Research Technical Completion Report
Project A-052-IDA

INTERACTING EFFECTS OF MINIMUM FLOW AND FLUCTUATING SHORELINES ON BENTHIC STREAM INSECTS

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ABSTRACT

A 50 mile (80 km) reach of the Clearwater River, Idaho was studied from its confluence with the Snake River upstream to Orofino, Idaho. The study examined two important changes in the River: 1) effects of hydropower releases from Dworshak Dam on the aquatic insect community in the free flowing reach of the Clearwater River, and 2) backwater effects of Lower Granite Dam on benthos in the lower five miles (8 km) of the Clearwater River.

As result of the operational mode of Dworshak Dam, late summer and fall flows are greater than during the pre-project era. Although hydropower releases cause frequent and marked fluctuations in discharge, there is a stable post project low flow. This higher late summer flow guarantees the submergence of additional substrate, thereby increasing macrobenthic habitat.

Over 120 species of aquatic insects exclusive of Chironomidae have been collected from the Clearwater River. While small to moderate shifts in seasonal densities of principal species have occurred between intensive study sites above and below the influence of Dworshak Dam, present evidence does not indicate these shifts are attributable to hydropower releases. Approximately one month was required for sterile rocks to support a standing crop similar to that of continually watered rocks. In most instances, numbers of species and densities increased with increasing depth of 15, 30 and 45 cm. Numbers of drifting insects were greatest during the nights. Drift rates and standing crop relationships above and below the influence of Dworshak Dam suggest insects drifted more in response to daily fluctuations than to the factor of bottom density.

Within the lower five miles of the Clearwater, variable backwater effects of Lower Granite Reservoir have a far more pronounced effect on the amount of potential benthic habitat available than do releases from Dworshak Dam. Formation of Lower Granite reservoir has resulted in insect community shifts from a riverine to a lentic community as a result of physical changes in water depth, velocity and substrate with dipteran midges the dominant insect group.

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INTRODUCTION

Insects represent an intermediate link in the plant-to-fish food chain. Their absence or presence greatly influences the productivity of a fishery since insects represent an essential food base for many fish species. Sensitivity to environmental stress and reduced mobility make insects excellent organisms for investigation. This study was conducted for the purpose of ascertaining shifts in community composition with respect to before, during, and after effects of controlled Dworshak Dam flows, as well as changes resulting from the filling of Lower Granite Pool in the lower Clearwater River, Idaho.

Damming of major waterways for hydroelectric power generation coupled with regulated discharges creates stress upon the aquatic biota. The ability of the organisms to persist and in some cases flourish is a mark of species and community stability. The Clearwater River by virtue of its unique location, geology, economic and environmental properties has generated much concern by State and Federal agencies since the completion of Dworshak Dam and the more recent formation of Lower Granite Pool near Lewiston, Idaho.

This study involves a natural progression in analyzing changes in insect communities as a result of controlled flows from Dworshak Dam, essentially encompassing the early post-impoundment period from 1970 to the present time. An earlier study conducted in the upper mainstem of the Clearwater River by University of Idaho researchers addressed the preimpoundment conditions of algal and insect communities (Walker, 1972). A latter study investigated insect communities during the filling phase of Dworshak Reservoir (MacPhee and Brusven, 1973). Additional studies in the Clearwater and Snake Rivers having relevance to the present study include works by Rades and Balch (1971) who conducted an invertebrate analysis of Lower Clearwater and Snake Rivers; Falter et al. (1973) who studied the physical, chemical, and biological parameters in the Lower Granite Pool area; and Brusven et al. (1974) who investigated the effects of water fluctuations on benthic insects in the middle reach of the Snake River.

Recently, a study completed by Edwards et al. (1974) concerned itself with benthic organisms of the Lower Granite Pool area in Washington. Several additional investigations have contributed to the evaluation of regulated flows on the aquatic biota. Kroger (1972) reported appreciable stranding of benthic insects during rapid draw-down and that the destruction of food organisms had a detrimental effect on higher tropic levels. A lack of colonization in littoral areas periodically watered and dewatered has been reported by Radford and Hartland-Rowe (1971) and Fisher and LaVoy (1972). Increases in benthic drift during periods of rapidly increasing and decreasing flows has been observed by Minshall and Winger (1968) and Pearson and Franklin (1968). Ward (1976) reported benthic composition and diversity considerably modified by upstream impoundments. Wade et al. (1978) reported benthic insect densities decreased with increasing distance downstream from a hydroelectric facility while the number of taxa increased.

The period during which this study was conducted (1975-1977) has allowed the investigators to examine two important changes in the Clearwater River: 1) effects of regulated flows on the insect community in the upper mainstem of the Clearwater River resulting from hydroelectric power releases from Dworshak Dam, and 2) back water effects of Lower Granite Dam on insect communities in the Lower Clearwater River. This study addressed the following specific objectives: 1) determine the effects of Lower Granite Pool on shifts in the benthic insect community as a result of slack water formation in lower reach of the Clearwater River, 2) determine the stability of insect communities in relation to minimum and fluctuating flows under present and proposed hydroelectric power generating cycles, 3) determine the fate of selected insect species displaced from free-flowing reaches of the river into slack water, and 4) determine discharge vs dewatered stream bank area relationships for specific sites and selected reaches of the Clearwater River.

CLEARWATER RIVER STUDY AREA

The Clearwater River was studied from its confluence with the Snake River to Orofino, Idaho, representing some 80 river kilometers (Fig. 1). Nine intensive study sites and three supporting sites were established to reflect spatial differences in insect distribution and habitat types. The intensive sites correspond to R. km 5.6, 7.4, 8.3, 14.6, 19.4, 38.0, 50.1, 57.9, and 72.9. These sites were selected on the basis of location, accessibility, sampling characteristics, and historical data base. The historical data base consideration pertains especially to sites I (R. km 72.9) which was located above the influence of Dworshak Dam and III (R. km 38.0); each of which had a five-year record. This data base was used for evaluating insect community shifts in relation to regulated flows from Dworshak Dam in the Clearwater River.

The lower mainstem of the Clearwater River has habitats ranging from deep pools to high-velocity riffles. The gradient through this reach is low to moderate, 4 to 6 ft/mile, with generally gradual, sloping shorelines. The bottom type is cobble or boulder in riffles. Sands are noticeably present on occasional beaches and variously intermixed with rubble in slower reaches of the river.

The flows in the Clearwater River are extremely variable, typically ranging from over 70,000 cfs in May to 3,000 cfs in October. Winter and spring runoff reflect a weak bimodal pattern with increases in discharge in December followed by a pronounced snow melt runoff in May. Water temperatures in the Clearwater River vary from $0^{o}C$ in January and February to 26^{o} in July and August.

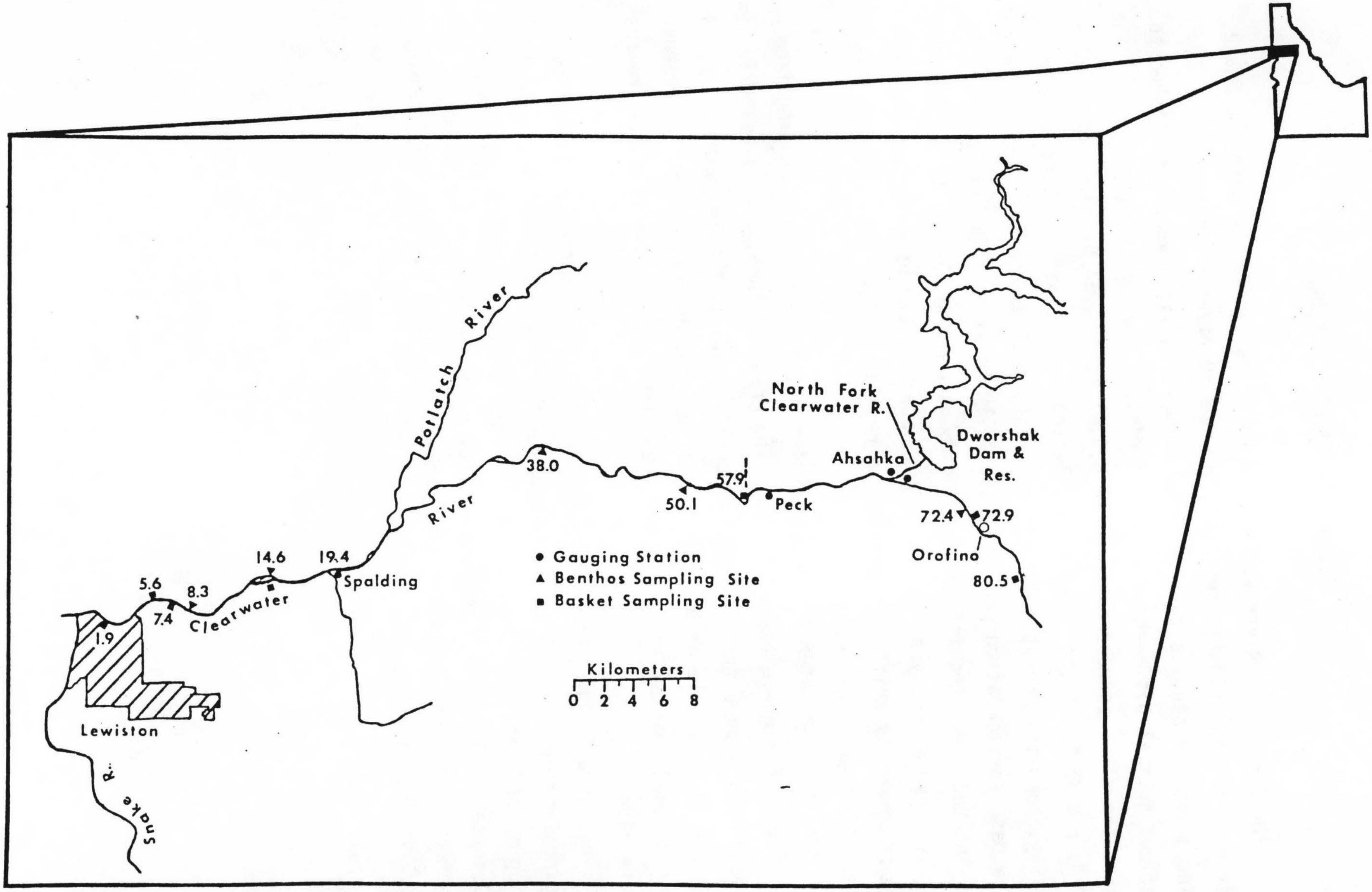

Fig. 1. The lower Clearwater River in Idaho, and associated collecting sites.

DEVELOPMENT AND OPERATION OF DWORSHAK AND LOWER GRANITE DAMS

Dworshak Dam, located on the lower reach of the North Fork of the Clearwater River near the town of Ahsahka, Idaho, was built for the purposes of hydroelectric power generation and flood control. Construction was initiated in 1965 on a diversion tunnel to bypass North Fork waters during the building of Dworshak Dam. In September, 1971, the gates were closed and the diversion and bypass tunnel valves were installed. During the spring of 1972, the low level outlet was used and by late summer of the same year the regulating outlet was installed. By March 1, 1973, Dworshak Dam became operational for power generation. While the dam has the capability of high level peaking, it has not been used in that capacity. Load factoring has been and is currently used to generate daily fluctuations in hydroelectric power needs. This has resulted in vertical fluctuations of 1 to 2 feet (0.3 to 0.6 m) daily in the Clearwater River during seasons of high electrical demands, i.e. fall and winter.

Lower Granite Dam is located approximately 35 miles downstream from the confluence of Clearwater and Snake Rivers and was built for the purpose of navigation and hydropower. The filling of Lower Granite Pool on the Snake River was initiated on February 15 and completed February 18, 1975, effectively making Lewiston, Idaho, an inland seaport. The lower 4.6 miles (7.4 kilometers) of the Clearwater River is now influenced by Lower Granite Pool. Stations located at River Mile 4.6 and 3.5 (R. km 7.4 and 5.6) are transitional in that a detectable current is evidenced throughout the year.

METHODS AND MATERIALS

Station Selection and Sampling Schedule

The intensive study sites on the Clearwater River 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 stream banks at the study sites is gentle to moderate and provides considerable stranding potential for insects during fluctuating flows. The substrate type at these stations is cobble and boulder which characterizes the majority of riffle-run habitats along the river. While all the stations were originally in a natural, free-flowing state, stations located downstream of River mile 4.6 (R. km 7.4) are now within the zone of influence of Lower Granite Pool. The station at River mile 5.2 (R. km 8.3) is our downstream most transect on the free flowing river, thus providing a base for comparison of pre- and post-impoundment community shifts in the lower Clearwater resulting from the filling of Lower Granite Pool.

Stations located upstream from River mile 4.6 to the confluence of the little North Fork (River mile 40.5 or R. km 64.8) have been influenced by regulated flows from Dworshak Dam since March 1973. The base line station for evaluating pre and post community shifts resulting from regulated releases at Dworshak Dam is located upstream on the Clearwater at River mile 45.5 (R. km 72.9).

River mile (R. km) designations used in this report were taken from U. S. Army Corps of Engineers aerial photographs and provide a basis for referencing river channel cross sections with current physical and biological data. River mile and River kilometer designations are used in this report, however, for utilitarian reasons, metric conversion were not always made where data were obtained from other State or Federal agencies.

Historical Flows

Streamflow records for the Clearwater River were examined to identify pre- and post-Dworshak flow regimes. Flow data from the U. S. Geological Survey were available for a 46-year pre-project and a five-year post-project period at the Spalding gauge, Clearwater River, Idaho (13342500). From these data a mean annual hydrograph, flood frequency analysis, and flow duration curve were prepared. Streamflow data for the 1972 water year were deleted from the analyses because it was during that period that the outlet on Dworshak Dam was phased into operation.

Total monthly stream discharge data in cfs days were arrayed in matrix format by water year and an average monthly discharge computed for the 1925-26 through 1970-71 water years. These average monthly discharges in cfs-days were converted to an average daily flow rate (cfs) and plotted to form a mean annual hydrograph.

Flood peaks (maximum daily discharge) for each water year (1926 through 71) were listed in order of descending value. Their respective plotting position was calculated ($\frac{m}{N+1}$) and a log-Pearson type III curve was fitted to the plot.

A daily flow-duration curve was also prepared for pre- and post-project periods. Average daily flows were recorded within a 13-element matrix which ranged from 1,000 to 50,000 cfs. Nine categories existed below 10,000 cfs, then increased at 10,000 cfs increments to 50,000 cfs. The number of daily flows within each element was tallied and recorded as the percent of the total number of days within the period of record.

Because of particular interest in the 1977 drought, a comparison was made of the 1977 regulated or "actual" and the unregulated or "natural" flows utilizing streamflow data provided by the U. S. Geological Survey and the U. S. Army Corps of Engineers. This comparison was made at the Spalding gauge and compared with the long term average annual pre-project hydrograph.

Existing data on the cross-sectional geometry of the Clearwater River were obtained from the Walla Walla District, U. S. Army Corps of Engineers. Data on 75 transects were provided for a 36 mile (58 km) reach between

Ahsahka and Lewiston, Idaho. Additional transect information was obtained at benthos sampling sites near Lewiston using stadia survey methods and a small boat equipped with an electronic depth finder. In applying conventional survey techniques in this manner, transects were obtained for channel widths in excess of 1400 feet (427 meters) and up to 25 feet (7.5 meters) deep.

Standing Crop - Shoreline Benthos

Benthic insects were collected with a cylindrical bottom sampler similar to that described by Waters and Knapp (1961). A randomized-block sampling design was used to sample insects at water depths of 6" (15 cm), 12" (30 cm), and 18" (45 cm). Three random samples were taken at each depth at each site on each sampling date. Water velocities at each depth were taken with a Gurley current meter. Samples were preserved in 70% ethanol for sorting and identification in the laboratory.

In order to monitor the relative position of samples within the stream bed, distances were measured between a stake located above the high water mark and the existing water levels, thus, permitted referencing cross-sectional locations of bottom samples to existing flows. These stake-to-water distances were compared with daily flow records at gauging stations making it possible to assess the relative "permanency" of the watered zone where samples were taken.

Standing Crop - Deepwater Benthos

Deepwater benthos was sampled using 12" (30 cm) x 12" (30 cm) x 6" (15 cm) wire baskets made of ½ inch (1.3 cm) mesh hardware cloth reinforced with heavy steel wire. Twenty fist-size rocks (ave. 4 inches (10 cm) diameter) were placed in each basket to serve as substrate for insect colonization. Aluminum window screen was used to line the bottom of the baskets to facilitate better recovery of insects during retrieval of the baskets. A subsurface styrofoam buoy was attached to each basket which aided in relocation and recovery of the baskets. Buoys were kept submerged in order to minimize vandalism and interference with boat traffic.

During initial investigations, baskets were placed in 3 to 6 feet (1 and 2 meters) of water near the head end of pools or in deep runs where water velocities were moderate. During 1976 and 1977, six baskets were equally spaced on line across the river at selected transects for the purpose of determining distribution and abundance of insects at varying depths and velocities across the river. Velocities were taken at each basket location to a maximum depth of 6 feet (2 m) with a Gurley current meter. Depth was determined with a weighted line having marked depth intervals.

Prelimary experimentation with sampling periods of two, four, and six weeks showed that colonization of basket samplers was essentially complete in four weeks in the Clearwater River (Brusven et al. 1976); the latter period was therefore adopted as the standard time interval. This time interval also allowed coordination with shoreline samples which were taken approximately monthly during the summer and fall and bimonthly thereafter.

In 1977, deep-water bottom samples were taken by scuba divers. Two bottom samples were taken with a cylindrical bottom sampler adjacent to the basket samples for correlational purposes.

Insect Drift

Insect drift in the Clearwater River was taken for two purposes: 1) to determine the diel drift periodicity of insects subjected to 24-hour power peaking cycles, and 2) to determine distances insects drifted in the upper reaches of Lower Granite Pool, and possible fate of insects drifting into a sublentic-reservoir condition.

Insect drift during daily power peaking cycles was taken with 12 x 24 inch (30 x 60 cm) nylon nets having a pore size of 0.8 mm. Drift nets were placed in approximately 6" (15 cm), 12" (30 cm), and 18" (45 cm) of water. Distances of drift nets and water line to high water mark were recorded along with water depth and velocity at net locations for each sample period.

Drift samples were taken during two, 1-hour periods in July and August 1976 at River mile 9.1 (R. km 14.6) (Hog Island) during a dark and light period. Sample times were chosen on the basis of time-of-travel estimates of flow changes from Dworshak Dam.

For purposes of determining standing crop-drift relationships, three samples were taken with a cylindrical bottom sampler in the same proximity, but down stream from the drift nets.

Insect drift in the upper reaches of Lower Granite Pool was taken with nets having a 12" x 12" (30 x 30 cm) orifice and fabric pore size similar to the previously described nets. For deep water sampling in depths of 3 to 13 feet (1-4 meters), 1.2 cm steel bars were weighted and attached at a point perpendicular to the net orifice. Guide lines were attached to the frame for lowering and retrieving the nets. Samples were taken at 30-min intervals during selected dark and light time periods. The riffle site at River mile 5.2 (R. km 8.3) served as the control since it represented the last riffle before the river character changed from lotic to sublentic. Conventional shallow water drift sampling was done at River mile 5.3 (R. km 8.3) at depths 30 and 45 cm. A boat was anchored and used to take deep water drift in the pool area. Spatial inferences to drift in the upper reach of the lower Granite Pool at River mile 3.5 (R. km 5.6) and 2.0 (R. km 3.2) were facilitated by moving to a new anchored position during consecutive 30-min intervals. Drift at the control site, River mile 5.2 (R. km 8.3), taken during the same 30-min intervals served as a control for standardizing drift in the pool stations. Water velocity near the orifice of the drift nets was taken with a Pygmy current meter. Insect drift was enumerated on a density basis (i.e., number of insects m^3 water).

Insect - Algae - Rock Colonization Studies

A laboratory experiment was conducted to measure the effects of periphyton development on the colonization behavior of selected species of aquatic insects. A plexiglass stream like that of Brusven (1973) was used for the test. The stream bottom was covered with a layer of sand, then six equally-spaced, fist-size rocks (10 cm) were placed in each of four quadrants. Two test quadrants contained rocks that were covered with periphytic algae, while two control quadrants contained rocks that had been autoclaved and scrubbed free of algae. Four test conditions were thus available to the insects: barren rocks with strong current (1 ft./1 sec.); barren rocks with slow current (0.2 ft/sec); algae-covered rocks with strong current; and algae-covered rocks with slow current.

Insect species used in the test included *Ephemerella grandis* Eaton (Ephemeroptera: Ephemerellidae), *Pteronarcys californica* Newport (Plecoptera: Pteronarcidae), *Brachycentrus* sp. (Trichoptera: Brachycentridae), and *Dicosmoecus* sp. and *Psychoglypha* sp. (Trichoptera: Limnephilidae). A variety of food and habitat requirements were thus represented. Only one species was used at a time except for *Dicosmoecus* sp. and *Psychoglypha* sp., which were combined for the test. Ten insects (40 total) were placed in each quadrant and allowed to redistribute and acclimate in the stream during a 24-hour period (one complete light-dark cycle). Insects were then removed from the stream and their positions recorded. Each species was tested from two to six times depending on the availability of test specimens. Only individuals recovered within the four quadrants were included in the test results; a test was not considered valid unless at least 20 insects were recovered in the test and control quadrants.

In order to test the effects of periphyton development and time on insect colonization under natural conditions, a field experiment was conducted in the Clearwater River. Wide, gently-sloping riffles at R. km 8.3 and 72.4 were used for the test. Two rectangular plots, approximately 2 x 4 m in size, were established. During initial tests in 1976, 50 autoclaved rocks (approximately 10 cm diameter) were placed in a "test" plot, and 50 algae-covered rocks from the river were placed in an adjacent "control" plot. In 1977, 25 rocks were used in each test and control plot. Rocks were arranged in staggered rows so that each rock would be theoretically subjected to similar flows. Water depth and velocities over the plots varied during 28-day colonization periods due to hydroelectric power generation and inherent variations in natural flows. If dewatering occurred, the test was invalidated.

Samples were taken on the 3rd, 7th, 14th, 21st, and 28th days of the test when possible. Starting at the downstream end of each plot, 10 rocks and 5 rocks respectively for 1976 and 1977 were sampled on each sampling day; each rock was treated as a separate sample. A nylon organdy net was placed downstream from a sample rock to capture displaced insects during sampling. Each rock was thoroughly scrubbed to remove attached insects.

Community Analysis

Insects collected during the study were preserved in 70% ethanol, sorted and identified in the laboratory using keys by Edmonson (1959), Usinger (1968), Jensen (1966), and several specific taxonomic works. Chironomidae (Diptera), by virtue of its unresolved status taxonomically, was not dealt with at the species level in this study. Questionable determinations and possible misidentification with yet-to-be-identified species potentially lead to gross errors in calculation of species diversity. Therefore, this group was treated at the family level. Most of the other encountered species were identified to species or morphospecies; therefore, contributed to an overall accurate assessment of species diversity. The Brillouin diversity index was used to calculate species diversity (Peet 1974). A Jaccard Coefficient of similarity was used to graphically portray community similarities in the form of a dendrogram (Kaesler and Cairns 1972).

RESULTS AND DISCUSSION

Historical Flows

The annual pre-project stream flow pattern of the Clearwater River was characterized by high flows from mid-March through June with the peak spring discharge occurring in May (Fig. 2). Average daily discharges range from a high of 50,000 cfs in May to 3,000 cfs during September. Late summer and early fall low flows range between 1500 and 2000 cfs, with annual peak daily discharges commonly observed in the 75,000 to 90,000 cfs range (Fig. 3). Peak flows of such magnitude are instrumental in transporting fine sediments and maintaining the existing channel.

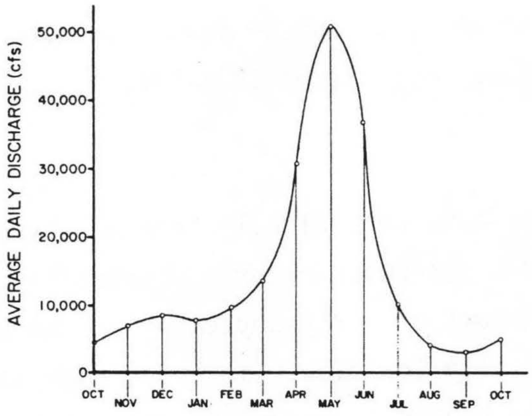

Figure 2. Average annual hydrograph for the Clearwater River, Spalding Gage, Idaho 1926-1971.

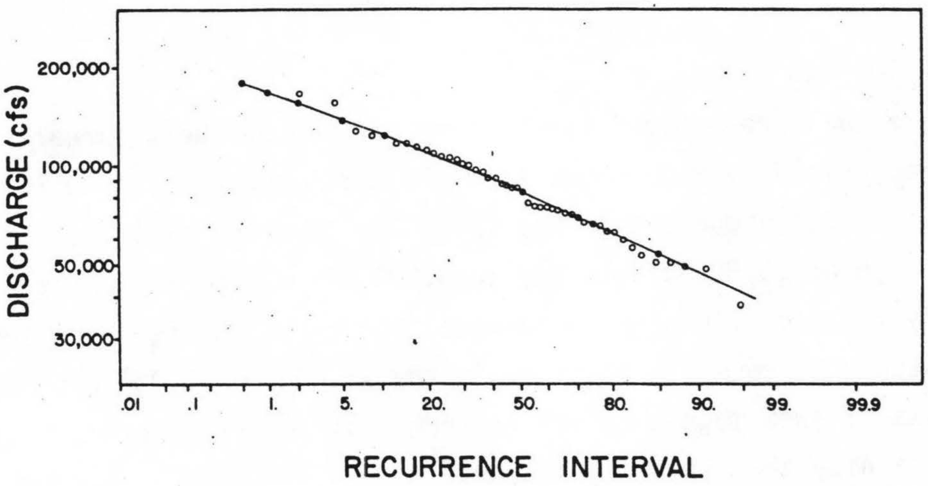

Figure 3. Recurrence interval of annual peak discharge for the Clearwater River, Spalding Gage, Idaho 1926-1971.

Minimum daily discharges have periodically been observed in the 2000 cfs range during the 1926-1971 per-Dworshak era. Ordinarily these flows have been observed in late August or early September in conjunction with 7 to 10-day periods of abnormally low flow. To date, regulated flows from Dworshak have been noticeably higher than the pre-project or "natural" flows for nearly 75% of the year (Fig. 4). In general, having more water available in the channel during late summer and fall would have a beneficial effect on aquatic life.

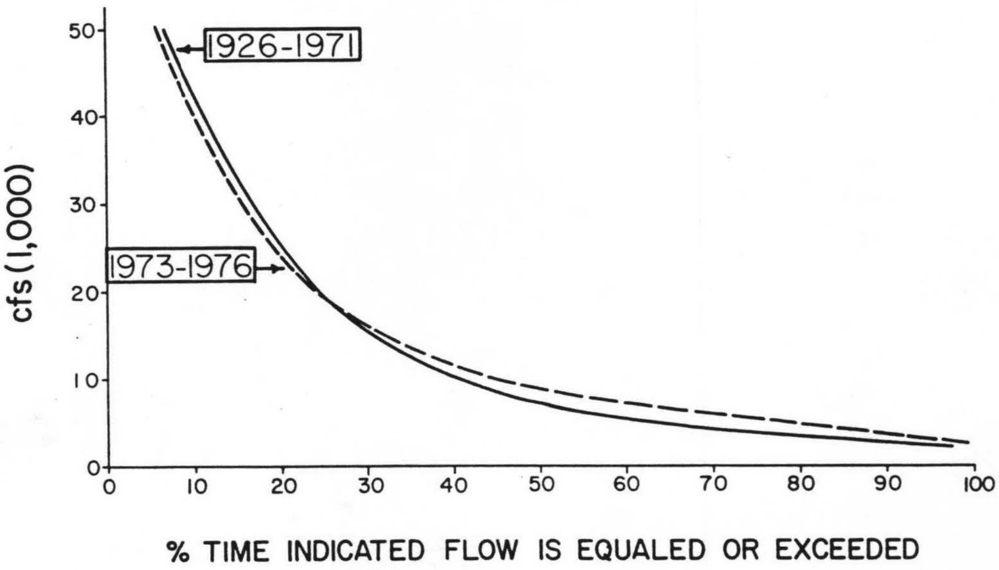

Figure 4. Comparison of average daily flow duration curves for the Clearwater River, Spalding Gage, Idaho. Pre project 1926 - 1971. Post Project 1973 - 1976.

In comparison with the long term average annual hydrograph for pre-project (natural) conditions, 1977 was clearly a drought year (Fig. 5). Reconstruction of natural flows indicate that without Dworshak Dam, flows at Spalding would have been 4000 cfs or less for approximately half the year. The long term historical flows indicate that flow should occur in this range for only 10 to 15% of the year. The peak runoff under pre-project conditions in 1977 would have been approximately 34,000 cfs, well below the long-term average peak discharge of 50,000 cfs and less than half the more commonly observed flood peaks of 70,000-80,000 cfs (Fig. 3).

Hydropower releases from Dworshak Dam during the fall and early winter of 1976 resulted in regulated or actual flows at Spalding which approximated the long-term unregulated or natural flows. Overall, the hydropower releases placed significantly more water in the channel than would have existed without the reservoir. However, these flows were characterized by erratic and marked fluctuations resulting from a varying power demand.

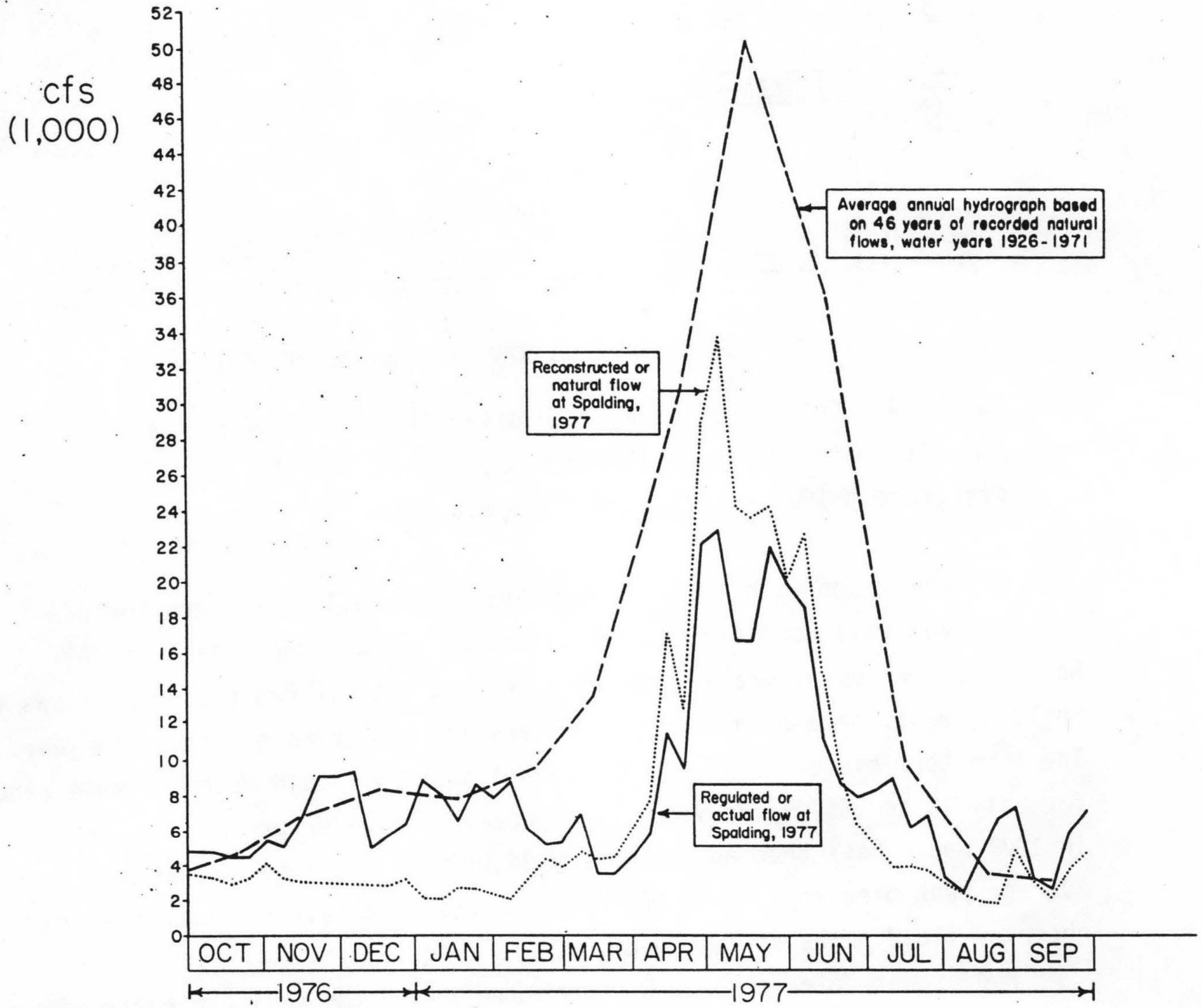

Figure 5. Comparison of the 1977 reconstructed natural flow of the Clearwater River with the 1977 actual and the long term average flows at the Spalding Gage, Idaho.

Similarly, regulated mid-summer and fall flows at the Spalding gauge were characterized by erratic and marked fluctuations. Most late-summer regulated flows during 1975, 1976, and 1977 approximated 5000 cfs, however, frequent peaks of two to three times that flow were apparent (Fig. 6). Pre-project late-summer natural flows approximated 3,000 cfs with occasional increases in response to precipitation in the watershed (Fig 7). Normally, natural-occurring late-summer peak discharges were neither as frequent nor as large as the peak discharges associated with post project regulated flows of August-October. Post-project mid-summer flows are characterized by frequent and larger fluctuations, but these fluctuations occur above a base flow which is considerably larger than that which would have existed under natural conditions. In summary, more water is present in the channel as a result of regulated flows from August through October than was available under natural conditions, however, the associated fluctuations are also more dominant and frequent.

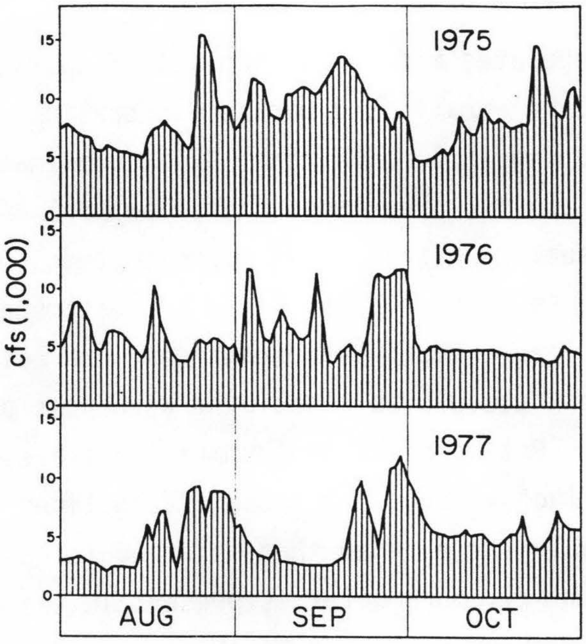

Figure 6. Average daily flows for late summer and early fall for the Clearwater River at Spalding; post project, "regulated" flows.

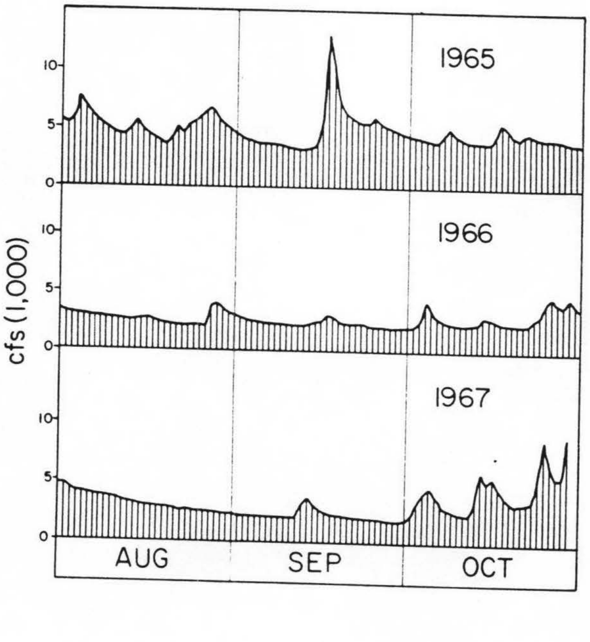

Figure 7. Average daily flows for late summer and early fall for the Clearwater River at Spalding; pre project "natural" flows.

Channel Geometry

The terminology used in this discussion of channel geometry is illustrated in Figure 8 and defined below.

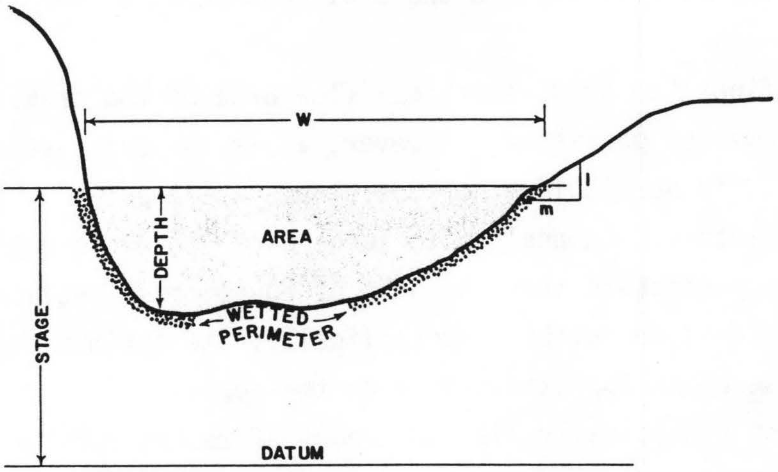

Figure 8. Channel Geometry Terminology.

Width (W) - the horizontal distance across a channel measured perpendicular to the flow at the water surface (from water's edge to water's edge).

Depth (d) - the vertical distance from a point on the channel bottom to the water surface.

Stage - the height of the water surface above a plane of known, or arbitrary elevation (datum).

Cross-sectional area (A) - the end area of the channel cross-section which conveys water normal to the direction of flow.

Wetted perimeter (P) - the lateral distance measured from water's edge to water's edge along the bottom of a channel cross-section. Roughly equal to the width + 2 times the mean depth.

Side slope (m) - the horizontal distance required to obtain a one unit vertical rise expressed as a dimensionless ratio (e.g., if m = 0 the stream bank is vertical; if m - 100 the stream bank slope is very gradual).

Cross-sectional area and wetted perimeter are of importance to both the hydraulics and biology of the stream. Cross-sectional area determines mean channel velocity with respect to discharge and provides potential habitat for aqueous medium-dependent organisms where wetted perimeter influences velocity distribution and provides potential habitat for the benthic organisms.

Stage defines the cross-sectional flow area of the channel, and the limits of the wetted perimeter. However, it is the cross-sectional shape of the channel, in particular the side slope, which actually dimensions these two parameters. Channels with large width to depth ratios have smaller wetted perimeters than channels of equal cross-sectional area and smaller width to depth ratios. Hydraulically, the optimum relationship occurs when the width approximates twice the depth.

Of interest biologically, is the amount of wetted perimeter at a transect; and, perhaps more importantly, the magnitude of the changes in that wetted perimeter with respect to changes in discharge. By plotting wetted perimeter against stage a graphic relationship can be presented which depicts both the amount of substrate habitat potentially available under various flows--and secondly, the sensitivity of the area to changes in discharge. Changes in wetted perimeter with stage are most pronounced in channels with very gradual side slopes. The transect at River mile 25.9 (R. km 41.7) is triangular shaped in cross section with a mild bank slope where the configeration at River mile 23.7 (R. km 38.2) is rectangular in cross section with a steep stream bank slope (Fig. 9).

At a discharge of 2800 cfs at Spalding the channel is completely wetted at both these transects and changes in wetted perimeter due to a change in stage (discharge) are dependent upon the shape of the channel and slope of the stream bank. A one foot (.3 m) change in stage at River mile 25.9 (R. km 41.7) will result in approximately a 12 foot (3.6 m) change in wetted perimeter, whereas at River mile 23.7 (R. km 38.4) less than a three foot (1.0 m) change would occur in wetted perimeter for the same one foot (0.3 m) change in stage. However, the channel is much wider at River mile 23.7 (R. km 38.2) than at River mile 25.9 (R. km 41.7) thus, a greater

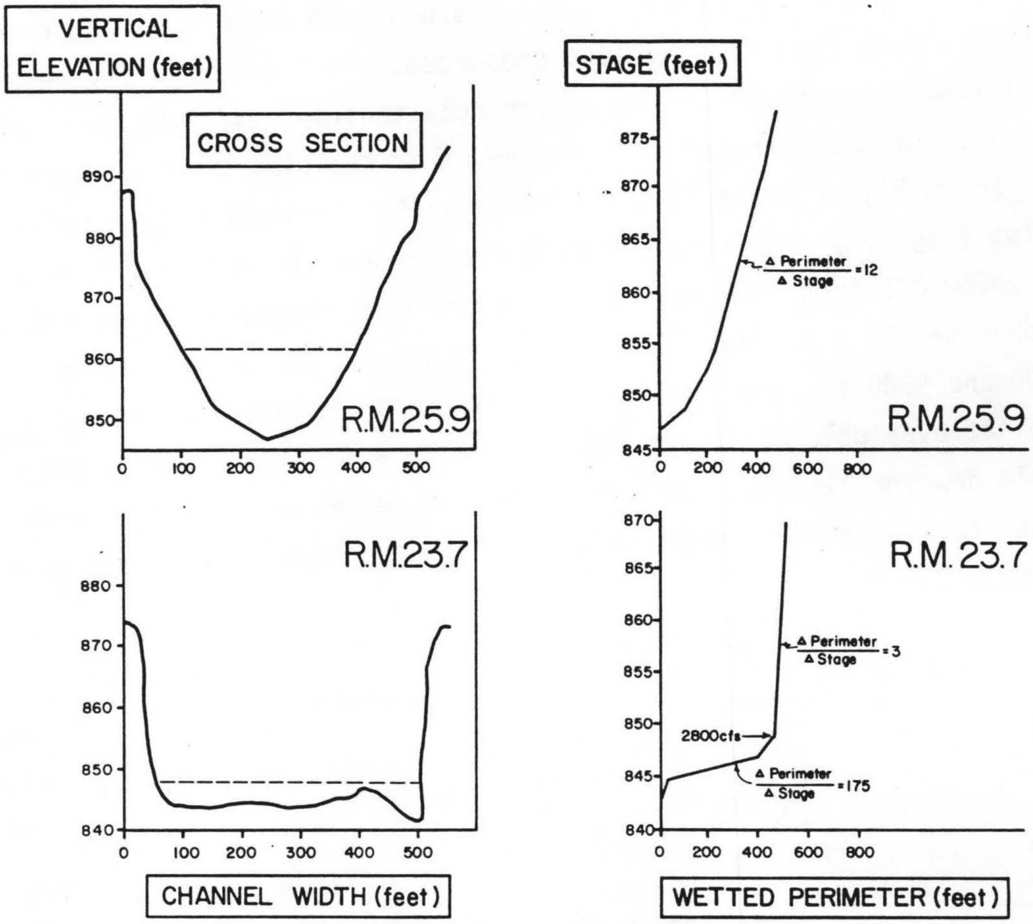

Figure 9. Comparison of wetted perimeter vs stage relationships for two reaches with different cross sectional shapes.

change in stage is observed at the upstream transect than the downstream site for the same incremental change in discharge.

Natural stream channels often possess much more irregular cross-sectional shapes than the two just presented. This irregularity results in different stage vs wetted perimeter relationships existing at a transect for incremental changes in discharge. For example, at River Mile 18.1 (R. km 29.2), at least five different wetted perimeter stage relationships exist (Fig. 10). At flows of 5700 cfs or less the water surface elevation is below 813 feet (248 meters) and a one foot change in stage results in approximately a 20 foot (6 m) change in wetted perimeter. Flows between 5700 and 9300 cfs have a very pronounced influence on the amount of substrate habitat available at this transect because a one foot (0.3 m) drop in stage would dewater 110 feet (33.5 m) of wetted perimeter. This is more than five times the amount dewatered for a similar reduction in stage at some flow below 5700 cfs.

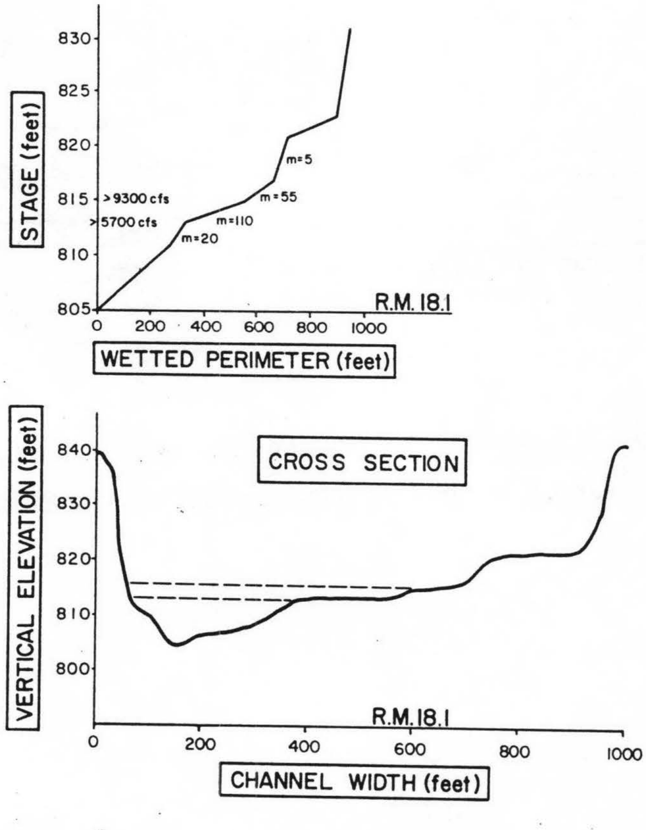

Figure 10. Wetted perimeter vs stage for an irregular shaped channel section of the Clearwater River, Idaho.

The purpose of this discussion has been to demonstrate certain dynamics of the relationship between incremental discharge and the potential availability of substrate habitat. The variations in stage-wetted perimeter relationships are a function of the cross-sectional channel geometry. As such, variations may occur either between different transects, or at an individual transect; depending upon the uniformity of the cross sectional channel geometry.

Shoreline Vulnerability to Dewatering

The lower reach of the Clearwater River can be classified into three major habitat types: reservoir pool, variable back water transition zone, and free-flowing river.

Reservoir - Pool. This reach of the Clearwater extends upstream approximately two miles (3.2 km) from its confluence with the Snake River. Water velocity is very slow, the channel is quite deep and wide and the stream banks are steep sided dikes riprapped with rock and boulders. Appreciable portions of the original river channel have been modified to obtain materials for construction of adjacent dikes. As a result, portions of the channel (reservoir) bottom are nearly flat. The substrate is being covered by a layer of silt and sand intermixed with organics as suspended solids in the river settle out in this zone.

Figure 11 presents a series of cross-sectional views of the lower portion of the Clearwater River R. M. 0.9., 1.5, 2.0 (R. km 1.5, 2.4, and 3.2) within Lower Granite Reservoir pool. The water surface elevation fluctuates between 730 and 740 feet (228 and 231 m) m.s.l. resulting in a mean channel depth of from 15 to 25 feet (4.6 to 7.6 m). Influence of the steep uniform side slope of the dikes, which contain the reservoir at all times, is very apparent in these stage vs wetted perimeter plots. Changes in the water surface elevation of the reservoir have a negligible impact on the total expanse of substrate potentially available for benthic insect inhabitation in this reach.

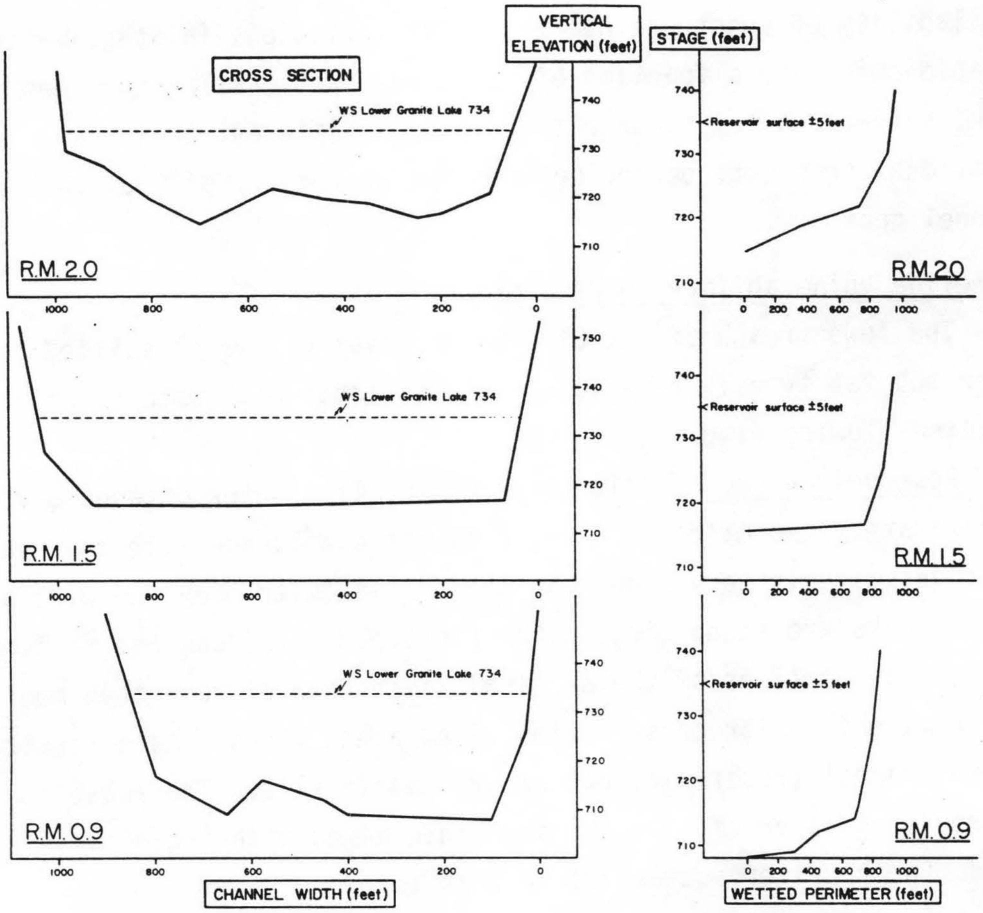

Figure 11. Cross sectional geometry, and wetted perimeter vs stage for three transects in the reservoir pool zone of the lower Clearwater River Idaho.

Transition Zone. This segment extends an additional two miles (3.2 km) upstream, with the water surface elevation of Lower Granite Reservoir causing a variable backwater effect which determines the upstream-most extent (usually R.M. 4.0 to 4.6) of this zone. This reach is also diked on both sides but differs from the reservoir pool section in that the river channel was not significantly reshaped during dike construction, and the velocities remain sufficiently strong to keep the fine sediments in suspension through this reach. The substrate is primarily cobble-boulder size which is from 50 to 100% imbedded in sand.

Water surface elevation below 735 feet (224 m) m.s.l. are primarily contained within the original stream channel, whereas water surface elevations above 735 feet (224 m) m.s.l. are constrained by dikes. This relationship is evident in Figure 12 which depicts a notable change in the slope of the corresponding wetted perimeter-stage plot at approximately 735 feet (224 meters) m.s.l.

Particularly during the late-summer and fall months, the variable backwater effects of Lower Granite Reservoir have a far more pronounced effect on the stage-wetted perimeter relationships for transects within this reach than does the discharge of the Clearwater River. The inflow from the Clearwater is rapidly absorbed by the reservoir, with little resulting effect on the amount of substrate being either watered or dewatered.

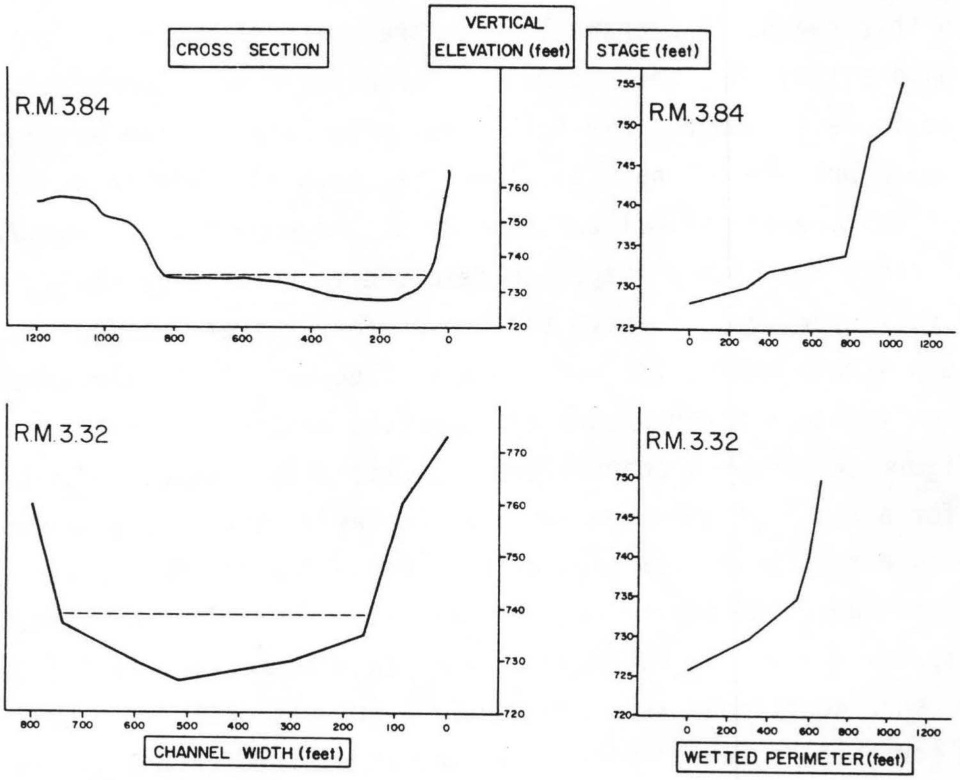

Figure 12. Cross sectional geometry, and wetted perimeter vs stage for two transects in the transition zone of the lower Clearwater River Idaho.

Free Flowing River. Upstream from River mile 4.6 (R. km 7.4) to River mile 40.5 (R. km 64.8) the river is free flowing, but it experiences daily water surface fluctuations as a result of hydro power releases from Dworshak Dam. The channel is over 300 feet (100 m) wide and several meters deep in the deeper runs and pools. The average channel gradient through this reach is approximately 6 feet per mile (1.13 m per kilometer). The substrate consists of coarse sediments, cobbles and boulders; few deposits of silt or sand occur in the thalweg portion of the channel.

The reach of the Clearwater River immediately upstream from the transition zone is primarily a riffle-run sequence. Cross-sectional profiles and wetted perimeter plots were established for a run which occupies a rather stable and well entrenched channel (Fig. 13). The water surface elevation for a discharge of 2300 cfs is approximately 773 feet (241.6 m) m.s.l. through this reach. The channel banks are quite steep, thus, changes in stage have a limited effect on wetted perimeter. Post-Dworshak operation has resulted in late-summer early-fall flows which are, on the average, noticeably higher than pre-project natural flows (Fig. 4,6 7). For this reach these higher flows are of minimal consequence to the amount of potential benthos habitat since the higher stage has resulted in relatively small increases in wetted perimeter over or above the pre-project values. Likewise, because of the steep stream banks, the amplitude of fluctuations in the water surface elevation impace a minor amount of potential benthos habitat.

Figure 14 presents channel cross sections and wetted perimeter relationships for a reach of the Clearwater which has substantially more wetted substrate as a result of flow regulation. Approximately four acres are contained within the "perched" portion of the streambed above 768 feet (233 m) m.s.l. From Figures 4 and 7 it is apparent that late summer and fall flows under pre-Dworshak conditions were frequently 3,000 cfs or less. Thus, it was common for this "perched" portion of the stream bed to possess rather marginal utility to the benthic insects because of varying degrees of dewatering, increased temperatures and sublentic conditions.

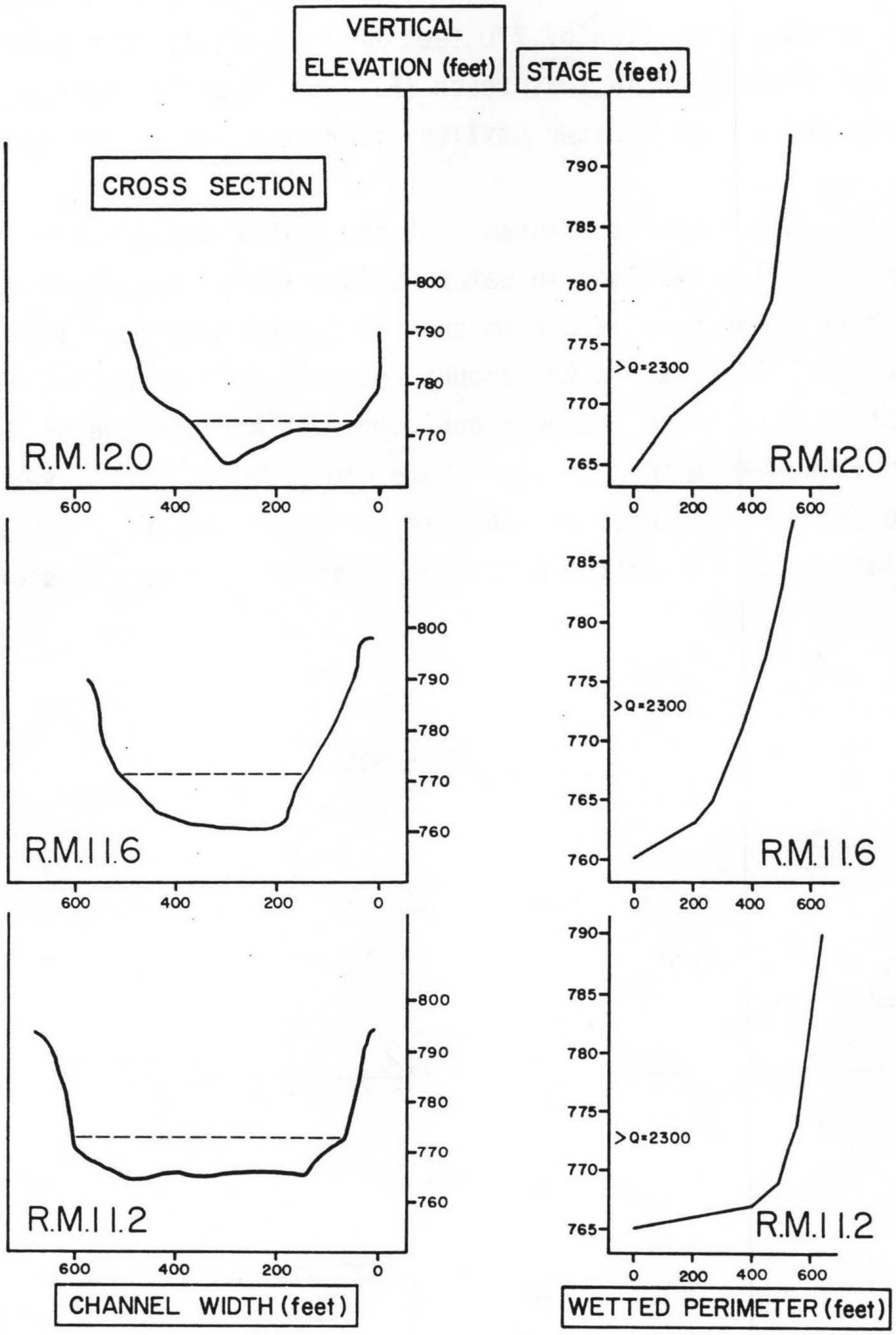

Figure 13. Wetted perimeter vs stage for a well defined channel; Clearwater River, Idaho.

However, regulated late summer flows now provide greater centainty that the water surface elevation of 770 feet (234 m) m.s.l. (Q = 5100 cfs) will be equalled or exceeded in this reach (Fig. 6), thereby, maintaining lotic conditions and a much greater utility of the perched substrate to benthos.

Additionally, since the stream banks become rather steep above 770 feet (234 m) m.s.l., fluctuations in water surface elevations above the 5100 cfs mark have a moderate effect on benthic insect habitat. The greatest incremental increase in the amount and certainly of potential benthos habitat in this reach has been achieved with a discharge of 5100 cfs. Additional increases in discharge above the 5100 cfs mark, even to bank full (780 ft. m.s.l.), will only add an incidental amount of substrate habitat as evidenced by the wetted perimeter vs stage relationships of Figure 14.

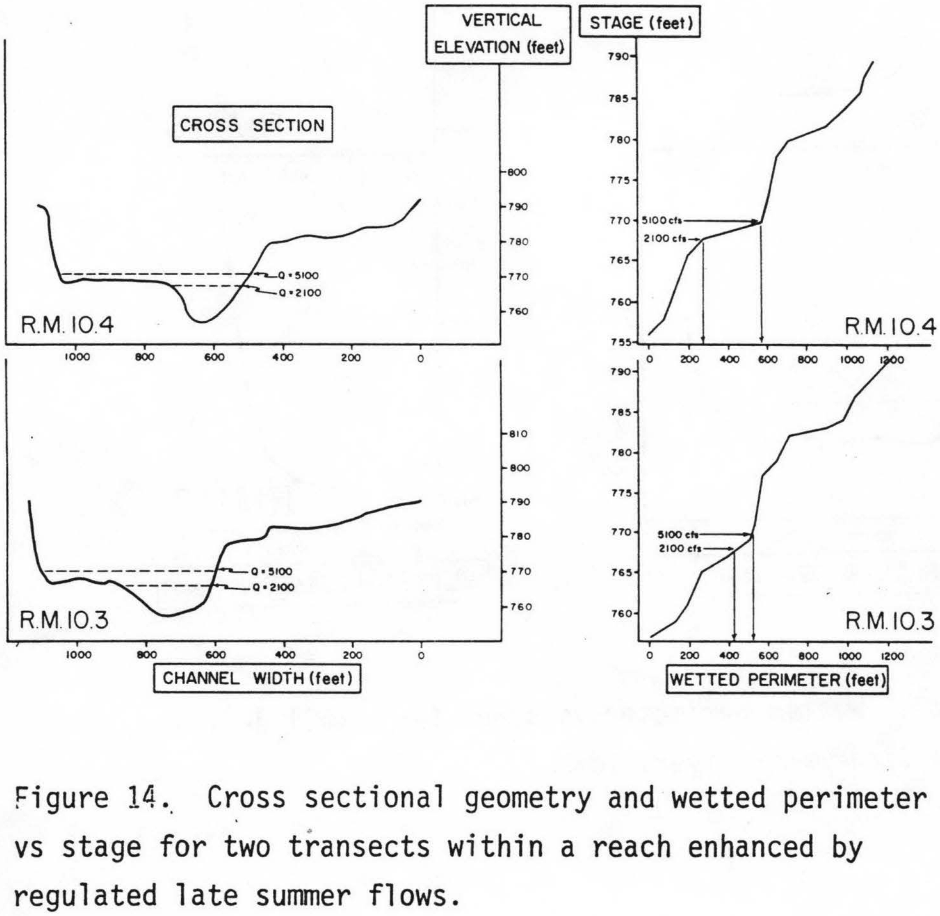

Figure 14. Cross sectional geometry and wetted perimeter vs stage for two transects within a reach enhanced by regulated late summer flows.

Figure 15 presents cross-secitonal profiles and wetted perimeter plots for a reach which remains highly sensitive to changes in stage even with the higher late-summer regulated flow. The cross-sectional channel geometry is such that minor changes in water surface elevation are translated into greatly amplified wetted perimeter changes. Only at very high discharges does the effect of fluctuations in stage become attenuated.

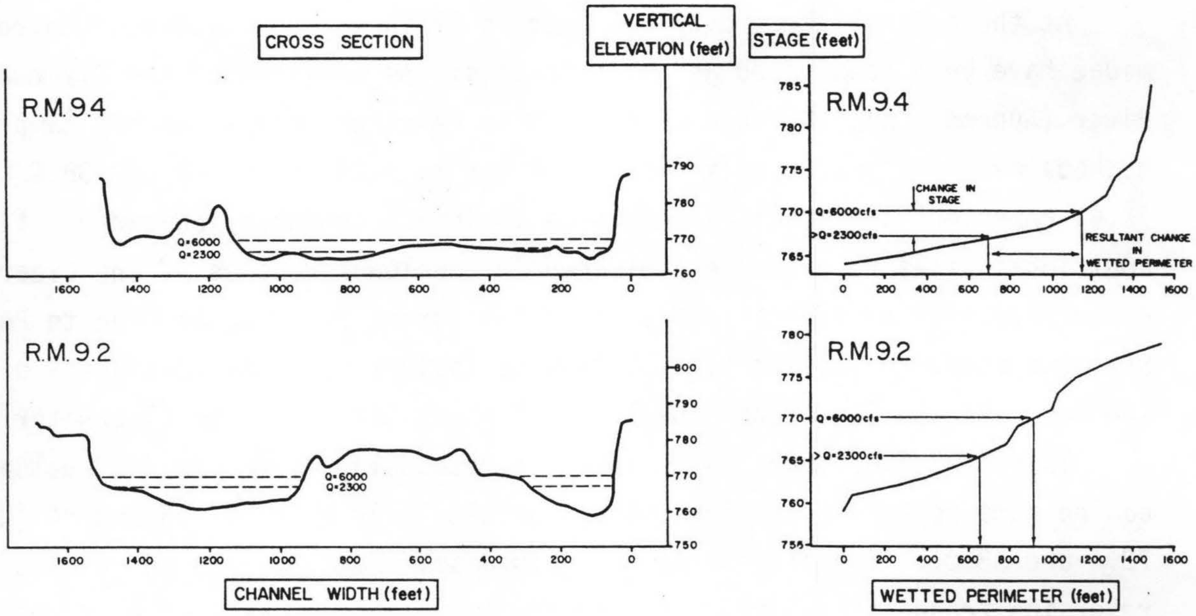

Figure 15. Cross sectional geometry and wetted perimeter vs stage for two transects at Hog Island (R.M. 9,2), Clearwater River.

Insect Species and Community Characteristics Above and Below the Influence of Dworshak Dam

This study represents a continuation and extension of earlier studies by Walker (1972), Peters (1973), and MacPhee and Brusven (1976), and Brusven et al. (1976), and provides an opportunity for historically evaluating insect communities before and after the construction of Dworshak Dam. However, because of differences in numerical abundance, classification, and uncertainty of some species determinations between earlier studies by Walker (1972) and Peters (1973) and the present, a critical evaluation of population changes cannot be made for all species.

At the present time, over 120 species of insects exclusive of Chironomidae have been identified as inhabitants of the mainstem of the Clearwater River (Appendix A). Because of changes in research objectives and sampling methods over the years, only sites at River mile 24 and 45 (R. km 38.0 and 72.4) represent a historical reference to insect community characteristics. Additional sites have been established in the lower reaches of the Clearwater River primarily to identify effects of the formation of Lower Granite Pool. Stations added subsequent to 1969 provide insight into the continuity of species distribution within the lower 45 miles (72 m) of the Clearwater River.

In spite of differences in sampling methodology some general evaluations can be made regarding species shifts, particularly at R. M. 45 and 24 (R. km 72.4 and 38.0). The stoneflies *Acroneuria* sp, and *Alloperla* sp. showed reversing trends since 1970. *Acroneuria* increased slightly at R. M. 24 (R. km 38.0) while going relatively unchanged at R. M. 45 (R. km 72.4). *Alloperla*, on the other hand, decreased during the initial years after 1970 at R. M. 24 (R. km 38.0), but remained relatively unchanged at the control site R. M. 45 (R. km 72.4). The trichopteran, *Lepidostoma* sp. increased in abundance during the same years at both sites R. M. 45 (R. km 72.4) and test site R. M. 24 (R. km 38.0). This caddisfly is a scraper, feeding on periphyton on the surfaces of rocks (Cummins, 1973). Three mayflies underwent moderate shifts in density. *Ameletus* sp. increased at R. M. 45 (R. km 72.4) and decreased slightly below Dworshak Dam. *Heptagenia simplicoides* showed a different trend in that it remained essentially unchanged at the control site but increased at R. M. 24 (R. km 38.0). Paraleptophebia heteronia, on the other hand, remained unchanged at the control site but decreased at R. M. 24 (R. km 38.0). We wish to clarify and emphasize that while shifts in seasonal density among years are evident, they do not reflect large magnitude shifts, therefore, we cannot definitively conclude that the shifts were the result of fluctuating flows from Dworshak Dam or other associated factors. Individual species, both in natural as well as perturbed systems, possess unique properties which result in population fluctuations from season to season and year to year. Most of the species listed in Appendix A are relatively rare and gave little indication of population shifts, therefore, are not specifically discussed.

Benthos samples were collected in this study for purposes of comparing species diversity, evenness, number of species and density in relation to water depth for stations upstream and within the influence of Dworshak Dam. These data are presented in Table 1. Selected data collected periodically since 1973 at two base line sample sites are presented in Table 2. While no absolute relationship is apparent for diversity, number of species, and density of insects with water depth. The general trend is for values for these population parameters to increase with increasing depths. This trend is most evident at River Mile 24 (R. km 38.0), which has been under the influence of Dworshak Dam since March 1973. Notable departures from this trend were evident at the control site. These deviations on certain dates can in part be explained by the nature of the shoreline at the control site. The near-shore area is relatively flat but gives way to a deep thalweg in mid-channel resulting in rather abrupt changes in depth over small horizontal distances near midchannel.

The time of sampling on a given date, also influences the relationship of water depth, velocity, substrate and benthic insect community particularly at sites below Dworshak Dam. For example, if the flows are high during the time of sampling, the newly watered region does not support densities comparable to low-water zones because of the successional nature of benthos colonization and the transitional instability of the frequently watered and dewatered areas.

The "evenness value" used in Table 1 of this report ranges in value from 0 to 1. As the species within the community approach a more even distribution with regard to their presence and density, the probability of encountering them in subsequent samples is greater, therefore, is reflected in a higher evenness expression. With the exception of August 1976 and July 1977, densities as well as numbers of species at R. M. 5.2 (R. km 8.3), on respective sampling dates, were generally greater at the control station R. M. 45 (R. km 72.4) which was above the influence of Dworshak Dam. This is not surprising, because the samples taken at stations below the influence of Dworshak Dam were taken on shorelines that were undergoing various stages of fluctuation.

The large densities occurring during July 1977 at R. M. 5.2 (R. km 8.3) were the result of high densities of trichopterans, Cheumatopsyche sp. and Brachycentrus sp. Midges in the family Chironomidae were also abundant and had a density of over $300/m^2$.

Hynes (1970) reported increases in filter feeding insects below dams because of increases in detrital matter. Apparently, these conditions more readily occur where the dams are a low vertical-face type and where detrital release mechanisms from an upstream reservoir are more readily facilitated than occur at Dworshak Dam. By contrast, Dworshak Dam is a high, vertical-face dam with selector gates which permit release of water of a desired temperature from specific reservoir strata. Thus, detrital and planktonic releases are theoretically less consistent than at dams having fixed level release gates.

For the most part, species occurring in the upper reaches of the main stem of the Clearwater River occur throughout the lower reaches. At the present time, we believe differences in species densities are due largely to inimicable population properties inherent within the species themselves which result in seasonal and annual fluctuations. As years progress, however, lower water temperatures during late-summer and fall months downstream from Dworshak Dam may have a notable bearing on the life cycles of some species.

Table 1. Species diversity, evenness, number of species and density/m^2 at 15, 30 and 45 cm depths at R. km 72.4, 38.0, 14.6, 7.4, Clearwater River. Chironomidae omitted in calculations of diversity, evenness, and number of species but included in total density.

STATION I - R. KM 72.4

	cm Depth	Stake to Depth (m)	Species Diversity	Evenness	# of Species	# of Insects/m^2
8/12/75	0	13.9				
	15		3.30	.79	20	1162
	30		3.21	.69	26	1212
	45		2.67	.63	19	1686
9/11/75	0	20.1				
	15		3.54	.77	29	1180
	30		3.14	.67	27	1478
	45		2.80	.62	25	1255
10/16/75	0	14.5				
	15		1.86	.60	9	240
	30		1.83	.43	21	1747
	45		3.19	.71	24	889
7/1/76	0					
	15		1.85	.78	5	197
	30		1.67	.45	13	334
	45		2.81	.65	21	926
7/22/76	0	5.5				
	15	6.6	2.77	.65	19	764
	30	8.1	3.07	.85	15	642
	45	9.5	3.17	.88	17	294
8/23/76	0	25.3				
	15	26.8	3.04	.64	27	2683
	30	31.9	3.47	.74	25	1367
	45	51.9	3.32	.67	32	5943
7/11/77	0	16.8				
	15	18.6	2.52	.59	19	3906
	30	20.4	2.19	.52	19	3927
	45	22.9	1.87	.41	23	8482

Table 1. continued

STATION III - R. KM 38.0

	cm Depth	Stake to Depth (m)	Species Diversity	Evenness	# of Species	# of Insects/m^2
8/12/75	0	-				
	15		3.09	.82	17	556
	30		3.13	.81	15	427
	45		2.88	.78	15	473
9/11/75	0	23.5				
	15		0	0	0	0
	30		0	0	1	7
	45		.90	.78	3	104
10/16/75	0	25.5				
	15		0	0	1	14
	30		1.05	.74	4	61
	45		2.02	.80	8	147
7/1/76	0					
	15		1.08	.70	3	32
	30		.52	.61	2	22
	45		1.80	.75	7	54
7/22/76	0	7.6				
	15	9.5	.52	.61	2	97
	30	13.3	1.47	.83	5	179
	45	16.2	2.72	.82	12	308
8/23/76	0	21.7				
	15	25.8	1.27	.49	7	240
	30	29.3	2.85	.72	18	567
	45	32.8	2.63	.58	24	2360
7/11/77	0	22.3				
	15	27.6	3.13	.85	16	656
	30	32.0	3.21	.83	18	527
	45	36.9	3.07	.74	22	904

Table 1. continued

CHIP TRUCK - R. KM 7.4

	cm Depth	Stake to Depth (m)	Species Diversity	Evenness	# of Species	# of Insects/m^2
8/12/75	0	72.3				
	15		2.51	.64	16	631
	30		2.65	.61	21	1973
	45		2.33	.56	19	1388
9/11/75	0	53.1				
	15		0	0	1	22
	30		.50	1.00	2	39
	45		1.38	1.00	5	215
10/16/75	0	66.8				
	15		0	0	1	50
	30		2.20	.81	10	294
	45		2.61	.64	16	1205
7/1/76	0	36.1				
	15	38.0	0	0	1	32
	30	40.4	1.42	.57	7	240
	45	43.8	2.29	.72	11	427
7/22/76	0	55.8				
	15	64.8	1.97	.85	8	161
	30	67.7	1.98	.60	11	423
	45	72.3	2.50	.70	15	391
8/23/76	0	72.4				
	15	75.8	2.87	.61	26	1456
	30	78.8	2.76	.57	28	2851
	45	82.5	2.59	.56	24	4207
7/11/77	0	72.0				
	15	75.3	2.79	.68	18	1449
	30	77.8	2.64	.62	20	3956
	45	81.1	2.63	.62	18	1230

Table 1. continued

HOG ISLAND RIFFLE - R. KM 14.6

	cm Depth	Stake to Depth (m)	Species Diversity	Evenness	# of Species	# of Insects/m^2
8/12/75	0	192.8				
	15		2.22	.65	11	240
	30		2.62	.71	16	499
	45		2.48	.57	20	861
9/11/75	0	165.0				
	15		0	0	1	4
	30		0	0	1	43
	45		1.34	.66	4	190
10/16/75	0	177.2				
	15		1.84	.56	12	319
	30		2.14	.57	15	466
	45		2.07	.55	14	879
7/1/76	0	83.4				
	15	95.5	.50	1.00	2	18
	30	101.7	1.21	.85	4	50
	45	111.9	2.15	.89	9	72
7/22/76	0	177.4				
	15	187.4	2.34	.74	11	301
	30	201.0	2.47	.86	12	283
	45	207.9	1.96	.68	9	133
8/23/76	0	130.1				
	15	139.2	2.20	.84	9	154
	30	149.9	2.23	.84	10	176
	45	160.0	2.64	.68	16	391
7/11/77	0	no samples taken				
	15					
	30					
	45					

Table 2. Number of species, and number of insects/0.28m^2 (3 ft^2) at shoreline study sites of 15, 30 and 45 cm, Clearwater River, 1973-76. All values exclude Chironomidae (Diptera).

	(R. KM 72.4)						(R. KM 38.0)					
	Species/Depth			Insects/Depth			Species/Depth			Insects/Depth		
Date	15cm	30cm	45cm	15cm	30cm	45cm	15cm	30cm	45cm	15cm	30cm	45cm
8/2/73	29	28	24	1241	914	1219	22	26	18	691	1069	1342
10/25/73	23	30	28	744	772	985	21	21	23	590	871	928
1/28/74	11	12	14	19	32	93	4	5	4	6	5	6
2/13/74	16	21	21	80	213	222	10	12	11	58	119	89
7/9/74	15	13	12	53	30	52	10	19	18	51	67	102
7/27/74	12	13	13	42	36	26	9	13	6	37	45	43
8/13/74	25	24	27	444	418	762	22	18	20	286	489	407
8/29/74	18	18	19	159	554	970	20	14	17	306	380	618
9/20/74	21	26	25	499	496	414	1	1	2	1	1	2
11/8/74	22	30	29	287	436	740	12	19	16	207	391	497
3/14/75	4	6	8	10	18	15	2	2	2	2	4	2
5/23/75	20	20	15	518	424	291	14	15	21	131	304	208
7/14/75	12	20	23	76	145	509	19	18	27	134	155	425
8/12/75	20	26	19	187	278	429	17	15	15	89	102	96
9/10/75	29	27	25	293	395	333	0	1	3	0	1	4
10/15/75	9	21	24	51	443	229	1	4	8	1	8	25
7/1/76	5	13	21	54	88	201	3	2	7	8	3	12

Insect Community Changes Subsequent to Lower Granite Pool Formation. Over 120 species of insects, exclusive of Chironomidae, have been collected from the intensive study sites in the lower 45 miles (72 km) of the Clearwater River (Brusven et al. 1976). Most of the species have been taken from both the upper and lower reaches of this section of river in varying densities. The lower 4.5 miles (7 km) of the Clearwater River have come under moderate to extreme changes as a result of the filling of Lower Granite Pool in February, 1975. At that time the lower reach of the Clearwater River was transformed from a true riverine condition to a sublentic condition with the river appreciably deepened and the velocities reduced as a result of pool formation. Intensive study sites located at R. M. 4.6 and 3.5 (R. km 7.4 and 5.6) represent transitional sites. A detectable current is evident throughout the year, however, the flows are greatly impeded because of the water levels from Lower Granite Pool on the Snake River. The intensive study site at R. M. 1.2 (R. km 1.9) is well within the Lower Granite Pool and had only a slow current during late summer, fall and winter months.

Benthic insect community characteristics at the control and three intensive study sites in the lower reaches of the Clearwater River are given in Table 3. Species diversity, evenness, numbers of species and density of the insect population are specifically addressed and reflect quantitative changes subsequent to the formation of Lower Granite Pool. Study sites located at R. M. 4.6, 3.5, and 1.2 (R. km 7.4, 5.6 and 1.9) are especially important since they were under the influence of Lower Granite Pool. Study site at R. M. 1.2 (R. km 1.9) was sampled only after the filling of Lower Granite Pool because of the hazardous water conditions for boating and sampling prior to creation of slack waters. The community characteristics are given for both shallow (1 m) and deep baskets (2 m) and are intended to reflect spatial and water depth relationships during colonization. Large densities of over 2000 insects per basket were witnessed from most stations except at R. M. 1.2 (R. km 1.9) on most sampling dates. Lowest insect densities were represented in basket samples at R. M. 1.2 (R. km 1.9) with most baskets at this station having less than 200 insects. The insect community was largely composed of midges in the family Chironomidae; however,

Table 3. Diversity, evenness, number of species and number of insects from shallow (1 m) and deep (2 m) baskets at four sites on Clearwater River, 1974-1975. * = Diversity, evenness and number of species exclude Chironomidae.

Site (R. km)	Date	Diversity Shallow	Diversity Deep	Evenness* Shallow	Evenness* Deep	No. Species* Shallow	No. Species* Deep	No. Insects Shallow	No. Insects Deep
14.6	8/28/74	2.45	2.82	.62	.66	16	20	2456	3008
	10/4/74	2.09	2.31	.45	.60	15	15	3976	4808
	12/19/74	1.90	1.06	.64	.34	8	9	2272	4672
	2/10/75	2.20	1.74	.64	.59	11	8	2672	2240
	4/4/75	1.87	2.24	.51	.60	13	14	2113	3128
	8/13/75	1.74	1.65	.44	.48	15	11	5984	1300
	9/16/75	2.46	2.54	.69	.65	12	15	2530	3256
	10/19/75	1.99	2.42	.58	.66	11	13	1392	2408
7.4	8/28/74	1.77	2.32	.58	.55	9	19	557	889
	10/4/74	2.51	2.03	.88	.64	8	9	1600	2032
	12/19/74	2.35	1.83	.78	.71	9	6	364	1184
	2/10/75	2.13	1.28	.68	.41	9	9	852	428
	8/13/75	2.00	1.59	.51	.41	15	15	2020	3056
	9/16/75	2.72	2.60	.68	.64	16	17	1632	2112
	10/19/75	2.52	2.95	.93	.89	7	10	448	1892
5.6	8/28/74	1.41	1.54	.33	.36	20	19	2414	5826
	10/4/74	3.35	3.36	.79	.82	19	17	3927	3463
	12/19/74	1.82	0.75	.61	.25	8	8	1573	4320
	2/10/75	0.58	0.55	.22	.17	6	10	1560	1840
	8/14/75	2.30	2.61	.59	.62	16	18	824	993
	9/18/75	-	3.11	-	.77	-	19	-	742
	10/19/75	2.33	2.26	.62	.59	13	14	686	623
1.9	8/13/75	2.08	1.68	.65	.63	11	8	129	227
	9/18/75	1.44	2.01	.45	.73	9	8	218	132
	10/19/75	0	1.29	0	.65	3	5	5	27

several species of mayflies were recorded, some of which are typical residents of more riverine habitats. High flows and muddy water for several months after the formation of Lower Granite Pool precluded early post-impoundment sampling. Large reversals in population trends were noted at River mile 4.6 and 3.5 (R. km 7.4 and 5.6) for the dates of February 10, 1975 and August 13, 1975, respectively. At River mile 4.6 (R. km 7.4), which was a backwater eddy formed as a result of the upper extension of Lower Granite Pool, the caddisfly *Cheumatopsyche* contributed importantly to the large increase in density with nearly 1000 members taken at the 1 m deep basket and approximately 2000 at the 2 m depth. Several mayfly species and midges (Chironomidae) were the other large components in the samples. At River mile 3.5 (R. km 5.6), however, a large decrease in total density was noted for the similar dates. Unlike River km 7.4 *Simulium* sp. was primarily responsible for the large densities occurring in February, 1975. No *Simulium* sp. was taken in August because of emergence and population turnover. Relatively few mayflies and caddisflies were taken during the same time period suggesting that species-specific differences in habitat requirements contributed to the large disparity in colonization of baskets. As a general rule, densities increased slightly from the 3 to 6 feet (1 m to 2 m) depth baskets. A similar trend was not noted with regard to numbers of species colonizing the baskets. Most of the diversity values were relatively low, ranging from 2.0 to 2.7 and were the result of a few species making up the majority of the community.

For purposes of comparison, Figures 16 and 17 reflect the percent composition by species and numbers of the principal aquatic insect orders in deep and shallow baskets at intensive study sites in the lower 73 km of the Clearwater River. Because of taxonomic uncertainties with species identification of midges, they were excluded from the analysis. Hence percent species composition tends to be magnified for orders other than Diptera. Mayflies had the richest species composition during February and September. By a large margin, Diptera had the highest density during February. A noticeable shift towards caddisflies was evident in September and coincides closely with the life cycles of three predominant species that occur at that time, e.g. *Cheumatopsyche* sp., *Brachycentrus* sp. and *Hydropshche* sp. The

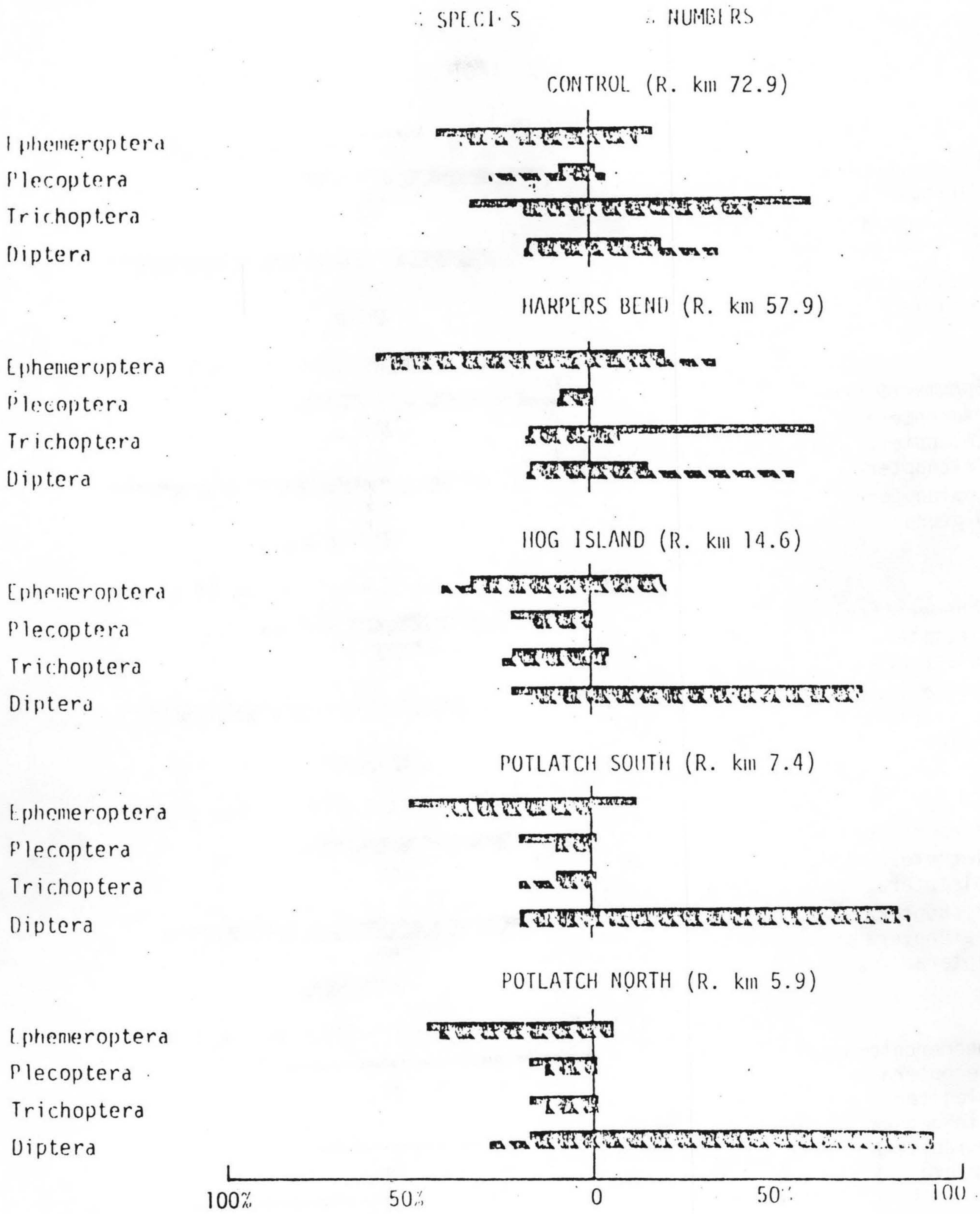

Fig. 16. Percent composition by species and numbers in deep and shallow basket samples in Clearwater River, Feb. 10-11, 1975.
Deep = ▬▬▬▬ Shallow = ▬ ▬ ▬ ▬
Chironomidae not included in percent species but included in percent numbers.

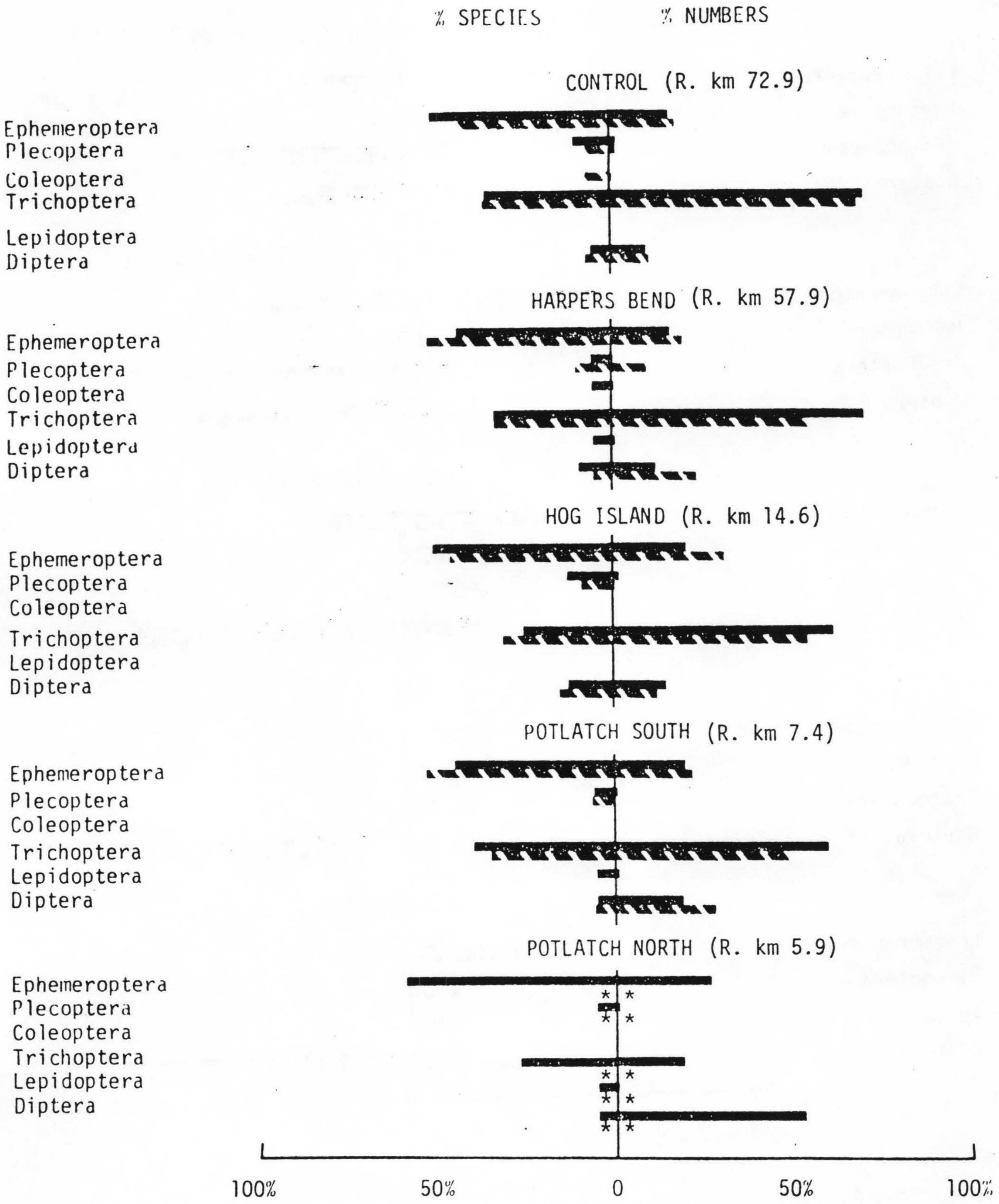

Fig. 17. Percent composition by species and numbers in deep and shallow basket samples in Clearwater River, Sept. 17-18, 1975.
Deep = ▬ Shallow = ▨
Chironomidae not included in percent species but included in percent numbers.

mayflies Ephemerella margarita, Ephemerella inermis and Rithrogena hageni were the dominant mayflies during September. It is evident that considerable similarities in the community existed among the well-spaced intensive study sites in spite of the fact R. M. 4.6 and 3.5 (R. km 7.4 and 5.6) were under the influence of Lower Granite Pool. Chironomid dipterans had the largest density during September at R. M. 3.5 (R. km 5.6) while the other four sites had a predominance of caddisflies.

Insect community shifts in the lower transition waters at R. M. 3.5 and 1.2 (R. km 5.6 and 1.9) of the Clearwater River and the Lower Granite Pool were apparent (Fig. 18 and 19). R. M. 3.5 (R. km 5.6) was located in the transition zone and had a detectable current. The insects, Brachycentrus sp., Cheumatopsyche sp., Rithrogena hageni and chironomids, were the dominant insects at that station during pre- and post-impoundment conditions, however, shifts in species dominance were evident. The mayfly Rithrogena hageni was a dominant species in basket samples prior to the filling of Lower Granite Pool (Mar. 1975), but subsequently was only nominally present. Mayflies as a group, however, maintained a relatively prominant role in the community. The caddisflies Brachycentrus sp. and Cheumatopsyce sp. showed somewhat similar trends. Chironomid dipterans were prevalent during all sampling periods, however, they represented a proportionately larger part of the insect community after filling of Lower Granite Pool, particularly in August, 1976.

The insect community at R. M. 1.2 (R. km 1.9) contrasted markedly with the flow-transition station at R. M. 3.5 (R. km 5.6) (Fig. 19). Here, the caddisflies Brachycentrus sp. and Cheumatopsyche sp. were either absent or minimally represented. Midges in the family Chironomidae again were the most prevalent insect group. During July 1977, nearly all insects in basket samplers were Procladius sp. chironomids. Because subfamily and generic determinations were not made prior to 1977, we cannot make comparisons with regard to shifts in the Procladius population. It is significant to note that mayflies were represented at this sublentic site in small to modest numbers even during the postimpoundment era. Densities were small, usually numbering less than 10 individuals per basket except during August 1975

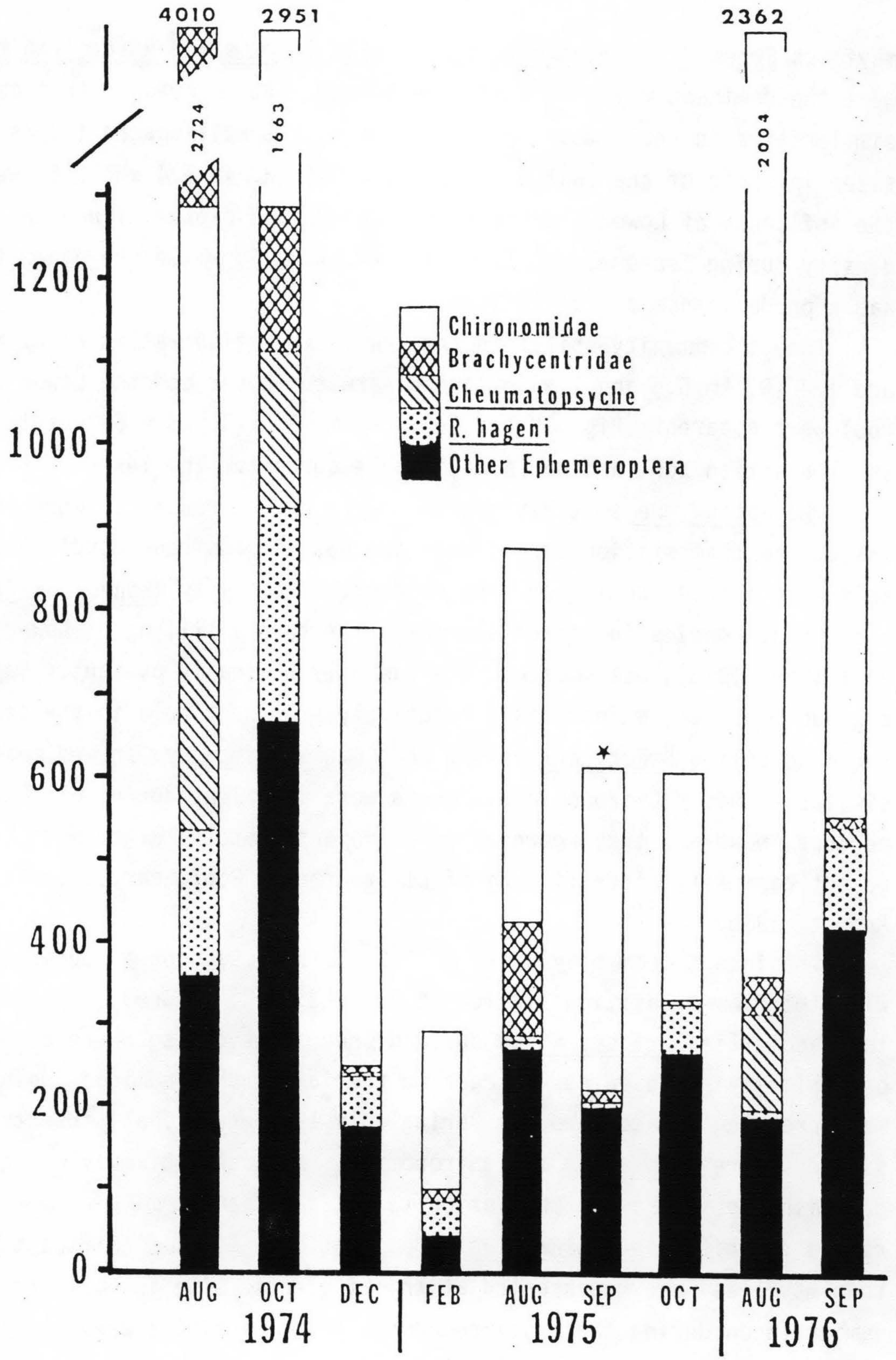

Fig. 18. Average density/basket of principal insects at R. km 5.6, Clearwater River, 1974-1976. * Only one basket recovered.

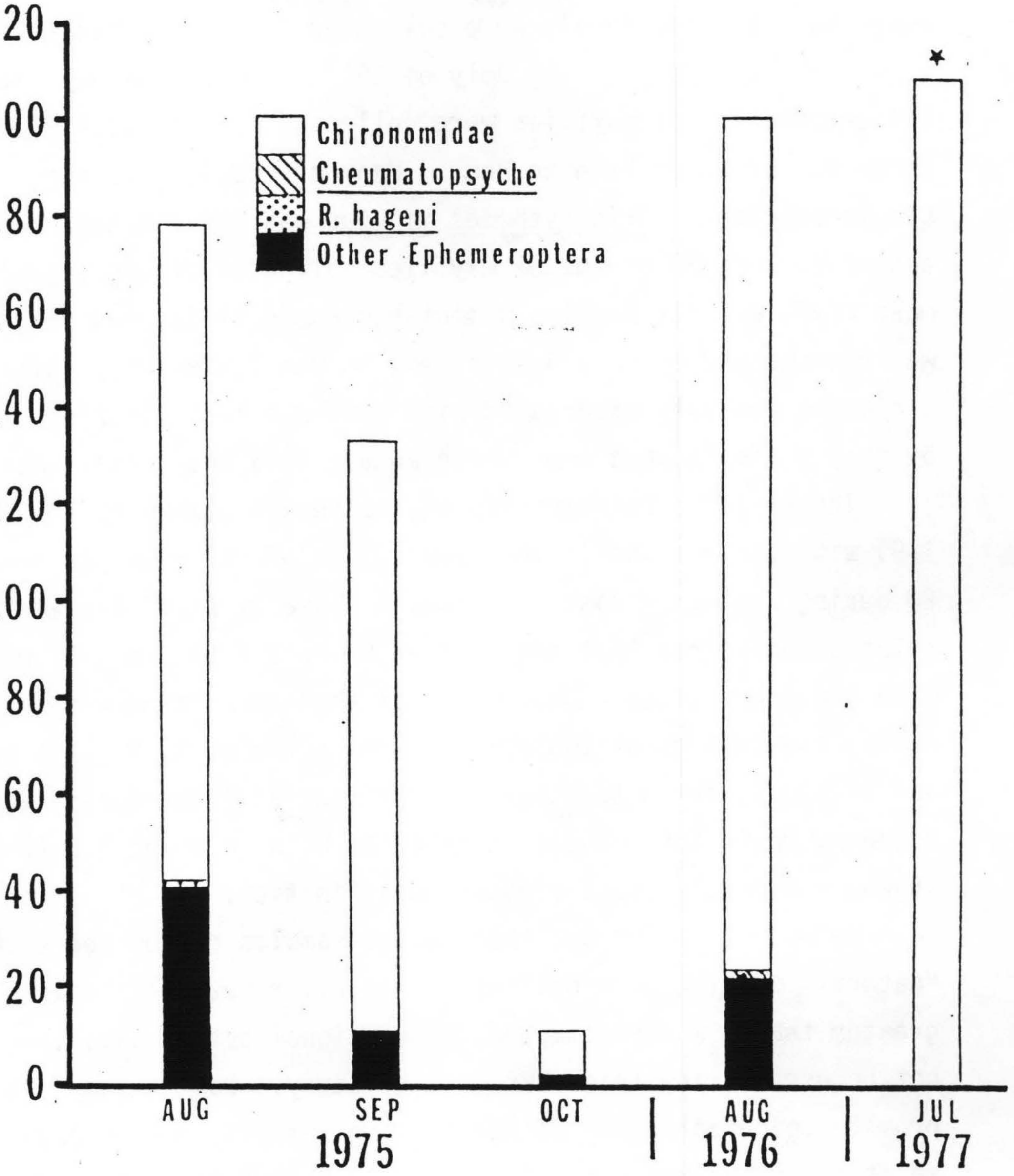

Fig. 19. Average density/basket of principal insects at R. km 1.9, Clearwater River, 1975-1977. * Only one basket recovered.

where some 50 individuals were collected in the 1 m basket and 25 specimens in the 2 m basket. During July of 1977, however, no mayflies were taken. Fifteen species of mayflies were collected at this site subsequent to the formation of Lower Granite Pool. Many of the species were represented by a single specimen. Tricorythodes minutus was the dominant mayfly, being represented by some 30 of the 57 mayflies collected during August, 1975. Like most mayflies, its numbers diminished appreciably, and during August of 1976 was represented by only 4 specimens in the 1 m basket. Rithrogena hageni, a species commonly associated with moderate to fast water, was represented by only a single specimen during August 1975 and totally absent thereafter.

The relative relationship of the insect community at R. M. 1.2 (R. km 1.9) with other sites in the lower 20 km of the river is reflected in Figure 20 during the early post-impoundment phase of Lower Granite Pool. Cluster relationships show that the site at R. M. 1.2 (R. km 1.9) was least associated with the other sites. During August the association was less obvious than during the subsequent two months. The sites at R. M. 12.1 and 9.1 (R. km 19.4 and 14.6) clustered together as expected, at least during September and October, while the transition sites at R. M. 4.6 and 3.5 (R. km 7.4 and 5.6) showed reasonably close clustering affinities.

We wish to point out that basket samples do not necessarily reflect "natural" population densities of the river bottom. Because water depths greater than 1 m were sampled, conventional bottom sampling devices could not be used during this phase of the study. Basket samplers admittedly promote colonization by filter feeding insects, but do provide a useful means for comparing population trends of certain insects among stations.

Whereas the previous discussion centered around the use of basket samplers as a measure of standing crop, insect drift provides insight into the displacement of insects in rivers. Daytime and nighttime drift at four locations in the transition and slack waters of the Clearwater River during July and August of 1976 were determined (Table 4). A specially-designed deep drift net was operated from a boat at R. M. 2.0, 3.5, and 4.6 (R. km 3.2, 5.6, and 7.4). The site at R. M. 5.2 (R. km 8.3) served as a control during each of the 30-minute drift sampling periods at the transition and pool sites.

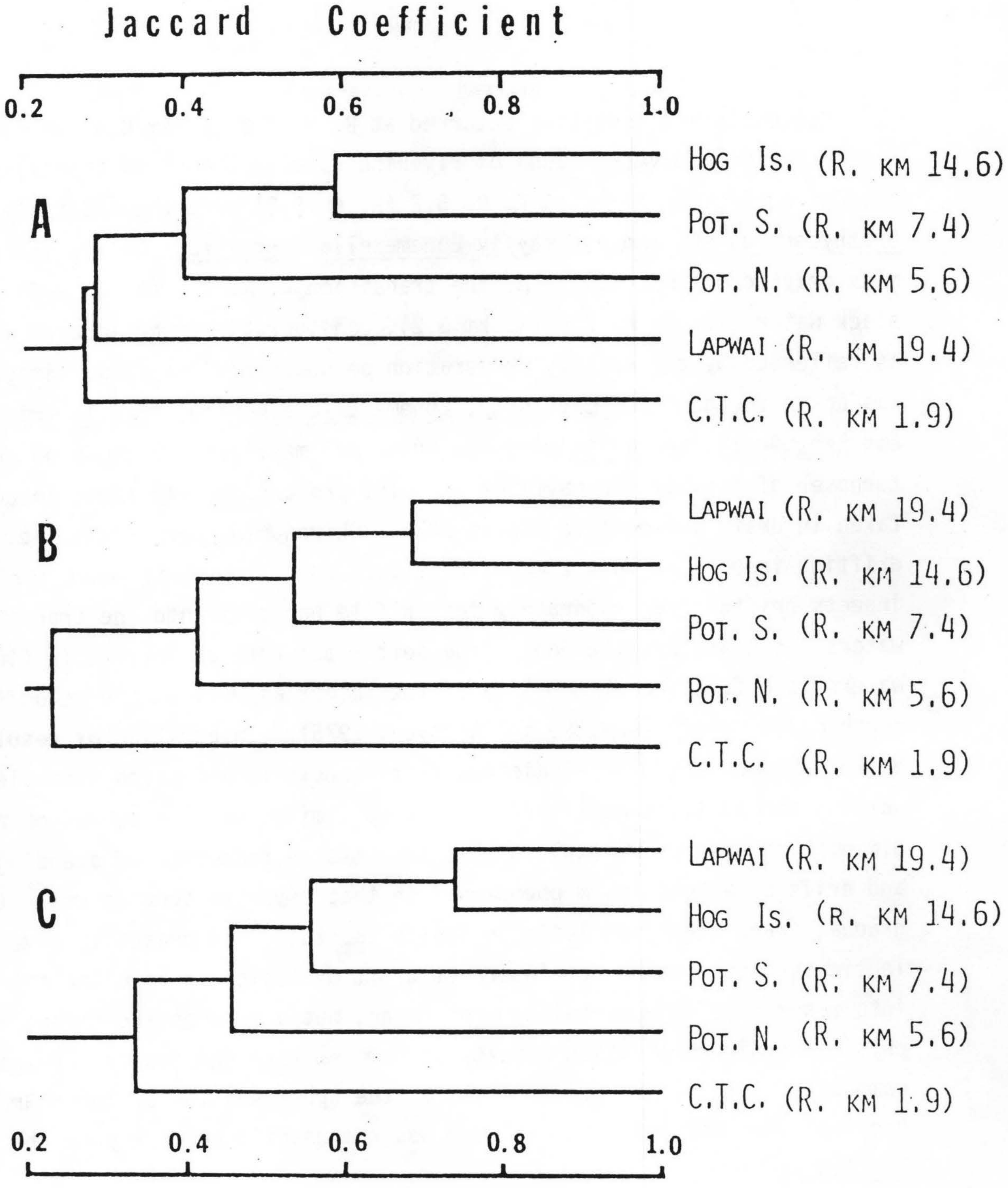

Fig. 20. Dendrogram depicting cluster relationships of 5 sites on Lower main stem Clearwater River during: A, Aug. 13, 1975; B, Sept. 10, 1975; and C, Oct. 19, 1975.

Largest drift densities occurred at R. M. 5.2 (R. km 8.3) which is a riffle having a diverse fauna of riverine species. Most of the drifting insects during the night at R. M. 5.2 (R. km 8.3) were the caddisfly *Brachycentrus* sp. and the mayfly *Ephemerella margarita*. Only a few chironomids drifted at that time. At the transition, R. M. 3.5 (R. km 5.6) and slack water site R. M. 2.0 (R. km 3.2), considerably fewer insects drifted as reflected by the density enumeration of numbers/m^3 of flow. *Brachycentrus* was again the dominant caddisfly; *Ephemerella albertae*, *Baetis tricaudatus* and *Ephemerella margarita* were the principal mayflies. Because of population turnover of many of the mayflies in July, proportionately fewer insects were taken in drift during late August 1976. Chironomids were the principal drifting insects at that time. These data suggest that at least for mayflies, insects drifted from moderately fast riffle habitats into the transition waters and Lower Granite Pool. The settle-out rate of insects in flowing waters is a function of mobility of the insect as well as the velocity and depth of the water (Luedtke and Brusven, 1976). Integration of results from basket samples and drift indicates that insects indeed moved into slack waters, and at least momentarily, took up limited residence, but on a density-diminishing basis. We explain this progressive reduction of standing crop and drift as a "continuum phenomena" in that riverine species reflect a gradual transition from lotic to lentic habitats, and gradually give way to lentic species. We do not interpret drift by typically riverine species into reservoirs as a mortality phenomenon, but a progressive change in the physical environment which results in commensurate changes in the insect community. During the summer of 1977, the upper section of lower Granite Pool had low "species richness" and was represented primarily by the midge *Procladius* sp.

Table 4. Insect drift at four locations in the lower Clearwater River encompassing riffle and pool transition habitats, 1976.

July 29, 1976

	R. km 8.3		R. km 7.9		R. km 5.6		R. km 2.4	
	Total Insects	Insects/m^3	Total Insects	Insects/m^3	Total Insects	Insects/m^3	Total Insects	Insects/m^3
4:00- 4:30 pm	15	.098	0	0	21	.245	-	-
5:00- 5:30 pm	9	.058	5	.035	-	-	2	.049
11:00-11:30 pm	898	5.876	76	.546	78	.912	-	-
12:00-12:30 am	643	4.207	-	-	-	-	23	.565
Vol. Water/30 min	152.82 m^3		138.96 m^3		85.5 m^3		40.68 m^3	
Velocity (m/s)	0.93		0.84		0.53		0.25	

August 30, 1976

	Total Insects	Insects/m^3	Total Insects	Insects/m^3	Total Insects	Insects/m^3	Total Insects	Insects/m^3
4:30- 5:00 pm	15	.098	1	.016	1	.012	-	-
5:30- 6:30 pm	18	.117	-	-	-	-	0	0
11:00-11:30 pm	68	.444	11	.180	13	.160	-	-
12:00-12:30 am	45	.294	-	-	-	-	0	0
Vol. Water/30 min	152.82 m^3		61.02 m^3		80.82 m^3		6.66 m^3	
Velocity (m/s)	0.93		0.38		0.55		0.04	

Insect Colonization Response to Algal Development and Time

Laboratory attempts to determine the effects of algal development on insect colonization behavior revealed that, of the five species tested, three occurred most often on algae-covered rocks (Table 5). *Ephemerella grandis* Eaton is a grazing mayfly, while the caddisflies *Dicosmoecus* sp. and *Psychoglypha* sp. are detritivores (Hynes 1970) which functionally act as shredders (Cummins 1973). Because of apparent niche similarities, the latter two caddisflies were combined for purposes of the test. Under laboratory conditions the distribution of these three species was closely associated with food availability.

Like most stoneflies, *Pteronarcys californica* Newport requires well oxygenated, running waters. This species congregated where current velocity was highest during most test replications, but colonized algae-covered rocks when the filamentous diatom *Gomphonema* sp. was the dominant periphyton. Richardson (1965) classed *P. californica* as an omnivore. Replicated trials suggested that turbulent flow within the artifical stream was a principal factor influencing distribution in the artificial stream. The factor of *Gomphonema's* importance in distribution was not apparent except in slow, nonturbulent sections of the stream.

The caddisfly *Brachycentrus* sp. feeds by filtering drifting plankton from the water (Hynes 1970). It was most common where current velocity was highest in the artificial stream. This behavorial response to habitat was not unexpected because of the nature of its feeding habits. Under natural conditions, this species generally avoids low-velocity shoreline areas.

The results of insect colonization on rocks under field situations are given in Figures 21-23. During August 1976, the test at R. M. 5.2 (R. km 8.3) was conducted for only 21 days because low flows on the 27th day caused at least partial dewatering of the test plot, thereby invalidating the 28th-day sample. Chironomid midges were the most abundant insects colonizing the rocks. Filamentous green algae were first observed on the sterilized test rocks on the 21st day.

Table 5. Colonization response (% recovered/habitat) of selected insect species from fast (0.5m/sec) and slow (0.2m/sec) velocities and algal growth (algae-covered rocks or clean rocks) in an artificial stream. Max = maximum, Min = minimum, and Ave = average % recovered in replications. Based on a minimum of twenty insects recovered in each replication.

Species	# of Tests		Algae-Fast	Algae-Slow	Clean-Fast	Clean-Slow	Algae	Clean	Fast	Slow
Ephemeroptera										
Ephemerella	2	Max	32.5	47.5	18.5	14.8	80.0	33.3	48.1	52.5
grandis		Min	29.6	37.0	15.0	5.0	63.6	20.0	47.5	51.8
Eaton		Ave	31.0	42.2	16.7	9.9	71.8	26.6	47.8	52.1
Plecoptera										
Pteronarcys	6	Max	41.4	37.9	63.6	21.9	79.3	75.0	93.5	37.9
californica		Min	18.7	0.0	20.7	0.0	25.0	20.7	62.1	6.4
Newport		Ave	31.4	13.3	45.1	10.2	44.7	55.3	76.5	23.5
Trichoptera										
Brachycentrus sp.	5	Max	63.3	16.7	82.0	9.8	80.0	87.1	92.2	23.4
		Min	5.3	2.6	13.3	2.6	12.8	20.0	76.6	7.7
		Ave	29.1	10.2	54.7	6.0	39.3	60.7	83.8	16.2
Dicosmoecus sp.	6	Max	45.5	50.0	31.8	17.2	95.5	45.4	68.2	58.6
and		Min	24.1	18.2	0.0	3.6	54.6	4.5	41.3	31.8
Psychoglypha sp.		Ave	36.6	33.0	17.6	11.2	71.2	28.7	54.2	45.8

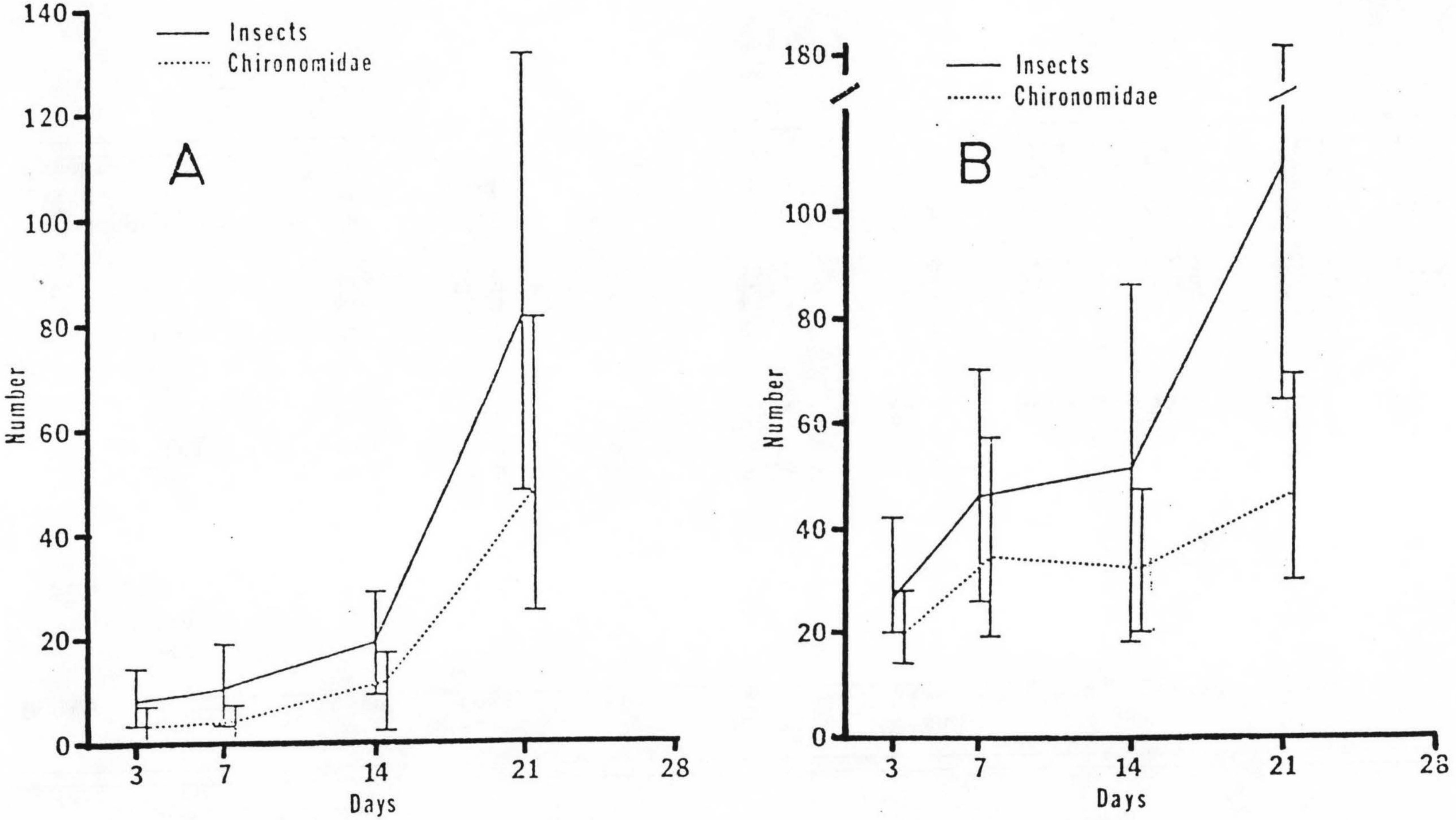

Fig. 21. Insect colonization times on A. sterilized and B. naturally colonized rocks during August, 1976 at River mile 5.2 (R. km 8.3), Clearwater River, Idaho. Vertical lines indicate colonization range of replicated rocks.

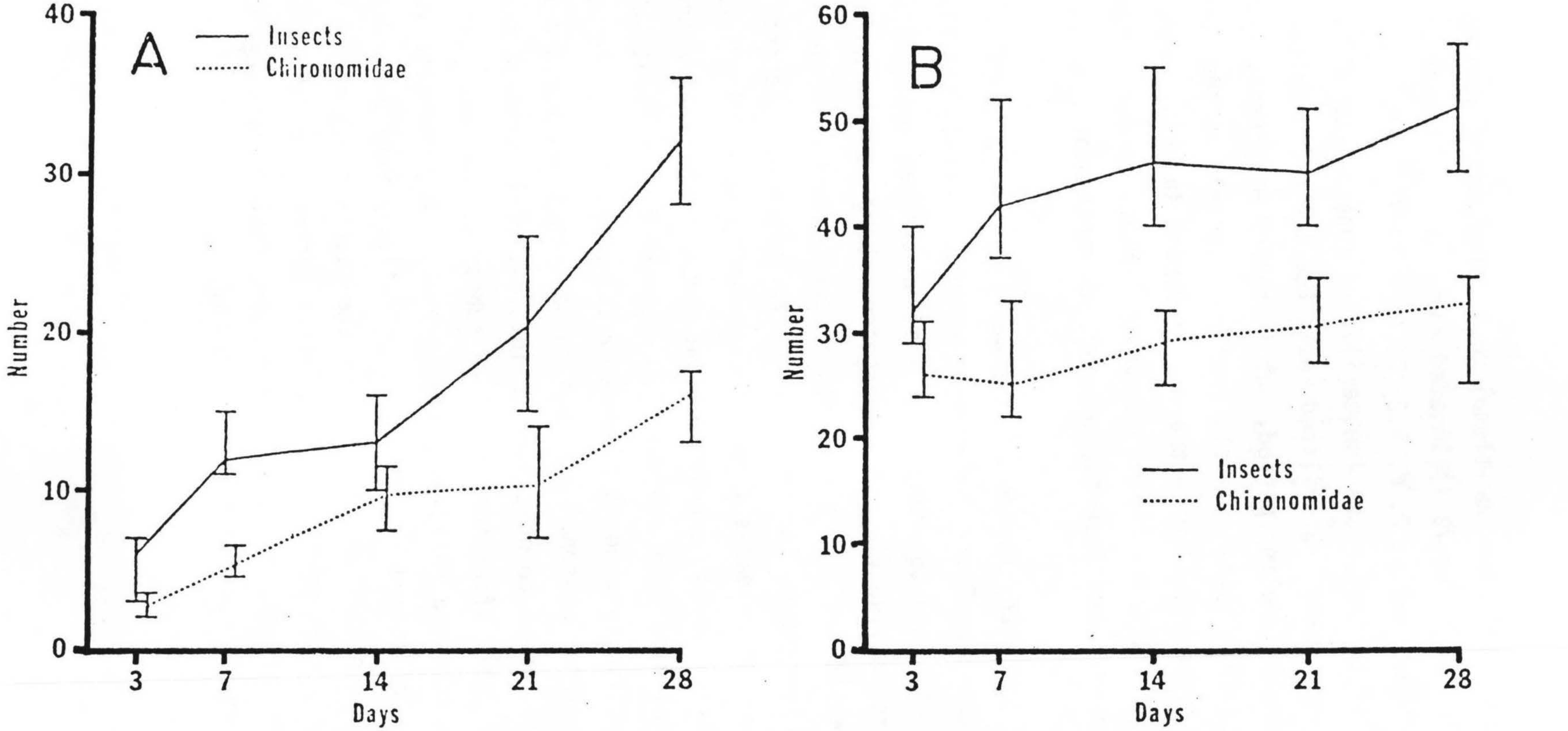

Fig. 22. Insect colonization times on A. sterilized and B. naturally colonized rocks during August 1977 at River mile 5.2 (R. km 8.3), Clearwater River, Idaho. Vertical lines indicate colonization range of replicated rocks.

During August, 1977, two additional rock colonization studies were conducted at R. M. 45 (R. km 72.4) located above the confluence of the North Fork Clearwater River, and at R. M. 5.2 (R. km 8.3) Fig. 22, 23). Average insect densities on control rocks (unsterilized) ranged from 33-51 during the 28-day sampling period. Sterilized rocks had low colonization during the initial three-day sampling period, but increased progressively through the 28th day, finally obtaining levels nearly comparable to the control rocks. Midges (Chironomidae) were the most dominant insects, being represented by 75-80% of the total insect ocmmunity. Mayflies and caddisflies were the next most abundant insects, however, no particular species was dominant.

Extension of the study beyond 28 days while desirable, poses difficulties in the Clearwater River for several reasons. First, the life stages of the insects tend to change with time so that as new species are hatching others are leaving via adult emergence. Large population turnovers during a 30-day period are common occurrences during summer months in the Clearwater River, therefore, influence colonization trends. Secondly, the unpredictable nature of releases from Dworshak Dam cause difficulties in sampling permanently watered near-shore areas for periods greater than 30 days. Regulated releases from Dworshak Dam are made to accomodate a variety of management objectives including Clearwater fishermen during the early fall months of steelhead season. Our data suggest that daily water fluctuations discourage insect colonization on intermittently watered and dewatered shoreline. Only after the shoreline substrate has been watered for 28 days do insects attain a relatively stable state. Any decrease in flow exposing previously colonized substrate, is potentially very destructive to insect and algal communities by turning back the successional process. Therefore, it is only that portion of the wetted perimeter which is consistently submerged for periods of 28 days or longer, that ocntributes significantly to benthic production and habitat stability.

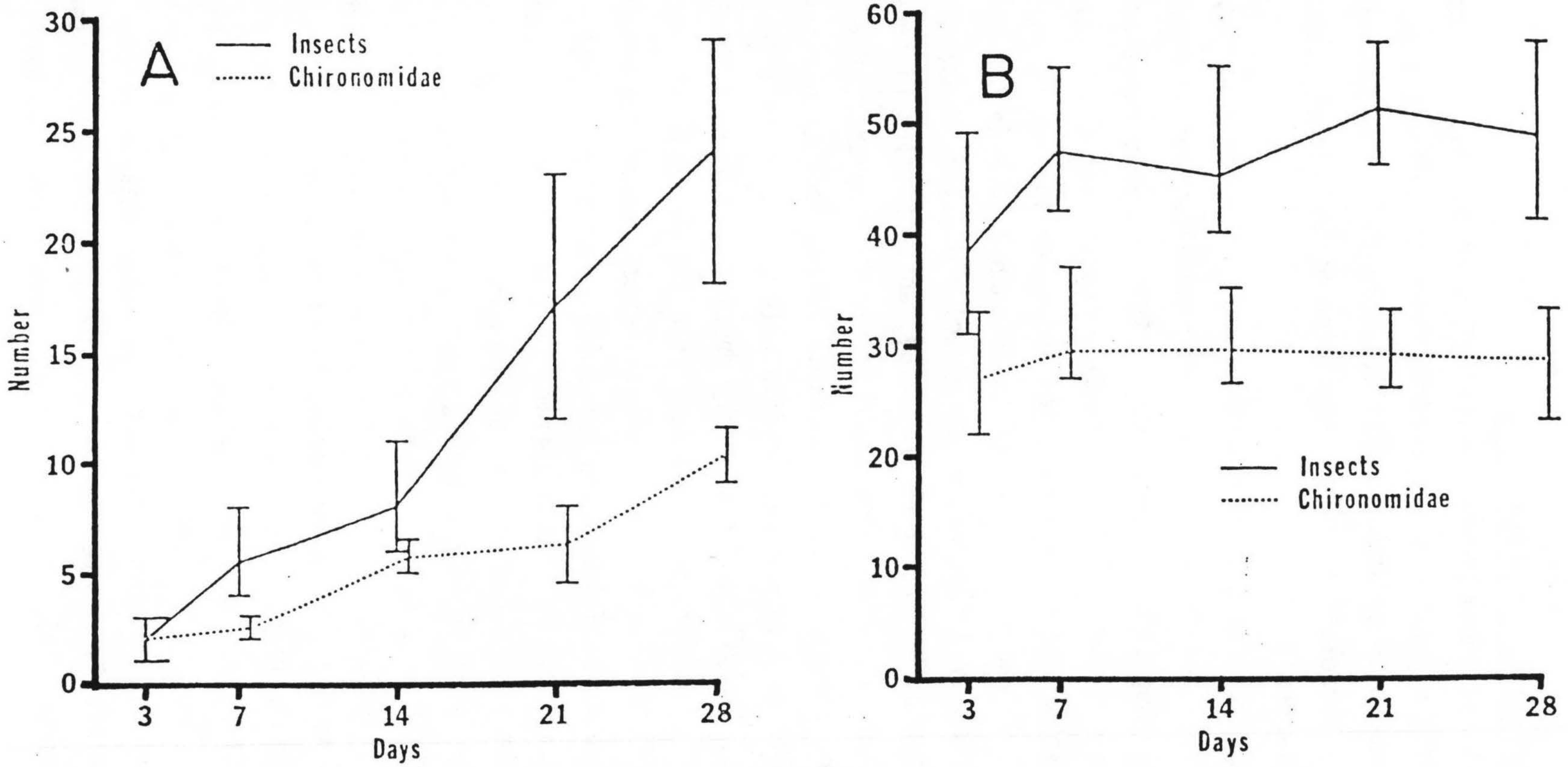

Fig. 23. Insect colonization times on A. sterilized and B. naturally colonized rocks during August, 1977 at River mile 44.9 (R. km 72.4), Clearwater River, Idaho. Vertical lines indicate colonization range of replicated rocks.

Cross-Sectional Distribution of River Benthos

Initially, cross-sectional channel distribution of benthic insects was evaluated with deep-water baskets placed in three to 16 feet (1 to 5 m) of water. With the addition of scuba capabilities in 1977, preliminary attempts were made to correlate species composition of the stream bottom with basket collections (Tables 6, 7).

Densities of over 2000 insects per basket were common for most dates and locations; over 9000 insects were taken from several depths at River Mile 9.1 (R. km 14.6) (Hog Island) during August 1976 and were represented by primarily chironomid dipterans, filter feeding caddisflies (especially, *Brachycentrus*, *Cheumatopsyche* and *Hydropsyche*) and seven species of mayflies. At R. M. 4.9 (R. km 7.9) where depths of 18 to 30 inches (0.5 to 0.8 m) and velocities of approximately 3 feet/second (1 m/sec) prevailed, densities were somewhat less than at R. M. 9.1 (R. km 14.6), while species richness was comparable. During July 1977, midges and filter feeding caddisfly *Brachycentrus* sp. were the overwhelming dominants in the pool transition waters at R. M. 3.5 (R. km 5.6) and deep riffle waters at R. M. 9.1 (R. km 14.6). During August, 7 mayfly and 4 stonefly species were common inhabitants of most baskets. Most, however, numbered less than 100 per basket.

Transectional distribution of the principal insects among the orders of Ephemeroptera, Plecoptera, Trichoptera and Diptera, at R. M. 9.1 (R. km 14.6) was relatively uniform in that a species that was dominant at one transectional point was also a dominant at one or more additional points. The water depth at this station ranged from 3 feet to 10 feet (0.9 to 3.2 m) and had velocities of 1.0 to 2.5 feet/second (0.3 to 0.8 m/sec). Only at the transition water site R. M. 3.5 (R. km 5.6), where velocities of 0.8 to 1.0 feet/second (0.25 to 0.3 m/sec) and depths in excess of 6 feet (2 m) occurred, were appreciable reductions in species richness noted. Mayflies were most adversely affected. As a point of clarification, the velocities reported in Table 8 are not static daily velocities, but subject to rather large daily variation commensurate with the power peaking cycle. The basket samples were generally removed during the low-flow cycle to better facilitate their recovery. Velocities of 1 m/sec or more would be expected

Table 6. Number of insects and species/basket at six transect points at R. km 5.6, 7.9 and 14.6, Clearwater River and number of species and average density/0.093m^2 using a conventional bottom sampler at R. km 5.6, Clearwater River. * = Basket not recovered.

	TRANSECT POINTS											
	1		2		3		4		5		6	
Date	No. Sp.	No. Insects	No. Sp.	No. Insects	No. Sp.	No. Insects	No. Sp.	No. Insects	No. Sp.	No. Insects	No. Sp.	No. Insects
Basket Samples R. km 5.6												
7/18/77	7	2243	6	972	6	887	6	2320	5	1148	6	1030
8/24/77	12	116	12	121	*	*	10	240	10	63	10	99
Bottom Samples R. km 5.6												
7/18/77	9	314.5	10	182.5	13	259.5	14	159	8	152.5	9	254.5
Basket Samples R. km 7.9												
8/19/76	18	4140	18	2160	*	*	*	*	11	5629	26	4284
9/20/76	15	5744	18	3260	15	2177	17	5212	14	2036	17	3480
Basket Samples R. km 14.6												
7/27/76	15	5436	16	9378	18	9641	16	5384	16	5392	18	9421
9/27/76	22	965	20	2016	*	*	*	*	17	1846	18	2546
7/19/77	10	4324	9	3184	8	3004	8	9047	7	9296	11	2884
8/25/77	24	1136	13	2172	13	1532	*	*	15	2404	23	1643

Table 7. Depth and velocity of six equally-spaced basket sampling points on a transect spanning the Clearwater River at R. km 5.6, 7.9 and 14.6. * = Baskets not recovered.

TRANSECT POINTS

	1		2		3		4		5		6	
Date	Depth m	Velocity m/sec	Depth m	Velocity m/sec	Depth m	Velocity m/sec	Depth m	Velocity m/sec	Depth m	Velocity m/sec	Depth m	Velocity m/sec
Basket Samples R. km 5.6												
7/18/77	-	-	-	-	-	-	-	-	-	-	-	-
8/24/77	2.44	.28	2.74	.30	*	*	4.57	.33	2.59	.27	1.37	.25
Basket Samples R. km 7.9												
8/19/76	.37	-	.46	-	*	*	*	*	.76	-	.76	.31
9/20/76	.15	-	.15	-	.15	.98	.30	1.16	.61	.91	.61	.98
Basket Samples R. km 14.6												
8/27/76	.91	.31	1.83	.54	1.22	.53	1.52	.55	1.22	.54	1.07	.32
9/27/76	1.52	.37	2.44	.88	*	*	*	*	1.83	.51	1.68	.56
8/25/77	1.07	.46	1.68	.79	1.22	.70	*	*	1.83	.85	.91	.49
7/19/77	1.22	.46	1.52	.73	2.13	.80	3.20	.88	3.05	.85	1.52	.49

during the high flow stage at several basket locations. Basket samplers cannot be used during all months of the year because of the inability to recover them during periods of turbid water or high discharge.

Insect densities determined with scuba bottom sample methods are given in Table 6 for R. M. 3.5 (R. km 5.6). Basket samples had more than 5 times the insects than average bottom sample densities, however, the bottom samples had ≥ 25% or more species, indicating the baskets were indeed selective for certain insects, especially filter feeders. Because the experiment was done only during July, 1977, additional seasonal studies need to be conducted.

Obvious difficulties are encountered in deep-water benthos sampling. In depths greater than three feet (1 m) it is necessary to mark the location of the baskets for future recovery with a buoy. Rafters and fishermen are often attracted to the markers resulting in their destruction or removal. Conventional bottom sampling employing scuba methods, on the other hand, also has difficulties. In turbid waters greater than 6 feet (2 m) deep or where velocities exceeded 2.2 feet/second (0.8 m/sec), considerable difficulties were encountered implanting the sampler and collecting the insects. We believe that multiple methods for collecting deep-water benthos are desirable and that scuba provides the best means for comparing bottom densities over large river areas encompassing deep and shallow waters.

Insect Community Stability During a Twenty-four Hour Power Peaking Cycle

Hydroelectric peaking cycles on the Clearwater River result in daily wetted perimeter changes throughout most months of the year. The slope of the stream bank, width of the river, and incremental change in discharge determine the amount of shoreline dewatered. Daily hydrographs for 24-hour hydroelectric peaking tests conducted in the summers of 1976 and 1977 are given in Fig. 24. The hydrographs are graphical in the sense that the "base" flows at Spalding are approximate and pegged at 5000 cfs while flows from Dworshak Dam are actual releases. Actual releases from Dworshak Dam were superimposed on a fixed 5000 cfs flow in the main stem and directly transferred to R. M. 9.1 (R. km 14.6). These hydrographs reflect approximate time of travel of a flow change from Dworshak Dam to R. M. 9.1 (R. km 14.6) as well as differences between the low and high discharge periods of the day.

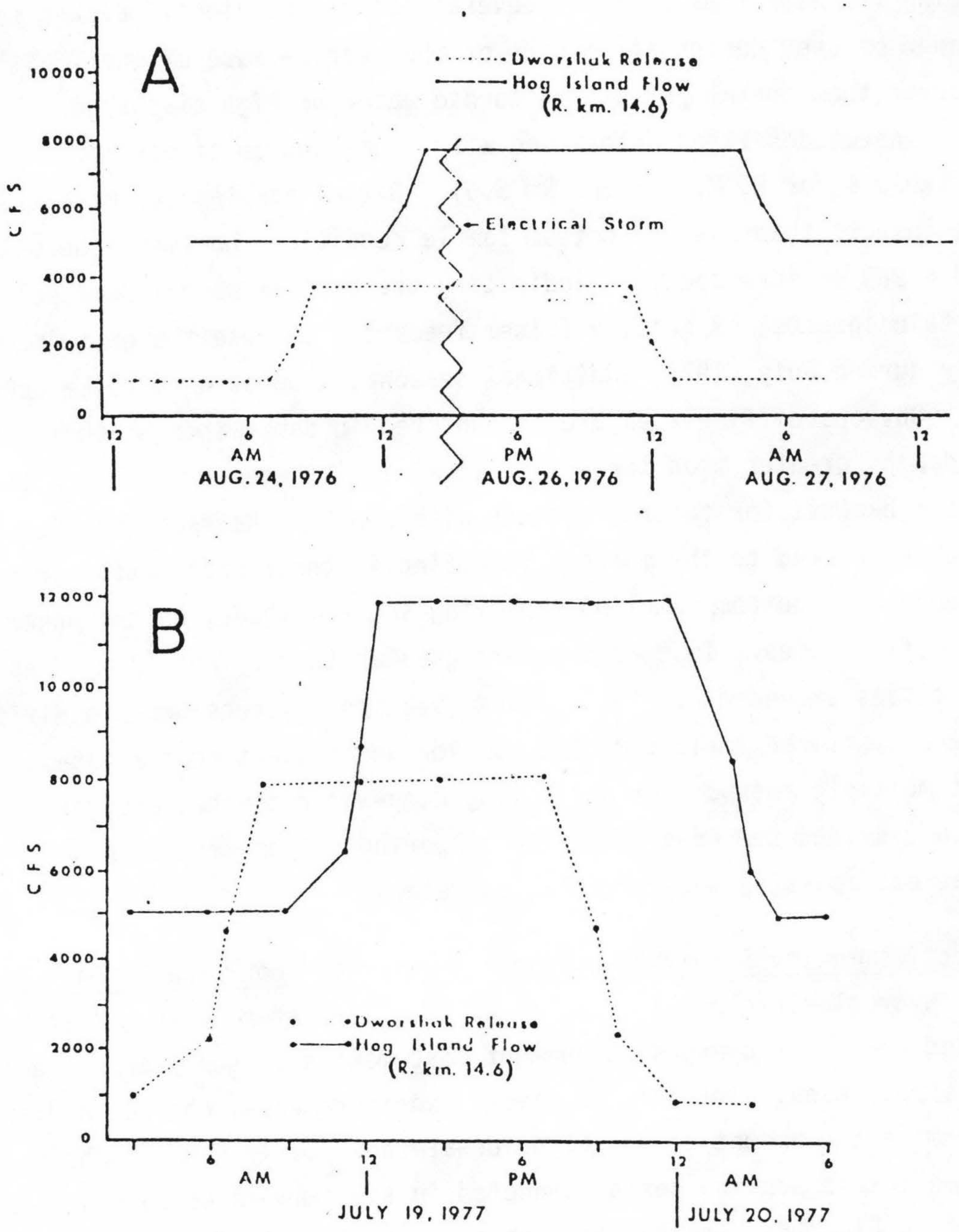

Fig. 24. Daily hydrograph depicting Dworshak release flows and time of travel flows for R. km 14.6 for: A. August 24-27, 1976, B. July 19-20, 1977.

During 1976, runoff more approximated an average condition than 1977 which was an extremely low water year in most Idaho streams. Differences in hydroelectric power generation is evident between the two years with much greater flow releases in 1977 than 1976 from Dworshak Dam. Because of the high vertical face of Dworshak Dam and its efficiency in power generation, large demands were placed upon Dworshak to generate additional power to offset deficiencies from other low-head dams on the Columbia River.

The time of travel of a given flow change requires approximately five hours between Dworshak Dam and R. M. 9.1 (R. km 14.6). Changes in discharge at Dworshak Dam are typically graduated over a one to two-hour period to minimize sudden and dramatic changes in flow levels at points downstream.

The study conducted during a hydroelectric power peaking cycle on August 24, 1976 was discontinuous in that a mid-afternoon electrical storm prohibited safe operation of boat and personnel in the water during regularly scheduled bottom and drift sampling times. Therefore, the study was continued on August 26. Discharges from Dworshak Dam were comparable during these two days, therefore, bottom and drift sample reference points were unaffected. Insect drift was taken during both daylight and dark hours of the high flow period of the cycle. We wanted to determine if insects drifted across newly watered shoreline during the high flow period and if they did, what effect the time of day had on drift and colonization. We also wanted to determine if insect standing crop changed as a result of the time of day and location on the shoreline.

During 1977, which was an extremely low water year, a similar study was conducted during July 19 at the same site R. M. 9.1 (R. km 14.6) and at R. M. 45 (R. km 72.4) which was located above the confluence of the North Fork Clearwater River and not under the influence of hydroelectric power generation.

The standing crops of principal insect groups at known distances from a permanent reference marker on shore to specified water depths are given in Tables 8-10. Species in the orders Trichoptera, Diptera and Ephemeroptera represented over 90% of the insects collected. With few exceptions, the number of species (exclusive of Chironomidae) increased with increasing

Table 8. Insect standing crop (numbers/m^2) in relation to distance from bench mark, depth, water velocity and time at R. km 14.6, August 24, 26, 1976.

Distance Stake to Sample Point (m)	Depth (cm)	Velocity m/sec.	No. Spp.	Density/m^2			
				Trichop.	Diptera	Ephem.	Total
LOW FLOW CONDITIONS (10 A.M.)							
186 (Low Water Mark)	0	-	-	-	-	-	-
195 (Benthos I)	5	.03	10	118	221	27	414
212 (Benthos II)	8	.09	18	328	845	226	1480
223 (Benthos III)	15	.09	10	124	237	172	549
228 (Benthos IV)	41	.24	18	624	280	172	1130
HIGH FLOW CONDITIONS (10 P.M.)							
163 (High Water Mark)	0	-	-	-	-	-	-
173 (Benthos I)	5	.20	0	0	0	0	0
186 (Low Water Mark)	5	.19	2	0	11	0	11
195 (Benthos III)	8	.21	5	0	11	11	32
212 (Benthos IV)	15	.78	14	140	301	140	603
223 Benthos V)	24	.85	15	70	371	151	624
228 (Benthos VI)		No Samples Taken					

Table 9. Insect standing crop (numbers/m^2) in relation to distance from bench mark, depth, water velocity and time at R. km 14.6, July 19, 1977.

LOW FLOW CONDITIONS (11-12 A.M.)

Distance Stake to Sample Point (m)	Depth (cm)	Velocity m/sec.	No. Spp.	Density/m^2 Trichop.	Diptera	Ephem.	Total
222 (Low Water Mark)	0	-	-	-	-	-	-
233	15	0.22	17	405	420	57	922
241	30	0.15	19	165	301	59	578
245	45	0.15	20	172	204	50	473

HIGH FLOW CONDITIONS (11-12 P.M.)

Distance Stake to Sample Point (m)	Depth (cm)	Velocity m/sec.	No. Spp.	Density/m^2 Trichop.	Diptera	Ephem.	Total
154 (High Water Mark)	0	-	-	-	-	-	-
169	15	0.32	1	0	4	0	4
189	30	0.78	6	22	36	0	68
207	23	1.22	11	215	233	11	491

Table 10. Insect standing crop (numbers/m^2) in relation to distance from bench mark on shore, depth and water velocity at R. km 72.4 (Control riffle), August 9, 1977.

Distance Stake to Sample Point (m)	Depth (cm)	Velocity m/sec.	No. Spp.	Density/m^2 Trichop.	Diptera	Ephem.	Total
50 (Waterline)	0	-	-	-	-	-	-
53	15	.20	22	563	481	190	1302
56	30	.32	26	1187	861	309	2496
58	45	.37	23	8034	1144	319	9562

distance from shore. A similar trend was not as clearly evident for total standing crop, i.e. as distance from shore increased, standing crop increased. During August 1976, highest densities were recorded at the 212 m distance marker. This large increase was contributed primarily by dipteran midges.

During the high flow phase of the power peaking cycle (10 p.m.), during Aug. 1976, samples were again taken at the same distance markers as well as two additional points that were newly watered. The water depths and velocities as expected were considerably greater at the sample areas. At the 198 m marker small numbers of Diptera were collected just above the low water mark established during the earlier part of the day indicating recruitment into the area or possible residual carryover of insects in the gravel and sand interstices. Considerably higher densities were recorded at the 195 m marker during the low flow period of the day than during the high flow. This is unexpected since the samples were taken in the same proximity at both times but under different light and flow conditions. The mayflies Ephemerella grandis and E. margarita and the caddisflies Glossosoma sp. and Cheumatopsyche sp. were the dominant non-dipteran species. It is significant to note that several of the Glossosoma sp. were in the pupal stage which renders them vulnerable to dewatering since they cannot move to new locations because of their rock-cemented cases. Diptera was represented almost exclusively by chironomid midges which were the dominant insects in the community. Samples taken at 10 p.m. at the 173 m marker located well up into the zone of fluctuation, had no insects even though the depth and velocities were adequate at that time to assure at least temporary colonization.

During July 1977 the flow conditions in the Clearwater River were some of the lowest on record, however, daily fluctuations were large because of increased power demands. While only 74 feet (23 m) of wetted perimeter was involved between the high and low water mark during the peaking cycle in 1976, 223 feet (68 m) was bracketed by the high and low water marks during the 1977 test.

In 1977, there was 728 feet (222 m) between the head pin and the low water line during the test, whereas 610 feet (186 m) represented a similar distance during the 1976 test. Highest densities in 1977 were recorded at the 764 foot (233 m) marker and decreased at increasing distances from shore (Table 9). Midges and caddisflies represented the majority of the standing crop during the low-flow sampling times. Mayflies were sparsely represented with densities not exceeding $60/m^2$. Because of large increases in flows, sample depths of 6", 12", and 18" (15, 30, and 45 cm) were all located above the low water mark indicating potential stress conditions to the insect community.

Drift samples taken commensurate with bottom samples during August 1976 provided little insight into drift-density relationships because of low numbers of drifting insects both during the day as well as at night. Drift studies conducted at R. M. 9.1 (R. km 14.6) during 1977, however, provided insights into insect colonization and power peaking cycles. At 12 a.m. on July 19, when flows were increasing because of increased power generation, a modest number of insects, primarily *Brachycentrus* sp. in the order Trichoptera, was collected in drift (Fig. 25). Increasing numbers were noted with increasing depths of 6", 12", and 18" (15, 30, and 45 cm), respectively. During high flows at 12:00 midnight, insect drift increased appreciably, with drift densities increasing with increasing depths. Caddisflies, particularly *Brachcentrus* sp. and *Hydropsyche* sp. were the principal drifters. *Cheumatopsyche*, the dominant species in standing crop at the 207 m marker, (located above the low water mark for the day) was represented by only 2 specimens in drift, therefore, lending credence to the notion that these insects did not drift into the area, but resided under rocks or within gravel interstices during the dewatered cycle of the day.

Drift at the control site (Fig. 26) had a similar nighttime increase with caddisflies again the dominant group. However, drift propensity was much less proportionate to the standing crop densities (Table 10).

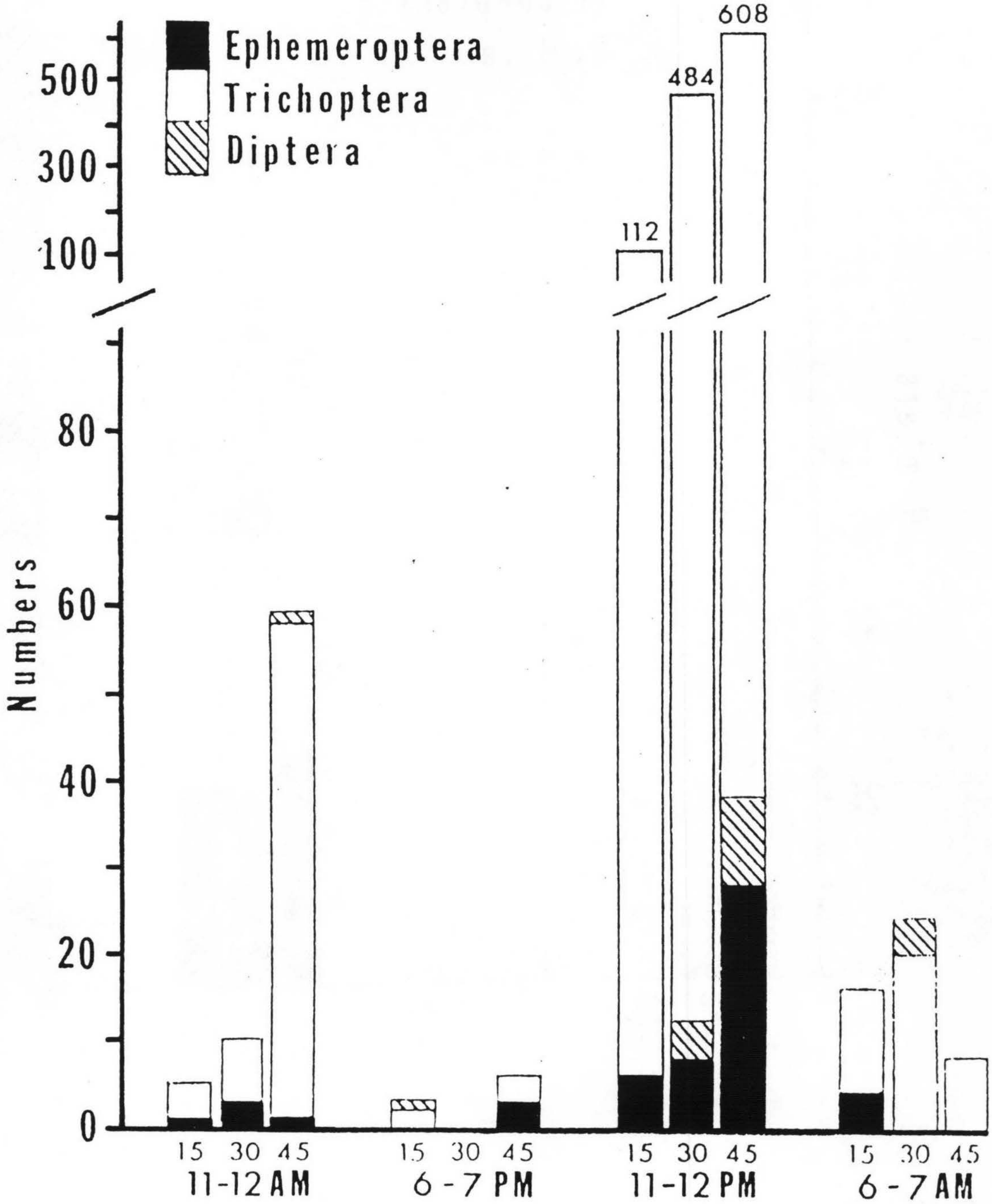

Fig. 25. Insect drift at R. km 14.6 during July 1977, Clearwater River.

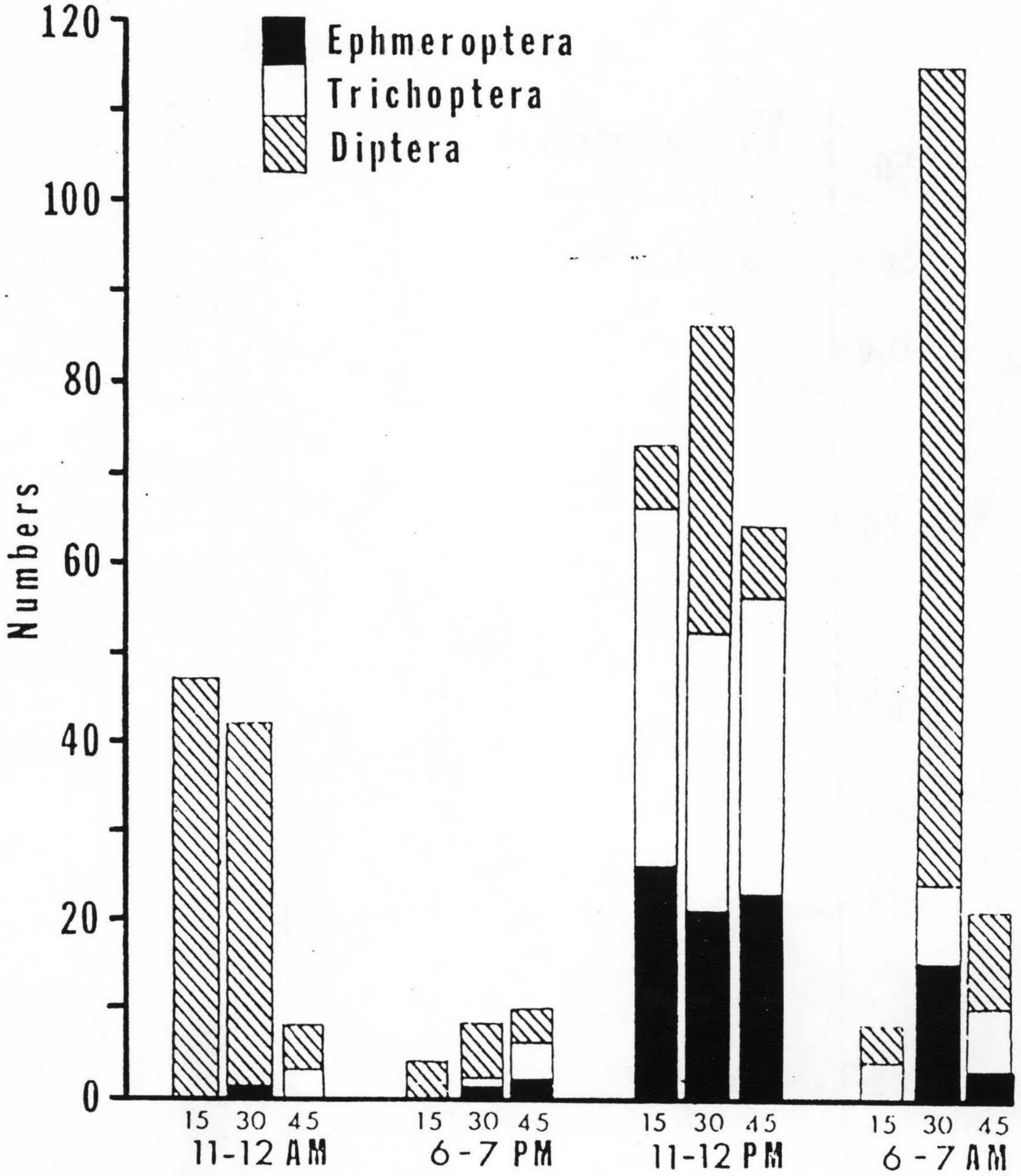

Fig. 26. Insect drift at R. km 72.4 during August, 1977, Clearwater River.

SUMMARY

The interacting effects of fluctuating flow and transient shorelines on aquatic insects resulting from hydroelectric power generation were investigated on the Clearwater River, Idaho.

As a result of the operational mode of Dworshak Dam since March 1973 Clearwater River flows are higher during the late summer and fall months than they were in the pre-project era. Although project releases are characterized by frequent and pronounced fluctuations, there is a stable post-project base discharge at Spalding of approximately twice the pre-project low flow (2,000 cfs). This additional flow guarantees the submergence of additional substrate thereby increasing potential benthic habitat.

These higher late-summer and fall discharges are made possible by the reduction of peak spring runoff. From a cursory examination of post-project peak discharges and work experience on the river it does not appear that spring flows have been so drastically reduced that unwanted fine sediments are being deposited in the main stem channel.

Two major concerns remain to be addressed before a definitive statement can be made concerning the net effect of post-project flows on benthic insect habitat. The effect of lower water temperatures on benthos metabolism and emergence has yet to be identified. Also, the frequency and amplitude of fluctuations in discharge result in rather notable shifts in the velocity of the river. Benthic insects inhabit a rather sheltered rock-water interface that is relatively immune from the direct forces of the current, however, velocity may well be "the" parameter which dictates the conditions of the physical habitat.

Over 120 species of aquatic insects exclusive of Chironomidae have been collected from the Clearwater River in Idaho. A majority of the species are relatively rare and never collected in large numbers. This pertains particularly to many species in the orders Coleoptera and Trichoptera. A few species in these orders, however, were abundant and common members in the community.

None of the principal species in the orders Ephemeroptera, Plecoptera, Trichoptera, Coleoptera and Diptera reflected exclusive distribution to the reach above or below the influence of hydroelectric power generation. While small to moderate shifts in seasonal densities of principal species have occurred above and below the influence of Dworshak Dam, evidence does not strongly suggest these were the result of hydroelectric power generation.

Subsequent to 1975 overall densities and numbers of species have been greater at the control site above the influence of Dworshak Dam than below. This difference is attributed primarily to sampling limitations and the instable nature of the relatively shallow (0-45 cm depth), near-shore sampling zone rather than the influence of power releases. As a general trend, both numbers of species and densities increased with increasing water depth (15, 30, and 45 cm) and distance from the transient shore line.

Insect colonization on newly watered sterile rocks requires approximately one month to approach the standing crop of continually watered rocks. Daily water fluctuations from Dworshak Dam do not promote short-term colonization in shore zones of fluctuation. Therefore, daily fluctuations within a defined zone potentially result in less direct stress and mortality to the insect community than stable periods of three to four weeks followed by moderate to extreme fluctuations that invades the previously established stable zone.

Within the lower 4 to 4.6 miles (6.4 to 7.4 km) of the Clearwater water surface elevations and the variable backwater effects of Lower Granite Reservoir have a far more pronounced effect on the amount of potential benthic habitat available in this reach than do releases from Dworshak. Within the Lower Granite pool area, changes in water surface elevations water or dewater large angular pieces of rip-rap. Because of the very steep side slope of the dikes, relatively little wetted perimeter is affected by fluctuations in the water surface elevation of the reservoir.

Formation of Lower Granite Pool has resulted in insect community shifts from a riverine to a lentic reservoir community. The pool community at River mile 1.25 (R. km 1.9) is now composed largely of chironomid midges. During post-impoundment analyses, occasional mayflies (Ephemeroptera) and caddisflies (Trichoptera) were collected at this site. These insects have been absent or rare during subsequent samples as silt, sand and organic debris are being deposited on this portion of the reservoir bottom. Sample sites located in the transition pool-river region reflect a transitional insect community composed of lotic and sublentic species. Chironomid midges were prevalent along with large densities of filter feeding Trichoptera, e.g. *Brachycentrus* sp. and *Cheumatopsyche* sp. Cluster analysis of lower Clearwater basket sampling sites during late-summer and fall of 1975 showed the insect community of the Lower Granite Pool proper to be least associated with the other four riverine and transition-water sites. In most cases the free flowing riverine sites clustered at a higher level of association than the transition water sites.

Results from basket samples and insect drift in the Lower Granite Pool transition region indicate that many insects initially residing or drifting into this region at least temporily took up limited residence in the region, but on a density diminishing basis. We define this change as a "continuum phenomenon" were orderly physical changes in the environment produce commensurate changes in the benthic insect fauna.

Scuba sampling of deep water benthos at depths of 4 to 14 feet (1.3 to 4.5 m) at a river-reservoir transition site revealed that insect densities were comparable to near shore densities. Basket samples taken adjacent to conventional bottom samples revealed that more species were taken in bottom samples but considerably fewer insects. Basket samples tend to promote selective colonization by species that have filter feeding characteristics. Basket samples are useful for between-site comparison rather than literal qualitative and quantitative comparison with other sampling methods.

APPENDIX

Append. A. Checklist and distribution of insect species in mainstream of Clearwater River.

ORDER: EPHEMEROPTERA	Stat. 1 Alternate (R.km 80.5)	Stat. 1 (R.km 72.9)	Harpers Bend (R.km 57.9)	N. Fork Clearwater Riv.	Stat. 2 (R.km 50.1)	Stat. 3 (R.km 38.0)	Lapwai Cr. (R.km 19.4)	Hog Island Riffle (R.km 14.6)	Hog Island Run (R.km 14.6)	Chip Truck (R.km 8.3)	Potlatch S. (R.km 7.4)	Potlatch N. (R.km 5.6)	CTC (Coast Trading Co., R.km 1.9)
Ameletus connectus					x	x	x	x	x		x	x	
A. cooki	x	x	x		x	x		x	x	x	x	x	x
A. oregonensis		x	x				x		x		x		
A. similer		x	x									x	
A. sparsatus	x								x	x			
A. validus		x	x			x							
Baetis bicaudatus	x	x	x		x	x	x	x	x	x	x	x	
Baetis parvus	x	x	x	x	x	x	x	x	x	x	x	x	
B. tricaudatus	x	x	x	x		x	x	x	x		x	x	
Caenis latipennis									x				
Centroptilum sp. #1	x	x	x		x	x		x	x	x	x	x	x
Centroptilum sp. #2		x	x		x		x	x	x	x	x	x	x
Cinygmula sp.	x	x	x		x	x							
Epeorus albertae	x	x	x		x	x	x	x	x	x		x	
Epeorus longimanus					x			x					
Ephemera simulans									x				
Ephemerella doddsi		x			x	x			x				
Ephemerella edmundsi		x											
Ephemerella flavilinea		x		x	x	x		x		x			
Ephemerella grandis	x	x	x	x	x	x	x	x	x	x	x	x	
Ephemerella hecuba		x			x	x	x						
Ephemerella heterocaudata		x			x			x					
Ephemerella hystrix		x			x								
Ephemerella inermis-infreq.	x	x	x	x	x	x	x	x	x	x	x	x	x
Ephemerella margarita	x	x	x		x	x		x	x	x	x	x	x
Ephemerella spinifera					x								
Ephemerella tibialis	x	x			x	x			x	x		x	
Heptagenia criddlei	x	x			x	x		x	x	x	x	x	x
Heptagenia elegantula	x	x											
Heptagenia simplicoides		x	x		x	x		x	x	x	x	x	x
Heptagenia solitaria	x	x	x		x	x	x	x	x	x	x	x	
Paraleptophlebia bicornuta	x	x	x		x	x	x	x	x	x	x	x	x

Append A. (continued)

ORDER: EPHEMEROPTERA (continued)	Stat. 1 Alternate (R.km 80.5)	Stat. 1 (R.km 72.9)	Harpers Bend (R.km 57.9)	N. Fork Clearwater Riv.	Stat. 2 (R.km 50.1)	Stat. 3 (R.km 38.0)	Lapwai Cr. (R.km 19.4)	Hog Island Riffle (R.km 14.6)	Hog Island Run (R.km 14.6)	Chip Truck (R.km 8.3)	Potlatch S. (R.km 7.4)	Potlatch N. (R.km 5.6)	CTC (Coast Trading Co., R.km 1.9)
Paraleptophlebia debilis								x				x	x
Paraleptophlebia heteronea	x	x	x		x	x	x	x	x	x	x	x	
Rithrogena hageni	x	x	x	x	x	x	x	x	x	x	x	x	x
Rithrogena robusta		x			x	x		x		x			
Siphlonurus columbianus					x				x			x	x
Stenonema reesi									x	x	x		
Tricorythodes minutus	x	x	x		x	x	x	x	x	x	x	x	x
ORDER: PLECOPTERA													
Acroneuria californica		x	x		x	x		x	x	x			
Acroneuria pacifica		x			x	x							
Alloperla sp.		x			x	x		x					
Arcynopteryx sp.	x	x	x		x	x		x	x	x	x	x	
Brachyptera sp.	x	x	x		x		x	x	x	x	x	x	x
Capnia sp.		x	x		x	x				x			
Claassenia sp.		x			x	x		x	x	x			
Isogenus sp.	x	x	x	x	x	x	x	x	x	x	x	x	
Isoperla sp.		x		x	x	x			x				
Nemoura sp.	x	x	x		x	x	x		x	x	x	x	
Peltoperla sp.		x											
Pteronarcella badia					x								
Pteronarcys sp.		x	x		x	x		x	x	x	x		
Taeniopteryx sp												x	
ORDER: COLEOPTERA													
Amphizoa insolens									x				
Ampumixus sp.		x			x	x				x			
Brychius sp.		x									x		
Cleptelmis sp.	x	x			x								
Haliplus sp.													x
Heterlimnius sp.		x	x		x	x							
Hydroporous sp.		x			x	x		x	x	x		x	
Narpus sp.		x			x	x		x	x	x		x	
Ordobrevia sp.							x						
Optioservus sp.		x			x	x	x	x	x	x	x		
Psephenus sp.		x	x		x	x		x	x	x			
Zaitzevia sp.	x	x	x		x	x	x	x	x	x		x	

Append. A.(continued)

ORDER: TRICHOPTERA	Stat. 1 Alternate (R.km80.5)	Stat. 1 (R.km 72.9)	Harpers Bend (R.km 57.9)	N. Fork Clearwater Riv.	Stat. 2 (R.km 50.1)	Stat. 3 (R.km 38.0)	Lapwai Cr. (R.km 19.4)	Hog Island Riffle (R.km 14.6)	Hog Island Run (R.km 14.6)	Chip Truck (R.km 8.3)	Potlatch S. (R.km 7.4)	Potlatch N. (R.km 5.6)	CTC (Coast Trading Co., R.km 14.9)
Agapetus sp.		x											
Arctopsyche grandis					x	x							
Athripsodes sp.		x	x		x		x	x	x	x	x	x	x
Brachycentrus sp.	x	x	x	x	x	x	x	x	x	x	x	x	
Cheumatopsyche sp.	x	x	x		x	x	x	x	x	x	x	x	
Chimarra sp.		x	x										
Dicosmoecus sp.	x	x											
Dolophilodes sp.		x				x							
Drusinus sp.					x	x							
Glossosoma sp.	x	x	x	x	x	x		x	x	x	x		
Helicopsyche sp.		x	x		x								
Hydropsyche sp.	x	x	x		x	x	x	x	x	x	x	x	
Hydroptila sp. A		x	x		x	x	x	x	x	x	x	x	x
Hydroptila sp. B												x	
Leucotrichia sp.		x			x	x							
Lepidostoma sp. A	x	x	x		x	x		x	x	x		x	x
Lepidostoma sp. B	x	x		x	x	x		x	x	x	x	x	
Leptoceridae (sp.)									x		x		
Micrasema sp.		x	x		x			x	x	x			
Neophylax sp.					x								
Neothremma sp.		x	x			x							
Neothrichia sp.		x			x	x							
Oecetis sp.	x	x	x		x	x		x	x	x	x		
Parapsyche elsis					x								
Polycentropus sp.		x			x	x	x		x	x	x	x	x
Psychoglypha sp.		x			x	x		x					
Psychomyia sp.					x			x					
Rhyacophila hyalinata		x			x								
Rhyacophila vagrita		x								x			
Rhyacophila verrula	x	x				x							
Wormaldia sp.		x				x							

	Stat. 1 Alternate (R.km 80.5)	Stat. 1 (R.km 72.9)	Harpers Bend (R.km 57.9)	N. Fork Clearwater Riv.	Stat. 2 (R.km 50.1)	Stat. 3 (R.km 38.0)	Lapwai Cr. (R.km 19.4)	Hog Island Riffle (R.km 14.6)	Hog Island Run (R.km 14.6)	Chip Truck (R.km 8.3)	Potlatch S. (R.km 7.4)	Potlatch N. (R.km 5.6)	CTC (Coast Trading Co., R.km 1.9)
ORDER: DIPTERA													
Antocha sp.		x	x		x	x		x					
Antherix variagata		x			x	x		x					
Blephariceridae (sp.)		x			x								
Chironomidae (spp.)	x	x	x	x	x	x	x	x	x	x	x	x	x
Dicranota sp.	x	x			x								
Dolichopodidae (sp.)		x	x		x	x							
Empididae (sp.)		x	x		x	x	x		x				
Ephydridae (sp.)		x			x								
Forcipomyia sp.		x			x								
Hexatoma sp.		x			x	x	x	x	x	x		x	
Limonia sp.					x								
Ormosia sp.					x								
Palpomyia sp.	x					x			x				
Philorus sp.		x			x								
Protanyderus margarita		x	x		x	x		x	x				
Trionocera sp.						x							
Simulium sp.	x	x	x	x	x	x	x	x	x	x	x	x	
Stratiomyidae (sp.)		x											
Tabanidae (sp.)					x								
Tipula sp.			x										
ORDER: ODONATA													
Ophiogomphus occidentis								x	x	x			
Ophiogomphus severus	x	x			x	x							
ORDER: HEMIPTERA													
Corixidae (sp.)		x					x	x	x			x	x
ORDER: NEUROPTERA													
Sialis sp.							x	x					
ORDER: LEPIDOPTERA													
Parargyractis sp.		x	x		x	x		x	x	x	x	x	

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