CHUM SALMON SURVIVAL AND PRODUCTION AT SEVEN IMPROVED GROUNDWATER-FED SPAWNING AREAS

BY

D.B. Lister, D.E. Marshall and D.G. Hickey

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Department of Fisheries and Oceans
1090 W. Pender St.
Vancouver, B.C. V6E 2P1

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D.B. Lister[2], D.E. Marshall and D.G. Hickey[2]

Enhancement Services Branch

Department of Fisheries and Oceans

1090 West Pender Street

Vancouver, B.C.

V6E 2P1

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[2] D.B. Lister and Associates Ltd., West Vancouver, B.C.

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ABSTRACT

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Chum salmon spawning, egg-to-fry survival and fry production were assessed in a one-year study of improved groundwater-fed spawning areas in southern British Columbia. Survival from potential egg deposition to fry emigration ranged from 1% to 33.5% and averaged 16.3%, approximately twice the average recorded at natural spawning areas in the province. Although maximum fry production per unit of spawning area ($517/m^2$) was achieved with the highest spawning density (2.5 females/m^2), fry output per area did not increase appreciably when density exceeded 0.5 female/m^2. The advantages of a graded gravel spawning substrate, which had been added to 5 of the 7 sites, were not apparent from the survival data. However, differences between sites in other physical features and in spawner density may have obscured the influence of substrate quality. Additional information is presented on characteristics of chum salmon spawning populations and fry migrations, as well as incidental data on utilization of the improved spawning areas by other salmonid species.

KEY WORDS: chum salmon, egg-to-fry survival, fry production, spawning density, age, size, migration timing, spawning area improvement.

RÉSUMÉ

Lister, D.B., D.E. Marshall and D.G. Hickey. 1980. Chum salmon survival and production at seven improved groundwater-fed spawning areas. Fish. Mar. Serv. MS Rep. 1595: 58 p.

Le frai du saumon kéta, la survie depuis la ponte jusqu'au stade d'alevin et la production d'alevin ont été évalués dans le cours d'une étude d'un an sur les frayères améliorées et alimentées par de l'eau de nappe phréatique, au sud de la Colombie-Britannique. Le taux de survie moyenne de 16,3%, soit près du double de la moyenne relevée pour les frayères naturelles de la province. La production maximale d'alevins par unité de frayère ($517/m^2$) a été obtenue avec la densité de reproducteurs la plus élevée (2,5 femelles/m^2), mais la production par unité de surface n'a pas augmenté sensiblement au-delà de 0,5 femelle/m^2. Les données sur la survie n'ont pas mis en évidence les avantages d'un substrat de gravier nivelé qui avait été placé à cinq des sept frayères. Toutefois, il se peut que les effets de la qualité du substrat ne soient pas ressortis en raison des différences de caractéristiques et de densité de reproducteurs d'un endroit à l'autre. Nous présentons des renseignements supplémentaires sur les caractéristiques des populations de reproducteurs et de la migration du frai de saumon kéta, ainsi que des données accessoires sur l'utilisation des frayères améliorées par d'autres espèces de salmonidés.

MOTS CLÉS: saumon kéta, survie depuis la ponte jusqu'au stade d'alevin, production d'alevins, densité de reproducteurs, âge, taille, moment de la migration, amélioration de la frayère.

INTRODUCTION

Chum salmon (Oncorhynchus keta) populations in southern British Columbia commonly spawn in groundwater-fed side channels of the larger rivers. These relatively stable environments afford protection from the extreme freshets which adversely affect salmon survival in main-river spawning areas. The salmon production potential of side channels is often limited, however, by low volume and depth of flow which may restrict spawner access or cause desiccation of redds during incubation and fry emergence.

Since 1977 the Department of Fisheries and Oceans has undertaken a program to develop new spawning areas and to improve existing areas in groundwater-fed side channels, primarily to increase chum salmon production. The program has utilized formerly active flood channels which are cut off from the main river and are fed by groundwater. Techniques to enhance these spawning areas have included the removal of obstructions to migration, excavation to increase groundwater flow and depth as well as the area available for spawning, installation of weirs to increase water depth and control gradient, and the addition of graded gravel to improve spawning bed quality.

This report presents the results of a study to assess chum salmon spawning, egg-to-fry survival and fry production at seven side channel improvement projects, chosen to represent various site conditions and improvement techniques employed in the program. Additional data were collected on characteristics of the chum salmon populations, such as spawning timing and distribution, spawner age and size composition, and fry size and migration timing, as well as incidental information on utilization by other salmonid species. The study was conducted at three sites in the Squamish River system and four sites in the lower Fraser Valley near Mission and Chilliwack (Fig.1). Data from one location, Billy Harris Slough on the lower Harrison River, were collected by the Chehalis Indian Band as part of another investigation contracted by the Department of Fisheries and Oceans.

DESCRIPTION OF THE STUDY AREAS

JUDD SLOUGH

Judd Slough, one of the major chum salmon producing side channels of the Squamish River, is located approximately 3 km north of Squamish near the community of Brackendale (Figs. 1 and 2). The slough has become basically a groundwater-fed stream, with local surface drainage contributing a minor portion of the flow. This situation developed in 1967 when the Department of Fisheries constructed a spur dyke at the upstream end to protect the slough from flooding. This dyke was replaced in 1975 by a

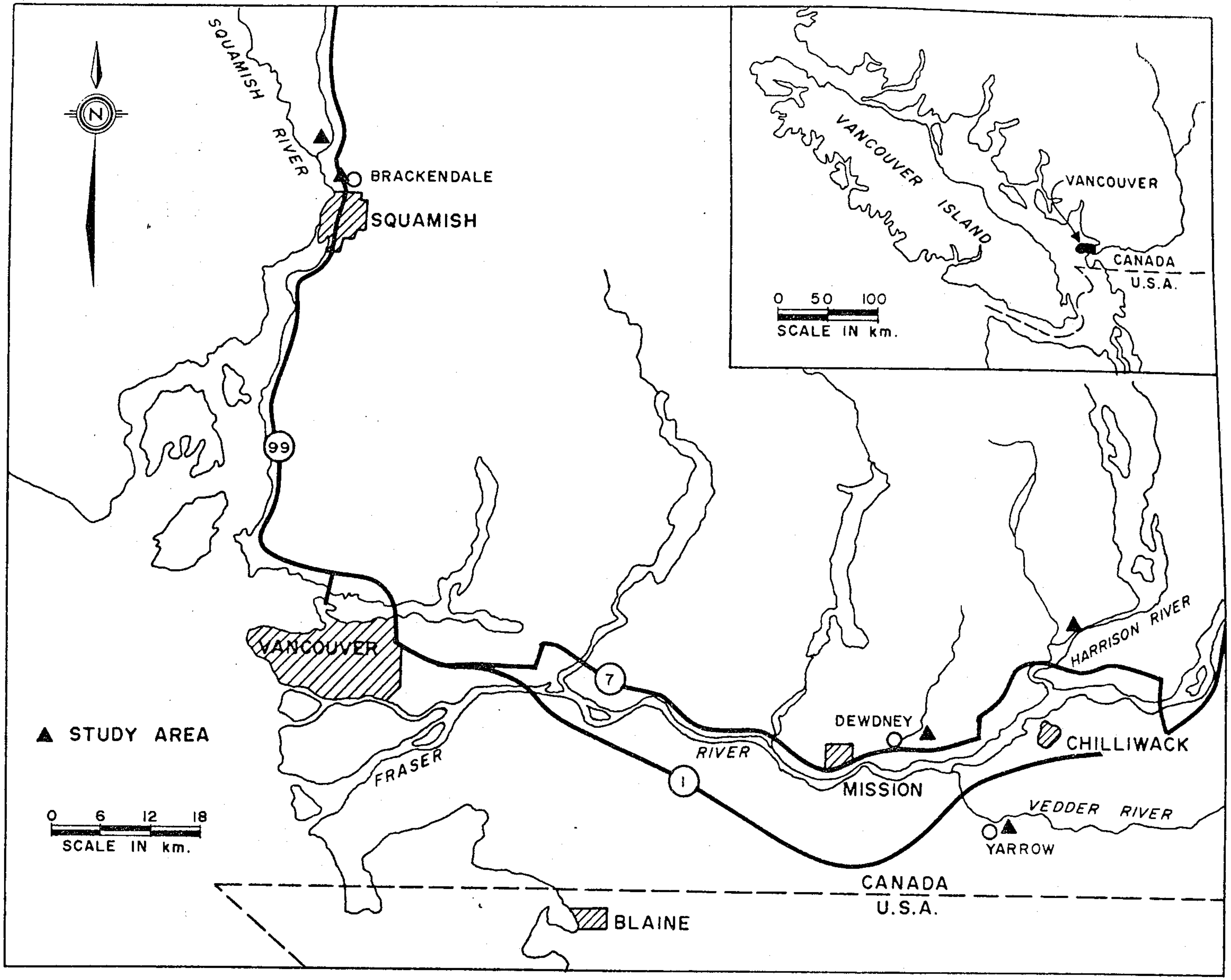

FIG. 1. Map of the lower mainland of British Columbia showing the locations of study areas.

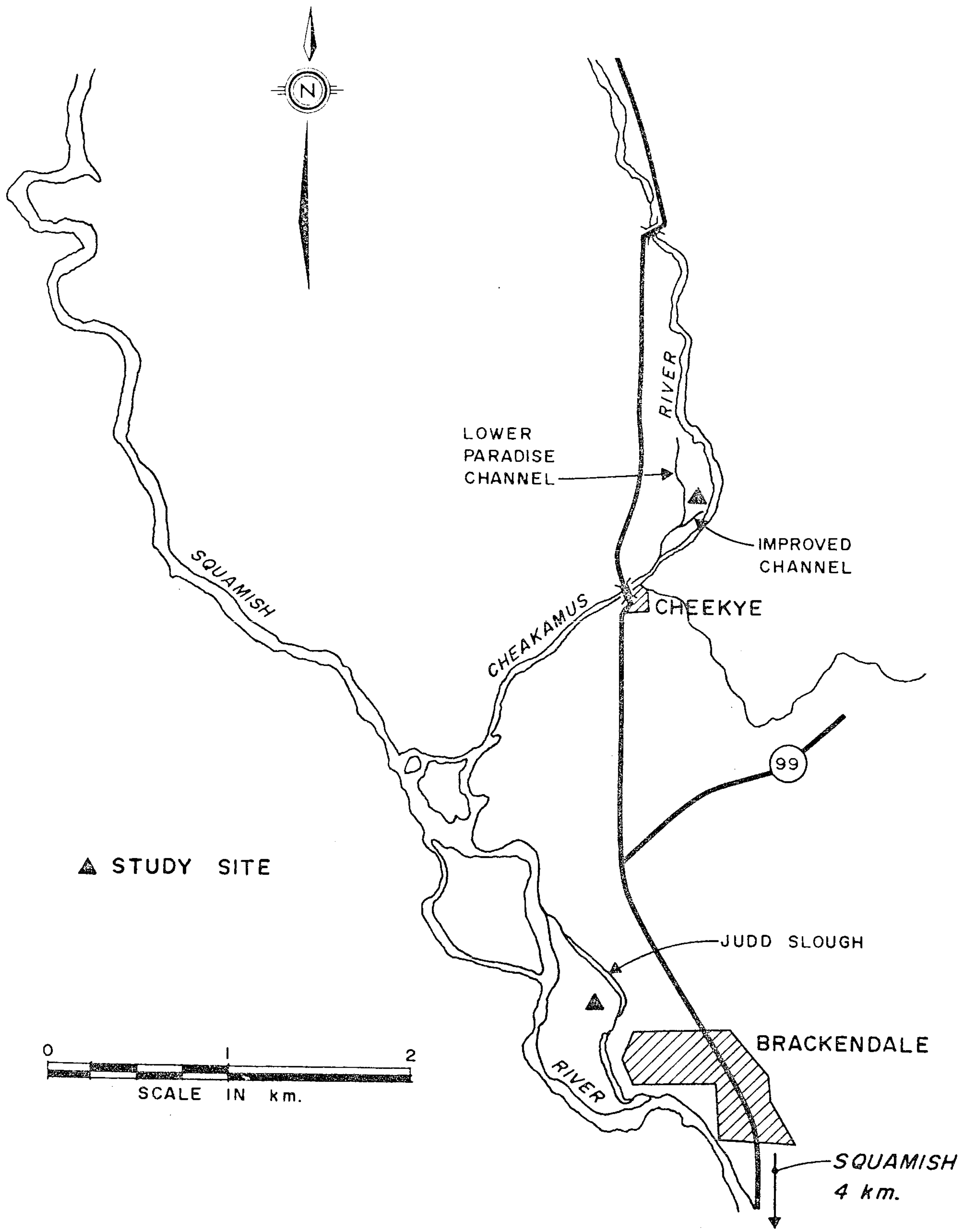

FIG. 2. Map of the Squamish area showing locations of study sites at Judd Slough and Lower Paradise Channel.

major flood control dyke constructed by the provincial government to protect local communities. Provision was made for controlled inflow from the Squamish River through an intake valve and culvert in the dyke (Fig.3). Squamish River water is normally introduced for a short period in the fall in the early stages of chum salmon migration. Flow measurements in February, 1980 showed that flow volume increases almost 8-fold between the upper reaches above Pond 1 (0.08 m^3/sec) and the bridge (0.6 m^3/sec), mainly due to groundwater input.

The main study site included the upper 1500 m of slough, extending from the intake to the lower drop structure (Fig. 3). The other study site was Pond 2, one of two ponds and two small tributary channels improved in this upper section of slough (Fig. 4).

Improvement of the main slough and side channels was carried out in 1978 and 1979. The two pond-type spawning areas were created in 1978 by excavation adjacent to the main channel. Graded gravel was added to Pond 2. In the main channel the stream bed profile was altered to produce a more even gradient overall. Coarse material was excavated from the stream bed and placed on the banks to increase their stability. Low wood drop structures were installed to increase water depth in shallow areas and to control gradient. The area of main channel improvement extended from 100 m below the intake to the lower weir, 100 m upstream of Tributary Channel 2 (Fig. 3).

The improved section of main channel is 1470 m long and averages 8 m wide, providing 11,600 m^2 of potential spawning area. Ponds 1 (510 m^2) and 2 (565 m^2) measure 15 m wide and 110 - 120 m long. Tributary channels 1 (645 m^2) and 2 (3280 m^2) are 135 and 480 m long respectively and average 7 m in width. Potential spawning area in Judd Slough and tributaries totals 16,600 m^2.

During salmon spawning water temperatures in the slough and Pond 2 averaged respectively 2.3° C and 3.1° C warmer than the Squamish River (Fig. 6). Spawning substrate in the main channel consisted of gravel under 3 in. (76 mm) diameter and sands, with approximately 30% by weight under 1/2 in. (13 mm) diameter (Fig. 5 and Appendix H). The graded gravel placed in Pond 2 ranged from 4 in. (102 mm) to 3/8 in. (10 mm) in diameter and contained no sands or silts (Fig. 5).

Judd Slough is used extensively for spawning by chum salmon and to a lesser extent by coho salmon (Oncorhynchus kisutch). In the 1970's annual escapements were estimated in the range of 4,000 to 10,000 chums and less than 50 coho (Marshall and Brown, MS 1977). The slough also serves as a rearing area for coho salmon and trout (Salmo sp.).

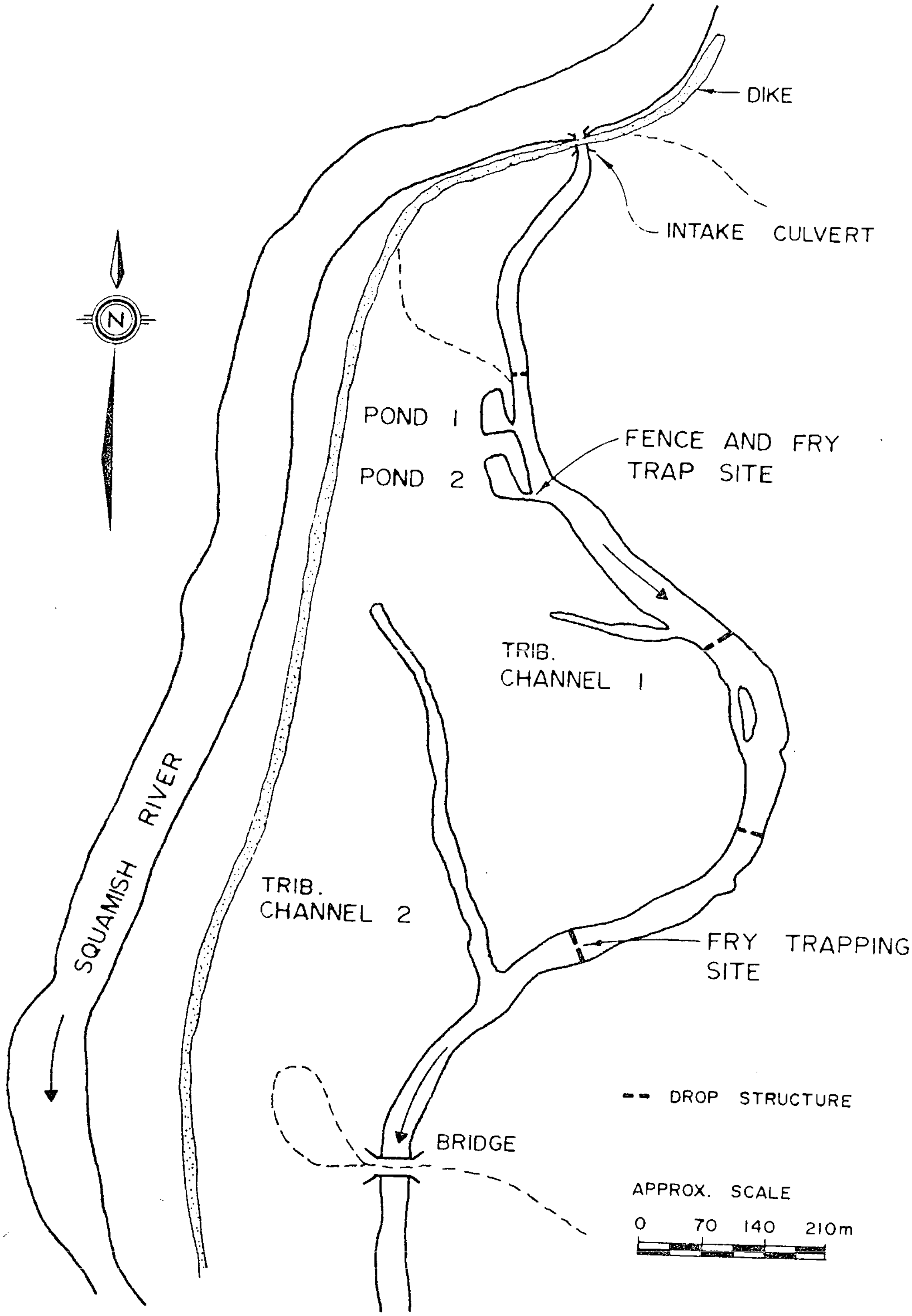

FIG. 3. Sketch map of the Judd Slough study site, tributary to the Squamish River.

FIG. 4. A major spawning area in Judd Slough (upper) and the Pond 2 study site adjacent to the slough (lower).

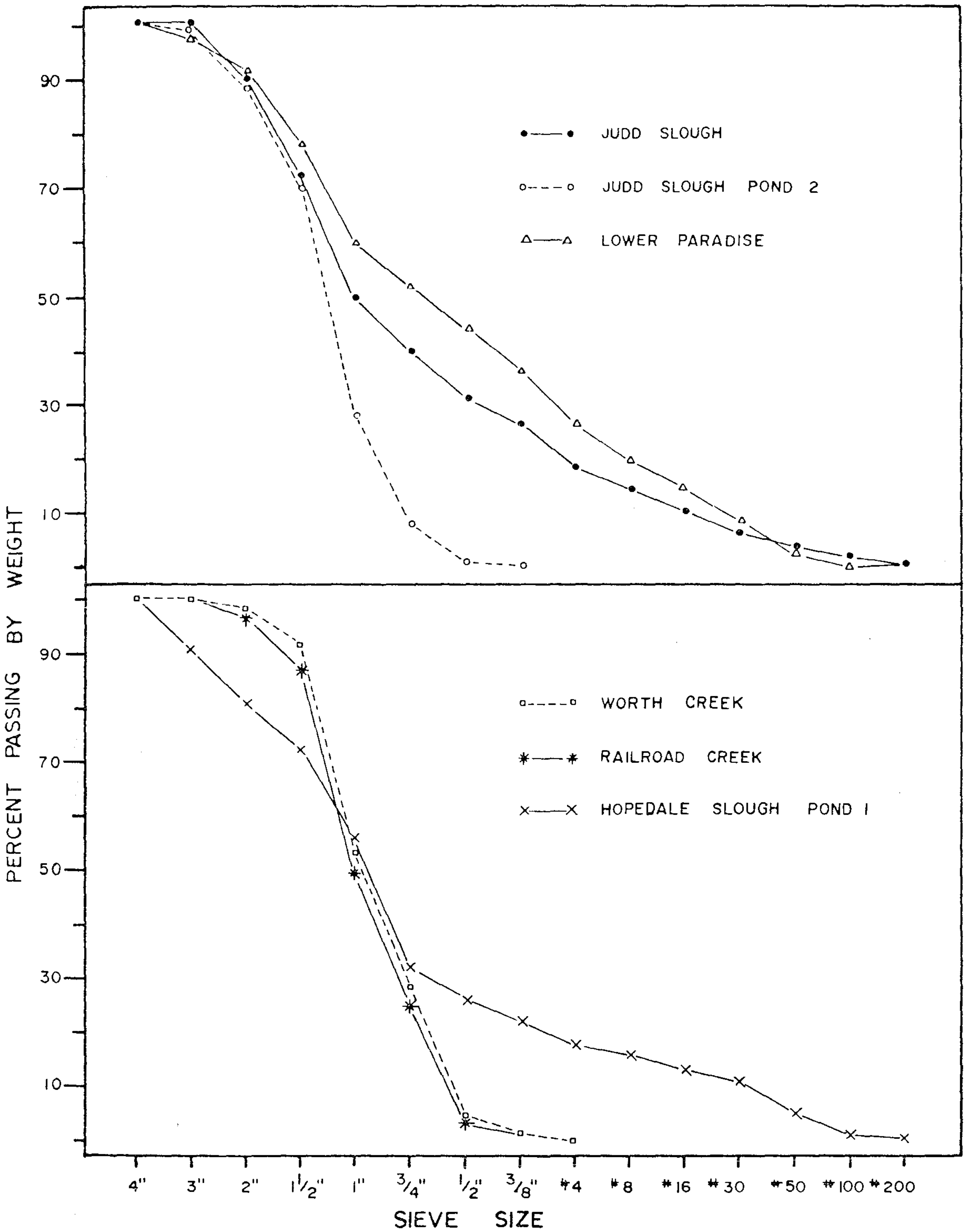

FIG. 5. Comparative size composition of spawning beds at the study sites.

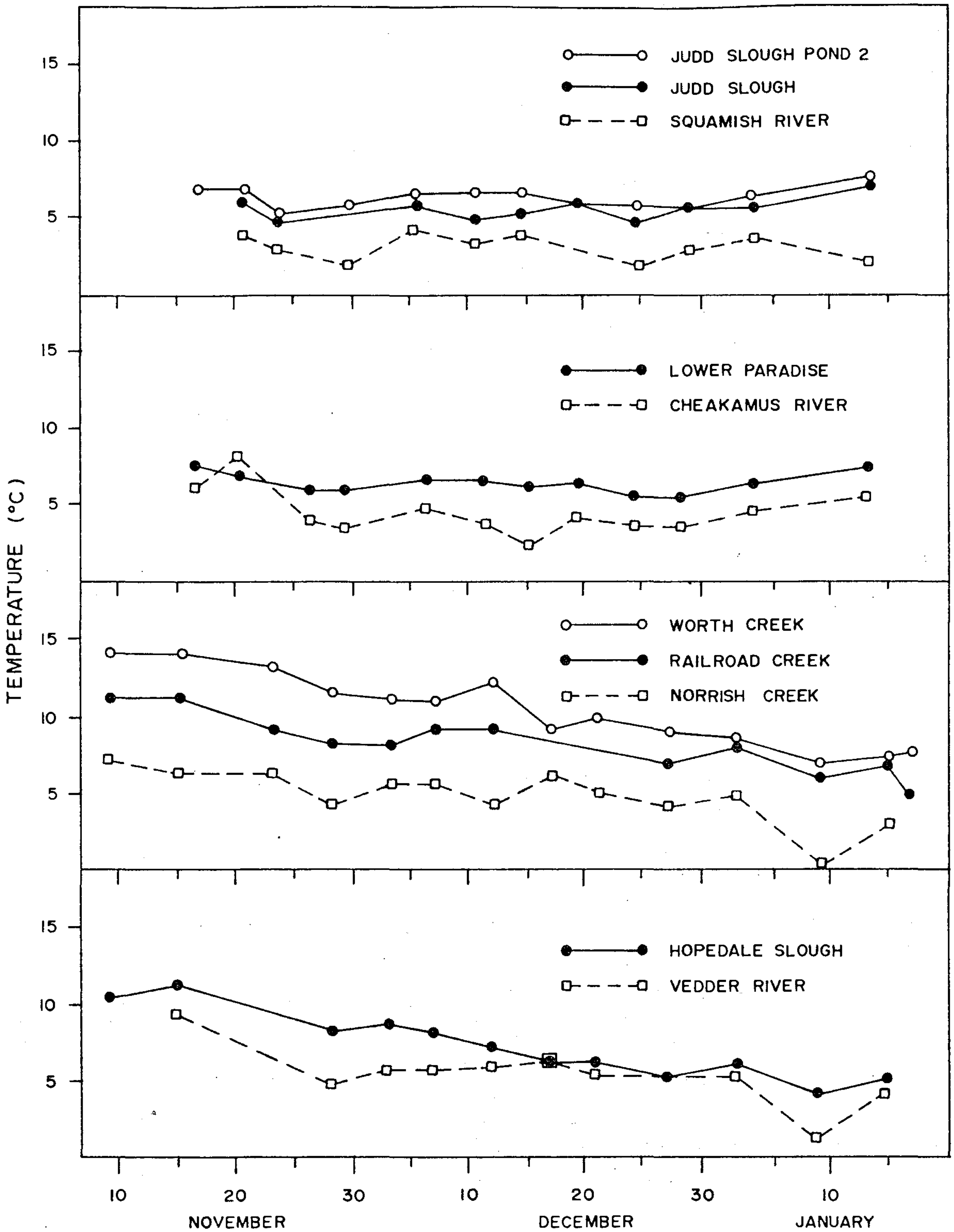

FIG. 6. Water temperatures at the study sites and adjacent surface-fed streams during chum salmon spawning.

LOWER PARADISE CHANNEL

Lower Paradise Channel is a flood channel of the Cheakamus River which receives occasional inflow from the main river during extreme freshets. It is situated approximately 8 km north of Squamish (Fig. 2). The study site is a small groundwater-fed tributary of Lower Paradise Side Channel. Prior to development it did not support salmon spawning, due to low flows. The flow in the developed channel is at all times comprised mainly of groundwater. Fluctuations in discharge of the Cheakamus River cause similar fluctuations in groundwater flow in the developed channel and the main Lower Paradise Channel. Under extreme high discharge conditions outflow from the developed channel may be restricted due to backwatering, thus increasing water depth in the lower section.

Development of the Lower Paradise tributary was carried out in the summer of 1979. The study site was deepened and widened, and a short dyke or plug was constructed at the head of the channel for flood protection (Fig. 7). Five laminated wood drop structures, approximately 30 cm high, were installed in the channel to produce a spawning depth of 20-30 cm and to control gradient. The developed channel is 320 m long, averages approximately 6 m wide, and contains 1940 m^2 of new spawning area.

The native material in the channel bed was retained as spawning substrate. It is comprised of gravel less than 4 in. diameter with a relatively high percentage of sand (Fig. 5). Minimal amounts of fine silt and organic material were present during sampling.

Spot temperatures taken during the spawning season indicated a close relationship between the developed channel and the adjacent Cheakamus River (Fig. 6). Temperature in both streams remained fairly constant during this period, but the developed channel was 2°C warmer on the average.

WORTH CREEK

Worth Creek is a small groundwater-fed tributary and former flood channel of Norrish (Suicide) Creek located approximately 13 km east of Mission (Fig. 8). Prior to improvement work salmon spawning was generally restricted to the lower reaches of the stream because of obstructions. During the 1969-1978 period an estimated 25-1500 chum and up to 25 coho salmon spawned in Worth Creek each year (Brown and Musgrave, 1979).

In 1979 the Department of Fisheries and Oceans widened and deepened the upper 150 m section of stream (Figs. 9 and 10). A 45 cm layer of graded gravel, from 2 in. to ¼ in. in diameter, was added to the channel (Fig. 5). To provide adequate depth for spawning, a wood drop structure was installed. Large boulders were placed along the banks to prevent erosion by spawners.

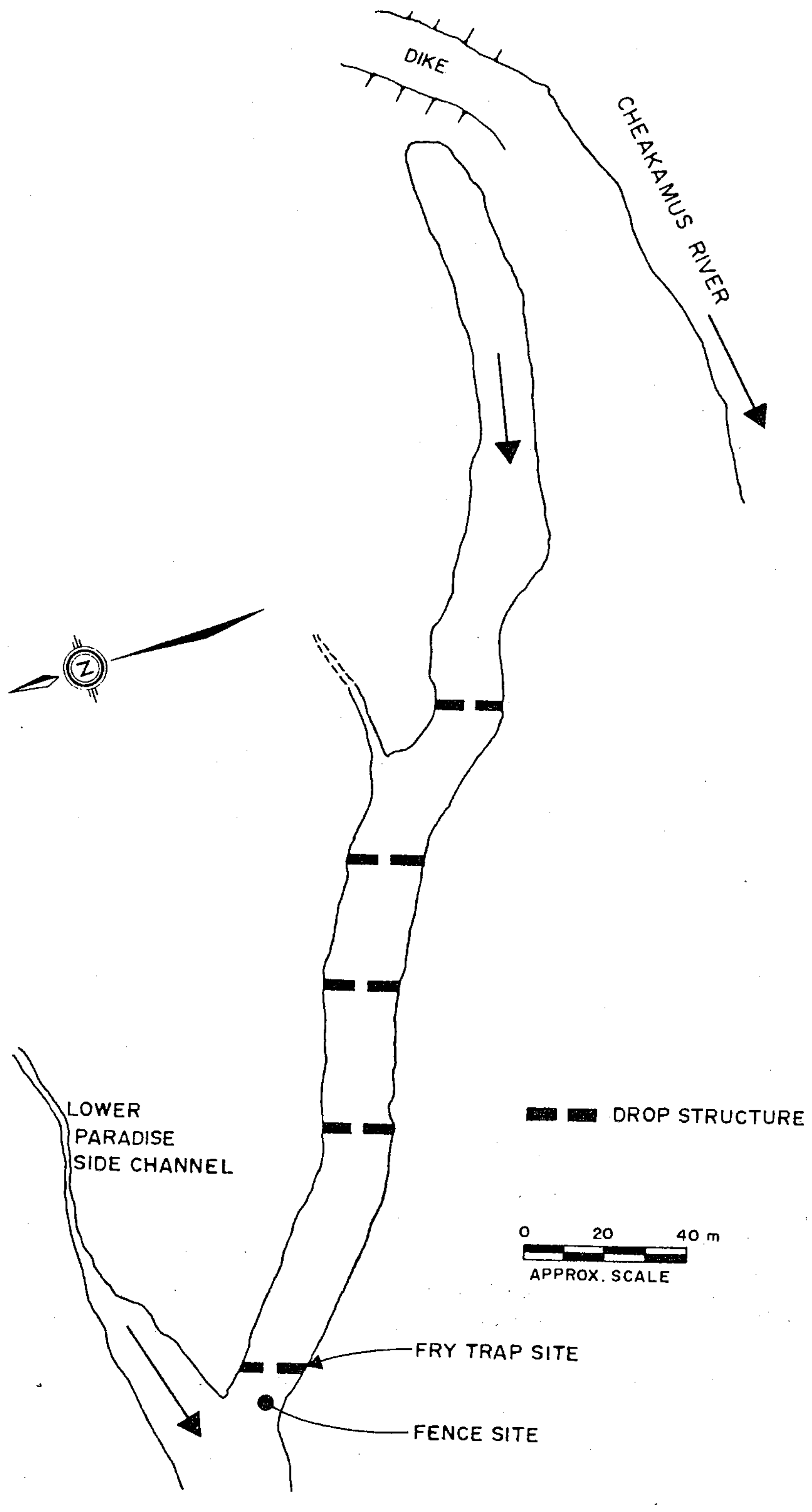

FIG. 7. Sketch map of the Lower Paradise Channel study site, tributary to the Cheakamus River.

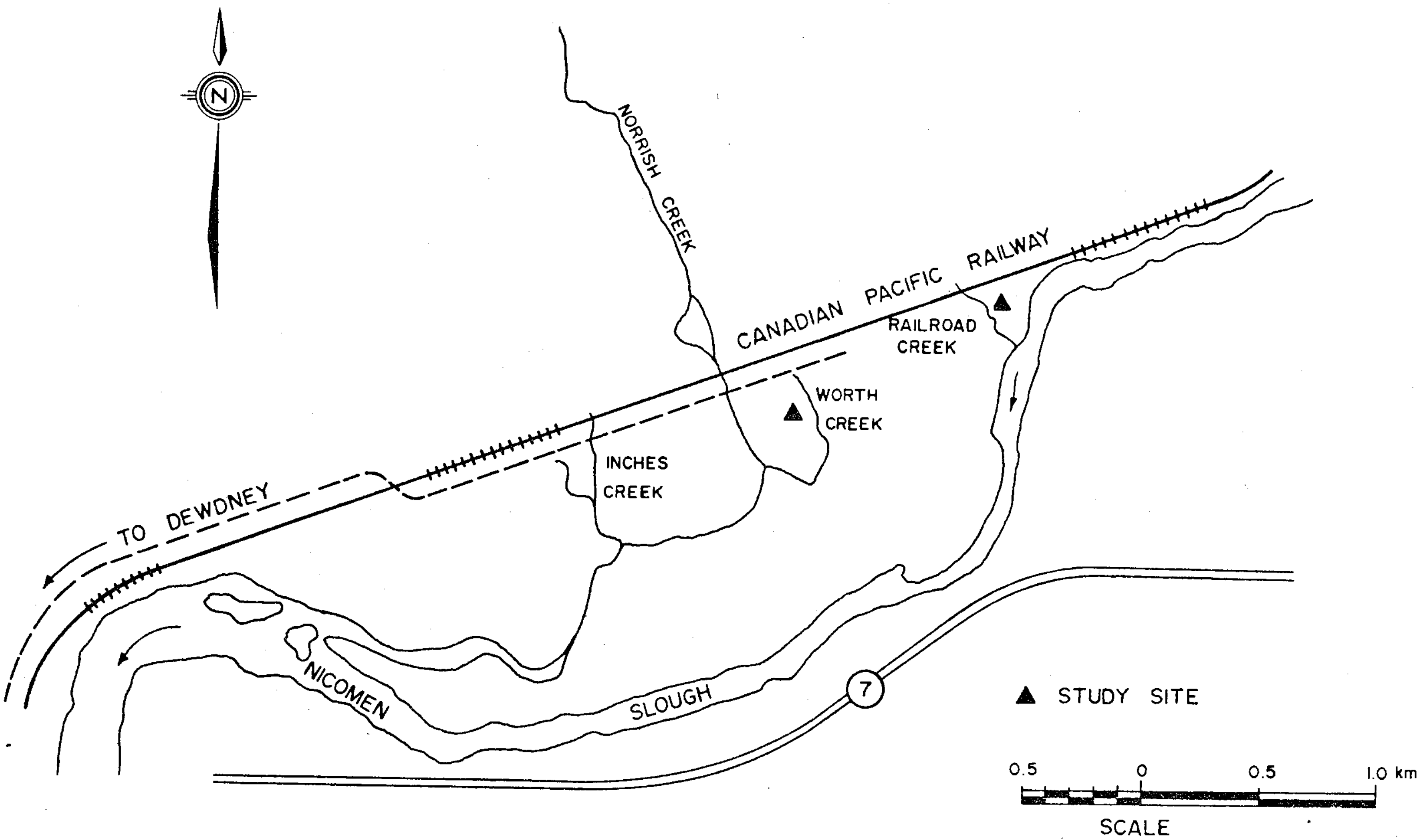

FIG. 8. Map showing the locations of the Worth Creek and Railroad Creek study sites near Dewdney.

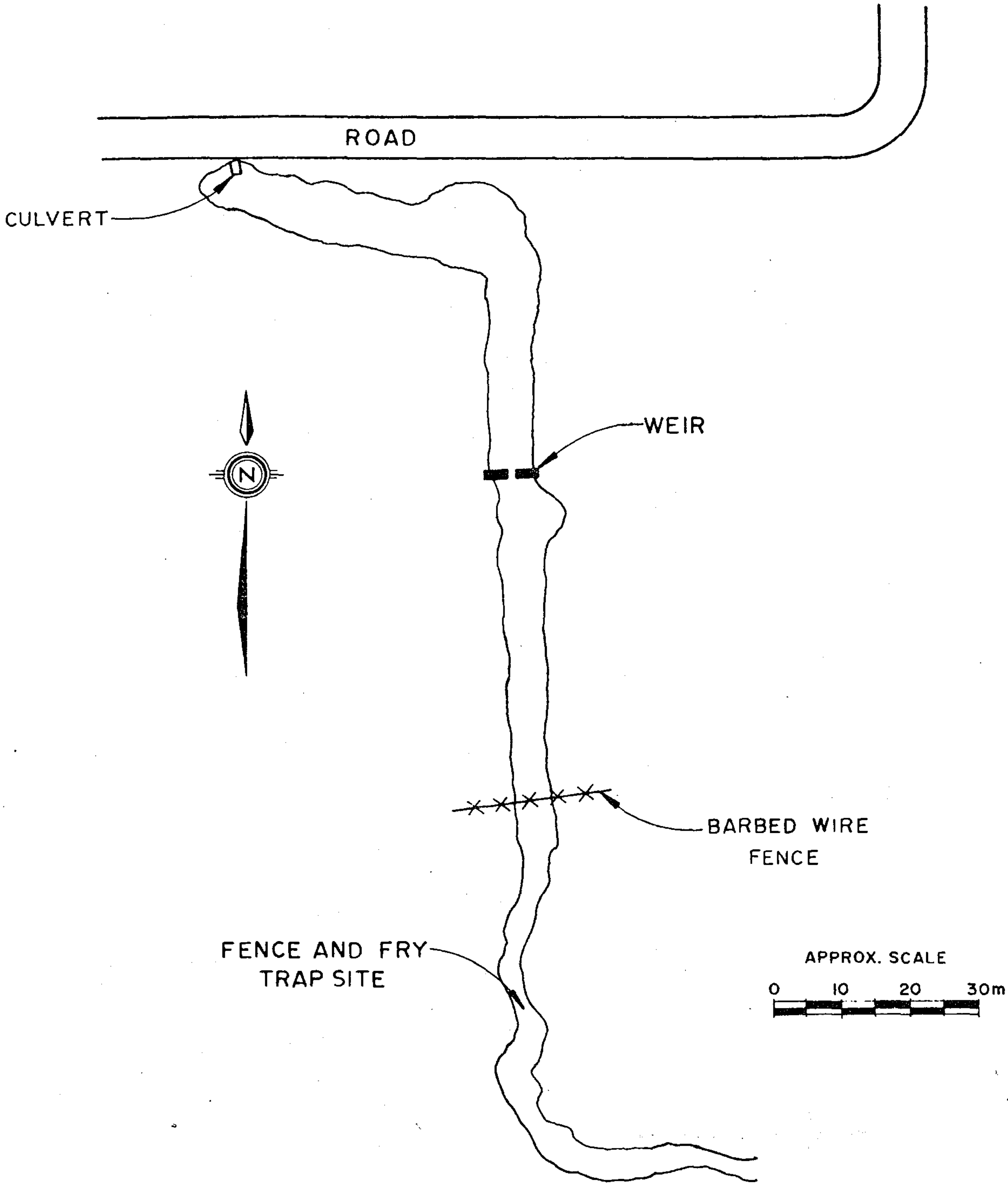

FIG. 9. Sketch map of the Worth Creek study site.

FIG. 10. Trout pool before (upper) and after (lower) opening of the improvement.

The improved channel is about 150 m long and 5-6 m wide, providing an additional 848 m^2 of spawning area.

Although Worth Creek has a relatively stable groundwater source, backwatering can occur when discharge in Norrish Creek is exceptionally high. On December 17, 1979, flood waters inundated the area immediately below the study site. This backwatered the channel and flooded the adult fence.

Spot temperature measurements show that Worth Creek averaged nearly 6^{o} C warmer than Norrish Creek during the salmon spawning period (Fig. 6).

RAILROAD CREEK

Railroad Creek is a groundwater-fed tributary of Nicomen Slough and former flood channel of Norrish Creek situated approximately 1 km east of Worth Creek (Figs. 8 and 11). Though the creek is primarily groundwater-fed, surface runoff from above the Canadian Pacific Railway track makes a significant contribution during periods of high rainfall. Railroad Creek is also subject to frequent backwatering from Nicomen Slough, because of the channel's low elevation relative to the slough.

Improvement work in 1979 consisted of deepening and widening the creek with excavating equipment (Fig. 12), and adding a 45-90 cm depth of 3 in. to 1/4 in. diameter graded gravel (Fig. 5). Large rocks were placed along the banks to minimize erosion by spawners and one drop structure was installed near the downstream end. The channel is approximately 135 m long and averages 5 m wide, providing a total of 770 m^2 of new spawning area.

Water temperatures recorded during spawning showed a similar gradual decline in both Railroad Creek and surface-fed Norrish Creek, with Railroad Creek averaging 4^{o} C warmer (Fig. 6).

Prior to improvement the lower reach of Railroad Creek supported an annual escapement estimated at 50-100 chum salmon.

HOPEDALE SLOUGH

Hopedale Slough is an old flood channel of the Vedder River located approximately 2 km northeast of Yarrow(Fig. 13). It parallels the Vedder River for almost 2 km, entering it near the B.C. Hydro railway bridge. The slough is now cut off from the Vedder River by a dyke which crosses its former point of departure from the river (Fig. 14). The study site, Pond 1, is part of a larger improvement project involving the main slough and other seepage areas. It is the furthest upstream in a series of five ponds. Pond 1, known as George's Pond, was excavated and a 45 cm

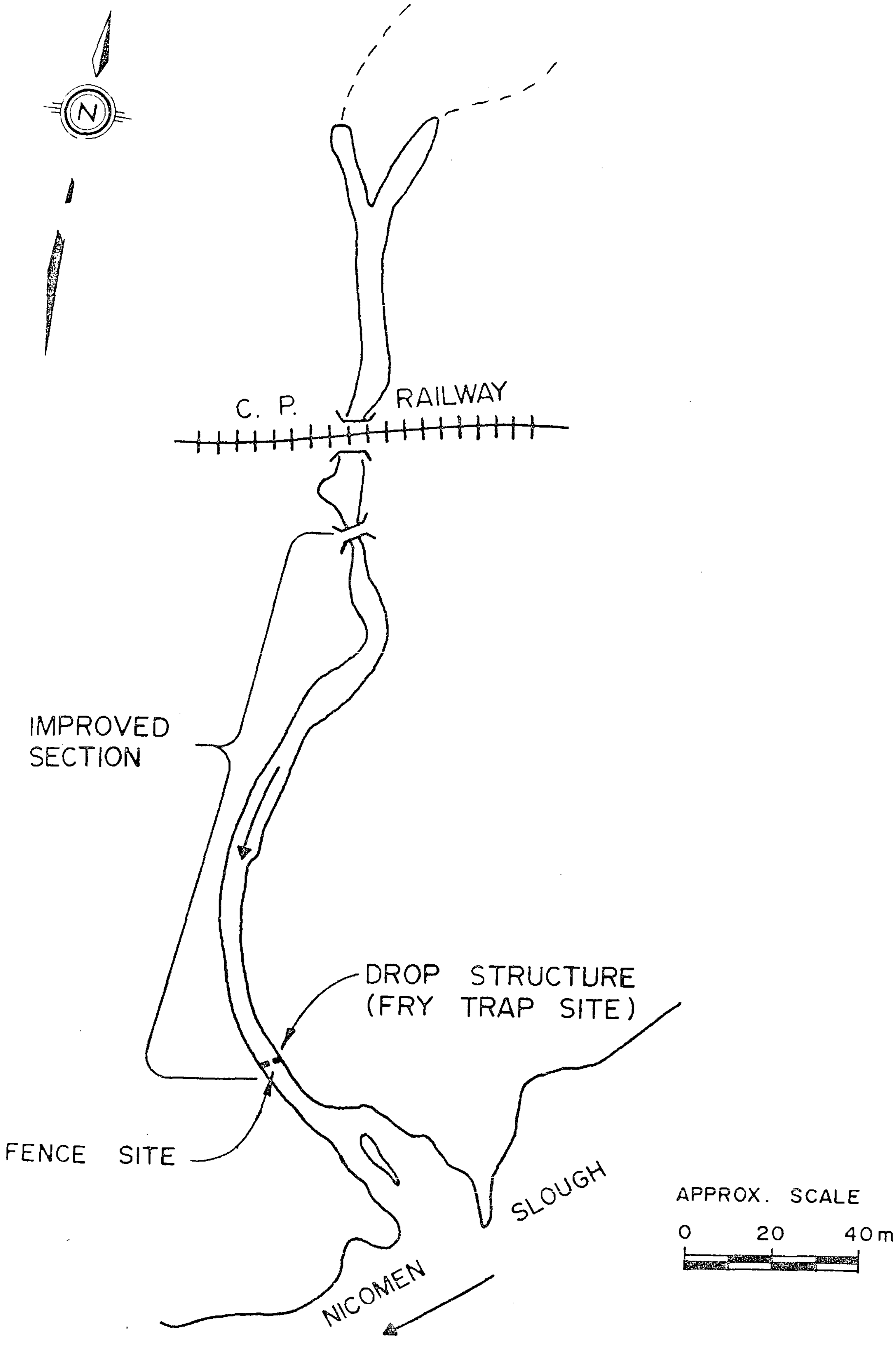

FIG. 11. Sketch map of the Railroad Creek study site.

FIG. 12. The Railroad Creek spawning area under low water conditions (upper) and a V-fence for carcass retention at the downstream end of the spawning area (lower).

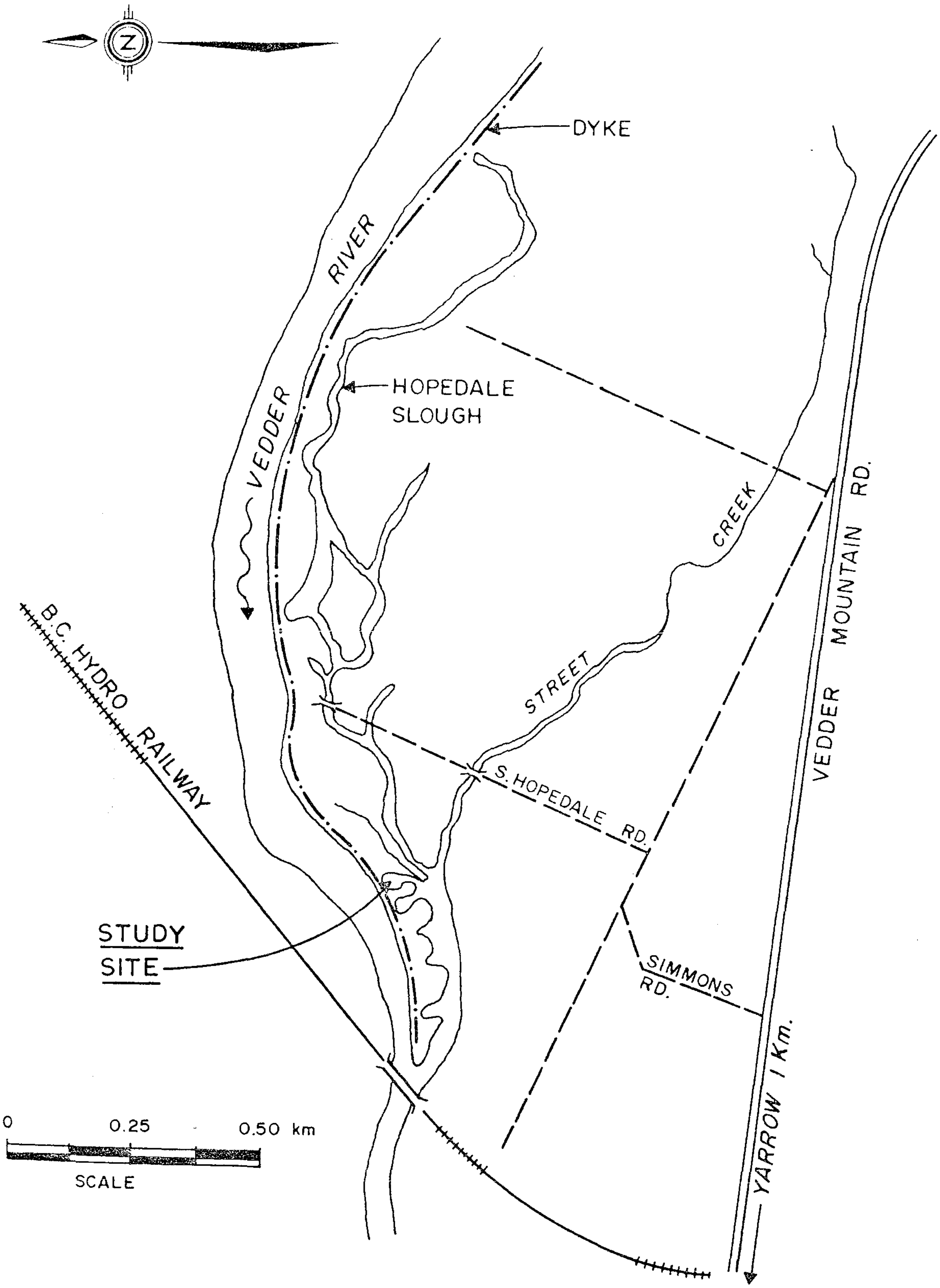

FIG. 13. Map of Hopedale Slough, tributary to the Vedder River.

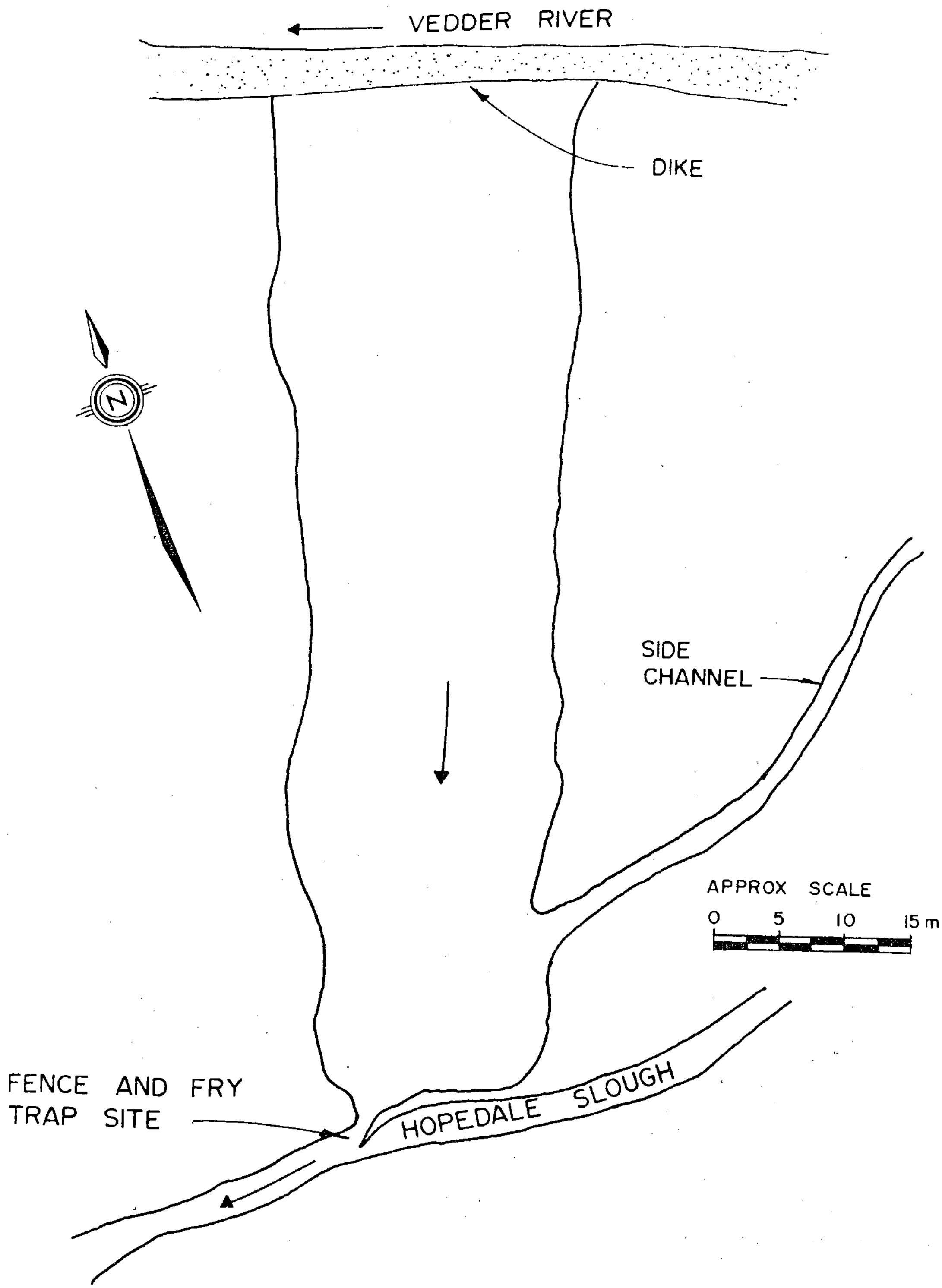

FIG. 14. Sketch map of the Hopedale Slough Pond 1 study site.

layer of graded gravel added during the summer of 1977. The improved area is approximately 75 m long and averages 20 m wide, providing 1675 m^2 of spawning area.

Groundwater seepage provides a stable flow to Pond 1. The flow volume was measured at 0.05 - .06 m^3/sec in February, 1980. During periods of high discharge in the Vedder River backwatering of Pond 1 can occur.

Samples of spawning substrate were obtained from the area of highest spawning density near the dyke. The substrate consisted of gravel less than 4 in. diameter and sands (Fig. 5). A relatively large amount of silt was evident during sampling but could not be retained in the sample.

The overall salmon escapement to various spawning areas in Hopedale Slough during 1977 to 1979 has been estimated at 50 - 1000 chum and 200 - 250 coho salmon (Marshall et al. 1980).

BILLY HARRIS SLOUGH

Billy Harris Slough is located on the Chehalis Indian Reserve approximately 35 km east of Mission (Fig. 1). It is one of several groundwater-fed chum salmon spawning areas flowing into the Harrison River on its north bank (Fig. 15). These blind sloughs appear to be old channels of the Chehalis River, a major tributary of the Harrison River.

In early 1979 the slough was cleared of a longstanding obstruction to adult chum salmon, excavated to enlarge and deepen the channel, and divided into three sections by rock groins (Fig. 15). Native gravel was replaced with graded material. Wooden weirs were also constructed in the channel to promote interchange of water between surface and intragravel flow. The weirs do not extend the full channel width, but alternate in a zig-zag pattern. Billy Harris Slough measures approximately 475 m long and has a total area of 8700 m^2, of which 7489 m^2 has been developed for spawning. The flow in February, 1980 was measured at 0.3 m^3/sec.

Billy Harris Slough is part of a larger area designated for escapement enumeration as Harrison River Area 5 B. Chum salmon escapements of up to 51,000 fish have been recorded in this area (Palmer, 1972).

METHODS

The field work for the study was carried out in two periods corresponding with chum salmon spawning (November 2, 1979 to January 19,1980) and fry migration (March 8 to June 17, 1980). The study was designed to gather necessary data on chum salmon populations, and to obtain incidental information on other fish species.

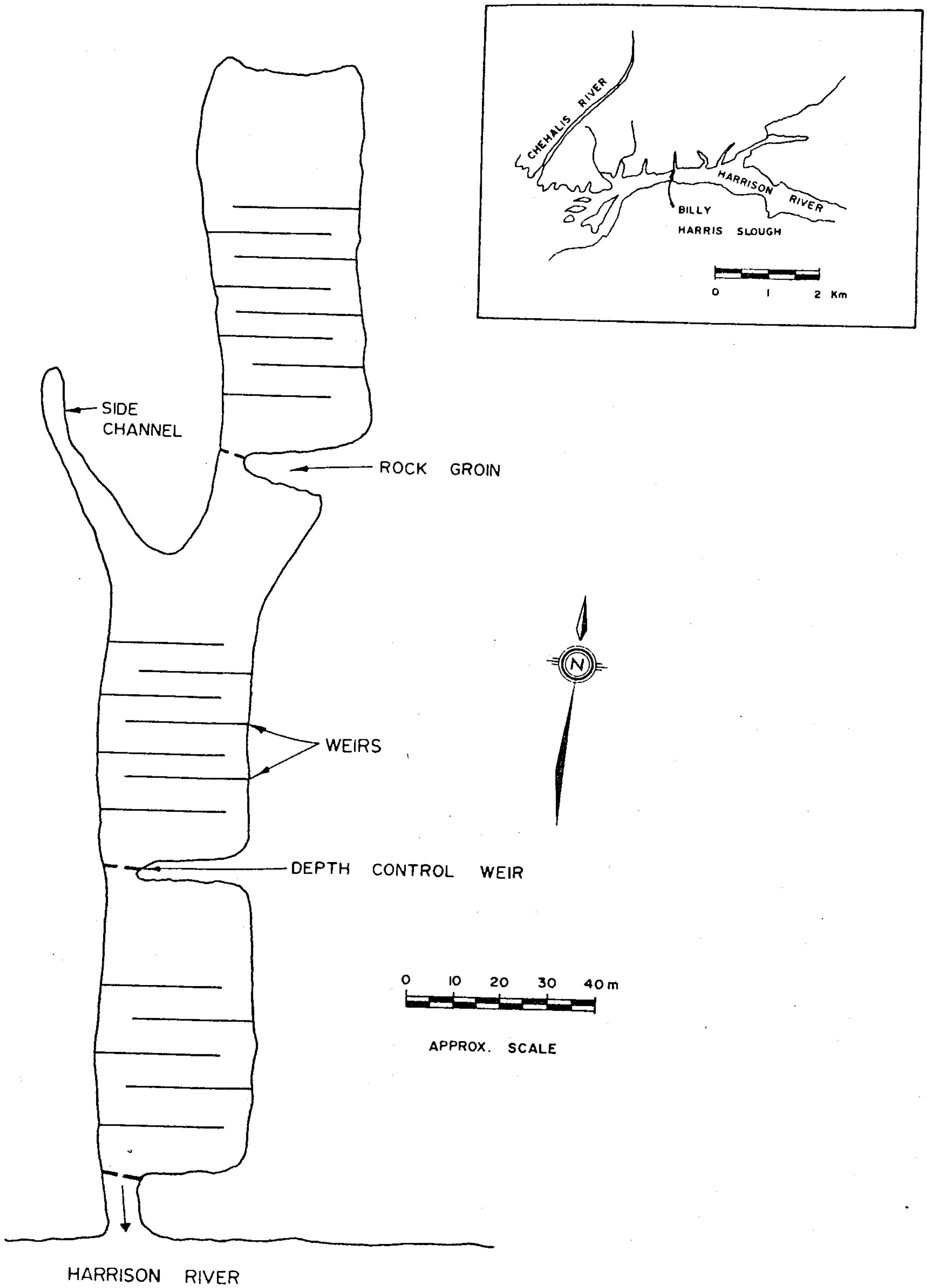

FIG. 15. Sketch map of the Billy Harris Slough study site.

ADULT CHUM SALMON

Population Estimates

Chum salmon escapements to each study site were estimated by tag-and-recovery. Chum salmon were captured for tagging by beach seining on the spawning grounds (Fig. 16). In most cases tags were applied at two stages of the run in a attempt to ensure that any differences in recovery rates between run segments would be detected. The tags used were 7/8 inch (22 mm) diameter Petersen disks. These were attached with a nickel pin inserted through the dorsal fin musculature. A clear plastic buffer disk was applied against the head of the tag pin to reduce the incidence of tag loss (Lister and Harvey, 1969).

Tagged:untagged ratios were established by examining all carcasses available in surveys conducted at 5-day intervals throughout the die-off. Carcasses were tallied by sex, checked for presence of a tag, and cut in two so as to prevent double counting. To reduce loss of carcasses and prevent emigration of tagged fish to adjacent spawning areas, V-shaped fences were installed at the downstream end of all sites except Judd Slough and Billy Harris Slough (Fig. 12). During December 13-18 the fences at Railroad and Worth creeks and Hopedale Slough were flooded out due to backwatering, resulting in loss of carcasses and lowered recovery rates from the mid-December tagging (Appendix I).

Population estimates were derived following the methodology for the Adjusted Petersen Estimate (Ricker, 1975). Male and female populations at each site were calculated separately. As tagging was conducted on the spawning grounds and the post-tagging life span for most fish was less than 6 days, we considered that tag shedding rates were probably lower than those reported by Lister and Harvey (1969), ie. 5% tag loss from females. Accordingly, we made no adjustments for this source of bias. Where tag recovery rates differed significantly from one period to another separate population estimates were derived for each tagging and recovery period. Ninety-five percent confidence limits were calculated for each sex and tagging period by the method outlined in Appendix II of Ricker (1975). The total population estimate for a given study site is therefore the sum of the estimates for given time periods and their respective upper and lower confidence limits. Data used to derive population estimates are presented in Appendices I, J and V.

Spawning Distribution

Two spawner distribution surveys were carried out by Department of Fisheries and Oceans personnel at each site during the period December 11 to 28. Billy Harris Slough was not included in the survey. The length of each study site was measured with a Top-O-Fill instrument and marked at intervals of 50 to 200 ft (15 to 61 m) depending on the total length of the site. Visual counts of live chum and coho salmon spawning in each section were recorded.

FIG. 16. Adult chum salmon tagging on the spawning grounds.

Fecundity

The method of estimating mean fecundity of chum salmon females differed between study sites, depending on availability of existing data and whether approval could be obtained to sacrifice fish for this purpose. For the Lower Paradise and Billy Harris Slough populations, length-fecundity regressions were developed from respective samples of 17 and 15 unspawned females (Appendices K and O). Regressions were calculated according to the formula $y = a + bx$, where y = number of eggs, and x = length in cm. Lengths of Lower Paradise samples were recorded as orbital-hypural measures, whereas the snout to fork length was used for Billy Harris Slough samples. The length-fecundity regression formulae were as follows:

Lower Paradise: $y = -1374 + 78.7x$

Billy Harris Slough: $y = -329 + 52.8x$

The Lower Paradise length-fecundity regression is shown graphically in Fig. 17. The length-fecundity relationship developed for the Lower Paradise population was also assumed to apply to the nearby Judd Slough population.

The mean fecundities of spawning populations at the three Squamish area study sites and at Billy Harris Slough were calculated by inserting the mean length of females at each site into the applicable length-fecundity regression formula.

In the case of the Worth Creek, Railroad Creek and Hopedale Slough populations, fecundity data from the Inches Creek population were assumed to apply. Inches Creek is a groundwater-fed tributary of Norrish Creek located 1 km west of Worth Creek. Fedorenko and Bailey (1980) reported an average apparent fecundity of 2,877 for Inches Creek chum salmon based on 5 years of data from hatchery spawning operations. However, they also estimated an approximate egg loss of 2% in the spawning operation. We have therefore assumed the actual mean fecundity of Inches Creek chums to be 2,936 after correction (2,877 x 100/98) for egg loss in spawn-taking.

Size and Age Data

We attempted to obtain length measurements and scale samples from at least 90 fish of each sex per study site to determine mean size and age composition. Samples were taken from spawning ground dead at the rate of 10-20 fish per visit throughout the die-off period. Orbital-hypural length measures (posterior edge of eye socket to posterior edge of hypural plate) were recorded to the nearest 0.5 cm. One scale was taken from each side of the sampled fish in the preferred area between the vent and the posterior insertion of the dorsal fin, either above or below the lateral line. Scales were interpreted by staff at the Vancouver scale laboratory of the Department of Fisheries and Oceans.

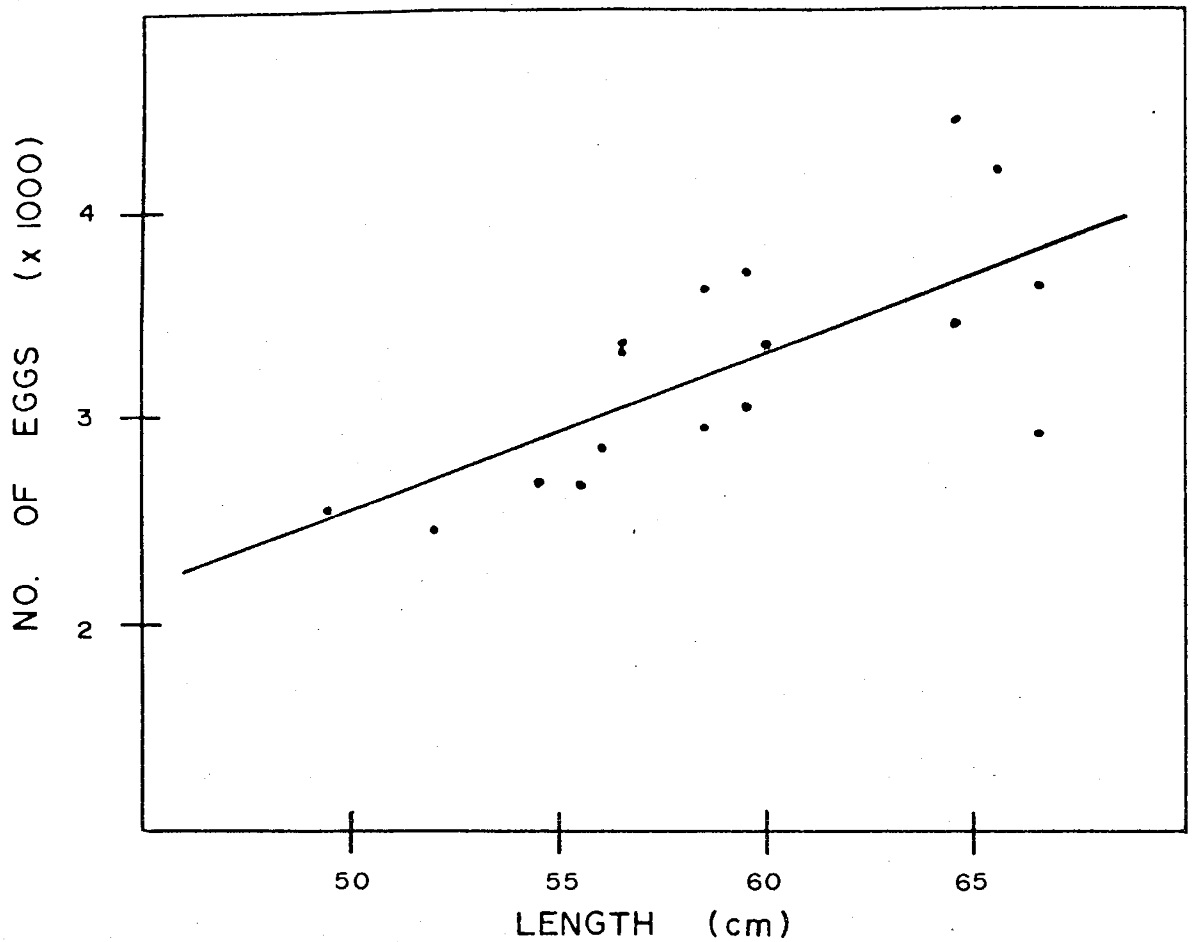

FIG. 17. Length-fecundity relationship for Lower Paradise chum salmon.

Egg Retention

Each female chum sampled for size and age was also examined to determine the number of eggs retained. Actual counts of eggs were obtained in cases where egg retention did not exceed 25%. Egg retention above this level was simply estimated as a percentage of fecundity.

Egg Deposition Estimate

Potential egg deposition was calculated from the point estimate of females in the spawning population and the estimated mean fecundity. Net egg deposition was calculated by subtracting the mean percent egg retention from the potential egg deposition for the population.

CHUM SALMON FRY MIGRATION

Trap Description

The type of trap used depended on site conditions. Where the drop was sufficient, such as at Lower Paradise and the main Judd Slough site, Wolf-type inclined screen traps were employed (Fig. 18). At the other sites traps with vertical screen leads (Armstrong and Argue, 1977) were used (Fig. 19).

The inclined screen traps were attached to the lower weirs at Lower Paradise and the main Judd Slough. At Lower Paradise two traps with 150 cm wide screens were installed. The Judd Slough trap arrangement consisted of three 120 cm wide screens attached to separate live boxes, with flexible hose pipes leading from the centre live box into two auxiliary live boxes (Fig. 18). The auxiliary live boxes were required to shelter fish from excessive turbulence in the centre box. The inclined screens were made of flattened, expanded metal (7 mm x 4 mm opening) which was painted and attached to a wood frame.

Traps installed at all other sites consisted of a 3 - 6 m long vertical screen (8 meshes/in. galvanized) on a wood frame, leading from each bank to a central trough and live box. The live box was raised and lowered to accommodate fluctuations in tailwater elevation.

At all trap installations sheet plastic was placed between the screen bottom and stream bed to ensure against fry leakage.

Trap Operation

At Squamish area sites, downstream migrant trapping started during the March 8 - 12 period and was terminated during May 16 - 23, depending on the site. Trapping at Fraser Valley sites commenced during March 11 - 22 and was terminated at Hopedale Slough and Worth Creek on June 10 and June 17 respectively. Backwatering from the Harrison River flooded out traps at Billy Harris Slough, causing termination of trapping on April 19, prior to completion of fry migration. The rising level of Nicomen Slough created a similar problem at Railroad Creek, with the result that trapping at that site was terminated on May 6.

Traps were operated at Billy Harris Slough continuously, ie. 7 days per week, but at other sites the operation was generally either 4 or 5 days per week. Prior to peak chum fry migration, which started during April 7 - 14, trapping at the other sites was conducted on a 4 days per week basis. During the peak migration period trapping effort was then increased to days per week. Traps were taken out of operation each week simply by attaching a removable screen on the downstream side of each live box. Fishing days and operating periods at individual sites are shown in Appendix S.

FIG. 18. Inclined screen downstream migrant traps at Lower Paradise (upper) and Judd Slough (lower).

FIG. 19. The downstream migrant trap at North Creek viewed from upstream (upper) and downstream (lower).

During each operating period, traps were fished continuously, commencing at 1800 - 1900 hr on the first evening and terminating at 0900 - 1200 hr on the last morning. The exception to this procedure was at the main Judd Slough trap site where severe fouling by filamentous algae necessitated continual brushing of screens and live boxes to prevent overflowing and thus maintain fishing capability. The Judd Slough traps were cleaned nightly from 2000 hr to 0600 hr. As it was not feasible to maintain the trap cleaning operation on a 24 hr basis, any daytime fry migration at Judd Slough may have been underestimated because live boxes tended to overflow due to algal fouling. Though three traps were installed at Judd Slough, during peak migration only one or two of these traps were actually fished. For most of this period the trap intercepting the main flow, Trap 1 on the right bank, could not be operated because of the practical difficulty posed by algal fouling. Trap 3 on the left bank was fished continuously throughout the program and Trap 2 was fished after April 16, when auxiliary live boxes were operating.

Fish Enumeration

When catches were large enough to make individual enumeration impractical fry catches were enumerated by weighing. This procedure entailed separation of salmonid fry, principally chum and coho salmon, from salmonid smolts, fingerlings and other fish species. Two 300 g samples of fry were then drawn randomly from the catch in each trap. Estimates of fry catch by species were then made by multiplying the fry per weight ratio for a given trap by the total weight of fry in that trap.

Population Estimates

Trap Efficiency: Mark and recapture data were used to derive estimates of fry migration at all sites but Billy Harris Slough where no releases of marked fry were conducted. The percent recovery of marked fry was assumed to indicate trap efficiency. Chum fry marked by immersion in Bismark Brown Y dye, or Neutral Red dye at Judd Pond 2, were held in live boxes at the release site approximately 30 m above the trap and released at darkness (2100 - 2200hr) on the night following capture. At four of the sites where traps covered the entire stream width gear efficiency was measured in the range of 86 - 96% (Appendix L).

Non-fishing Days: Estimates of chum fry migration on days when traps were not fishing were derived by interpolation. Trend-line analysis was used to extrapolate the migration for short periods immediatley before and after the trapping season.

Railroad Creek: At this site the marked fry recovery rate averaged only 31%. Fry were reluctant to enter the Railroad Creek trap, apparently because there was no significant directional current into the trap. This conclusion was supported by observations of fry, both marked and unmarked, accumulating above the trap. Of 147 marked fry released above the trap in the evening of April 22, only 21 had moved into the trap by the morning of April 24. Beach seining above the trap on April 24 subsequently yielded

74 marked fry, 59% of the number theoretically available for recovery. On the same date an estimated 60,600 chum fry had accumulated above the trap (Appendix S).

Fry accumulation above the Railroad Creek trap was first noted during the week of April 14 - 18. On April 23 - 24, May 5 - 6, May 13 and May 22 beach seining was carried out in conjuction with releases of dye-marked fry on each date to estimate the population of chum fry above the trap and to transfer fry below the trap site. Estimates of the residual fry population and fry emigration at Railroad Creek are presented in Appendix S. In estimating fry emigration we have assumed that trap efficiency was the same as that measured at Worth Creek (86%).

Our estimate of chum fry emergence from the Railroad Creek spawning area to May 6, when the trap was flooded out, was the sum of (i) the estimated emigration to May 5, (ii) the number of fry removed from above the trap on April 23, April 24 and May 5, and (iii) the estimated number of fry remaining in the creek on May 6. Chum fry emergence after May 6 was estimated on the basis of the following assumptions:

- no natural mortality occurred in the residual fry population above the trap;
- daily fry emergence during May 7 - 13 continued at the average apparent rate (10,350 per day) measured over the April 25 - May 6 period;
- the decline in standing population between May 13 (19,900) and May 22 (2,500) reflected a proportionate decline in daily fry emergence rate;and
- fry emergence after May 22 continued to decline at the rate observed during May 13 - 22 and reached zero by June 1.

Judd Slough: Gear efficiency at this site varied according to the number of traps fishing (Appendix L). During periods when all three traps were fished, ie. Releases 1, 8 and 9, marked:unmarked ratios differed between traps, with marked fry distributing more evenly across the stream than unmarked fry. A chi-square test for independent samples (Siegel, 1956) indicated that the distribution of marked fry between traps was significantly different from unmarked fry (X^2 = 53.04; df = 4; P = <.001). Accordingly, the numbers of marks recovered with only Traps 2 and 3 fishing were adjusted upward to reflect a random distribution of marks.

As noted in the Trap Operation section, the Judd Slough traps were not cleaned to control algal fouling during daytime hours. Fry migration during this period may therefore have been underestimated. However, the error may not have been large, as observations of chum fry migration near the spawning grounds have indicated daytime migration to be generally less than 2% of the 24-hr total (Lister et al. 1979).

The intake from the Squamish River, though closed during fry migration, actually leaked a flow of .02 -.03m^3/sec into Judd Slough. To establish whether a significant number of chum fry had entered from the Squamish River, a trap was installed at the intake to screen the entire flow as it passed from the culvert to the slough. In 14 fishing days from May 2 to May 23 this trap caught 58 coho smolts, 1 trout fry and several sculpins, stickleback and lamprey. As no chum fry were caught we concluded that fry input from spawning areas further upstream was not a source of error in this study.

Billy Harris Slough: Chum fry trapping at this site was terminated on April 19 due to flooding, well before the end of migration. An estimate of the approximate total emigration from the slough was derived by examination of the seasonal migration pattern and comparison with that at other sites. Fry migration data and a detailed explanation of the method used to estimate total emigration are presented in Appendix W.

Fry Length and Weight

Random samples of 40 chum fry were taken at each study site for length and weight measurement twice weekly during peak migration and once weekly in non-peak periods. Measurements obtained from live, anesthetized (MS 222) fry were fork length to the nearest mm and blotted weight to the nearest 0.01 g.

OTHER FISH SPECIES

Counts of other fish species observed in the course of the chum salmon study were recorded. Except for coho frymigrants, which were abundant at several sites (Appendix U), no attempt has been made to develop estimates of abundance for species other than chum salmon.

STREAM TEMPERATURES

During the adult chum salmon study spot measurements of water temperature were taken at each study site and at the stream into which the study stream flowed (Appendices A and C). On all fishing days during fry migration temperature records were obtained at each site using maximum-minimum thermometers. Short-term records of temperature ranges in adjacent streams were also obtained for comparison (Appendices B, D and E).

SPAWNING SUBSTRATE

To characterize spawning bed quality at each study site we obtained three gravel samples in June from the more heavily utilized spawning areas. The three samples per study site were then combined into one composite sample for sieve analysis. Substrate samples were collected by trowel and hand within the perimeter of an aluminum corer or cylinder 30 cm in diameter and

45 cm high. The corer was worked into the gravel to a depth of 15 cm. Samples were transported from the field in plastic buckets to a Vancouver laboratory for drying and sieve analysis.

RESULTS

CHUM SALMON SPAWNING

Spawning Timing

As counts of live spawners were not conducted on a regular basis the time of spawning must be inferred from seasonal die-off timing (Appendices M and N). Assuming an average of 7 days active spawning prior to death (Lister and Harvey, 1969), the die-off pattern probably reflects spawning intensity 5 - 10 days previous.

The carcass recovery patterns indicate that at most study sites spawning occurred from mid-November to early January and peaked during early to mid-December (Figs. 20 and 21). Fifty percent die-off occurred at the Squamish sites and Worth Creek during the December 10 - 17 period. Visual observations suggest that this was also the case at Railroad Creek where high water levels prevented carcass recovery on December 17, delaying the peak recovery until December 21 - 22 (Fig. 21).

The Hopedale Slough population spawned over a longer period than other populations. Spawning and die-off were well underway at this site on November 2 and extended into mid-January.

Chum spawning at Worth Creek started later and took place over a shorter period (35 versus 55 days) than at other study sites (Fig. 21). It is likely that spawners could not reach the improved section until flows increased sufficiently to permit migration over shallow sections of stream in the lower part of Worth Creek.

Carcass recovery data from Billy Harris Slough indicate that chum spawning at that site extended from late October to early January, with approximately 80% taking place between November 10 and December 27.

Spawning Distribution

Spawner distribution at the four stream-like study sites is compared in Fig. 22. In Worth and Railroad creeks spawning was distributed quite evenly over the entire length of improved channel, whereas in Judd Slough and Lower Paradise channel it was concentrated in certain sections. In Judd Slough spawning was concentrated in the middle third of the improved channel, with approximately 95% being observed in 50% of the channel area.

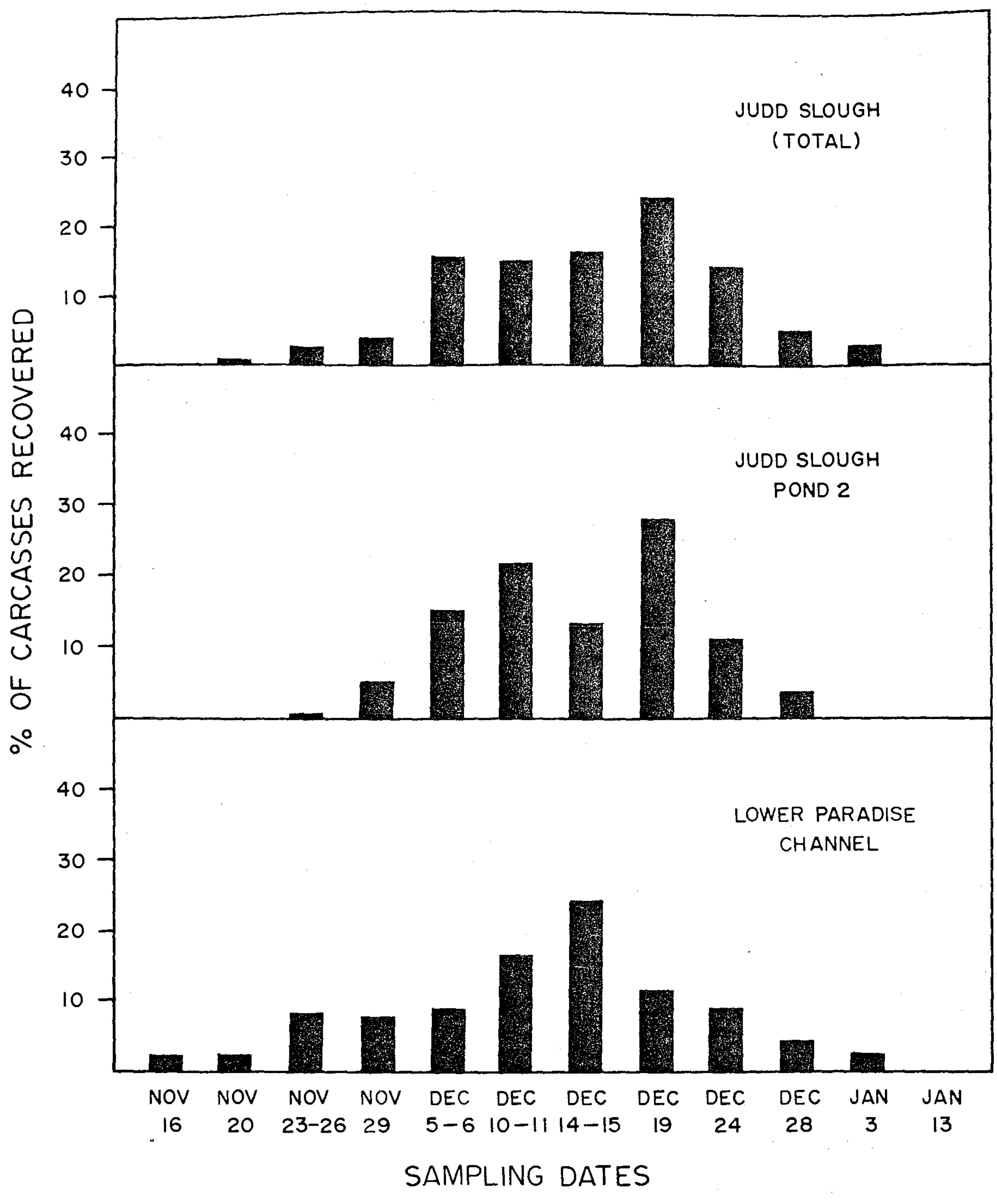

FIG. 20. Timing of chum salmon carcass recoveries at Squamish area study sites.

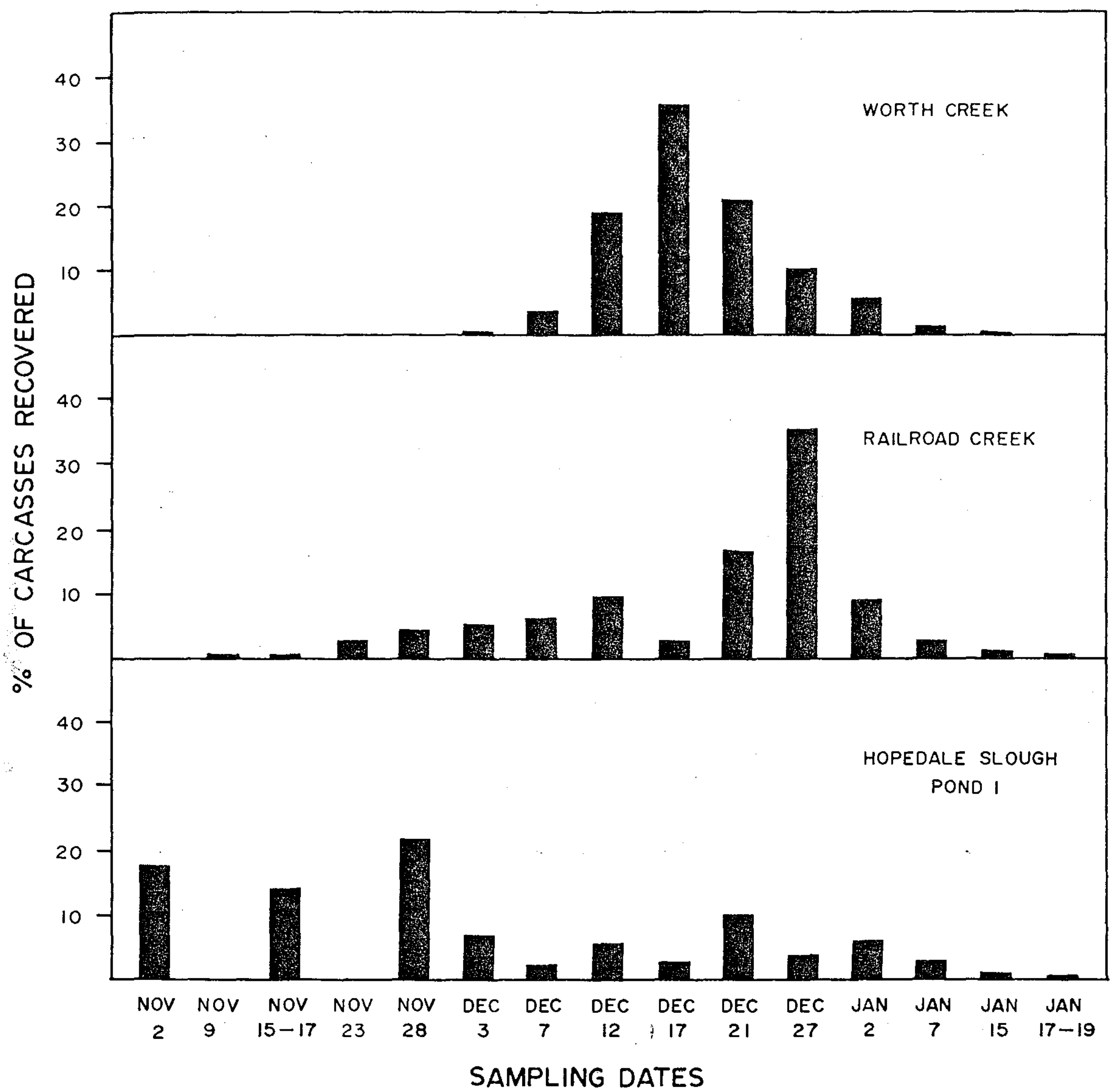

FIG. 21. Timing of chum salmon carcass recoveries at Fraser Valley study sites.

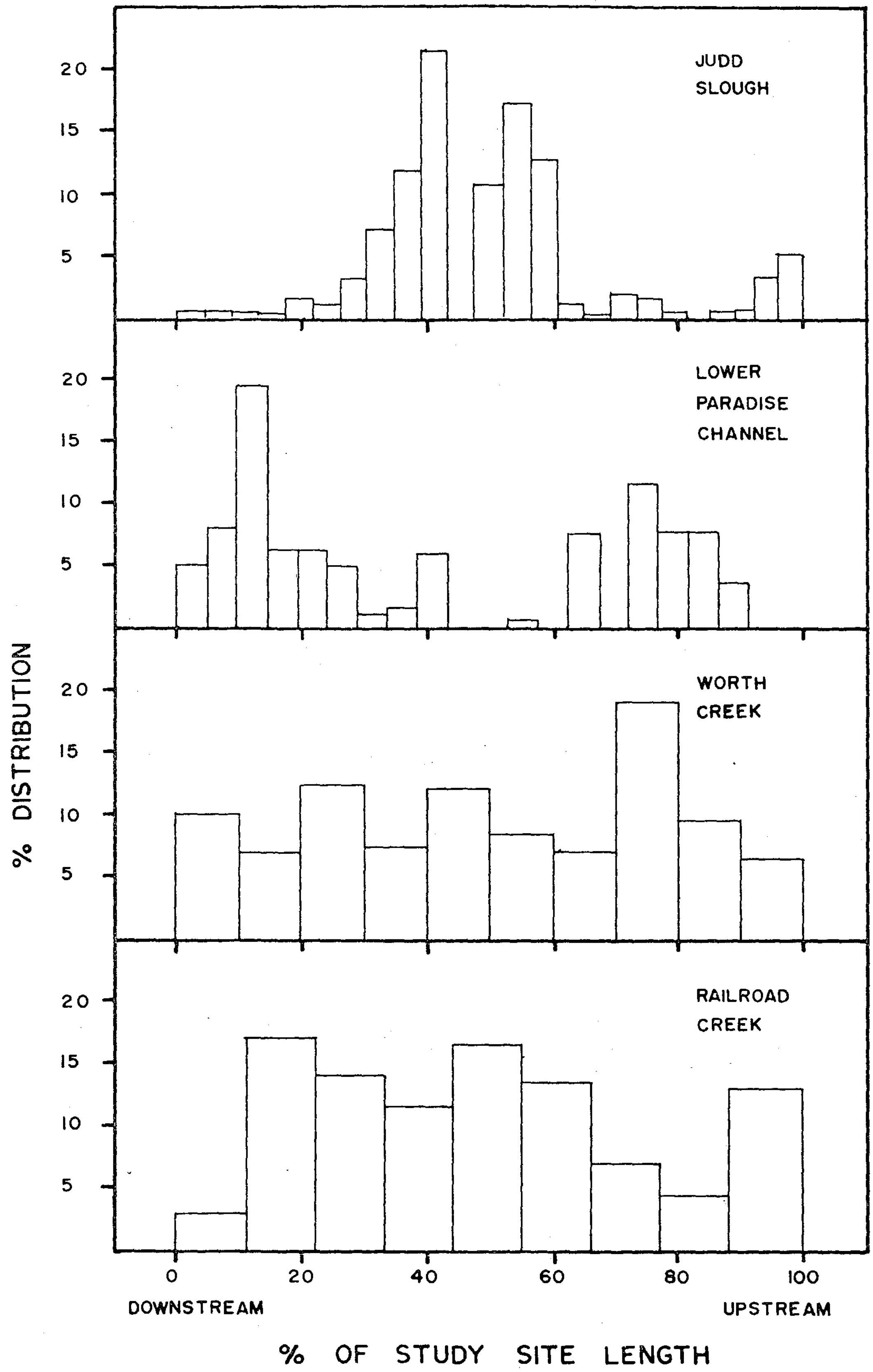

FIG. 22. Spawning distribution of chum salmon at the four stream-type study sites.

At Lower Paradise spawning was heaviest at the upper and lower ends; 60% of the channel area supported approximately 95% of the spawning.

In Judd Slough Pond 2 the heaviest concentration of spawning occurred in the northwest corner of the pond, along the side adjacent to the Squamish River. Ninety-eight percent of the spawners were observed in approximately 52% of the pond area. Though the distribution survey missed the main spawning period at Hopedale Slough Pond 1, observations made in the course of tagging and dead recovery surveys indicated that the heaviest spawning occurred at the upstream end of the pond, adjacent to the dyke.

It should also be noted that during the mid-December high water period at Railroad Creek a portion of the chum salmon population migrated above the Canadian Pacific Railway tracks to spawn in seasonal creeks draining pasture land. A total of 399 chum carcasses, 14.8% of the Railroad Creek total, were recovered in this area upstream of the improved channel.

Age and Size Composition

Spawning escapements to all study sites included age groups 3, 4 and 5. Age 4 fish comprised the majority at each site except Worth Creek, where age 3 predominated (Table 1). Spawners were older on the average in the Squamish area, where age 5 fish comprised 14.9 - 20.2% of samples compared to 1.6 - 10% in the Fraser Valley. At a given age Squamish chum salmon were also slightly larger than Fraser Valley chums, with the difference in length among age 4 males and females averaging 1.1 cm.

Population Size and Egg Deposition

Estimates of spawning populations and egg deposition are presented in Table 2. Appendices J and V show the 95% confidence limits for each population estimate.

Egg retention, which ranged from 0.9% to 5.2% at the various sites, could not be considered excessive. The highest egg retention occurred at Railroad Creek where population density (2.5 females/m^2) was also highest.

Straying to Study Sites

Recoveries of fin-marked adult chum salmon at Worth and Railroad creeks indicated that some straying from nearby Inches Creek occurred in 1979. Six and 7 marked fish were recovered at Worth and Railroad creeks respectively. These fish are believed to have been returns from releases of fin-marked fry at Inches Creek hatchery in 1977 (Fedorenko and Bailey, 1980). Details of marked fish recoveries are presented in Appendix R.

TABLE 1. Age composition and mean length at age of adult chum salmon at six study sites in 1979.

Site		Male 3	Male 4	Male 5	Male Sample Size	Female 3	Female 4	Female 5	Female Sample Size
Judd Slough	%	22.4	59.2	18.4	98	28.3	51.5	20.2	99
	Mean Length(cm)	55.4	61.8	64.4		54.3	59.7	62.0	
Lower Paradise Channel	%	27.9	54.9	17.2	122	25.6	59.5	14.9	121
	Mean Length(cm)	55.8	60.7	62.5		54.6	59.6	62.3	
Worth Creek	%	57.3	37.1	5.6	89	68.5	28.7	2.8	108
	Mean Length(cm)	53.9	60.5	63.0		53.0	58.0	54.7	
Railroad Creek	%	30.3	68.0	1.6	122	29.2	67.7	3.1	130
	Mean Length(cm)	53.7	60.3	64.8		52.2	59.5	58.8	
Hopedale Slough	%	32.2	57.8	10.0	90	40.9	50.0	9.1	88
	Mean Length(cm)	53.7	59.4	61.7		52.7	58.3	59.8	
Billy Harris Slough[1]	%	28.0	67.2	4.8	186	17.8	78.8	3.4	118

1 Comparable length data not available.

TABLE 2. Estimated chum salmon spawning populations and egg deposition at the seven study sites.

Site	Population Estimates			Mean	Potential	Egg	Net Egg
	Male	Female	Total	Fecundity	Egg Deposition	Retention(%)	Deposition
Judd Slough	1599	1536	3135[a]	3234	4,945,000[b]	2.4	4,826,000
Judd Slough Pond 2	176	66	242	3337	220,000	0.9	218,000
Lower Paradise	870	488	1358	3250	1,586,000	1.4	1,564,000
Worth Creek	665	384	1049	2936	1,127,000	2.2	1,102,000
Railroad Creek	1558	1630	3188	2936	4,786,000	5.2	4,537,000
Hopedale Slough Pond 1	279	200	479	2936	587,000	1.5	578,000
Billy Harris Slough	4107	2475	6582	3524	8,722,000	___[c]	___

[a]Includes all of Judd Slough and tributaries minus Pond 2.

[b]Based on adjustment in number of females (-7) to reflect spawning below fry trap site.

[c]Egg retention measures not taken.

CHUM SALMON FRY MIGRATION

Migration Timing

The seasonal pattern of chum salmon fry migration at six of the seven sites is shown in Figs. 23 and 24. Data from Billy Harris Slough have not been graphed because trapping was terminated at that site well before migration was complete.

At five of the seven study sites 50% of migration had occurred by mid- to late April (Table 3). At Worth Creek and Hopedale Slough 50% migration did not occur until mid- to late May. The late migration timing at Worth Creek may have been due to a relatively cold temperature regime during incubation and emergence, eg. Worth Creek averaged 1.2^{o}C cooler than nearby Railroad Creek in April, however the lack of continuous temperature records over the incubation period precludes analysis. The relatively late emigration from Hopedale Slough may have resulted from the tendency for fry to rear in the pond for a period (see section on Migrant Size), combined with low population pressure.

Migration Estimates

The estimated chum salmon fry migration from each study site is presented in Table 4. Estimates ranged from 6,000 fry at Hopedale Slough to 1.5 million fry at Billy Harris Slough. It should be noted that the Railroad Creek and Billy Harris Slough estimates are based on extrapolations from data which were incomplete due to flooding of traps prior to the end of fry migration.

Migrant Size

Length and weight measures were obtained from samples of chum fry migrants at all study sites except Billy Harris Slough (Appendix Y). Seasonal trends in mean weight and sample variation in weight are shown for each study site in Figs. 25 and 26. At all Squamish sites mean fry weight tended to increase as migration progressed, whereas no consistent seasonal trend in weight was evident at the Fraser Valley sites.

Over the migration period chum fry were larger on the average at Squamish than at the Fraser Valley sites (Table 5). However, individual fry weight varied more in the Fraser Valley, being greatest at Railroad Creek and Hopedale Slough Pond 1. This relatively large variation was apparently due to fry in the 500 - 1200 mg size range which had achieved considerable growth prior to emigration. The pond-like conditions at these two sites may have influenced fry to take up residence for a period.

Seasonal changes in the length-weight relationship of migrating fry were also apparent at some study sites. Plots of the weight-frequency distribution of fry in the modal length class (38 mm) indicated an increase in weight as migration progressed, particularly in the Squamish area (Fig. 27).

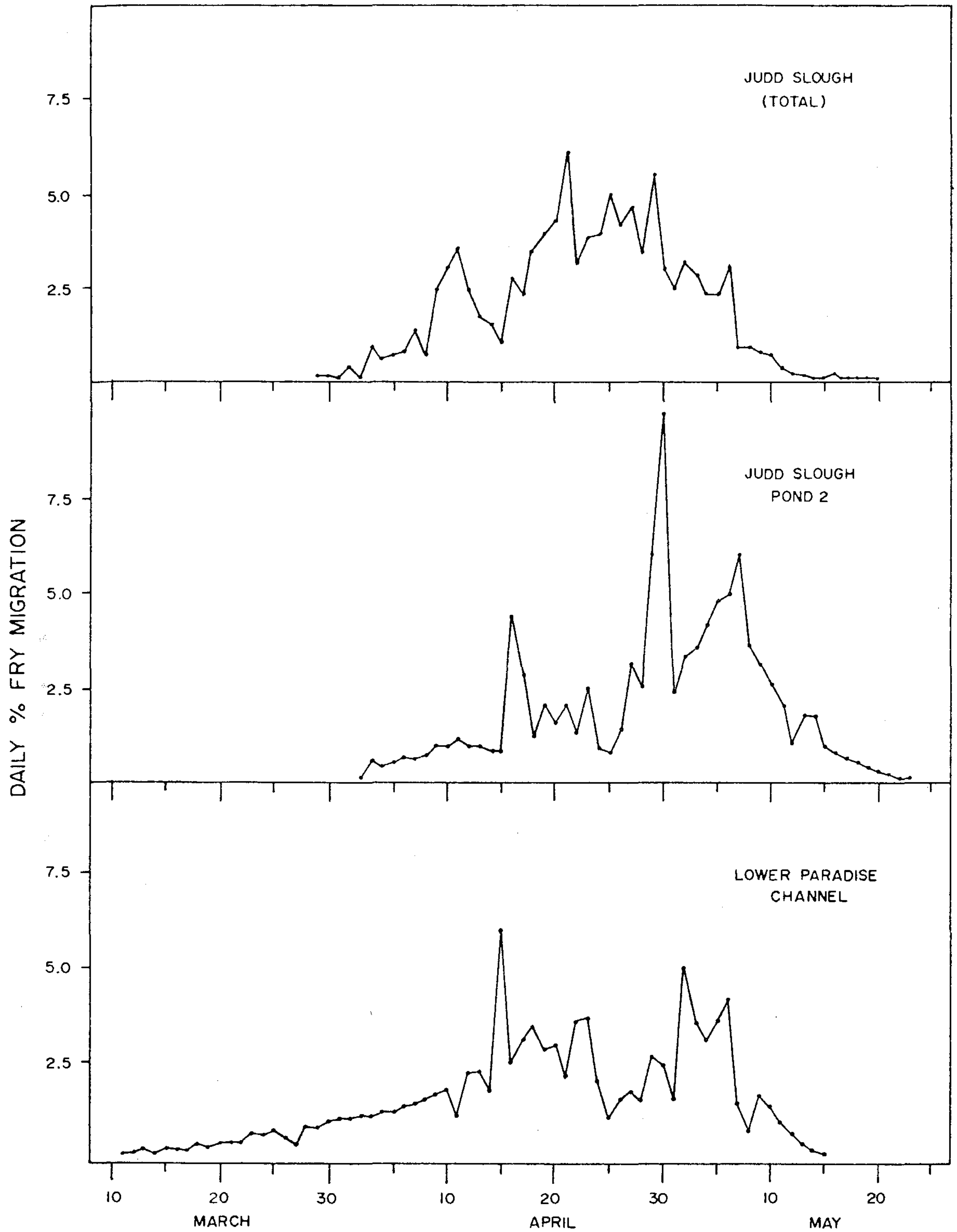

FIG. 23. Downstream migration timing of chum salmon fry at Squamish area study sites.

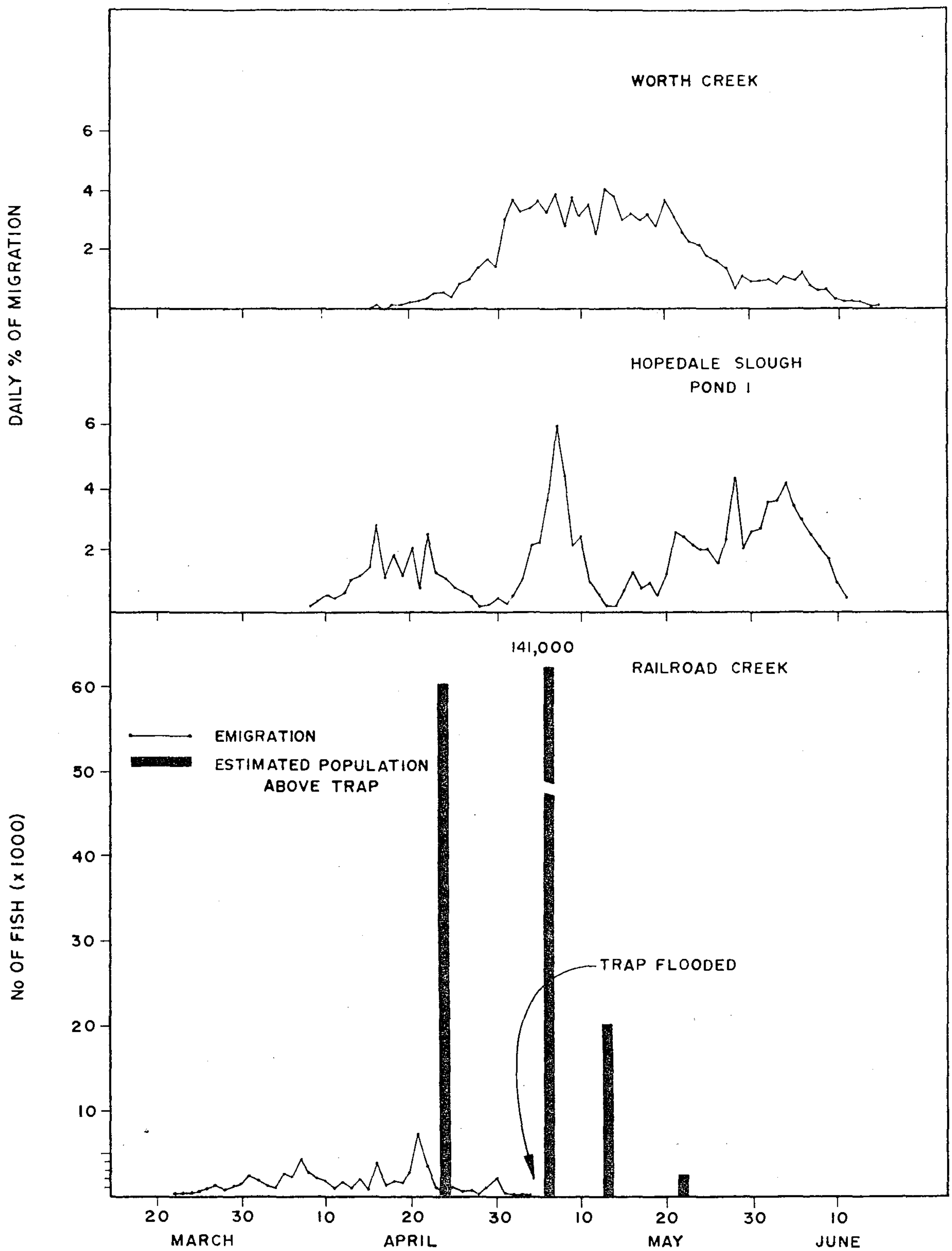

FIG. 24. Downstream migration timing of chum salmon fry at Fraser Valley study sites.

TABLE 3. Timing of chum salmon fry migration at study sites, as indicated by dates of 10%, 50% and 90% migration.

Study Site	Stage of Migration		
	10%	50%	90%
Judd Slough	April 9	April 23	May 4
Judd Slough Pond 2	April 15	April 30	May 10
Lower Paradise	April 1	April 20	May 5
Worth Creek	April 30	May 12	May 29
Railroad Creek	April 10	April 29	___[a]
Hopedale Slough Pond 1	April 18	May 20	June 4
Billy Harris Slough	March 27	April 14	___[a]

[a]Trapping data incomplete.

TABLE 4. Estimates of chum salmon fry migration at study sites.

Study Site	Point Estimate	95% Confidence Limits
Judd Slough	844,000	740,000 - 974,000
Judd Slough Pond 2	37,600	33,300 - 41,800
Lower Paradise	329,000	302,000 - 355,000
Worth Creek	378,000	363,000 - 392,000
Railroad Creek	341,000	251,000[a]- _____
Hopedale Slough Pond 1	6,000	4,800 - 7,200
Billy Harris Slough	1,543,000	986,000[a]- _____

[a]At these sites the lower confidence limit corresponds to fry emergence and migration enumerated before premature termination of trapping.

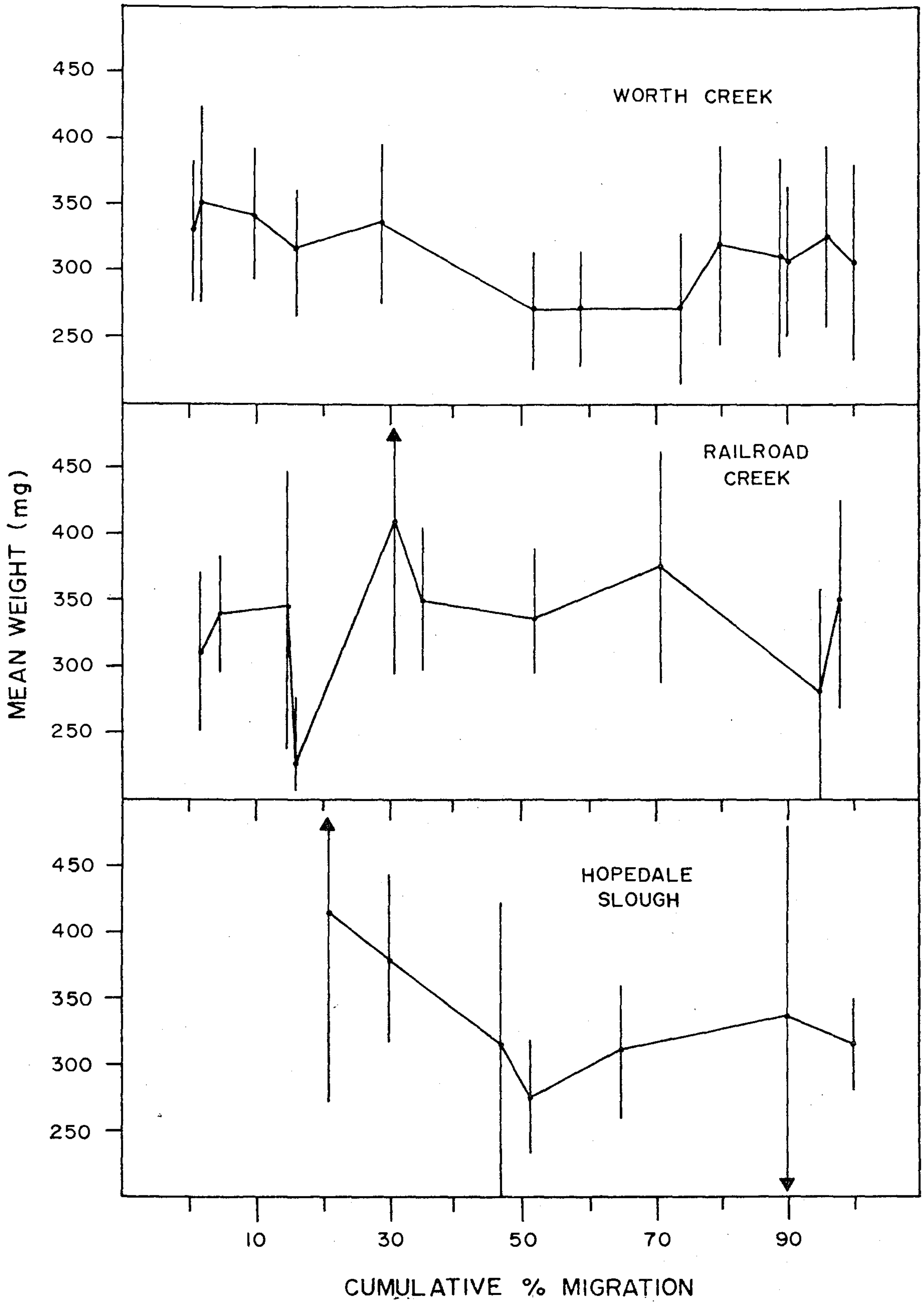

FIG. 25. Seasonal trend in mean weight of migrant chum salmon fry at Squamish area study sites. Vertical lines represent ±1 standard deviation.

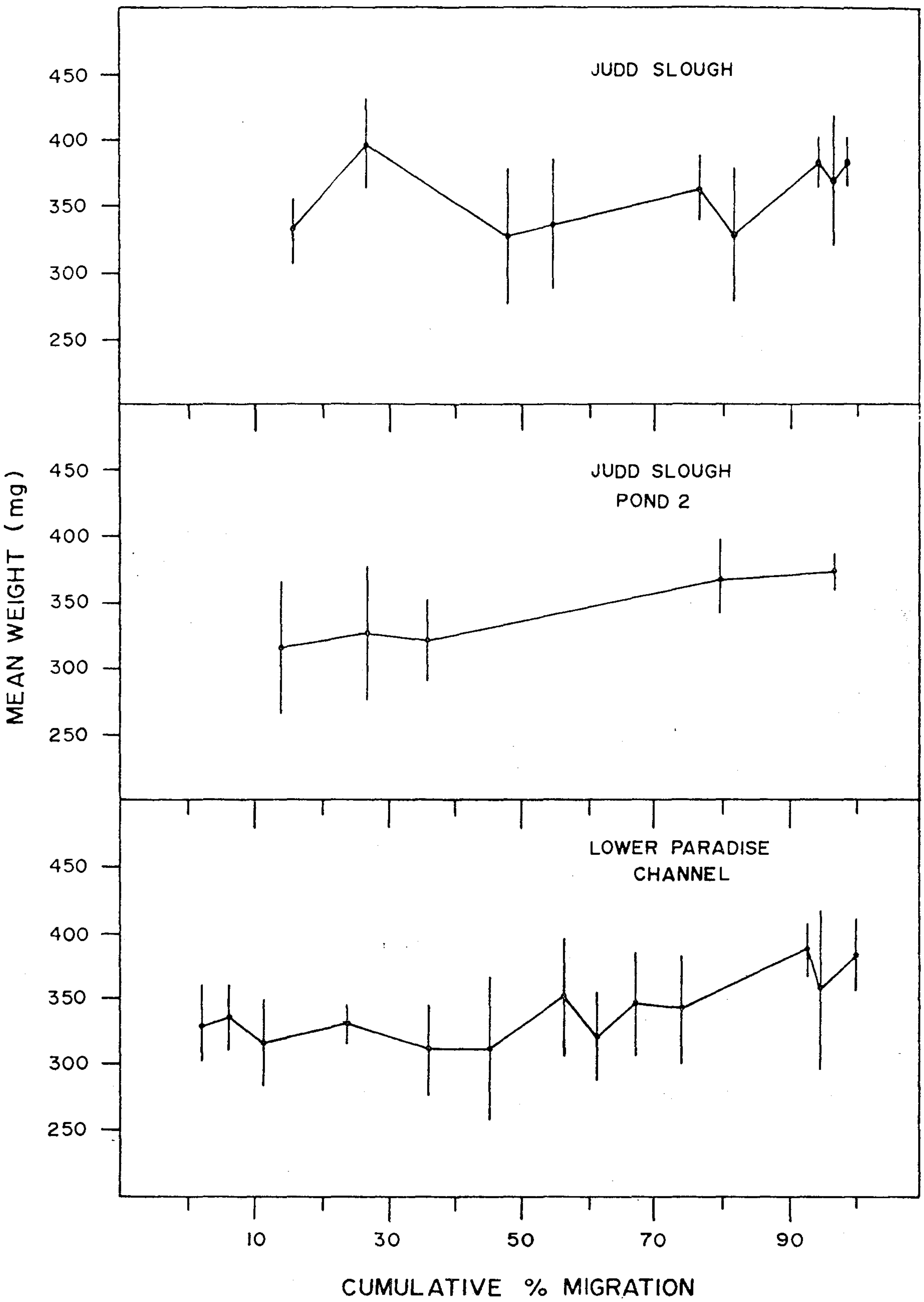

FIG. 26. Seasonal trend in mean weight of migrant chum salmon fry at Fraser Valley study sites. Vertical lines represent ±1 standard deviation.

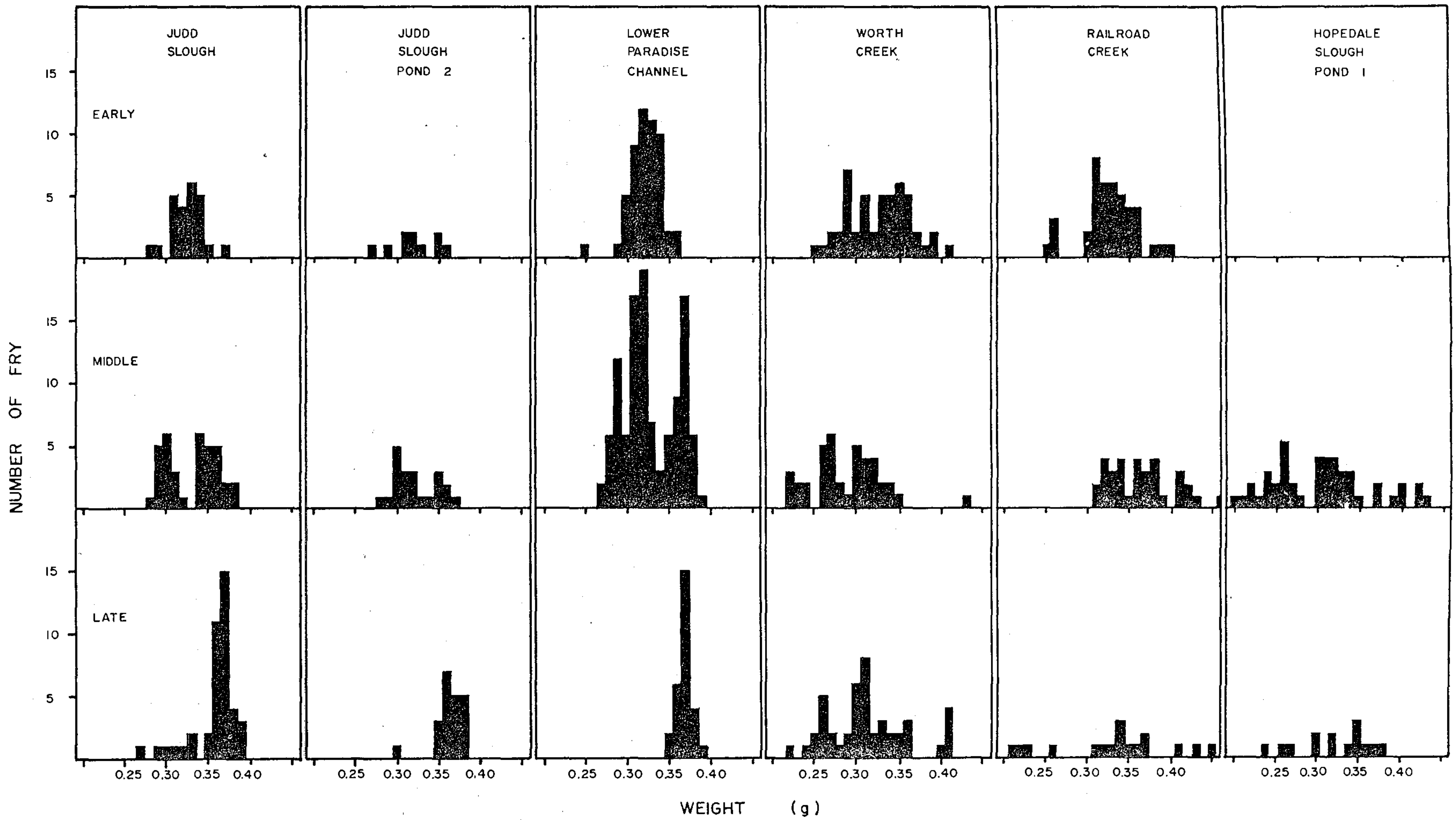

FIG. 27. Weight frequency distribution of 38 mm chum salmon fry during the early (0–25%), middle (25–75%) and late (75–100%) stages of migration.

TABLE 5. Summary of chum salmon fry weight data from each study site.

Study Site	Seasonal Mean Weight(mg)	Range in Individual Weights(mg)	Mean Coefficient of Variation(%)[a]
Judd Slough	354	240 - 470	7.8
Judd Slough Pond 2	340	220 - 420	10.1
Lower Paradise	338	240 - 450	10.5
Worth Creek	313	150 - 670	19.2
Railroad Creek	333	120 - 720	27.4
Hopedale Slough	334	170 - 1,200	26.0

[a]Coefficient of variation is the sample standard deviation expressed as a percentage of the sample mean.

At Judd Slough and Lower Paradise the weight frequency was characterized by a unimodal distribution (principally 300 - 350 mg) during the early stages of migration, a bimodal distribution at peak migration, and a shift to a unimodal distribution at larger size (350 - 400 mg) in the later stages. Weight-frequency distributions for 38 mm fry in the Fraser Valley showed more variation at all stages of migration and a slight tendency toward increased weight as the migration progressed.

CHUM SALMON EGG-TO-FRY SURVIVAL

Egg-to-fry survival rates, calculated from both potential and net egg deposition, are presented for all study sites in Table 6. At five of the seven sites survival rates from potential egg deposition were relatively high, ranging from 17.1% to 33.5%. Lower survival rates were measured at Railroad Creek (7.1%) and Hopedale Slough (1.0%).

As noted earlier, the estimates of fry emigration from both Railroad Creek and Billy Harris Slough were based on extrapolations from incomplete trapping data. A lower level of confidence therefore applies to the survival estimates for these sites. Minimum egg-to-fry survival rates at Railroad Creek and Billy Harris Slough, calculated from the number of fry actually enumerated (Table 4), would amount to 5.2% and 11.3% respectively.

TABLE 6. Chum salmon egg deposition, fry emigration and egg-to-fry survival rates at the seven study sites.

Study Site	Egg Deposition Potential	Egg Deposition Net	Fry Emigration	Percent Survival From Potential Deposition	Percent Survival From Net Deposition
Judd Slough	4,945,000	4,826,000	844,000	17.1	17.5
Judd Slough Pond 2	220,000	218,000	37,600	17.1	17.2
Lower Paradise	1,586,000	1,564,000	329,000	20.7	21.0
Worth Creek	1,127,000	1,102,000	378,000	33.5	34.3
Railroad Creek	4,786,000	4,537,000	341,000	7.1	7.5
Hopedale Slough Pond 1	587,000	578,000	6,000	1.0	1.0
Billy Harris Slough	8,722,000	———	1,543,000	17.7	———

DENSITY OF SPAWNING AND FRY PRODUCTION

Chum salmon spawning density and fry production per area are presented for each study site in Table 7. As a major portion of the developed spawning area was not utilized at some sites, density and fry production were expressed in relation to both total area and area actually used for spawning. Of the six sites where spawner distribution was documented, only at Worth and Railroad creeks did utilization approach 100% of the available area.

Density of chum spawning and fry production varied considerably between sites, ranging from 2.5 females and 517 fry per m^2 at Railroad Creek to 0.12 females and 3.6 fry per m^2 at Hopedale Slough. The relationship of fry production to spawning density indicates that a density greater than 0.5 females per m^2 does not appreciably increase fry production (Fig. 28). Railroad Creek, which accommodated approximately 5 times as many female spawners per area as Worth Creek, produced only 15% more fry per area (517 vs $450/m^2$).

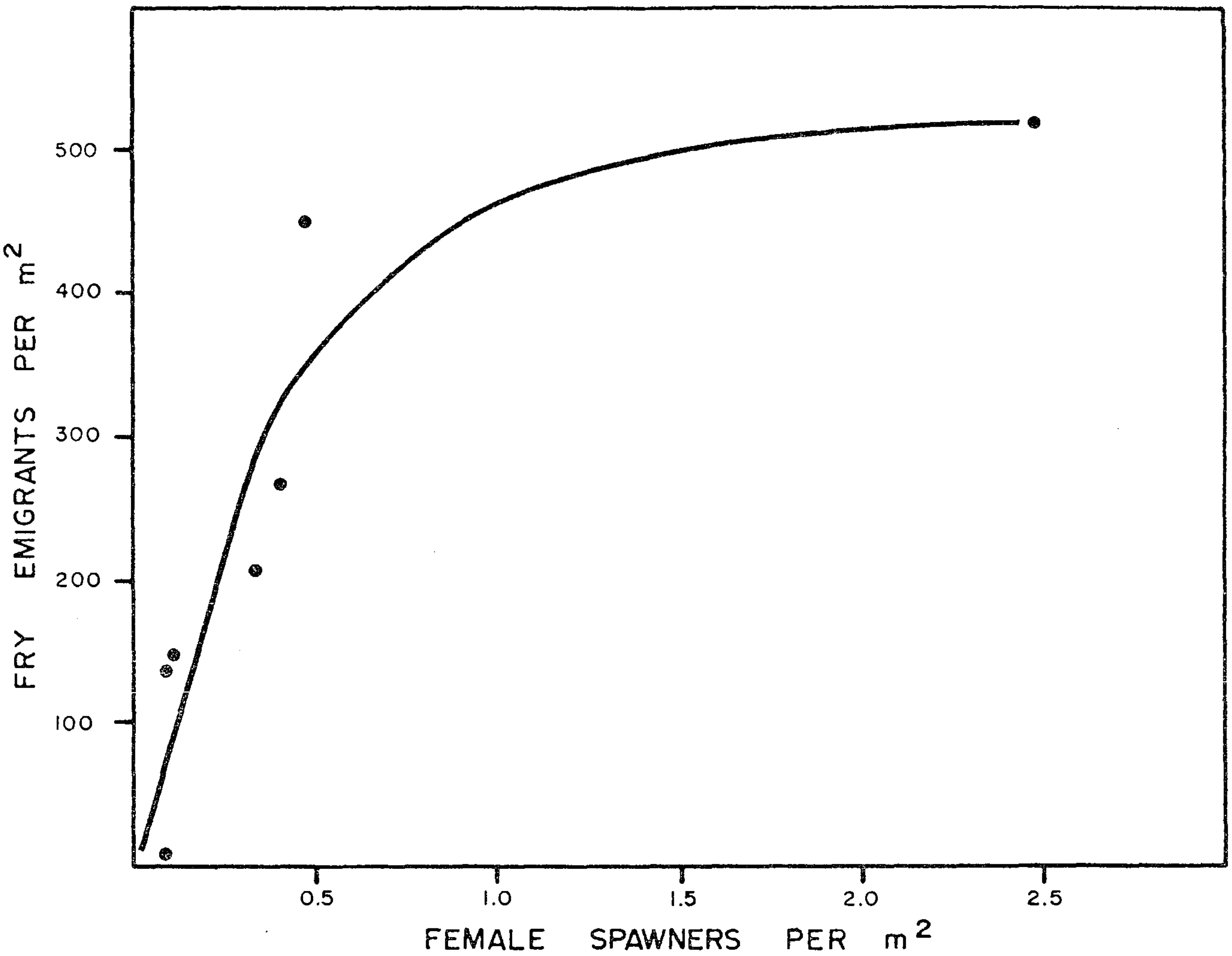

FIG. 28. Relationship between the number of female chum salmon spawners and the number of chum fry emigrants per m^2 of utilized spawning area at study sites. The curve is fitted by eye.

OTHER FISH SPECIES

The abundance of species other than chum salmon was recorded incidentally at all sites but Billy Harris Slough.

Coho Salmon

Numbers of coho salmon adults, fry and smolts observed at the various sites are compared in Table 8. Significant numbers of adult coho were encountered only at Judd Slough, Lower Paradise channel and Worth Creek.

TABLE 7. Density of chum salmon spawning and fry production per m^2 of developed spawning area.

Study Site	Developed Area (m^2)	Utilized Area (m^2)[a]	No. of Females	Potential Egg Deposition	Fry Production
Judd Slough	11,610	5,770	0.13 (.26)	426 (857)	73 (146)
Judd Slough Pond 2	560	270	0.12 (.24)	393 (815)	67 (139)
Lower Paradise	2,040	1,230	0.24 (.40)	767 (1,272)	161 (267)
Worth Creek	840	840	0.46	1,342	450
Railroad Creek	660	660	2.47	7,252	517
Hopedale Slough Pond 1	1,670	1,085	0.12 (.18)	351 (541)	3.6 (5.5)
Billy Harris Slough	7,480	___[b]	0.33	1,166	206

[a] Area utilized by 95% of spawning population. Figures in brackets represent numbers per area actually utilized.

[b] Spawner distribution surveys were not conducted at this site.

As no tagging was conducted to measure the actual recovery rate of coho carcasses, the number of carcasses recorded at each site should be considered only a minimum estimate of spawning population. Some spawning also took place after our carcass recovery surveys were terminated in early to mid-January.

Recoveries of coho carcasses started in late November and peaked during the December 24 - January 3 period, depending on site. The peak of coho fry emigration occurred during April at Squamish sites and during late April and May at Worth Creek. Coho smolt migration timing varied between locations, peaking in late March - early April at Lower Paradise, in May at Judd Slough and in late May at Hopedale Slough.

Other Salmon Species

Four sockeye salmon (*Oncorhynchus nerka*) carcasses were recovered from Hopedale Slough Pond 1 during late December. At Lower Paradise 4 chinook salmon (*O. tshawytscha*) fry were caught in the downstream migrant traps.

TABLE 8. Comparative abundance of adult and juvenile coho salmon at study sites.

Study Site	Adult Dead Count			Estimated Fry Emigration	Total Smolt Catch[b]
	Male	Female	Total		
Judd Slough	32	18	50	26,000	324
Judd Slough Pond 2	3	0	3	1,500	11
Lower Paradise	15	9	24	8,600	215
Worth Creek	36	35	71	29,100	81
Railroad Creek	4	0	4	190	11
Hopedale Slough Pond 1	1	7	8	120	175

[a]Estimate based on assumption that trap efficiency for coho fry is the same as that measured for chum fry.

[b]Actual catch with no adjustment for non-fishing days or trap efficiency.

TABLE 9. Total catches of trout and non-salmonid fish species in downstream migrant traps.

Study Site	Trout	Three-spine Stickleback	Sculpin	Lamprey
Judd Slough	11	8	9	28
Judd Slough Pond 2	0	0	0	2
Lower Paradise	12	0	0	1
Worth Creek	10	2	1089	4
Railroad Creek	10	15	373	0
Hopedale Slough	23	1860	87	84

As no adult chinook were observed to spawn in the channel it seems likely that these fry had immigrated from the Cheakamus River before traps were installed on March 10.

Trout

Trout fingerlings (Salmo sp.), likely yearlings in most cases, were taken in the downstream migrant traps at all sites but Judd Slough Pond 2 (Table 9). As the numbers of trout were relatively low at all sites, no differentiation of species was attempted.

Non-Salmonids

Catches of non-salmonid fish species in downstream migrant traps are presented in Table 9. Non-salmonids were much more abundant at Fraser Valley sites than at Squamish. Relatively large catches of sculpins (Cottus sp.) were made at Worth and Railroad creeks. Significant numbers of three-spine stickleback (Gasterosteus aculeatus) were only encountered at Hopedale Slough. Lamprey were not identified as to species.

DISCUSSION

The following discussion concentrates on the more important findings pertaining to chum salmon.

SURVIVAL RATE COMPARISON

In this study chum salmon egg-to-fry survival averaged 16.3%, approximately twice the average (7.9%) documented at six natural spawning areas in British Columbia (Table 10). Survival rates at Worth Creek (33.5%) and Lower Paradise (20.7%) exceeded egg-to-fry survivals previously reported for chum salmon under natural conditions, and compared favourably with the average survival (27%) achieved with controlled flow at Big Qualicum River on Vancouver Island (E. A. Perry, pers. comm.).

FACTORS AFFECTING SURVIVAL

High spawning density probably reduced egg-to-fry survival of chums at Railroad Creek, but it was not clearly a factor at other sites (Fig. 28). Potential egg deposition at Railroad Creek (7300 eggs/m^2) approximated 3 times the optimum (2300 eggs/m^2) indicated for chum and pink (Oncorhynchus gorbuscha) salmon in studies at Sashin Creek, Alaska (McNeil, 1969). Thorsteinson (1965) found that with a potential egg deposition of 6,000 eggs per m^2, mortality of chum and pink salmon eggs at spawning amounted to 45%. Though excessive spawning density may have caused the low survival (7.1%) at Railroad Creek, it could not be implicated at Hopedale Slough where survival was 1% despite the lowest spawning density of any site.

At 5 of the 7 study sites native gravel was replaced with artificial grades of spawning gravel (cobbles and fine material removed) to improve conditions for egg incubation. Based on experiments relating chum salmon egg-to-fry survival to the proportion of fine material in spawning gravel (Koski, 1971) we would have expected the use of graded gravel to improve survival rates. However, the advantages of a graded gravel substrate were not clear from the survival data (Table 6). The highest (33.5%) and lowest (1%) survivals occurred at Worth Creek and Hopedale Slough where artificial grades of gravel were added. The sites with the native spawning bed material, Lower Paradise and Judd Slough, produced relatively high survivals of 20.7% and 17.1% respectively. Any benefits of graded spawning gravel may well have been obscured in this study by other factors which could have affected survival, such as spawning density and differences in physical characteristics of the various sites, eg. gradient, groundwater flow and quality, extent of back-watering.

FRY PRODUCTION PER AREA

The highest production of chum salmon fry per area occurred at Railroad (517 fry/m^2) and Worth (450 fry/m^2) creeks, the sites which experienced the highest spawning densities. Though these values are significantly

TABLE 10. Comparison of chum salmon survival (from potential egg deposition to fry emigration) in the present study with survival rates recorded at natural spawning areas in British Columbia.

Study Site	Survival Rate		No. of Observations	Investigator(s)
	Mean	Range		
Groundwater-fed side channels	16.3%	1–33.5%	7	Present study
Nile Creek	2.2%	0.4–6%	5	Neave, 1953
Hooknose Creek	9.4%	1–19.4%	10	Hunter, 1959
Big Qualicum River	11.2%	5–17%	4	Lister & Walker, 1966
Harrison River tributaries	6.9%	5.1–7.4%	3	Dietz, MS 1968
Inches Creek	5.5%	1.6–9.3%	4	Fedorenko & Bailey, 1980
Barnes Creek	12.3%	4.6–18.8%	4	Fedorenko & Bailey, 1980

below the 1600 fry per m^2 achievable in an artificial spawning channel for chum salmon (Fisheries & Environment Canada, 1978), they do compare with maxima observed at natural spawning areas supporting mixed populations of chum and pink salmon. McNeil (1969) reported up to 463 fry per m^2 migrating from Sashin Creek, and Hunter (1959) estimated the upper limit of fry production at Hooknose Creek, British Columbia, to approximate 330 per m^2.

Fry production per area did not increase appreciably when spawning density exceeded 0.5 females/m^2. Though Railroad Creek accommodated 5 times as many female spawners per area as Worth Creek (2.5/m^2 versus 0.5/m^2) it produced only 15% more fry per area.

REDD SAMPLING

In February, 1980, Department of Fisheries and Oceans personnel conducted hydraulic sampling of chum salmon redds to compare survival at the study sites and to determine whether hydraulic sampling results, ie. the ratio of live to dead embryos, could be used as an index of survival from potential egg deposition to fry migration (Comfort, MS 1980). Most chum salmon embryos had either hatched or reached the advanced eyed stage at the time of sampling. The overall percentages of live embryos at each site are shown in the following table:

Judd Slough	Judd Slough Pond 2	Lower Paradise	Worth Creek	Railroad Creek	Hopedale Slough	Billy Harris Slough
88%	64%	88%	86%	36%	23%	48%

Fig. 29 relates the percentage of live embryos in sampled redds to egg-to-fry survival at a given site. Where graded spawning gravel had been added, survival was significantly correlated ($r = .97$; $P = < .01$) with the percentage of live embryos in redds. However, survival in native spawning bed material at Judd Slough and Lower Paradise did not reflect the high proportion of live embryos found in redd sampling. Two possible explanations for this anomaly are: (i) a higher percentage of eggs deposited in the natural bed material was dislodged during spawning and therefore did not appear as dead eggs in the February redd sampling (under similar circumstances the greater void area in the artificially graded gravel may serve to retain eggs that would otherwise be dislodged by later-spawning waves of salmon); or (ii) post-hatching mortality was higher in the natural spawning bed material than in the graded gravel. In case (i) mortality due to superimposition and dislodging of eggs is not fully accounted for in the redd sampling.

FRY MIGRANT SIZE

Post-emergent stream rearing of chum salmon fry before seaward migration has been observed in several previous British Columbia studies (Sparrow, 1968; Fraser et al, 1978). In the present study, chum fry migrants with obvious post-emergence growth were most common at Fraser Valley sites, particularly at Railroad Creek and Hopedale Slough. The pond-like conditions at these sites may have reinforced the tendency of some fry to rear for a period before emigrating.

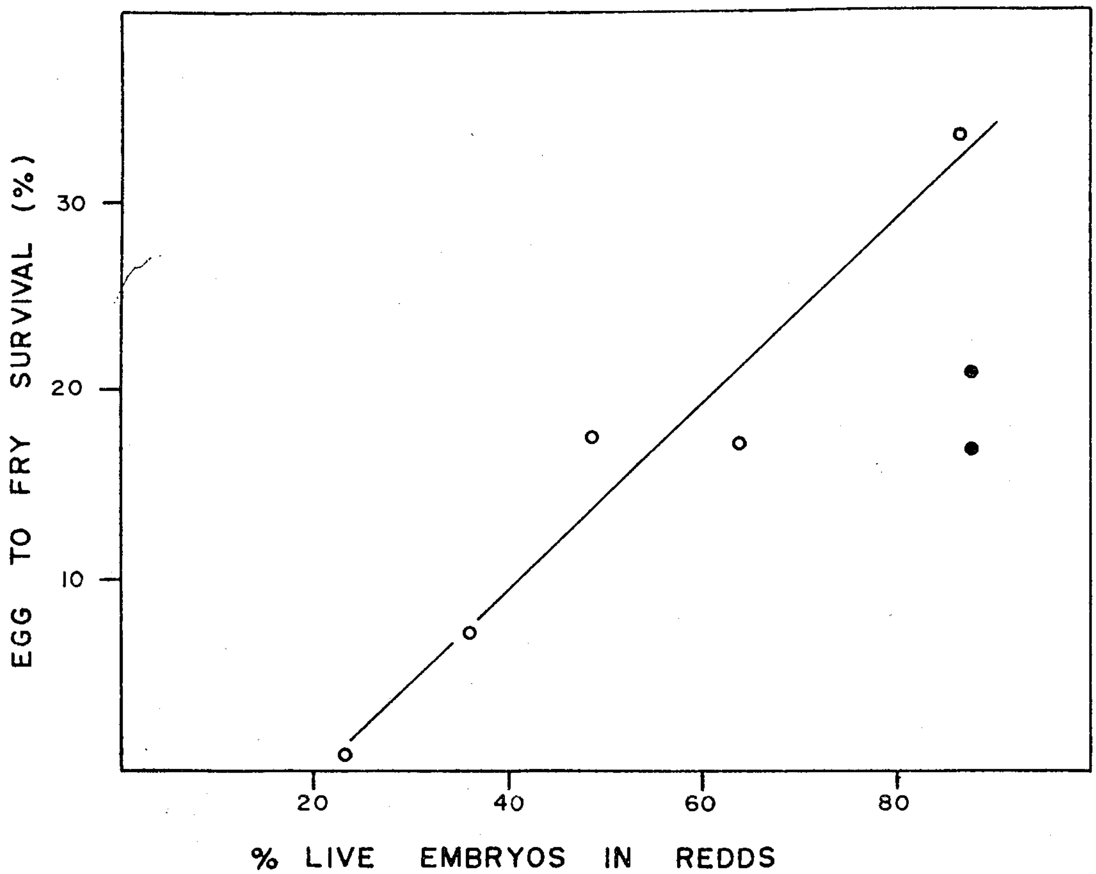

FIG. 29. Relationship between the percentage of live chum salmon embryos determined from redd sampling and survival from potential egg deposition to fry emigration at study sites. Open circles denote sites where graded gravel substrate was added; solid circles denote sites with the native spawning bed material. Regression line is fitted to the open circles.

At the Squamish area study sites chum fry of a given length class were shown to increase in weight as the migration progressed. The bimodality we observed in weight frequency distribution during peak migration has not, to our knowledge, been previously reported. Bams (1974) used the length-weight relationship of pink salmon fry migrants to demonstrate their stage of embryonic development, with greater weight at a given length indicating higher yolk content and thus an earlier stage of development. He reported that among naturally produced fry weight at a given length declined as migration progressed, opposite to the trend we observed in chum fry at Squamish. We can only speculate that the seasonal changes in the length-weight relationship noted in this study may have been due to differences in the extent of feeding among chum fry migrants, either within or above the gravel, at different stages of migration.

Chum fry migrants at Squamish study sites were larger over the season than fry at the Fraser Valley sites (mean weight of 344 mg versus 327 mg). This difference in fry size may have been related to the greater age and size of female chum salmon at Squamish, perhaps through larger egg size. Koski (1966) observed a positive correlation between the size of coho salmon fry at emergence and size of parent females.

SUMMARY

1. A study was conducted during November, 1979 to June, 1980 to assess chum salmon spawning, incubation survival and fry production in groundwater-fed spawning areas which had been developed or improved to enhance salmon production. The seven study sites were situated on the lower mainland of southern British Columbia, three near Squamish and four in the Fraser River valley.

2. At each site the chum salmon spawning population was estimated by tag-and-recovery and chum fry emigration was determined by total enumeration. Information was also obtained on chum spawning time and distribution, spawner age and size, fry size and migration timing, and utilization of the areas by other fish species.

3. Chum spawning took place between late October and mid-January, and peaked at most study sites during December 1 - 15. Age groups 3, 4 and 5 were present in all escapements; age 4 fish comprised the majority at all but one site. Chum spawners at Squamish area sites were older and larger for a given age than spawners at Fraser Valley sites.

4. The estimated escapement of chum salmon to individual study sites ranged from 479 to 6572 fish. Seasonal spawning density was 0.5 females/m^2 or less at all but one site, where it was estimated at 2.5 females/m^2.

5. Chum salmon fry emigrated from the study areas between early March and mid-June. At 5 of the 7 study sites the date of 50% migration occurred during the April 14-30 period.

6. The estimated migration of chum fry from individual study sites ranged from 6,000 to 1,543,000. Maximum fry production per unit of spawning area was estimated at 517/m^2. The relationship between spawner density and fry production indicated that fry output per area did not increase appreciably at spawning densities exceeding 0.5 females/m^2.

7. Over the migration period chum fry were larger on the average at Squamish than in the Fraser Valley, possibly the result of the larger size of female spawners at Squamish. Individual fry weight varied more at Fraser Valley sites due to the presence of fry which had achieved considerable growth before seaward migration.

8. Chum salmon survival from potential egg deposition to fry migration ranged from 1% to 33.5% at individual study sites. The average survival (16.3%) at the seven sites was approximately twice that recorded for chum salmon at natural spawning areas in British Columbia.

9. Examination of factors potentially affecting survival indicated that excessive spawner density (2.5 females/m^2) probably reduced egg-to-fry survival at one site. The advantages of a graded gravel spawning substrate, which had been added to 5 of the 7 sites, were not apparent from the survival data. However, between-site differences in spawner density and other physical characteristics may have obscured the effect of substrate character.

10. Coho salmon used all study sites for spawning and rearing. Small numbers of juvenile trout were captured at all but one site, as were stickleback, sculpin and lamprey.

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APPENDICES

APPENDIX A SPOT TEMPERATURES (°C) TAKEN IN JUDD SLOUGH AND SQUAMISH RIVER, NOVEMBER, 1979 TO JANUARY, 1980.

	Judd Slough Sites						Squamish R.
Date	Above Ponds	Pond 1	Pond 2	Side Channel 1	Side Channel 2	Bridge	
Nov. 16	5.0	7.0	7.0	-	-	7.0	-
Nov. 20	5.0	6.0	7.0	-	6.0	6.0	4.0
Nov. 23	3.5	4.0	5.5	-	6.0	5.0	3.0
Nov. 29	3.0	4.0	6.0	5.0	6.0	-	2.0
Dec. 5	5.0	6.0	7.0	-	-	6.0	4.5
Dec. 10	4.0	6.0	7.0	7.0	8.0	5.0	3.5
Dec. 14	6.0	7.0	7.0	7.0	8.0	7.5	4.0
Dec. 19	7.0	6.0	6.0	-	7.0	6.0	6.5
Dec. 24	6.0	6.0	6.0	6.0	6.0	5.0	2.0
Dec. 28	6.0	5.0	6.0	6.0	6.0	6.0	3.0
Jan. 3	6.0	6.0	7.0	6.0	6.5	6.0	4.0
Jan 13	7.0	7.0	8.0	-	-	7.5	2.5

APPENDIX B DAILY TEMPERATURE (^{o}C) OF JUDD SLOUGH, JUDD POND 2 AND SQUAMISH RIVER, MARCH TO MAY, 1980.

Date		Judd Slough			Judd Pond 2			Squamish River		
		Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
Mar.	13	-	-	-	7.0	6.0	6.5			
	14	-	-	-	7.0	6.0	6.5			
	17	9.0	7.0	8.0	7.0	6.0	6.5			
	18	8.0	7.0	7.5	12.0	6.0	9.0			
	20	8.0	7.0	7.5	7.0	6.0	6.5			
	21	10.0	7.0	8.5	7.0	6.0	6.5			
	24	10.0	7.0	8.5	8.0	6.0	7.0			
	25	9.0	7.0	8.0	8.0	5.0	6.5			
	27	9.0	7.0	8.0	7.0	6.0	6.5			
Apr.	2	10.0	7.0	8.5	8.0	6.0	7.0			
	3	10.0	6.0	8.0	9.0	5.0	7.0			
	8	9.0	9.0	9.0	9.0	7.0	8.0			
	9	10.0	8.0	9.0	10.0	5.0	7.5			
	10	8.0	8.0	8.0	-	-	-			
	11	8.5	5.0	6.75	8.0	5.0	6.5			
	14	8.0	8.0	8.0	10.0	6.0	8.0			
	15	8.0	8.0	8.0	8.0	7.0	7.5			
	16	9.0	7.0	8.0	9.0	7.0	8.0			
	17	10.0	7.0	8.5	9.5	6.0	7.75			
	18	11.0	8.0	9.5	9.0	7.0	8.0			
	21	8.5	5.0	6.75	-	-	-			
	22	14.0	6.0	10.0	-	-	-			
	23	10.0	9.0	9.5	-	-	-			
	24	10.0	8.0	9.0	9.0	8.0	8.5	8.0	7.0	7.5
	25	10.0	9.0	9.5	9.0	7.0	8.0	6.0	5.0	5.5
	28	9.0	8.0	8.5	8.0	7.0	7.5	6.0	6.0	6.0
	29	9.0	9.0	9.0	9.0	7.0	8.0	7.0	5.0	6.0
	30	10.0	8.0	9.0	9.0	7.0	8.0	7.0	7.0	7.0
May	1	8.0	8.0	8.0	10.0	7.0	8.5	7.0	6.5	6.75
	2	9.0	9.0	9.0	9.0	7.0	8.0	7.0	7.0	7.0
	5	11.5	7.0	9.25	7.5	7.0	7.25	7.0	7.0	7.0
	6	8.0	8.0	8.0	8.0	7.0	7.5	8.0	7.0	7.5
	7	11.0	7.0	9.0	10.0	7.0	8.5			
	8	11.0	8.0	9.5	10.0	7.0	8.5			
	9	9.0	9.0	9.0	8.0	8.0	8.0			
	12	9.0	9.0	9.0	8.0	7.0	7.5			
	13	9.0	8.0	8.5	7.0	7.0	7.0			
	14	9.0	8.0	8.5	7.5	7.0	7.25			
	15	9.0	9.0	9.0	8.0	8.0	8.0			
	16	9.0	8.5	8.75	7.5	7.0	7.25			

APPENDIX C SPOT TEMPERATURES (°C) TAKEN IN LOWER PARADISE CHANNEL AND CHEAKAMUS RIVER, NOVEMBER, 1979 TO JANUARY, 1980.

Date	Lower Paradise	Cheakamus River
Nov. 16	7.5	6.0
Nov. 20	7.0	8.0
Nov. 26	6.0	4.0
Nov. 29	6.0	3.5
Dec. 6	7.0	5.0
Dec. 11	7.0	4.0
Dec. 15	6.5	2.5
Dec. 19	7.0	4.5
Dec. 24	6.0	4.0
Dec. 28	6.0	4.0
Jan. 3	7.0	5.0
Jan. 13	8.0	6.0

APPENDIX D DAILY TEMPERATURE (°C) OF LOWER PARADISE CHANNEL AND CHEAKAMUS RIVER, MARCH TO MAY, 1980.

Date		Lower Paradise Channel			Cheakamus River		
		Max.	Min.	Mean	Max.	Min.	Mean
Mar.	13	7.0	5.0	6.0			
	14	7.0	5.0	6.0			
	17	8.0	6.0	7.0			
	18	7.0	7.0	7.0			
	20	10.0	7.0	8.5			
	21	11.0	6.0	8.5			
	24	9.0	5.0	7.0			
	25	11.0	4.0	7.5			
	27	8.0	5.0	6.5			
Apr.	2	7.0	5.0	6.0			
	3	14.0	5.0	9.5			
	8	10.0	7.0	8.5			
	9	9.0	5.0	7.0			
	10	10.0	6.0	8.0			
	11	11.0	7.0	9.0			
	12	11.0	7.0	9.0			
	13	10.0	7.0	8.5			
	14	8.0	8.0	8.0			
	15	9.0	7.0	8.0			
	16	9.0	6.0	7.5			
	17	–	–	–			
	18	–	–	–			
	21	9.0	7.0	8.0			
	22	8.0	6.0	7.0			
	23	9.0	6.0	7.5			
	24	9.0	7.0	8.0			
	25	10.0	6.0	8.0	7.0	5.0	6.0
	28	9.0	7.0	8.0	7.5	5.5	6.5
	29	10.0	6.5	8.25	6.0	6.0	6.0
	30	10.0	6.5	8.25	8.0	5.0	6.5
May	1	11.0	5.0	8.0	8.0	6.0	7.0
	2	11.0	7.0	9.0	7.0	7.0	7.0
	5	9.0	6.0	7.5	8.0	5.0	6.5
	6	9.0	7.0	8.0	7.0	6.0	6.5
	7	9.0	7.0	8.0	8.0	5.0	6.5
	8	9.5	6.5	8.0	7.5	6.0	6.75
	9	9.0	7.0	8.0	8.0	6.0	7.0
	12	10.0	6.0	8.0	7.5	6.0	6.75
	13	8.0	7.0	7.5	6.0	4.0	5.0
	14	9.0	7.0	8.0	6.0	6.0	6.0
	15	9.5	8.5	9.0	7.0	6.0	6.5
	16	9.5	8.5	9.0	6.0	5.0	5.5

APPENDIX E SPOT TEMPERATURES (^{o}C) TAKEN AT FRASER VALLEY STUDY SITES, NOVEMBER, 1979 TO JANUARY, 1980.

Date	Worth Creek	Norrish Creek	Railroad Creek	Nicomen Slough	Hopedale Slough	Vedder River
Nov. 9	14.0	7.0	11.0	11.0	10.0	-
Nov. 15	14.0	6.0	11.0	8.0	11.0	9.0
Nov. 23	13.0	6.0	9.0	8.0	-	-
Nov. 28	11.5	4.0	8.0	7.0	8.0	4.5
Dec. 3	11.0	5.5	8.0	7.0	8.5	5.5
Dec. 7	11.0	5.5	9.0	7.0	8.0	5.5
Dec. 12	12.0	4.0	9.0	5.5	7.0	5.5
Dec. 17	9.0	6.0	-	-	6.0	6.0
Dec. 21	10.0	5.0	-	6.5	6.0	5.0
Dec. 27	9.0	4.0	7.0	6.0	5.0	-
Jan. 2	8.5	5.0	8.0	5.0	6.0	5.0
Jan. 9	7.0	0.0	6.0	-0.5	4.0	1.0
Jan. 15	7.5	3.0	7.0	1.0	5.0	4.0
Jan. 17	8.0	-	5.0	-	-	-

APPENDIX F DAILY TEMPERATURES OF HOPEDALE SLOUGH AND VEDDER RIVER, MARCH TO MAY, 1980.

Date		Hopedale Slough			Vedder River		
		Max.	Min.	Mean	Max.	Min.	Mean
Mar.	21	8.0	5.5	6.75			
	24	6.0	3.5	4.74			
	25	9.5	6.0	7.75			
	27	6.0	5.5	5.75			
	31	11.0	4.5	7.75			
Apr.	1	11.0	6.5	8.75			
	3	11.0	5.0	8.00			
	4	11.0	5.5	8.25			
	7	12.0	6.0	9.00			
	8	10.5	5.0	7.75			
	9	11.0	6.0	9.5			
	10	12.0	6.5	9.25			
	11	13.0	6.0	9.5			
	14	11.5	7.0	9.25			
	15	11.0	7.5	9.25			
	16	9.5	7.0	8.25			
	17	13.0	7.5	10.25			
	18	10.0	7.5	8.25			
	21	9.5	6.0	7.75			
	22	10.0	8.0	9.0			
	23	8.5	6.0	7.25			
	24	12.0	8.0	10.0			
	25	12.0	7.5	9.75			
	28	12.0	7.0	9.5			
	30	12.0	7.0	9.5			
May	1	11.0	8.0	9.5			
	2	13.0	9.0	11.0			
	5	21.0	8.0	14.5			
	6	11.0	7.0	9.0			
	7	10.0	7.5	8.75			
	8	13.0	9.5	11.25			
	9	10.0	8.5	9.25			
	12	10.0	9.0	9.5			
	13	10.0	9.0	9.5			
	14	10.0	8.5	9.25			
	15	10.0	9.0	9.5			
	16	10.0	9.0	9.5			
	19	12.0	10.0	11.0			
	20	8.5	8.0	8.25			
	21	9.0	8.0	8.25			
	22	9.5	8.5	8.75			
	23	9.5	8.5	9.0			
	26	13.0	8.5	10.75	10.0	9.0	9.5

APPENDIX F (cont.)

Date		Hopedale Slough			Vedder River		
		Max.	Min.	Mean	Max.	Min.	Mean
	27	9.5	8.5	9.0			
	28	10.0	10.0	10.0	10.0	9.5	9.75
	29	15.0	10.0	12.5			
	30	11.5	10.0	10.75	10.5	9.0	9.75
June	1				10.0	9.0	9.5
	2	10.0	9.0	9.5	10.0	9.0	9.5
	3	10.0	9.0	9.5			
	4	11.0	10.0	10.5	11.0	10.0	10.5
	5	10.0	9.0	9.5	11.0	10.0	10.5
	8				15.0	10.0	12.5
	9	13.0	11.0	12.0	15.0	9.5	12.25
	10	19.0	11.0	15.0			

APPENDIX G DAILY TEMPERATURES OF WORTH, RAILROAD AND NORRISH CREEKS, MARCH TO MAY, 1980.

Date		Worth Creek			Railroad Creek			Norrish Creek		
		Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
Mar.	12	12	6	9						
	13	9	5	7						
	14	9	5	7						
	17	8	5	6.5						
	18	7	5	6						
	20	9	5	7						
	21	6	5	5.5						
	23				8	6	7			
	24	7	5	6	7	5	6			
	25	6	5	5.5	7	7	7			
	27	5.5	5	5.25	7	5	6			
	28	7	4.5	5.75	7	6	6.5			
	31	8	6	7	8	7	7.5			
Apr.	1	7	5.5	6.25	9	7	8			
	3	13	4.5	8.75	8	7	7.5			
	4	7	4	5.5	14	8	11			
	7	13	9	11	14	8	11			
	8	10	3	6.5	8	8	8			
	9	10	5	7.5	8	5	6.5			
	10	10.5	5.5	8	9	5	7			
	11	7	5	6	10	4	7			
	14	12	5	8.5	11	8	9.5			
	15	8	5.5	6.75	11	8.5	9.75			
	16	7	5	6	9	7	8			
	17	9	5	7	10	3	6.5			
	18	9	5	7	10	7.5	8.75			
	19				9	8	8.5			
	20				8	8	8			
	21	7	5	6	10	7	8.5			
	22	10	6	8	10	7	8.5			
	23	11	6	8.5	10	8	9			
	24	9	6	7.5	12	9	10.5			
	25	11	4.5	7.75	12	7	9.5			
	28	15	5	10	19	7	13			
	30	12	7	9.5	14	5	9.5			
May	1	9	6	7.5	9	6	7.5			
	2	18	6	12	21	9.5	15.25			
	3							18	5	11.5
	6	16	6	11						
	7	13	6	9.5						
	8	15	7	11						
	9	10	6	8				10	5	7.5
	12	12	7	9.5						
	13	9	5.5	7.25						
	14	10	5.5	7.75						
	15	7	6	6.5						
	16	7	5	6				10.5	5	7.75
	19	14	7	10.5						

APPENDIX G (cont.)

Date		Worth Creek Max.	Worth Creek Min.	Worth Creek Mean	Railroad Creek Max.	Railroad Creek Min.	Railroad Creek Mean	Norrish Creek Max.	Norrish Creek Min.	Norrish Creek Mean
May	20	10	6	8						
	21	7	6	6.5						
	22	8	6	7						
	23	7	6	6.5				12	5	8.5
	26	13	7	10						
	27	13	7	10						
	28	13	6	9.5						
	29	11	7	9						
	30	13	6	9.5						
								15	5	10
June	2	7	7	7						
	3	10	6	8						
	4	12	7	9.5						
	5	12	6	9						
	6							14	5	9.5
	9	15	7	11						
	10	16	8	12						
	13	15	8	11.5						

APPENDIX H SPAWNING BED COMPOSITION AT STUDY SITES EXPRESSED AS PERCENT BY WEIGHT PASSING A GIVEN SIEVE SIZE.

Sieve Size	Judd Slough	Judd Slough Pond 2	Lower Paradise Channel	Worth Creek	Railroad Creek	Hopedale Slough Pond 1
4 in.	100.0	100.0	100.0	100.0	100.0	100.0
3	100.0	98.3	97.6	100.0	100.0	90.6
2	89.9	88.5	91.0	98.2	97.6	80.2
1 1/2	71.9	69.9	77.8	91.5	86.4	72.1
1	49.1	27.6	59.6	53.3	49.3	45.6
3/4	39.3	7.8	51.2	28.9	24.8	31.6
1/2	30.9	0.7	43.5	4.9	4.2	25.1
3/8	25.2		35.7	1.0	0.7	21.4
# 4	17.5		25.5			17.2
# 8	13.6		19.6			14.9
# 16	9.7		14.6			12.8
# 30	5.9		8.7			10.2
# 50	2.8		2.6			4.8
# 100	0.7		0.4			0.9
# 200	0.3		0.1			0.2

APPENDIX I SUMMARY OF ADULT CHUM SALMON TAGGING AND RECOVERY DATA FROM SIX STUDY SITES, NOVEMBER, 1979 TO JANUARY, 1980.

Study Site	Tagging Date	No. Tagged		No. Recovered		Percent Recovery	
		Male	Female	Male	Female	Male	Female
Judd Slough (including tag recoveries from ponds 1 & 2)	Nov. 27	74	76	53	65	71.6	85.5
	Dec. 6	26	42	17	37	65.4	88.1
		100	118	70	102		
Judd Slough Pond 2	Nov. 27	20	21	11	19	55.0	90.5
	Dec. 6	21	15	15	13	71.4	86.7
		41	36	26	32		
Lower Paradise	Nov. 21	34	37	22	22	64.7	59.5
	Nov. 30	45	19	37	19	82.2	100.0
	Dec. 11	22	55	17	42	77.3	76.4
		101	111	76	83		
Worth Creek	Dec. 17	37	43	19	35	51.4	81.4
Railroad Creek	Nov. 23	50	34	49	33	98.1	97.1
	Dec. 13	50	85	41	62	82.0	72.9
		100	119	90	95		
Hopedale Slough Pond 1	Nov. 17	21	20	21	20	100.0	100.0
	Dec. 13	44	32	15	25	34.1	78.1
		65	52	36	45		

APPENDIX J SUMMARY OF CHUM SALMON CARCASS RECOVERY DATA AND POPULATION ESTIMATES AT SIX STUDY SITES, NOVEMBER 1979 TO JANUARY, 1980. 95% CONFIDENCE INTERVALS FOR POPULATION ESTIMATES ARE SHOWN IN BRACKETS.

Study Site	Recovery Period	No. of Carcasses Examined			Population Estimates		
		Male	Female	Total	Male	Female	Total
Judd Slough[a]	Nov. 16 - Jan. 13	1248	1387	2635	1775 (1369 - 2181)	1602 (1296 - 1908)	3377 (2665 - 4089)
Judd Slough Pond 2	Nov. 16 - Jan. 13	112	58	170	176 (115 - 257)	66 (45 - 93)	242 (160 - 350)
Lower Paradise Channel	Nov. 16 - 30	146	79	225	224 (141 - 338)	132 (83 - 199)	356 (224 - 537)
	Dec. 1 - 11	160	104	264	195 (137 - 269)	105 (64 - 164)	300 (201 - 433)
	Dec. 12 - Jan. 13	352	192	544	451 (263 - 722)	251 (163 - 369)	702 (426 - 1091)
		658	375	1033	870 (541 - 1329)	488 (310 - 732)	1358 (851 - 2061)
Worth Creek	Nov. 9 - Jan. 17	349	313	662	665 (403 - 1036)	384 (267 - 534)	1049 (670 - 1570)
Railroad Creek	Nov. 9 - Dec. 12	440	377	817[b]	469 (354 - 631)	403 (277- 565)	872 (631 - 1196)
	Dec. 13 - 27	755	739	1494	918 (658 - 1245)	1010 (756 - 1264)	1928 (1414 - 2509)
	Dec. 28 - Jan. 17	168	211	379	171 (129 - 230)	217 (149 - 304)	388 (278 - 534)
		1363	1327	2690	1558 (1141 - 2106)	1630 (1182 - 2133)	3188 (2323 - 4233)
Hopedale Slough Pond 1	Nov. 2 - 17	57	62	119[b]	70 (44 - 107)	78 (48 - 120)	148 (92 - 227)
	Nov. 18 - Dec. 12	86	53	139	87 (54 - 133)	54 (33 - 83)	141 (87 - 216)
	Dec. 13 - 28	37	28	65	107 (60 - 177)	37 (24 - 54)	144 (84 - 231)
	Dec. 29 - Jan. 19	14	30	44	15 (9 - 23)	31 (19 - 48)	46 (28 - 71)
		194	173	367	279 (167 - 440)	200 (124 - 305)	479 (291 - 745)

[a] Study site includes all of Judd Slough, tributaries and Ponds 1 and 2.

[b] Numbers adjusted for estimated loss before fence installation.

APPENDIX K LENGTH AND FECUNDITY DATA FROM A SAMPLE OF 21 FEMALE CHUM SALMON, LOWER PARADISE CHANNEL, 1979.

Collection Date	Orbital-hypural length(cm)	No. of eggs
Dec. 7	61.0	960[a]
8	66.5	3660
8	65.5	4220
8	66.5	1885[a]
8	62.5	2090[a]
8	50.5	990[a]
9	60.0	3360
9	66.5	2930
9	56.5	3330
9	56.5	3360
9	59.5	3710
9	59.5	3060
9	64.5	3480
9	64.5	4460
9	58.5	2970
9	49.5	2540
9	55.5	2690
9	58.5	3630
9	54.5	2700
9	52.0	2480
9	56.0	2880

[a]Rejected from length-fecundity regression sample because of suspected partial spawning prior to capture.

APPENDIX L RESULTS OF MARKED CHUM SALMON FRY RELEASES TO TEST TRAP EFFICIENCY AT STUDY SITES.

Site	Release No.	Release Date	No. Marked	No. Recaptured	Percent Recapture	No. of Traps Operating
Judd Slough (Main Trap)	1	April 14	293	47	16.0[a]	3
	2	21	497	182	36.6[b]	2
	3	23	1046	195	18.6[c]	2
	4	28	1988	965	48.5[c]	2
	5	30	1994	782	39.2[c]	2
	6	May 5	449	132	29.6[c]	2
	7	7	978	228	23.3[c]	2
	8	12	493	101	20.5[d]	3
	9	15	880	527	59.9[c]	3
	10	21	83	2	2.4[f]	3
Judd Slough Pond 2	1	April 15	294	218	74.1[g]	1
	2	22	300	183	61.0[g]	1
	3	28	325	196	60.3[g]	1
	4	May 6	383	332	86.7[g]	1
	5	13	318	299	94.0	1
Lower Paradise Channel	1	April 10	298	280	94.0	2
	2	14	298	289	97.0	2
	3	21	999	1375	137.6[hj]	2
	4	28	500	403	80.6[i]	2
	5	May 6	719	510	70.9[i]	2
Worth Creek	1	April 12	49	31	63.3	1
	2	21	97	86	88.7	1
	3	29	298	240	80.5	1
	4	May 6	998	989	99.1	1
	5	13	499	537	107.6[j]	1
	6	19	498	499	100.2[j]	1
	7	26	200	125	62.5	1
Railroad Creek	1	April 8	299	121	40.5	1
	2	14	294	25	8.5	1
	3	17	94	28	29.8	1
	4	22	147	21	44.7	1
Hopedale Slough Pond 1	1	April 24	49	45	91.8	1
	2	May 5	50	43	86.0	1

[a] Only recoveries in Trap 3 used, to establish efficiency during early stages of migration when only Trap 3 was operated.

[b] Test not used; fry released too close to traps for proper lateral distribution.

[c] Tests used to establish efficiency with Traps 2 and 3 operating, with adjustment for difference in lateral distribution of marked fry.

[d] Test not used; fry released prematurely, before peak migration.

[e] Tests used to establish efficiency with all 3 traps operating, with adjustment for difference in lateral distribution of marked fry.

[f] Test not used; release late in migration and fry did not return.

[g] Tests not used; marked fry observed to take up residence in pond above trap.

[h] Test not used; incorrect mark enumeration.

[i] Test not used; debris clogged trap, causing fry loss.

[j] Recaptures estimated from total weight of fry and conversion samples providing number per weight.

APPENDIX M SEASONAL TIMING OF CHUM SALMON CARCASS RECOVERY AT SQUAMISH AREA STUDY SITES, 1979-80.

	Judd Slough		Judd Slough Pond 2		Lower Paradise Channel	
Sampling Date	No. recovered	%	No. recovered	%	No. recovered	%
Nov. 16	1	-	0	-	28	2.7
20	19	0.7	0	-	28	2.7
23-26	74	2.8	1	0.6	87	8.4
29	106	4.0	9	5.2	82	7.9
Dec. 5-6	397	15.1	27	15.5	91	8.8
10-11	396	15.1	38	21.8	173	16.7
14-15	424	16.2	23	13.2	254	24.6
19	629	24.0	49	28.2	121	11.7
24	373	14.2	20	11.5	93	9.0
28	131	5.0	7	4.0	51	4.9
Jan. 3	68	2.6	0	-	25	2.4
13	4	0.2	0	-	0	-
Totals	2622		174		1033	

APPENDIX N SEASONAL TIMING OF CHUM SALMON CARCASS RECOVERY AT FRASER VALLEY STUDY SITES, 1979 - 80.

Sampling Date	Worth Creek No. recovered	Worth Creek %	Railroad Creek No. recovered	Railroad Creek %	Hopedale Slough Pond 1 No. recovered	Hopedale Slough Pond 1 %
Nov. 2	-	-	-	-	65	17.7
9	-	-	7	0.3	-	-
15-17	-	-	25	0.9	54	14.7
23	-	-	80	3.0	-	-
28	-	-	132	4.9	82	22.3
Dec. 3	4	0.6	136	5.1	27	7.3
7	26	3.9	170	6.3	9	2.4
12	129	19.5	267	9.9	22	6.0
17	240	36.3	73[a]	2.7	12[a]	3.3
21	142	21.5	458[a]	17.0	37	10.1
27	70	10.6	963	35.8	16	4.3
Jan. 2	40	6.0	255	9.5	25	6.8
9	8	1.2	85	3.2	12	3.3
15	3	0.5	35	1.3	6	1.6
17-19	-	-	4	0.1	1	0.3
Totals	662		2690		368	

[a] Fences flooded and/or high water prevented total carcass recovery.

APPENDIX O LENGTH AND FECUNDITY DATA FROM A SAMPLE OF 15 FEMALE CHUM SALMON, BILLY HARRIS SLOUGH, 1979.

Nose to Fork length(cm)	No. of eggs
78	3,300
76	3,129
85	4,596
83	4,447
71	2,724
83	3,720
70	3,638
69	3,418
68	4,202
66	2,887
69	4,482
67	2,101
67	4,109
69	3,731
68	2,058

APPENDIX P LENGTH FREQUENCY DISTRIBUTION OF CHUM SALMON BY AGE GROUP AT SQUAMISH AREA STUDY SITES IN 1979.

Length (cm)	Judd Slough						Lower Paradise Channel					
	Male			Female			Male			Female		
	3	4	5	3	4	5	3	4	5	3	4	5
49.5				1								
50.0	1			1						2		
50.5				2								
51.0				1			1			1		
51.5										1		
52.0	1			1						1		
52.5	1				1		1			2	1	
53.0	1			5	1		1			4		
53.5							4			2	3	
54.0	3			1			4	2		4	2	
54.5				1			2			2	1	1
55.0	2	1		3	1	1	4			1		
55.5	1			1	1			1		1	1	
56.0	6	1		4	2		2	3			2	
56.5		2		3	3		3	1	1	2	1	
57.0	2	1		2	1		6			2	3	
57.5	3	1		1	2		2	1		1	2	
58.0		1			2			3	1	1	2	1
58.5		1	1	1				5		2	7	
59.0		5			8	2	1	4	1	1	3	
59.5		1			2	1		5			7	
60.0	3				3	1	1	5			5	
60.5	1	4			6	2	1	6	1		5	1
61.0		3	1		7	2		4	1	1	4	3
61.5		2	1		1	1		3	4		7	1
62.0		4	1		1	1	1	1	1		5	2
62.5		6	2		2	1		7			2	1
63.0		1	1		1			2	2		2	
63.5		4			3	1		3	3		3	2
64.0		7	2			4		3	2		3	
64.5		4	2		1			2	1		1	1
65.0		2	1			2		2	1			4
65.5			1					1				1
66.0		1	1		1			2				
66.5			1					1				
67.0		2							1			
67.5												
68.0		1			1							
68.5			1									
69.0			1			1			1			
69.5												
70.0												
70.5												
71.0												
71.5			1									
Totals	22	58	18	28	51	20	34	67	21	31	72	18

APPENDIX Q LENGTH FREQUENCY DISTRIBUTION OF ADULT CHUM SALMON BY AGE GROUP AT FRASER VALLEY STUDY SITES IN 1979.

	Worth Creek						Railroad Creek						Hopedale Pond					
	Male			Female			Male			Female			Male			Female		
Length (cm)	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5
45.0										1								
45.5																		
46.0																		
46.5																		
47.0				1						1						1		
47.5										1								
48.0													1			1		
48.5	1			1												1		
49.0	1			2			3						3			1		
49.5				3			1			2								
50.0	5			6	1		1			2						1		
50.5	1			3			1			1						2		
51.0	2			5		1	4	2		6						3		
51.5	1			2			2						1	1		3		2
52.0	3			8	1	1	1			4			1			4	1	
52.5	3					1	2	1		2			5			2	1	
53.0	5	1		14	1		3			6	1		1	1		5		
53.5	3			5			2			4			4			3	1	
54.0	5			6	1		2	1			1		2			2		
54.5	2			3			1	3		2	1		1			1	1	
55.0	4			4	1		1	2		4	3		2	1		1	1	
55.5	1		1	1	1		3	1			2		2	2			6	
56.0	3	1		1	3		4	1		1	6		1	1		1	3	
56.5	2	2	1	2	1		1	2			2			1		1		
57.0	2	1		1	1			1			5	1	1	2	1		1	
57.5	2			2	2		1	2			3		3	2			2	
58.0	2	1			4			4		1	4			2			4	
58.5		2		2			2	1			7			4	1		3	
59.0	2	1			3			4			8	2		2			3	1
59.5		4						1			8			5	3	3	3	
60.0		2			1		2	5			5		1	1			6	
60.5		2			2			8			4			1				1
61.0	1	1		2	1	1		9			4			2				
61.5		2						4			6			2			3	
62.0		1	1		1			7			1			3			2	1
62.5		1	1		2			6			2			3				
63.0		3						7			4			3	1			1
63.5		2			2			1			4			1			1	
64.0		2						4	1		2			4			1	1
64.5		1	1					2						1	1		1	
65.0								3						4				
65.5		1							1		1			1				
66.0					1						3							
66.5								1							1			1
67.0		1												1	1			
67.5														1				
68.0																		
68.5																		
69.0																		
69.5			1															
Totals	51	33	5	74	31	3	37	83	2	38	88	4	29	52	9	36	44	8

APPENDIX R RECOVERIES OF CHUM SALMON FIN-MARKED (Ad LV) AT INCHES CREEK IN WORTH AND RAILROAD CREEKS.

Recovery Location	Recovery Date (1979-80)	Sex	Length (cm)	Age
Worth Creek	Dec. 12	M.	52.5	3
		M.	51.0	-
		M.	54.5	-
	Dec. 17	F.	51.5	3
	Dec. 27	F.	53.0	3
	Jan. 15	F.	50.0	3
Railroad Creek	Dec. 27	F.	60.0	4
		F.	51.5	R*
		F.	51.0	3
	Jan. 2	F.	52.0	3
		F.	53.0	3
		M.	51.5	3
		M.	49.0	3

* R = regenerate scale.

APPENDIX S DAILY CATCH AND ESTIMATED MIGRATION OF CHUM SALMON FRY AT 1980 STUDY SITES.

JUDD SLOUGH (MAIN TRAP)

Date	Catch				Estimating Factor	Estimated Migration
	Trap 1	Trap 2	Trap 3	Total		
March 12	0	0		0		0
13	0			0		0
14	0			0		0
15						0*
16						0*
17	0			0		0
18	0			0		0
19						6*
20	1	11	1	13	1.67[a]	22
21	0		0	0	11.11[b]	0
22			1	1	11.11	11
23			1	1	11.11	11
24	11	8[d]	3	22	1.67	37
25	16	0[d]	0	16	1.67	27
26						21*
27	0		0	0	11.11	0
28						352*
29						462*
30						616*
31						704*
April 1						3,435*
2	40	351	229	620	1.67	1,035
3			771	771	11.11	8,566
4						5,186*
5						6,570*
6						7,431*
7						12,010*
8	670	1,902	995	3,567	1.67	5,957
9						21,506*
10			2,444	2,444	11.11	27,153
11			2,827	2,827	11.11	31,408
12						21,913*
13						15,739*
14			646	646	11.11	7,177
15			777	777	11.11	8,632
16			2,177	2,177	11.11	24,186
17						21,062*
18		7,160	2,542	9,702	2.71[c]	26,292
19						33,909*
20						35,123*
21			4,894	4,894	11.11	54,372
22		5,341	3,775	9,116	2.71	24,704
23		5,936	5,181	11,117	2.71	30,127
24						30,972*

APPENDIX S (cont.)

Judd Slough

Date		Catch				Estimating Factor	Estimated Migration
		Trap 1	Trap 2	Trap 3	Total		
April	25		10,095	3,959	14,054	2.71	38,086
	26						33,440*
	27						37,263*
	28			2,814	2,814	11.11	31,263
	30		6,019	2,499	8,518	2.71	23,084
May	1		4,994	1,972	6,966	2.71	18,878
	2		6,521	2,408	8,929	2.71	24,198
	3						23,318*
	4						19,299*
	5						19,440*
	6			2,419	2,419	11.11	26,877
	7		2,244	429	2,673	2.71	7,244
	8		2,521	225	2,746	2.71	7,442
	9		1,544	848	2,392	2.71	6,482
	10						5,378*
	11						3,421*
	12			199	199	11.11	2,210
	13	109	446	385	940	1.67	1,570
	14	36	268	239	543	1.67	907
	15	62	161	49	272	1.67	454
	16	262	649	175	1,086	1.67	1,814
	17						759*
	18						861*
	19						543*
	20						471*
	21						341*
	22	2	2	2	6	1.67	10
				Total			844,228

[a] Estimating factor for all 3 traps fishing (1.67).

[b] Estimating factor of 11.11 (recovery rate from Apr.15 release), using Trap 3 catch.

[c] Estimating factor of 2.71 from average recovery rate in Traps 2 and 3 from 5 mark releases.

[d] Trap 2 catch estimated from Trap 3 catch based on average ratio of 2.55 : 1.

* Interpolated data.

APPENDIX S (cont.)

JUDD SLOUGH POND 2

Date	Catch	Estimated Migration (Catch x 1.06)	Date	Catch	Estimated Migration (catch x 1.06)
March 12	0	0	April 21	721	764
13	0	0	22	458	485
14	0	0	23	898	952
15		0*	24	301	319
16		0*	25	293	311
17	0	0	26		523*
18	0	0	27		1,150*
19		0*	28	885	938
20	0	0	29	2,078	2,203
21	0	0	30	3,466	3,674
22		0*			
23		0*	May 1	823	872
24	0	0	2	1,175	1,246
25	0	0	3		1,324*
26		0*	4		1,550*
27	0	0	5		1,776*
28		0*	6	1,748	1,853
29		0*	7	2,101	2,227
30		0*	8	1,258	1,333
31		0*	9	1,096	1,162
			10		956*
April 1		7*	11		740*
2	19	20	12	351	372
3	175	186	13	648	687
4		158*	14	617	654
5		203*	15	329	349
6		209*	16	299	317
7		225*	17		213*
8	249	264	18		182*
9	304	322	19		152*
10		334*	20		121*
11	393	417	21	56	59
12		345*	22	27	29
13		339*	23	26	28
14	268	284			
15	299	317		Total	37,586
16	1,532	1,624			
17	986	1,045			
18	411	436			
19		748*			
20		562*			

*Interpolated data.

APPENDIX S (cont.)

LOWER PARADISE CHANNEL

Date		Catch			Estimated Migration
		Trap 1	Trap 2	Total	(catch x 1.045)
March	8				0*
	9				42*
	10				118*
	11				268*
	12	208	213	421	440
	13	393	238	631	659
	14	178	267	445	465
	15				644*
	16				777*
	17	352	419	771	806
	18	436	579	1,015	1,061
	19				1,068*
	20	558	623	1,181	1,234
	21	694	426	1,120	1,170
	22				1,423*
	23				1,801*
	24	1,071	714	1,785	1,865
	25	1,237	817	2,054	2,146
	26				1,713
	27	672	408	1,080	1,129
	28				2,185*
	29				2,342*
	30				2,747*
	31				2,934*
April	1				3,384*
	2	2,715	838	3,553	3,713
	3	2,460	895	3,355	3,506
	4				4,148*
	5				4,293*
	6				4,555*
	7				4,691*
	8				5,258*
	9	3,742	1,257	4,999	5,224
	10	3,423	2,184	5,607	5,859
	11	2,328	1,004	3.332	3,482
	12	4,860	2,029	6.889	7,145
	14	3,524	2,030	5,554	5,804
	15	12,236*	6,502	18,738	19,581
	16	5,175	2,662	7,819	8,171
	17	6,121	3,338	9,459	9,885
	18	6,828	3,809	10,637	11,116
	19				9,346*
	20				9,459*

APPENDIX S (cont.)

Lower Paradise Channel

Date		Catch			Estimated Migration (catch x 1.045)
		Trap 1	Trap 2	Total	
April	21	4,439	2,297	6,736	7,039
	22	7,326	3,595	10,921	11,412
	23	7,204	4,051	11,255	11,761
	24	4,253	2,143	6,396	6,684
	25	1,989	1,443	3,432	3,586
	26				5,032*
	27				5,706*
	28	1,600	3,018	4,618	4,826
	29	3,956	4,374	8,330	8,705
	30	3,985	3,591	7,576	7,917
May	1	1,788	2,825	4,613	4,821
	2	9,652	6,6167	15,819	16,531
	3				11,605*
	4				9,866*
	5				11,547*
	6	8,638	4,244	12,882	13,462
	7	2,603	1,847	4,450	4,650
	8	1,223	1,005	2,228	2,328
	9	2,539	2,439	4,978	5,202
	10				2,630*
	11				2,731*
	12				1,907*
	13				885*
	14	200	145	345	361
	15	182	188	370	387
	16	89	61	150	157

* Interpolated data.

APPENDIX S (cont.)

WORTH CREEK

Date	Catch	Estimated Migration (Catch x 1.16)	Date	Catch	Estimated Migration (Catch x 1.16)
March 11	14	16	April 21	763	885
12	42	42	22	1,078	1,250
13	58	67	23	1,578	1,830
14	74	86	24	1,619	1,878
15		80*	25	1,400	1,624
16		103*	26		2,934*
17	75	87	27		3,502*
18	118	137	28		4,916*
19		152*	29		5,947*
20	127	147	30	4,568	5,299
21	205	238	May 1	9,413	10,919
22		153*	2	11,661	13,527
23		137*	3		12,091*
24	65	75	4		12,623*
25	83	96	5		13,527
26		63*	6	10,195	11,826
27	38	44	7	12,260	14,222
28	27	31	8	8,948	10,380
29		35*	9	12,138	14,080
30		43*	10		11,221*
31	24	28	11		12,797*
April 1	60	70	12	7,933	9,202
2		51*	13	13,026	15,110
3	37	43	14	12,204	14,157
4	53	43	15	9,571	11,102
5		68*	16	10,096	11,711
6		73*	17		10,957*
7	86	100	18		11,793*
8	49	57	19	8,670	10,057
9	76	88	20	11,732	13,609
10	55	64	21	9,765	11,327
11	71	82	22	8,189	9,499
12		58*	23	7,104	8,241
13		73*	24		7,904*
14	23	27	25		6,396*
15	96	111	26	5,149	5,973
16	224	260	27	4,289	4,975
17	148	172	28	2,287	2,653
18	261	303	29	3,432	3,981
19		454*	30	2,959	3,432
20		813*	31		3,434*

APPENDIX S (cont.)

Worth Creek

Date	Catch	Estimated Migration (catch x 1.16)
June 1		3,531*
2	2,488	2,886
3	3,684	4,273
4	2,944	3,415
5	3,769	4,272
6		2,964*
7		2,427*
8		2,097*
9	952	1,104
10	704	817
11		812*
12		715*
13	445	516
14		282*
15		153*
16		26*
17		0*
	Total	377,739

* Interpolated data.

APPENDIX S (cont.)

RAILROAD CREEK

Date	Catch	Estimated Migration (catch x1.16)	Estimated Standing Population Above Trap[a]
Mar. 22	230	267	
23	474	550	
24	402	466	
25	624	724	
26		1,097*	
27	1,266	1,469	
28	832	965	
29		1,319*	
30		1,526*	
31	1,225	1,421	
April 1	2,373	2,753	
2		2,115*	
3	1,273	1,477	
4	997	1,157	
5		2,845*	
6		2,397*	
7	3,770	4,373	
8	2,502	2,902	
9		2,429*	
10	1,746	1,956	
11	802	930	
12		1,776*	
13		1,190*	
14	1,817	2,108	
15	684	793	
16	3,596	4,171	
17	1,325	1,537	
18	1,690	1,960	
19	1,604	1,861	
20	2,602	3,018	
21	6,547	7,595	
22	3,049	3,537	
23	1,051	1,219	
24	326	378	
25	910	1,056	
26		550*	
27		550*	
28	38	44	
29		1,100*	
30	1,859	2,156	

APPENDIX S (cont.)

Railroad Creek

Date	Catch	Estimated Migration (catch x 1.16)	Estimated Standing Population Above Trap[a]
May 1	101	117	
2	88	102	
3		100*	
4		100*	
5		100*	
6			141,100 (126,600 - 159,500)
13			19,943 (15,400 - 26,800)
22			2,500 (2,200 - 2,800)

* Interpolated data.

a 95% confidence limits shown in brackets.

APPENDIX S (cont.)

HOPEDALE SLOUGH POND 1

Date	Catch	Estimated Migration (catch x 1.12)
April 1	0	0
2		0*
3	0	0
4	0	0
5		0*
6		0*
7	1	1
8	0	0
9		11*
10	20	22
11	19	21
12		37*
13		56*
14	59	66
15	71	80
16	148	166
17	48	54
18	90	101
19		63*
20		122*
21	30	34
22	208	233
23	59	66
24	51	57
25	30	34
26	27	30
27		21*
28	1	1
29		8*
30	14	16
May 1	6	7
2	20	22
3		53*
4		122*
5	116	130
6	190	213

Date	Catch	Estimated Migration (catch x 1.12)
May 7	329	368
8	235	263
9	112	125
10		138*
11		50*
12	21	24
13	1	1
14	2	2
15	25	28
16	59	66
17		39*
18		50*
19	21	24
20	54	60
21	133	149
22	126	141
23	112	125
24		118*
25		114*
26	76	85
27	118	132
28	228	255
29	103	115
30	136	152
31		161*
June 1		207*
2	194	217
3	226	253
4		172*
5		157*
6		125*
7		109*
8		58*
9	41	46
10	18	20
	Total	5,996

* Interpolated data.

APPENDIX T CHUM FRY MIGRATION TIMING AT STUDY SITES, EXPRESSED AS DAILY AND CUMULATIVE PERCENTAGE OF TOTAL MIGRATION.

SQUAMISH AREA SITES

	Judd Slough (total)		Judd Pond 2		Lower Paradise	
Date (1980)	Daily %	Cumulative %	Daily %	Cumulative %	Daily %	Cumulative %
March 8						
9						
10						0.1
11					0.1	0.2
12					0.1	0.3
13					0.2	0.5
14					0.1	0.6
15					0.2	0.8
16					0.2	1.0
17					0.2	1.2
18					0.3	1.5
19					0.3	1.8
20					0.4	2.2
21					0.4	2.6
22					0.4	3.0
23					0.6	3.6
24					0.6	4.2
25					0.7	4.9
26					0.5	5.4
27					0.3	5.7
28					0.8	6.5
29	0.1	0.1			0.8	7.3
30	0.1	0.2			0.9	8.2
31	0.1	0.3			1.0	9.2
April 1	0.4	0.7			1.0	10.2
2	0.1	0.8	0.1	0.1	1.1	11.3
3	1.0	1.8	0.5	0.6	1.1	12.4
4	0.6	2.4	0.4	1.0	1.2	13.6
5	0.8	3.2	0.5	1.5	1.2	14.8
6	0.9	4.1	0.6	2.1	1.3	16.1
7	1.4	5.5	0.6	2.7	1.4	17.5
8	0.7	6.2	0.7	3.4	1.5	19.0
9	2.5	8.7	0.9	4.3	1.6	20.6
10	3.2	11.9	0.9	5.2	1.8	22.4
11	3.7	15.6	1.1	6.3	1.1	23.5
12	2.6	18.2	0.9	7.2	2.2	25.7
13	1.9	20.1	0.9	8.1	2.2	27.9
14	0.9	21.0	0.8	8.9	1.8	29.7
15	1.0	22.0	0.8	9.7	5.9	35.6
16	2.9	24.9	4.3	14.0	2.5	38.1

APPENDIX T (cont.)

Date (1980)	Judd Slough (total) Daily %	Cumulative %	Judd Pond 2 Daily %	Cumulative %	Lower Paradise Daily %	Cumulative %
April 17	2.5	27.4	2.8	16.8	3.0	41.1
18	3.1	30.5	1.2	18.0	3.4	44.5
19	4.0	34.5	2.0	20.0	2.8	47.3
20	4.2	38.7	1.5	21.5	2.9	50.2
21	6.4	45.1	2.0	23.5	2.1	52.3
22	2.9	48.0	1.3	24.7	3.5	55.8
23	3.6	51.6	2.5	27.2	3.6	59.4
24	3.7	55.3	0.9	28.1	2.0	61.4
25	4.5	59.8	0.8	28.9	1.1	62.5
26	4.0	63.8	1.4	30.3	1.5	64.0
27	4.4	68.2	3.1	33.4	1.7	65.7
28	3.7	71.9	2.5	35.9	1.5	67.2
29	5.0	76.9	5.9	41.7	2.6	69.8
30	2.7	79.6	9.8	51.5	2.4	72.2
May 1	2.2	81.8	2.3	53.8	1.5	73.7
2	2.9	84.7	3.3	57.1	5.0	78.7
3	2.8	87.5	3.5	60.6	3.5	82.2
4	2.3	89.8	4.1	64.7	3.0	85.2
5	2.3	92.1	4.7	69.4	3.5	88.7
6	3.2	95.3	4.9	74.3	4.1	92.8
7	0.9	96.2	5.9	80.2	1.4	94.2
8	0.9	97.1	3.6	83.8	0.7	94.9
9	0.8	97.9	3.1	86.9	1.6	96.5
10	0.6	98.5	2.6	89.5	1.3	97.8
11	0.4	98.9	2.0	91.5	0.9	98.7
12	0.3	99.2	1.0	92.5	0.6	99.3
13	0.2	99.4	1.8	94.3	0.4	99.7
14	0.1	99.5	1.7	96.0	0.2	99.9
15	0.1	99.6	0.9	96.9	0.1	100.0
16	0.2	99.8	0.8	97.7		
17	0.1	99.9	0.6	98.3		
18	0.1	100.0	0.5	98.8		
19	0.1	100.1	0.4	99.2		
20	0.1	100.2	0.3	99.5		
21			0.2	99.7		
22			0.1	99.8		
23			0.1	99.9		

APPENDIX T (cont.)

WORTH CREEK AND HOPEDALE SLOUGH

Date (1980)	Worth Creek Daily %	Worth Creek Cumulative %	Hopedale Slough Pond 1 Daily %	Hopedale Slough Pond 1 Cumulative %
March 11				
12				
13				
14		0.1		
15				
16				
17		0.2		
18				
19		0.3		
20				
21	0.1	0.4		
22				
23		0.5		
24				
25				
26		0.5		
27				
28				
29				
30				
31				
April 1		0.7		
2				
3				
4				
5		0.8		
6				
7				
8		0.9		
9			0.2	0.2
10			0.4	0.6
11		1.0	0.3	0.9
12			0.6	1.5
13			0.9	2.4
14			1.1	3.5
15		1.1	1.3	4.8
16	0.1	1.2	2.7	7.5
17			0.9	8.4
18	0.1	1.3	1.7	10.1
19	0.1	1.4	1.0	11.1
20	0.2	1.6	2.0	13.1
21	0.2	1.8	0.6	13.7
22	0.3	2.1	3.8	17.5

APPENDIX T (cont.)

Date (1980)	Worth Creek Daily %	Worth Creek Cumulative %	Hopedale Slough Pond 1 Daily %	Hopedale Slough Pond 1 Cumulative %
April 23	0.5	2.6	1.1	18.6
24	0.5	3.1	0.9	19.5
25	0.4	3.5	0.6	20.1
26	0.8	4.3	0.5	20.6
27	0.9	5.2	0.3	20.9
28	1.3	6.5		
29	1.6	8.1	0.1	21.0
30	1.4	9.5	0.3	21.3
May 1	2.9	12.4	0.1	21.4
2	3.6	16.0	0.4	21.8
3	3.2	19.2	0.9	22.7
4	3.3	22.5	2.0	24.7
5	3.5	26.0	2.1	26.8
6	3.1	29.1	3.5	30.3
7	3.8	32.9	6.0	36.3
8	2.7	35.6	4.3	40.6
9	3.7	39.3	2.0	42.6
10	3.0	42.3	2.3	44.9
11	3.4	45.7	0.8	45.7
12	2.4	48.1	0.4	46.1
13	4.0	52.1		
14	3.7	55.8		
15	2.9	58.7	0.5	46.6
16	3.1	61.8	1.1	47.7
17	2.9	64.7	0.6	48.3
18	3.1	67.8	0.8	49.1
19	2.7	70.5	0.4	49.5
20	3.6	74.1	1.0	50.5
21	3.0	77.1	2.4	52.9
22	2.5	79.6	2.3	55.2
23	2.2	81.8	2.0	57.2
24	2.1	83.9	1.9	59.1
25	1.7	85.6	1.9	61.0
26	1.6	87.2	1.4	62.4
27	1.3	88.5	2.2	64.6
28	0.7	89.2	4.2	68.8
29	1.1	90.3	1.9	70.7
30	0.9	91.2	2.5	73.2
31	0.9	92.1	2.6	75.8
June 1	0.9	93.0	3.4	79.2
2	0.8	93.8	3.5	82.7
3	1.1	94.9	4.1	86.8
4	0.9	95.8	3.3	90.1
5	1.2	97.0	2.9	93.0
6	0.8	97.8	2.4	95.4
7	0.6	98.4	2.0	97.4

APPENDIX T (cont.)

Date (1980)	Worth Creek Daily %	Worth Creek Cumulative %	Hopedale Slough Pond 1 Daily %	Hopedale Slough Pond 1 Cumulative %
June 8	0.6	99.0	1.6	99.0
9	0.3	99.3	0.8	99.8
10	0.2	99.5	0.3	100.1
11	0.2	99.7		
12	0.2	99.9		
13	0.1	100.0		
14	0.1	100.1		

APPENDIX U COHO SALMON FRY MIGRATION DATA FROM ALL STUDY SITES IN 1980.

SQUAMISH AREA SITES

Date	Judd Slough (total)			Judd Slough Pond 2			Lower Paradise Channel		
	Daily Catch	Expansion Factor	Estimated Migration	Daily Catch	Expansion Factor	Estimated Migration	Daily Catch	Expansion Factor	Estimated Migration
March 21	0	11.11	0		1.06			1.045	
22			0*		(all			(all	
23			4*		dates)			dates)	
24	2	1.67	3						
25	5	1.67	8	0		0	0		0
26			4*			0*			3*
27	0	11.11	0	1		1	10		10
28			7*			0*			14*
29			8*			0*			29*
30			8*			0*			37*
31			9*			0*			41*
April 1			9*			0*			59*
2	8	1.67	13	0		0	51		53
3	37	11.11	411	3		3	110		115
4			337*			0*			134*
5			395*			0*			161*
6			453*			0*			177*
7			511*			0*			488*
8	409	1.67	683	0		0	225		235
9			1,954*	2		2	1,006		1,051
10	225	11.11	2,500	0		0	151		158
11	241	11.11	2,678	4		4	115		120
12			1,876*			6*	513		536
13			1,195*			19*	434		454
14	144	3.13	451	13		14	255		266
15	146	3.13	457	28		30	376		393
16	243	11.11	2,700	14		15	188		196
17			1,500*	11		12	168		176
18	429	3.13	1,343	23		24	420		439

APPENDIX U (cont.)

Date		Judd Slough (total) Daily Catch	Expansion Factor	Estimated Migration	Judd Slough Pond 2 Daily Catch	Expansion Factor	Estimated Migration	Lower Paradise Channel Daily Catch	Expansion Factor	Estimated Migration
April	19			1,277*			12*			233*
	20			952*			10*			243*
	21	316	3.13	989	1		1	81		85
	22	167	3.13	523	6		6	188		196
	23	157	3.13	491	7		7	420		439
	24			372*	0		0	271		283
	25	33	3.13	103	19		20	74		77
	26			179*			34*			168*
	27			168*			59*			150*
	28	20	3.13	63	78		83	137		143
	29	108	3.13	338	69		73	221		231
	30	84	3.13	263	282		299	135		141
May	1	55	3.13	172	100		106	27		28
	2	30	3.13	94	79		84	32		33
	3			117*			68*			58*
	4			94*			60*			73*
	5			68*	12		13			87*
	6	27	3.13	85	77		82	109		114
	7	8	3.13	25	69		73	110		115
	8	8	3.13	25	26		28	30		31
	9	3	3.13	9	48		51	122		127
	10			12*			32*			55*
	11			5*			37*			53*
	12	1	3.13	3	16		17	6		6
	13	2	1.67	3	40		42	24		25
	14	1	1.67	2	26		28	5		5
	15	0	1.67	0	21		22	15		16
	16	2	1.67	3	11		12	6		6
	17			0			13*			8*
	18			0			11*			7*
	19			0			9*			6*
	20			0			7*			5*

APPENDIX U (cont.)

Date	Judd Slough (total)			Judd Slough Pond 2			Lower Paradise Channel		
	Daily Catch	Expansion Factor	Estimated Migration	Daily Catch	Expansion Factor	Estimated Migration	Daily Catch	Expansion Factor	Estimated Migration
May 21			0	3		3			4*
22	0	1.67	0	1		1			4*
23				9		10			3*
Totals	2,911		25,952	1,097		1,543	6,035		8,600

* Interpolated data.

APPENDIX U (cont.)

FRASER VALLEY SITES

Date	Worth Creek Daily Catch	Worth Creek Expansion Factor	Worth Creek Estimated Migration	Railroad Creek Daily Catch	Hopedale Slough Pond 1 Daily Catch	Hopedale Slough Pond 1 Expansion Factor	Hopedale Slough Pond 1 Estimated Migration
March 8	0*	1.16	0			1.12	
9	5*	(all	6			(all	
10	13*	dates)	15			dates)	
11	31		36				
12	31		36				
13	38		44				
14	73		85				
15	53*		61				
16	75*		87				
17	49		57				
18	102		118				
19	49*		57				
20	14		16				
21	29		34				
22	16*		19	7			
23	13*		15				
24	6		7				
25	4		5				
26	4*		5				
27	4		5				
28	0		0				
29	4*		5				
30	9*		10				
31	9		10		2		2
April 1	17		20		0		0
2	11*		13		3*		3
3	4		5		6		7

APPENDIX U (cont.)

Date	Worth Creek Daily Catch	Worth Creek Expansion Factor	Worth Creek Estimated Migration	Railroad Creek Daily Catch	Hopedale Slough Pond 1 Daily Catch	Hopedale Slough Pond 1 Expansion Factor	Hopedale Slough Pond 1 Estimated Migration
April 4	15		17	2	4		4
5	23*		27		4*		4
6	37*		43		2*		2
7	50		58	5	1		1
8	45		52	21	1		1
9	96		111	25	1*		1
10	99		115	31	2		2
11	61		71	28	1		1
12	74*		86		3*		3
13	88*		102		6*		7
14	63		73	14	6		7
15	141		164	23	10		11
16	85		99	3	4		4
17	51		59	4	3		3
18	143		166	1	0		0
19	97*		113	2	1*		1
20	123*		143	6	0*		0
21	98		114	3	0		0
22	127		147		0		0
23	98		114	2	3		3
24	74		86		0		0
25	81		94	4	0		0
26	111*		129		0		0
27	149*		173		0*		0
28	194*		225		0		0
29	256*		297		0*		0
30	178		206	2	0		0
May 1	509		590	2	0		0
2	421		488	1	0		0

APPENDIX U (cont.)

Date		Worth Creek			Railroad Creek	Hopedale Slough Pond 1		
		Daily Catch	Expansion Factor	Estimated Migration	Daily Catch	Daily Catch	Expansion Factor	Estimated Migration
May	3	1,367*		1,586		0*		0
	4	1,485*		1,723		1*		1
	5	1,810*		2,100		1		1
	6	3,172		3,680		2		2
	7	1,837		2,131		3		3
	8	572		664		4		4
	9	1,401		1,625		0		0
	10	851*		987		1*		1
	11	843*		978		0*		0
	12	580		673		0		0
	13	547		635		0		0
	14	491		570		1		1
	15	633		734		1		1
	16	954		1,107		7		8
	17	636*		738		3*		3
	18	671*		778		2*		2
	19	322		374		0		0
	20	737		855		0		0
	21	389		451		0		0
	22	158		183		0		0
	23	180		209		0		0
	24	117*		136		1*		1
	25	78*		90		1*		1
	26	13		15		2		2
	27	41		48		2		2
	28	16		19		0		0
	29	26		30		0		0
	30	28		32		1		1
	31	36*		42		1*		1

APPENDIX U (cont.)

Date	Worth Creek Daily Catch	Worth Creek Expansion Factor	Worth Creek Estimated Migration	Railroad Creek Daily Catch	Hopedale Slough Pond 1 Daily Catch	Hopedale Slough Pond 1 Expansion Factor	Hopedale Slough Pond 1 Estiamted Migration
June 1	88*		102		1*		1
2	53		61		2		2
3	184		213		5		6
4	32		37		0		0
5	92		107		0		0
6	53*		61		0*		0
7	48*		56		0		0
8	54*		63		0*		0
9	36		42		0		0
10	33		38		0		0
11	41*		48				
12	43*		50				
13	54		63				
14	12*		14				
15	12*		14				
16	0*		0				
Totals	25,076		29,088	186	107		120

* Interpolated data

APPENDIX V   SUMMARY OF CHUM SALMON TAGGING AND RECOVERY DATA FOR BILLY HARRIS SLOUGH.

Tagging Date	No. of Tags Available for Recovery			No. of Tags Recovered				% of Tags Recovered		
	Male	Female	Total	Male	Female	Total		Male	Female	Total
Nov. 14, 1979	100	74	174	73	69	142		73.0	93.2	81.6
Nov. 26, 1979	100	51	151	78	51	129		78.0	100.0	85.4
Nov. 29, 1979	66	33	99	38	32	70		57.6	97.0	70.7
Subtotals	266	158	424	189	152	341	ave.	69.5	96.7	79.2
Dec. 12, 1979	129	67	196	25	38	63		19.4	56.7	32.1
Season Totals	395	225	620	214	190	404	season ave.	57.0	86.7	67.5

Recovery Period	No. of Carcasses Examined			Population Estimates and 95% Confidence Intervals								
				Male			Female			Total		
	Male	Female	Total	Lower Limit	Point	Upper Limit	Lower Limit	Point	Upper Limit	Lower Limit	Point	Upper Limit
Oct.30-Dec.11,1979	1121	1038	2159	1355	1577	1799	910	1080	1250	2265	2657	3049
Dec.12-1979, - Jan. 17,1980	505	799	1304	1639	2530	3724	983	1395	1917	2622	3925	5641
Total	1626	1837	3463	2994	4107	5523	1893	2475	3167	4887	6582	8690

APPENDIX W METHODOLOGY FOR ESTIMATING CHUM SALMON FRY EMIGRATION FROM BILLY HARRIS SLOUGH.

Chum Fry Catch Data

Date	Catch	Date	Catch
March 15	7,364	April 1	10,040
16	3,848	2	14,456
17	16,467	3	13,922
18	10,235	4	27,151
19	14,987	5	24,152
20	13,443	6	57,313[a]
21	6,142	7	90,473
22	8,926	8	24,869
23	13,482	9	40,922
24	12,825	10	48,098
25	18,103	11	35,951
26	18,076	12	30,170
27	19,463	13	36,349
28	17,045	14	78,226
29	21,003[a]	15	54,186
30	24,961	16	60,523
31	20,522	17	57,340
		18	35,360
		Total	986,393

[a]Interpolated

Termination of Trapping

On April 19 the rising level of the Harrison River flooded out the fry trap at Billy Harris Slough, at a time when significant chum fry migration was still underway.

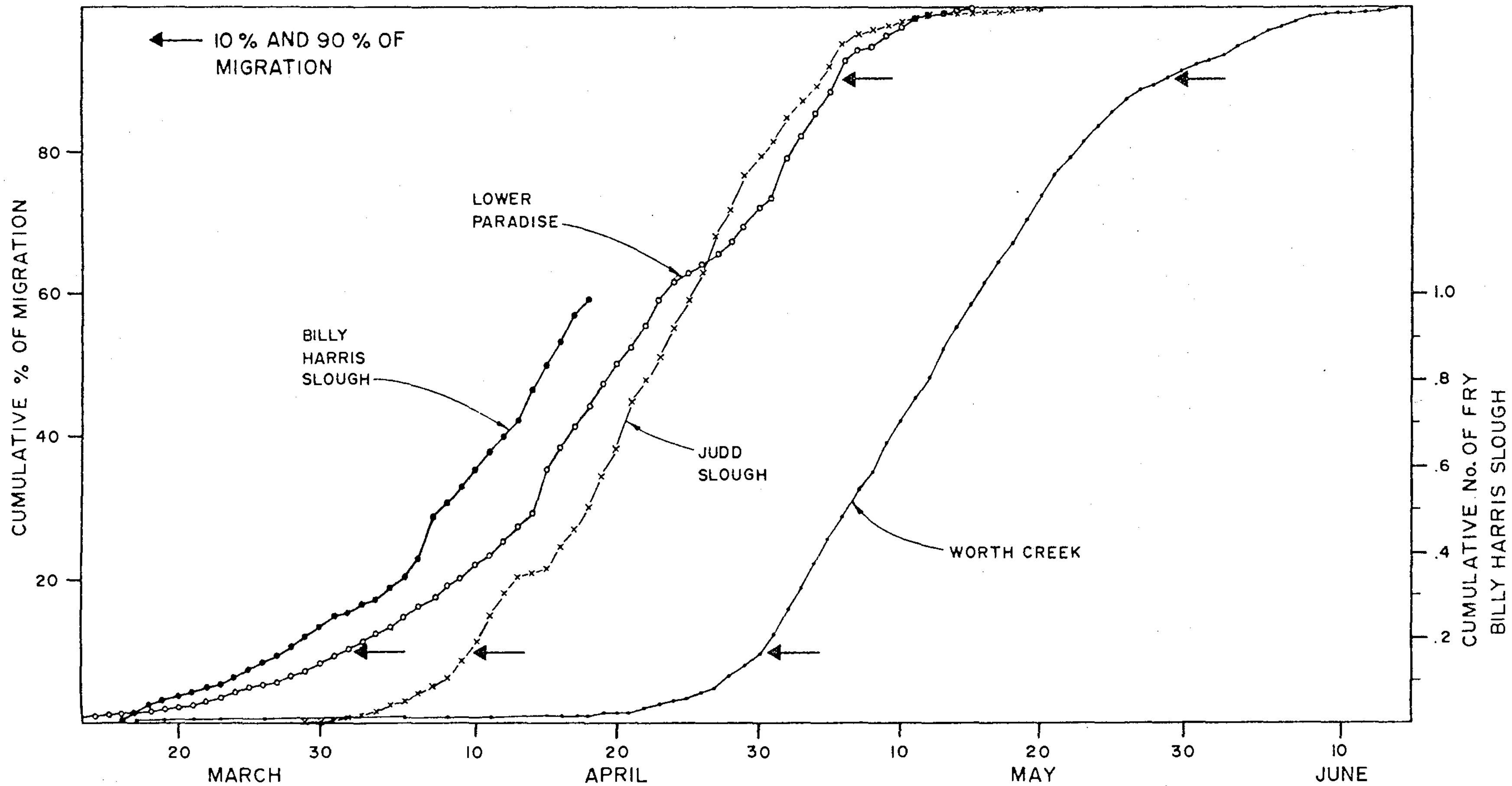
Gear Efficiency

As no marked fish releases were made at this site to test gear efficiency, it was assumed that traps were 100% efficient in capturing fry. It should be noted that the trap arrangement was similar to that used at other Fraser Valley study sites.

Estimating the Total Migration

The approach to estimating the total migration from data covering only a portion of that migration was based on the observation that: (i) between the 10% and 90% points on the curve of cumulative migration the number of migrants increases at a reasonably constant or linear rate (see following graph); and (ii) the period between 10% and 90% of the migration averages

APPENDIX W (cont.)



Chum salmon fry seasonal migration patterns at four study sites as shown by curves of cumulative migration. The Billy Harris Slough migration is plotted as cumulative numbers; the migration at other sites is plotted as cumulative percent.

30 days, based on data from groundwater-fed spawning areas near Billy Harris Slough such as Worth Creek (present study) and Barnes and Inches creeks (Fedorenko and Bailey, 1980). Three years of data were available from Barnes and Inches creeks.

Estimating the total migration from partial data required the following steps:

- plotting the cumulative daily catch of chum fry on graph paper;
- identifying the 10% point of migration (the point where migration increases at a linear rate), judged to be April 2 in the case of the Billy Harris Slough data:
- determining the average daily rate of migration over the first 12 days following the 10% migration point (ie. the period April 3 - 14) and multiplying by 30 to obtain the total migration between the 10% and 90% points; and
- multiplying the estimate for the peak 80% of migration by 100/80 to estimate total migration.

Accuracy of the Method

The accuracy of the method was tested using chum fry migration data from the present study and published reports which presented estimates of both daily and total chum migrations over the season. The following table compares migration estimates derived from partial data (ie. 12 days of peak migration) with the actual migration estimated from a total season of trapping.

Except for the 1974 Big Qualicum migration estimate, the estimates from partial data agree reasonably well with the estimates from trapping throughout the season. It should be noted that during the 1970's the Big Qualicum chum fry migration period may have been more contracted than under natural conditions, due to selection of particular run segments for Spawning Channel No. 2 and the fact that a major portion of the total fry output came from that channel. This would increase the likelihood that duration of peak migration would be unusually short, eg. 21 days in 1974. Under these circumstances the method outlined above (which assumes a 30 day peak migration period) would tend to overestimate the fry migration.

APPENDIX W (cont.)

Comparison of Chum Fry Migration Estimates (Using Method Applied to Billy Harris Slough Data) with Actual Migrations at Several British Columbia Sites

Site	Year	No. of Days Peak Migration	Estimated Migration	Actual Migration	% Difference
Big Qualicum River	1960	28	22,271,875	17,695,000	+ 25.9[b]
	1961	25	401,075	451,590	- 11.2[b]
	1973	34	13,081,963	13,145,717	- 0.5[c]
	1974	21	82,841,203	52,320,943	+ 58.3[d]
	1975	26	58,342,188	64,354,125	- 9.3[e]
Little Qualicum River	1979	22	27,614,069	31,096,386	- 11.2[f]
Worth Creek	1980	30	444,303	377,739	+ 17.6
Judd Slough	1980	25	659,453	844,228	- 21.9
Lower Paradise	1980	36	331,741	328,547	+ 1.0
		Overall Totals	205,987,870	180,614,280	+ 14.0%
			(123,146,670)	(128,293,340)	(- 4.0%)[a]

[a] 1974 Big Qualicum data were omitted from calculations in brackets.

[b] Anon. 1961, 1962

[c] Paine et al. 1975

[d] Sandercock & Minaker, 1975

[e] Minaker et al. 1979

[f] Lister et al. 1979

APPENDIX X CHUM SALMON SPAWNING DISTRIBUTION AT FOUR STUDY SITES DURING DECEMBER 11 - 14, 1979.[a]

Judd Slough

Section (m)	Spawners Observed No.	%
0- 60	3	0.3
60- 120	4	0.4
120- 180	2	0.2
180- 240	2	0.2
240- 300	16	1.5
300- 360	11	1.0
360- 420	31	2.9
420- 480	78	7.3
480- 540	126	11.8
540- 600	226	21.2
600- 660		
660- 720	110	10.3
720- 780	182	17.1
780- 840	132	12.4
840- 900	11	1.0
900- 960	2	0.2
960-1020	19	1.8
1020-1080	14	1.3
1080-1140	3	0.3
1140-1200		
1200-1260	3	0.3
1260-1320	4	0.4
1320-1380	34	3.2
1380-1470	54	5.1
Total	1067	

Lower Paradise Channel

Section (m)	Spawners Observed No.	%
0- 15	14	5.2
15- 30	22	8.1
30- 45	53	19.6
45- 60	17	6.3
60- 75	17	6.3
75- 90	13	4.8
90- 105	3	1.1
105- 120	4	1.5
120- 135	16	5.9
135- 150		
150- 165		
165- 180	2	0.7
180- 195		
195- 210	21	7.8
210- 225	6	2.2
225- 240	31	11.5
240- 255	21	7.8
255- 270	21	7.8
270- 285	9	3.3
285- 300		
300- 325		
Total	270	

Worth Creek

Section (m)	Spawners Observed No.	%
0- 15	42	10.0
15- 30	30	7.2
30- 45	52	12.4
45- 60	32	7.6
60- 75	50	11.9
75- 90	35	8.4
90- 105	30	7.2
105- 120	80	19.1
120- 135	41	9.8
135- 150	27	6.4
Total	419	

Railroad Creek

Section (m)	Spawners Observed No.	%
0- 15	10	3.0
15- 30	57	17.3
30- 45	45	13.7
45- 60	38	11.6
60- 75	54	16.4
75- 90	44	13.4
90- 105	23	7.0
105- 120	15	4.6
120- 135	43	13.1
Total	329	

[a] Sections listed from bottom to top of each channel.

APPENDIX Y LISTING OF CHUM SALMON FRY LENGTH AND WEIGHT STATISTICS.

Date	Sample Size	Length(mm) Mean	Length(mm) Range	Length(mm) SD	Weight(mg) Mean	Weight(mg) Range	Weight(mg) SD
Judd Slough							
Apr. 11	39	38.1	36-40	0.9	329	260-390	26
17	42	39.3	37-42	1.1	393	280-420	34
22	42	38.5	36-42	1.4	324	260-470	52
24	42	38.4	35-40	2.1	334	240-440	47
29	42	38.2	35-41	1.3	357	290-400	24
May 1	43	38.2	36-43	2.5	324	270-430	49
6	43	38.7	35-40	1.6	380	320-410	21
8	42	38.4	36-42	1.4	363	310-410	50
13	41	39.0	37-42	1.4	378	350-410	21
Judd Slough Pond 2							
Apr. 16	42	38.0	34-40	1.6	315	230-390	49
23	41	38.2	35-40	1.5	325	220-410	48
28	42	38.7	37-41	1.1	320	270-350	28
May 7	42	38.6	36-42	1.5	366	300-420	25
15	42	38.8	35-41	1.3	372	350-400	16
Lower Paradise Channel							
Mar. 18	39	37.9	35-41	2.0	331	290-410	31
27	40	38.2	37-40	1.0	336	270-350	24
Apr. 2	40	37.9	35-41	1.3	315	240-410	34
11	40	37.9	37-40	0.7	329	300-360	14
15	43	38.1	35-41	1.3	308	240-410	36
18	38	38.3	33-41	1.4	309	270-380	57
22	36	38.7	37-42	1.3	347	290-430	43
24	43	38.1	36-41	1.8	319	270-370	33
28	42	38.7	36-41	1.3	344	280-420	40
May 1	45	38.3	31-41	1.8	340	260-450	38
6	41	39.6	36-43	1.7	386	340-420	18
8	39	38.0	35-41	1.5	355	290-420	61
13	41	38.6	36-46	2.2	378	340-470	28
Worth Creek							
Mar. 28	27	38.6	36-40	1.2	328	270-400	36
Apr. 8	40	38.0	35-43	2.1	336	220-450	53
15	40	36.3	32-45	2.9	325	200-500	69
21	25	37.7	35-48	2.4	348	320-670	75
30	40	37.0	35-39	1.0	340	240-390	48
May 2	40	37.0	34-40	1.7	315	210-400	53
6	40	37.9	35-40	1.4	333	220-500	62
13	40	37.6	35-40	1.2	267	150-320	46
15	34	37.8	35-41	1.5	268	170-340	45
20	40	37.7	36-40	1.0	271	150-400	58
22	40	37.7	35-40	1.5	320	210-500	76
27	40	38.0	35-43	1.6	311	200-540	74
29	40	37.9	35-40	1.4	306	210-420	61
June 4	40	38.2	35-42	1.7	323	220-510	69
10	40	37.9	35-43	1.5	304	170-570	75

APPENDIX Y (cont.)

Date		Sample Size	Length (mm)			Weight(mg)		
			Mean	Range	SD	Mean	Range	SD
Railroad Creek								
Mar.	28	40	37.5	34-42	2.3	312	230-440	59
Apr.	4	40	37.9	36-42	1.4	340	250-420	45
	14	42	38.7	37-41	2.5	346	270-580	106
	15	40	36.1	32-40	2.3	226	210-410	49
	21	41	40.7	37-41	1.4	410	240-720	113
	23	40	37.6	36-40	1.0	348	240-430	54
	29	40	38.1	34-42	2.1	336	230-420	57
May	5	6	38.5	35-47	2.2	375	270-560	92
	13[a]	40	37.7	35-42	1.8	280	120-420	79
	22[a]	43	37.7	34-43	1.9	353	240-550	78
Hopedale Slough Pond 1								
Apr.	30	14	38.6	35-41	2.7	413	260-750	147
May	6	40	39.0	37-45	2.1	378	250-540	64
	15	22	37.5	35-49	2.8	314	170-800	115
	15[a]	20	38.9	35-53	3.7	347	220-1040	173
	20	40	37.7	36-40	1.0	274	200-400	47
	27	40	38.4	36-41	1.2	308	230-460	49
June	4	33	38.8	36-53	2.9	334	200-1200	160
	10	10	37.7	37-39	0.7	314	230-360	37

[a]Samples collected by seining.