
Escalante Pt.
NOOTKA SD.
Estevan Pt.
JERVIS INLET
16
DISTRICT 3
DISTRICT 1
WESTVIEW
SQUAMISH
HOWE SOUND
28
PENDER HARBOUR
SECHELT
COURTENAY
STRAIT OF GEORGIA
14
17
NORTH VANCOUVER
VANCOUVER
NEW WESTMINSTER
MISSION
STEVESTON
(SEE INSERT)
NANAIMO
PORT ALBERNI
24
CLAYOQUOT SD.
Rafael Pt.
TOFINO
Cox Pt.
Amphitrite Pt.
KILDONAN
ALBERNI INLET
UCLUELET
49°N
LADYSMITH
ACTIVE PASS
Point Roberts
BLAINE
U.S.A.
BELLINGHAM
23
BARKLEY SD.
C. Beale
Pachena Pt.
NITINAT LAKE
22
DUNCAN
18
SIDNEY
20
Bonilla Pt.
Port San Juan
21
Cape Flattery
STRAIT OF JUAN DE FUCA
SOOKE
Beechey Head
19
VICTORIA
For all fish caught off the coast of the State of Washington south of Cape Flattery report as area "C".
THIRD EDITION: JUNE 1957
INSERT MAP • FRASER RIVER
29·A
PT. GREY
29·C
PATULLO BRIDGE
29·D
FORT LANGLEY
MISSION
LIGHT SHIP
JETTY
STEVESTON
LADNER
29·A
29·B
BOUNDARY BAY
29·E
SCALE IN MILES
0 5 10 20

FIGURE 3

spawning reports for the area are not complete prior to 1950. Catch figures have been reconstructed from other statistics available for the area, however, dating back to 1930. These figures, shown graphically in Figure 4, illustrate that in 1955, following several years of high production, the stock as represented in this instance by total study area catch, declined to a low level in 1955 and that it has not demonstrated a significant recovery since that time. The pattern described is not unique to this particular area but in fact extends not only to the British Columbia coastwise condition described in Figure 4 but also to the stocks of southeastern Alaska.

Reason for Decline

The reason, which emerges from the analysis, for the decline of the total study area stock is comprised of a number of factors, all of which can be associated with local conditions.

(a) Survival

In order to measure the over-all survival of the total chum salmon stock indigenous to the area, a ratio of returning adults per unit of brood escapement has been calculated for the years 1953 to 1961 inclusive. This measure indicates as presented below, that the over-all survival rate dropped drastically during the three years following 1954, rose again in 1958 and 1959, then dropped to the lowest recorded ratio in 1961.

Year	Return/unit Escapement	Year	Return/unit Escapement
1953	2.8:1	1958	2.4:1
1954	2.9:1	1959	2.8:1
1955	1.1:1	1960	1.7:1
1956	1.1:1	1961	.8:1
1957	1.5:1		

Although the survival rates in 1958 and 1959 were high, the stocks were the progeny of the lean 1955-57 period and the return in terms of numbers of fish was not strong. One of the complicating factors involved, and one which extends the effects of poor survival conditions, is that an apparent relationship exists in the production of age 3 and age 4 fish from any single brood stock. Over the period of the last three brood stocks (1955, 1956, 1957) the ratio of age 3 : age 4 has been calculated at 43.5 : 56.5 and the relationship for the 1958 brood will approximate this closely. In effect this means that a strong stock in any single year is

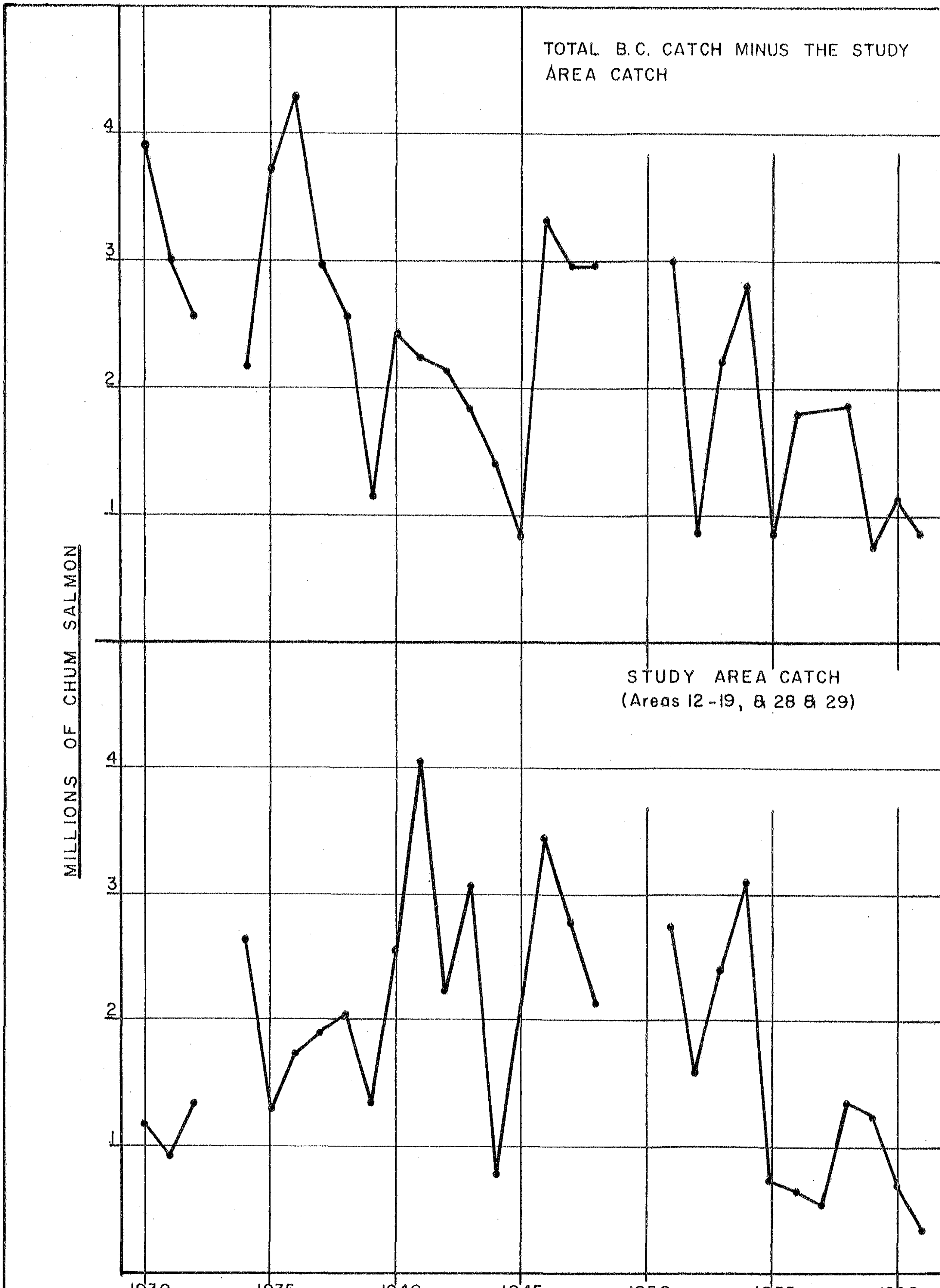


Figure 4. Chum salmon catches in pieces for the period 1930-61 inclusive.

almost certainly dependent upon the good return of both major age segments of the stock and also that low survival of one brood will affect the total return in two consecutive years.

(b) Commercial Exploitation

Efficient regulation of the commercial fishery in this area is particularly complex. Stocks destined for areas over the entire 225-mile length of coastline from Kingcome Inlet at the north to the Fraser and Cowichan Rivers at the south, enter at the north end of the study area to be intercepted by an intense Johnstone Strait fishery and, in several instances, efficient local fisheries as well. In addition, a significant segment of the migration enters the area from the south via Juan de Fuca Strait.

Certain of the factors associated with commercial exploitation and which have affected the current status of the stocks are these:

(1) Increase in efficiency of gear.

Immediately preceding and during the period of reduced stock size, which began in 1955, a dramatic change in efficiency of the commercial fishery developed in the form of increased units of gear, conversion to nylon gill-nets and the advent of the power block and drum seine to seining. This increase in fleet efficiency at a time of reduced stock size more than offset the pattern of reduced fishing time which was initiated in 1955 and which has become increasingly severe since that time.

There is associated with this increase of efficiency at a time of reduced stock, another complicating factor. The susceptibility of the stock to exploitation apparently increases with decreasing stock size.

(2) Allowable Exploitation

In an attempt to define the general degree of exploitation that the chum salmon stock of this study area can withstand, an interpretation of the calculated ratios of returning adults per unit of brood escapement has been made in terms of allowable exploitation. The calculated ratios of return indicate that in order to just maintain the escapement at its brood level, the ratio of catch : escapement, under conditions of the average survival recorded during the 1953-61 period, would have to approximate 0.9 : 1.0 for an allowable exploitation rate of 47.4 percent. A similar calculation for the even-year pink salmon stocks of the area suggests an allowable average exploitation of 64.3 per cent.

In seven of the nine years during the period 1953-61, the actual exploitation as calculated from the available data, has exceeded the calculated allowable level.

(3) Timing

Chum salmon are present in the Johnstone Strait fishery throughout August, September, October and into November. Beginning in 1955 and continuing through 1959, one general effect of the fishing pattern has been the provision of more protection to the later migrating stocks than to the others. As a result, the general stock is weak but several of the late running stocks are demonstrating relatively good strength.

(4) Fraser River Mainstem Stock

The effect that the reduction in escapement size of this stock has had on the entire study area commercial catch has been described under the heading "Fraser River

Chum Salmon Investigation" (See Section 4.1, page 190). As pointed out in that section, this stock at one time constituted not only the major stock of the area but in actuality comprised the foundation for both the Johnstone Strait and Fraser River chum salmon fisheries.

The history of the decline in strength of the chum salmon stocks indigenous to the area could be summarized as follows:

The catch pattern, described in Figure 4, when compared to those of other areas indicates that effective utilization of chum salmon in this study area did not begin until around 1940. Throughout the war years and coinciding with the decline of certain other stocks, including those of the west coast of Vancouver Island, the catches particularly in the Johnstone Strait area were increased. The increase in fleet efficiency following the war period was not reflected in increased catches in this study area but the high catches were at least maintained. The increase in fleet size and gear efficiency at this time, without a commensurate increase in catch indicates that the catch, during the last of the good years, was being maintained at the expense of the escapement. In 1955, the stocks of the area declined and have never returned to their former level.

The general picture which emerges from the analysis conducted to date therefore, is that in this study area, chum salmon were not fully utilized prior to 1940. In the following 15 years, less than the span of four life cycles, the utilization pattern ran the course from under-exploitation to over-exploitation to near collapse of stock; all in such a short period that the degree of optimum stock utilization was never accurately determined.

Operational Value of the Analysis

Assessment of Escapement

In order to assess the current strength of the stocks originating within the study area, the escapements must be evaluated in terms of past, or if possible, optimum escapement. In the absence of an accurate measure of optimum spawning escapement, a measure has been developed and proposed to serve as a temporary escapement goal until an accurate assessment can be made. This goal is based on the total of the highest recorded actual escapement to each stream in the area in any year during the period 1950-61. The total study area goal for greater effectiveness has been divided into sub-areas set up within the total area. The major assumption made in arriving at this figure is that over-escapement did not occur in any of the streams during the period of time chosen.

The goal proposed for the total study area chum escapement, excluding the Fraser River mainstem stock, is 2,400,000. Current escapements are now assessed by the comparison of sub-area escapements against the respective sub-area escapement goal. By way of comparison to this proposed optimal escapement, the 1960 and 1961 escapements totalled 518,000 and 546,500 respectively; the highest recorded escapement in the 1950-61 period occurred in 1951 and totalled 1,700,000.

<u>Defining Anticipated Return</u>

The data available cannot be used as a basis for accurate prediction of return but two factors can be utilized to at least define the general magnitude which can be expected.

(a) From the apparent relationship between production of the age 3 and age 4 segments of an individual brood, the number of age 3 salmon in the total stock of year "n" is used as a basis to calculate the expected contribution at age 4 of the same brood in year "n + 1".

(b) The size of the brood escapement three years previous is taken as a general measure, refined by data available on production of adult return per unit of brood escapement, of the strength of the age 3 segment of the returning stock.

Recommendations on Fishing Pattern

From the calculations on the range of return and from the calculated exploitation imposed on the stock during recent seasons, fishing patterns can be developed to meet a range in sizes of returning stock. This is done to serve as a guide once the relative size of the returning stock is established.

The 1961 Stock

The returning stock in 1961 totalled only 906,500 and thereby constituted the poorest return to the study area during the period 1949 to 1961 inclusive. The ratio of returning adults per unit of brood escapement was calculated at .8 adults per unit of escapement; the brood escapements therefore failed to produce their own level. The low 1961 return resulted from a dismal return of age 3 fish superimposed on an anticipated low return of age 4's from the 1957 brood. No detailed explanation is offered for the poor return of the age 3 segment but incubation conditions were apparently poor throughout the study area during the winter of 1958-59.

The catch for the entire study area totalled only 360,000 and represented an exploitation rate of 39.8 per cent; the lowest recorded in the 1949-61 period. The rate was surprisingly high, however, in view of the stringent regulations applied.

The 1962 Stock

The total study area catch, reflecting a year of low stock and stringent regulation, totalled only 260,000. Complete escapement figures are not available at this time but the total will exceed that of 1961 by a considerable margin.

PINK SALMON

As stated earlier, an analysis of available catch and escapement data, similar to that described for chum salmon was conducted on the even-year pink salmon stocks of the study area. During the even year, pink salmon in this area return only to streams situated within commercial fishing areas 12, 13 and 14 (Figure 3).

Status of the Stocks

In terms of the past even-year escapements recorded during the 1950-60 period, the 1960 escapement, which constituted the brood stock for the 1962 return, totalled only 221,500; 40.5 percent of the previous low of 547,200 recorded in 1956 and 35 percent of the even-year 1950-58 average.

As described for chum salmon, an escapement goal based on maximum recorded stream escapement has been calculated for the even-year pink salmon stocks; that figure totals 1,301,500. The 1960 escapement comprised only one-sixth of that proposed goal.

Reason for the Low Status of Even-Year Stocks

The low level of the 1960 pink salmon study area escapement resulted from the combined effects of two factors.

(a) Low Survival to Adult

The ratio of returning adults per unit of brood escapement in 1960, as calculated from the available data, was only .8:1 as compared to the 1950-58 average of 2.8:1. In terms of numbers of fish, an escapement of 710,000 adults in 1958 produced a total returning stock of only 566,700 in 1960.

(b) Over-Exploitation

(1) General Exploitation

As stated above, the 1958 escapement of 710,000 adult pink salmon produced returning stock of only 566,700. This stock, the total of which would have constituted less than an average escapement, totalled only 221,500 after exploitation.

(2) Differential Exploitation

Salmon stocks passing through Johnstone Strait are vulnerable to a very efficient commercial fishery which extends for a length of more than 90 miles. Within this fishery the length of time that individual stocks are vulnerable to the fishery varies greatly, the rate of exploitation of local fisheries varies, and in certain instances stocks are not subjected to any local exploitation. As a result each stock of salmon returning to this general area will be susceptible to a different degree of exploitation.

In 1960, the pink salmon stocks in this study area which demonstrated the lowest level were those lying south of Area 12, specifically those situated on the mainland shore of Area 13 and from the entire region of Area 14. Undoubtedly the length of the combined Area 12 and 13 fishing area has resulted in differential exploitation of the stocks returning to those areas. In effect, the southern portion of the Johnstone Strait fishing area constitutes a local fishery on stocks originating south of Area 12. The catch in Area 13 during the five even-year cycles prior to 1962, had accounted for only 12.7 percent of the total Johnstone Strait catches but this catch had represented an average exploitation on stocks escaping from the Area 12 fishery of

37.1 percent.

In emphasis of the low status of the Area 13 and 14 stocks in 1960, the calculated escapement goal for the combined areas totals 520,000 or 40 percent of the even-year study area goal. In 1960, the escapement to these areas totalled only 69,600 and 35,000 of these returned to one stream.

Reason for the Present Status

The low status of the 1960 stock was not interpreted as being the result of a downward trend in the strength of the stock but rather the result of over-exploitation of a single year class returning at an already low level. The data does indicate, however, that an overfishing trend has developed on populations originating south of Area 12.

Operational Value of Analysis

As described in the previous section for chum salmon, the value of the analysis being conducted is in:

(a) Assessment of Escapement

This is done in terms of both past escapement and calculated stream potential, and by relative annual strength of the various sub-area escapements.

(b) Defining Anticipated Return

On the basis of the range and the

past ratios of returning adults per unit of brood escapement a range of anticipated return is calculated.

(c) Recommendation of Fishing Pattern

As described for chum salmon, proposed fishing patterns can be developed from the calculations on the range of anticipated return and from calculations of recent exploitation on the stock. Further to this, the relative size of escapement within the study area may be used as a basis to recommend additional protection to specific stocks.

The 1962 Stock

Complete escapement figures are not available at this time, but the stocks of this area demonstrated a high ratio of return comparable to that recorded generally over the central and northern coast. The commercial catch for the area totalled 704,000, and this in spite of the stringent regulations applied. These included a virtual closed season on pink salmon in Areas 13 and 14 and a two-week special closure during mid-August in Area 12, all designed to initiate rehabilitation of the low stocks originating in Areas 13 and 14. Although final spawning ground figures are not available at this time, the general picture was one of good escapements to all streams with the exception of those in the Area 14. The low 1960 escapement of 221,500 produced, therefore, a catch of 704,000 pieces and a generally good escapement throughout the area.

SUMMARY

A general summary of the analysis conducted to date on the Johnstone Strait chum and pink fisheries has been presented along with a description of certain of the problems associated with maintaining and in some instances rehabilitating certain of the stocks through regulation of the commercial fishery.

The task of rebuilding the chum salmon stocks of the area to their former level, which supported a catch of between two and four million pieces annually, is perhaps a formidable one but the prospects would appear bright.

The even-year pink salmon stocks of the area have not demonstrated any real decline and as indicated earlier, have in fact demonstrated a "bounce-back" from the very poor seeding of 1960. In the central Vancouver Island area, the stocks of certain of the streams, particularly those of the Tsolum and Oyster Rivers, have suffered a drastic decline and may require assistance additional to that possible through regulation of the fishery.

4.3 OPERATIONS ROOM

As mentioned previously, a salmon management operations centre was established in the Vancouver headquarters office during the spring of 1962 and subsequently maintained the operation throughout the balance of the season. The reason for maintaining such a section is one of providing, for the Area Director and senior staff associated with regulation of the commercial fishery, a day-by-day report, which can be quickly and easily assimilated, on the operation of each of as many as 40 individual salmon fisheries. In effect, the main function of this operation is that of an information centre and as such it represents the end product of the facilities of three branches:

(a) Economics Branch

For most areas of the coast, the current seasonal strength of returning stocks are determined from the comparison of present and past size of catch. The catch statistics produced by this branch provide the basis for this comparison.

(b) Protection Branch

One of the most vital tasks conducted by the field staff of this branch during the commercial fishing season is one of collecting daily catch figures for each commercial fishery operating on the British Columbia coast. These figures are relayed daily to the district and headquarters offices via a complex communication network which includes the use of both land and ship based radio-telephone as well as land based telephone facilities. On arrival at the headquarters office these reports are supplied to the staff of the operations room for processing.

(c) Fish Culture Development Branch

The responsibility of tabulating and of illustrating graphically the catch and escapement data available for all areas is that of the personnel of this branch. During the initial preparations, catch data was presented on an annual, weekly and, where possible, daily basis by species and by commercial fishing area for the period 1951-1961; escapement data were tabulated for the same period. Throughout the season, as catch reports were received from the respective fishing areas, the current figures were tabulated, graphed and a summary comparison made with past catch data. This information was then furnished to the headquarters management staff at daily "briefing" sessions for their interpretation.

The operation described above functioned effectively throughout the past season and has now become an integral part of the salmon management machinery of the Pacific Area. Preparations are now underway to further extend the tabulation and analysis of catch and escapement data beyond that provided in 1962.

5. MISCELLANEOUS

5.1 GLENDALE TRAPPING FACILITIES

In response to a request from the Pacific Biological Station this Branch provided engineering advice in connection with the design and construction of the fish-collection facilities which were employed in 1962 at Glendale River, Knight Inlet, B. C., to obtain pink salmon eggs for a transplant to Newfoundland.

A low weir, 136 feet long by two feet high, was constructed across the entire width of the river. It is fitted with a row of horizontal screens, supported by the weir crest at the one end and by timber pilings at the other, which extend downstream from the crest. This arrangement is designed to allow free passage of river discharges while acting as a barrier to all upstream migrants (at low flows). As this structure had to be constructed on gravel it has been equipped with a cut-off wall, consisting of a row of steel sheet-piling at the upstream face, which prevents scouring of the foundation. The barrier is aligned at an angle of

70 degrees to the river flow in order that fish will be led directly to a holding pool entrance situated on the left bank. Counting traps, located near the two ends of the structure, provide the means by which normal escapements to the upriver spawning grounds can be maintained.

A holding pool, having a surface area of 1,100 square feet, has been excavated on the left bank adjacent to the barrier structure. This pool is lined with timber and is so equipped that it can be divided into pens of various sizes for the holding and sorting of fish. Water is supplied to the pool by an open-cut channel which has been excavated to connect with the river approximately 200 feet upstream from the barrier.

These facilities were completed in July, 1962 at a total estimated cost of $60,000.

5.2 TAHSIS OFFICE-RESIDENCE

Plans of an office-residence and garage for the local Fishery Officer at Tahsis were completed in August, 1961. Construction commenced in September and the buildings were completed in February, 1962. The total cost of the buildings including the purchase of a stove, refrigerator, drapes, fencing materials, and rough landscaping was $23,400.

The office-residence is 25 feet by 41 feet in plan and the garage is 12 feet by 24 feet. The total finished floor area of the office-residence is approximately 1,600 square feet, which is made up of two bedrooms, a bathroom, a kitchen, and an L-shaped living-dining-room on the main floor; and two bedrooms, a bathroom, an office, and an unfinished area for a utility room and storage in the basement.

Considerable flooding occurred during the fall of 1962 in the general area of the office-residence. On September 30, a nearby creek overflowed its banks causing some damage to the Department's property. Again, on November 23, heavy rains in the area caused the creek to over-top its banks with the result that the entire property was inundated to a depth of approximately three feet. This flood caused extensive damage to the office-residence as a result of the deposition of a large quantity of silt and debris in the basement.

Repairs were effected in December, and the recommendation has been advanced that flood protection measures be employed to prevent such incidents in future.

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