The Role of Spring Ponds in the Winter Ecology and
Natural Production of Coho Salmon *(Oncorhynchus kisutch)*
on the Olympic Peninsula, Washington

by

N. Phil Peterson

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(Chairman of the Supervisory Committee)

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Master's Thesis

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Abstract

THE ROLE OF SPRING PONDS IN THE WINTER ECOLOGY AND NATURAL PRODUCTION OF COHO SALMON *(Oncorhynchus kisutch)* ON THE OLYMPIC PENINSULA, WASHINGTON

By N. Phil Peterson

Chairman of the Supervisory Committee: Professor Ernest L. Brannon
College of Fisheries

Movements of juvenile coho *(Oncorhynchus kisutch)* into two tributary spring ponds (Copper Mine Bottom Pond and Pond 2) of the Clearwater River, Washington, were monitored during 1977 and 1978. Marking experiments of fingerling in the Clearwater River during the summer were designed to reveal rearing areas of pond immigrants. Growth, survival and food habits of the coho during pond residence were determined and compared between ponds. The standing crop of insects and physical characteristics of both ponds were also assessed and compared.

Over 4,000 juvenile coho moved into each pond between September 1977 and January 1978. Immigration correlated with sudden discharge increases of the Clearwater River resulting from winter storms. With one exception, marked coho entering the ponds had travelled downstream from their summer rearing areas. The longest distance travelled was 33 km and three other fish travelled 25 km. Survival of coho was 80 percent in Copper Mine Bottom and 31 percent in Pond 2. During pond residence coho increased their weight by 49 percent in Copper Mine

Bottom and 94 percent in Pond 2. Larval chironomids were the major prey for coho in Copper Mine Bottom, whereas the pharate adult stage of the chironomids predominated in stomach samples from Pond 2.

Pond 2 had a significantly higher standing crop of benthic insects than Copper Mine Bottom. Temperatures of both ponds were nearly the same, ranging from 3 to 16°C between December, 1977 and May, 1978. Pond 2 is the larger (1.29 ha), but shallower pond, with a maximum depth of 1.2 m while Copper Mine Bottom is smaller, but deeper, with a maximum depth of 3.5 m. Extensive beds of aquatic macrophytes cover areas < .9 deep in both ponds.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Number *Page*

LIST OF APPENDIX TABLES

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INTRODUCTION

The behavior and ecology of juvenile salmonids in streams has been the subject of many publications (Kalleberg 1958, Chapman 1962, Hartman 1963, Mason 1966, Ruggles 1966, Hartman 1965, Chapman and Bjornn 1969, Everest 1969, Lister and Genoe 1970, Griffith 1972, Stein et al 1972, Allee 1974). These studies have described the interaction between the animal and its physical and biological environment. Most of these studies have focused on the spring and summer rearing period, as sampling in streams during the winter is often hampered by winter-time conditions and the hiding behavior of fish. Some studies indicate that stream conditions during the winter can significantly influence fish production (Elwood and Waters 1969, Allee 1974, Mason 1976, Bustard and Narver 1975b).

Winter microhabitat important to juvenile salmonids has only recently been described (Bustard and Narver 1975b) and in this regard spring fed tributaries and ponds are now recognized as especially valuable winter refuge areas (Craig and Poulin 1975, Skeesick 1970, Elliott 1974). This paper describes some aspects of the winter behavior and movement patterns of juvenile coho *(Oncorhynchus kisutch)*, in relation to spring ponds on the Olympic Peninsula, Washington.

Old flood plains of most Peninsula rivers contain some ponds which had their origin as oxbows. These ponds are fed by springs flowing from adjacent gravel terraces and are connected to the river by small outlet streams. In this region, ponds were thought to play an important role in the winter ecology of coho and this study was designed to document that role. Specific objectives were: 1) to determine use patterns of two tributary spring ponds by juvenile coho, 2) to identify recruitment areas within a large river system for two of its tributary ponds, 3) to compare the growth, survival and food habits of populations of coho overwintering in two ponds of different sizes and depths and 4) to measure, document and compare the physical characteristics and the benthic insect fauna of the two ponds.

DESCRIPTION OF STUDY AREA

Clearwater River Basin

The Clearwater River is located on the Olympic Peninsula in Washington and is the major tributary of the Queets River (Fig. 1). It originates on the western slope of the Olympic Mountains and flows southwesterly 60 km (37.5 mi), dropping 365 m (1200 ft) to its confluence with the Queets, 8 km (5 mi) above tide water.

Discharge of the Clearwater River at its mouth has varied seasonally from less than 2 m^3/sec (100 cfs) to over 600 m^3/sec (30,000 cfs). During the period of this study discharge at river mile 15.5 ranged from 1.72 m^3 (86 cfs) in August of 1977, to 285 m^3/sec (14,250 cfs) on November 1, 1977. Summer low to winter high flow ratios of small tributary streams approach 1:400-500 (Lestelle 1978). Average annual precipitation, mainly in the form of rain, is between 350-640 cm (150-184 in). In recent years, 24-hour precipitation of 24 cm (9.6 in) has been recorded and during November and December of 1977, over 150 cm (60 in) of rain fell.

Temperate rainforests of the watershed are dominated by western hemlock (*Tsuga heterophylla)*; sitka spruce *(Picea sitchensis)*; western red cedar *(Thuja plicata)*; douglas fir *(Pseudotsuga menziesii)*; and white fir *(Abias amabilis)*.

The Clearwater was not scoured by the last alpine glacial advance but fingers of the adjacent Hoh and Queets Glacier crested

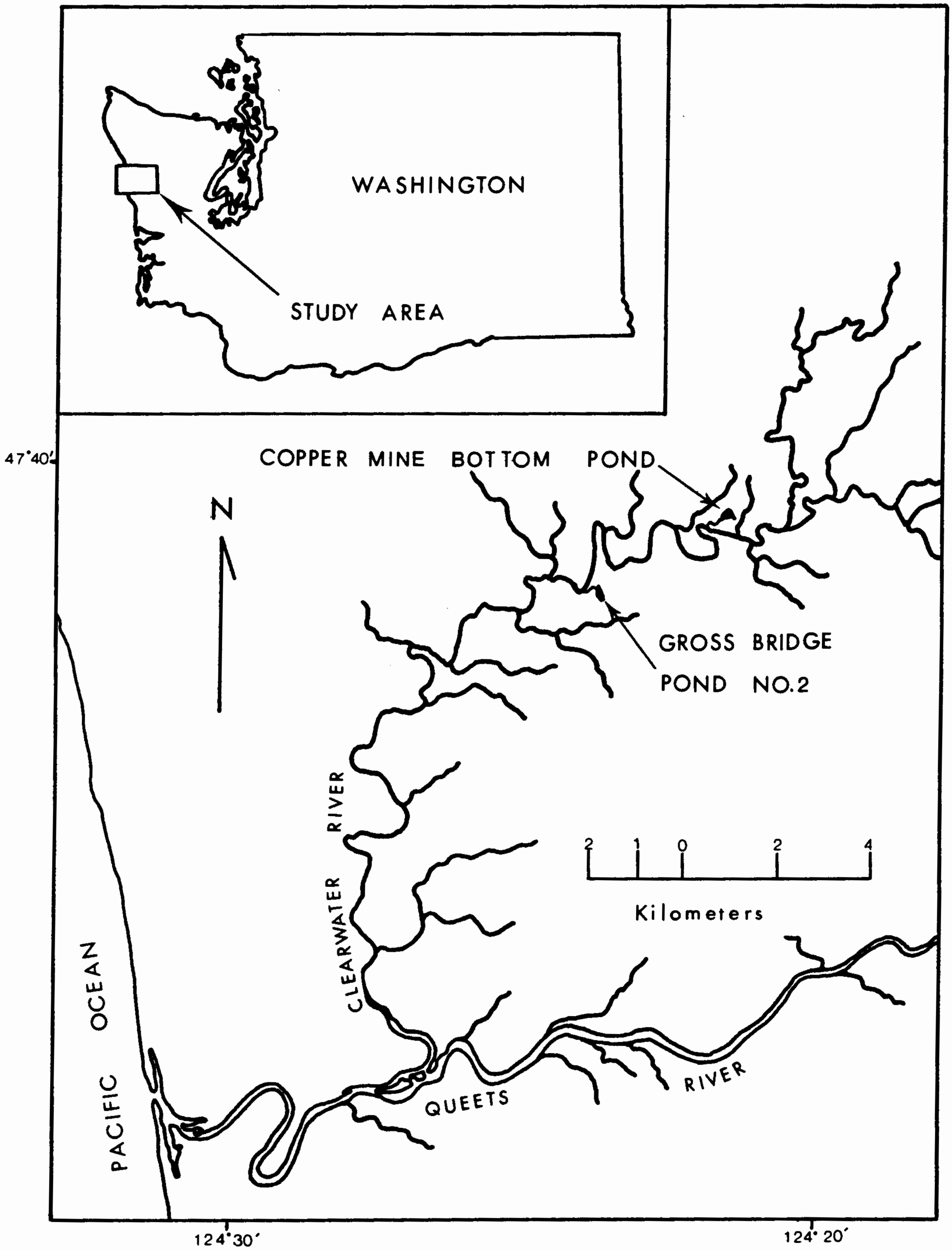

Fig. 1. Index map of the Clearwater River and the study ponds.

over low divides into the Snahapish River and Hurst Creek, respectively, which are tributaries of the Clearwater River.

Spring Ponds

Definition

In this paper, use of the term "spring pond" will closely follow Carline's (1977) definition. A spring pond is characterized by: a) a surface area less than 4 ha (10 acres), b) the major water supply is from nearby springs, c) a well defined outlet and d) a water retention time usually less than 10 days.

Processes forming pond depressions vary with local geology. Ponds discussed in this paper appear to be old oxbows of the Clearwater River.

Copper Mine Bottom Pond

Copper Mine Bottom Spring Pond, hereafter referred to as Copper Mine Bottom, is tributary to the Clearwater River on the north bank, 29.3 km (18.3 mi) above its confluence with the Queets (Fig. 1). The pond lies in an old flood plain of the Clearwater River and appears to be a deep hole scoured out by the river next to a bedrock wall rather than a shallow oxbow. A similar feature in the present day Clearwater occurs just downstream from Copper Mine Bottom (Plate I). Species of fish that are resident, or transient in Copper Mine Bottom are coho salmon, cutthroat trout *(Salmo clarki)*, steelhead trout *(Salmo gairdneri)*, prickly sculpin *(Cottus asper)*, western speckled dace *(Rhynicthyes cataractae)* and torrent sculpin *(Cottus rotheus)*.

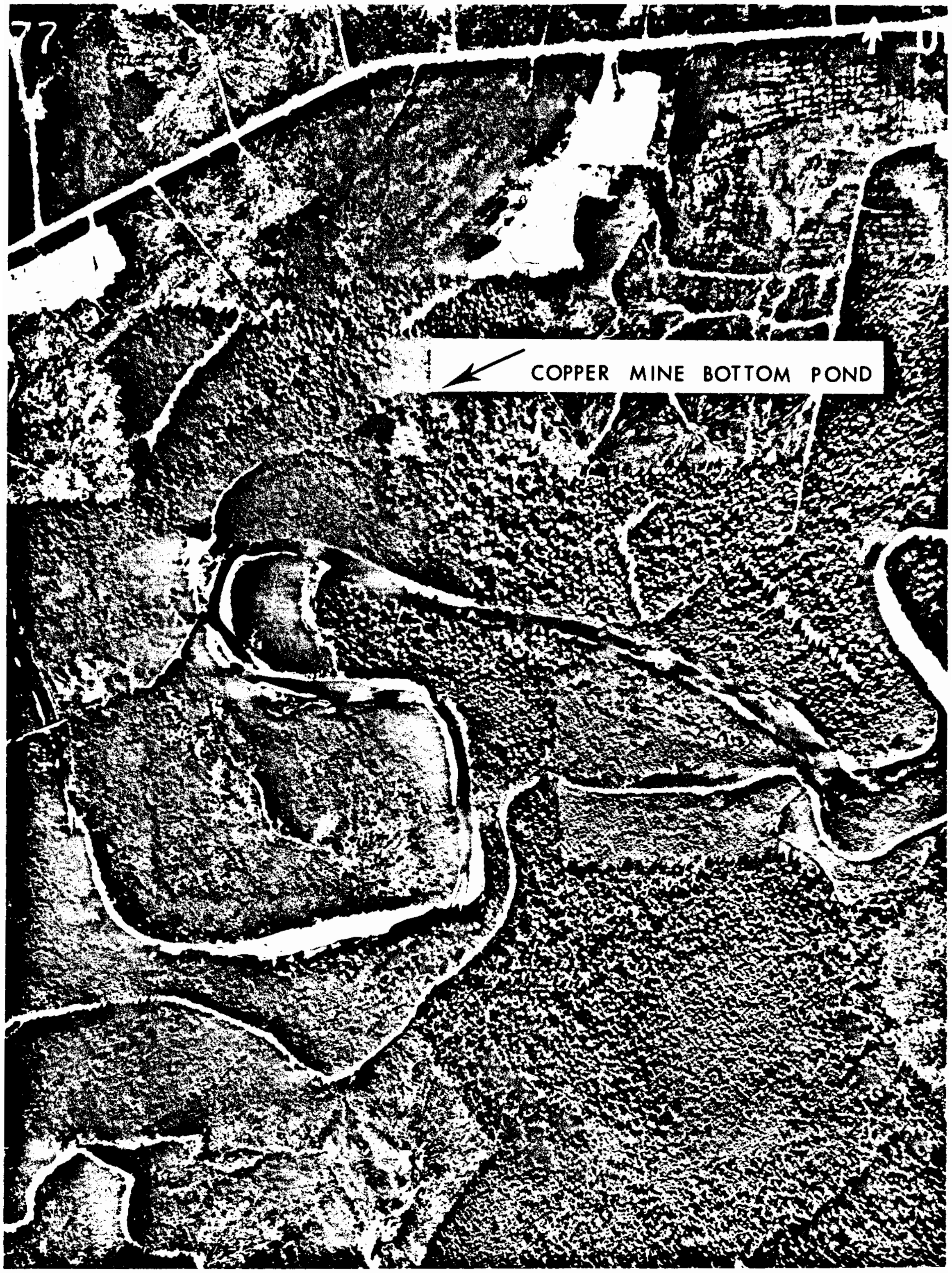

Plate I. Aerial photograph of Clearwater River region in the area of Copper Mine Bottom Spring Pond.

Table 1 gives the area, depth and other physical characteristics of Copper Mine Bottom and compares them with those of Gross Bridge Pond No. 2, the other pond studied.

Discharge during the year ranges from 9.5 l/sec (150 gpm) for short periods in late summer to over .16 m^3/sec (8 cfs) during extreme winter storms. Copper Mine Bottom is 2.1 m (7 ft) above present river level and during extreme storm events such as occurred on November 1, 1977, is backed up by the river. The outlet stream flows about 280 m (920 ft) to its entry with the Clearwater.

Shoreline vegetation consists mainly of red alder *(Alnus rubra)*, big leaf maple *(Acer macrophyllum)*, sitka spruce *(Picea sitchensis)*, western hemlock *(Tsuga heterophylla)*, salmonberry *(Rubus spectabilis)*, blackberries *(Rubus laciniatus)*, bracken fern *(Pteridium aqualinum)*, sedges *(Carex sp)*, horsetail *(Equisetum sp)* and bedstraw *(Galium sp)*.

From late spring through early fall yellow pond lilies *(Nuphar variegatum)* grow in areas less than .9 m (3 ft) deep (Plate II). Other common aquatic macrophytes include broadleaf pondweed *(Potamogeton natans)*, narrowleaf pondweed *(Potamogeton berchdolti)*, floating bladderwort *(Utricularia sp)* and macroscopic algae *(Nitella sp)*. Both species of *Potamogeton* encroach to depths of about 1.5 m (5 ft) but deeper areas of the pond lack aquatic macrophytes (Plate II).

Gross Bridge Pond No. 2

Gross Bridge Pond No. 2, hereafter referred to as Pond 2, is tributary to the Clearwater River on the south bank, 21.8 km (13.6 mi) above its confluence with the Queets (Fig. 1). The pond lies in an

Table 1. Physical characteristics of the study ponds.

CHARACTERISTIC	COPPER MINE BOTTOM POND	GROSS BRIDGE POND NO. 2
DISTANCE FROM MOUTH OF CLEARWATER RIVER	29.5 km (18.4 mi)	21.8 km (13.6 mi)
AREA	.85 ha (2.10 acres)	1.29 ha (3.18 acres)
VOLUME	10,313 m^3 (13,824 yd^3)	7,586 m^3 (9,923 yds^3)
MODAL WINTER DISCHARGE	28 1/sec (1 cfs)	28 1.sec (1cfs)
RETENTION TIME AT LISTED DISCHARGE	4.2 days	3.1 days
MAXIMUM DEPTH	3.5 m (11.5 ft)	1.3 m (4.2 ft)
PERCENT AREA < .75 m (2.5 ft) deep	46.5%	84%
PERCENT AREA > 1.2 m (4 ft) deep	37.5%	.3%

Plate II. Aerial view of Copper Mine Bottom Spring Pond in the summer showing the limited beds of aquatic macrophytes.

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old flood plain of the Clearwater River with its long axis in a NW, SE aspect. A sister pond lies 300 m (1,000 ft) to the west in the same aspect (Plate III). Together, these two long, narrow, shallow ponds appear to represent parts of an old oxbow of the Clearwater. Fish species using Pond 2 are the same ones listed for Copper Mine Bottom.

Pond 2 has a larger surface area, a long, narrow configuration and is considerably shallower than Copper Mine Bottom, as shown in Table 1. Discharge during the year ranges from zero outflow for short periods in late summer to greater than .16 m^3/sec (8 cfs) during peak storm events in the winter. Pond 2 is 3.4 m (11 ft) above present river elevation which at this location precludes flooding by the river even during the severest storms. The outlet stream flows about 470 m (1,550 ft) to its entry with the Clearwater.

Shoreline vegetation is similar to that described for Copper Mine Bottom, as are the aquatic macrophytes. Yellow pond lilies cover the entire pond with the exception of the areas deeper than .9 m (3 ft) (Plate IV) from late spring through early fall.

Plate III. Aerial photograph of Clearwater River region in the area of Gross Bridge Ponds No. 1 and 2.

Plate IV. Aerial view of Gross Bridge Pond No. 2 during the summer showing the extensive beds of aquatic macrophytes.

METHODS AND MATERIALS

Fish Observations

To understand the role of tributary ponds in the production of coho, it is important to understand the habitat and behavior of fish that are being recruited. Since the main Clearwater River was the area that most fish would likely come from, I began the research there, looking at the distribution and relative magnitude of coho populations in nearby reaches of the river.

These observations were used in implementing marking experiments designed to reveal the summer rearing locations of pond immigrants. To monitor fish movements into two spring ponds fish traps were installed on their outlet streams which were capable of monitoring upstream and downstream movements.

Clearwater River Snorkling Observations

Observations of juvenile coho rearing in the Clearwater River were made by snorkling. The purpose of the observations were: 1) to observe the relative magnitude of rearing populations in specific reaches of the main Clearwater River and 2) to observe distribution of juvenile coho in the mainstem with regard to physical aspects of the stream. This information was applied in marking experiments to determine the extent of coho recruitment to the study ponds. The 10 km (6.3 mi) stretch of river between Bull Creek and Christmas Creek was examined in August, 1977 (Fig. 2).

Coho behavior and distribution were reported to a second person following in a raft. Stream margins and areas with debris cover

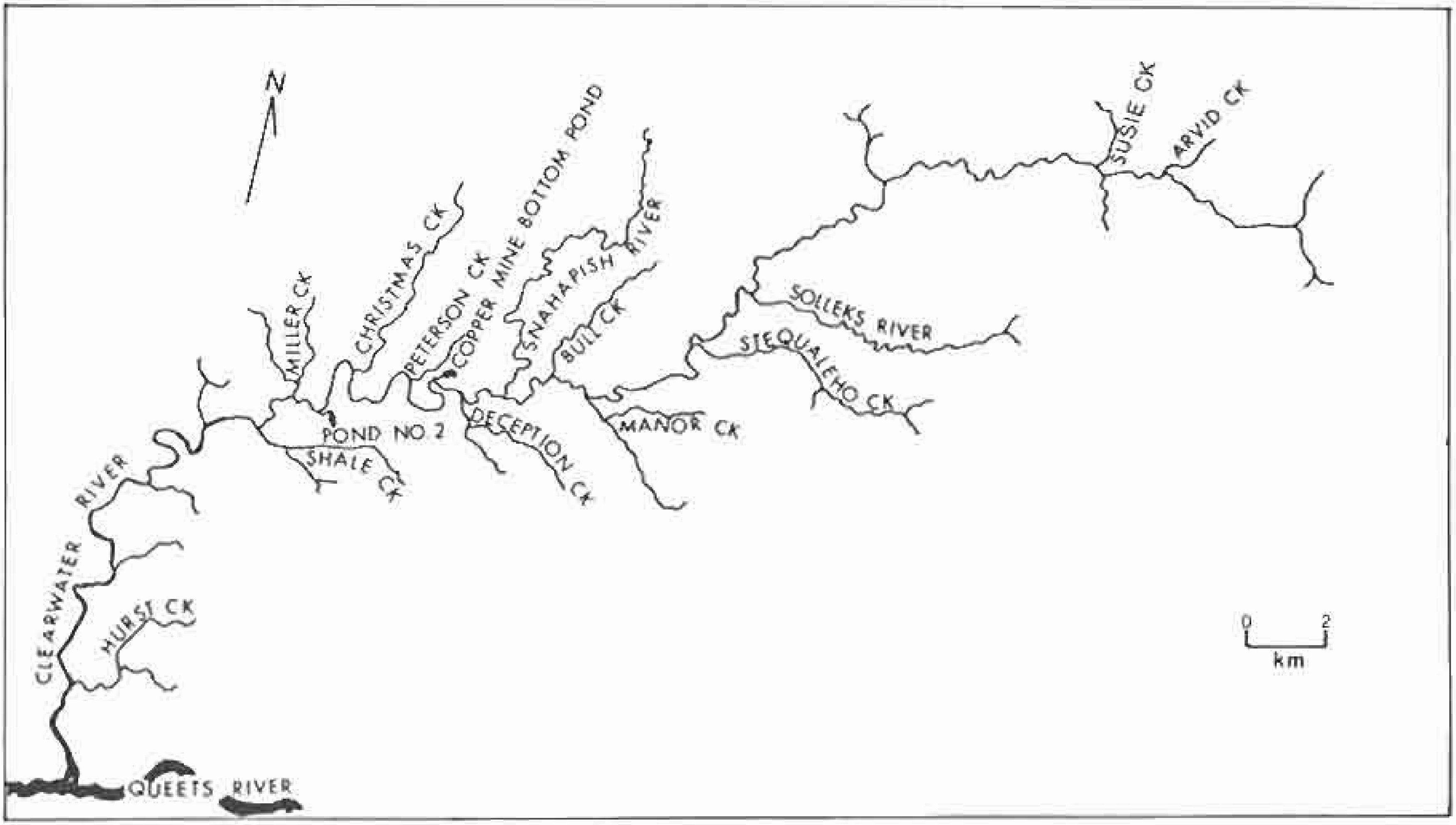

Fig. 2 The Clearwater River and major tributaries.

were closely inspected. Counts of juvenile coho were made along the stream section inspected.

Clearwater River Marking Experiments

Between August 25 and September 17, 1977 409 juvenile coho were captured in various sections of the Clearwater River and freeze branded using dry ice and acetone techniques of Everest and Edmundson (1967). Capture sites in the Clearwater were limited to a 12.6 km (8.7 mi) section from Manor Creek to Pond 2 and one location just below Susie Creek (Fig. 2).

Fish were captured by netting after they were stunned with a Coeffelt electro shocker powered by a portable generator. Shocking and netting was done from a fiberglass drift boat. A Mark V Smith Root battery powered back pack shocker and a small seine were used to catch fish at the Susie Creek site.

When a specific area such as a large root ball, debris pile or log jam had been sampled, the boat was beached, and the fish, which had been placed in a plastic bucket, processed. The fish were anesthetized, measured, weighed, branded and placed in another bucket to revive. When fully recovered, fish were returned to the spot where they were caught.

Each river section where fish were branded was given a four letter code designation determined by the brand letter and its position and orientation on the fish. For this project each fish was marked by applying a cold (-86°C) branding iron to its side for from 1 to 3 seconds. The letter "V" in any one of 4 orientations, applied to either the right or left side in an anterior or posterior position permits easy identification for as many as 16 sites. The branding code is fully explained in Figure 3.

Pond Traps

Traps located at the pond outlets caught all fish migrating in either direction. Traps were 2.4 x 1.2 m (8 x 4 ft) plywood boxes with screened ends, set into the substrate of the outlet stream. Enough water to attract fish was kept flowing through the trap and the rest was bypassed through .6 cm (1/4 in) mesh hardware cloth panels that prevented fish from avoiding the traps in either direction (Figs. 4 and 5).

Fish entered the Copper Mine Bottom trap from either direction through a 20 cm (8 in) diameter vexar (plastic mesh) cone that tapered to about 5 cm (2 in) on the inside (Fig. 4). The lead cone and the .3 cm (1/8 in) mesh nylon holding net were fastened to a .3 cm (1/8 in) sheet metal plate that slid into tracks at the end of the trap. When removing fish from the trap, the assembly cone was slid upward out of the track, fish crowded to the end of the holding net and dipped out (Plate V).

The trapping of upstream migrants at Pond 2 was similar to that at Copper Mine Bottom but downstream migrants entered through a 10 cm (4 in) PVC plastic pipe that ran through an existing 60 cm (24 in) concrete culvert (Plate VI). The pipe was attached by a plywood apron to .6 cm (1/4 in) mesh hardware cloth panels in the pond (Fig. 5).

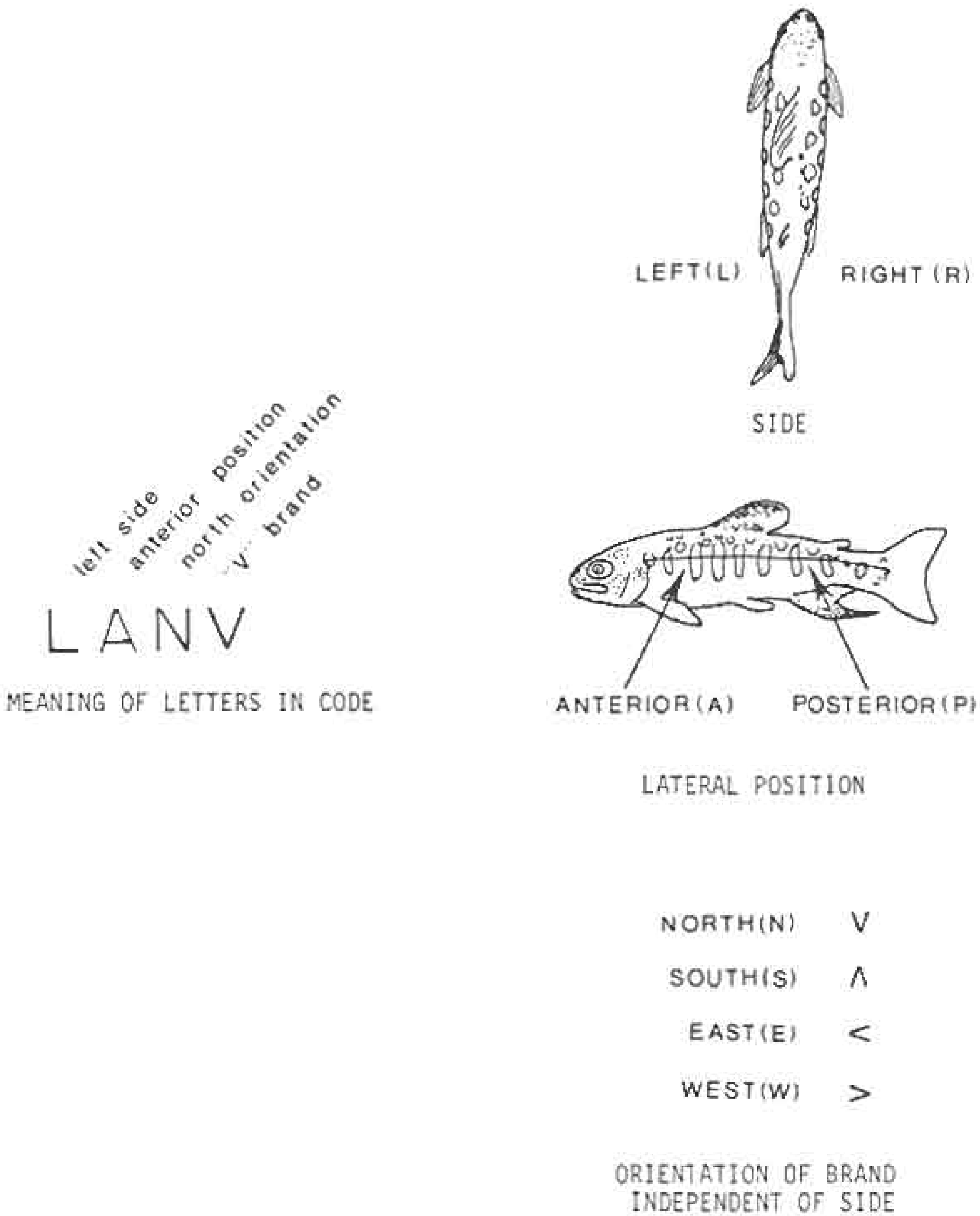

Fig. 3. Explanation of the brand code used in marking experiments.

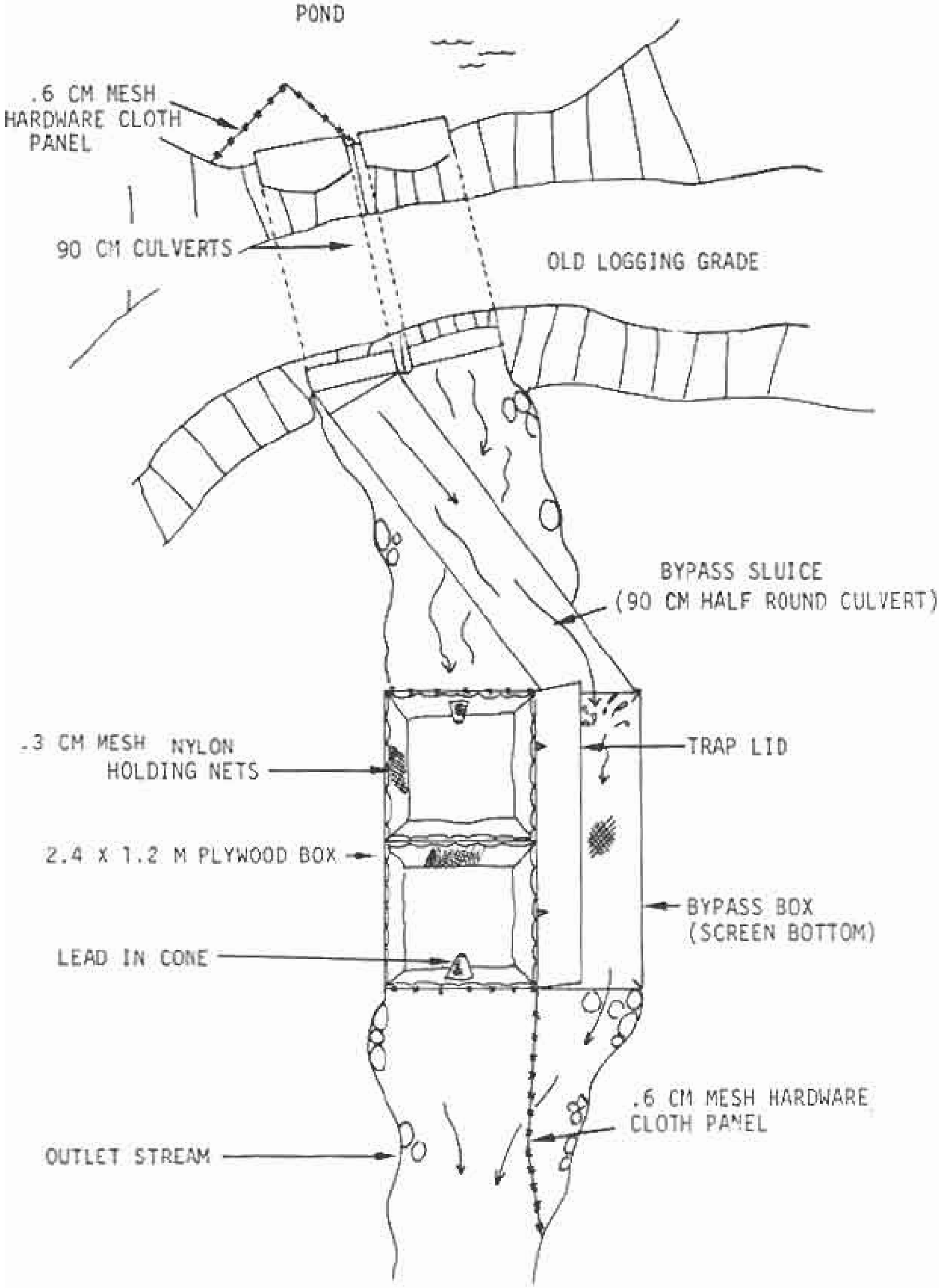

Fig. 4. Diagram of the Copper Mine Bottom trap.

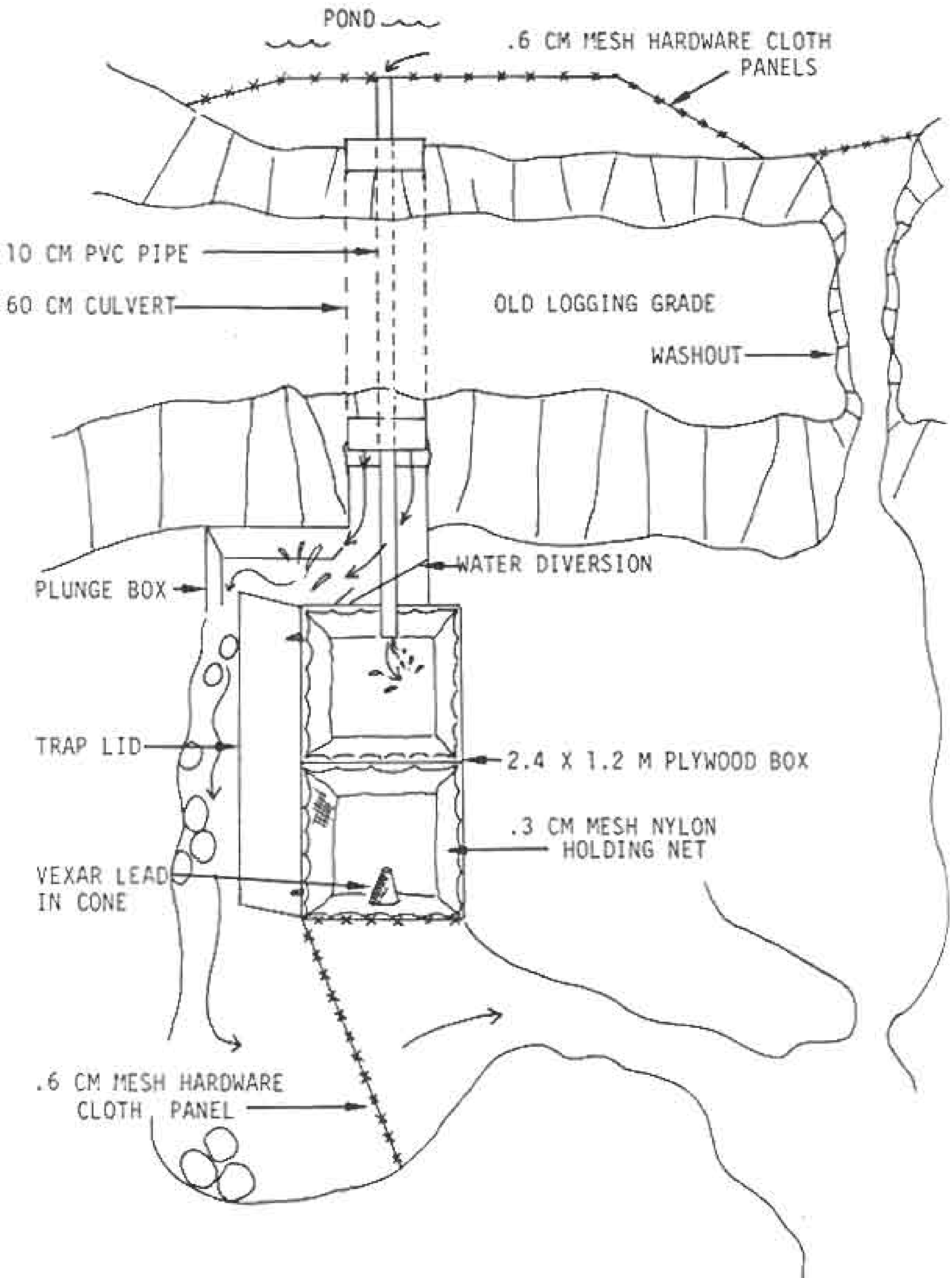

Fig. 5. Diagram of the Pond 2 trap.

Plate V. Juvenile coho salmon being removed from Copper Mine Bottom fish trap.

Plate VI. Gross Bridge Pond No. 2 trap. Downstream migrating fish enter the trap through the pipe.

There was a 30 cm (12 in) drop from the pipe to the water level in the trap, and a jumping barrier prevented fish from getting back into the pipe.

All fish were removed from the pond traps daily during peak migrations. Only coho, cutthroat and steelhead were anaesthetized, measured to the nearest millimeter and weighed to the nearest .1 gram. Other fish species were identified and counted. Fish caught by the traps were in excellent condition. Total coho mortality associated with trapping and handling over the course of the study was only 0.28 percent.

Pond Marking Experiments

All immigrating coho caught in the pond traps during specific weekly periods in November and December were marked with a freeze brand or an adipose clip. About 20 percent of the population in both ponds were marked. A coded wire tag was implanted in all adipose fin-clipped fish upon outmigration using a hand held applicator. Six different brands in Copper Mine Bottom and seven in Pond 2 identified groups of fish by specific weekly periods and two sizes, *i.e.* those < 80 mm and those > 80 mm at the time of immigration. Growth and survival of marked fish were assumed to be representative of the entire population.

Growth, Survival and Production of Coho

Absolute and relative weight increases and instantaneous growth rates were calculated from length and weight measurements taken on the marked individuals. The measurements were made three times: first at pond entry, again in February in the pond when fish were collected by boat shocking and at outmigration.

To avoid bias in average weight statistics length and weight data pairs measured on fish from both ponds in the spring and fall were used to calculate predictive length-weight relationships for each pond for the fall and spring populations. For Copper Mine Bottom 521 measurements made in the fall and 1,147 made in the spring were used in the calculations. For Pond 2, 471 fall measurements and 393 spring measurements were used.

Growth statistics for the groups of marked fish were determined by first calculating an average length for each group. The predicted weights for these lengths were then calculated from the appropriate length weight regression, and these weights were used to establish absolute and relative size increases and the instantaneous growth rate using formulas given in Ricker (1975). The difference in the size of smolts between each pond was tested with an unpaired T test for unequal sample sizes (Snedecor and Cochran 1967).

Ricker (1958) points out that the calculated weight of the mean length fish from a population is not the population's mean weight since weight increases as the cube of length. However, Pienaar and Ricker (1968) give methods for predicting mean weight from length statistics. These methods were applied and it was found that the predicted weight of the mean length fish underestimated the population mean weight between 2 and 4 percent in the fall and 1 and 2 percent in the spring. In the comparative application of growth statistics in this study this error is insignificant; therefore all growth statistics and production values are based on calculated weights from mean lengths.

Since traps were inoperable for very short periods and only during winter storms, the total number of fall immigrants had to be estimated. This was done in two ways each for a specific application.

There were six days when daily fish counts were incomplete. To complete the analysis in Figure 10 these missing counts had to be estimated. I assumed that the rate of immigration during trap inoperation was the same as the two days previous and subsequent to the inoperative period. The number of hours when the trap was inoperable was multiplied times an average hourly rate of fish passage (developed from counts two days prior and subsequent to the missing count). The product of these figures was taken as the incomplete fish count for that day.

The second method gives a better estimate of the total number of fall immigrants and assumes that: 1) all smolts were caught, 2) all branded smolts were identified and 3) the only recruitment to the smolt population came from the fall immigrant population. This method solves the equality given in equation 1 and uses the ratio of marked smolts to the total number of smolts and the number of marked fish in the fall over the unknown variable, the total number of fall immigrants.

$$\frac{\text{NO. MARKED FISH IN FALL POP.}}{\text{X (UNKNOWN FALL POP. SIZE)}} = \frac{\text{NO. MARKED FISH IN SPRING POP.}}{\text{NO. SMOLTS FROM FALL POP}} \quad (1)$$

Assumption three is invalid because there are some large two year old smolts that cannot be accounted for from the fall population. To identify the number of these smolts, the percentage of fish greater than an "arbitrarily large" length was determined for the fall population. This length was selected so that when the average length increase over the winter was added to it the sum would approximate the length of two year old smolts as determined from scale analysis. The percentage of smolts greater than this new calculated length was then determined. Any increase in the percentage of these "large" fish above what would be expected, given the percentage in the fall population and overwinter survival, was interpreted as recruitment from sources other than the fall immigrants. Two possible sources for these fish exist; either they had remained in pond residence a second year after immigration as subyearlings or had immigrated to the pond as fry and experienced unusually rapid growth their first summer. Before solving equation 1 the number of these smolts was subtracted from the outmigrant population size

Overall survival rates were determined by dividing the number of marked smolts by the number of fish marked in the fall. Population survival curves were defined with three points. The first is based on the number of fish marked entering the pond in the fall, and the last is the number of marked smolts emigrating from the pond. The intermediate point estimates population size in late February and is calculated by dividing the smolt population by the absolute survival from February until outmigration (as determined from marking experiments). Instantaneous mortality rates were computed using the formula given in Ricker (1975).

Total production, production per m^2 per day and net yield per m^2 were calculated only for the fall immigrant coho population, using the usual techniques given by Ricker (1975).

Benthos

Field Sampling

Benthos samples were collected from each pond on the same days, in December, February and April. Sampling in each pond was stratified by three stations selected for depth and substrate character (Figs. 6 and 7). Three replicate samples were taken at each station on all sampling dates.

Core samples were removed with a 10 cm diameter by 40 cm deep sampler fabricated of 18 gauge sheet metal (Fig. 8). The bottom of the corer was sharpened to cut roots and detrital material. This method removed an undisturbed sample from the flocculent organic sediments of the ponds. Cores were washed through a 420 micron sieve and preserved in 70% ethanol.

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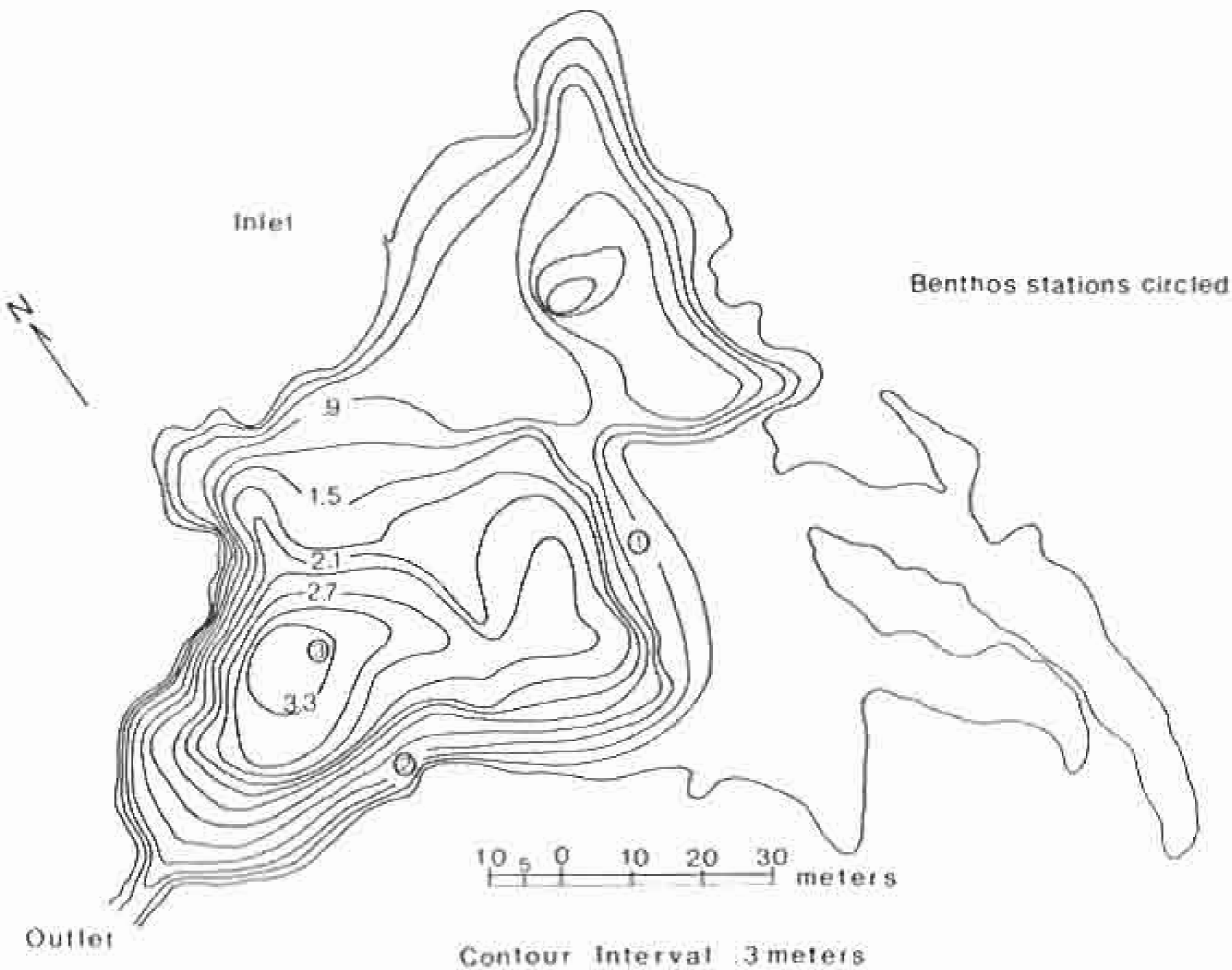

Fig. 6. Bathymetric chart of Copper Mine Bottom Pond.

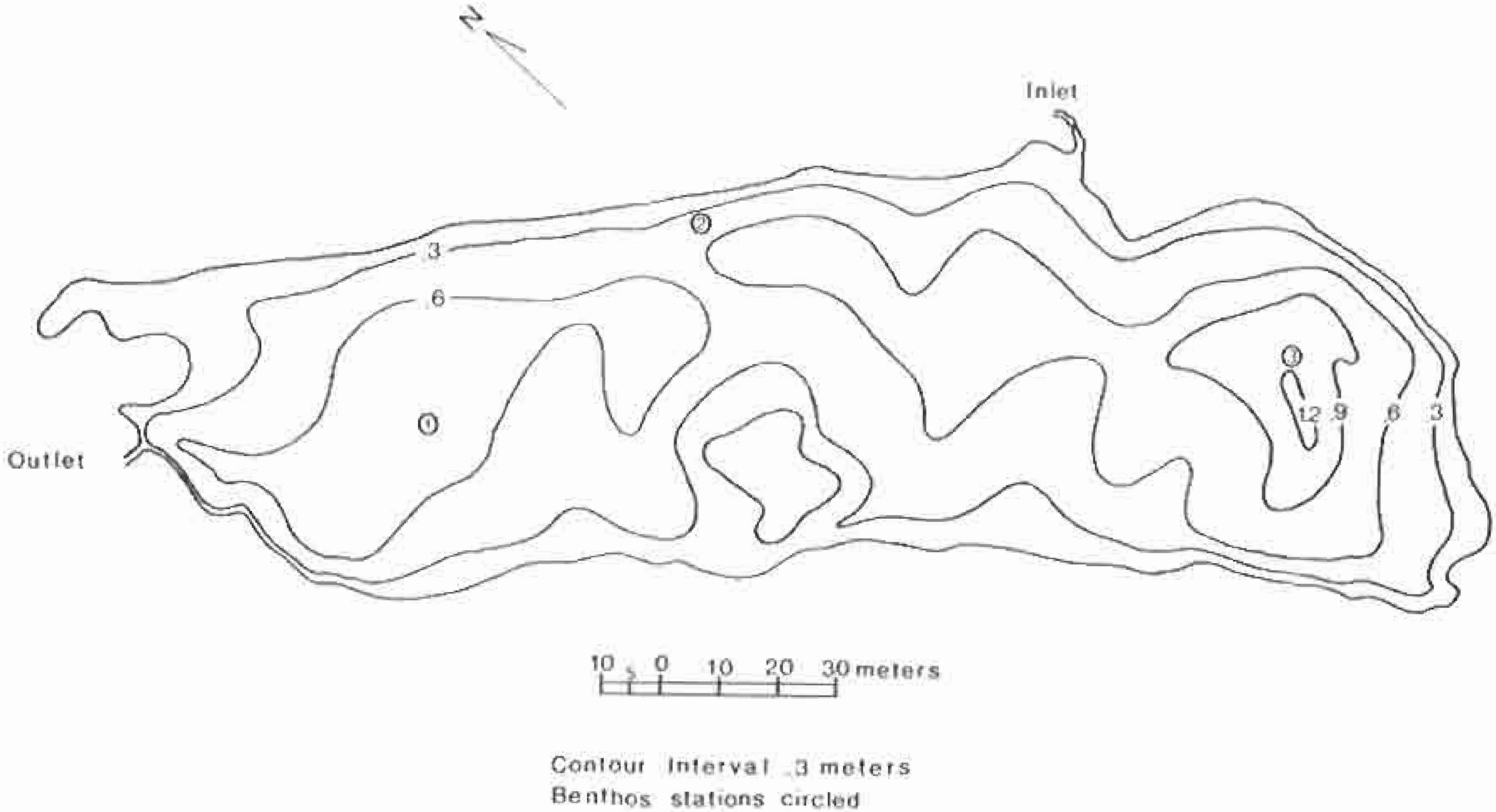

Fig. 7. Bathymetric chart of Gross Bridge Pond No. 2.

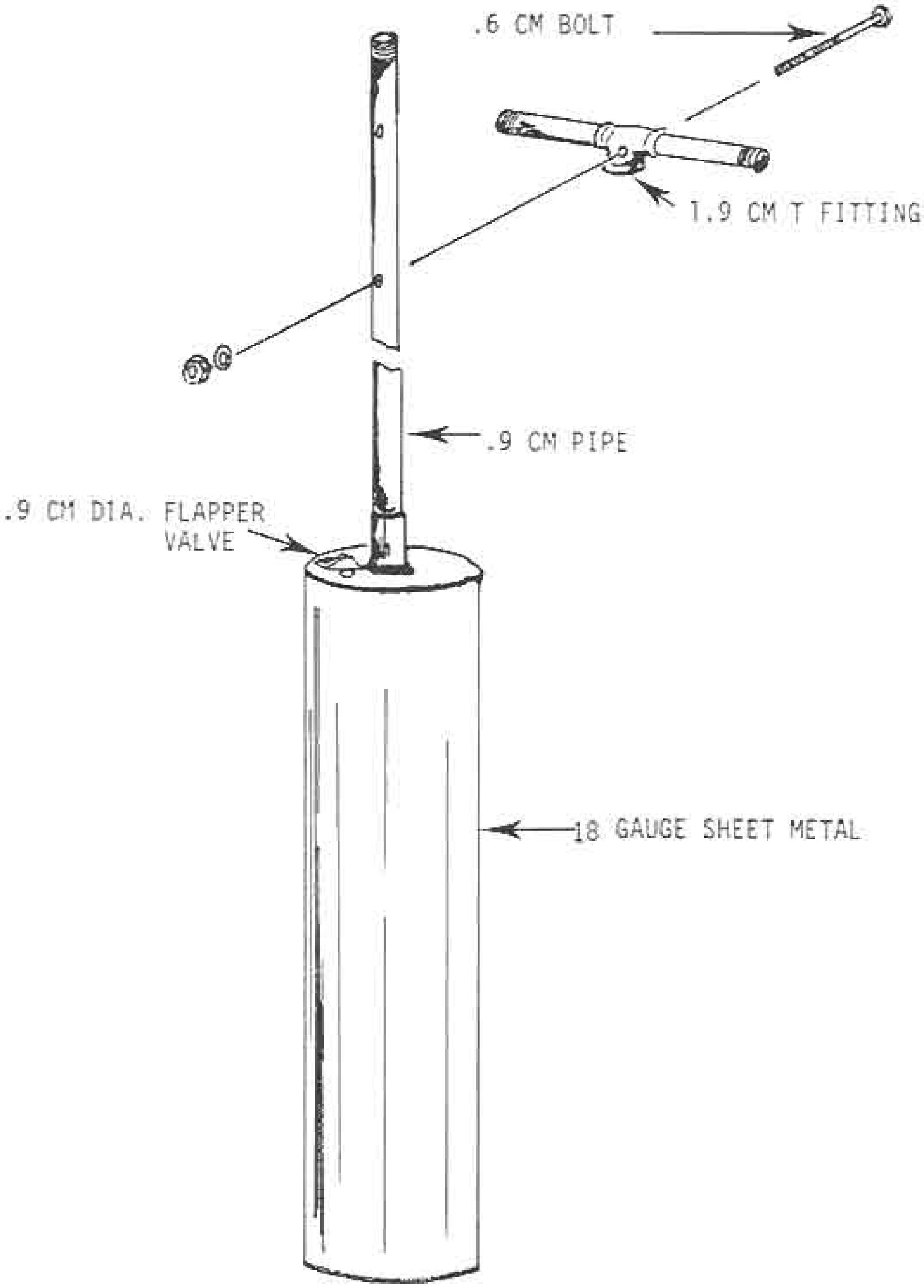

Fig. 8. Benthos core sampler.

Laboratory Processing

Insects were separated from the detritus in a white enamel pan under an illuminated magnifier with a three diopter bi-convex lens. Most insects were identified to family. They were then counted and placed on predried and weighed filters for drying at 60°C for 24 hours and reweighed to the nearest .1 mg on a Metler H35AR electronic balance.

Count and weight data were analyzed for independence of variance and distribution character (Elliott 1977). These tests indicated that count data should be transformed to logarithms but that weight data were suitable for parametric testing.

To test differences in the benthic insect standing crops between ponds a three way analysis of variance (ANOV) with interactions was used. The variables tested were sample dry weights and transformed sample counts. Pond, month, and station were held as main effects for the three way ANOV. A two way ANOV was used to test within ponds for differences due to the effects of month and station.

Mean dry weight per m^2, derived mean numbers per m^2 and associated 95% confidence intervals were calculated from strata means and their associated variances (Snedecor and Cochran 1967).

Food Habits

Field Sampling

Stomach contents from 30 and 15 fish from Pond 2 and Copper Mine Bottom, respectively, were collected on consecutive days in

February. Weather conditions on both days were identical. Fish were captured by netting after they were stunned with a Coeffelt electro shocker powered by a portable generator and operated from a small aluminum boat.

Contents of the foregut were flushed using techniques described by Meehan and Miller (1978). They showed this method can remove 96 percent of the stomach content by weight from 52-92 mm coho salmon with no observable mortality. Stomach contents were preserved in 45 percent ethanol.

Laboratory Processing

Prey items from each stomach sample were sorted into taxonomic groups, usually family. All items from each group were placed on a predried and weighed 4.5 cm GF/A filter. Unidentifiable material left after sorting was filtered onto another filter. All filters and contents were then dried at 60°C for 24 hours and reweighed to the nearest .1 mg. on a Metler H35AR electronic balance.

Data was processed through a food habit analysis program developed at the Fisheries Research Institute, University of Washington (Swanson and Simenstad 1978).

Stomach content weights, expressed as a percent of the dry weight of the fish, (assumed to be .20 wet weight) were compared between ponds with non-parametric rank tests.

Maps, Hydrograph, Temperature, Dissolved Oxygen and Water Chemistry

Maps of both ponds (Figs. 6 and 7) were developed using standard survey methods. Shoreline hubs were located and intermediate positions shot to outline the pond. Depth soundings were located similarly as a man in a boat traversed the pond with a rod. About 300 shots were taken for each pond. Maps were drawn and contour depths interpolated by hand. Total surface area and area of depth contours were calculated with a compensating polar planimeter.

A continuous water level recorder is positioned at river mile 15.5 on the Clearwater River and maintained by the Forest Hydrology Research Unit from the University of Washington, College of Forestry. Discharge equations and a computer program developed by the Forest Hydrology Unit were used in constructing the hydrograph of the Clearwater River. Level records from staff gauge readings in the ponds and discharge measurements taken with a pigmy, Gurley current meter were used in calculating the discharge of pond outlets.

Pond temperatures were recorded by continuous recording Partlow thermographs at .3 m (1 ft) depth. Pond outlet temperature was similarly monitored at the mouth of the outlet streams and temperature of the Clearwater River was recorded on a Honeywell continuous recording thermograph at river mile 15.5.

Water samples taken at three stations at several depths for dissolved oxygen determinations were analyzed using an azide modification of the Winkler method.

Water samples for chemical analysis were collected in acid washed, 1 liter bottles at the spring sources, in the ponds, at the mouth of the outlet streams and in the Clearwater River. The analysis was contracted to the Washington Department of Ecology water quality laboratory.

RESULTS

Fish Observations

Recruitment of Coho to the Ponds

Some movement into the ponds occurs in most months, but there are two major periods of coho recruitment to the ponds. Small numbers of coho fry immigrate into the ponds from early spring through early summer but the major recruitment occurs when fingerling immigrate into the ponds in the fall and early winter. These distinct recruitment periods coincide with the dispersive stream colonization phase of fry behavior and the winter habitat preference changes of fingerling.

Magnitude and Timing of Pond Immigration. Between August 29, 1977 and March 7, 1978, 3,297 and 4,029 juvenile coho were caught as they migrated into Copper Mine Bottom and Pond 2, respectively (Table 2). Because of short periods of time when traps were not operating, estimates of total coho numbers entering for this same period are 4,150 and 4,710 for Copper Mine Bottom and Pond 2, respectively.

A more conservative technique of estimation, the first one described in the Methods section, estimated that 390 and 435 coho bypassed the Copper Mine Bottom and Pond 2 trap respectively. This method was used in the analysis illustrated in Figures 9 and 10 because it estimates incomplete daily counts.

Between October 23 and November 30, 1977 82 and 88 percent of

Table 2. Numbers of juvenile coho in the fall upstream migration and spring smolt migration from Copper Mine Bottom and Pond 2.

POND	NUMBER OF FALL POND IMMIGRANTS		NUMBER OF SPRING DOWNSTREAM MIGRANTS
	Actually Counted	Total Estimate	
COPPER MINE BOTTOM POND	3,297[1]	4,150	3,613[2]
GROSS BRIDGE POND NO. 2	4,029[3]	4,710	1,534[4]
TOTAL	7,326	8,860	5,147[5]

[1]From 8-29-77 to 3-7-78 inclusive.
[2]From 1-1-78 to 8-4-78 inclusive.
[3]From 8-29-77 to 3-7-78 inclusive.
[4]From 12-1-77 to 7-21-78 inclusive.
[5]Includes smolts resulting from two-year pond residents and fry immigrating early in their first summer, 373 in Copper Mine Bottom and 34 in Pond 2.

the immigrating coho entered Copper Mine Bottom and Pond 2, respectively. Observed peak fish movement into Pond 2 occurred on October 24, 1977 when 353 coho were captured in a 24-hour period. Fish movement into Copper Mine Bottom through this period was also high and on November 4, 1977 a record 212 fish were caught in a 24-hour period in the Copper Mine Bottom trap.

Early summer fry recruitment to Pond 2 was not measured, but a block in the outlet stream likely prevented most fry passage. Between February 1 and August 29, 1977 about 450 coho fry immigrated into Copper Mine Bottom.

Pond migrations are not random phenomena. Movement into the pond correlates directly with flow fluctuations in the Clearwater River (Fig. 9). Regardless of season, when discharge of the Clearwater suddenly increases many juvenile coho respond by seeking refuge in tributary spring ponds.

The predictability of this relationship was tested by performing a correlation analysis with the LOG_{10} of the daily total number of fish entering both ponds, and the LOG_{10} of the corresponding peak daily discharge of the Clearwater River. Only data from August, September, October and November were included, since by the end of November major recruitment to the ponds was over. An r^2 value of .71 was obtained through the correlation analysis that used the 165 data pairs of daily fish counts and peak daily discharge from August through November (Fig. 10).

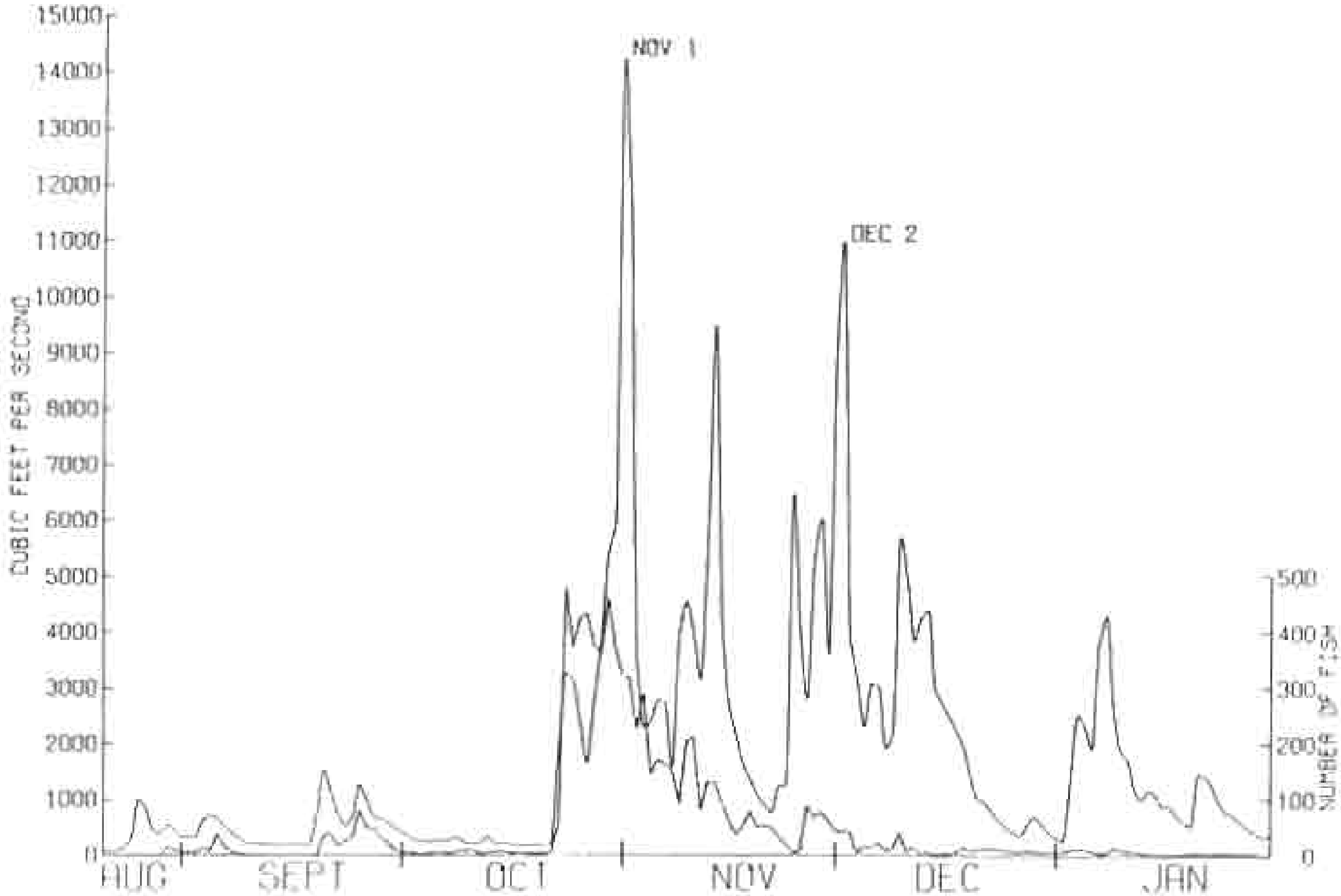

Fig. 9. Plot of the peak daily discharge of the Clearwater River and the total number of fish entering both ponds. The shaded area represents fish numbers and the scale is on the right vertical axis.

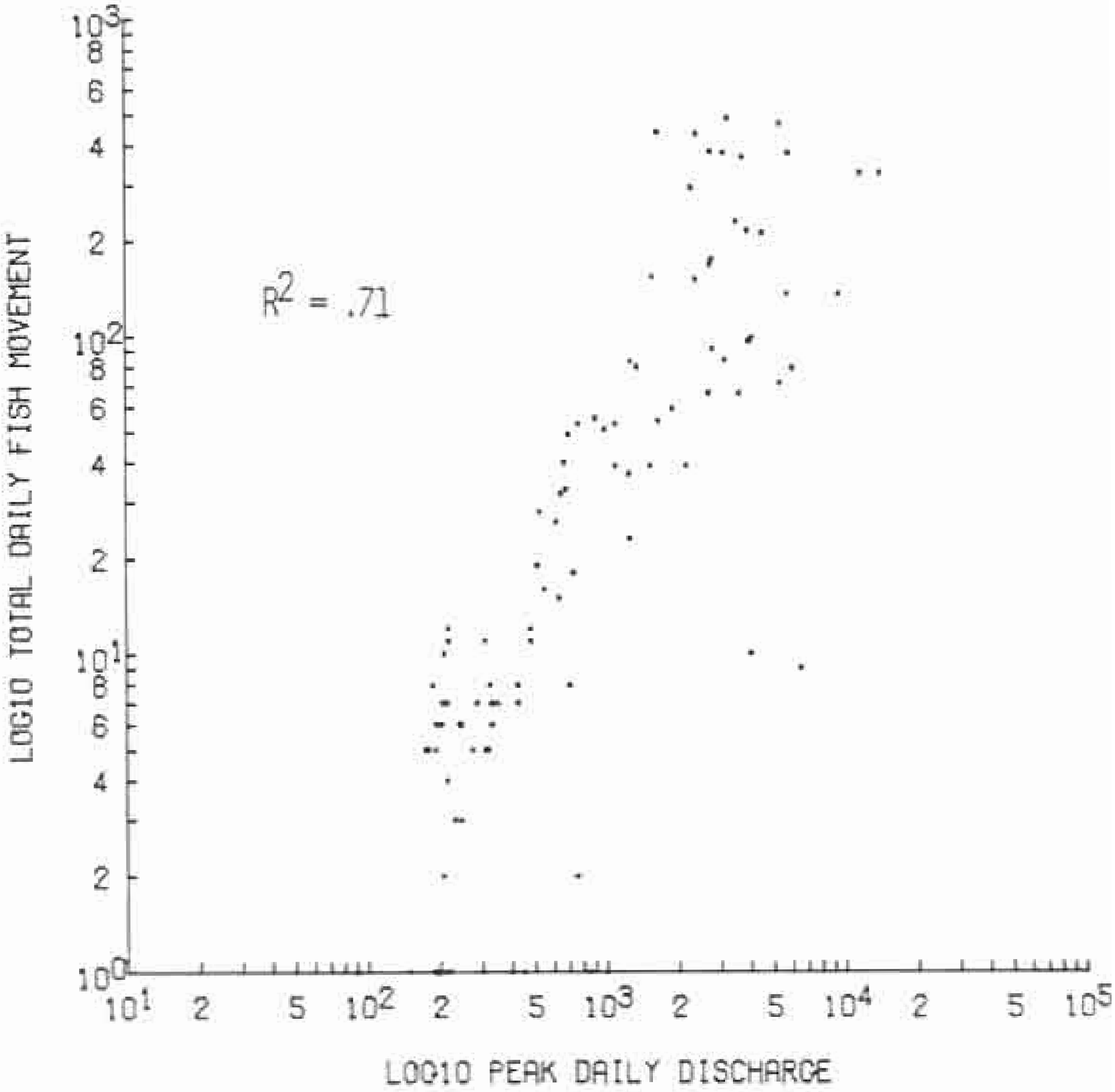

Fig. 10. Correlation analysis of the Log_{10} peak daily discharge and the Log_{10} of the total number of juvenile coho entering both ponds.

Summer Rearing Locations of Fall Recruits. Of the 409 juvenile coho branded and released in the Clearwater River in August and September of 1977, 39 marked fish, or 9.4 percent of the total, were recaptured at the pond traps during the fall immigration. Percent recovery from marked groups ranged from a high of 20.6 percent for the LAEV group to a low of 3.0 percent for the LAWV group (Table 3).

All recaptured fish had moved downstream from the marking location except one. The one exception had travelled a minimum of .5 km (.3 mi) upstream to Copper Mine Bottom and was from the LAWV group (Fig. 11). This group also had the lowest recapture rate (Table 3).

The longest distance travelled by a marked fish was 32.6 km (20.3 mi). This individual was from the RANV group, branded and released just downstream from Susie Creek (Fig. 11) on September 10, and recaptured in the Pond 2 trap on October 28 (Appendix Table A-1). Three other fish from this group were captured in the Copper Mine Bottom trap, one each on October 31, November 9 and November 19. They had travelled 24.9 km (15.5 mi) downstream.

All fish recaptured from the LASV and LPSV groups which were all released upstream from Copper Mine Bottom (Fig. 11) were recaptured in the Copper Mine Bottom trap. However, some fish from the RANV and LPNV groups, which were also all released upstream from Copper Mine Bottom, bypassed it and were recaptured in the Pond 2 trap.

Table 3. Location of groups of juvenile coho marked in the summer of 1977, their distance from the mouth of the Clearwater River, number and median length of group and recapture data.

MARK	LOCATION OF GROUP	DISTANCE[1]	NUMBER OF FISH IN GROUP	MEDIAN LENGTH IN mm	TOTAL NUMBER RECAPTURED	PERCENT RECAPTURE FROM GROUP	NUMBER RECAPTURE TO		PERCENT RECAPTURE TO	
							CMB	Pond 2	CMB	Pond 2
RANV	400 m below Susie Ck.	54.4 km (33.9 mi)	97	66	4	4.1	3	1	75	25
LPSV	Manor Ck. Downstream to Bull Ck.	35.7 km (22.3 mi)	16	89	2	12.5	2	0	100	0
LPNV	Bull Ck. Downstream to Deception Ck.	34.1 km (21.3 mi)	72	90	8	11.1	3	5	37.5	62.5
LASV	Deception Ck. Downstream to Copper Mine Bottom	30.9 km (19.3 mi)	43	86	4	9.3	4	0	100	0
LAWV	Copper Mine Bottom Downstream to Peterson Ck.	29.5 km (18.4 mi)	67	90	2	3.0	1	1	50	50

Table 3. Location of groups of juvenile coho marked in the summer of 1977, their distance from the mouth of the Clearwater River, number and median length of group and recapture data.

MARK	LOCATION OF GROUP	DISTANCE[1]	NUMBER OF FISH IN GROUP	MEDIAN LENGTH IN MM	TOTAL NUMBER RECAPTURED	PERCENT RECAPTURE FROM GROUP	NUMBER RECAPTURE TO CMB	NUMBER RECAPTURE TO Pond 2	PERCENT RECAPTURE TO CMB	PERCENT RECAPTURE TO Pond 2
LAEV	Peterson Ck. Downstream to Christmas Ck.	27.0 km (15.6 mi)	34	89	7	20.6	0	7	0	100
LANV	Christmas Ck. Downstream to Pond 2	23.1 km (13.6 mi)	80	87	12	15.0	0	12	0	100

[1] Distance from the mouth of the Clearwater to upper boundary of mark section.

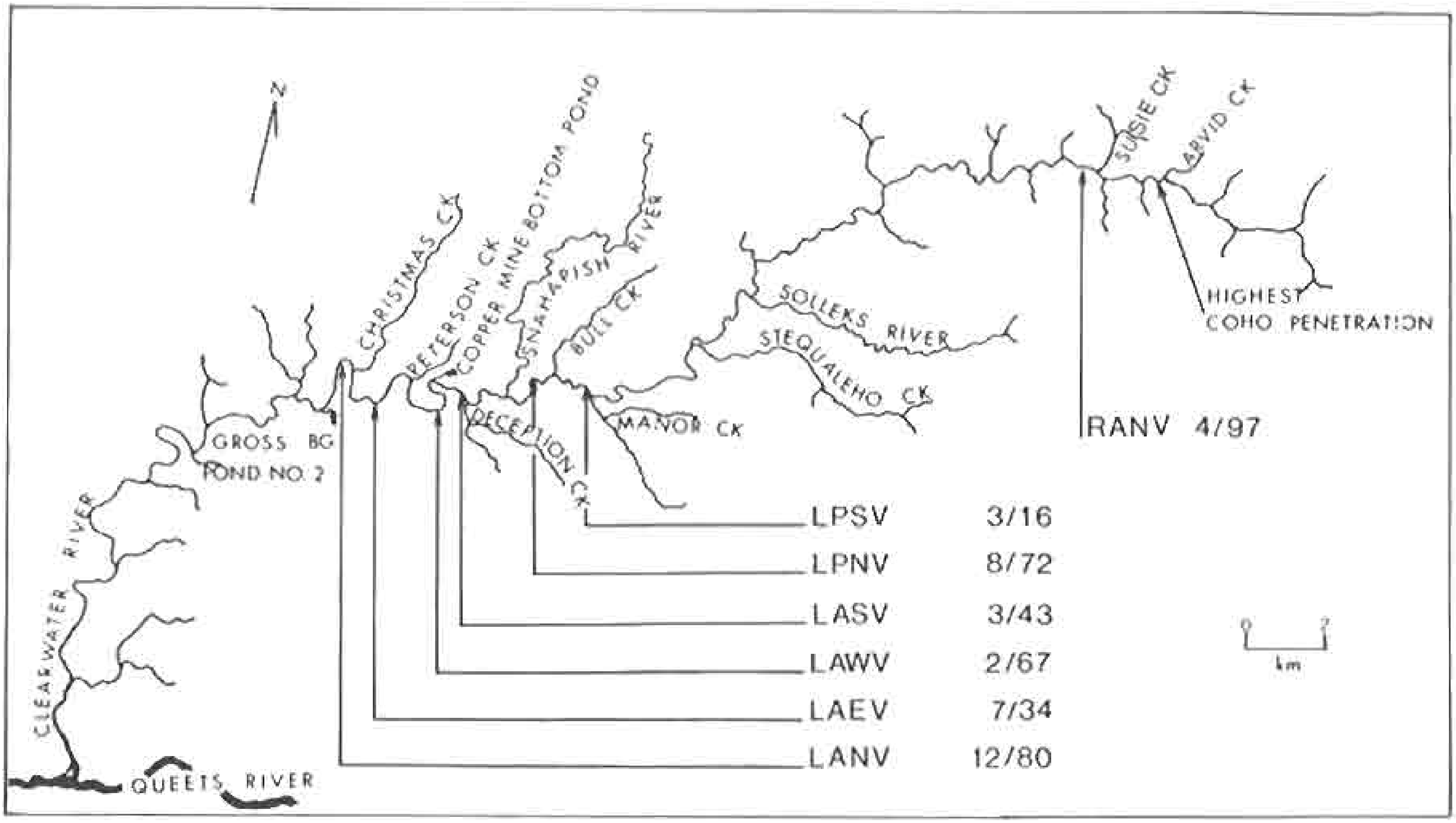

Fig. 11. Map of the Clearwater River showing locations of branded groups of juvenile coho. Brand codes are followed by the number of fish recaptured at pond traps over the total in group.

Smolt Migrations

The coho smolt migration from Copper Mine Bottom numbered 3,613, of which 3,240 were fall immigrants (Table 2). Pond 2 produced 1,534 downstream migrants, of which about 1,500 were fall immigrants.

Peak outmigration differed by more than a month between study ponds. On March 26, 1978 downstream migration peaked in Pond 2 when 328 fish emigrated in a 24-hour period. During the preceding 24 hours a high of 229 fish emigrated from Copper Mine Bottom but median outmigration from Copper Mine Bottom did not occur until April 25, 1978 and emigration remained high through the first two weeks of May.

Size of fish appeared to be important in the timing of the smolt migrations as the Pond 2 smolts which were larger than the Copper Mine Bottom smolts emigrated first. Larger fish within each pond also migrated before their smaller cohorts. Fish emigrating from Pond 2 in March were very consistent in outward signs of smoltification. All fish were very silvery and had the characteristic dark tipped caudal fins of coho smolts. Copper Mine Bottom downstream migrants, throughout most of the spring were a mixture of smolts and presmolts. The other important factor in outmigration timing was discharge. The peak in the outmigration in March from both ponds coincided with a spring storm that more than doubled the discharge of streams in the Clearwater.

During March the percentage of smolts emigrating from Copper Mine Bottom that were marked was 16.6. Later in May this percentage increased to 18.8. Many of the March smolts were large, and the infestation by parasitic *Neascus sp.* was 9.9 percent, as compared with the

1.5 percent parasitism of the May smolts. These data indicate that many smolts emigrating from Copper Mine Bottom in March were two year old smolts from the previous winter's population or large one year old smolts that had immigrated to the pond as fry early in their first summer.

Growth in Pond Populations

Growth of coho between study ponds differed significantly. The average size of smolts from all groups in Pond 2, when compared with the same group in Copper Mine Bottom, was statistically different ($P < .01$). These size differences are even more significant since the fish from Pond 2 spent considerably fewer days in pond residence because of earlier outmigration (Table 4). However, the overall instantaneous growth rates which incorporate this time element may be misleading. These rates reflect a period of no growth which was different in each pond. This influence may affect the instantaneous rates more than actual differences in daily growth increments between the ponds during the period of time when fish were growing.

Between their fall entry to the pond and the end of February, fish in Copper Mine Bottom did not grow at all. The large 95 percent confidence interval for the February average weight of the RMNV group (fish entering the pond in the first week of November and > 80 mm in length) (Fig. 12) is a function of the small sample size of RMNV-marked fish captured while boat shocking ($N = 8$). This interval includes the fall entry size of this group to Copper Mine Bottom. Even if all

Table 4. Absolute and relative weight increase and instantaneous growth rates of juvenile coho in marked groups in Copper Mine Bottom and Pond 2.

MARK	POND	MEDIAN DATE IN OR MARKED	MEDIAN DATE OUT OR RECAPTURED	MEDIAN RESIDENCE IN DAYS	NUMBER IN	NUMBER OUT	MEAN SIZE IN GRAMS	MEAN SIZE OUT GRAMS	AVERAGE INCREASE ABSOLUTE GRAMS	AVERAGE INCREASE RELATIVE PERCENT	INSTANTANEOUS GROWTH RATE (G)
RMNV	CMB	11-07-77	04-25-78	169	578	464	8.77	13.09	4.37	49.26	.002370
	Pond 2	11-10-77	03-21-78	131	408	127	9.34	18.14	8.80	94.22	.005067
RMNV	CMB	11-07-77	02-25-78	110	578	8[1]	8.77	8.54	-.23	-2.6	-.000242
	Pond 2	11-10-77	02-26-78	108	408	13[1]	9.34	17.05	7.71	82.55	.005573
AD	CMB	11-03-77	04-27-78	175	133	106	8.90	13.50	4.60	51.69	.002381
	Pond 2	11-02-77	03-24-78	142	258	79	9.43	19.21	9.78	103.71	.005011
RMSV	CMB	11-08-77	05-12-78	185	39	29	4.59	12.17	7.58	165.14	.005271
	Pond 2	11-10-77	03-30-78	140	26	7	5.11	19.31	14.20	277.89	.009496
RMNT	CMB	11-29-77	05-03-78	155	49	25	7.87	12.33	4.46	56.67	.002897
	Pond 2	11-29-77	03-26-78	117	101	11	8.72	16.40	7.68	88.07	.005399
RMST	CMB	11-30-77	05-12-78	163	12	8	5.04	13.50	8.46	167.86	.006045
	Pond 2	11-29-77	03-30-78	121	11	1	4.97	17.60	12.63	254.12	.010450
RPEV	CMB	02-25-78	05-04-78	68	64	51	9.49	13.89	4.4	46.37	.005602
	Pond 2	02-26-78	03-26-78	28	112	55	16.89	19.95	3.06	18.12	.005947
LPEV	Pond 2 only	03-21-78	04-17-78	27	36	21	18.24	22.62	4.38	24.01	.007971

[1] Recaptured in February by boat shocking.

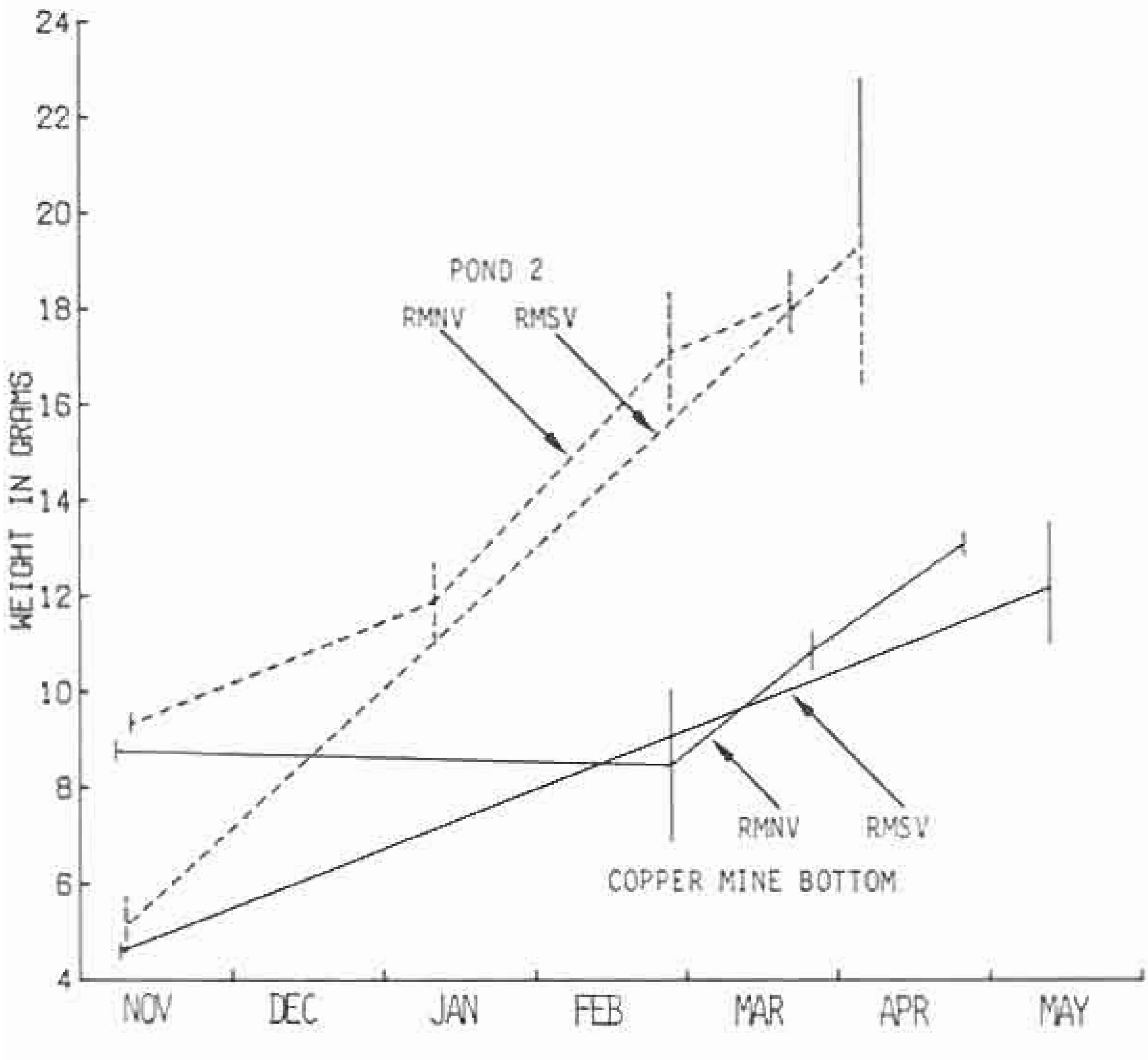

Fig. 12. Absolute growth of two size groups of juvenile coho in Copper Mine Bottom and Pond 2.

fish sampled from the pond in February are included without regard to marks (N = 65), the average size increase is only .72 grams, just an 8.2 percent average increase instead of the -2.6 percent decrease (Table 4), calculated only for the RMNV fish.

During this same period fish in the same group (RMNV) in Pond 2 had increased their weight by an average of 82.6 percent, or 7.71 grams (Table 4). The relatively wide confidence interval around the February average weight of the Pond 2 fish is also a function of the small sample size of RMNV-marked fish captured while boat shocking (N=13). However, if the sizes of all fish sampled (N = 135) are averaged, the increase is still 80.8 percent or an average increase of 7.55 grams.

The January and March sample points for the RMNV groups from Pond 2 and Copper Mine Bottom (Fig. 12) are the average sizes of RMNV-marked fish emigrating in a three day period at those times. Since larger smolts migrate first, these points overestimate the average size fish in the population. However, these points place upper limits on fish size at those times and are included only to help define the growth curves.

Individuals in the small fish size groups (RMSV) at pond entry, caught up in size with their larger cohorts (RMNV-marked fish), by spring outmigration (Table 4). Since the number of fish in these groups was small, I was not able to collect enough marked fish in February by boat shocking, nor did enough emigrate early to calculate averages for intermediate points on the growth curves in Figure 12;

therefore the RMSV growth curves are depicted by straight lines connecting their average size at immigration and emigration (Fig. 12). These smaller fish remained in the pond an average of 16 and 9 days longer than their larger cohorts in Copper Mine Bottom and Pond 2, respectively. A comparison of their instantaneous growth rates with those of their larger cohorts in the respective pond show that the smaller fish grew faster.

A result of the faster growth of the smaller fish was the tightening of the length frequency distributions between the fall and spring populations. This tendency towards a more kurtose distribution was not as noticeable in Copper Mine Bottom (Figs. 13 and 14) as it was in Pond 2 (Figs. 15 and 16). A slight size-selective mortality on the smaller fish (as determined from marking) may have played a very minor role in this distributional shift.

Survival of Pond Populations

Absolute survival in all groups was markedly higher in Copper Mine Bottom than in Pond 2. The RMNV group in Copper Mine Bottom had an 80.3 percent survival, whereas in Pond 2 this same group had a 31.1 percent survival (Table 5). Since residence time was significantly different between ponds, a comparison of the instantaneous mortality rates is useful. These rates show that fish in Pond 2 did have a much higher mortality than those in Copper Mine Bottom (Table 5).

Smaller fish in both ponds did not survive as well. Absolute survival of fish in the small size group (RMSV) was 5.9 and 4.2

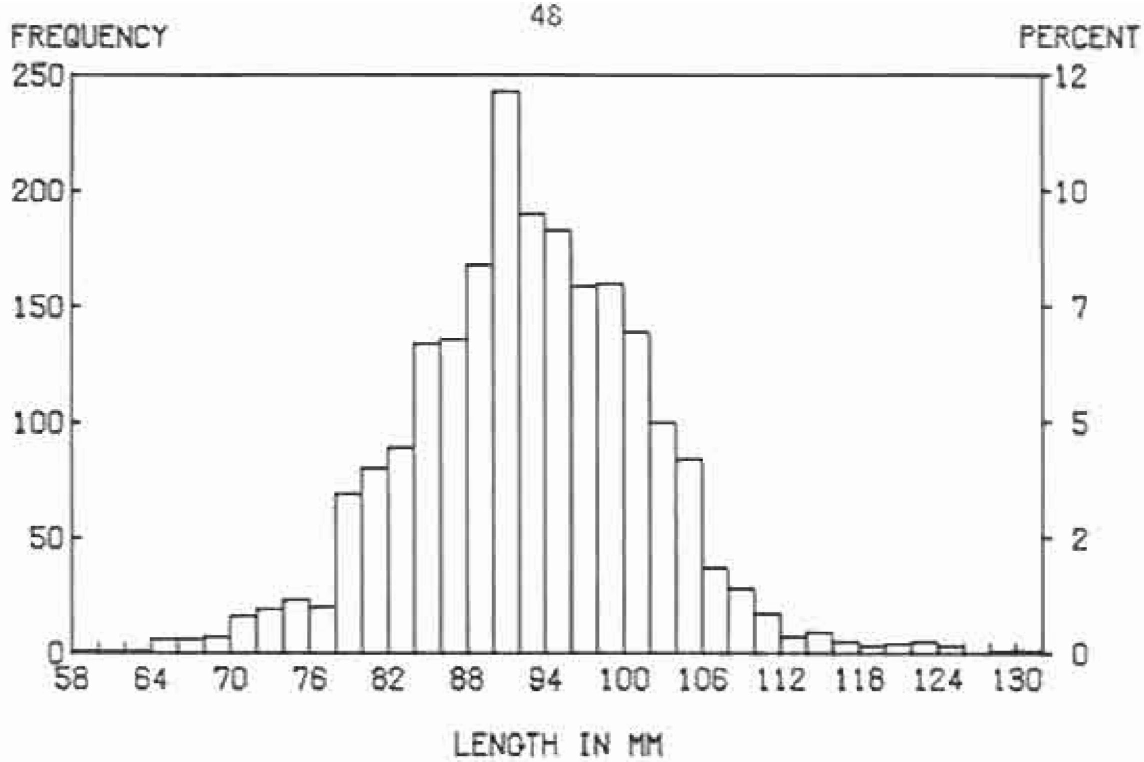

Fig. 13. Length frequency histogram of the fall population of juvenile coho in Copper Mine Bottom.

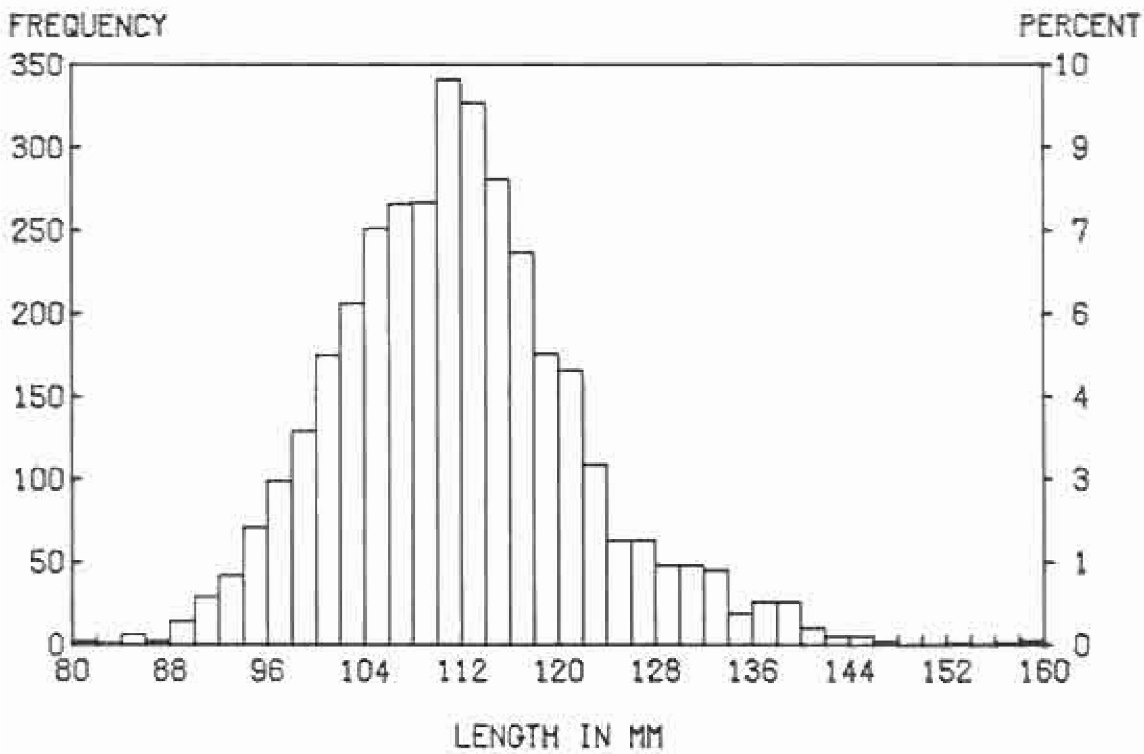

Fig. 14. Length frequency histogram of the spring population of juvenile coho in Copper Mine Bottom.

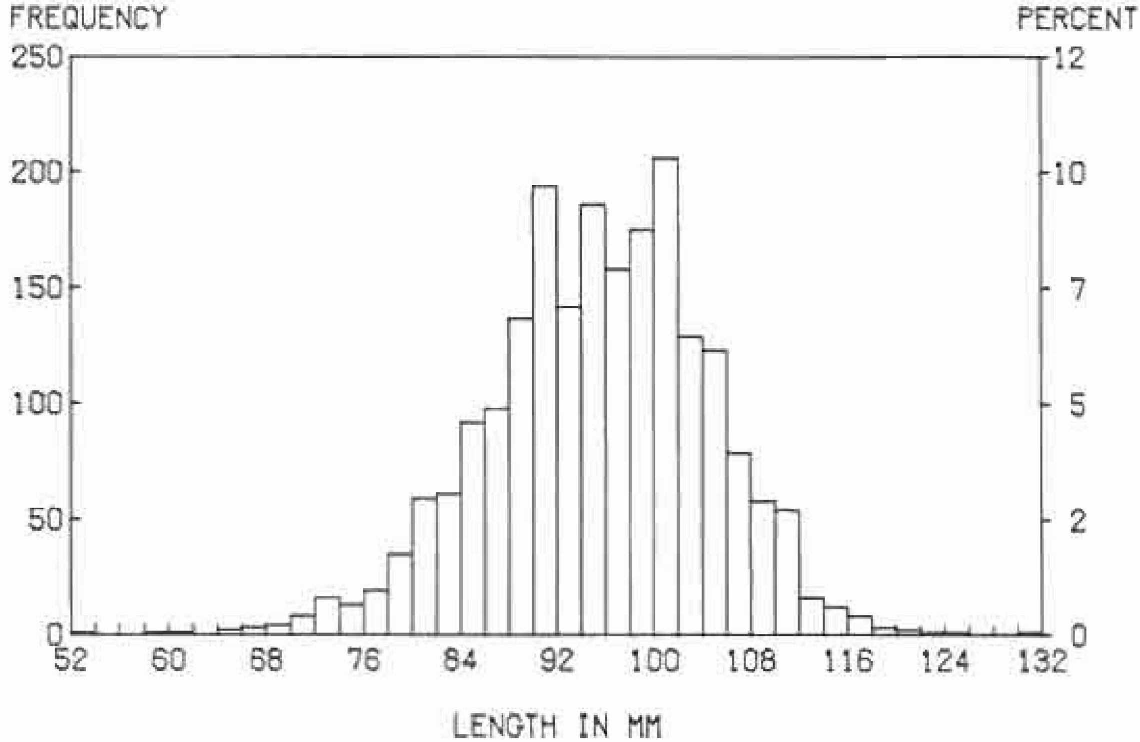

Fig. 15. Length frequency histogram of the fall population of juvenile coho in Pond 2.

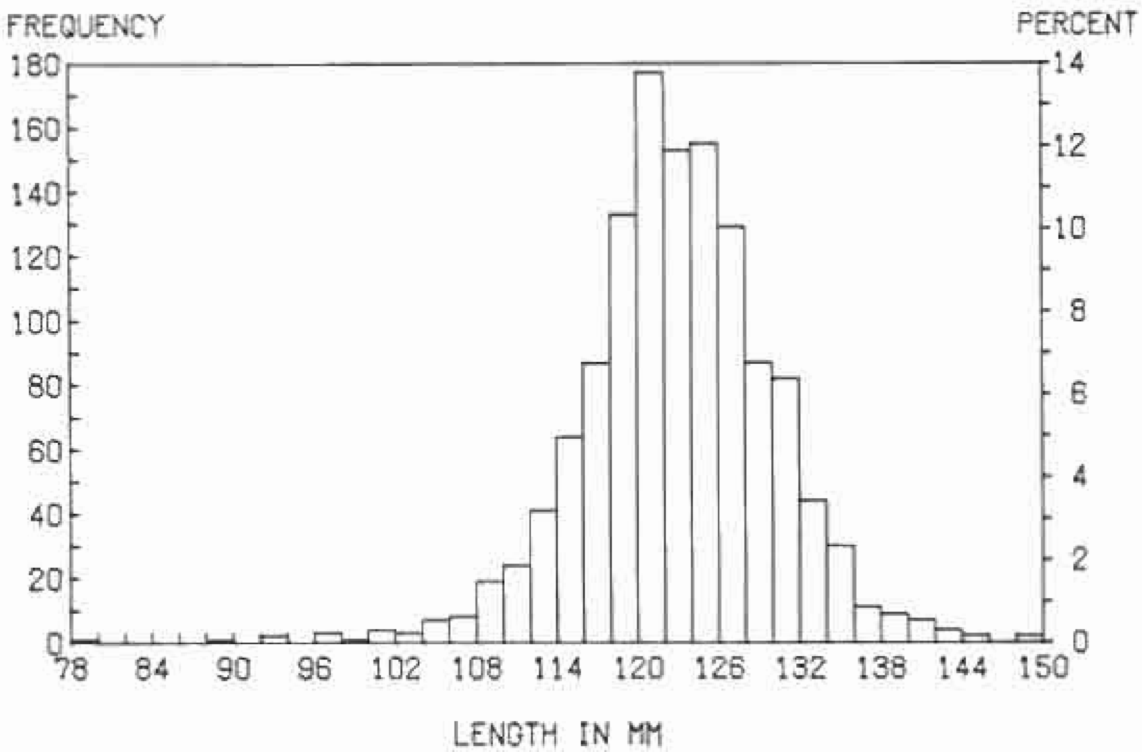

Fig. 16. Length frequency histogram of the spring population of juvenile coho in Pond 2.

Table 5. Absolute survival and instantaneous mortality rates of juvenile coho in marked groups in Copper Mine Bottom and Pond 2.

MARK	POND	MEDIAN DATE IN OR MARKED	MEDIAN DATE OUT	MEDIAN RESIDENCE IN DAYS	NUMBER IN	NUMBER OUT	PERCENT ABSOLUTE SURVIVAL	INSTANTANEOUS MORTALITY RATE (z)
RMNV	CMB	11-07-77	04-25-78	169	578	464	80.3	.00130
	Pond 2	11-10-77	03-21-78	131	408	127	31.1	.00891
AD	CMB	11-03-77	04-27-78	175	133	106	79.7	.00130
	Pond 2	11-02-77	03-24-78	142	258	79	30.6	.00834
RMSV	CMB	11-08-77	05-12-78	185	39	29	74.4	.00160
	Pond 2	11-10-77	03-30-78	140	26	7	26.9	.00937
RMNT	CMB	11-29-77	05-03-78	155	49	25	51.0	.00434
	Pond 2	11-29-77	03-26-78	117	101	11	10.9	.01895
RMST	CMB	11-30-77	05-12-68	163	12	8	66.7	.00249
	Pond 2	11-29-77	03-30-78	121	11	1	9.1	.01982
RPEV	CMB	02-25-78	05-04-78	68	64	51	79.7	.00334
	Pond 2	02-26-78	03-26-78	28	112	55	49.1	.02540
LPEV	Pond 2 only	03-21-78	04-17-78	27	36	21	58.3	.01996

percent lower in Copper Mine Bottom and Pond 2, respectively. A comparison of the instantaneous mortality rates between the fish in the smaller size group (RMSV) and those in the larger size group (RMNV) shows that there was a size selective mortality. Copper Mine Bottom smaller fish (RMSV) had an instantaneous mortality rate of .00160 as compared with the larger fish (RMNV), which had a rate of .00130. Instantaneous mortality rates of the small fish in Pond 2 were .00937 as compared with .00891 for the larger fish.

The RMNT and RMST groups in both ponds had the poorest survival. Fish in these groups entered the ponds at the end of November after most of the fall population had already immigrated. Larger and smaller fish from this entry period survived nearly the same in Pond 2. This did not, however, hold true for Copper Mine Bottom as the RMST group (smaller fish) survived better than the RMNT group (larger fish). Numbers in these groups were small, so the size of the sample may have been a factor in this anomalous result.

Survival was not constant through time in either pond (Fig. 17). Between entry in November and the February sampling date, there had been little mortality in the Copper Mine Bottom population. In Pond 2 during this same period 40 percent of the population had died. During the spring months both pond populations had their highest mortality as the RPEV groups show (Table 5).

Production from Ponds

Total production attributable to the entering fall coho popula-

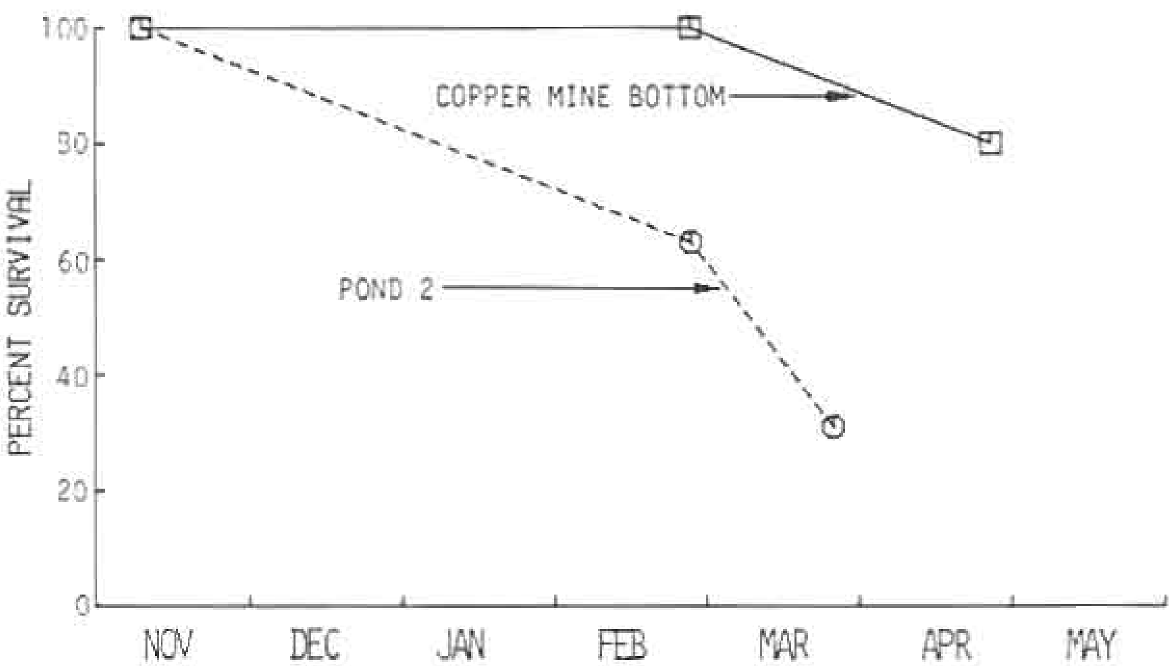

Fig. 17. Survival of pond populations through time.

tion was 209.4 and 483.5 grams in Copper Mine Bottom and Pond 2, respectively (Tables 6 and 7). As ponds receive only seasonal use, production was calculated on a daily or instantaneous rate. Production in g/m^2/day was .00015 and .00028 in Copper Mine Bottom and Pond 2, respectively, but probably a more useful unit of production when assessing the value of these areas is a net production or yield value. Copper Mine Bottom yielded 5.0 g/m^2 and Pond 2 2.3 g/m^2 during the spring outmigration in 1978.

Benthos

Larval stages of Diptera, mainly the Chironomidae, were the major taxonomic component, accounting for 85.2 and 78.5 percent of the benthos on a numerical basis in Copper Mine Bottom and Pond 2 respectively (Table 8). In Copper Mine Bottom the amphipods were the next largest group comprising 3.3 percent of the benthos numerically while the oligochates were secondarily important in Pond 2 accounting for 11.9 percent of the benthos numerically.

The three-way ANOV on sample dry weights showed the only significant main effect is due to pond ($P < .01$, Table 9). Other statistically significant sources of variability are the two-way interaction of month and station ($P < .05$), and the three-way interaction of pond, month, and station ($P < .008$). Overall significance level of the analysis to explain the variability between sample dry weights is .01. However, as can be seen from the size of the residual sums of squares, relative to the total sum of squares, there is still a considerable

Table 6. Production attributable to fall upstream coho population in Copper Mine Bottom from median entry date (November 11, 1977) through the median smolt migration date (April 25, 1978).

DATE	MEAN WGT. $\bar{W}$	INST. GROWTH G	STOCK NO. N	STOCK BIOMASS GRAMS B	MEAN BIOMASS GRAMS $\bar{B}$	PRODUCTION GRAMS
NOV.	8.77		4,152	36,395.0		
		-.000242			35,918.0	-8.69
FEB.	8.54		4,150	35,441.0		
		.005602			38,926.3	218.10
APRIL	13.09		3,240	42,411.6		

209.41 grams

* 169 days
1.24 g/day
.00015 g/m²/day

Table 7. Production attributable to fall upstream juvenile coho population in Pond 2 from median entry date (November 10, 1977) through median smolt migration date (March 21, 1978).

DATE	MEAN WGT. $\bar{W}$	INST. GROWTH G	STOCK NO. N	STOCK BIOMASS GRAMS B	MEAN BIOMASS GRAMS $\bar{B}$	PRODUCTION GRAMS
NOV.	9.34		4,710	43,991.4		
		.005573			46,488.9	259.1
FEB.	17.05		2,873	48,986.4		
		.005947			39,056.7	224.4
MARCH	18.14		1,460	29,127.0		

483.5 grams

* 136 days
3.56 grams/day
.0003 g/m²/day

Table 8. Representation of major taxa in benthos by numerical percentages for Copper Mine Bottom and Pond 2.

TAXA	COPPER MINE BOTTOM Percent by No.	POND 2 Percent by No.
NEMATOMORPHA	.10	.50
OLIGOCHAETA	1.31	11.94
HIRUDINEA	.20	.50
AMPHIPODA	3.33	.2
ASSELIDAE	.20	.78
HYDRACARINA	.10	.28
COLLEMBOLA	.71	.35
BAETIDAE	.20	1.84
COENAGIRONIDAE	.10	.71
LIMNEPHILIDAE	2.42	.85
CHRYSOMELIDAE	.00	1.00
SIALIDAE	.61	.00
CHAOBRIDAE	1.62	.20
CHIRONOMIDAE	85.17	78.45
ANCYLIDAE	.40	1.13
SPHAERIIDAE	2.63	1.82

Table 9. Results of three-way analysis for variance testing the differences in benthos sample dry weight between study ponds.

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIFICANCE OF F
MAIN EFFECTS	11.803	5	2.361	2.406	.056
Pond	7.216	1	7.216	7.355	.010
Month	.355	2	.178	.181	.835
Station	4.231	2	2.116	2.156	.130
2-WAY INTERACTIONS	14.089	8	1.761	1.795	.110
Pond Month	2.723	2	1.362	1.388	.263
Pond Station	1.056	2	.528	.538	.589
Month Station	10.310	4	2.578	2.627	.050
3-WAY INTERACTIONS	15.955	4	3.989	4.065	.008
Pond Month Station	15.955	4	3.989	4.065	.008
EXPLAINED	41.847	17	2.462	2.509	.010
RESIDUAL	35.321	36	.981		
TOTAL	77.168	53	1.456		

Table 10. Results of three-way analysis of variance testing the differences in logarithms of sample benthic organism counts between study ponds.

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIFICANCE OF F
MAIN EFFECTS	2.909	5	.582	8.651	.001
Pond	.898	1	.898	13.354	.001
Month	.335	2	.167	2.487	.097
Station	1.677	2	.838	12.463	.001
2-WAY INTERACTIONS	1.346	8	.168	2.502	.028
Pond Month	.041	2	.021	.307	.738
Pond Station	.322	2	.161	2.397	.105
Month Station	.983	4	.246	3.652	.013
3-WAY INTERACTIONS	1.868	4	.467	6.942	.001
Pond Month Station	1.868	4	.467	6.942	.001
EXPLAINED	6.123	17	.360	5.355	.001
RESIDUAL	2.421	36	.067		
TOTAL	8.545	53	.161		

amount of variability unaccounted for (Table 9).

The three-way ANOV using LOG_{10} transformed count data also indicates pond is a significant main effect ($P < .001$, Table 10). In this analysis station also has a significant ($P < .001$) influence on the transformed count data. The two-way interactions of month and station and the three-way interaction of all the main effects are also statistically significant in explaining variability among the logarithmically transformed counts.

The comparison between ponds of derived mean densities of all benthic organisms (Fig. 18) and the expanded dry weights per m^2 (Fig. 19) supports the major result of the three-way ANOV; that Pond 2 has a higher standing crop of benthic insects. Overall mean dry weights per m^2, .756 grams in Copper Mine Bottom and 1.687 grams in Pond 2, and the derived density of organisms, 2,930 per m^2 in Copper Mine Bottom and 5,332 per m^2 in Pond 2 also illustrate this result (Table 11).

Two-way ANOV of LOG_{10} transformed count data for Copper Mine Bottom, with station and month as main effects, indicates that station is statistically significant ($P < .01$) in affecting sample means (Table 12). Station number 3, located in water about 3.1 m (10 ft) deep (Fig. 5), had the lowest estimated mean number per m^2 on two of the three sample dates and is responsible for this significant source of difference. A two-way ANOV of the same data for Pond 2 does not indicate any statistically significant differences within the pond due to the effects of station, month or the two-way interaction term (Table 13).

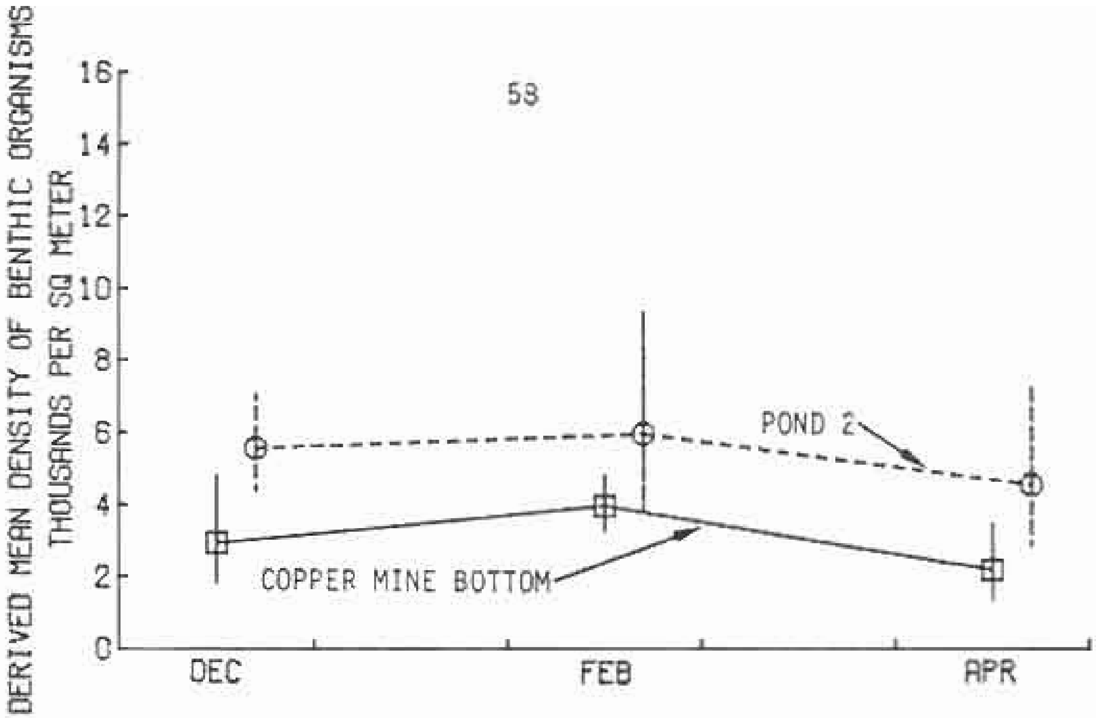

Fig. 18. Derived mean densities of all benthic organisms in Copper Mine Bottom and Pond 2 for three sampling dates.

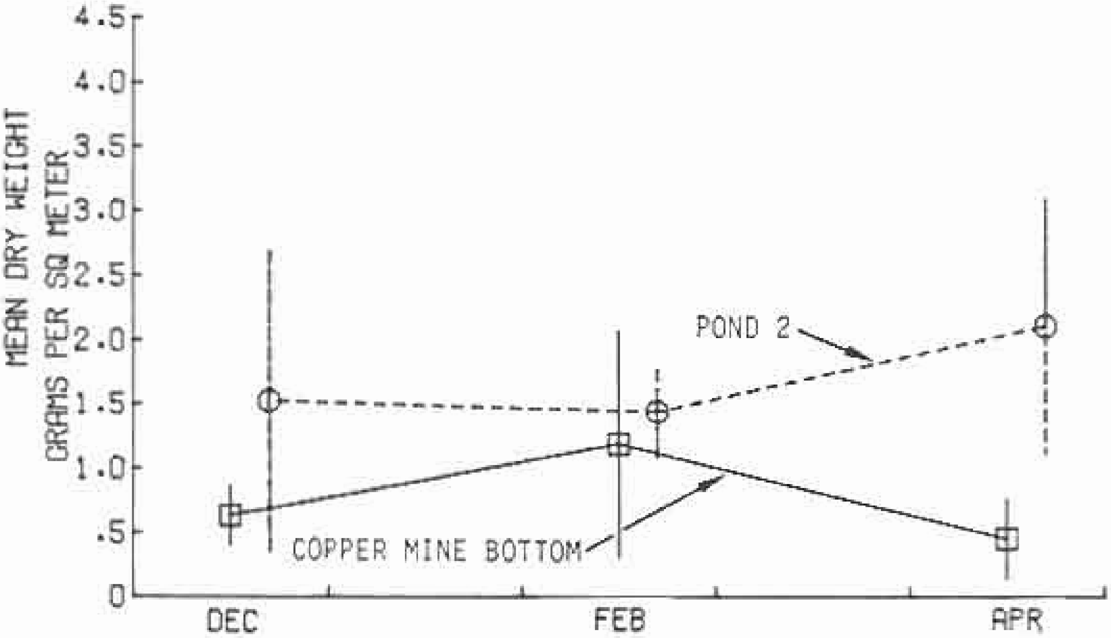

Fig. 19. Mean dry weight per m^2 of all benthic organisms in Copper Mine Bottom and Pond 2 for three sampling dates.

Table 11. Derived mean density and relative dry weight of benthic organisms in Copper Mine Bottom and Pond 2.

	COPPER MINE BOTTOM	POND 2
No. of samples	27	27
Derived mean g/m^2 (dry weight)	.756	1.687
95% CI	(.419 -- 1.094)	(.980 -- 2.394)
Derived mean no./m^2	2,930	5,332
95% CI	(2,098 -- 4,092)	(4,110 -- 6,917)

Table 12. Results of two-way analysis of variance testing the difference in logarithms of sample counts between stations in Copper Mine Bottom.

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIFICANCE OF F
MAIN EFFECTS	2.013	4	.503	7.734	.001
Station	1.716	2	.858	13.185	.001
Month	.297	2	.149	2.284	.131
2-WAY INTERACTIONS	2.070	4	.517	7.951	.001
Station Month	2.070	4	.517	7.951	.001
EXPLAINED	4.083	8	.510	7.843	.001
RESIDUAL	1.171	18	.065		
TOTAL	5.254	26	.202		

Table 13. Results of two-way analysis of variance testing the difference in logarithms of sample counts between stations in Pond 2.

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIFICANCE OF F
MAIN EFFECTS	.362	4	.090	1.302	.307
Station	.283	2	.142	2.038	.159
Month	.079	2	.039	.566	.578
2-WAY INTERACTIONS	.781	4	.195	2.810	.057
Station Month	.781	4	.195	2.810	.057
EXPLAINED	1.142	8	.143	2.056	.097
RESIDUAL	1.250	18	.069		
TOTAL	2.392	26	.092		

Food Habits

Taxonomic composition of the diet of fish in both ponds was determined using numerical and gravimetric measurements from stomach contents collected in February 1978. An index of relative importance (*IRI*) was calculated for each prey taxon observed in the pooled sample from each pond. Calculation of this unitless index gives a single value for ranking the importance of prey taxa in the diet. The *IRI* for a taxon is calculated by adding the products of its numerical composition and frequency of occurrence, and its gravimetric composition and frequency of occurrence. These indexes are graphically represented as the area of the boxes in Figures 20 and 21, and numerically given under the heading *Prey IRI* in Tables 14 and 15. This *Prey IRI* is then expressed as a percent of the total *IRI* and is found under the heading *Percent Total IRI*, in Tables 14 and 15.

The Chironomidae were the most important prey for fish in both ponds, occurring in all stomachs. In Copper Mine Bottom, chironomid larvae comprised 71.9 percent of the diet numerically, and 39.6 percent gravimetrically (Table 14). With the frequency of occurrence for chironomid larvae at 100 percent, this gives an *IRI* of 11,149.3, which was 78.6 percent of the total *IRI* for Copper Mine Bottom (Table 14 and Fig. 20).

In Pond 2 the pharate adult stage of the Chironomidae were more important numerically and gravimetrically than larval chironomids. Qualitative observations of insect emergence patterns indicated that Pond 2 had a protracted emergence of chironomids in late winter and

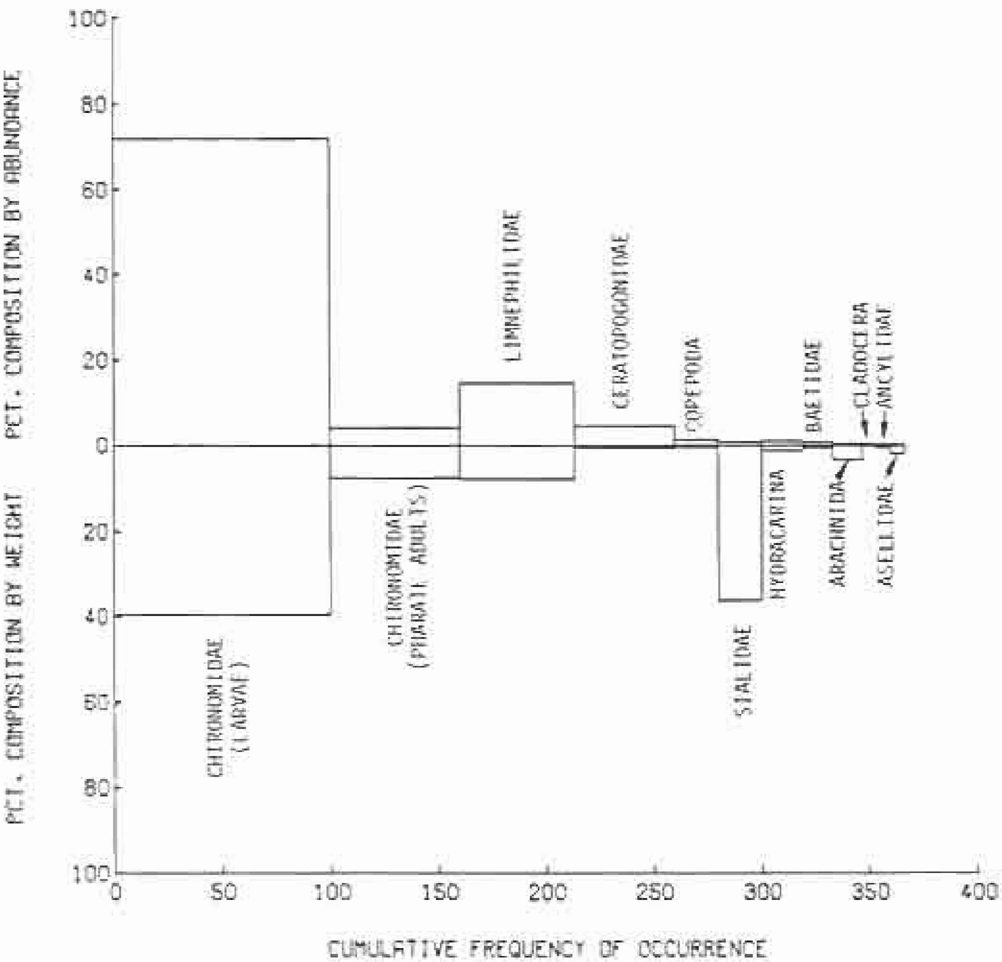

Fig. 20. Index of Relative Importance diagram illustrating the taxonomic composition of the diet of juvenile coho in Copper Mine Bottom.

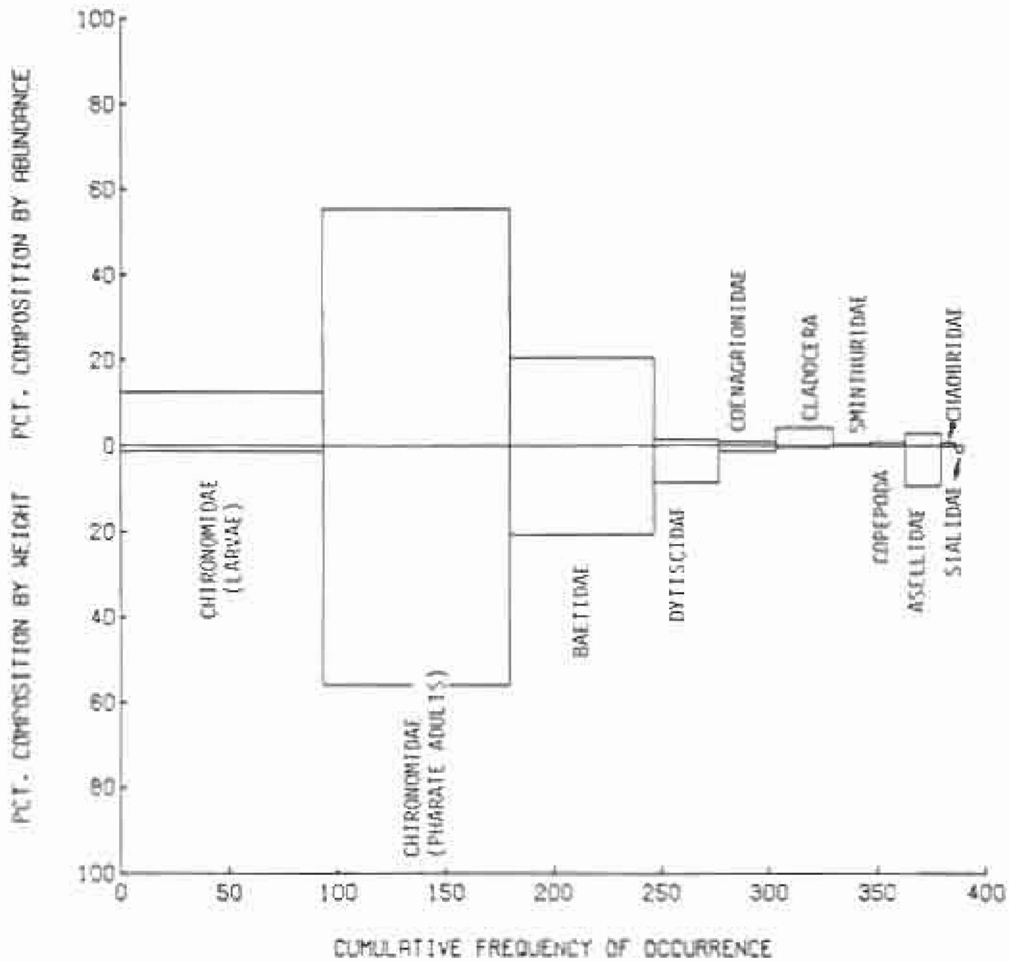

Fig. 21. Index of Relative Importance diagram illustrating the taxonomic composition of the diet of juvenile coho in Pond 2.

Table 14. Index of Relative Importance table characterizing the diet of juvenile coho from Copper Mine Bottom Frequency of occurrence (A), numerical composition (B), and gravimetric composition (C), are listed for each prey taxa. Prey IRI (D) is computed by: (A*B) + (A*C) = D.

PREY TAXA	FREQ. OCCUR (A)	NUM. COMP. (B)	GRAV. COMP. (C)	PREY IRI (D)	PERCENT TOTAL IRI
CHIRONOMIDAE (Larvae)	100.00	71.87	39.62	11,149.3	78.55
CHIRONOMIDAE (Pharate Adults)	60.00	4.07	7.58	698.6	4.92
LIMNEPHILIDAE	53.33	14.63	7.84	1,198.9	8.45
CERATOPOGONIDAE	46.67	4.55	.54	237.6	1.67
COPEPODA	20.00	1.30	.40	34.0	.24
SIALIDAE	20.00	.81	36.17	739.6	5.21
HYDRACARINA	20.00	.98	1.33	46.1	.33
BAETIDAE	13.33	.81	.53	17.9	.13
ARACHNIDA	13.33	.33	3.46	50.4	.36
CLADOCERA	6.67	.33	.00	2.2	.02
ANCYLIDAE	6.67	.16	.53	4.6	.03
ASELLIDAE	6.67	.16	1.99	14.4	.10
				14,193.6	100.02

Table 15. Index of Relative Importance table characterizing the diet of juvenile coho from Pond 2. Frequency of occurrence (A), numerical composition (B), and gravimetric composition (C), are listed for each prey taxa. Prey IRI (D) is computed by: (A*B) + (A*C) = D.

PREY TAXA	FREQ. OCCUR (A)	NUM. COMP. (B)	GRAV. COMP. (C)	PREY IRI (D)	PERCENT TOTAL IRI
CHIRONOMIDAE (Larvae)	93.33	12.51	1.41	1,299.2	9.01
CHIRONOMIDAE (Pharate Adults)	86.67	55.41	55.97	9,653.4	66.92
BAETIDAE	66.67	20.45	20.81	2,750.4	19.07
DYTISCIDAE	30.00	1.44	8.60	301.2	2.09
COENAGRIONIDAE	26.67	.96	1.37	62.3	.43
CLADOCERA	26.67	4.17	.32	119.7	.83
SMINTHURIDAE	16.67	.40	.05	7.6	.05
COPEPODA	16.67	.72	.16	14.7	.10
ASELLIDAE	16.67	2.89	9.36	204.0	1.41
CHAOBORIDAE	6.67	.72	.28	6.7	.05
SIALIDAE	3.33	.08	1.60	5.6	.04
				14,424.8	100.00

early spring. Resident coho appeared to feed heavily on this emergence. Chironomid pharate adults occurred in 86.7 percent of the stomachs and accounted for 55.4 and 56 percent of the Pond 2 diet based on numbers and weight, respectively, or 67 percent of the total *IRI* for Pond 2 (Table 15 and Fig. 21).

Limnephilid caddis fly larvae and baetid mayfly nymphs were next in order of importance in Copper Mine Bottom and Pond 2, respectively. Limnephilid larvae in Copper Mine Bottom comprised 8.5 percent of the total *IRI* and in Pond 2 Baetidae nymphs accounted for 19 percent of the total *IRI* (Tables 14 and 15).

Copper Mine Bottom fish had a higher proportion of plant and unidentifiable material in their guts than did those from Pond 2. This material was ingested incidentally with encased chironomid and limnephilid larvae which were major components of the diet in Copper Mine Bottom. Most of the unidentifiable weight fraction in the diet of fish from Copper Mine Bottom was unincorporated plant material that was not easily sorted with forceps. Pond 2 fish had little plant material in their stomachs.

When tested by non parametric rank tests, total stomach dry weights (expressed as a percent of the dry weight of the fish) showed no statistical difference between ponds. However, when plant and unidentifiable weight fractions were subtracted from all data, statistical differences surfaced (Table 16).

Table 16. Results of non parametric rank test comparing stomach content weights of fish from Copper Mine Bottom and Pond 2. Mann-Whitney U. and Wilcoxon Rank Sum W. test:
H_o: Samples are from populations with the same median.
H_1: (2-tailed) Samples are from populations with unequal medians.

VARIABLE	POND	MEAN RANK	U	W	Z	SIGNIFICANCE OF 2-TAILED P
PER TOTAL[1]	CMB	21.5	241.0	329.0	.3852	.7001
	POND 2	23.5				
PER PLANT[2]	CMB	20.1	269.0	301.0	1.0594	.2894
	POND 2	24.5				
PER UNIDENT[3]	CMB	17.4	309.0	261.0	2.0225	.0431
	POND 2	25.8				

[1] Total stomach content weight expressed as percent of dry weight of fish.

[2] Total stomach content weight minus plant material fraction expressed as percent of dry weight of fish.

[3] Total stomach weight minus plant material and unidentifiable fraction expressed as percent of the dry weight of fish.

The Physical Environment

There was usually less than one degree difference in mean daily temperature between the pond outlets and the Clearwater River during the period of fish immigration. These temperatures are graphed in Figures 22 and 23.

Pond temperatures from December through May, measured at .3 m (1 ft) of depth, ranged from 4.8 to 15.0°C in Copper Mine Bottom and from 3.7 to 15.1°C in Pond 2. Temperatures in the ponds were nearly identical through the winter (Fig. 24). Inlet water in both ponds was a constant 8.3°C through the winter. This warmer water only influenced a limited area in each pond, and when the ponds iced over for short periods, these areas remained open. In December temperatures in Copper Mine Bottom were 5.0°C at all depths.

Dissolved oxygen measurements collected in the winter of 1977 were discarded when it was determined that the dissolved oxygen meter used was inaccurate. Samples taken in the winter of 1978 were chemically analyzed and showed dissolved oxygen levels of 11.0 and 9.5 mg/ℓ and 10.6 to 7.7 mg/ℓ in Copper Mine Bottom and Pond 2 respectively. In both ponds the lowest readings came from the deepest areas. Conditions during sampling in 1978 closely approximate those in 1977.

The water chemistry analysis is given in Table 17. The higher color units of the pond and outlet water reflect the dissolved organic compounds which could provide olfactory cues to fish at pond immigration.

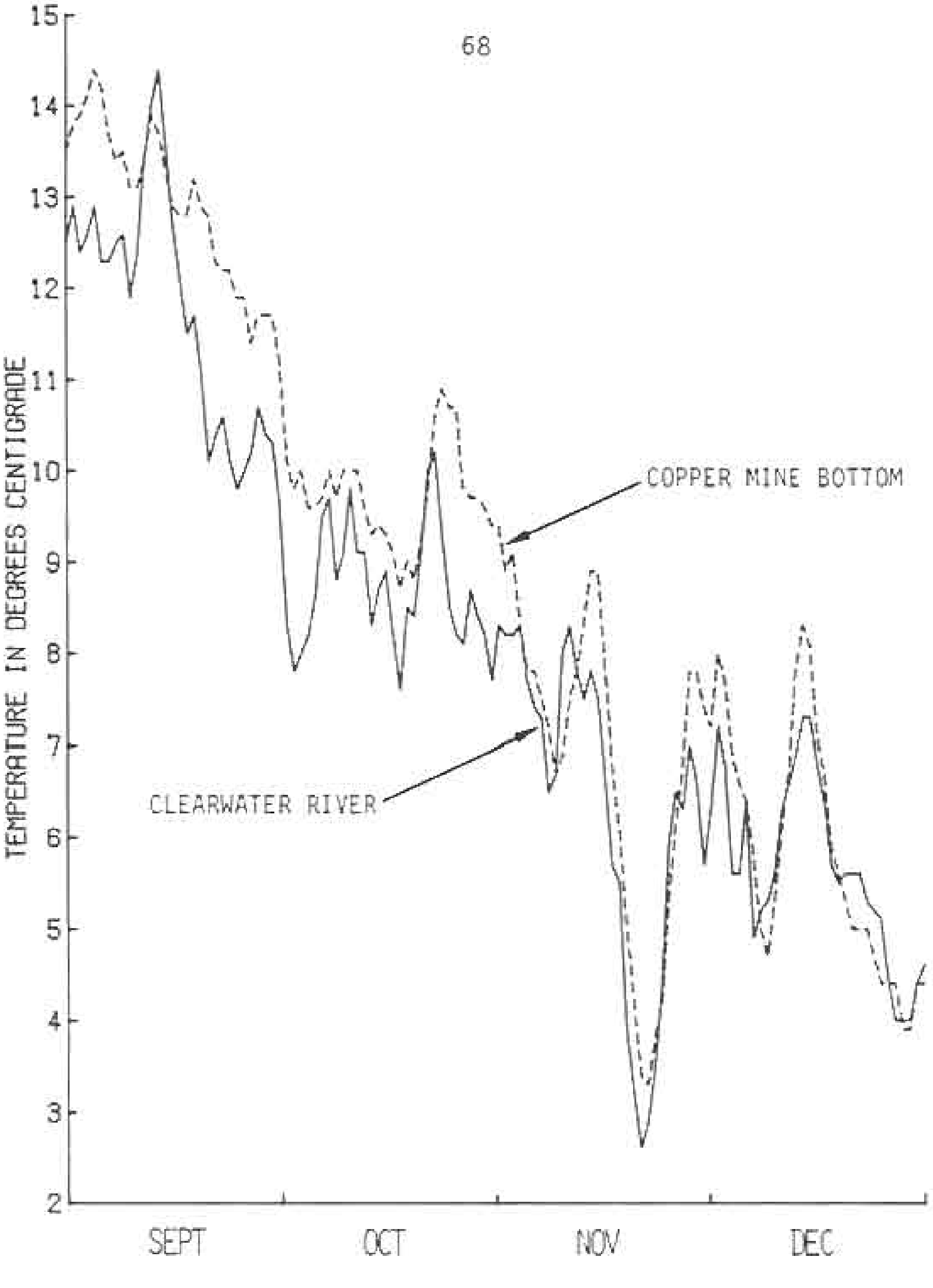

Fig. 22. Mean daily temperatures of the Clearwater River and the Copper Mine Bottom outlet stream.

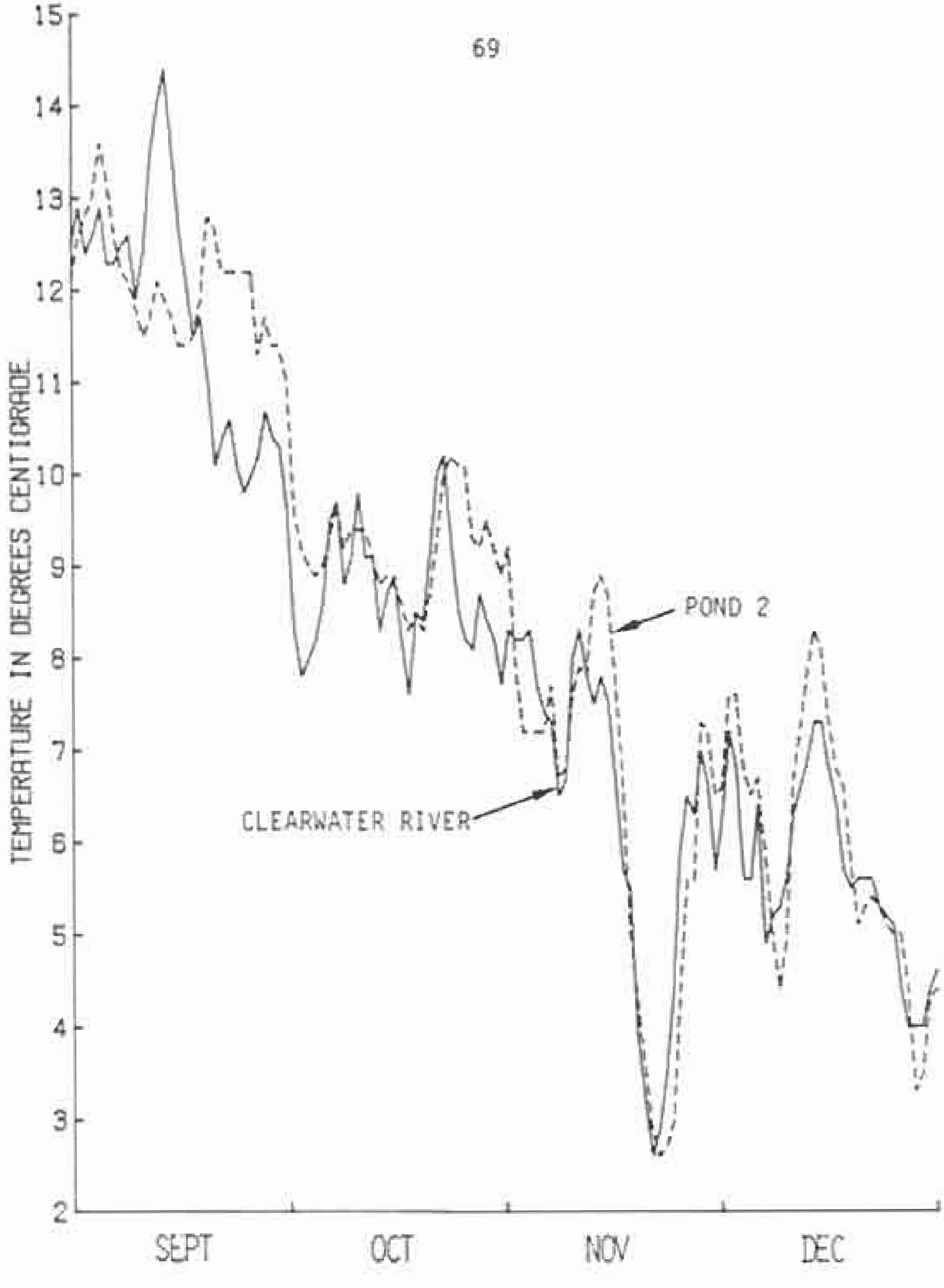

Fig. 23. Mean daily temperatures of the Clearwater River and the Pond 2 outlet stream.

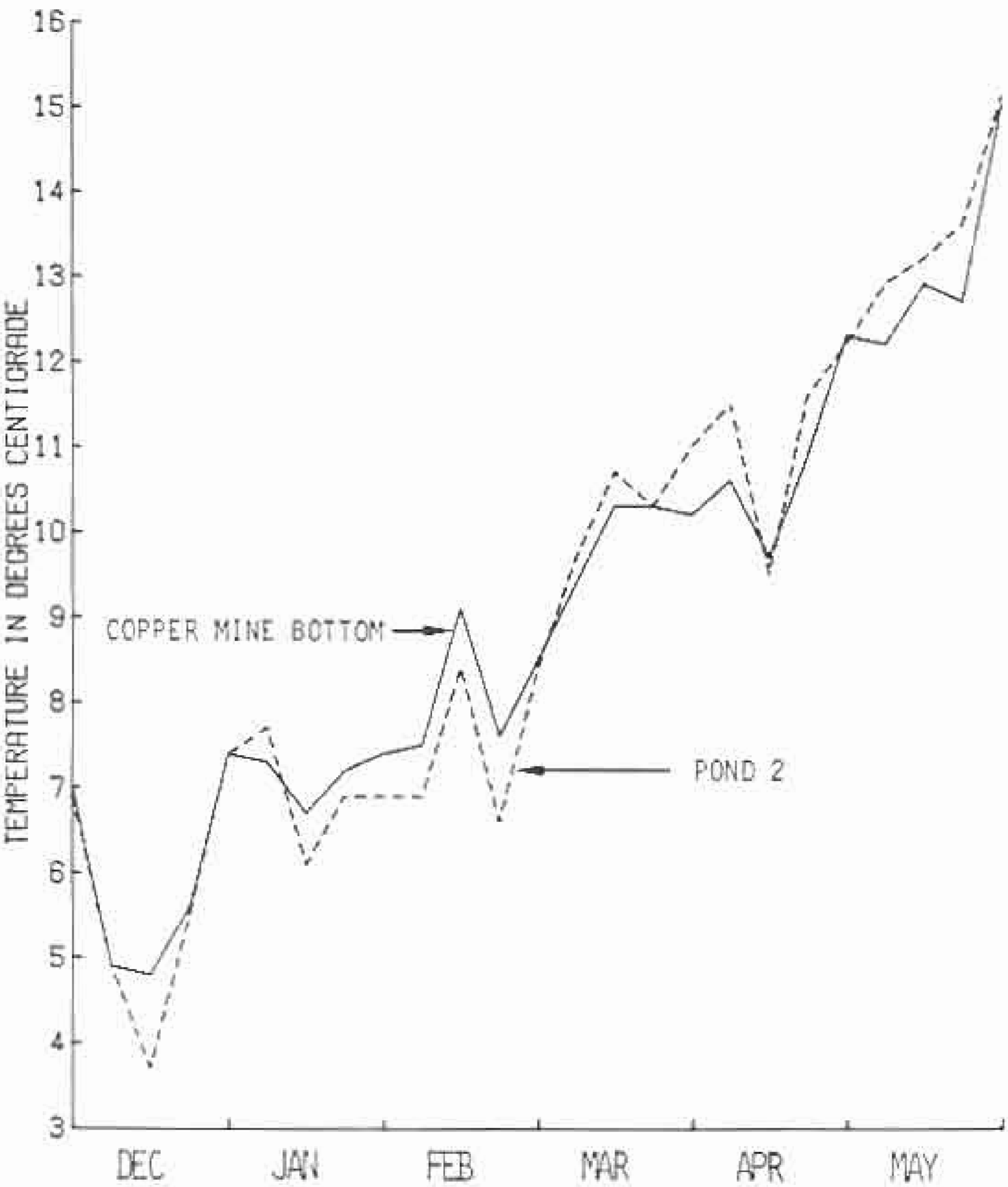

Fig. 24. Mean weekly temperatures of Copper Mine Bottom and Pond 2 at the .3 meter depth.

Table 17. Chemical analysis of water samples from the Clearwater River, the pond outlets, the ponds and the spring sources for Copper Mine Bottom and Pond 2. All parameters measured in mg/l unless otherwise indicated.

	Pond 2 Pond	Pond 2 Spring	Pond 2 Outlet	Copper Mine Bottom Pond	Copper Mine Bottom Spring	Copper Mine Bottom Outlet	Clear-water River
pH	6.3	6.4	6.6	7.2	7.3	7.5	7.4
Turbidity (NTU)	3	1	1	1	1	2	1
Sp. Conductivity (umhos/cm)	42	35	57	71	62	69	78
Chlorides	2	2	2	4	2	2	3
Sulfates	5	5	4	4	<1	12	16
Total Carbon	35	36	17	41	16	16	14
NO_3-N (Filtered)	<.02	.19	.05	<.02	.17	.02	.02
NO_2-N (Filtered)	<.02						
NH_3-N (Unfiltered)	.01	<.01					
T. Kjeldahl-N (Unfiltered)	.40	.06	.30	.20	.04	.22	.11
O-PO4-P (Filtered)	.01	.02	.04	.01	.01	.01	<.01
Total Phos.-P (Unfiltered)	.10	.05	.06	.07	.04	.06	.03
Alkalinity ($CaCO_3$)	5	15	27	27	21	26	9
(Color units)	67	8	63	29	4	38	8
Total Sus. Non Vol. Solids							
Iron	0.75	<.05	1.5	0.37	<0.05	0.33	<.05
Sodium	4.5	4.0	4.2	5.3	5.3	5.3	4.0
Potassium	.21	.21	.31	.52	.34	.51	.44
Magnesium	0.85	.60	1.1	1.8	1.6	1.6	1.4
Calcium	1.8	1.2	2.8	3.4	2.3	3.3	8.5

DISCUSSION

Spring ponds on the Olympic Peninsula are important refuge areas for coho fingerling displaced by freshets. Major recruitment to the ponds occur in late fall and early winter but regardless of season, many coho rearing in mainstem rivers respond to freshets by immigrating into spring ponds. I conclude that pond immigration and the preceding downstream movement in the main river are adaptive behaviors that have been selected for by winter discharge extremes of Olympic Peninsula rivers.

After entering the pond coho fingerling remain there until smoltification. Growth and mortality between pond populations over this period differ significantly and reflect the physical and biological character of the pond. The smolts produced from spring ponds illustrate the interrelated nature of widely separated rearing areas and the seasonal dependence of juvenile salmonids on specific microhabitat.

Recruitment to the Ponds

Winter behavior of fingerling coho salmon in the Clearwater River is characterized by immigration into spring ponds during freshets. On the Olympic Peninsula this behavior is also seen in the Quinault (Lestelle pers. comm.) and Bogachiel Rivers (Miller pers comm.) and must occur throughout the region. However, this phenomenon is not limited to the Olympic Peninsula or spring ponds.

Coincident with winter freshets coho fingerling have been reported to enter a spring fed tributary of the Wilson River in Oregon (Skeesick 1970), a back water tributary that is intermittent in the summer and abandoned beaver ponds in Carnation Creek on Vancouver Island, British Columbia (Bustard and Narver 1975a) and both spring fed and run off type tributaries in the Starrigavin Creek watershed in Alaska (Elliott and Reed 1974). Throughout their range in North America coho seek out small tributaries for overwinter refuge. Coho also migrated into the Clearwater study ponds in August and September during storms, a time when juvenile salmonids normally display the well known home territory behavior (Edmundson and Everest 1968, Allee 1974, Au 1972). This observation underscores the role of flow fluctuations in these types of movements.

Another physical factor that may modify the timing and intensity of winter migrations is temperature. Winter migrations have been reported to cease when water temperatures drop below 4°C. In the Starrigavin Creek study in Alaska all migration ceased at 4°C regardless of flow conditions (Elliott and Reed 1974). This same threshold temperature has been reported from Idaho (Bjornn 1971, Morrill 1972) and British Columbia (Bustard and Narver 1975b). Temperatures in this study fell below 4°C only for short periods (Figs. 22 and 23) and, although cutthroat migration ceased, coho immigration only decreased. Cold weather patterns decreased rainfall and resulted in stable flows during this period and since flow plays such an important role in these migrations it is difficult to isolate the effect of temperature in this case.

Winter coho movements described in this study are composed of two discrete phases and each phase of the movement probably is stimulated by a different cue. The first phase is a downstream drift from rearing locations throughout the main Clearwater and is stimulated by freshets. The second is the opposite rheotactic response of upstream migration through the outlet stream to the pond. These small outlet streams are choked with debris and fry and fingerling that reach the pond must traverse a difficult water course.

Pond water may contain organic compounds that prompt vigorous upstream movement from juvenile salmonids when registered through olfaction. Olfactory recognition of lake water by sockeye salmon *(Oncorhynchus nerka)* is expressed behaviorally in rheotactic responses that lead to lake nursery areas (Brannon 1972). Pond immigration may be an example of a somewhat similar behavior.

Another factor that may play a role in upstream pond immigration is the clarity of pond outlet water. A recent study on the Olympic Peninsula indicates juvenile coho do not avoid suspended sediment concentrations up to 4,000 mg/l (Noggle 1978). Fish tested in these experiments were in a resident phase of their freshwater life, a time when juvenile salmonids normally maintain home territories. The interpretation of these results was that the fish tolerated these concentrations since in their natural environment at this time, the benefit of maintaining a territory may have outweighed any short term benefits of suspended sediment avoidance (Noggle 1978). If this interpretation is correct, juvenile coho observed in this study that had already given up summer territories and were exhibiting migratory behavior, might be expected to show a preference for clear water since there would be no cost of territory abandonment.

Although major recruitment to the ponds comes from fingerling in the fall some newly emerged fry enter the ponds in the spring and early summer. During this stream colonization phase of their behavior (Au 1972), fry entry patterns do follow spring and summer storms but seem more independent of flow fluctuations than the fall immigration. That more fry do not seek out these ponds may be explained by the presence of cutthroat trout in the ponds through the summer. Local anglers have reported finding small coho fry in the stomachs of cutthroat trout caught in Copper Mine Bottom in the summer. This predation would select against early recruitment of fry to the ponds until they had grown enough to be relatively unaffected by cutthroat predation.

The 8,500 coho that migrated into the Clearwater Ponds represent a much larger winter movement than has so far been reported. In Skeesick's (1970) study a maximum 374 coho immigrated into Spring Creek during several winters and Bustard and Narver (1975a) counted only 358 coho moving into a tributary of Carnation Creek during the winter of 1972. Elliott (pers. comm.) feels that tributary streams of Starrigavin Creek may collectively receive 1,000 coho immigrants each winter, but actual counts and estimates from marking experiments show about 260 in 1973. The magnitude of winter immigrations must be primarily regulated by availability of fingerling in the system and secondarily by the discharge and temperature regimes during the winter. The size of the Clearwater system in relation to other streams where winter immigration has been observed and the extreme flows of the 1977 winter probably combine to explain the large immigrations observed. The mild fall temperatures preceding the first large storm event (Figs. 22 and 23) may also have contributed to large migrations since many fish had not yet responded to low temperatures by hiding in cover.

It is rare when the complete migratory path of individual fish from rearing site to overwintering area is traced. This was accomplished in this study and the distances traveled by the coho originally marked at the Susie Creek site are the longest recorded for this type of movement. Coho immigrating into tributaries in the Starrigavin watershed in S. E. Alaska usually are recruited from main-stem areas .8 km (.5 mi) upstream and downstream from the tributary but one coho had traveled 1.6 km (1.0 mi) (Elliott and Reed 1974).

The movement patterns described in this study illustrate the interrelationship of widely separated and different aquatic habitats of a major river system in the production of coho salmon smolts. Arctic char and grayling in streams draining the north slope in Alaska show similar complex movement patterns involving the entire network of their rearing stream and are seasonally dependent upon spring fed areas of the system (Craig and Poulin 1975).

Smolt Production from the Ponds

Coho smolt yield in the spring of 1978, from both study ponds combined, was equal to the smolt yield from about 14 km (9 mi) of fully utilized Clearwater River tributary. Edie (in press), has established maximum coho smolt yield levels for small Clearwater River tributaries at between 125-625 smolts per kilometer. Within this range the number of smolts is primarily influenced by the size and gradient of the stream. At the high end of this scale this represents about 5 g/m^2 pool area. These figures are thought to have the confusing variable of differential fry recruitment removed since the streams, after study under natural recruitment levels, were then saturated with fry plants in the following years. Smolt yield from the ponds in 1978 equaled 3.7 g/m^2. Regardless of what the ponds could produce at optimum loading, even at present levels of recruitment they make a valuable smolt contribution.

Comparing production values between study ponds should be done cautiously. Fish utilization of the ponds is not thoroughly understood and describing gross or net production on an area basis is misleading. In Pond 2, from January when fish were first seen rising to feed, until outmigration at the end of March, coho were in a tight school (possibly a defense against avian predators), and only appeared to utilize a small portion of the pond near the outlet. Coho were distributed evenly around cover sites throughout Copper Mine Bottom. Production values from situations like these cannot be compared directly since resources are not being similarly exploited.

Pond morphometry is fundamental to the ecology of pond fish and insect densities. This is the most basic of all differences between the study ponds and appears to directly or indirectly affect all biological characteristics.

Depth limits the growth of aquatic macrophytes and in Pond 2 these plants cover the entire pond except for a small area near the east end. Aside from providing a high quality detrital base for insect consumption in the fall (Hodkinson 1975), there is a rich invertebrate fauna directly associated with *(Potamogeton sp)* (Berg 1950), which proliferates year round in Pond 2. Pond morphometry then directly controls an important part of the detrital food base and microhabitat of the insects which is reflected in prey availability and therefore growth of the fish.

Pond morphometry has an even more direct link to survival. Herons and kingfishers frequent both ponds daily and avian predation is thought to be the main cause of mortality to pond fish. Deeper areas of Copper Mine Bottom and more overhanging shoreline vegetation probably provide the cover from bird attacks that is lacking in Pond 2. In his work in Wisconsin spring ponds, Carline (pers. comm.), has been unable to detect any correlation with survival and pond morphometry because of migratory fish behavior, but does note that the wild brook trout stay in the deep areas of the pond during the day and move into the shallows at night. However, domesticated brook trout do not exhibit this behavior, and Carline feels this contributes to the fairly high incidence of kingfisher wounding observed in planted fish. Few attempts to define the extent of avian predation on juvenile salmonids have been made but indications are that it can be a serious factor (Elson 1962).

Fish that entered the ponds in late November and early December had a lower survival rate than earlier pond immigrants. By this time coho entering the ponds had survived several severe storms and a period of low temperatures in the main river. This may have reduced the fitness of these fish and resulted in poorer survival. Mason (1976) has demonstrated that coho with lower lipid reserves do not survive the winter as well as their cohorts with higher reserves. If the early December immigrants had used stored energy during the storms and cold weather of the preceding month, this may explain the lower survival.

Growth of fish in Pond 2 was twice as great as for those in Copper Mine Bottom and since temperatures were nearly the same, prey availability and ration must be examined as explanations. Pond 2 during the study period had higher densities of benthic insects than Copper Mine Bottom. The different growth rates of fish from the two ponds appear to be an example of the positive correlation between prey density and growth as outlined by Brocksen et al. (1970).

The relationship between growth and food consumption in coho has been well documented in laboratory experiments and may be a reasonable way of back calculating consumption in field studies if specifically applied (Carline and Hall 1973). High growth rates are directly related to high consumption which is controlled by ration and evacuation. Comparisons of stomach weights by the non parametric tests suggest that coho in Pond 2 had eaten larger meals. However, the food habits of the fish in the two ponds reveal more about their diet and ration. Since coho depend almost entirely on insect drift in streams (Mundie 1971), or water column prey in lakes and ponds (Hostick and McGie 1974), it is noteworthy that coho in Copper Mine Bottom had fed largely from the benthos on encased limnephilid and chironomid larvae. This indicates that they were on a marginal diet and probably explains their zero growth between pond entry and late February. If the coho in Copper Mine Bottom avoided predators early in the winter by staying in the deep part of the pond this would also have impacted their growth since that area of the pond had the lowest benthos densities.

Smaller fish in both ponds had the same relative growth differences between ponds as did their larger cohorts. In both ponds the smaller fish grew considerably faster than the larger fish.

However, it should also be considered that these observations might in part be an artifact of the time between sampling. As salmonid juveniles approach smoltification growth rates decline (Warren 1971), and if the larger fish slowed down because of physiological changes from smoltification and the smaller fish did not, since they were not smolting yet, this may have produced the appearance of faster growth in the smaller fish. Add to this the additional residence time during optimal growth conditions and it may only appear that the smaller fish grew faster. I do not reject this explanation out of hand, but judging from the zero growth, probably for all sizes of fish in Copper Mine Bottom between November and February, it seems unlikely that the larger fish would have slowed down long enough near outmigration to allow this artifact to surface.

If the smaller fish are in fact growing faster there must be a physiological reason. Freshwater growth stanzas, characterized by increasingly slower growth rates as the size of fish increases, have been identified for juvenile sockeye salmon (Brett et al 1969). That larger fish have slower growth rates has also been shown by others as well (Warren 1971). Whether or not these growth stanzas are detectable between fish sizes of 5 and 10 grams is questionable, but data by Brett et al (1969) suggest that this is possible for juvenile sockeye. This may be part of the reason for the greater growth of smaller fish in the ponds.

Since growth is a product of net energy derived from the ration, factors affecting consumption and the efficiency of ration utilization should be examined. As fish increase in size a larger portion of energy derived from the ration is used for maintenance (Brett 1970). The question again is whether or not this is significantly different over a range of 5 to 10 grams. A standardized relation of energy deposition in growth and that expended for total metabolism is given by Brett (1970), and this relationship appears to change within size ranges of 5 grams. If it does, this may be a partial physiological explanation of higher growth rates of smaller fish.

The other important factor to consider is gastric evacuation. Some data suggest that the evacuation rate of salmonids under 25 g varies with the size of the fish, but above 25 g it is fairly constant (Stauffer 1973). If the smaller fish have higher evacuation rates they would be physically capable of higher consumption rates which directly affect growth.

Timing of coho smolt outmigrations varies within early spring to early summer throughout their North American range. This general timing is characterized as an endogenous rhythm (Wagner 1973). Control within this general time frame appears to be regulated by photo period, fish size and temperature interaction.

Earlier outmigration from Pond 2 is attributable to fish size. Temperatures were nearly identical in both ponds. At the same time in March when peak outmigration occurred in Pond 2 a large number of fish emigrated from Copper Mine Bottom. Many of these fish were larger than even the average May smolt which supports the contention that larger fish emigrate sooner.

The other major influence on the timing of outmigration in March appeared to be related to flow. On March 24 and 25, 1978 when smolts emigrated from both ponds a spring storm more than doubled the discharge of Clearwater River tributaries. Fish that were apparently ready to smolt migrated out on these higher flows.

Aside from the value of the absolute smolt contribution there is another related value that may even be more significant. Many coho fry emigrate in late spring into main rivers during the colonization phase of fry behavior (Au 1972, Moring and Lantz 1975). The coho population in the main Clearwater River is probably composed of fry that emigrated from every coho spawning tributary in the system. Lestelle (unpubl. MS) and Edie (pers. comm.) have seen fry emigration from Clearwater River tributaries. Since the pond populations are recruited from this main river population there are probably fish produced from the ponds as smolts that are imprinted to all the tributaries of the Clearwater upstream from the pond. Returning adults that wintered as juveniles in the ponds may spawn in many tributaries. This would ensure fry recruitment to these tributaries regardless of how many smolts were produced directly from those streams.

Adaptive Significance of Observed Behavior

Adaptation is defined as genotypic or phenotypic changes in response to the environment (Grant 1963). Winter behavior discussed in this study is probably a true example of adaptation. Coho that immigrated to the ponds grew better than fish overwintering in tributary streams and in most cases have higher overwinter survival rates. These fitness advantages would select for pond immigration.

The question might then be asked, why isn't this behavior exhibited by all coho in the system or why isn't there a specific sub-stock within the Clearwater adapted to the use of these ponds?

There are other selective tests that face coho fry prior to the opportunity of pond immigration. Behavioral reponses and movement patterns that lead to pond residence are not necessarily the same ones that optimize survivorship up to the point when pond immigration occurs. Poorer survival prior to pond residence for fry that emigrate into the main river and rear there must outweigh the singular benefit of winter pond residence. This selective disadvantage prior to pond immigration would preclude the development of a specific sub-stock that utilizes certain mainstem spring ponds.

RECOMMENDATIONS

1. Spring ponds and spring-fed tributaries are important winter habitat for juvenile salmonids and should be protected from adverse impacts of road construction, logging and gravel pit operation. Specific protective measures should include:
   a. Spring ponds, their outlet streams, spring sources and spring fed tributaries should be recognized as at least type 3 waters under the Washington State Forest Practices Act, regardless of physical criteria, summertime appearances or seasonal fish use patterns.
   b. Culverts carrying pond outlets, spring fed tributaries and intermittent swamps should be installed in a manner that allows upstream juvenile fish passage.
   c. Special care should be taken when logging around pond outlet streams so that they do not become blocked with debris.
   d. Ponds and swamps should never be filled with overburden from gravel pits or end haul material from road construction.
   e. Spring sources for ponds should be treated as temperature sensitive waters during logging operations since pond temperatures during the summer are typically high.
   f. Gravel pits, road construction and logging near ponds should be planned to avoid sediment runoff into ponds.
   g. All shoreline vegetation should be left around ponds to provide cover from bird predators.

2. Spring ponds offer unique opportunities for general ecological study of juvenile salmonids, especially coho and cutthroat. Future research topics should address the following questions:
   a. What is the reaon for survival differences of fish in different ponds?
   b. Are coho recruited to spring ponds from tributary streams or is the only recruitment from the main river rearing populations?
   c. What is the carrying capacity of physically different spring ponds?
   d. What is the reason for different emergence patterns of insects in spring ponds?
   e. How can natural ponds be used to enhance native coho stocks?
   f. Is the creation of winter refuge areas a cost effective method of natural enhancement and what is the form that encourages the most fish use and optimizes growth and survival?

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Appendix Table A-1. Location and date of marking and recapture of juvenile coho and distance from marking location to recapture site.

MARK	LOCATION OF GROUP	DATE MARKED	LOCATION RECAPTURED	DATE RECAPTURED	DISTANCE TRAVELLED Min.	DISTANCE TRAVELLED Max.	LENGTH MM
RANV	400m below Susie Ck.	9-10-77	Pond 2	10-28-77	32.6 km (20.3 mi)	32.6 km (20.3 mi)	88
RANV	"	"	CMB	10-31-77	24.9 km (15.5 mi)	24.9 km (15.5 mi)	76
RANV	"	"	CMB	11-09-77	24.9 km (15.5 mi)	24.9 km (15.5 mi)	88
RANV	"	"	CMB	11-19-77	24.9 km (15.5 mi)	24.9 km (15.5 mi)	77
LPSV	Manor Ck. downstream to Bull Ck.	9-17-77	CMB	9-20-77	4.6 km (2.9 mi)	6.2 km (3.9 mi)	83
LPSV	"	"	CMB	10-29-77	4.6 km (2.9 mi)	6.2 km (3.9 mi)	99
LPSV	"	"	CMB	11-03-77	4.6 km (2.9 mi)	6.2 km (3.9 mi)	97
LPNV	Bull Ck. downstream to Deception Ck.	9-15-77 9-17-77	CMB	10-26-77	1.4 km (.9 mi)	4.6 km (2.9 mi)	98

Appendix Table A-1. Location and date of marking and recapture of juvenile coho and distance from marking location to recapture site. (Cont.)

MARK	LOCATION OF GROUP	DATE MARKED	LOCATION RECAPTURED	DATE RECAPTURED	DISTANCE TRAVELLED Min.	DISTANCE TRAVELLED Max.	LENGTH MM
LPNV	Bull Ck. downstream to Deception Ck.	9-15-77 9-17-77	CMB	10-29-77	1.4 km (.9 mi)	4.6 km (2.9 mi)	102
LPNV	"	"	CMB	11-03-77	1.4 km (.9 mk)	4.6 km (2.9 mi)	104
LPNV	"	"	Pond 2	9-26-77	8.9 km (5.6 mi)	12.1 km (7.6 mi)	90
LPNV	"	"	Pond 2	10-25-77	8.9 km (5.6 mi)	12.1 km (7.6 mi)	107
LPNV	"	"	Pond 2	10-27-77	8.9 km (5.6 mi)	12.1 km (7.6 mi)	92
LPNV	"	"	Pond 2	10-28-77	8.9 km (5.6 mi)	12.1 km (7.6 mi)	106
LPNV	"	"	Pond 2	10-29-77	8.9 km (5.6 mi)	12.1 km (7.6 mi)	103
LASV	Deception Ck. downstream to CMB	8-25-77 9-14-77	CMB	10-26-77	0.0 km (0.0 mi)	1.4 km (.9 mi)	90

Appendix Table A-1. Location and date of marking and recapture of juvenile coho and distance from marking location to recapture site. (Cont.)

MARK	LOCATION OF GROUP	DATE MARKED	LOCATION RECAPTURED	DATE RECAPTURED	DISTANCE TRAVELLED		LENGTH
					Min.	Max.	MM
LASV	Deception Ck. downstream to CMB	8-25-77 9-14-77	CMB	10-28-77	0.0 km (0.0 mi)	1.4 km (.9 mi)	85
LASV	"	"	CMB	11-03-77	0.0 km (0.0 mi)	1.4 km (.9 mi)	107
LAWV[1]	CMB downstream to Peterson Ck.	9-8-77 9-14-77	CMB	11-03-77	.5 km (.3 mi)	2.2 km (1.4 mi)	99
LAWV	"	"	Pond 2	10-26-77	5.3 km (3.3 mi)	7.5 km (4.7 mi)	107
LAEV	Peterson Ck. downstream to Christmas Ck.	9-8-77 9-14-77	Pond 2	9-27-77	2.1 km (1.3 mi)	5.3 km (3.3 mi)	95
LAEV	"	"	Pond 2	10-24-77	2.1 km (1.3 mi)	5.3 km (3.3 mi)	108
LAEV	"	"	Pond 2	10-25-77	2.1 km (1.3 mi)	5.3 km (3.3 mi)	104

Appendix Table A-1. Location and date of marking and recapture of juvenile coho and distance from marking location to recapture site. (Cont.)

MARK	LOCATION OF GROUP	DATE MARKED	LOCATION RECAPTURED	DATE RECAPTURED	DISTANCE TRAVELLED Min.	Max.	LENGTH MM
LAEV	Peterson Ck. downstream to Christmas Ck.	9-8-77 9-14-77	Pond 2	10-26-77	2.1 km (1.3 mi)	5.3 km (3.3 mi)	90
LAEV	"	"	Pond 2	10-31-77	2.1 km (1.3 mi)	5.3 km (3.3 mi)	106
LAEV	"	"	Pond 2	11-02-77	2.1 km (1.3 mi)	5.3 km (3.3 mi)	98
LAEV	"	"	Pond 2	11-04-77	2.1 km (1.3 mi)	5.3 km (3.3 mi)	100
LANV	Christmas Ck. to Pond 2	9-8-77 9-14-77	Pond 2	10-24-77	0.0 km (0.0 mi)	2.1 km (1.3 mi)	103
LANV	"	"	Pond 2	10-25-77	0.0 km (0.0 mi)	2.1 km (1.3 mi)	101
LANV	"	"	Pond 2	10-26-77	0.0 km (0.0 mi)	2.1 km (1.3 mi)	106
LANV	"	"	Pond 2	10-26-77	0.0 km (0.0 mi)	2.1 km (1.3 mi)	105

Appendix Table A-1. Location and date of marking and recapture of juvenile coho and distance from marking location to recapture site. (Cont.)

MARK	LOCATION OF GROUP	DATE MARKED	LOCATION RECAPTURED	DATE RECAPTURED	DISTANCE TRAVELLED Min.	DISTANCE TRAVELLED Max.	LENGTH MM
LANV	Christmas Ck. to Pond 2	9-8-77 9-14-77	Pond 2	10-28-77	0.0 km (0.0 mi)	2.1 km (1.3 mi)	94
LANV	"	"	Pond 2	10-29-77	0.0 km (0.0 mi)	2.1 km (1.3 mi)	110
LANV	"	"	Pond 2	10-29-77	0.0 km (0.0 mi)	2.1 km (1.3 mi)	100
LANV	"	"	Pond 2	10-31-77	0.0 km (0.0 mi)	2.1 km (1.3 mi)	102
LANV	"	"	Pond 2	11-03-77	0.0 km (0.0 mi)	2.1 km (1.3 mi)	105
LANV	"	"	Pond 2	11-11-77	0.0 km (0.0 mi)	2.1 km 1,3 mi)	103
LANV	"	"	Pond 2	11-11-77	0.0 km (0.0 mi)	2.1 km (1.3 mi)	100
LANV	"	"	Pond 2	01-06-78	0.0 km (0.0 mi)	2.1 km (1.3 mi)	105

[1] Only recaptured fish that travelled upstream.