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THE EFFECT OF RIVER FLUCTUATIONS RESULTING FROM HYDROELECTRIC PEAKING ON SELECTED AQUATIC INVERTEBRATES AND FISH

by

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FOREWORD

The Water Resources Research Institute has provided the administrative coordination for this study and organized the interdisciplinary team that conducted the investigation. It is the Institute's policy to make available the results of significant water related research conducted in Idaho's universities and colleges. The Institute neither endorses nor rejects the findings of the authors It does recommend careful consideration of the accumulated facts by those who are assuredly going to continue to investigate this important field.

ACKNOWLEDGMENTS

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ABSTRACT

Diel changes in discharge caused by hydroelectric peaking directly affect water levels and velocities and indirectly alter benthos and fish abundance and distribution. The effect of discharge on aquatic insect population below Dworshak Dam on the Clearwater River, Idaho was measured during different peaking regimes. Insects were sampled using a cyclindrical bottom sampler, drift nets, basket samplers and embedded cannisters. The benthic insect community below Dworshak Dam has remained relatively stable during and after the filling of Dworshak Dam but shorelines experiencing daily fluctuations are not readily colonized by stoneflies, mayflies and caddisflies; chironomid midges are the most resilient stranded insects in these unstable areas and the first ones to recolonize the flooded areas. The insects collectively reflected an obvious diel drift pattern with largest numbers drifting at night. Samples selected from three depths (15, 30 and 45 cm) yielded the largest numbers of insects at the 45 cm depth. When converting numbers of drifting insects to a volume-flow relationship, largest numbers of insects were captured at the 15 cm depth. Basket sampling at depths of 1 and 2 m revealed no major differences in the insect community at these depths. A total of 98 species from eight orders of insects were recorded from the Clearwater River.

Flows in a diversion channel (3.5 m in width) on the South Fork of the Salmon River were manipulated to experimentally simulate flow fluctuations below a power dam. An upstream section (20 m in length) tested insects; a downstream section (60 m in length) tested fish at 24-hour sequences of 57, 17, 3 and 51 l/sec. Analysis of vertical distribution of insects in the controlled flow channel indicated that the insects did not generally seek greater interstitial depths during dewatering and that many of the insects had become displaced via drift during the dewatering cycle. Stepwise reduction of discharge caused corresponding reductions in the number of chinook salmon (Oncorhynchus tshawytscha). The carrying capacity of the channel was 250% greater in the summer when salmon were smaller (<59 mm) and stream temperatures were higher (8-17 C) than in the fall when fish were larger (95-102 mm) and temperatures lower (4-15 C). Although the summer and fall carrying capacities differed, the proportion of fish remaining in the channel after each reduction in flow was about the same. The number of chinook in an experimental laboratory flume also changed directly with variation in the rate of flow. These findings corroborated with those for the diversion channel. Extreme reductions in flow significantly increased the amount of insect drift and the rate of ingestion by salmon in the diversion channel.

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INTRODUCTION

This study was initiated to evaluate the effects of diel fluctuations in discharge on aquatic insects below Dworshak Dam on the Clearwater River. The period from July 1971 to June 1973 represented a pre-impoundment phase of the project (MacPhee and Brusven, 1973); the period since June 1973 represents a post-impoundment phase in which detailed benthic samples were obtained at the earlier pre-impoundment sites.

The post-impoundment phase expanded the original objectives to provide for experimental studies in which flows were manipulated in a small diversion channel. The flows were altered to simulate the effect of diel discharge patterns below power dams on fish and aquatic insects. The channel research was aimed at determining the vertical distribution of insects in experimental canisters, the insect standing crop and the fish carrying capacity of the channel at different levels of discharge.

The specific objectives of this project were as follows:

1. To monitor composition and numbers of benthos and drift organisms in the lower Clearwater River during the post-impoundment period of Dworshak Reservoir.
2. To determine differential migration and distribution of selected aquatic insects subjected to water fluctuations.
3. To determine the effects of shoreline stranding on different age groups of selected invertebrate fish-food organisms.
4. To determine the effect of discharge alterations on the abundance of fish.
5. To determine the effects of altered flows on insect drift and fish feeding behavior.

A hydroelectric power facility such as that at Dworshak Dam is used for hydroelectric peaking and results in rapid changes of downstream river levels. The ecological impact of these fluctuations in water level and water quality on aquatic organisms must be determined to find the optimum relationship between power production and aquatic habitat.

The North Fork of the Clearwater River contributes about 37% of the flow in the Clearwater below Ahsahka. Since the filling of Dworshak Reservoir, the North Fork is regulated, with the spring runoff being stored and then released during the normal low flow seasons. With the initial three power units already installed, the minimum and maximum planned releases range from 30 to 340 m^3/sec. Unrestricted powerplant peaking operations could result in rapid fluctuations between the two release extremes and could cause a change in the water level in the lower Clearwater (that portion of the river below the North

Fork) of up to 0.9 m.

The natural water temperatures of the lower Clearwater varied from approximately 0 C in February to over 24 C in July and August prior to the existence of Dworshak Dam. The multi-level power penstock intake and release system at Dworshak Dam will allow regulation of the water temperature of the river below the reservoir. Thus, it would be possible to closely match the natural temperatures in the main stem of the river during most months of the year. Alternatively, if reservoir withdrawals were taken only from the lower levels, maximum summer downstream water temperatures would be approximately 8°C colder and winter releases would be 3 C to 6 C warmer than the natural river temperature.

Existing benthic algal and insect populations have become genetically adapted over a long period of time to the pre-impoundment regime of the river. With altered discharges and sharp temperature fluctuations at critical periods in their life cycles, indigenous benthic organisms might be adversely affected In turn, a reduction in benthos could cause a decline in the resident fish populations in the lower Clearwater.

The first two-year phase of this project (1971-1973) provided valuable background information on water fluctuations on the Clearwater River during the filling of Dworshak Reservoir. Simulation studies in the field and laboratory have also produced information on ecological resilience of shoreline benthos. Because fish and benthic populations are collectively influenced by water level changes, changes in aquatic productivity are complex and difficult to understand.

METHODS AND MATERIALS

Clearwater River Study

Station Selection and Sampling Schedule

The region of the Clearwater River that was used for the hydroelectric peaking phase of the study encompassed that portion of the river from the confluence of the Snake River to Orofino, Idaho, representing some 72 km (Figure 1). Three sites (river km 38, 50 and 72) were selected primarily in riffle-run type habitats. These habitats traditionally support the largest diversity of aquatic insects and are most reflective of changing environmental conditions. The slope of the banks of these intensive study sties was gentle to moderate and provided the greatest amount of stranding potential for insects during fluctuating flow conditions. The substrate type for these stations was cobble and rubble. These sites were selected secondarily on the basis of location, accessibility, sampling characteristics, and historical data base.

The sampling schedule employed to evaluate benthic insect communities in the Clearwater River involved monthly samples during the summer and early fall months and two-month intervals during winter. Samples were taken during the time the water was relatively clear and safe for sampling. Muddy waters and high flows commencing in February and culminating with the high spring runoff in May generally precluded effective sampling.

Physical-Chemical Parameters

The flows in the Clearwater River are extremely variable, varying from 300 m^3/sec in October to 2000 m^3/sec in May. Winter and spring runoff over the last ten years generally reflect a bimodal pattern with noticeable increases in discharge in February followed by a more pronounced increase in May. Temperatures in the Clearwater River vary from 0 C in January and February to 26 C in July and August. These two parameters potentially influence the aquatic biota supported in the Clearwater River and have been changed to some degree as a result of the operational flows from Dworshak Dam.

The physical-chemical parameters of flow, dissolved oxygen, and water temperature were evaluated as parameters potentially influencing benthic insect communities inthe mainstem of the Clearwater River. Dissolved oxygen values expressed in milligrams per liter were taken monthly by personnel from the Walla Walla District, U.S. Army Corps of Engineers and made available to this study. Weekly temperature data were obtained from the United States Department of the Interior, Geological Survey reports and from the Hydrology Division, U.S. Army Corps of Engineers (Walla Walla District). Water temperature data were obtained for four locations on the Clearwater River: Orofino, North Fork Clearwater River, Peck and Spalding. Flow records for the Clearwater River were obtained through the weekly reporting service of the United State Geological Survey Office, Portland, Oregon.

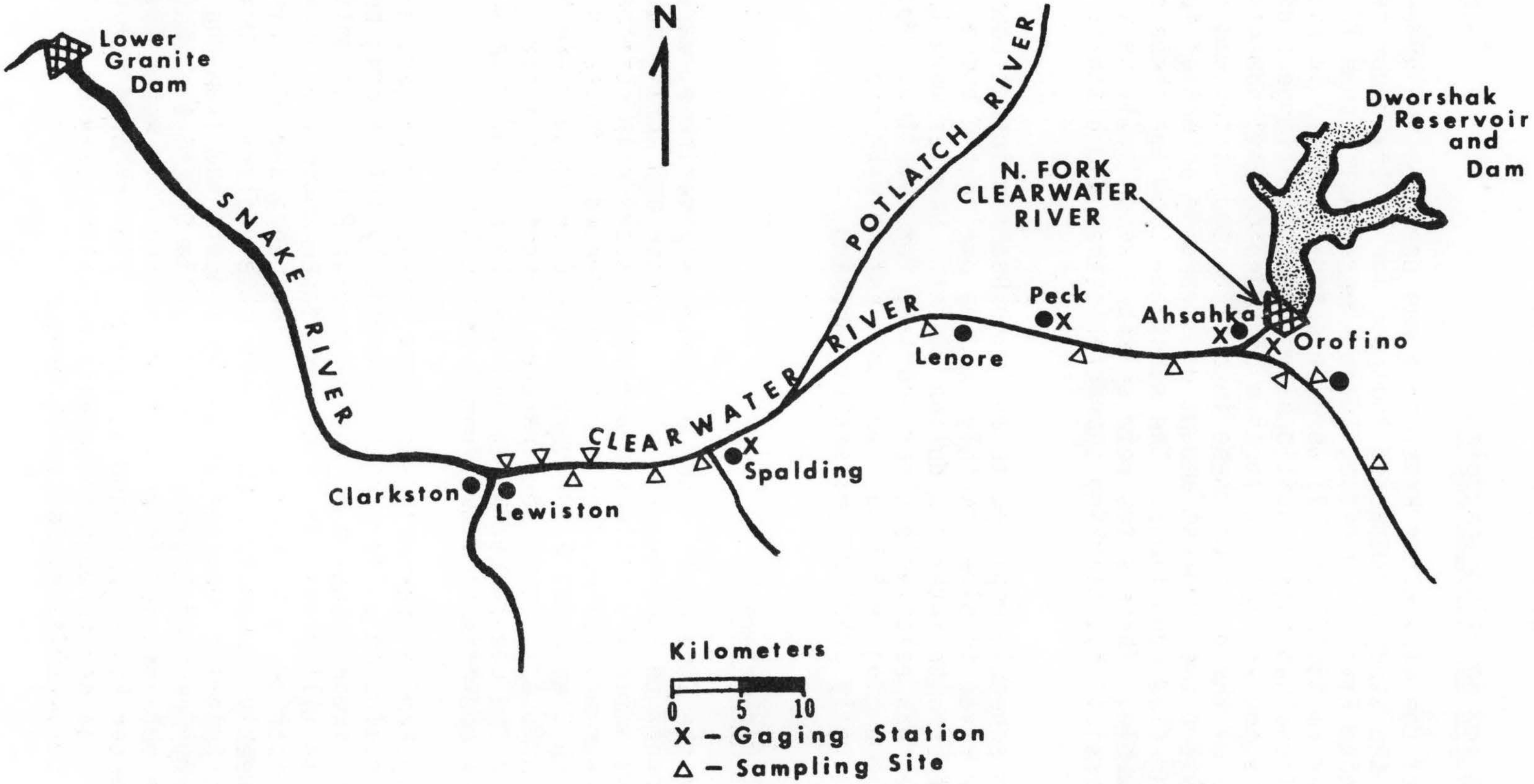

Figure 1. Clearwater River study area showing gauging stations and sampling sites

Insect Drift

Insect drift was taken during a time Dworshak Dam was operating on a load factoring schedule. Drift net stations were established at river km 38 upstream from the mouth of the Clearwater River and at river km 72 (Orofino) which served as the control. Insect drift was taken with three 30 cm x 60 cm drift nets with 1.2 m nylon bags (0.8 mm pore size). These were placed at three water depths of 15, 30, and 45 cm. One-hour drift samples were taken at 1200, 1800, 2100, 2400, 0600, and 0900 h, to reflect drift diel periodicity. The water discharge through each net was calculated and insect numbers converted to a density relationship expressed as numbers per m^3 of water through the nets. It was occasionally necessary to reposition the nets during the load factoring schedule to maintain the relatively consistent 15, 30 and 45 cm depths.

Benthos

Benthic insects were collected using a cylindrical bottom sampler (area, 924 cm^2) similar to that described by Waters and Knapp (1961). A random block sampling design was used to sample insects at depths of 15, 30 and 45 centimeters.

Daily and seasonal changes in flow necessitate an accurate accounting of the position of the random block sampling design. A permanent reference point was established at each site by using a steel stake drive into the stream bank at some distance from the water's edge. When taking bottom samples, a record was made of the distance from stake to water on each of the sample dates, thus permitting analysis of shifts in community structure commensurate with short term shifts in watered and dewatered areas.

In addition to the cylindrical bottom sampler, basket devices were employed to evaluate the insect community at depths greater than 1 m. Baskets (30 cm x 30 cm x 15 cm) made of 13 mm square hardware cloth were used for this purpose. The baskets were filled with 20 fist-size rocks and attached to a buoy for relocation. The baskets were placed in pairs at water depths of approximately 1.0 and 1.8 m. Colonization time periods of 2, 4 and 6 weeks were initially used. Later, a standard period of 4 weeks was used for colonization.

In all of the above methods for insect benthic analysis, insects were collected from the samplers, stored in 70% ethanol, and analyzed in the laboratory.

Diversion Channel Study

Because of relatively stable flow conditions in the Clearwater River during the summer and fall of 1974, an artificial salmon spawning channel was converted into an experimental diversion channel (3.5 m in width and 90 m in length) in which a headgate (60 cm in diameter) controlled the rate of discharge (Figure 2). The channel was located in lower Stolle Meadow in the headwater area of the South Fork of the Salmon River (Figure 2).

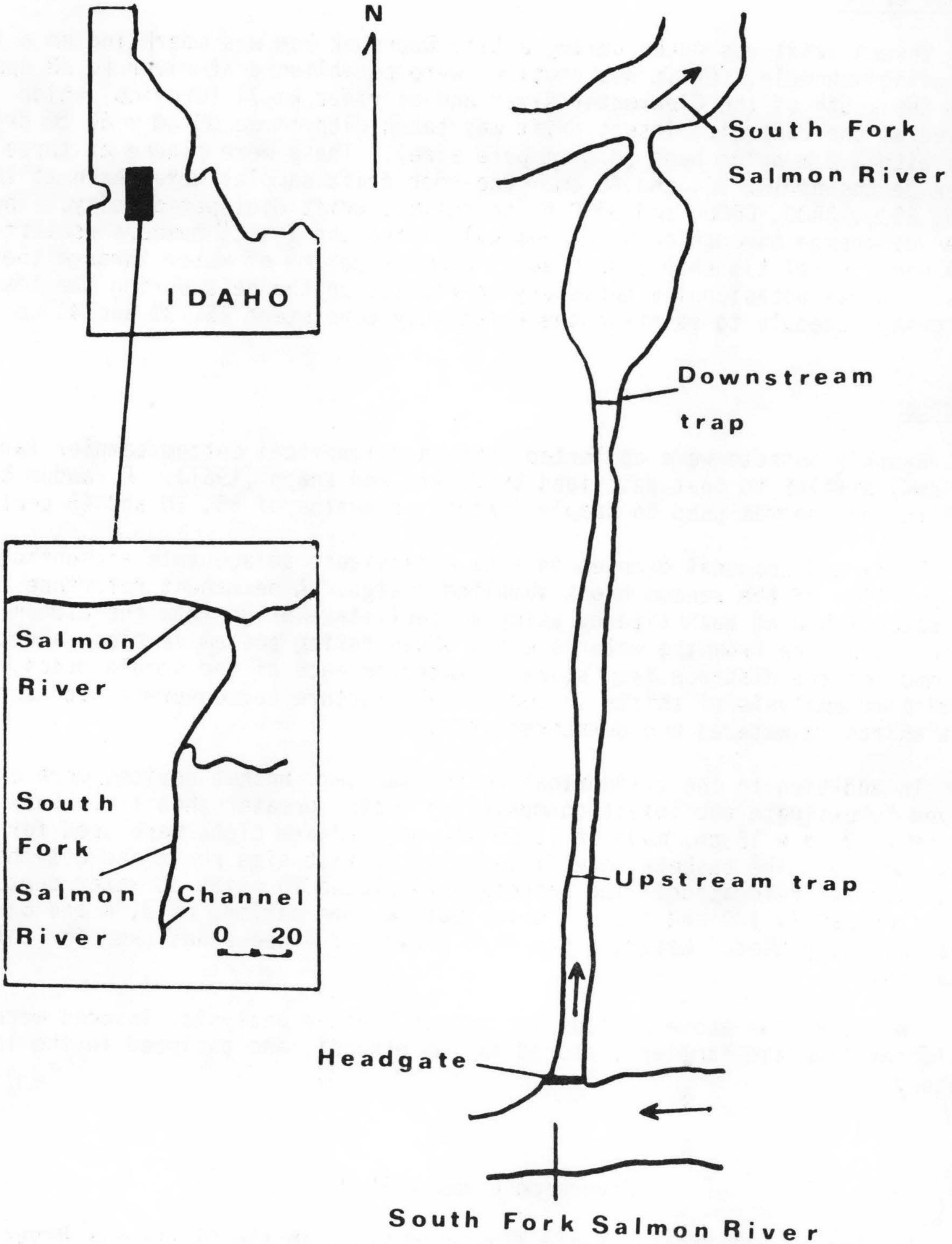

Figure 2. Location of the South Fork of the Salmon River and the diversion channel

At the upstream end, for a distance of about 20 m, the original pebble and sand substrate of the channel was covered with an 8-10 cm layer of new gravel. Three flow depths were used over the experimental substrate; 0, 5 and 10 cm which corresponded approximately to 3, 17 and 51 l/sec of discharge.

Steel canisters (14 cm x 30 cm) were made of porous sheet metal (1.5 mm in diameter) and were used to evaluate the vertical distribution of insects with flow. The canisters were divisible into 3 depth zones of 0-10, 10-20 and 20-30 cm. The canisters were imbedded in the substrate for approximately four weeks and removed. Then, the insects were separated and identified.

The lower 60 m of the channel was used for fish experiments. Fines were partially flushed out and rocks were placed in the channel to simulate natural cover for fish and aquatic invertebrates.

The channel was divided into 13 five-meter long sections to facilitate plotting the location of fish during tests. Section 13 was located at the upstream end and section 1 at the downstream end of the channel. Transects, one meter apart, were used to obtain water depths, surface and mid-water velocities, and substrate types for mapping. Measurements were made every 0.25 m along each transect. Midget Bentzel tubes were used to determine water velocities (Everest, 1967).

V-type fish traps were constructed with 6 mm square hardware cloth and placed below the insect study area and at the downstream end of the channel to monitor fish movements within the channel.

Wild, juvenile chinook salmon were seined with a 6 mm square mesh from quiet, slack-water areas in the South Fork of the Salmon River upstream from the diversion channel. Hatchery juvenile chinook salmon were provided by the Idaho Fish and Game Department's Rapid River hatchery near Riggins, Idaho.

The fish were placed in the channel in section 11 while the V-traps were closed. A superabundance of fish were placed in the channel to ensure that all available niches in the channel during high discharge (51 l/sec) would be utilized.

Traps remained closed for about 48 hours so that the fish could adjust to the channel. The traps were then opened so that nomads could leave the channel via the V-traps. Four to five days was usually needed for most nomads to enter the V-traps. When less than five fish per day were trapped, the fish carrying capacity of the channel was deemed stabilized and discharge was reduced to 17 l/sec.

Four tests were completed using wild juvenile salmon in the diversion channel; one test in August, 1974 and three others in 1975. Three tests simulated severe dewatering conditions in regulated steps. For this purpose the rate of discharge was changed from 51 to 17 to 3 to 51 l/sec. A fourth test used a daily peaking schedule decreasing discharge from 51 to 17 l/sec at 2300 and increasing discharge to 51 l/sec at 0500 hours.

Table 1. Time schedule and specific details of diversion channel experiment with wild juvenile chinook salmon during which discharge was altered at 1200 h.

Date	Time (hour)	Event	Traps	Discharge (l/sec)
12 July 1975	1420	Salmon placed in diversion channel	Closed 45.5 h	51
14 July 1975	1200	Discharge 51 l/sec End of adjustment period	Open	51
	1230 to 1400	Traps checked once/0.5 h	Open, checked	51
	1600 to 2400	Traps checked once/2.0 h	Open, checked	51
15-19 July 1975	0600 to 2400	Traps checked once/210 h	Open, checked	51
20 July 1975	0600 to 1200	Traps checked once/2.0 h	Open, checked	51
	1200	Discharge reduced to 17 l/sec	Open, checked	17
	1320 to 1400	Traps checked once/0.5 h	Open, checked	17
	1600 to 2400	Traps checked once/2.0 h	Open, checked	17
21 July 1975	0600 to 1200	Trpas checked once/2.0 h	Open, checked	17
	1200	Discharge reduced to 3 l/sec	Open, checked	3
	1230 to 1400	Traps checked once/0.5 h	Open, checked	3
	1600 to 2400	Traps checked once/2.0 h	Open, checked	3
22 July 1975	0600 to 1200	Traps checked once/2.0 h	Open, checked	3
	1200	Discharge increased to 51 l/sec	Open, checked	51
	1230 to 1400	Traps checked once/0.5 h	Open, checked	51
	1600 to 2400	Traps checked once/2.0 h	Open, checked	51
23 July 1975	0600 to 1800	Traps checked once/2.0 h	Open, checked	51
	1800	Traps closed; experiment ends; discharge reduced to 3 l/sec; two shocking operations were completed in channel	Closed	3

Table 2. Time schedule and specific details of diversion channel experiments with wild juvenile chinook salmon during which discharge was altered at 2300 h.

Date	Time (hour)	Event	Traps	Discharge (l/sec)
31 July 1975	1500	Salmon placed in diversion channel	Closed 45-0 h	51
2 Aug 1975	1200	Discharge 51 l/sec End of adjustment period	Open	51
	1230 to 1400	Traps checked once/0.5 h	Open, checked	51
	1600 to 2400	Traps checked once/2.0 h	Open, checked	51
3-7 Aug 1975	0600 to 2400	Traps checked once/2.0 h	Open, checked	51
8 Aug 1975	0600 to 2300	Traps checked once/2.0 h and at 2300 h	Open, checked	51
	2300	Discharge reduced to 17 l/sec	Open, checked	17
	2330, 2400	Traps checked once 0.5/h	Open, checked	17
9 Aug 1975	0500	Traps checked, discharge increased to 51 l/sec	Open, checked	51
	0530 to 0700	Traps checked once/0.5 h	Open, checked	51
	0800 to 2300	Traps checked once/2.0 h and at 2300 h	Open, checked	51
	2300	Discharge reduced to 17 l/sec	Open, checked	17
	2330, 2400	Traps checked once/0.5 h	Open, checked	17
10 Aug 1975	0500	Traps checked, discharge increased to 51 l/sec	Open, checked	51
	0530 to 0700	Traps checked once/0.5 h	Open, checked	51
	0800 to 2300	Traps checked once/2.0 h and at 2300 h	Open, checked	51
	2300	Discharge reduced to 17 l/sec	Open, checked	17
	2330, 2400	Traps checked once/0.5 h	Open, checked	17
11 Aug 1975	0500	Traps checked, discharge increased to 51 l/sec	Open, checked	51
	0530 to 0700	Traps checked once/0.5 h	Open, checked	51
	0800 to 1300	Traps checked once/2.0 h	Open, checked	51
	1800	Traps closed, discharge reduced to 3 l/sec; two shocking operations were completed		

Three tests were completed with hatchery salmon in 1974. Testing procedures were similar to those used during the three regulated discharge experiment with wild juvenile chinook salmon except for a 14 to 16 h instead of a 48 h adjustment period when a 17 l/sec instead of a 51 l/sec rate of discharge was used. Representative schedules of changes in discharge and fish trap observations are given in Tables 1 and 2.

The 18 August 1974 and 17 August 1975 test followed a schedule similar to those in Tables 1 and 2 but discharges were changed at 1800 h, not 1200 h as in the 20 July 1975 test. Discharges were changed at 1800 h for all three tests in September and October 1974.

Fish were located and counted between 1000 and 1115 h for each day of the experiment starting with the last day of maximum discharge. An observer moved stealthily upstream on one bank and them upstream on the other bank. This procedure allowed the observer to spot fish blocked from view by grass on each bank.

During tests using wild, juvenile chinook salmon, fish trapped from 1300 to 2000 h were preserved for stomach analysis to assess the impact of dewatering on utilization of food organisms. The data are described by number and taxa.

At the end of each test two collections were made with an electric fish shocker and the number of chinook recorded. Fish retrieved from traps or shocked were released alive downstream from the pond outlet into the South Fork of the Salmon River. The downstream release point reduced the chance of re-using previously tested fish.

Laboratory Flume Study

Two similar oval flumes with clear plastic inner walls were used for altered discharge experiments in the University of Idaho fisheries laboratory. Electric powered paddlewheels provided current in the flumes. Heating and cooling units maintained the water temperature near 12.5 C. Artificial light occurred automatically at 0745 h and terminated at 2010 h. Traps were installed at the upstream and downstream ends of the flumes.

Artificial substrate composed of gravel and rock were placed in both channels to form a pool-riffle sequence. Larger rocks were used to provide cover for fish. The size and placement of gravel and rocks were similar in both flumes.

Chinook fingerlings (38-46 mm) from the U.S. Fish and Wildlife Service National Fish Hatchery at Eagle Creek, Washington were used in the laboratory tests. A gravity fed feeding apparatus supplied brine shrimp through hoses for fish. The hoses were designed to allow brine shrimp to emerge through the substrate that partially covered the hoses. This arrangement presented food to fish in an unobtrusive manner. Two grams of brine shrimp were placed in the feeding bins every 2 h from 0800 h. Shrimp drifted for about a period of 0.25 h after placement in the feeding bins.

Two sets of tests were made in which control and treatment flumes were interchanged. For each test, 130 fish were placed in each flume at 1200 h. Fish were counted at 2-hour intervals between 0800 and 2000 h before they were fed.

Each experiment required a preliminary conditioning period in which the carrying capacity of a flume became stabilized. A fish population was deemed stable when traps ceased to capture fish in 24 h. After the stabilization period, flow and water level were reduced in 24-hour steps. Water velocity, depth and the schedule of events are presented in Table 3.

Community Analysis

All insects collected during the study were preserved in 70% ethanol, sorted and identified in the laboratory using keys by Edmondson (1959), Usinger (1968), Jensen (1966), and several specific taxonomic works. Chironomidae (Diptera), by virtue of their unresolved status taxonomically, were not dealth with at the specific level in this study.

Most of the other encountered species were identified specifically to species or morphospecies, therefore permitting an overall accurate assessment of species diversity calculations. The Shannon-Weaver diversity equations were used to calculate species diversity and are essentially those given by Patten (1962).

Table 3. Schedule of events in laboratory flume test with hatchery chinook salmon

Day	Time (hour)	Event	Traps
1	1200	Fish placed in flumes, fed every 2.0 h after trap checks from 0800 to 1800. Water velocity 17 cm/sec, mean depth 17.5 cm	Closed
2	1200	Traps opened, end of adjustment period	Open
	1230 to 1400	Traps checkec once/0.5 h	Open
	1600 to 2000	Traps checked once/2.0 h	Open
3-6	0800 to 2000	Traps checked once/2.0 h	Open
7	0800 to 1200	Traps checked once/2.0 h	Open
	1200	Water velocity reduced to 10.5 cm/sec. Mean depth, 9 cm	Open
	1230 to 1400	Traps checked once/0.5 h	Open
	1600 to 2000	Traps checked once/2.0 h	Open
8	0800 to 2000	Traps checked once/2.0 h	Open
9	0800 to 2000	Traps checked/2.0 h	Open
10	0800 to 1200	Traps checked once/2.0 h	Open
	1200	Water velocity reducec to 7.5 cm/sec. Mean depth 4.5 cm	Open
	1230 to 1400	Traps checked once/0.5 h	Open
	1600 to 2000	Traps checked once/2.0 h	Open
11	0800 to 2000	Traps checked once/2.0 h	Open
12	0800 to 2000	Traps checked once/2.0 h	Open
13	0800 to 1200	Traps checked once 2.0/h	Open
	1200	Traps closed, experiment ends	Closed

RESULTS

Clearwater River Study

Physical-Chemical Parameters

Substrate characteristics from the intensive sampling sites varied spatially as a function of location, slope, steepness of the bank, and flow conditions. The thalweg of the river stations generally reflected a rubble bottom characterized by cobble and boulders. Various amounts of gravel and sand were present around or under the dominant substrate type. The cobble and rubble for the most part reflected an unimbedded to 1/3 imbedded condition, i.e., the cobbles were imbedded or partially imbedded in finer surrounding sediments. Notable departure from this conditions was apparent on the north side of the river at the Orofino station (river km 72) where heavy sediment loads were contributed by Orofino Creek.

Extreme seasonal variations in flow are evident in the Clearwater River (Figure 3). The eight-year hydrograph indicates that the annual flows in the Clearwater River are bimodal, i.e., a late winter rainy season or thaw causes a noticeable increase in discharge followed by a pronounced increase in flow during the spring runoff period of May and June. Low flows in August and September were about 100 m^3/sec at Spalding and 37-49 m^3/sec at Orofino. The hydrograph reflects a very close correlation between Spalding and Orofino flows up to the time that power was generated which was 1 March 1973. Subsequent to that time increased discharge from North Fork Clearwater River resulted in proportionally higher flows at Spalding than during the pre-impoundment period.

High and low monthly temperatures showed equally as dramatic variation as flows (Figures 4 and 5). With the creation of the Steelhead Fish Hatchery at Ahsahka, water temperatures were recorded at that facility for both the North Fork and the Clearwater River above the confluence of the North Fork. Data are available for three years dating back to 1972 for these two locations. Water temperature data at Ahsahka during 1968 and 1969 reflect the same approximate water temperatures as would have been obtained at the fish hatchery and so are included in Figure 4b. The recorded high and low temperatures of the North Fork of the Clearwater River are approximately 3 to 10 C cooler than similar temperatures in the main Clearwater River above the confluence. The extreme high temperature of 36 C recorded during September 1974 probably represents sampling error.

In an obviously different manner, the wintertime high and low temperatures at the Ahsahka fish hatchery are appreciably warmer than in the Clearwater River above the confluence, averaging 3 to 5 C warmer. The monthly high and low temperatures at Peck and Spalding reflect the mixing effects of the Middle Fork and North Fork waters. Cold waters from the Dworshak Reservoir again are reflected at the Spalding station (Figure 5). High and low temperatures generally range from 2 to 5 C colder during July and August than during the pre-impoundment period. This is especially true in 1973 when the first generators were put into operation at Dworshak. In 1974 the high and low

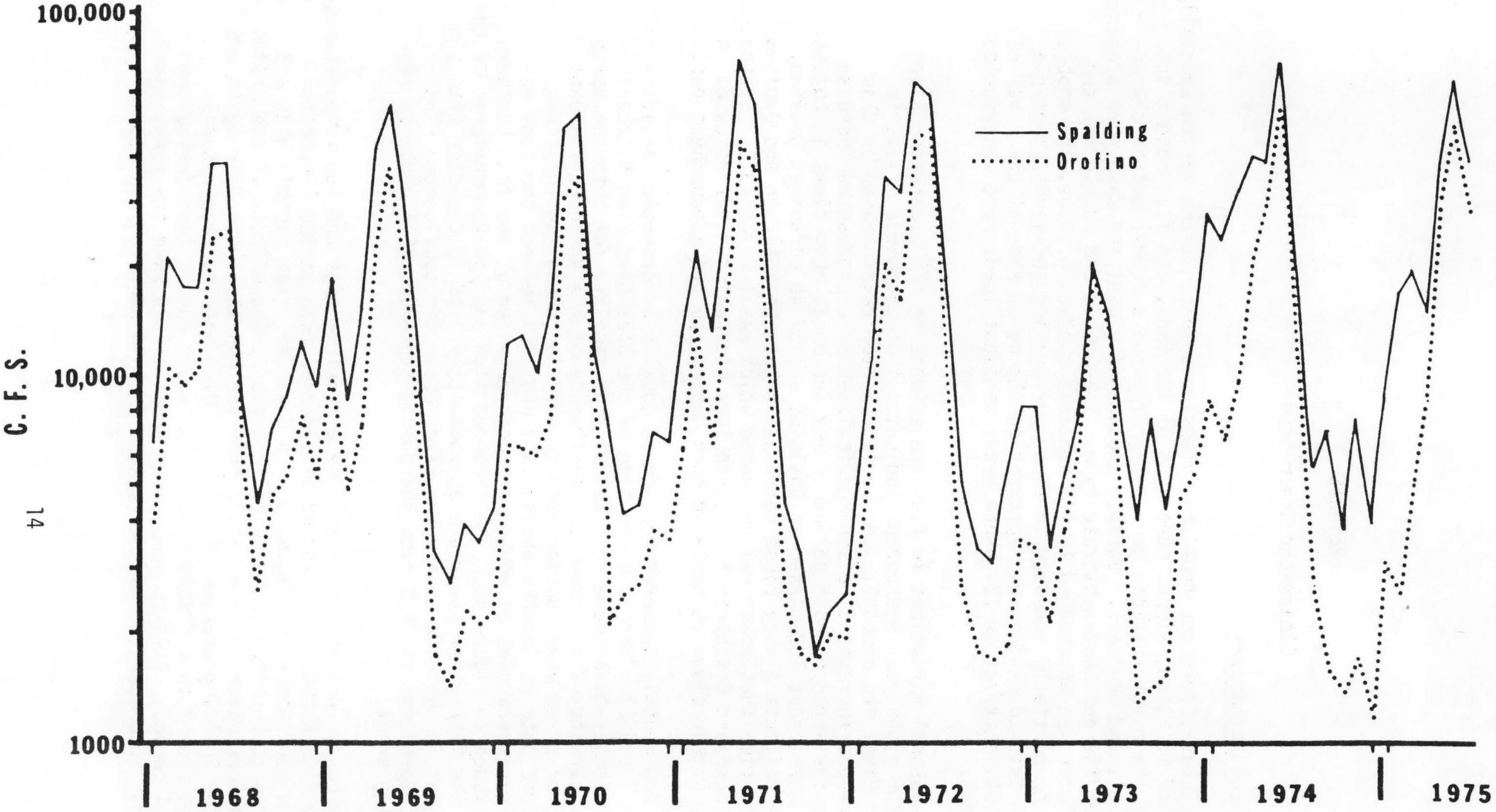

Figure 3. Monthly discharge for water gauging stations at Orofino and Spalding, Clearwater River, 1968-1975. (Data from U.S.D.I., Geological Survey)

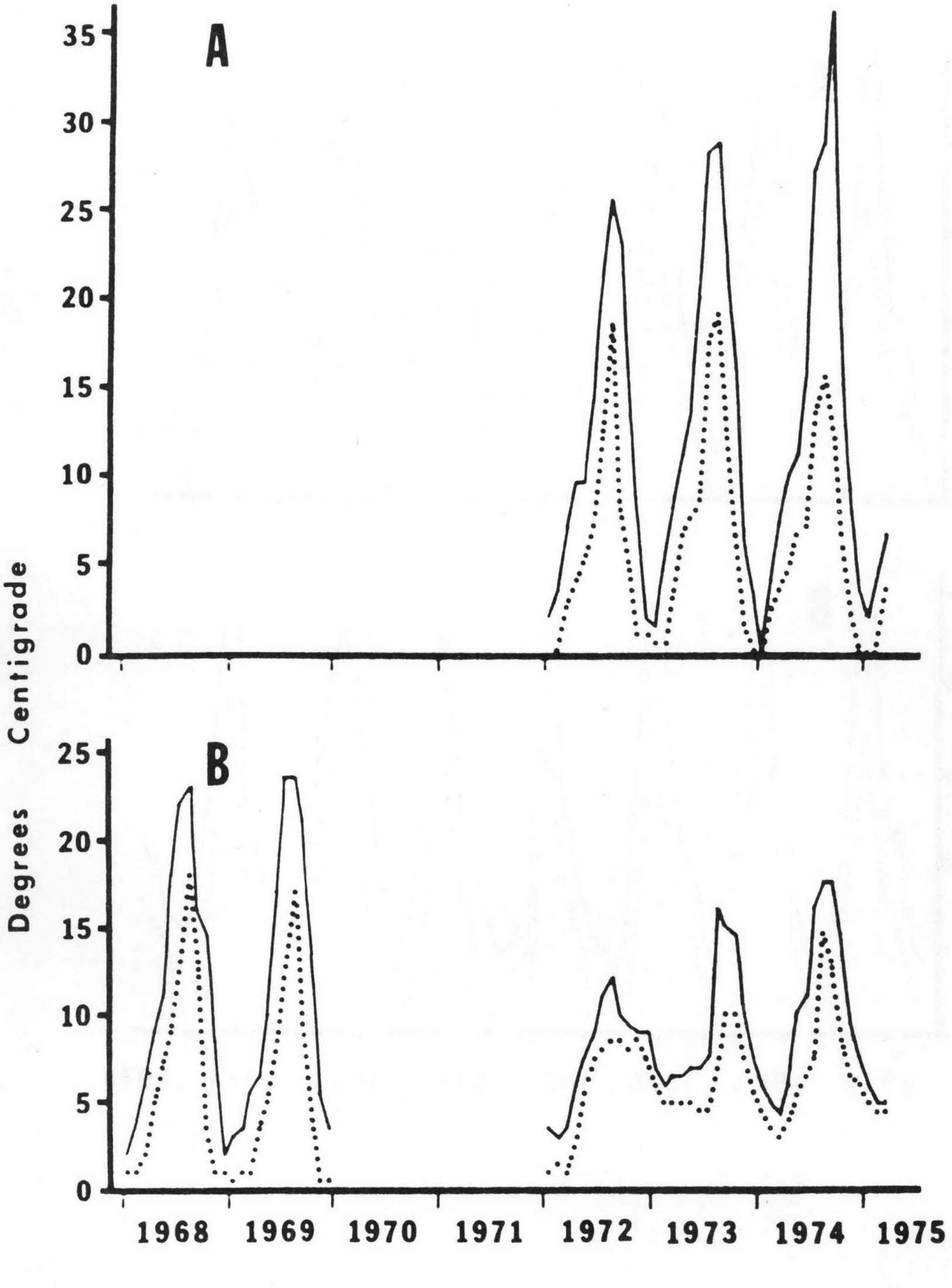

Figure 4. High (solid line) and low (dotted line) monthly temperatures (0 C) at: A. Middle Fork Clearwater River near Orofino, B. North Fork Clearwater River at Ahsahka. (Data from U.S.D.I., Geological Survey)

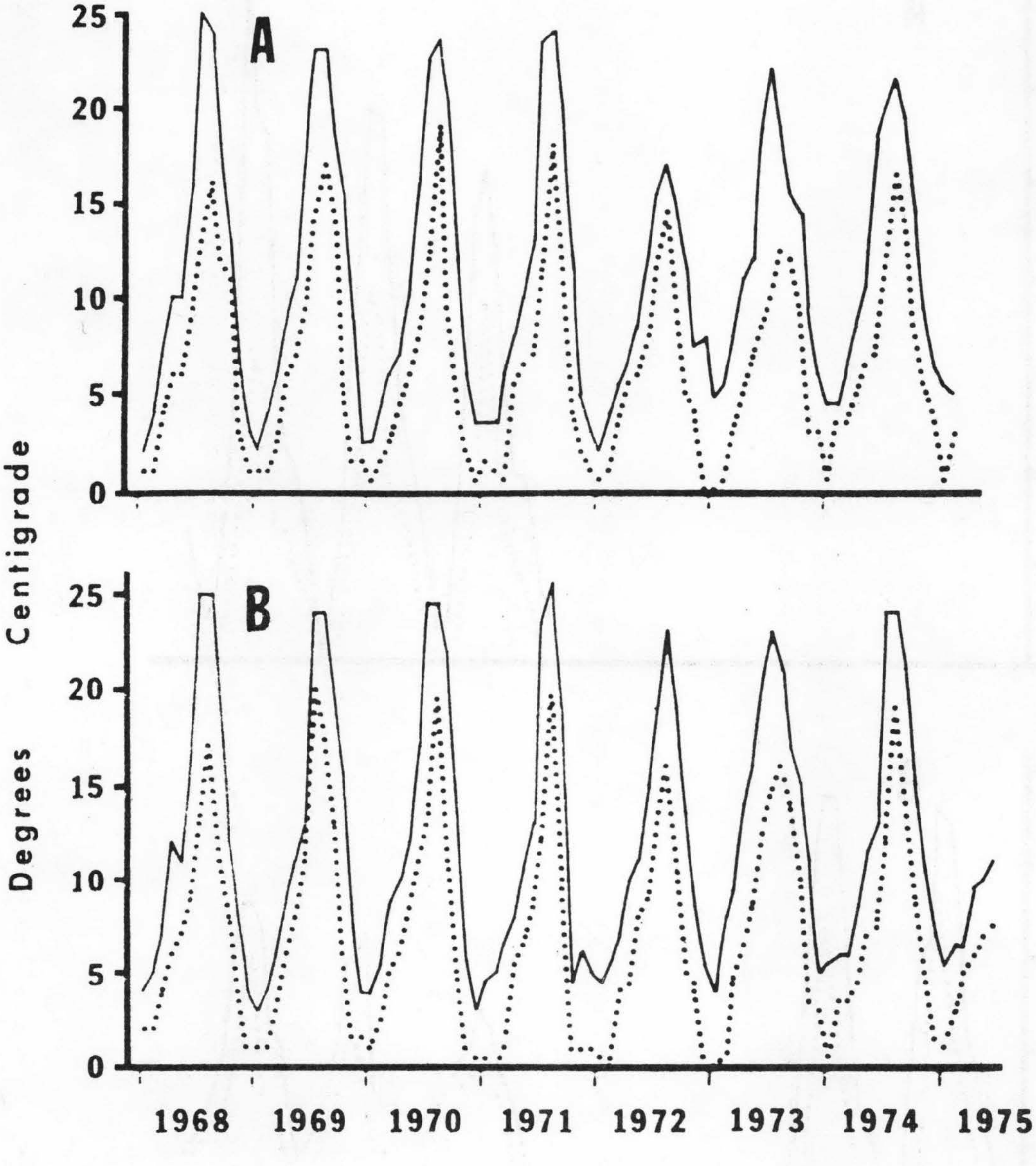

Figure 5. High (solid line) and low (dotted line) monthly water temperatures (C) at; A. Peck gauging station and B. Spalding gauging station. (Data from U.S.D.I. Geological Survey.)

temperatures during midsummer more closely approximate the temperatures that prevailed during the period of 1968 to 1972.

Dissolved oxygen was recorded at five points along the mainstem of the Clearwater River from May 1974 to 19 June 1975 inclusive (Figure 6). The total range in dissolved oxygen varied from 9.1 to 13.9 mg/l from all stations monitored. Highest values were obtained from the Clearwater River above the confluence of the North Fork, lowest values from the North Fork. Lowest seasonal oxygen levels were obtained during the months of August and September from all stations monitored.

Insect Drift

Periodicity of insect drift reflected marked differences among the three depth zones at a station (Figures 7-9). Overall differences in species composition and densities existed between stations. The control and two test stations reflected highest drift at night and lowest during the daylight hours. Mayflies and caddisflies represented the principle components in the drift, representing some 90% of all the insects collected in drift.

Total drift numbers during the midnight sampling period were greater at the 30 and 45 cm depth zone at river km 50 that at the control stations near Orofino, but appreciably less than the numbers obtained at the control station at the 15 cm depth zone. When converting numbers drifting per unit time to a density relationship, i.e., numbers/m^3 of water, the control station reflected highest drift.

The midafternoon drift at river km 72 (control station) and river km 38 is a graphic artifact in that the numbers have been plotted in a logarithmic scale. Thus, small numbers tend to overemphasize the actual difference between noon and 1800 h counts. The Hemipteran family Gerridae (Water strider) contributed to the daytime drift. These are water-surface-inhabiting insects and were not significant in nighttime drift. Caddisfly drift was largely represented by the two genera Brachycentrus and Wormaldia. Hydropsyche sp. contributed minimally to drift at river km 38. Brachycentrus comprised over 95% of the caddisfly drift at the 45 cm depth and became proportionately less dominant at the 30 cm and 15 cm depths. At river km 38, Brachycentrus comprised approximately 66% of the drift at 15 cm water depth while Wormaldia contributed 25%.

Mayflies were the most diverse group of insects in drift. Spatial differences in species composition both within a station and between stations are apparent. At both the control (river km 72) and test sites (river km 38) Baetis tricaudatus was the most abundant drift insect at 45 cm of water. Baetis bicaudatus (14%), Ephemerella margarita (11%), and Ephemerella doddsi (11%) were principle associated components in the drift at the control station at Orofino. At river km 28, Epeorus albertae (20%) was the single important associated species at the 45 cm depth. At the intermediate water depth of 30 cm, Baetis Tricaudatus again was one of the abundant drift components; however, at the control station, Ephemerella doddsi (33%) replaced it as the principle drift species. Ephemerella margarita (14%), Baetis bicaudatus (10%),

Figure 6. Dissolved oxygen at mg/l at five locations on the Clearwater River, May 1974 to June 1975

Station	7May	12Jun	9Jul	6Aug	5Sept	11Oct	22Nov	18Dec	13Feb	26Mar	16Apr	20May	19Jun
Above North Fork	13.9	10.3	13.4	10.0	10.1	11.1	11.9	12.1	13.5	13.0	13.3	11.6	10.9
North Fork	11.7	10.8	9.9	9.4	9.5	10.3	10.4	10.9	9.6	11.9	9.3	10.0	10.5
Peck	11.7	10.9	10.8	9.6	9.5	11.0	11.0	11.7	11.0	12.4	11.4	11.4	10.7
Spalding	-	-	-	9.5	9.5	10.6	11.4	11.8	11.6	12.1	11.8	11.3	10.9
Lewiston (Memorial Bridge)	-	-	-	9.1	9.5	11.0	12.1	12.0	11.7	12.0	12.3	11.4	10.9

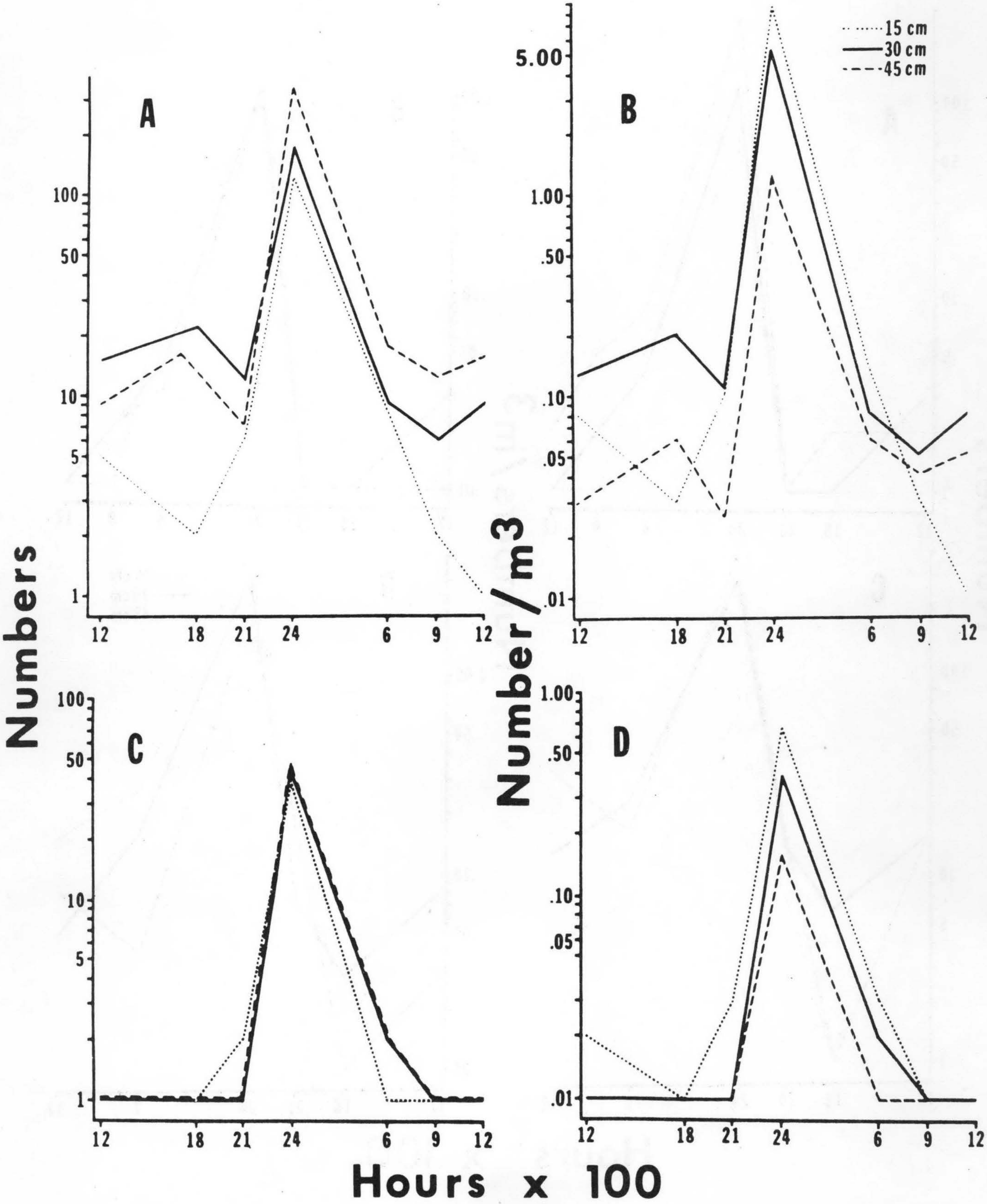

Figure 7. Insect drift at River Km 72 (control). A. Total numbers - all insects; B. Numbers/m^3 flow - all insects; C. Total number of mayflies; and D. Mayfly numbers/m^3 flow.

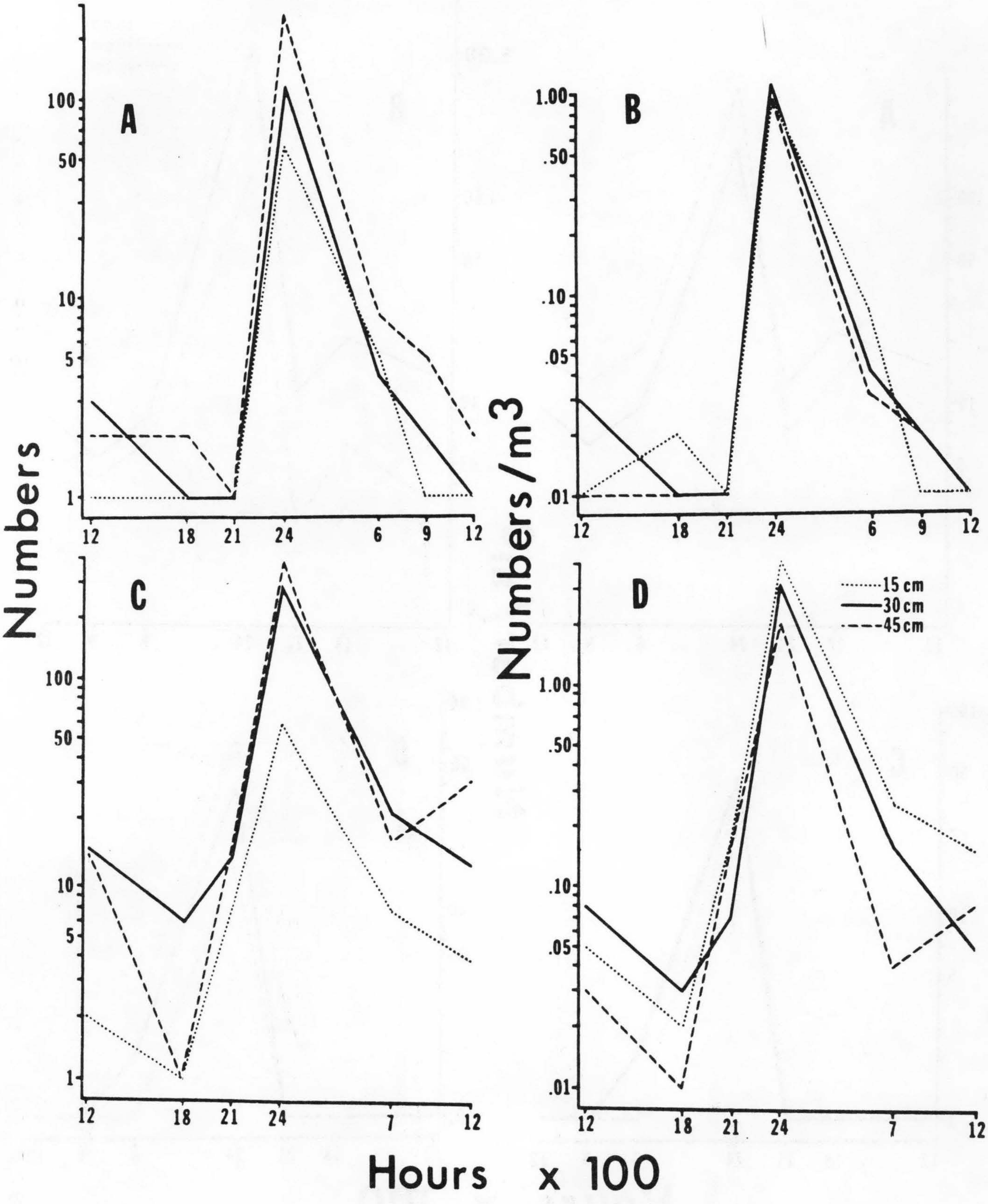

Figure 8. Insect drift. A. Total number of caddisflies, River Km 72 (control); B. Caddisfly numbers/m^3 flow, River Km 72; C. Total numbers - all insects, River Km 38; and D. Total numbers/m^3 flow - all insects, River Km 38.

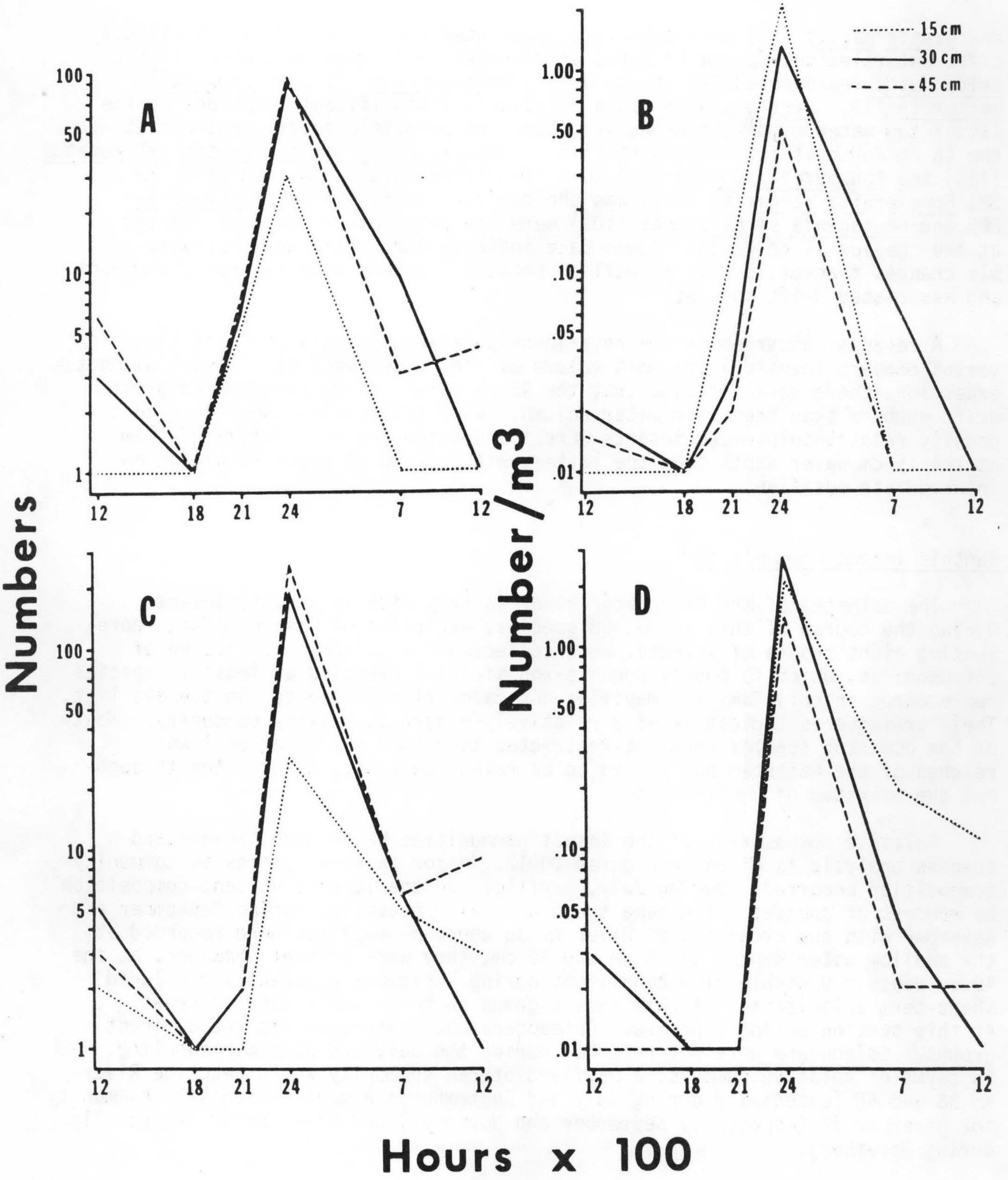

Figure 9. Insect drift at River Km 38. A. Total numbers of mayflies; B. Mayflies/ m^3 flow; C. Number of caddisflies; D. Caddisflies/m^3 flow.

and Baetis parvus (8%) were principle associated species in drift. A slightly different relationship can be noted at River Km 38 (Figure 9a), where Baetis tricaudatus represented 57% of the drift, Centroptilum 16% and Ephemerella margarita 11%. Baetis parvus was a relatively insignificant component at the latter two water depths, however it became the principle drift component at the 15 cm depth at the control station. Ephemerella margarita, Baetis tricaudatus (16%) and Ephemerella doddsi (8%) were associated components. At River Km 38, Ephemerella margarita (50%) was the dominant drift mayfly; Centroptilum 20% and Heptagenia simplicoides (10%) were the principle associated species at the shallow 15 cm depth. These data indicate that there were appreciable changes transectionally as well as between stations with regard to dominant and associated drift species.

A reversal occurred in the relationship between numbers per unit time versus numbers (density) per unit volume of flow (Figures 7-9). Almost without exception, these data indicate that the 45 cm water column transported greater drift numbers than the 15 cm water column. When transposing these data to a density relationship, more insects were transported per unit volume of flow at the 15 cm water depth than the latter, with the 30 cm depth retaining an intermediate position.

Benthic Insect Communities

The mainstem of the Clearwater River is very rich in aquatic insects. During the course of this study, 98 species, exclusive of Chironomidae, representing eight orders of insects, were collected. A cursory examination of Chironomidae, which is poorly known taxonomically, revealed at least 12 species represented in this family. Mayflies and caddisflies dominate the species list. Their presence is indicative of a relatively vigorous, healthy community. Most of the dominant species were not restricted to either the upper or lower reaches of the mainstem but tended to be rather uniformly distributed throughout the mainstem of the Clearwater.

Relative composition of the insect communities based upon ordinal and species analysis is given in Figures 10-12. Major seasonal shifts in community composition occurred. During July, mayflies had the largest percent composition by numbers of species. The same trend generally prevailed during September and November with the exception of River Km 38 where no mayflies were recorded at the shallow water depths of 15 cm and 30 cm; they were present, however, at the 45 cm depth. Unstable flow conditions during September apparently precluded short-term colonization of this insect group on these newly watered areas. At this station during September, Coleoptera and Diptera became the dominant groups. Coleoptera were not recorded during the July and November sampling. In terms of relative numbers, a mayfly-dipteran community would describe River Km 38 and 50 (especially during July and September); a mayfly-caddisfly community for River Km 72 (especially September and November) and River Km 38 (especially during November).

An analysis of number of species, number of individuals and species diversity indicates that for most stations and on most dates, numbers of species and density generally increased with increasing depths from 15, 30 and 45 cm.

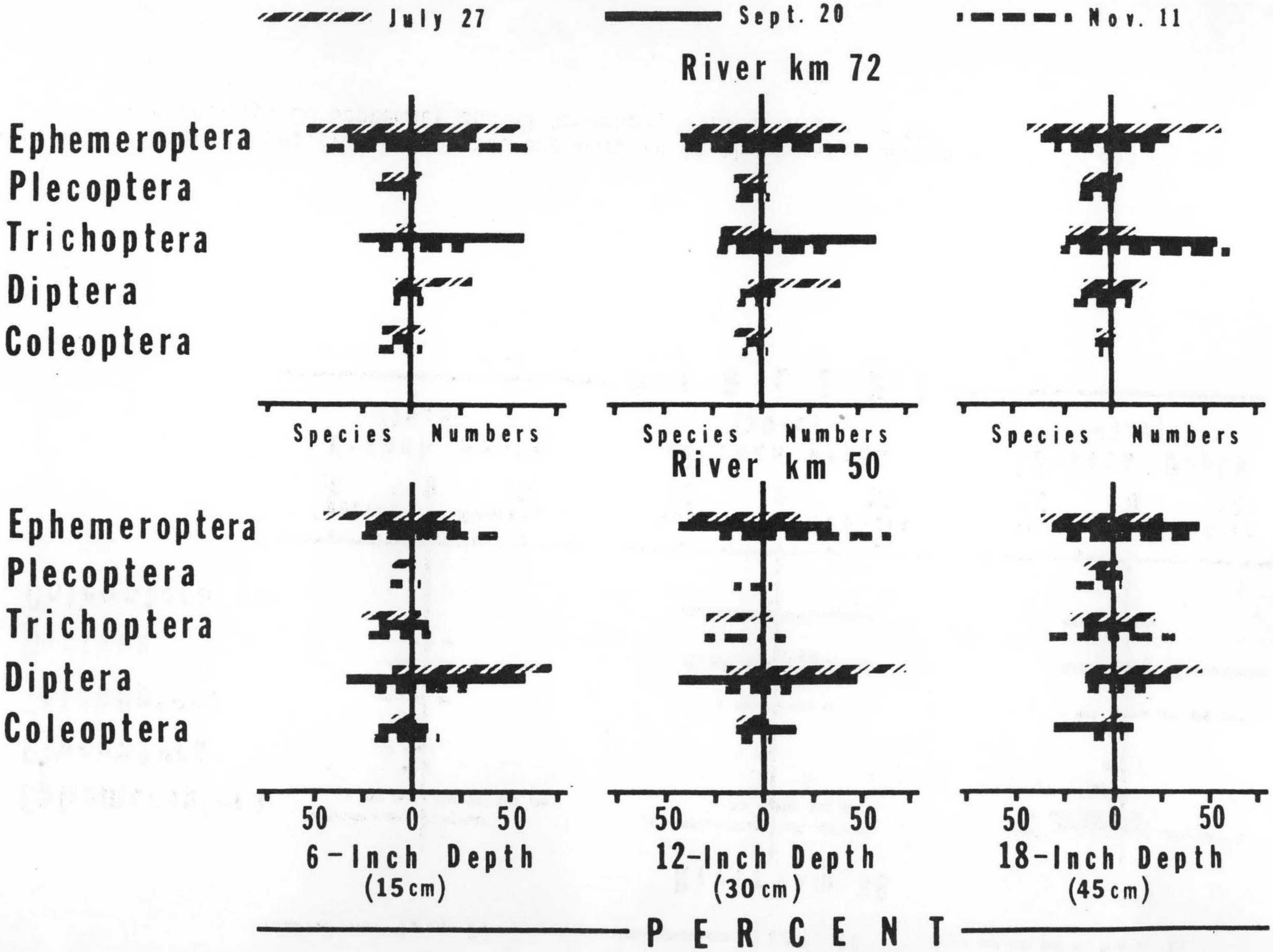

Figure 10. Percent composition by species and numbers at three water depths of 15, 30 and 45 cm for 27 July, 28 September and 11 November, 1974 at River Km 50 and 72.

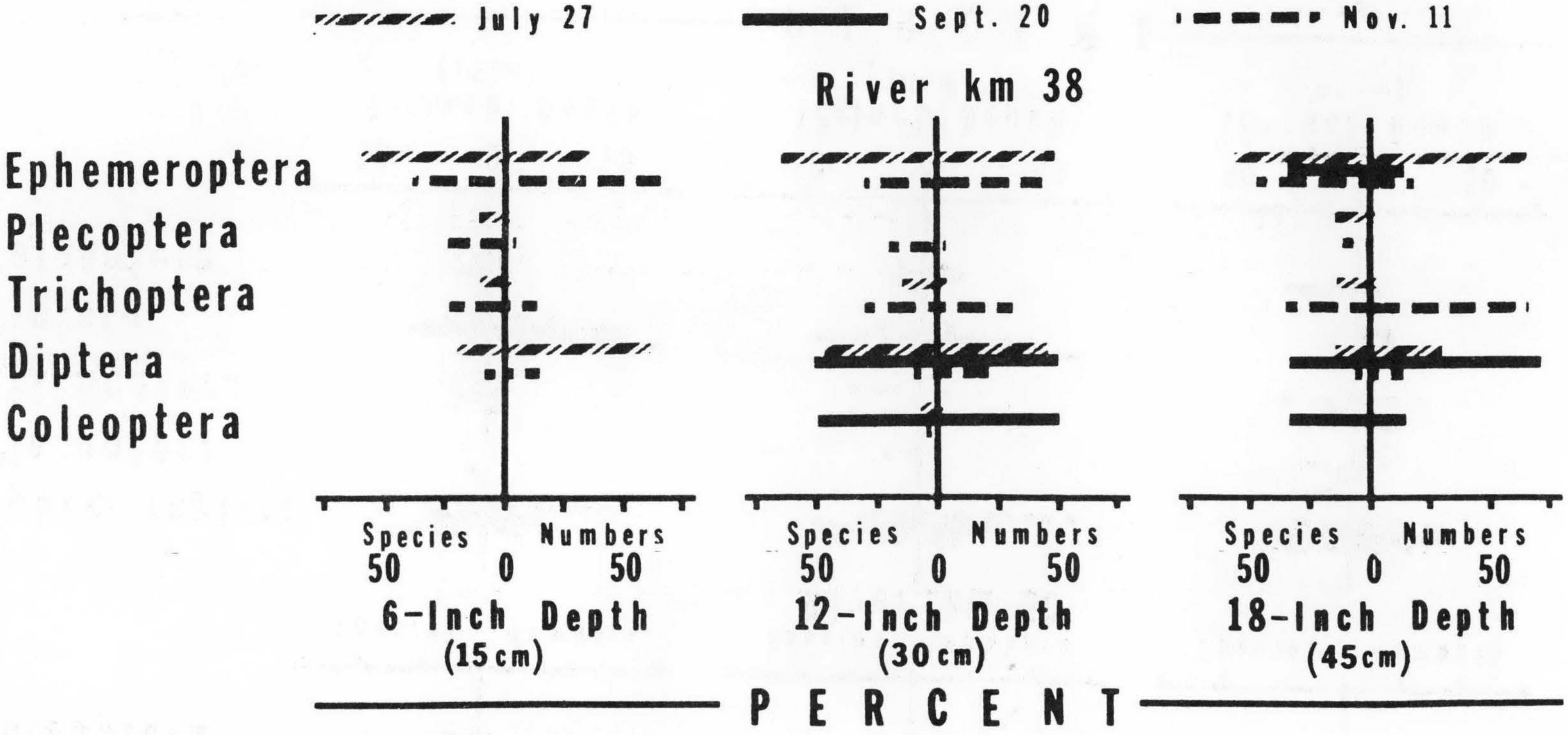

Figure 11. Percent composition by species and numbers at three water depths of 15, 30 and 45 cm for 27 July, 20 September and 11 November, 1974 at River Km 38.

Figure 12. Diversity, redundancy, number of species andnumber of insects colonizing shallow (1 m) and deep (2 m) sampling baskets from two location on Clearwater River, 1974. Calculations do not include Chironomidae

Site		Diversity			Redundancy			Number of Species			Number of Insects		
		Shallow	Deep	Total	Shallow	Deep	Total	Shallow	Deep	Total	Shallow	Deep	Total
River Km 72	8/28/74	2.97	2.34	2.89	.35	.43	.38	24	17	25	6080	2816	8897
	9/30/74	3.03	3.39	3.19	.25	.09	.24	16	13	18	776	152	928
	12/23/74	3.58	2.93	3.39	.18	.26	.26	21	14	23	237	321	558
River Km 50	8/28/74	2.71	2.79	2.79	.36	.30	.36	19	16	21	8016	4560	12552
	9/30/74	2.78	2.82	2.95	.31	.32	.33	16	17	21	1504	2832	4336
	12/23/74	2.27	2.78	2.56	.51	.35	.45	22	18	24	1473	728	2201

A similar positive trend was not evident with regard to diversity per individual values calculated for the same stations.

A diversity analysis of deep water baskets positioned at approximately 1 and 2 m deep revealed generally consistent values for the two depths. There was no predictable trend with respect to increasing or decreasing diversities as a function of the three sampling dates of August, October and December among the three stations (Figure 12).

The number of species colonizing the 1 and 2 m baskets, like the diversity values, was remarkably similar. Differences of one or two species between basket depths on a given sampling date were noted. Baskets located at River Km 72 and River Km 50 (Harper's Bend) decreased in density with increasing depth of the basket.

Caddisflies, especially Hydropsyche sp., Brachycentrus sp., and Cheumatopsyche sp. were the principle inhabitants colonizing the baskets during August, while mayflies predominated during late September and October, especially Ephemerella margarita, Ephemerella (inermis-infrequens complex), and Rithrogena hageni. December baskets had the greatest variation in dominant species between sites. Baetis parvus and B. Bicaudatus were abundant inhabitants at River Km 72 and Harper's Bend.

Colonization of artificial substrate mats and baskets during the filling of Lower Granite Pool (February 1975) was small, with numbers seldom exceeding five per sampler. On a comparative basis, the baskets were more readily colonized than nets. Over 90% of the insects colonizing baskets and mats were Chironomidae and 5%-30% of the insects that colonized the baskets were stranded during the reduction of flows after the filling of Lower Granite Pool.

Diversion Channel

In simulation studies in an artificial spawning channel the vertical distribution of aquatic insects was noticeably different in graded substrate over which water flowed at 0.5 and 10 cm depths (Figure 13). Largest numbers of insects were recorded in the upper one-third of the canisters, the lower one-third the least. The canisters were colonized primarily by dipterans, chironomids, stoneflies and mayflies. Diptera far exceeded otherinsects in the canisters and most prominently colonized the upper 10 cm stratum. A similar distributional trend was reflected by mayflies; however, stoneflies, especially Alloperla, were rather evenly distributed throughout the three canister levels.

During July and August 1974, more than 100-fold increase was noted in departure of insects across the lower sill when the diversion channel was dewatered. This indicated high levels of stress resulting in a massive emigration downstream (Figures 14-17). Drift in the main South Fork of the Salmon River (control) did not show a similar increase. Heavy rains during the 17 l/sec discharge sampling period of August did not permit the taking of samples. Mayflies represented nearly 90% of the drifting insects. Midges in the family chironomidae represented the other major component.

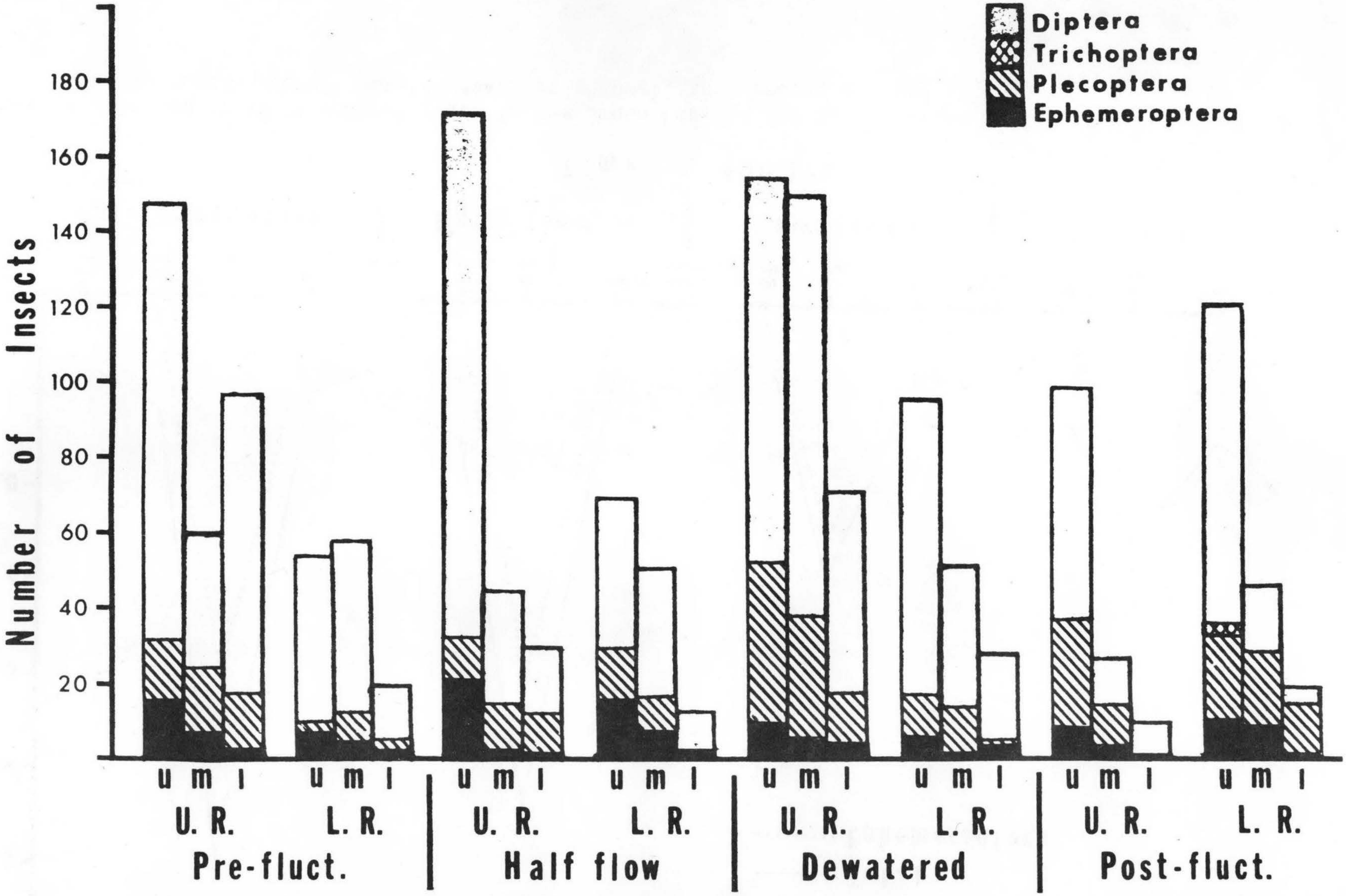

Figure 13. Vertical stratification of insects from three interstitial depth zones of 0-10 cm (U), 10-20 cm (M), and 20-30 cm (L) from two riffles (upper riffle U.R. and lower riffle L.R.) during pre-fluctuation, half flow, dewatered and post-fluctuation conditions in diversion channel.

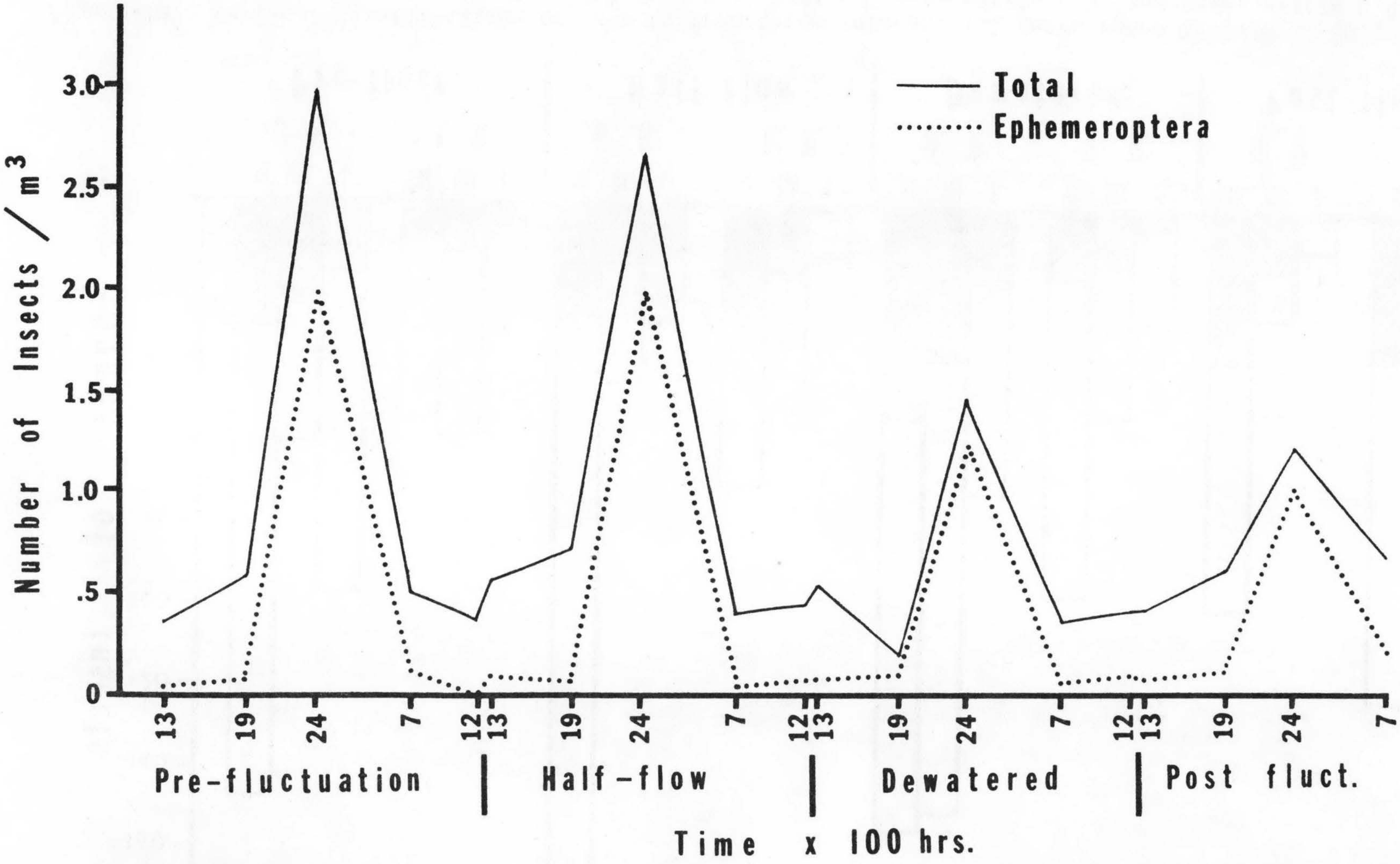

Figure 14. Insect drift in control reach in the South Fork of the Salmon River during four flow fluctuation conditions in diversion channel, test reach, in July 1974.

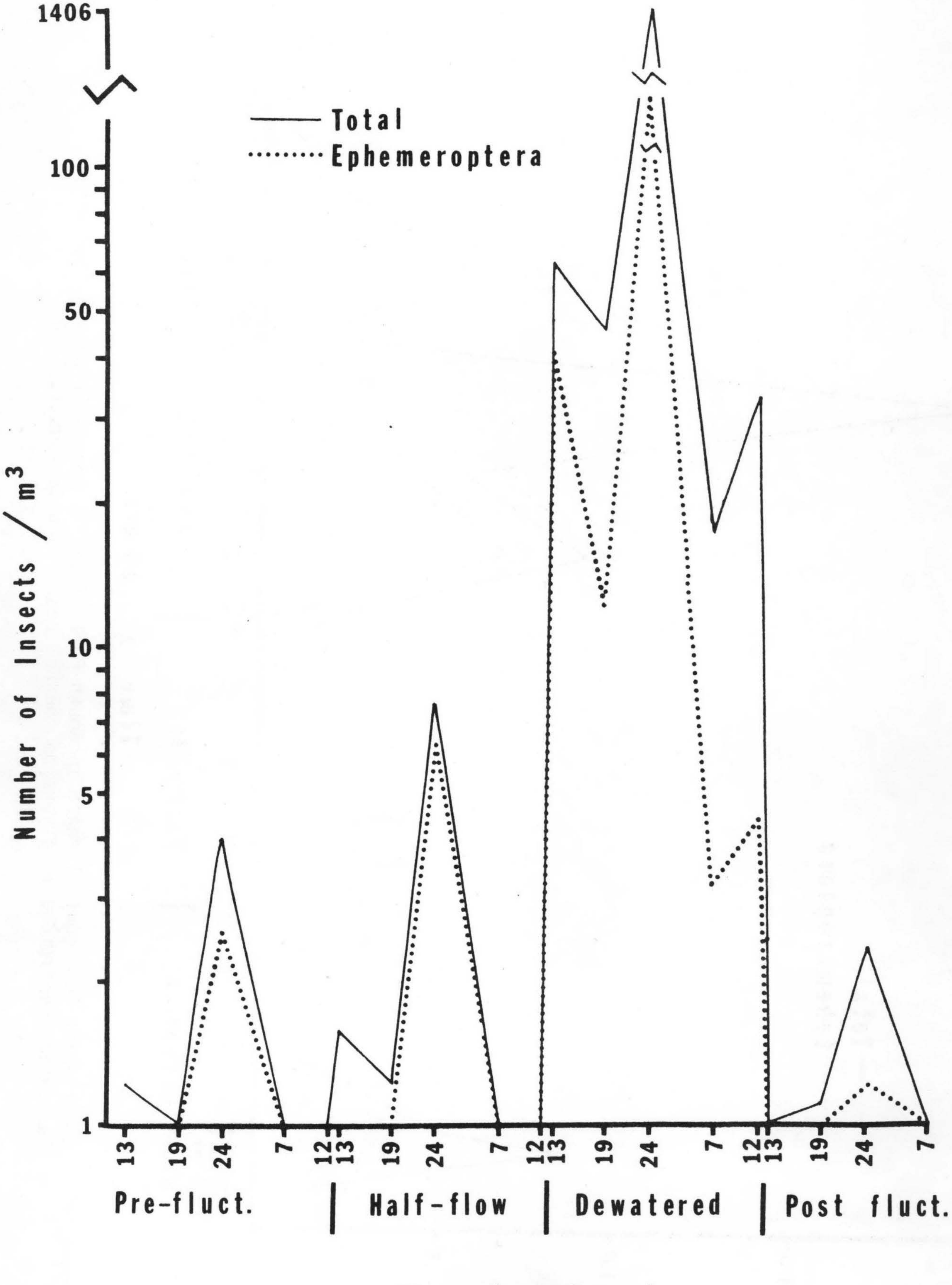

Figure 15. Insect in a test reach of the diversion channel during flow fluctuation conditions in July, 1974.

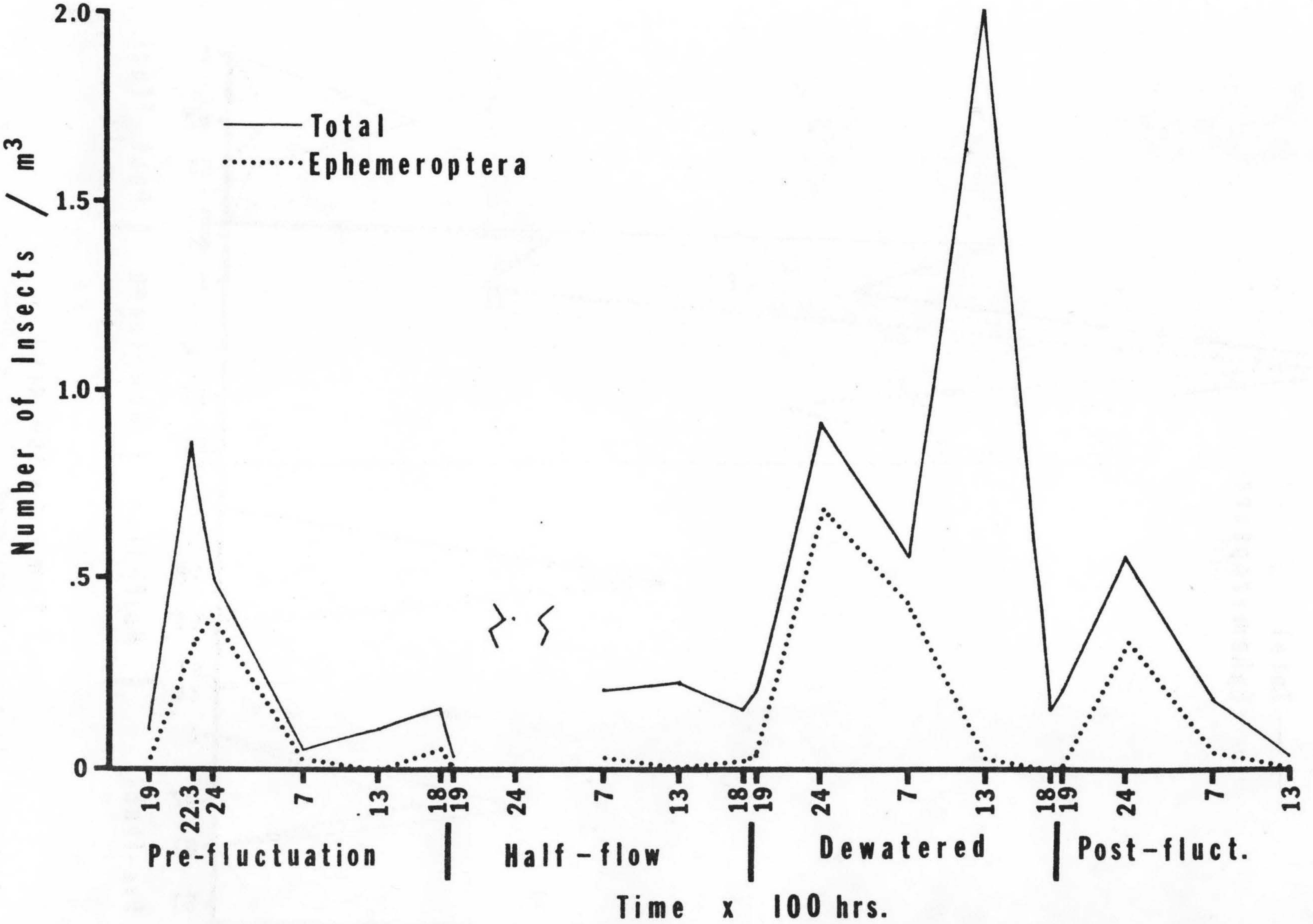

Figure 16. Insect drift in a control reach in South Fork of the Salmon River during four water fluctuation conditions in diversion channel test reach in August, 1974.

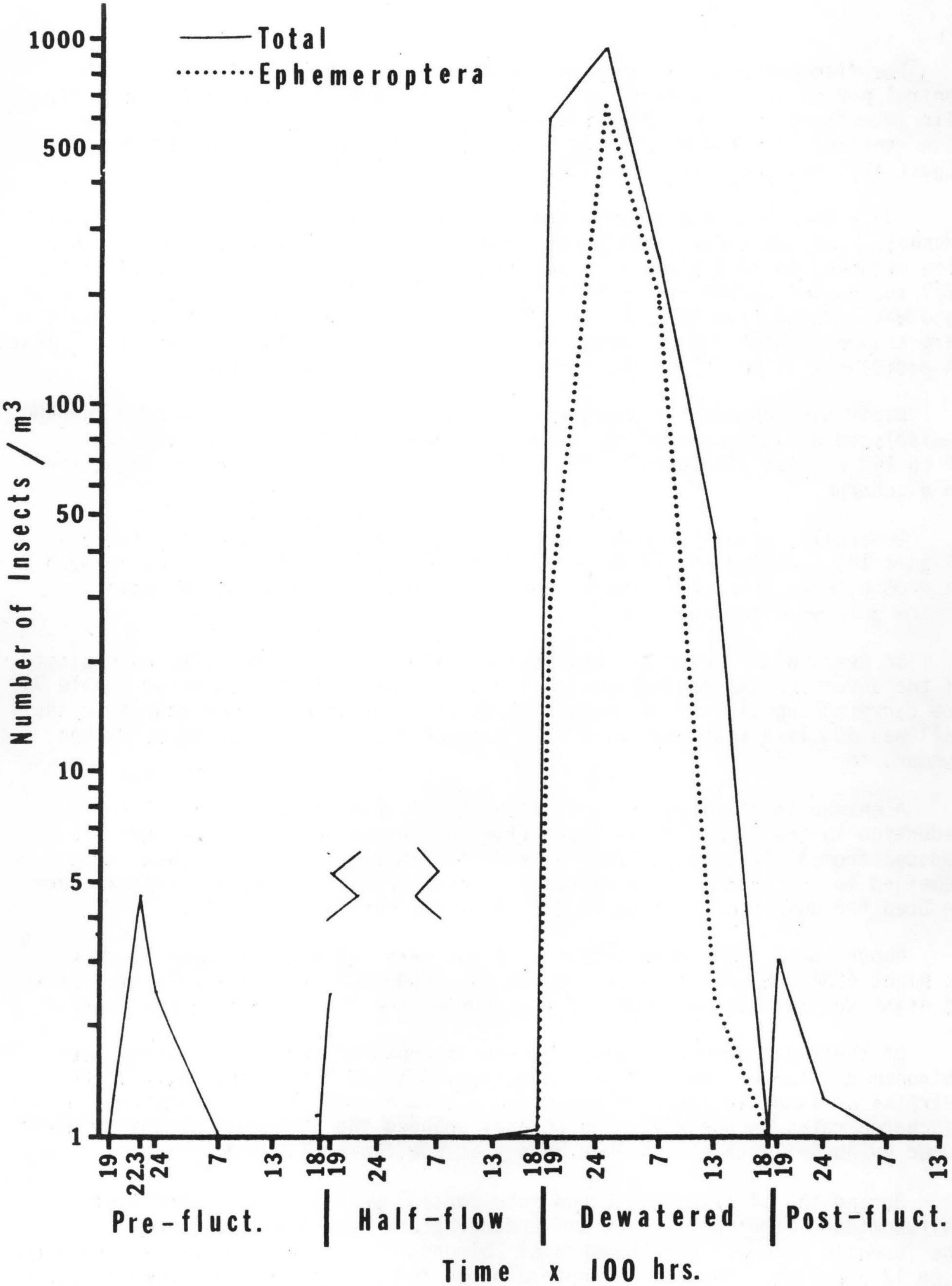

Figure 17. Insect drift in a test reach of a diversion channel during flow fluctuation conditions in August 1974.

The fish carrying capacity of the diversion channel varied during the control period at a discharge of 51 l/sec. For the 16 August 1974 test, 310 wild juvenile chinook occupied the channel; for the 8 July 1975 test, 289 fish remained; for the 20 July 1975 test 286 fish remained; and for the 17 August 1975 test, 252 fish remained in the channel (Tables 5 and 6).

Any alteration in discharge reduced the numbers of fish staying in the channel. For the three tests in which discharge was rapidly reduced (within five minutes) in 24 h steps a reduction from a discharge rate of 51 l/sec to 17 l/sec caused 12-16% of the fish to move into the traps. When the discharge rate was reduced from 17 l/sec to 3 l/sec, 30 to 36% of the carrying capacities were trapped. When the discharge was rapidly increased from 3 l/sec to 51 l/sec an additional 11 to 13% of the carrying capacities were displaced.

Rapid diel changes in discharge from 51 l/sec to 17 l/sec at 2300 to 0500 h displaced only 2 to 7% of the salmon per day. This contrasted with the 12 to 16% of fish displaced in the 51 l/sec to 17 l/sec sequential reduction in discharge.

Generally, more fish were trapped during the night than during the day (Figure 18). During the 20 July 1975 test when discharge rates were changed at 1200 h, more fish were trapped during the day than at night, especially at the 3 l/sec discharge rate.

In tests with age 0 hatchery chinook salmon in 1974 the carrying capacity of the diversion channel became smaller with time as fall progressed (Table 7). The carrying capacity of hatchery chinook at lower stream temperatures in the fall was 40% less than that with wild chinook at higher temperatures in the summer.

A change in discharge from 51 l/sec to 17 l/sec resulted in a 7 to 11% reduction in the number of hatchery fish in the channel. When discharge was reduced from 17 l/sec to 3 l/sec only 36 to 52% of the carrying capacity remained in the channel. An increase in discharge from 3 to 51 l/sec further reduced the number of fish by 12 to 15% of the carrying capacity.

About three times more hatchery salmon were captured per hour in traps at hight (2000-0600 h) than during the day (0600-2000 h). The rate of capture at night was 18 fish per hour and that during the day was 6 fish per hour.

Of the total number of aquatic insects consumed at all discharge rates, Chironomidae larvae composed 95%; Simulium, 3%; and Ephemeroptera, 2%. No detritus or sand was found in the chinook salmon stomachs. Alterations in discharge rates in the diversion channel changed the number of organisms consumed by juvenile chinook salmon mainly at low flows (Table 8).

During the 51 l/sec discharge rate control period, small numbers of Chironomidae, Simulium larvae, and Ephemeroptera numphs were consumed by the juvenile salmon. Mean numbers of Chironomidae larvae consumed ranged from 3 to 12 per fish. Mean Ephemeroptera numph and Simulium larvae numbers never exceeded one per fish.

Table 4. Effect of daily changes in discharge on the abundance of wild, age 0 chinook salmon in a diversion channel.

Date	Discharge, liter/sec	Number Migrants Trapped			Number of Fish Remaining in Diversion Channel	Percent of Carrying Capacity	Temperature, C	
		Day	Night	Total			Max	Min
16 Aug 1974[1]	51	0	4	4	310	100	17	11
17 Aug 1974	17	11	36	47	263	85	16	11
18 Aug 1974	3	41	73	114	149	48	17	11
19 Aug 1974	51	16	25	41	108	35	17	10
		68	138	206				
20 July 1975[1]	51	0	0	0	289	100	16	8
21 July 1975	17	5	41	46	243	84	16	8
22 July 1975	3	44	42	86	157	54	17	9
23 July 1975	51	17	21	38	119	41	16	8
		66	104	170				
17 Aug 1975[1]	51	0	0	0	252	100	15	9
18 Aug 1975	17	9	22	31	221	88	15	10
19 Aug 1975	3	21	57	78	143	57	16	8
20 Aug 1975	51	6	21	27	116	46	17	9
		36	100	136				

[1] Discharge altered at 1800 h

[2] Discharge altered at 1200 h

Table 5. Effect of changes in discharge from 51 l/sec to 17 l/sec at 2300 h and 17 l/sec to 51 l/sec at 0500 h on the abundance of age 0 wild chinook salmon in a diversion channel in 1975

Date	Number of Migrants Trapped			Number of Fish Remaining in Diversion Channel	Percent of Carrying Capacity	Temperature, C	
	Day	Night	Total			Max	Min
8 Aug 1975	0	1	1	286	100	17	10
9 Aug 1975	5	12	18	268 268	93	17	10
10 Aug 1975	8	8	16	252	88	17	9
11 Aug 1975	1	4	5	247	86	17	10
	14	26	30				

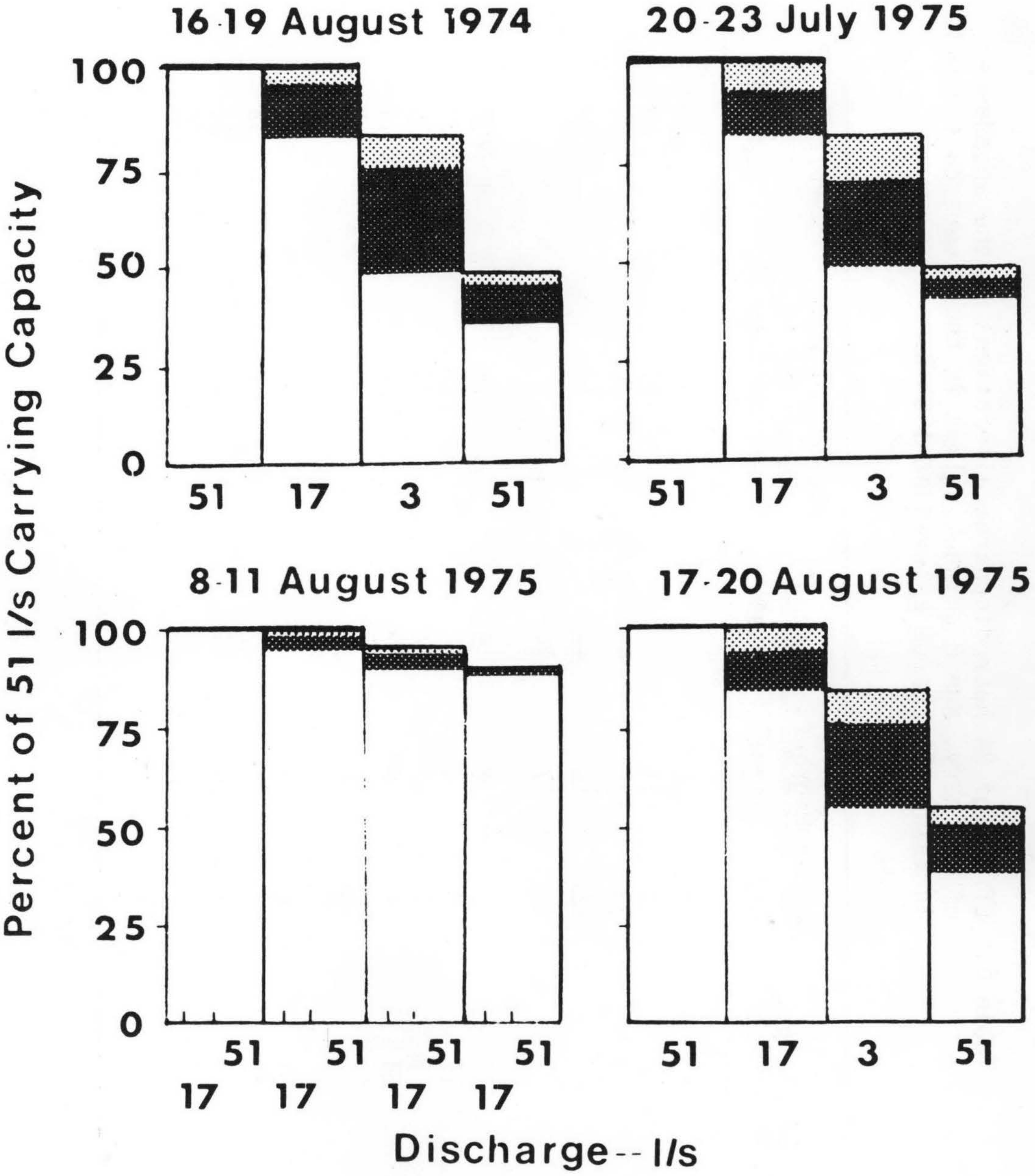

Figure 18. Percent of wild age 0 chinook salmon remaining in diversion channel at 51 l/sec discharge rate. A diel peaking schedule alternated discharge between 17 and 51 l/sec during 8-11 August 1975. Cross-hatch lines represent the percentage of emigrants trapped at night (2000-0600 h). Dotted areas represent the percentage of emigrants trapped during the day (0600-2000 h).

Table 6. Effect of 24 hour discharge alterations on the abundance of hatchery, age 0 chinook salmon in the diversion channel in 1974. Discharge altered at 1800 h.

Date	Discharge, liters/sec	Number Migrants Trapped			Number of Fish Remaining in Diversion Channel	Percent of Carrying Capacity	Temperature, C	
		Day	Night	Total			Max	Min
19 September	51	0	4	4	123	100	13	7
20 September	17	3	13	16	107	89	14	5
21 September	3	23	39	62	45	37	15	4
22 September	51	17	18	25	27	22	14	5
		33	67	110				
27 September	51	0	6	6	115	100	12	7
28 September	17	6	4	10	105	91	11	6
29 September	3	17	47	64	41	36	13	7
30 September	51	5	8	13	28	24	11	4
		28	65	83				
4 October	51	1	5	6	101	100	11	4
5 October	17	3	4	7	94	94	10	4
6 October	3	11	30	41	52	52	11	3
7 October	51	7	6	13	39	38	9	3
		22	45	67				

Table 7. Daily consumption of insects by age 0, wild chinook salmon at different rates of discharge in a diversion channel

Date	Discharge, liters/sec	Number of Stomachs Examined	Number of Stomachs Empty	Mean Number of Organisms in Stomachs: Chironomidae Larvae	Simulium Larvae	Ephemeroptera Larvae
15 Aug 1974	51	5	3	4	1	1
16 Aug 1974	51	2	2	0	0	0
17 Aug 1974	17	8	2	6	2	0
18 Aug 1974	3	10	0	113	2	2
19 Aug 1974	51	8	1	34	0	0
19 July 1975	51	6	3	12	0	0
20 July 1975	51	5	2	7	1	0
21 July 1975	17	5	1	13	1	0
22 July 1975	3	10	0	146	4	3
23 July 1975	51	10	1	52	2	0
16 Aug 1975	51	6	4	3	0	0
17 Aug 1975	51	8	5	7	0	0
18 Aug 1975	17	10	2	12	0	1
19 Aug 1975	3	10	0	96	2	5
20 Aug 1975	51	10	3	14	0	0

At the 17 l/sec discharge rate, mean numbers of insects consumed by the salmon remained small. The occurrence of Chironomidae larvae ranged from 6 to 13 per fish.

During the 3 l/sec discharge rate the numbers of Chironomidae larvae consumed increased greatly. Chironomidae larvae numbers ranged from 96 to 146 per fish, representing an increase of 8 to 19 fold over mean numbers consumed at the two higher discharge rates. The numbers of Simulium larvae and Ephemeroptera numphs in stomachs remained small in all three tests.

With an increase in discharge to 51 l/sec all taxa were less abundant in chinook stomachs. Only 7 to 36% of the mean number of Chironomidae larvae eaten at the 3 l/sec discharge rate were eaten at the 51 l/sec discharge rate.

Laboratory Flume Study

Alteration of flows in the laboratory flume yielded few juvenile chinook salmon in the traps (13%). Of the few fish trapped in the treatment flume, more fish were trapped during the night (9 fish) than day (2 fish).

With a 67% discharge reduction emigration resulted in a range of 7 to 13% loss of fish from the high discharge carrying capacity. More emigration took place during the 33% discharge level than during the 10% discharge level. Control channels experienced only 2-5% losses during the entire experimental period (Table 9).

Table 8. Effect of altered flow on the abundance of hatchery chinook juveniles in a laboratory flume at 12.5 C.

Flume Number	Test	Flow (l/sec)	Water Velocity (cm/sec)	Water Depth (cm)	Number Migrants			Number of Fish at End of Flow Period	Percent of Carrying Capacity
					Day	Night	Total		
April 1, 1975									
1	Control	17.8	17.0	17.5	0	0	0	48	100
		17.8	17.0	17.5	0	1	1	47	98
		17.8	17.0	17.5	0	0	0	47	98
2	Treatment	17.8	17.0	17.5	0	0	0	45	100
		5.5	10.5	9.0	1	5	6	39	87
		2.0	<7.5	4.5	0	1	1	38	84
April 17, 1975									
2	Control	17.8	17.0	17.5	0	0	0	40	100
		17.8	17.0	17.5	0	1	1	39	98
		17.8	17.0	17.5	0	1	1	38	95
1	Treatment	17.8	17.0	17.5	0	0	0	41	100
		5.5	10.5	9.0	1	2	3	38	93
		2.0	7.5	4.5	0	1	1	37	90

DISCUSSION

Clearwater River Study

Insect Communities

This study represents a continuation and extension of earlier studies and provides an opportunity for an historical evaluation of shifts in insect community subsequent to the formation of Dworshak Dam (MacPhee and Brusven, 1973). Major shifts in the insect community have not occurred in the study site below the dam (River Km 38) for the last five years.

Because of differences in numerical classification of abundance from earlier studies (Walker, 1972; Peters, 1973) to the present, a critical evaluation of population increases and decreases cannot be made for all species. Some trends are evident, however, e.g., the stonefly *Acroneuria* sp. increased at River Km 38 during the 1970 and 1974 period, while *Alloperla* sp. decreased at the same site, but remained unchanged at the control site (River Km 72). The trichopteran, *Lepidostoma* sp. demonstrated a surprising increase in abundance during the same years at both the control site and the test site (River Km 38). This caddisfly is a scraper, feeding on periphyton on the surface of rocks (Cumming, 1973). Three mayflies showed shifts in abundance during the same period: *Ameletus* sp. increased at River Km 72 and decreased at River Km 50; *Heptagenia simplicoides* remained essentially unchanged at River Km 72 but increased at River Km 38; and *Paraleptophlevia heteronea* remained essentially unchanged at River Km 72 but decreased at River Km 38. While these shifts in abundance are evident, they do not reflect large magnitude shifts. The remaining species at these stations changed little during this time period.

Fluctuating Shorelines and Insect Survivability

Fluctuating shorelines in streams caused by hydroelectric power generation represent one of the most dynamic changes in environmental characteristics of a stream. Insects potentially suffer great stress when subjected to fluctuating flows because many of them occupy the surface and undersides of gravel, pebble and cobble. Each insect species, by virtue of its unique biological attributes has different levels of adaptation and resiliency to fluctuating flows. Stoneflies, caddisflies and mayflies do not readily colonize shore regions in a daily state of fluctuation. This was reflected in studies conducted by Brusven et al. (1974) in the middle reaches of the Snake River and in other studies by Trotzky and Gregory (1974), Walker (1972) and Edwards et al. (1974). Chironomid dipterans, however, have greater diversity in habitat selection and are the principle insect inhabitants in zones of fluctuation.

Drift studies conducted during this study established that insects indeed pass over shallow water areas, particularly during the nighttime, and potentially colonize newly watered substrates. Results obtained during and following the formation of Lower Granite Pool indicated that relatively few insects colonized shallow 45 cm water depths during a 24-hour period.

It was originally hypothesized that stranded insects would potentially utilize the interstices of the dampened gravel to excape surface desiccation. Because flows were generally stable on the Clearwater River during the time of this investigation, this condition was tested in an artificial, flow-controlled channel. While the substrate conditions used in the simulation channel were different from those found in the Clearwater River, the results are meaningful in interpreting possible escape mechanisms of insects. Dipteran chironomids were distributed largely in the upper 15 cm of the canister sampler, and by far outnumbered all other insects in the canisters. The mayflies showed a similar trend, but total numbers were much less than those for chironomids. Stoneflies on the other hand, were evenly distributed in all three sampling depths of the canister.

Heavy mats of algae were never present near the shore-water interface on the Clearwater River during the study. Algal mats may serve as an escapement mechanism and provide a means for surfival during short periods of dewatering (Brusven et al, 1974).

When evaluating community stability in a river system, it is important that the specific insect species be examined with respect to their own specific and inimical biological attributes. For example, some species have a univoltine life cycle, i.e., having a single generation per year; others require several years to complete their life cycle. Additionally, time of oviposition is critical when examining life cycles influenced by fluctuating flows. It is anticipated that different life stages will have different sensitivities to out-of-water exposure. Definitive statements about an insect community at a given point in time can only be made on a subjective basis since complicated and diverse life cycles are involved.

Insect Drift

Insect drift serves as one of the most dynamic processes by which stream insects can be displaced and colonize new habitats. Further, drift serves as one of the prime ways by which insects can avoid stranding and possible demise when colonizing habitats subject to water fluctuations. The overall drift tendencies by insects at the three stations sampled during August 1 and 2, 1974, revealed a very high propensity for drifting at night. The dominant drift insects were mayflies and caddisflies. Mayflies far outnumbered caddisflies in number of species. Only two caddisfly genera, *Brachycentrus* and *Wormaldia*, were important in drift.

Because most insects inherently drift during the night, moderate flow regulation during the dark hours would be less devastating to insects than during daylight hours because of the greater propensity for drift during night. Many stream insects respond negatively to bright light. Inactivity during daylight hours potentially subjects them to a greater chance of stranding when experiencing dewatering condition.

Rapidly fluctuating flows from power generating plants have been shown to cause drastic changes in stream flow and do not allow sufficient time for stream animals to adjust (Foye, Ritzi and AuClair, 1969). Powell (1958) indicated that fast water releases from a hydroelectric power dam reduced insect populations in the immediate vicinity below a dam and that populations increased at distances farther down the stream.

Water Chemistry

Because much of the mainstem of the Clearwater River is above major pollution sources, water chemistry analysis was not performed for specific ions other than idssolved oxygen. Dissolved oxygen values obtained during a 14-month period from May 1974 to June 1975, reflected extremes of 9.1 - 13.9 mg/l. North Fork Clearwater River waters generally ran 0.5 to 2.0 mg/l less than waters above the North Fork. It is our conclusion that dissolved oxygen values obtained during this time fell within the tolerance range of the species inhabiting this reach of the river based upon values obtained by Surbur & Bessey (1974), Roback (1965) and Leonard (1965). Many of the common genera referred to in these studies were also present in the Clearwater River.

Water temperatures potentially have a greater influence on benthic insects in the Clearwater River than dissolved oxygen. Based upon the monthly high and low temperatures at the Peck and Spalding gauging stations, temperatures have decreased by several degrees subsequent to the completion of Dworshak Dam.

Decreasing temperatures potentially influence the life cycle of insects by retarding development, thus preventing completion of life cycles in some cases. Examination of the checklist of species at River Km 72 and River Km 38 indicate that water temperature or various combinations of other factors has not caused large changes in species composition to date.

Marked changes in the annual flow pattern as a result of controlled flow from Dworshak Dam are evident when viewing an 8-year hydrograph. While the peak flows in June have been essentially similar to those of pre-impoundment years, flows during August and September have been appreciably higher at Spalding than during pre-impoundment years.

The insect communities that have prevailed at the different study sites have been relatively stable subsequent to the full operation of Dworshak Dam, indicating that fluctuations have not caused serious detrimental effects. Longer-term analysis may reveal otherwise, however.

Diversion Channel and Flume Study

Most fish in the diversion channel could be accounted for in spite of the small size of the age-0 wild chinook salmon. However, small numbers of fish may have escaped from the channel during tests as they could not be found in the traps or in the diversion channel at the end of the experiments. These included 15 chinook salmon in the August 1974 test, 18 in the 12 July 1975 test, 13 in the 31 July 1975 test, and 12 fish in the 14 August 1975 test.

Not all fish in the diversion channel were spotted during fish observations at each rate of discharge. Of the total amount of fish calculated to be in the diversion channel experiments after stabilization (carrying capacity) was reached, 79% were observed while plotting fish positions.

Fish were harder to observe at the 51 l/sec discharge rate than at the two lower discharge rates (17 l/sec and 3 l/sec) due to deeper, faster water and submerged vegetation along the banks of the diversion channel.

The carrying capacities of the channel may have been a size related phenomenon. As the wild chinook became larger during the summer, the carrying capacity of the channel decreased. The wild fish never exceeded 59 mm in fork length whereas the hatchery chinooks were considerably larger (95-102 mm in length). The carrying capacity of the channel was much less for the larger hatchery chinook than the smaller wild fish.

Lack of cover in the form of deep pools in the diversion channel may have caused abnormally large amounts of fish to leave the channel at all discharge rates. Had deep pools been present more fish might have collected in them instead of being trapped.

Many fish hide by day and forsake cover at night (Jones 1956). Nocturnal increase in activity could have resulted in fish in the diversion channel losing their stations and becoming more easily trapped at night.

Any alteration in flow displaced juvenile salmon in the diversion channel. On a 24-hour basis only an extreme reduction in flow of 94% had a pronounced effect on out-migration of juvenile salmon. On a 3-month basis in a larger stream with age 1 and older brook trout (Kraft 1972) demonstrated that a 90% reduction in flow decreased the number of resident fish significantly in riffles whereas a 75% reduction showed no consistent population changes.

Dewatering of the diversion channel increased the amount of drift insects available for fish. Excessive numbers of Chironomidae occurred in the stomachs of fish that were collected during the 3 l/sec discharge rate.

Long term increases of drift in natural ecosystems under the influence of fluctuating discharge probably would not occur. Colonization would be limited with alternate submerged and exposed substrate. Reduced drift rates from exposed areas would adversely affect diet, growth and behavior of stream fishes depending on the severity of dewatering, the size of the stream and other factors.

Burns (1971) found that low flows which decreased the amount of living space was responsible for low numbers of young salmonids in California streams.

The implications of the effects of altered discharge observed in this study could be expected to be more relevant to streams of like size and characteristics than to larger streams and/or streams with different attributes.

Groundwater and water from tributaries contribute to flow in a mainstem of a stream. Thus, the impact of altered flows on the aquatic biota would become minimized as the downstream distance progressed.

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