A-035-

5

POST-IMPOUNDMENT EFFECTS OF REGULATED FLOWS FROM DWORSHAK DAM ON THE BENTHIC INSECT COMMUNITY OF THE CLEARWATER RIVER, IDAHO

A Thesis

Presented in Partial Fulfillment of the Requirements for the

MASTER OF SCIENCE DEGREE

Major in Entomology

in the

UNIVERSITY OF IDAHO GRADUATE SCHOOL

by

JAMES EDWARD STANTON

January, 1977

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

LIST OF TABLES

LIST OF TABLES (cont.)

LIST OF FIGURES

LIST OF FIGURES (cont.)

LIST OF APPENDICES

ACKNOWLEDGEMENTS

I would like to thank the Department of Entomology, University of Idaho, for its financial and logistical support during my term as a graduate student, and the Idaho Water Resources Research Institute for its financial support during the first year of my research (OWRT Project A-035-IDA). I would particularly like to thank Dr. Merlyn A. Brusven, who served as my major professor, and whose technical expertise, encouragement, and critical review brought this thesis to its present form. Thanks also go to Dr. L. E. O'Keeffe of the Department of Entomology, and to Dr. C. M. Falter of the College of Forestry, for serving as committee members and providing technical expertise; to Dr. D. O. Everson of the College of Agriculture for his help with the statistical analysis of my data; to Russell Biggam of the Department of Entomology for his help in the field and particularly for his help in identifying insects; and finally to Mrs. Greetis Berry of the Idaho Water Resources Research Institute for typing the final manuscript.

ABSTRACT

A study to determine the post-impoundment effects of Dworshak Dam on aquatic insects in northern Idaho's Clearwater River was carried out from August, 1973, to September, 1976. Selected shoreline riffles and pools were sampled monthly during the summer and irregularly during the remainder of the year. A cylindrical square-foot bottom sampler, rock-filled wire baskets, and drift nets were used to measure benthic insect populations and community dynamics. Laboratory and in-stream simulation tests were conducted in order to provide an understanding of insect habitat preferences and colonization behavior.

Dworshak Dam has had little appreciable effect on yearly maximum and minimum flows in the main Clearwater River during most years. Although dam operation usually causes daily water-level fluctuations of up to 60 vertical centimeters, low natural flows in 1973 caused the dam to release above-normal amounts of water on a non-fluctuating basis that year. The dam thus had a stabilizing effect on river benthos during 1973.

Small changes in river temperatures have occurred below Dworshak Dam since it became operational, but these changes have apparently had little effect on aquatic insects below the dam. The dam has had little effect on dissolved oxygen concentrations in the main Clearwater River.

Dworshak Dam has had few detrimental effects on river benthos during the post-impoundment period. Insect communities in the upper main stem of the Clearwater River remained healthy and well balanced since the dam went into operation.

Decreases in insect density have occurred on shoreline substrate that is subjected to daily dewatering because drifting insects do not readily colonize these areas. Under natural conditions, colonization time was found to be more important than periphyton development in determining insect density on cobble substrate. Two to three weeks were required for colonization by most species to be statistically equal on newly-watered and permanently-watered substrates. Insect density in shoreline riffles increased with increasing depth to 45 cm even under stable flow conditions.

Drift studies near shore revealed that most insects were night active and that, while the highest total number per hour drifted at the 45 cm depth, the largest number per m^3 of flow drifted at the 15 cm depth. A larger percentage of the insect community drifted at the shallower depth, thus supporting the idea that habitat quality for many riverine species is less near the water's edge even under natural flow conditions.

INTRODUCTION

Most post-impoundment studies have dealt directly with fish rather than with their food supply. This has been particularly true in the West, where large, fast-flowing rivers have been largely neglected by aquatic entomologists. Previous post-impoundment studies of benthic insects have been done under conditions that were not exactly comparable to those of the Dworshak project (Brusven et al. 1974; Briggs 1948; Edwards et al; 1974; Falter et al. 1973; Fisher & LaVoy 1972; Geen 1974; Kroger 1973; Minshall & Winger 1968; Pearson & Franklin 1968; Powell 1958; Radford & Hartland-Rowe 1971; Spence & Hynes 1971; Trotsky & Gregory 1974). The concensus of these studies, however, is that significant losses of invertebrate fauna can be expected below dams as a result of the rapid, large-scale flow changes which usually occur during hydroelectric power production. Changes in limnological conditions (water chemistry, temperature, etc.) resulting from impoundment formation can also affect downstream invertebrates.

The Dworshak project on the Clearwater River differs from other studies in a number of ways: (1) the Clearwater River is much larger and faster than most of the streams covered by the aforementioned studies; (2) Dworshak Dam is on a tributary rather than on the main river, making control of the entire stream flow impossible; (3) pre-impoundment data is available for comparison with post-impoundment conditions; (4) the timing and magnitude of flow changes produced by Dworshak Dam are different, and their effect on river benthos may be different; (5) the insect fauna of the Clearwater River differs from that of other areas, so their ecological requirements and resiliancy to changes in the environment may be different.

With these considerations in mind, the post-impoundment phase of this research was developed with three main objectives: (1) determine the effects of Dworshak Dam on aquatic insects in the Clearwater River; (2) develop methods for studying post-impoundment effects on aquatic insects in large river systems; (3) make recommendations aimed at minimizing future effects of Dworshak Dam on river benthos.

Dworshak Dam produces power through load factoring; flows through the Dam are increased in the morning, held relatively constant during daylight hours, and then decreased at night in order to match consumer demand for electricity. This pattern continues as long as reservoir inflow is less than the desired outflow, which is the case during most of the year (R. George, U.S. Army Corps of Engineers' River Control Center, Portland, Oregon, pers. comm. 1976). Also, flows from the dam must be at least 1000 cubic feet per second (cfs) at all times (U.S. Army Corps of Engineers 1974).

Dworshak Dam was also built for flood control, which it accomplishes through the storage of water in Dworshak Reservoir. The reservoir is maintained at maximum pool level during the summer months, but its volume is reduced by nearly 60% during the fall, winter, and following spring (USGS 1975). The reservoir refills rapidly during May and June when runoff is at its peak. Because of this annual change in reservoir volume, the magnitude of annual flow variation in the North Fork of the Clearwater River (the site of Dworshak Dam) is much less than it was under natural conditions (USGS 1968-69 & 1974). But daily or weekly flow variations in the North Fork are much greater than they were prior to impoundment (Ibid.).

While daily flow fluctuations seldom exceed 60 vertical centimeters, these fluctuations are greater in September than in August or October. Dworshak Reservoir is held at full pool during August to allow for maximum recreational use and because the demand for electricity is low. In response to the fall steelhead season on the Clearwater River, daily flow fluctuations are held to 40% of the previous week's average daily flow from October 1 to November 15 of each year (R. George, U.S. Army Corps of Engineers' River Control Center, Portland, Oregon, pers. comm. 1976). During September, however, flows from the dam are increased in order to reduce the water level in Dworshak Reservoir in preparation for the next spring's runoff. Since power needs are still relatively low in September, flows are reduced to a minimum at night to avoid spillage. Running water through the generators at night would produce electricity with no place to be used and no possibility of being stored for future use, while spilling water past the generators produces no electricity and is therefore considered a waste of resources. With even lower energy needs during September weekends, daily maximum flows are reduced during these periods in order to avoid the need for spillage (Ibid; W. Larson, Dworshak Dam powerhouse, pers. comm. 1976). The total effect of these restrictions is that September water levels below the dam are highly unstable.

Because of the large area of gently-sloping shoreline present in the Clearwater River, daily flow fluctuations could destroy large numbers of insects through de-watering of their habitat. Of the various environmental changes which could occur as a result of Dworshak Dam, unstable flows have the greatest potential for causing harm to aquatic insect communities below the dam. The main emphasis of my research has been the detection and understanding of this phenomenon, if indeed it has occurred.

Water-temperature changes are another potential source of danger to aquatic insects. Such changes occur most often when generator intakes are either very deep or very shallow in relation to the surface of a reservoir. Dworshak Dam has multi-level intakes, allowing water to be taken from various depths in order to meet the temperature requirements of Dworshak National Fish Hatchery, which is located on the North Fork of the Clearwater River below the dam (W. Larson, Dworshak Dam powerhouse, pers. comm. 1976).

River temperatures below the dam do not match pre-impoundment conditions during certain parts of the year in spite of the temperature-regulating capacity of the dam. These temperature changes could eliminate some insect species or alter their life cycles. A species with a changed life cycle might be of either greater or lesser value as fish food if its size or availability was altered during that period of the year when gamefish feed most actively.

Entomological studies in conjunction with the construction of Dworshak Dam began in 1969 (Walker 1972) and continued through 1972 (Peters 1973), covering the pre-impoundment and early post-impoundment phases of the project. The present study covered the period from August, 1973, to September, 1976, in order to assess the post-impoundment effects of Dworshak Dam on aquatic insects in the main Clearwater River for a downstream distance of approximately 30 kilometers. In addition to the main river study, laboratory and field simulation tests of insect colonization behavior were conducted.

DESCRIPTION OF THE STUDY AREA

The Clearwater River flows in a generally east-west direction across northern Idaho. Formed by the Lochsa and Selway Rivers, the Clearwater carries water from the Montana border to Lewiston, Idaho, where it joins the Snake River. Paralleled for its entire length by U.S. Highway 12, the Clearwater lies in a narrow, steep-sided canyon. Most of the upper drainage consists of heavily-forested mountains. Downstream from Orofino, timber gives way to cheatgrass and medusahead on the hillsides; grain fields occupy the upland plateaus. The drainage area upstream from Peck covers some 21,000 km^2 (8,000 mi^2) (USGS 1974).

The North and Middle Forks of the Clearwater River meet at Orofino. Dworshak Dam is located on the North Fork at River Kilometer (R.K.) 3.2 (Ibid.). Prior to impoundment, the North Fork provided an average of 37% of the annual flow of the main Clearwater River. Constructed for power generation and flood control, Dworshak Dam became fully operational during the spring of 1973. With a height of over 215 m (710 ft), Dworshak is one of the highest dams in the Nation.

The study area covered that portion of the main Clearwater River from R.K. 38.0 to R.K. 80.5 (Figure 1). Shoreline sampling sites were located at R.K. 72.4 (Site I, control), 50.1 (Site II, test), and 38.0 (Site III, test). Deepwater sampling sites were located at R.K. 80.5 (Site IA, alternate control), 72.9 (Site IB, control, Orofino), and 57.9 (Site HB, test, Harper's Bend).

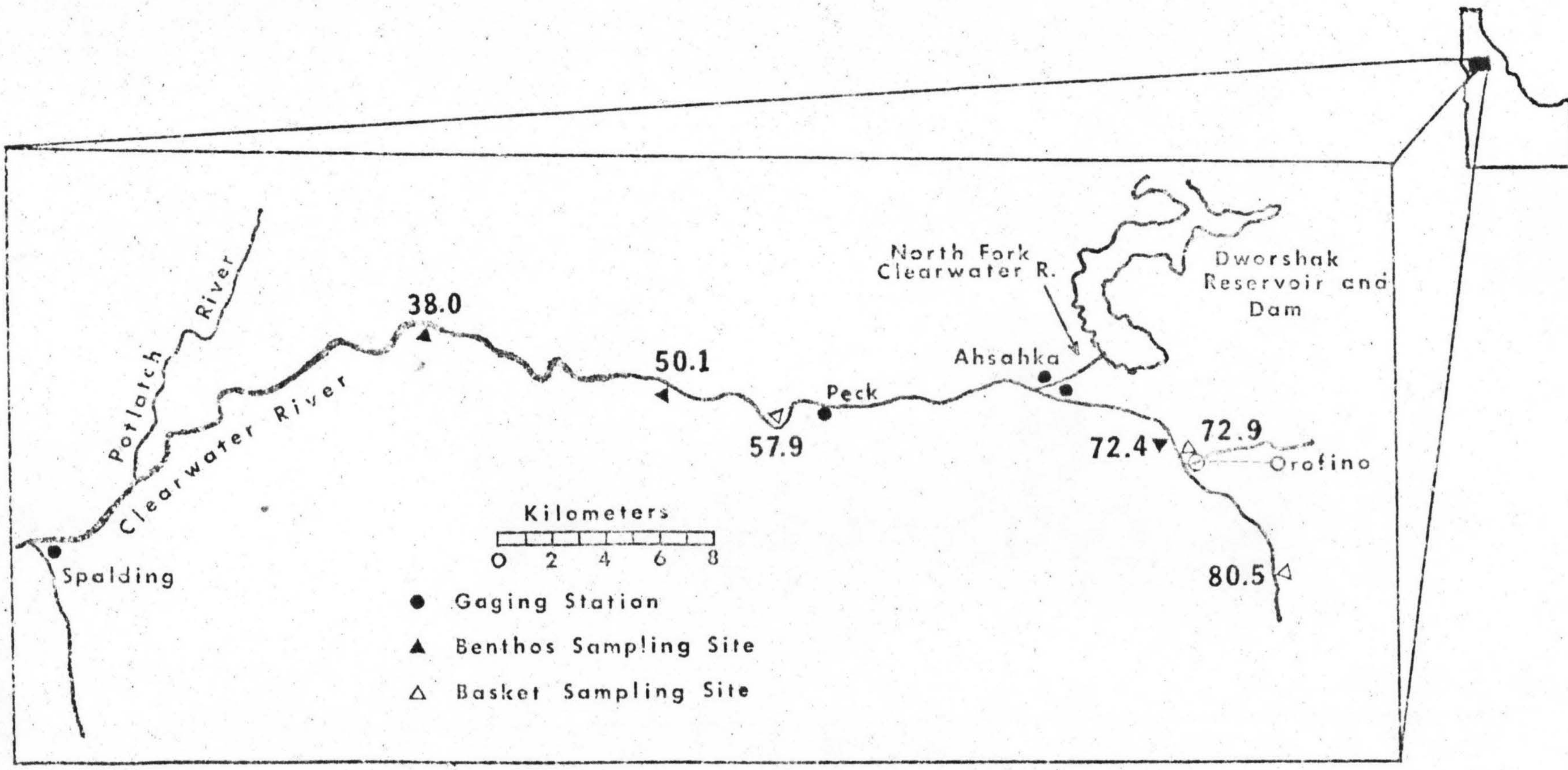

Figure 1. Clearwater River study area including gaging stations and sampling sites. Numbers indicate site location in kilometers upstream from the river's mouth at Lewiston, Idaho.

Within the study area, river width varies from 75 to 200 m (240 to 640 ft); the average width is 120 m (400 ft) (E. Trihey, Idaho Water Resources Research Institute, pers. comm. 1976). Riffles range from 25 to 75 cm (10-30 inches) deep in late summer. Stream gradient averages 1.125 m/km (6 ft/mi) (Walker 1972). Substrate consists mainly of cobble and boulders from 5 to 30 cm (2-12 inches) in diameter, and gravel from 2.5 to 5 cm (1 - 2 inches) in diameter. Siltation is minimal at most study sites.

River flows vary greatly throughout the year. Recorded flows at Peck, a U.S. Geological Survey gaging station at R.K. 60.2, varied from over 100,000 cfs in May to less than 1,000 cfs in October before the construction of Dworshak Dam (USGS 1965-72). Spring flows still exceed the former figure, but fall flows have not gone below 1,000 cfs since the dam went into operation. Runoff generally reflects a bimodal pattern; a noticeable February increase is followed by much higher flows in May as the spring thaw begins in earnest.

Water temperatures at Peck range from $0^{\circ}C$ in winter to $20.5^{\circ}C$ in August, reflecting a reduction of $30^{\circ}C$ in the maximum temperature observed during pre-impoundment conditions (USGS 1975). Temperatures at Orofino exceed $26^{\circ}C$ in August (Ibid.).

MATERIALS AND METHODS

Station Selection and Sampling Schedule

Sampling sites were chosen on the basis of location, access, similarity of habitat, and historical data base. Sites at R.K. 72.4 and above, which were not affected by flows from Dworshak Dam, served as controls. Shoreline Sites I and III (R.K. 72.4 and 38.0, respectively) have been sampled since 1969, thereby providing continuity with pre-impoundment studies. Site II (R.K. 50.1) represented a new location, and was closer to the dam than test sites used by Walker (1972) or Peters (1973).

The three shoreline sites were chosen for their riffle-run type habitat, since this habitat traditionally supports the highest quantity and diversity of aquatic insects (Ruttner 1963; Stalnaker & Arnette 1976) and is therefore most reflective of environmental changes. Banks at Sites I and III have a gentle slope under all but the highest flow conditions, while the steeper bank at Site II prevents full access to the permanent stream bed until flows are much lower. A gentle slope is needed in order to subject the maximum amount of surface area to the effects of rapid flow changes.

Shoreline samples were taken monthly during the summer and fall, and irregularly during the rest of the year, in order to monitor changes in population density and life cycles. From February through June, muddy water and high flows made sampling difficult and often dangerous.

Deepwater benthos was monitored at two sites (IB andHB) during the study; a second control site (IA) was also used during 1975. The increasing siltation of the original control site (IB) by Orofino Creek, which enters the main Clearwater directly above the site, prompted selection of an alternate control site. The Orofino deepwater site was abandoned in 1976.

While not comparable to shoreline samples either qualitatively or quantitatively, deepwater samples provided data from the permanently-watered portion of the stream bed. Shoreline samples, on the other hand, were usually taken on substrate that was dewatered at some time during the year.

Physical and Chemical Parameters

Flow, water temperature, and dissolved oxygen were evaluated in light of their potential effects on aquatic insects below Dworshak Dam, since they are directly affected by its operation. Average daily flows and daily maximum-minimum water temperatures were provided by the Boise, Idaho, office of the U.S. Geological Survey. Average daily flows and monthly oxygen concentrations were provided by the Walla Walla District, U.S. Army Corps of Engineers.

Biological Parameters

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 15, 30, and 45 cm (6, 12, and 18 inches, respectively). Three samples were taken at each depth at each site on each sampling date. 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, a permanent marker was positioned at each site before any samples were taken; a steel stake located near the high-water line served as a permanent reference point. The distance between this point and the water's edge was measured and recorded for each sampling date. This information was then compared with daily stream-flow records, making it possible to determine how long water levels were stable prior to sampling.

In order to randomize the positions of the nine samples taken at the same site on the same date, a steel rod was driven into the substrate at each of the three sampling depths previously described. Three random locations above and/or below each stake were chosen for sampling. The composition of the substrate at each location was recorded. Water velocity at each stake was measured with a Gurley current meter. The distance from the waterline to each of the three stakes was also recorded.

Deepwater Benthos. Deepwater benthos was sampled using 30 cm x 30 cm x 15 cm wire baskets made of 1.3 cm (1/2") hardware cloth reinforced with heavy steel wire. Twenty fist-size rocks from the nearby shore amd stream bed were placed in each basket to serve as substrate for insect colonization. Window screen lined the bottom and lower one-third of each side, thereby keeping insects from washing out of the basket during the recovery operation. The flexible hardware-cloth lid was wired shut before the basket was lowered to the bottom of the river. A styrofoam buoy attached to each basket aided in its relocation and recovery. Buoys were kept submerged in order to minimize both vandalism and interference with boat traffic.

During 1974 and 1975, baskets were placed in 1 and 2 meters of water near the heads of pools or in deep runs where water velocity was moderate. Baskets were also placed at 45 cm deep during 1975 so that shoreline and basket samples from this depth could be compared. A single basket was used at each depth.

Preliminary 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; the latter period was therefore adopted as the standard. This time interval also allowed coordination with shoreline samples, which were taken approximately one month apart.

Baskets were placed and retrieved with the aid of a boat. Placement was made in line with some fixed shoreline object so that baskets could be relocated more easily. A wooden pole tipped with metal hooks was used to retrieve the baskets; baskets were placed in metal tubs for washing. The bottom screening and rock substrate from each basket was then washed thoroughly to remove all insects. Each sample was then filtered through an organdy net and preserved in 70% ethanol. Baskets were then refilled with rocks and put back in the river to start the next colonization period.

Insect Biomass (Gravimetric Analysis). During July and August of 1976, the amount of insect biomass present at shoreline-sites I and III was determined by gravimetric analysis. Four samples were taken at each of three water depths (15, 30, and 45 cm) with the cylindrical bottom sampler used for shoreline sampling. Samples were rough sorted to remove most non-insect material. The only non-insect material included in the sorted samples was Brachycentrus cases (Trichoptera: Brachycentridae), since the plant bits from which these cases are made could provide some energy to higher trophic levels.

Samples were then placed in clean, dry crucibles which had previously been weighed. Dry weights were determined after the samples were dried for 24 hours at 95°C (Fisher & LaVoy 1972; EPA 1973). Samples were then burned at 550°C for approximately one hour (Ibid; C.M. Falter, College of Forestry, University of Idaho, pers. comm. 1976). The remaining ash weight was then subtracted from the dry weight to give ash-free dry weight. Water of hydration, which is present in dried samples but not in ashed ones, could cause an over-estimation of insect biomass if not compensated for (EPA 1973). In order to determine the amount of compensation required for water-of-hydration loss during ignition, one-third of the samples were rewetted and then redried at 95°C after their ash-free dry weights were determined. Weight determinations were made to the nearest 0.0001 grams on a Mettler H15 balance.

Insect Drift. Insect drift was measured in August, 1974, when Dworshak Dam was operating on a load-factoring schedule (daily flow fluctuations for power generation) (Brusven et al. 1976). Nylon nets of 30 cm x 60 cm size, with a pore diameter of 0.8 mm, were used to collect drifting insects. Nets were placed in water depths of 15, 30, and 45 cm at shoreline sites I and III (R.K. 72.4 and 38.0, respectively), and were left in place for one-hour periods beginning at 1200, 1800, 2100, 2400, 0600, and 0900 hours in order to reflect daily drift cycles. Water discharge through each net was calculated, and insect numbers were converted to numbers per m^3 of water through the nets. Nets were repositioned as needed to maintain the proper depth during daily flow fluctuations.

Insect Behavior In Response To Daily Flow Fluctuations. During late August of 1976, insect drift and colonization response to daily flow cycles were measured at shoreline-site III. Shoreline bottom samples were taken at 5, 15, 30, and 45 cm depths at 0900 (low flow) and 2030 hours (high flow); two samples were taken at each depth at each sampling time. Drift samples were taken at 1500 and 2000 hours (dusk) during the daily high-flow period; nets were placed at 30 and 45 cm depths in order to sample both permanently-watered and diurnally-watered substrate. Insect stranding was measured at 1000 hours (low flow) using the wire grid device described by Brusven et al. (1974).

Dam releases ranged from 1000 cfs to 3600 cfs during the test (D. Carpenter, Dworshak Dam powerhouse, pers. comm. 1976). This amounted to a horizontal change of 8.5 m and a vertical change of 15 to 20 cm between daily maximum and minimum flows at Site III.

Laboratory Colonization Response to Algal Development. The majority of immature aquatic insects are primary consumers, feeding on a variety of periphyton and drifting plankton (Hynes 1970). The presence or absence of periphyton could therefore have a significant effect on substrate colonization by these insects. A laboratory experiment was conducted to measure the effects of periphyton development on the colonization behavior of selected species of aquatic insects.

A rectangular plexiglass stream was used for the test (Brusven 1973). The stream bottom was covered with a layer of white sand, and six fist-size rocks were placed in each quadrant. 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 ($\geq$1.0 fps); barren rocks with slow current ($\geq$0.25 fps); algae-covered rocks with strong current; 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 were placed in each quadrant and allowed to move around 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 those individuals recovered within the four quadrants were included in the test results; a test was not considered valid unless at least twenty insects were so recovered.

In-Stream Colonization Response to Algal Development And Colonization Time. In order to test the effects of periphyton development and colonization time on insect colonization under natural conditions, a field simulation experiment was conducted in the Clearwater River. A wide, gently-sloping riffle was used for the test, which was conducted from August 17 to September 16 of 1976.

Two rectangular plots, approximately 2 x 4 m in size, were cleared of debris and small stones. Fifty autoclaved rocks were placed in the "test" plot, and fifty algae-covered rocks from the river were placed in the "control" plot. Rocks were arranged in staggered rows so that each rock would be subjected to similar current flow. Plots were located side by side with their long axis parallel to the current. The test plot was closest to shore. Water depth over the plots varied from 35 to 45 cm at the start of the test, but had decreased to 17 to 27 cm by the end of the test.

Samples were taken on the 3rd, 7th, 14th, 21st, and 30th days of the test. Starting at the downstream end of each plot, ten rocks from each plot were sampled on each sampling day; each rock was treated as a separate sample. An nylon organdy net was placed downstream from a sample rock. Each rock was then scrubbed thoroughly so that all attached insects would collect in the net. Preliminary sampling had indicated that considerable amounts of organic debris collected around the bases of the rocks and that many insects inhabited this debris, so the collecting net was held near the water surface to avoid sampling this debris.

Community Analysis. Insects were primarily identified using keys by Edmundson (1959), Jensen (1966), Jewett (1959), and Usinger (1968). Most taxa were identified to species or morphospecies to facilitate community analysis. Midge larvae (Diptera: Chironomidae) were not identified below the family level due to taxonomic uncertainties within this group.

Species diversity and evenness were calculated using the Shannon-Weaver equation (Margalef 1957; Patten 1962; Pielou 1967; Poole 1974; Wilhm & Dorris 1966). Because of the gross errors which could arise from treating Chironomidae as a single taxon during diversity calculations, diversity and evenness were calculated without this group.

Insect Age-Class Analysis. Insect development patterns were monitored carefully during the study in order to determine whether or not phenological changes have occurred during the post-impoundment period. Insects were classified according to body size or the size of body parts as follows: age 1 (early instars); age 2 (middle instars); age 3 (late instars). Wing-pad development was particularly useful for distinguishing age classes of the hemimetabolous orders (mainly Ephemeroptera and Plecoptera). Age-class analysis was most difficult with the smaller holometabolous species in the orders Diptera and Trichoptera. Pupae were not included in sample counts. Because of the numerous species of Chironomidae present in the Clearwater River and my inability to classify them, age-class analysis was not performed on this group.

RESULTS AND DISCUSSION

Physical and Chemical Parameters

Flow. During normal-water years, annual maximum and minimum flows in the Clearwater River below Orofino have not differed appreciably from pre-impoundment conditions. Although minimum annual flows at Peck appear to have increased since the closure of Dworshak Dam, this has not been the case except during years of extremely-low natural flows (such as 1973); the use of daily average flows instead of daily minimums in USGS flow records accounts for this apparent increase (Figures 2-3). Although flows at Peck dropped below the pre-impoundment September minimum when the North Fork diversion tunnel was closed in September of 1971, a similar flow reduction has not occurred since then.

Figures 4-6 show the extrapolated position (the Om line) of the permanently-watered stream bed based on the lowest average daily flow occurring at each shoreline study site since August 1, 1972. This permanent waterline was 2, 10, and 13 meters lower for Sites I, II, and III, respectively, than the lowest waterline encountered during the study period (August, 1973, to August, 1976). Since no major inflows occur in the study area below the North Fork, Peck flows were used for shoreline-sites II and III (R.K. 50.1 and 38.0, respectively). The relative position of the waterline on sampling days was determined; since samples were usually taken after 1000 hours, these figures reflect daily high flows at Sites II and III resulting from the operation of Dworshak Dam. The position of the 15, 30, and 45 cm test depths in relation to the waterline was measured beginning in August of 1974. Visual examination of the stream bed was

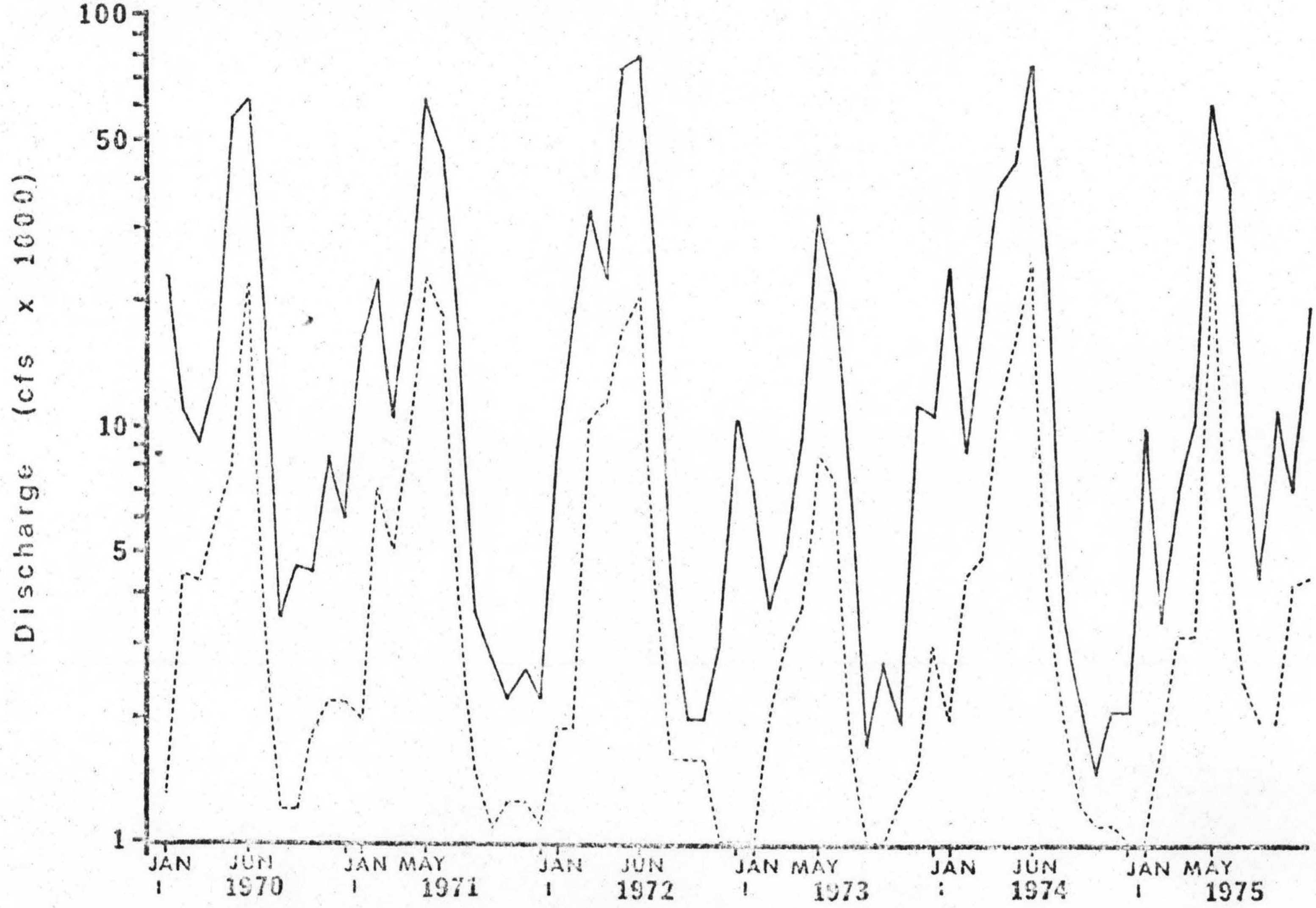

Figure 2. Monthly high and low flows for the Middle Fork of the Clearwater River, 1970-1975, at the Orofino gaging station. Based on average daily flows. USGS data.

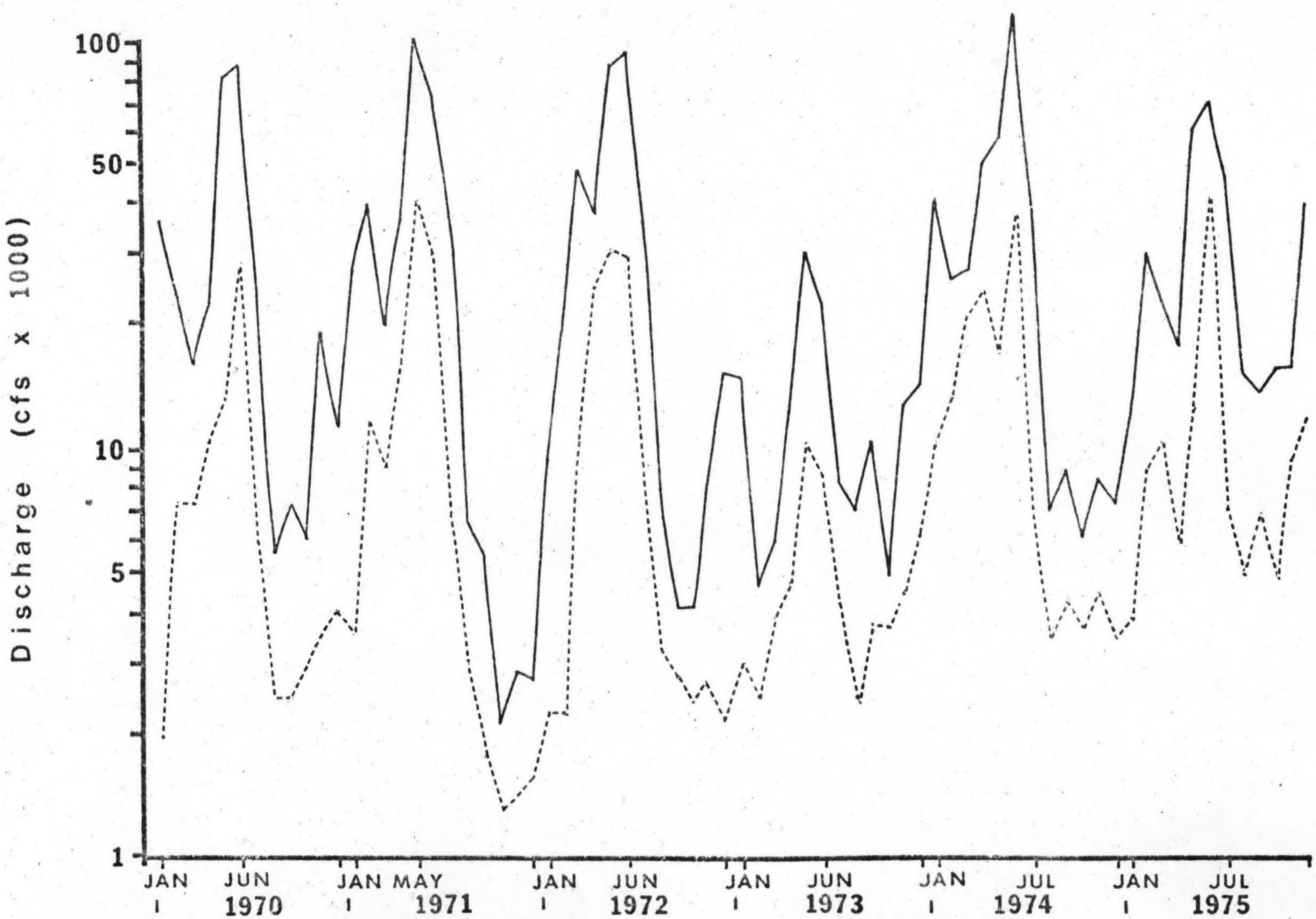

Figure 3. Monthly high and low flows for the main Clearwater River, 1970-1975, at the Peck gaging station based on average daily flows. USGS data.

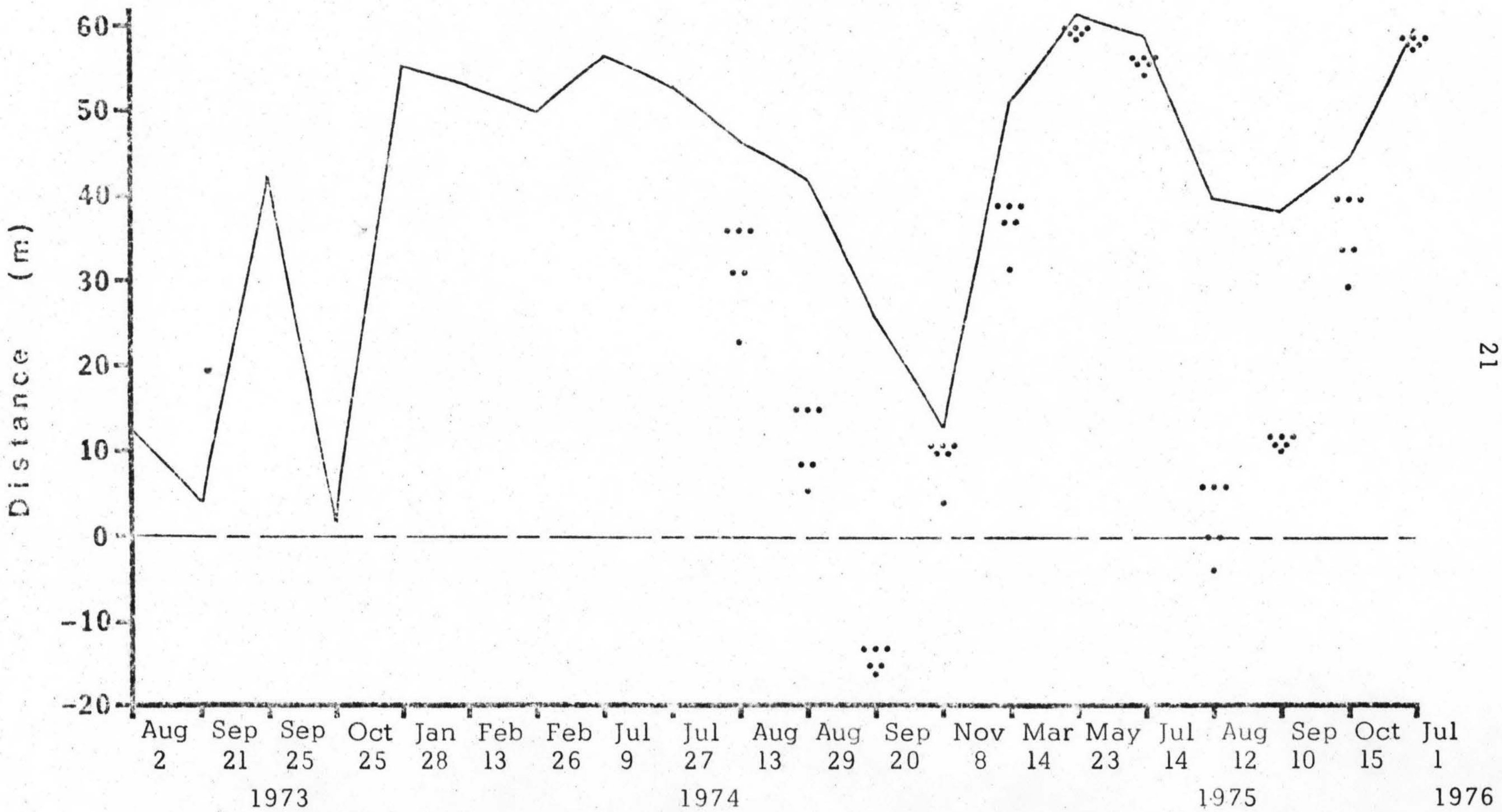

Figure 4. Distance from edge of permanently-watered stream bed (Om) to waterline (solid line) on sampling days, and relative position of sampling depths, at shoreline site I (R.K. 72.4), Clearwater River, 1973-1976. .... = 15 cm depth, .. = 30 cm depth, and . = 45 cm depth.

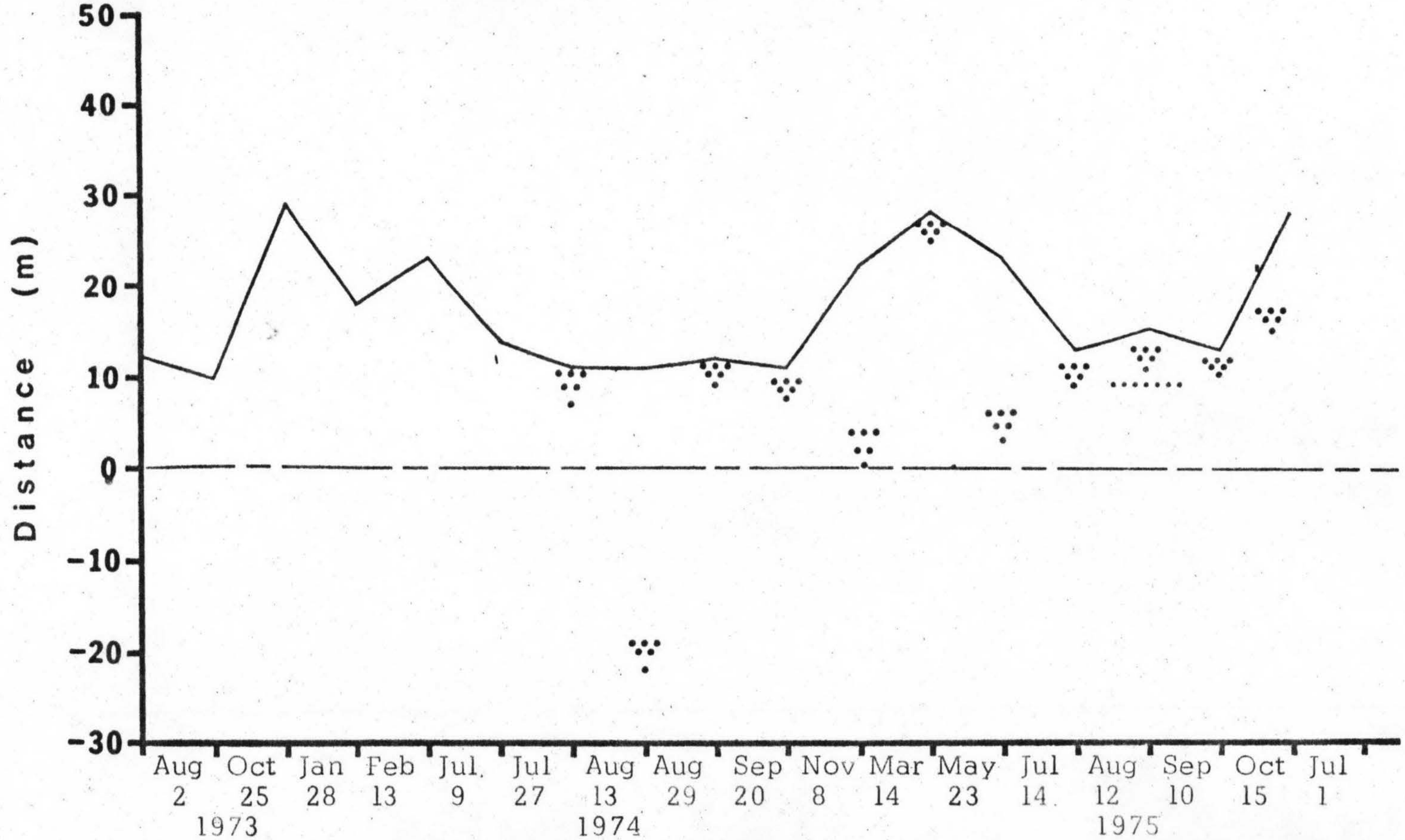

Figure 5. Distance from edge of permanently-watered stream bed (0 m) to waterline (solid line) on sampling days, and relative position of sampling depths, at shoreline site II (R.K. 50.1), Clearwater River, 1973-1976. ...= 15 cm depth, ..= 30 cm depth, and .= 45 cm depth. ......= position of algal line (if known).

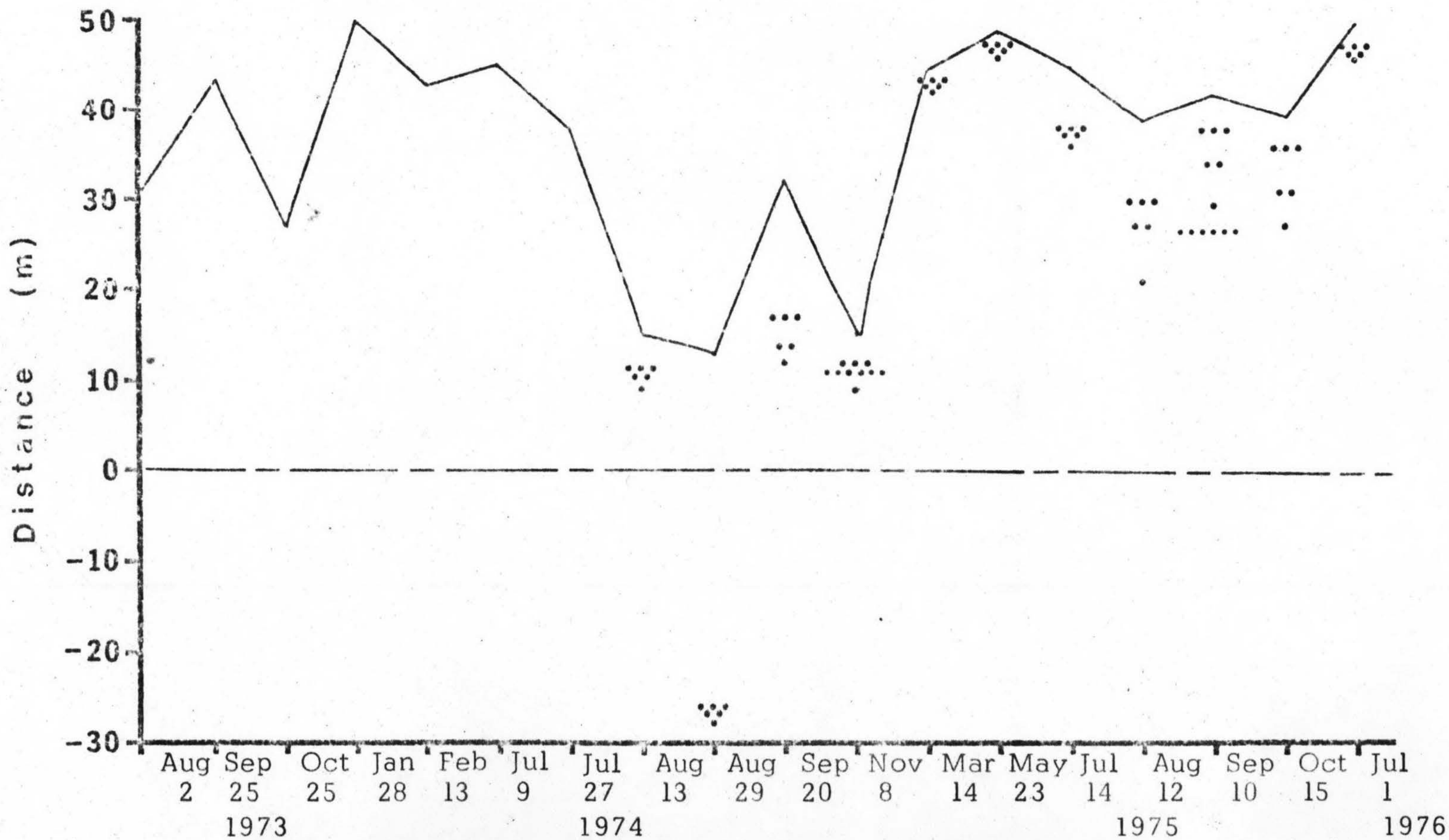

Figure 6. Distance from edge of permanently-watered stream bed (0 m) to waterline (solid line) on sampling days, and relative position of sampling depths, at shoreline Site III (R.K. 38.0), Clearwater River, 1973-1976. ...= 15 cm depth, ..= 30 cm depth, and .= 45 cm depth. ......= position of algal line (if known).

used to determine the position of the algal line at irregular time intervals; no algal growth was noticeable between the algal line and the waterline. Because diurnal flow fluctuations at shoreline-control-site I were normally very small, the algal line and the waterline were nearly equal during the summer and fall months; no separate algal line is shown for Site I (Figure 4). Since the majority of aquatic insects have a one- to three-year life cycle (Hynes 1970), and since the present study began one year after the August, 1972, baseline date, Figures 4-6 are indicative of the water-level conditions which affected insects collected during this study.

Several trends are evident in Figures 4-6. It is evident that almost all shoreline samples were taken well outside the permanently-watered stream channel. The algal line re-establishes itself each summer in relation to the lowest stable position of the waterline; excluding outside influences such as rain, the distance between the algal line and the waterline on any given day indicates the diurnal change in the waterline which occurred during the previous three weeks (refer to section on in-stream colonization response). The extremely-low water levels at Site I in 1973 were caused by a general lack of precipitation during the winter and spring months. Water levels at Sites II and III did not reflect this condition, however. Because of reduced power generation at other Columbia River dams that year, Dworshak Dam increased its flows in order to meet regional power demands. These higher flows were relatively constant on a daily basis, rather than exhibiting the diurnal fluctuations of other years (R. George, U.S. Army Corps of Engineers' River Control Center, Portland, Oregon, pers. comm. 1976).

The actual amount of stream substrate available to aquatic insects on a permanent basis has not decreased due to the operation of Dworshak Dam, but the magnitude of daily flow fluctuations below Orofino has increased considerably except during low-water years like 1973. As has been previously stated, dam outflow cannot fall below 1000 cfs at any time; while this flow is maintained at night during the summer and fall months, daytime flow releases are near 3600 cfs during these months (D. Carpenter, Dworshak Dam powerhouse, pers. comm. 1976). This amount of fluctuation represents a horizontal distance of 8.5 m at shoreline-site III (R.K. 38.0). September fluctuations are of even greater magnitude.

Although the load-factoring schedule presently used by Dworshak Dam causes a daily increase in the amount of stream habitat available to aquatic insects in the Clearwater River, I believe that this habitat is largely unused by these insects. High-water conditions exist mainly during the daylight hours when aquatic insects are generally inactive. By the time the normally-nocturnal insects become active on a given day, the amount of available habitat is decreasing back to daily low-flow levels. Entrapment due to receeding water levels is therefore minimized. Since flow reductions occur during the cooler evening hours, dessication of stranded insects would be less than if flow reductions took place during the day; this is especially important during the summer months, when air temperatures often exceed 35°C during the day.

Insect losses from stranding would be expected to increase as the distance below Dworshak Dam increases. Due to the time required for flows to change downstream, water levels remain high for a longer period of darkness. More insects would move into shoreline areas during the high-water period, thus subjecting themselves to possible entrapment.

By increasing river flows during low-water years, as was done in 1973, Dworshak Dam might be of considerable benefit to aquatic insects during such periods. Since Dworshak flows showed little daily variation during the summer and fall of 1973, the amount of usable stream habitat below Orofino was increased considerably over pre-impoundment conditions that year. The long-term stabilizing effects of the dam could thus outweigh its negative effects as long as present operating procedures are not drastically altered.

Water Temperature. Water temperatures are expressed as monthly highs and lows at Orofino, Ahsahka, and Peck (Figure 7). The Orofino recording station was not established until 1972, while the Peck station has been in operation for many years (USGS 1975).

Water temperatures in the North Fork at Ahsahka have decreased by 5^{o} - $11^{o}C$ during August and September, and increased by 1^{o} - $3^{o}C$ during December through February, compared to pre-impoundment conditions (Figure 7). These changes have resulted in a decrease of 2^{o} - $3^{o}C$ in summer temperatures and an increase of 1^{o} - $3^{o}C$ in winter temperatures at Peck. The moderating effects of the Middle Fork of the Clearwater are obviously greatest during the summer. The abnormally-high temperature recorded at Orofino in 1974 was probably an erroneous reading caused by partial or complete dewatering of the probe (Brusven et al. 1976).

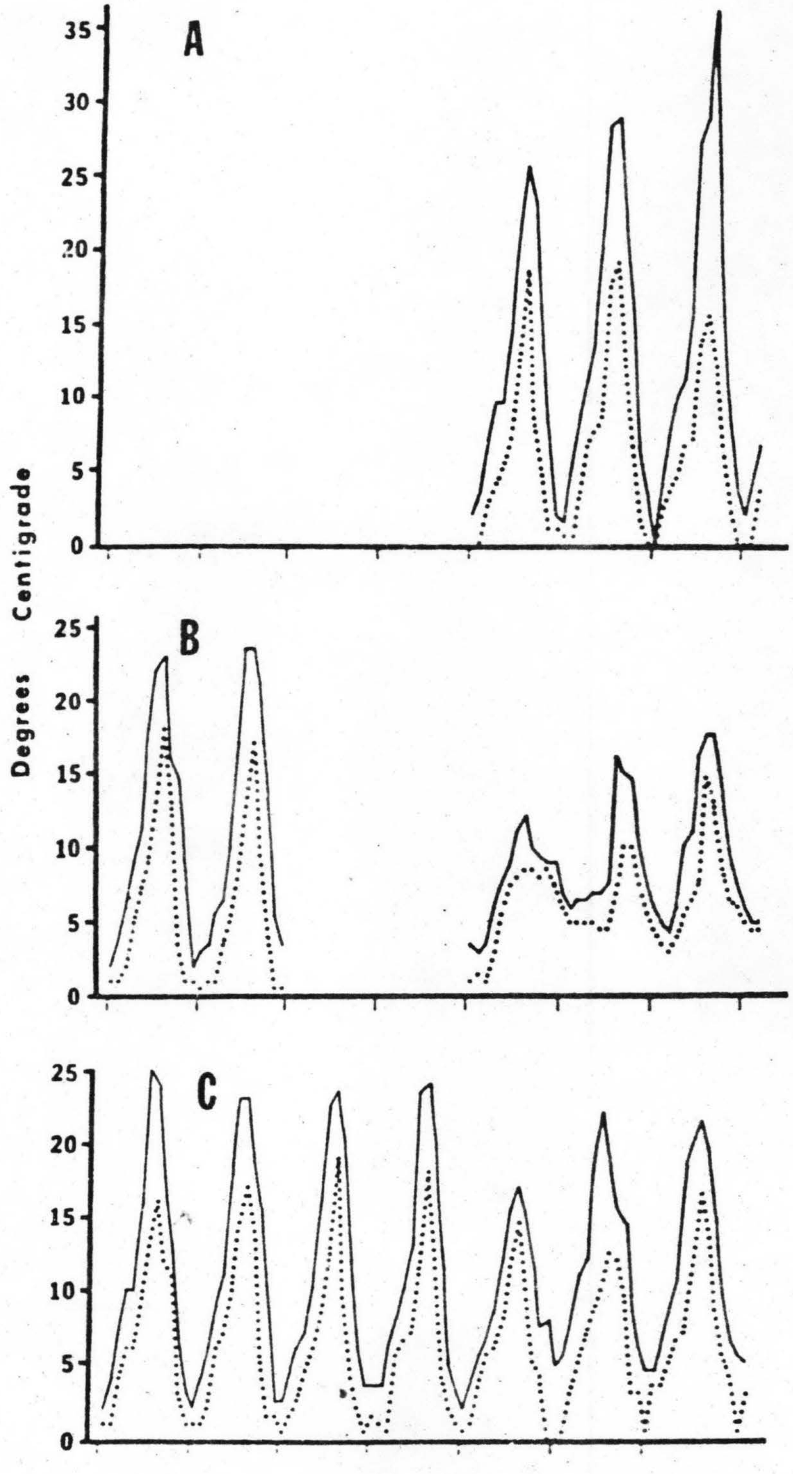

Figure 7. Monthly high and low water temperatures (°C) at: (A) Middle Fork Clearwater River at Orofino, (B) North Fork Clearwater River at Ahsahka, (C) main Clearwater River at Peck gaging station. USGS data.

Water Chemistry. Oxygen concentrations in the main Clearwater River remained well above the 6 parts per million recommended as a minimum for most aquatic life (Idaho Dept. of Environ. &Community Services 1973) (Table 1), and were similar to those reported by Peters (1973). Any changes in the aquatic-insect communities below Dworshak Dam are probably due to factors other than dissolved oxygen, since this parameter has not changed significantly from pre-impoundment conditions.

Other aspects of water chemistry, such as nitrate and phosphate concentrations, were not measured. A detailed study of Dworshak Reservoir by Falter (1976) indicated that changes in ion concentrations in the reservoir outflow probably did not occur during my study.

Biological Parameters

Benthic Insect Community. The distribution and relative abundance of aquatic insects at intensive study sites are presented in Appendix A. Taxa are ranked according to relative abundance using a base-ten logarithmic scale; each rank is ten times the minimum number of insects needed to enter the next lower rank. Although shoreline and basket samples are not comparable either numerically or taxonomically (Mason et al. 1973; Wene & Wickliff 1940), data from both sampling methods is presented together for convenience.

In order to provide a better understanding of community trends, insect densities are tabulated by date, order, and sampling depth for all sites (Tables 2-5). High water velocity made it unsafe to sample the 45 cm depth at Site II in August of 1973 and July of 1975, causing the loss of 45 cm data on these occasions (Tables 2-3).

Table 1. Dissolved oxygen (mg/l) from the Clearwater River, May 1974 to December 1975. (Data from Walla Walla District, U.S. Army Corps of Engineers).

Site: Date	Main Clearwater R. at Orofino (RK 67.6)	North Fork at Ahsahka (RK 0.5)	Main Clearwater R. at Peck (RK 60.2)
V-7-74	13.9	11.7	11.7
VI-12-74	10.3	10.8	10.9
VII-9-74	13.4	9.9	10.8
VIII-6-74	10.0	9.4	9.6
IX-5-74	10.1	9.5	9.5
X-11-74	11.1	10.3	11.0
XI-22-74	11.9	10.4	11.0
XII-18-74	12.1	10.9	11.7
I-75	No Data	No Data	No Data
II-13-75	13.5	9.6	11.0
III-26-75	13.0	11.9	12.4
IV-16-75	13.3	9.3	11.4
V-20-75	11.6	10.0	11.4
VI-19-75	10.9	10.5	10.7
VII-20-75	8.6	11.1	9.2
VIII-21-75	8.7	10.1	9.4
IX-75	No Data	No Data	No Data
X-3-75	10.2	10.2	9.8
XI-13-75	13.2	10.9	12.4
XII-11-75	11.5	9.5	11.2

Table 2. Insect density (number/m^2) at Shoreline study sites on the Clearwater River, 1973-76. Numbers over 100 rounded to nearest 10. ND = no data.

Location	Depth	Aug 2 73	Oct 25 73	Jan 28 74	Feb 13 74	Jul 9 74	Jul 27 74	Aug 13 74	Aug 29 74	Sep 20 74	Nov 8 74	Mar 14 75	May 23 75	Jul 14 75	Aug 12 75	Sep 10 75	Oct 15 75	Jul 1 76	Average
Site I (R.K. 72.4)	15 cm	5290	3050	100	690	270	220	1880	630	1860	1080	75	1980	330	1170	1170	240	210	1191
	30 cm	3880	4240	200	1180	150	220	1640	2030	1880	1610	82	1590	630	1200	1470	1740	330	1416
	45 cm	4860	5200	480	1220	250	110	2840	3580	1640	2920	79	1050	2490	1680	1260	900	930	1852
	Average	4680	4160	260	1030	220	180	2120	2080	1790	1870	79	1530	1150	1350	1300	960	490	1486
Site II (R.K. 50.1)	15 cm	3130	1660	7	480	690	970	1560	470	43	1210	110	3390	250	1580	11	7	50	861
	30 cm	2010	3180	39	510	900	1350	1020	1830	82	2160	200	1280	1110	1210	21	82	46	1002
	45 cm	ND	6750	36	1660	1710	1260	2270	1000	290	1120	240	1890	ND	1790	79	880	43	1401
	Average	2570	3860	27	880	1100	1190	1620	1100	138	1500	180	2190	680	1530	37	323	46	1076
Site III (R.K. 38.0)	15 cm	6060	2370	28	250	200	330	1490	1290	3	870	11	550	600	560		14	32	862
	30 cm	4890	3490	18	510	250	300	2030	1490	7	1760	36	1340	660	430	7	61	21	1018
	45 cm	5470	3850	25	390	440	220	1680	2330	25	2080	32	1120	1840	470	100	150	54	1193
	Average	5650	3240	24	380	300	280	1730	1700	12	1570	26	1000	1040	490	36	75	36	1024

Table 3. Insect density (number/m^2) at shoreline study sites on the Clearwater River, 1973-76. Numbers over 100 rounded to nearest 10.

Order	Site	Aug 2 73	Oct 25 73	Jan 28 74	Feb 13 74	Jul 9 74	Jul 27 74	Aug 13 74	Aug 29 74	Sep 20 74	Nov 8 74	Mar 14 75	May 23 75	Jul 14 75	Aug 12 75	Sep 10 75	Oct 15 75	Jul 1 76	Average
Ephemeroptera	I	370	210	60	190	110	100	630	480	550	740	45	1380	360	210	430	330	340	384
	II	590	600	14	270	320	270	390	250	57	800	150	1250	340	340	6	180		342
	III	360	1230	14	130	120	140	350	280	1	570	8	700	570	86	2	24	2	270
Plecoptera	I	110	36	2	26	2	8	58	33	42	50	1	42	15	37	33	15	7	30
	II	150	45	2	23	31	9	32	28	5	67	5	33	54	25		3		30
	III	58	76	2	3	2	2	8	19		55	1	9	6	20		2		15
Trichoptera	I	3340	2480	100	380	14	9	1170	1460	1030	870	5	7	460	700	650	490	15	775
	II	680	2430	2	100	520	130	750	640	12	240	1	61	72	330	5	45	3	354
	III	3200	1470	3	170	100	8	970	1210		680		36	240	210	1	11	7	489
Diptera	I	680	1230	93	430	63	58	190	76	140	150	27	85	280	290	89	98	81	239
	II	850	620	8	480	140	760	350	120	51	280	31	750	180	770	25	75	25	324
	III	1970	410	3	76	49	130	320	140	8	260	17	240	200	150	31	34	18	239
Coleoptera	I	150	89	3	8	30	9	63	27	20	50		21	31	20	19	11	37	33
	II	310	140		7	54	30	92	70	15	100	2	94	20	81	1	17	18	62
	III	62	23		3	13	1	28	6	2	1		18	23	40	2	1	8	14
Lepidoptera	I	14	120							8	6					11	12		10
	II		36					3			9				3		1		3
	III	1									1						1		1
Odonata	I	8	1		1		1			1	2					2			1
	II		1			2	i	3							1				1
	III					1					1								1

Table 4. Insect density (number/basket) at deepwater (basket) sites, Clearwater River, 1974-75. Average densities 1 and 2 m depths. ND = No data.

Location	Depth	Aug 28 74	Sep 30 74	Dec 23 74	Feb 11 75	Sep 17 75	Oct 29 75	Nov 17 75	Avg.
Site IA (R.K. 80.5)	45 cm	ND	ND	ND	ND	4456	ND	ND	
	1 m	ND	ND	ND	ND	7520	2890	ND	5207
	2 m	ND	ND	ND	ND	5152	2363	ND	3758
	Average					6336	2629		4482
Site IB (R.K. 72.9)	45 cm	ND	ND	ND	ND	904	ND	824	
	1 m	9752	2304	823	688	1928	ND	1280	2767
	2 m	3384	592	512	1056	2808	ND	2136	1640
	Average	6568	1448	668	872	2368		1708	2204
Site HB (R.K. 57.9)	45 cm	ND	ND	ND	1000	3856	380	ND	
	1 m	14207	5984	3944	1232	5107	2600	ND	5512
	2 m	5536	9520	2265	1784	7680	1272	ND	4676
	Average	9872	7752	3105	1508	6394	1936		5094

Table 5. Insect density (number/basket) by order at deepwater (basket) sites on the Clearwater River, 1974-75. Average density of 1 m and 2 m depths. ND = No data.

Order	Site	Aug 28 74	Sep 30 74	Dec 23 74	Feb 11 74	Sep 17 74	Oct 29 74	Nov 17 74	Avg/Site
Ephemeroptera	IA	ND	ND	ND	ND	1661	842		1252
	IB	2121	220	208	136	404	ND	528	603
	HB	2425	860	914	404	1136	750		1082
Plecoptera	IA	ND	ND	ND	ND	123	156		140
	IB	43	10	16	28	52	ND	43	32
	HB	28	92	28	8	20	64		40
Trichoptera	IA	ND	ND	ND	ND	4291	1206		2749
	IB	2901	234	11	476	1657	ND	1056	1056
	HB	3827	1200	49	608	4140	306		1688
Diptera	IA	ND	ND	ND	ND	264	424		344
	IB	2127	983	434	232	252	ND	76	684
	HB	3598	5599	2114	488	1092	814		2284
Coleoptera	IA	ND	ND	ND	ND		2		1
	IB	2	2			4	ND	4	2
	HB		4	1		4			2
Lepidoptera	IA	ND	ND	ND	ND				
	IB						ND		
	HB					4	2		1

Unless otherwise specified, abundance ratings and numerical tables for shoreline samples are based on the number of insects per square meter. Due to the three-dimensional nature of basket samplers, basket data was not so converted; the same abundance scale applies to both shoreline and basket samples, however.

It is significant to note that shoreline-site I (R.K. 72.4), which was not affected by daily flow fluctuations from Dworshak Dam, exhibited a noticeable increase in insect density with increasing depth (Table 2). This phenomenon could not be explained on the basis of habitat stability alone, and was probably due to insect food requirements, factors related to current velocity, and decreased light penetration (most aquatic insects are negatively phototactic) (Hynes 1970). In the case of Diptera and Trichoptera, avoidance of very-shallow areas by late-instar larvae may be a pre-adaptive mechanism to avoid dessication during pupation (Smith 1964; Walker 1972).

Insect density was much greater at all shoreline sites in 1973 than in years since then (Table 2). This could be expected at Site I, since extremely-low natural flows that year allowed samples to be taken on a part of the stream bed that was undisturbed for a long period; that part of the river was not available for sampling during subsequent years, which could cause an apparent decline in density even though none actually occurred. But the decline over time occurred at all sampling sites, including basket sites. I believe that 1973 was an unusually-favorable year for insect survival. Unusually-low flows, especially during spring runoff, probably decreased insect mortality from stream-bed scour and forced insect drift. Reduced mortality, combined with stable, above-normal flows below the North Fork in 1973, could cause a large number of insect progeny to be produced for 1974. But Clearwater flows were extremely high and fast in 1974, with spring runoff lasting several weeks longer than normal. It is likely that insect mortality was also above normal during this period; increased runoff mortality, plus a return to pre-impoundment summer habitat levels, would cause fewer insects to be available during the 1974 sampling period, and would cause fewer insects to be produced for 1975 (assuming no density-dependent increase in fecundity). The normal flow conditions of 1975 (USGS 1965-75) probably did not allow insect density in the study area to return to 1973 levels.

The number of insect species present at shoreline sites varied with both time and location, being lowest at all sites in 1973 (Table 6). An increase in 1974 at Sites I and II was followed by a decline in 1975. Species counts also increased at Site III in 1974, although to a lesser degree than at the other sites, but did not decline in 1975. The larger number of species collected in 1974 and 1975 probably reflect the larger number of sampling dates in those years (7-8) as compared to 1973 (2). Such species as *Ephemerella flavilinea*, *E. tibialis*, and Empididae (sp.) were only collected in years after 1973, as were many other rare or sparse species (Appendix A).

Table 6. Total and average number of species present at intensive study sites on the Clearwater River, 1973-75. Numbers exclude Chironomidae (Diptera).

Location	Year: 1973	1974	1975	Average
Shore Site I (R.K. 72.4)	54	69	65	63
Shore Site II (R.K. 50.1)	52	73	65	63
Shore Site III (R.K. 38.0)	44	53	54	50
Ave.	50	65	61	
Basket Site IA (R.K. 80.5)			36	36
Basket Site IB (R.K. 72.9)		39	42	41
Basket Site HB (R.K. 57.9)		36	32	34
Ave.		38	37	

Table 7 shows the ordinal composition of the insect communities at all sampling sites. While there was little variation among shoreline sites for Ephemeroptera, Trichoptera was less important at Site II (R.K. 50.1) than at Sites I and III (R.K. 72.4 and 38.0, respectively). Brachycentrus sp. was less dense in 1975 at Site II, which reduced the average density of Trichoptera and therefore its relative importance at Site II. Diptera (mainly Chironomidae) was densest at Site II, which accounted for part of the apparent decrease in Trichoptera at the site.

Insect biomass at Sites I and III in July and August of 1976 is shown in Table 8. During July, large maximum weights usually resulted from the

Table 7. Ordinal composition (average %) of aquatic-insect communities at intensive study sites, Clearwater River, 1973-76 (1974-75 for basket sites). River kilometer in parenthesis.

Order	Shoreline Sites			Basket Sites		
	I (72.4)	II (50.1)	III (38.0)	IA (80.5)	IB (72.9)	HB (57.9)
Ephemeroptera	26.6	30.1	26.3	27.9	25.4	21.2
Plecoptera	2.1	2.7	1.5	3.1	1.3	0.8
Trichoptera	53.7	31.2	47.6	61.3	44.4	33.1
Diptera	16.6	29.1	23.2	7.7	28.8	44.8
Coleoptera	2.3	5.5	1.3	0.1	0.1	0.1
Odonata	0.1	0.1	0.1	0	0	0
Lepidoptera	0.7	0.3	0.1	0	0	0.1

Table 8. Insect biomass (ash-free dry weight; kg/hectare & lbs/acre) at two shoreline study sites, Clearwater River, VII-22-76 and VIII-22-76. Lbs/acre in parenthesis. N = 4.

		Shore Site I (R.K. 72.4)			Shore Site III (R.K. 38.0)		
Date		15 cm	30 cm	45 cm	15 cm	30 cm	45 cm
VII-22-76	Max	2.045 (11.117)	1.086 (5.904)	2.840 (15.439)	0.028 (0.153)	0.060 (0.326)	1.562 (8.490)
	Min	0.331 (1.799)	0.351 (1.908)	0.337 (1.832)	0.018 (0.096)	0.023 (0.125)	0.129 (0.700)
	Ave	0.935 (5.083)	0.591 (3.213)	1.582 (8.60)	0.023 (o.127)	0.042 (0.230)	0.863 (4.689)
VIII-23-76	Max	2.657 (14.443)	1.513 (8.223)	2.960 (16.091)	0.522 (2.837)	0.410 (2.204)	2.241 (12.182)
	Min.	0.776 (4.217)	0.235 (1.275)	1.135 (6.172)	0.064 (0.345)	0.229 (1.246)	0.790 (4.294)
	Ave	1.758 (9.558)	0.801 (4.354)	2.310 (12.560)	0.202 (1.10)	0.353 (1.917)	1.465 (7.964)

presence of a single large stonefly numph, <u>Claassenia</u> <u>sabulosa</u> (Banks), in one or more of the samples from a given site and depth. Fewer August samples contained these numphs, with larger numbers of a variety of species being present. Taking this sample difference into account, Site I had approximately twice as much insect biomass in August as did Site III. Depth had little effect on biomass at Site I in August, as evidenced by the wide overlap of sample ranges for the three sampling depths. Biomass was similar at the 15 and 30 cm depths in August at Site III, but much greater at 45 cm; the magnitude of this increase was much greater than was expected according to density data (Table 2), and was probably due to flow conditions prior to sampling rather than to "average" conditions at the site.

Diversity and evenness, which are two commonly-used indices of community structure, provide a better understanding than straight numerical analysis on how aquatic-insect communities vary under a variety of post-impoundment conditions (Appendices B & C). In general, Shannon-Weaver diversity values from 2.5 to 3.5 indicate a healthy, well-balanced community (Patten 1962; Wilhm & Dorris 1966). Values less than 2.5 indicate decreasing habitat quality due to siltation, organic pollution, or some other factor, while values greater than 3.5 indicate increasingly sterile conditions where many species are present but few are abundant (Ibid.). An evenness of 0.5 or greater indicates an increasing evenness in species abundance, while values below 0.5 indicate increasing domination of the insect community by a few very-abundant species.

Diversity and evenness were affected by both site and depth at the shoreline sites. Nearly three-fourths of the samples taken at Site I were within the optimum 2.5 - 3.5 diversity range. This decreased to one-third at Site II and one-half at Site III. Samples outside the optimum range were usually below it. But 1/4 of the samples were above the optimum diversity range at Site II, and I am unable to explain this on the basis of community density. All sampling depths at Sites II and III experienced a similar number of low diversity values; these low values usually occurred when samples contained very few insects, or were dominated by Brachycentrus sp. or Chironomidae. While most low evenness values occurred at the 15 and 30 cm depths at Site II, all depths at Site III experienced these low values. As with low diversity values, low evenness values occurred when samples contained very few insects, or when one or a few species such as Brachycentrus sp. was very numerous. Diversity and evenness were quite similar at Sites I and III when samples were taken on permanently-watered stream bed; Site II had even fewer low values than Sites I and III, suggesting that increasing shoreline slope discourages the buildup of dense populations of particular species.

Table 9 shows the seasonal occurrence of selected insect species at shoreline sampling sites. Of these species, only Rithrogena hageni Eaton appeared to experience phenological changes due to the influence of Dworshak Dam; age-3 numphs persisted for a longer period of time at Site III. But this did not occur at Site II or at the Harper's Bend basket site, making it doubtful that the dam affected the phenology of any of the species listed. Since these were among the most-common species collected during the study, it is unlikely that Dworshak Dam has had any

Table 9. Seasonal occurrence of immature aquatic insects at shoreline sampling sites, Clearwater River, 1973-76. Solid line (——) = known periods of occurrence. Dashed line (---) = extrapolated occurrence. * = month(s) when largest numbers were collected. X = age-class 3 immatures present. No samples taken in April, June, and December.

Taxa	Site	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Ephemeroptera													
Ephemerella margarita Needham	All		X*	X									
Paralepto-phlebia heteronea (McDunnough)	All			*	*								
Rithrogena hageni Eaton	I	X		*					X				
	II	X			*	*				X			
	III				*	X			X			X	
Trichoptera													
Brachycentrus sp.	All		*	X	X				X				
Cheumatopsyche sp.	All		X	X*	X*			X					
Glossosoma sp.	All		X*	X	*								
Hydropsyche sp. A	All		*	*									
sp. B	All		*	X									
Hydroptila sp.	I			*	*	?	?	?					
	II& III		*		*	?	?	?					
Lepidostoma sp. A	All	X		*	*				X			X	

significant effect on river benthos through changes in water temperatures below the North Fork.

Location had a considerable effect on deepwater benthos. The two original basket sites (IB and Harper's Bend; R.K. 72.9 and 57.9 , respectively) were not comparable in insect density (Table 4). If shoreline trends were also reflected in basket samples, Harper's Bend would have had fewer insects than the Orofino sites; just the opposite was true, however. I believe that this reflected the atypical habitat present at the Orofino basket site, which was located directly below the mouth of Orofino Creek. Logging and agricultural activities have caused Orofino Creek to carry a heavy silt load for many years. It is likely that the high runoff of 1974 removed accumulated silt from the Orofino basket site, causing a temporary increase in habitat quality at the site. Siltation from the creek was fairly light in 1974, but was so heavy in 1975 that the site was finally abandoned. I believe that siltation accounted for most of the decrease in insect density that occurred at the Orofino basket site in 1975, while runoff-caused mortality was responsible for the decrease in density at Harper's Bend (Table 4). The largest amount of silt accumulated at the 1 m depth at Orofino; while insect density was always greatest at the 1 m depth in 1974, density was greatest at 2 m in 1975, indicating a movement of insects away from the zone of siltation (Table 4). This movement was particularly noticeable for the caddisfly Cheumatopsyche sp. and the dipteran Chironomidae. There was no consistent relationship between depth and insect density at Harper's Bend. Density was greatest at 1 m at the alternate control site above Orofino (R.K. 80.5).

Conclusions based on depth were complicated by the very-large number of insects which occurred in the August, 1974, 1 m basket samples (Table 4). Average density was similar for both the 1 and 2 m depths at Orofino and Harper's Bend without the August, 1974 samples. Including these samples caused the overall average density to be greatest at 1 m depths at both sites. Chironomidae was the most-abundant taxon in the August samples, followed by Hydropsyche sp., the Ephemerella inermis-infrequens complex, and Cheumatopsyche sp. The overall conclusion is that thriving, healthy insect communities exist to depths of at least 2 m in the Clearwater River; these deeper areas may support even more insects than do shoreline riffles, which contradicts the findings of Needham (1934) and Pate (1931, 1932). This, plus the high density of insects found at Harper's Bend, supports the idea that the reduction in density that occurred at the shoreline test sites was confined to those areas subjected to daily flow fluctuations (Tables 2, 4).

Trend comparisons of 45 cm shoreline and basket samples at Site II (R.K. 50.1) and Harper's Bend (R.K. 57.9) showed that basket samples had from 4.6 to 500 times as many insects in 1975 as did shoreline samples when both sample types were compared on the basis of equal sampling areas (Tables 2 & 4). This broad range of differences was probably due to the variable effects of fluctuating flows, since both sites are under the influence of Dworshak Dam. The continued greater colonization of basket samplers supports the idea that baskets offer a superior habitat for insect colonization to some species; by rising above the natural substrate, baskets serve as a collection point for drifting insects & organic detritus, and provide a place of attachment for filter-feeding organisms such as the caddisfly Brachycentrus sp. Basket cobbles are completely unimbedded, allowing maximum utilization of their surface area.

The ordinal composition of deepwater insect communities varied mainly in the percentage of Diptera and Trichoptera present (Table 7). Among the Trichoptera, Hydropsyche sp., Cheumatopsyche sp., and Brachycentrus sp. were the most-common species at all basket sites; ordinal differences by site for this order were due mainly to density differences for these species (Appendix A). The filter-feeding caddisflies should have been more common below Dworshak Reservoir, but were actually less prevalent below it. Part of the apparent decrease in Trichoptera was due to a large increase in Diptera (mainly Chironomidae) at Harper's Bend (Table 5). Chironomidae also increased at Site II, adding to an apparent decrease in Trichoptera there. The only ordinal change that might be expected on the basis of observed site differences was the decrease in Diptera at Orofino. Edwards et al. (1974) found that some species of Chironomidae required free-flowing, unsilted conditions in order to reach maximum abundance, and that few species were common in transition zones where habitat conditions were unstable; conditions at the Orofino site were not stable during the 1974-1975 sampling period.

Diversity and evenness at the three basket sites did not show a high degree of correlation with community density (Appendix C). Although density was similar at the alternate control site (R.K. 80.5) and at Harper's

Bend (R.K. 57.9) in 1975, diversity and evenness were usually lower at Harper's Bend. This was due to the larger numbers of *Brachycentrus* sp., *Cheumatopsyche* sp., *Hydropsyche* sp. A, and the *Ephemerella inermis-infrequens* complex present at Harper's Bend (Appendix A). Diversity decreased over time at the two lower basket sites; evenness also decreased at both sites, but remained fairly high throughout the study period.

Insect Colonization Response To Algal Development and Colonization Time. Laboratory attempts to quantify the effects of algal growth on insect colonization behavior revealed that, of the four species or species complexes tested, two occurred most often on algae-covered rocks (Table 10). *Ephemerella grandis* Eaton is a grazing mayfly, while the caddisflies *Dicosmoecus* sp. and *Psychoglypha* sp. are detritivores (Hynes 1970). Because of apparent niche similarities, these two caddisflies were combined for the test; both species were collected from identical natural habitats. At least under test conditions, these species distributed themselves according to food availability.

Like most stonefiles, *Pteronarcys californica* Newport requires large amounts of oxygen and/or rapid current velocity in order to survive (Ibid.). 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, feeding on whatever was available (including *Gomphonema* sp.); this large stonefly was observed grazing on *Gomphonema* sp. when this alga was present on the test rocks. The large

Table 10. Colonization response (% recovered/habitat) of selected insect species to two levels of current speed (fast or slow) 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										
<u>Ephemerella</u>	2	Max	32.5	47.5	18.5	14.8	80.0	33.3	48.1	52.5
<u>grandis</u>		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										
<u>Pteronarcys</u>	6	Max	41.4	37.9	63.6	21.9	79.3	75.0	93.5	37.9
<u>californica</u>		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										
<u>Brachycentrus</u>	5	Max	63.3	16.7	82.0	9.8	80.0	87.1	92.2	23.4
sp.		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
<u>Dicosmoecus</u> sp.	6	Max	45.5	50.0	31.8	17.2	95.5	45.4	68.2	58.6
<u>Psychoglypha</u>		Min	24.1	18.2	0.0	3.6	54.6	4.5	41.3	31.8
sp		Ave	36.6	33.0	17.6	11.2	71.2	28.7	54.2	45.8

variation in test results was due to the presence or absence of this alga, since *P. californica* seldom left areas of maximum current unless *Gomphonema* sp. was present.

The caddisfly *Brachycentrus* sp., which feeds by filtering drifting plankton from the water (Hynes 1970), was most common where current velocity was highest; this would be expected because of its feeding habits. Under natural conditions, this species would probably avoid low-velocity shoreline areas.

Although only a few species of insects were used in the laboratory test, the test does show the importance of food in the distribution of immature aquatic insects in other-wise suitable habitat.

The results of algal development and time of insect colonization, involving whole insect communities, are given in Tables 11-12 and Figure 8. Although this test was scheduled to run for four weeks, low natural flows on the 27th day caused at least partial dewatering of the test plot. High flows from Dworshak Dam on the 28th day made it impossible to collect the final set of samples until two days later. Because these flow changes invalidated the last set of samples, test results are shown for only the first 21 days. Colonization for non-sampling days was estimated from regression analysis (Table 11), which determined the following relationships:

Plot A (control) $Y = -3.70 + 13.589 \text{ Day} - 1.241 \text{ Day}^2 + 0.0405 \text{ Day}^3$;

Plot C (test) $Y = -1.36 + 4.557 \text{ Day} - 0.6066 \text{ Day}^2 + 0.0274 \text{ Day}^3$.

These formulae accounted for 88% of the variation in the control plot and 96% of the variation in the test plot. The coefficient of variation was 32% and 31%, respectively.

Table 11. Insect colonization behavior (insects/cobble-sized rock) in response to colonization time and algal development in the lower Clearwater River, VIII-17-76 to IX-16-76. Based on samples taken after 3, 7, 14, and 21 days. Numbers in parenthesis estimated from regression. * = significant difference between plots for the same day. ** = significant difference within the same plot. $P \leq 0.05$. Significance not applied to regression data.

		Colonization Period (Days)						
Rock Condition	Count	3*	7*	14*	18	21	25	30
Clean (Plot C)	Max	14	19	39	(50)	131	(171)	(353)
	Min	3	3	9	(38)	48	(152)	(305)
	Ave	8	10	19	(44)	**81	(161)	(329)
Algae-Covered (Plot A)	Max	42	70	86	(86)	184	(211)	(424)
	Min	20	26	18	(64)	64	(175)	(335)
	Ave	27	46	51	(75)	**109	(193)	(380)

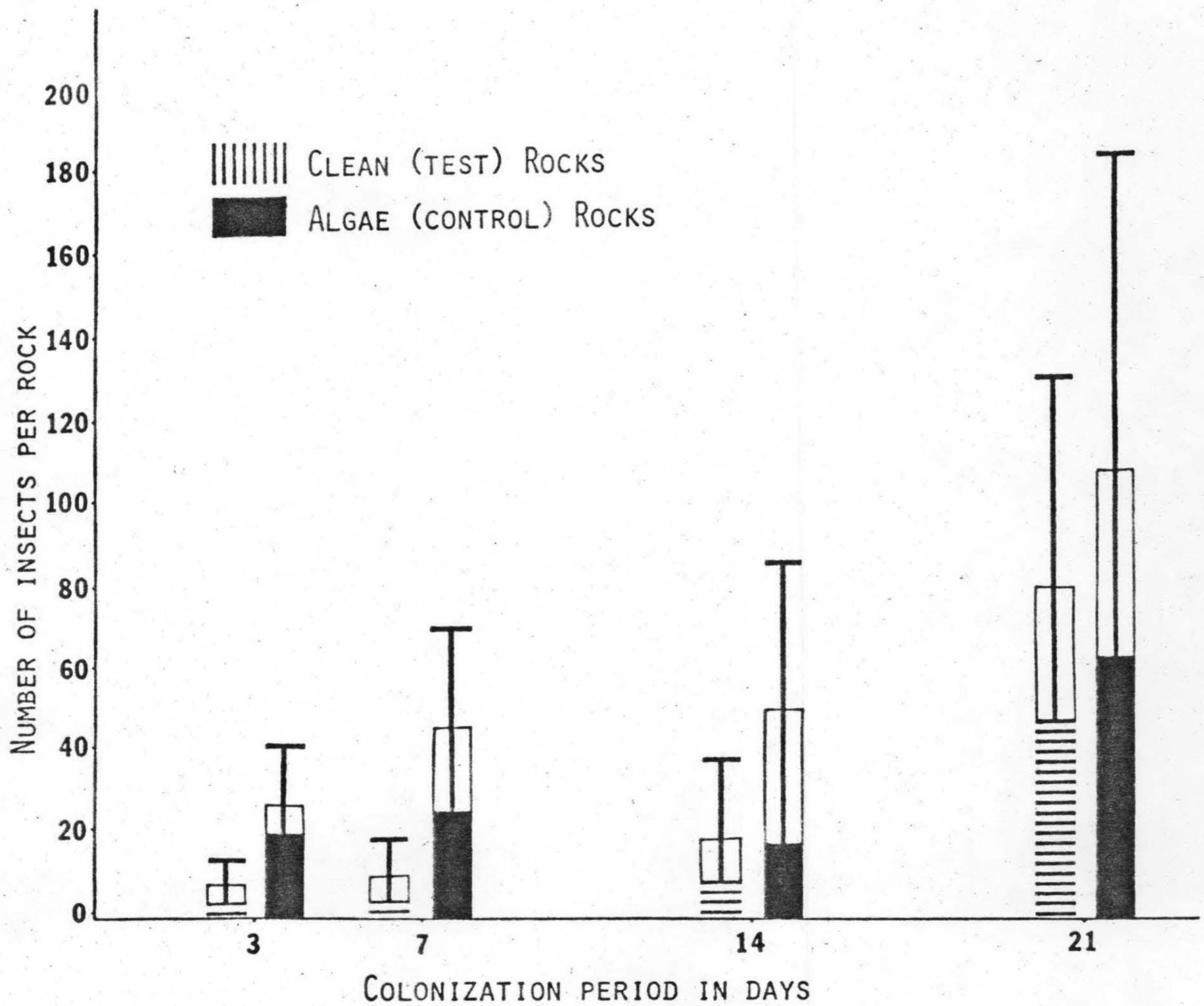

Figure 8. Maximum, minimum, and average number of insects colonizing cobble-sized rocks after a period of 3, 7, 14, and 21 days, Clearwater River, VIII-17-76 to IX-7-76. Based on 10 rocks per sampling day per plot. Vertical line = range in replications.

Table 12. Density of selected insect taxa (average number/cobble-sized rock) during a substrate colonization test in the Clearwater River, VIII-16-76 to IX-7-76. Based on ten rocks per plot, for clean rocks (Plot C) and algae-covered rocks (Plot A). Range (low-high) in parenthesis.

Taxa	Days 3		Days 7		Days 14		Days 21	
	C	A	C	A	C	A	C	A
Ephemeroptera								
Baetis bicaudatus Dodds	2.4 (0-8)	1.1 (0-5)	3.3 (1-10)	1.0 (0-4)	2.8 (0-14)	0.7 (0-2)	1.2 (0-4)	3.0 (0-11)
Baetis parvus Dodds	0.3 (0-2)	0.0	0.4 (0-3)	0.2 (0-2)	0.5 (0-3)	0.8 (0-3)	0.0	0.6 (0-3)
Cinygmula sp.	0.0	0.0	0.0	0.0	0.3 (0-2)	0.8 (0-3)	6.1 (3-17)	4.3 (1-7)
Ephemerella inermis -infrequens complex	0.0	0.0	0.0	0.0	0.3 (0-2)	0.4 (0-2)	4.3 (1-9)	2.3 (0-11)
Rithrogena hageni Eaton	0.3 (0-1)	0.0	0.1 (0-1)	0.2 (0-1)	0.2 (0-2)	0.7 (0-3)	1.3 (0-4)	0.6 (0-2)
Trichoptera								
Brachycentrus sp.	0.2 (0-1)	2.0 (0-4)	0.6 (0-2)	2.9 (0-12)	0.7 (0-2)	4.4 (0-9)	1.3 (0-3)	2.4 (1-6)
Cheumatopsyche sp	0.7 (0-2)	2.0 (0-6)	0.8 (0-2)	2.3 (0-7)	1.1 (0-3)	3.4 (0-7)	7.9 (0-19)	3.6 (0-12)
Glossosoma sp.	1.0 (0-4)	0.7 (0-2)	0.2 (0-2)	1.8 (0-4)	0.2 (0-1)	3.0 (0-7)	2.2 (0-5)	5.8 (1-15)
Hydropsyche sp.	0.0	0.2 (0-2)	0.2 (0-1)	0.6 (0-2)	0.8 (0-7)	1.3 (0-7)	1.4 (0-3)	3.7 (0-12)
Hydroptila sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.9 (0-4)	0.5 (0-3)
Diptera								
Chironomidae	2.7 (0-7)	20.0 (14-28)	4.2 (0-7)	34.5 (19-57)	11.3 (2-17)	32.6 (19-47)	47.9 (25-81)	46.7 (30-69)
Lepidoptera								
Parargyractis sp.	0.0	0.6 (0-3)	0.3 (0-2)	0.7 (0-4)	0.2 (0-1)	5.7 (2-16)	2.3 (0-9)	33.2 (7-57)

The number of insects per rock in the test plot did not increase significantly during the first two weeks of the test ($P \leq 0.05$)(Steele & Torrey 1960); no algae was evident on the test rocks during this period. Algae was noticeable on test rocks by the 21st day, and insect colonization of these rocks increased significantly between the 14th and 21st days of the test.

This same pattern also occurred in the control plot (Table 11; Figure 8). There was no significant increase in colonization during the first two weeks of the test, although insect counts were significantly higher in the control plot than in the test plot during this period. Even though the control rocks had a well-developed growth of periphyton during the test (Cyanophyta: Oscillatoria sp.), it took between two and three weeks for colonization in the test and control plots to be statistically equal. Control rocks undoubtedly supported some insects at the start of the test, which accounted for some of the initial differences between plots. Current velocity through the control plot was approximately 30% greater than through the test plot, which could have increased the rate of colonization in the control plot. Although current differences were not evaluated during the first two weeks of the test, average counts for the 21st day were nearly 30% higher for the control plot than for the test plot; considering the wide overlap in colonization ranges for the two plots on that day, this may or may not be a coincidence (Figure 8).

Regardless of periphyton development or colonization time, almost any insect species could be absent from suitable cobble substrate (Table 12). Most species collected during the test appeared to be opportunists;

they needed time to colonize newly-watered substrate more than they needed a particular level of algal growth, since their average colonization rate increased over time while the minimum number of insects per rock did not. This was true even for most of the mayflies, which feed mainly on algae (Gilpin & Brusven 1970; Hynes 1970).

There were three exceptions to the opportunist theory. Chironomidae (Diptera) was closely associated with algal development, colonizing readily once a covering of periphyton was established. Parargyractis sp. (Lepidoptera) was even more demanding in its habitat requirements, needing both well-developed periphyton and a fully-watered period of at least three weeks before colonization occurred in large numbers. Baetis bicaudatus Dodds, on the other hand, colonized newly-watered substrate almost immediately; this was particularly true in the test plot, where an average density of more than 100 Baetis bicaudatus per m^2 was realized within three days (Table 12). Walker (1972) also noticed that Baetis sp. moved rapidly into newly-watered areas.

Colonization values for the 25th and 30th days of the test are probably overestimates (Table 8). The average number of insects per rock in the test plot on the 25th day would equal at least 7,000 insects per m^2, which exceeds the highest density found in shoreline samples (Table 2). Due to the presence of squared and cubed terms in the regression equations, calculated values increased rapidly as colonization time increased. The regression formulae did not recognize such factors as insect requirements for food and space, uneven distribution due to negative phototaxis, and physical limits of the rocks. It is likely that these factors reduced the rate of colonization after three weeks, since colonization of basket samplers was found to be essentially complete in four weeks (baskets were not tested for a three-week period).

I believe that the overall conclusion to be drawn from both the laboratory and in-stream colonization tests is that, although a few species may require a certain level or type of algal growth before they will inhabit otherwise-suitable substrate, most species of aquatic insects present in the Clearwater River simply require time in which to colonize an area of habitat. Although the initial colonization rate was higher when algae was present, there was no mass movement of insects (except possibly Chironomidae) onto the substrate just because algae was present. Few insects would colonize an area of shoreline habitat unless it was fully watered for more than two weeks. Small daily flow fluctuations therefore present minimal danger to immature aquatic insects below Orofino as long as the integrity of the stable portion of the river bed is maintained, which refutes Ward's (1976) suggestion that diurnal flow fluctuations could decimate insect communities even without stranding.

Results of the in-stream colonization test suggest that several flow conditions could reduce the number of insects collected in shoreline samples: 1) samples could have been taken on substrate that was subjected to daily flow fluctuations, which was often the case at Sites II and III; 2) flows could have increased within two weeks of sampling, remaining high during the interim period; or 3) flows could have been steady prior to sampling except for a short-term decrease, which could cause massive abandonment of the substrate by insects which had already colonized it. In every instance where low numbers of insects were collected at the two test sites, Peck flows had increased by at least 44% within two weeks of sampling; either the magnitude of daily flow fluctuations had increased, or the water level had increased and remained high. Low densities were thus caused by where the samples were taken within the stream bed rather than by changes in the insect communities present at the test sites. The one instance of low densities at the shoreline control site resulted from a large flow increase at Orofino prior to sampling. Low insect densities consisted mainly of mayflies and midge larvae, with caddisflies usually poorly represented. Some of these insects probably inhabited clumps of organic detritus, or lived in the gravel interstices of the stream bed; neither of these habitats were sampled during the in-stream colonization test, but were included in regular shoreline sampling.

Short-term field studies revealed that little colonization occurs on substrate subjected to daily dewatering (Table 13). Samples taken on August 24 were taken on substrate that was partially dewatered during daily minimum flows; although most of the substrate was covered with periphyton, the upper surface of some cobbles was barren (indicating dewatering). While the 30 and 45 cm depths were relatively stable prior to August 24, heavy rains raised the water level in the river so that August 27 samples taken shallower than 45 cm were taken on substrate that was newly watered. Visual inspection of the dewatered habitat on August 24 revealed no insects, living or dead.

Table 13. Volumetric (ml) comparison of benthos and drift samples taken during daily maximum and minimum flows at shoreline-site III (R.K. 38.0), Clearwater River, 1976. Based on two benthos and one drift sample taken at each depth.

			Depth			
Date	Sample	Flow (cfs)	5 cm	15 cm	30 cm	45 cm
Aug 24	benthos	4300 (min.)	1-1	1-1	1-2	1.5-2.5
Aug 27	benthos	7500 (max.)	0-0	0-0	1-1	1-2
Aug 27	drift (3-4 pm)	"			1	1
Aug 27	drift (8-9 pm)	"			5.5	14.5

Insect Drift. The results of drift studies are presented as both the total number of insects drifting through the nets per hour, and the number drifting per cubic meter of flow per hour (Figures 9 - 11). Mayflies and caddisflies, which made up the majority of insect drift, are included in the total and are considered separately.

Drift results support earlier statements concerning the degree of insect colonization occurring at the three shoreline sampling depths. Although the largest total number of insects per hour drifted at the 45 cm depth at both Sites I and III, the largest number per m^3 of flow drifted at the 15 cm depth at both sites. This reflects the increase in insect density that occurred with increasing depth, and the lower quality of habitat present at the 15 cm depth. Insects residing in relatively poor habitat would tend

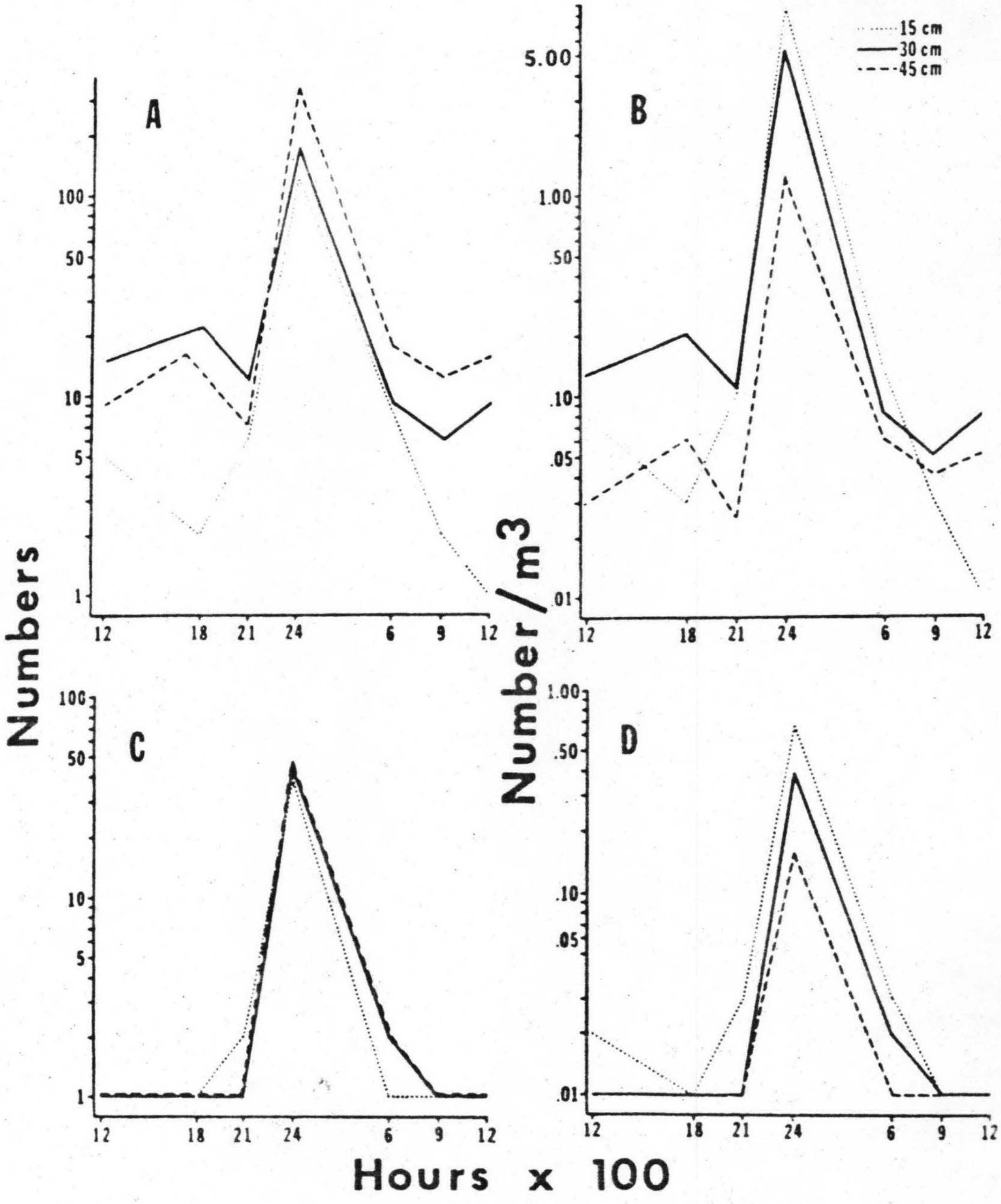

Figure 9. Insect drift at shoreline site I: (A) total number of insects drifting per hour, (B) number of insects per m^3 of flow, (C) total number of mayflies drifting per hour, (D) number of mayflies per m^3 of flow.

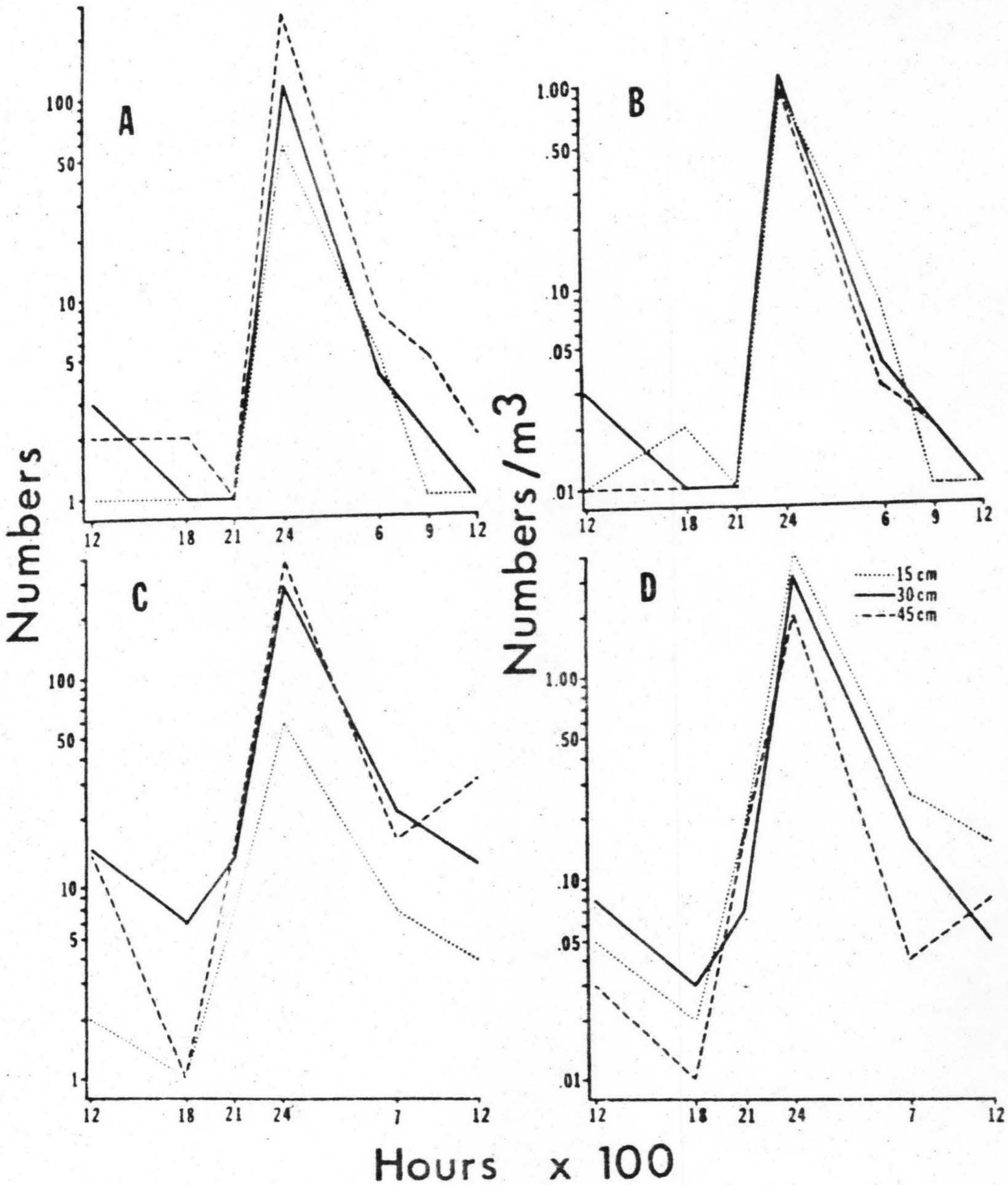

Figure 10. Insect drift: (A) total number of caddisflies drifting per hour at Site I, (B) number of caddisflies per m^3 of flow at Site I, (C) total number of insects drifting per hour at Site III, (D) number of insects per m^3 of flow at Site III.

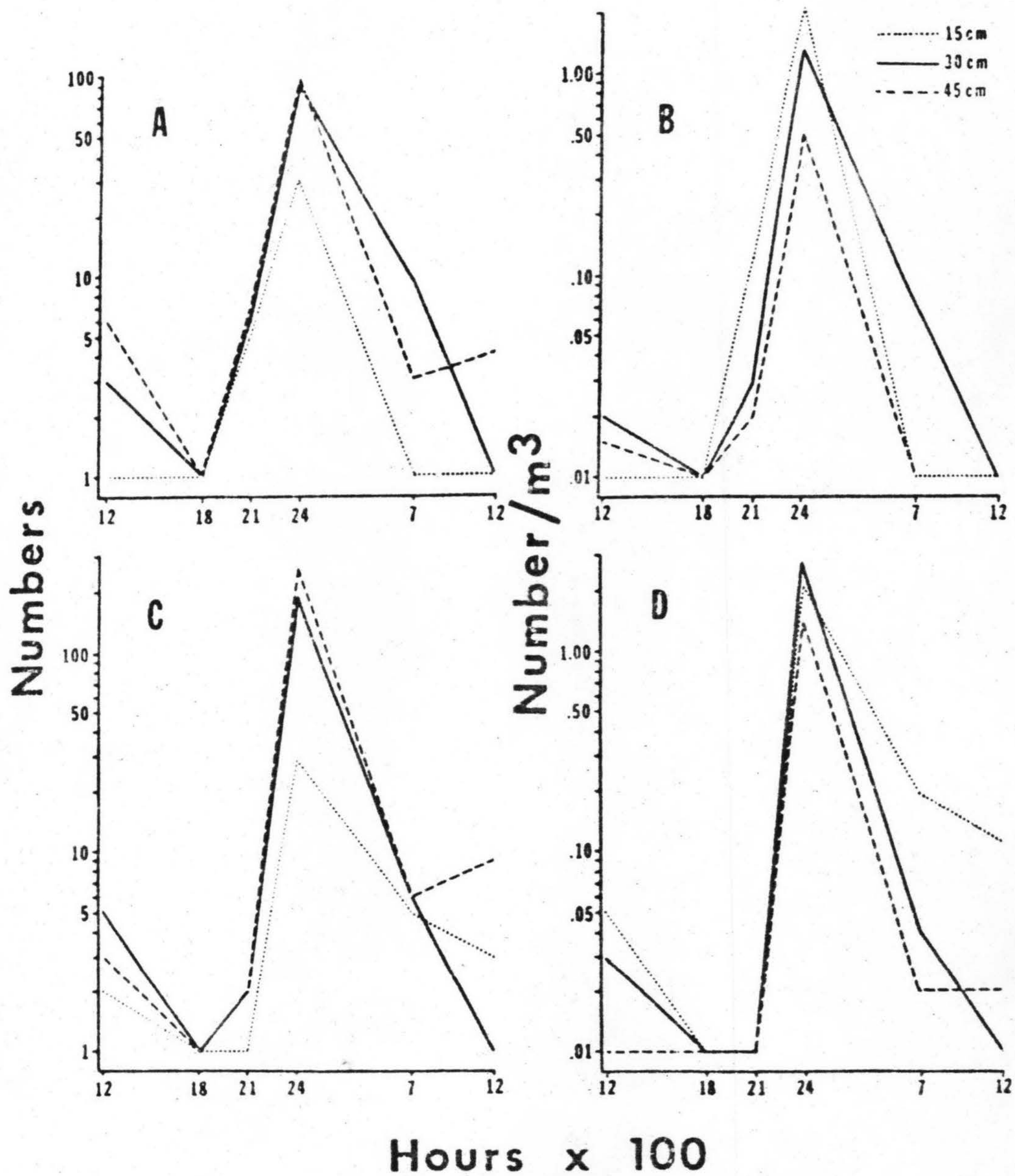

Figure 11. Insect drift at shoreline site III: (A) number of mayflies drifting per hour, (B) number of mayflies per m^3 of flow, (C) number of caddisflies drifting per hour, (D) number of caddisflies per m^3 of flow.

to drift in larger numbers in search of better habitat, and would probably drift for a longer distance for the same reason.

Although insect drift in regulated streams may increase with both increasing and decreasing discharge (Anderson & Lehmkuhl 1968; Minshall & Winger 1968), this apparently did not generally occur in the Clearwater River below Orofino (Figures 9 - 11). As is the case in non-regulated streams, drift increased rapidly at dusk, peaking at approximately 2400 hours; like results were found by Pearson & Franklin (1968), Radford & Hartland-Rowe (1971), and Peters (1973).

Drift samples taken during daily maximum flows at Site III showed a three-fold increase in drift volume between the 30 and 45 cm depths (Table 13). The 45 cm net was placed on substrate that was continually watered or subjected to only partial dewatering, while the 30 cm net was on substrate that was completely dewatered each night. Judging by the small volume of benthos collected on this dewatered substrate, it is likely that much of the 30 cm drift was carried towards shore by eddies from deeper areas. Much of this drift consisted of emerging adults, which would be subjected to a greater variety of currents than would immature insects living on the stream bed.

Insect Community Changes Over Time. During the present study, a number of community and species changes have apparently occurred in the Clearwater River from what was reported by Walker (1972) and Peters (1973).

My conclusions concerning mayflies generally differ from those of earlier authors. Although Walker theorized that *Baetis* spp. might decline under fluctuating flows because of a possible tendency to occupy newly-watered substrate, such a decline did not occur. The large-scale drift increase exhibited by Baetis spp. in response to rapid flow reductions, observed by Peters (1973), probably minimized stranding of this group. Although Peters found that Ephemerella margarita Needham was noticeably less abundant at 15 cm than at 30 and 45 cm, I found no such trend; density was either not affected by depth (Sites I and II), or was actually greater at 15 cm (Site III). Peters also reported that Righrogena hageni Eaton (R. undulata of Peters) increased in abundance with depth; this was only observed at my Site III. I cannot attribute these differences solely to post-impoundment conditions.

Two species of caddisflies appear to have increased during the post-impoundment period. Walker (1972) did not list Hydroptila sp. or Lepidostoma sp. A, while Peters (1973) listed the former as rare (unknown Trichoptera of Peters) and the latter as common (Micrasema sp. of Peters). Examination of Peters' specimens revealed that his Lepidostoma sp. was actually a species of Limnephilidae. Because Peters and I used different abundance scales, the actual magnitude of these apparent population increases cannot be determined. Filter-feeding organisms could be expected to increase below a reservoir, but this apparently has not occurred in the Clearwater.

The direct relationship between larval size and water depth that Walker found for Brachycentrus sp. was not evident in my samples, with size being mainly a function of sampling date. Walker suggested that small

Brachycentrus sp. larvae might suffer high mortality in temporarily-wetted habitat, but this apparently did not occur at my test sites because this species did not readily colonize such habitat.

While pre-impoundment studies recognized only a single species of Hydropsyche (Trichoptera), I have recognized two species in this genus in the study area. Hydropsyche sp.A. larvae have a dark head with no light markings, while sp. B has noticeable lighter markings on top of the head which vary from faint to very distinct; the genae of sp. B are also lighter in color than those of sp. A. When collected together, larvae of sp. B were usually larger than those of sp. A; there is not sufficient information to assume that sp. B emerges first, however. I did not rear either species in the laboratory. Because there are no larval keys for this genus, identification beyond morphospecies is not possible. All of Peters' specimens appear to be sp. B, while Walker's specimens were not available for comparison. This may represent either an increase in sp. A since 1972 or simply a failure of earlier studies to recognize the species; even the present study did not separate the two species until 1975.

The increase in Chironomidae (Diptera) in shoreline areas expected by Walker in response to daily flow fluctuations did not occur during my study. Populations either remained stable or declined. The strong correlation between periphyton development and the presence of Chironomidae accounts for its low density in areas subjected to daily dewatering, since little periphyton is present under such conditions. Edwards et al. (1974) also noted a decline in some species of midges in areas of unstable habitat.

Although Peters found Chironomidae (Tendipedidae of Peters) to be more common in very-shallow areas, my findings did not corroborate this except at shoreline-site III (R.K. 38.0).

Differences between Peters' results and mine may be partly attributed to different analysis methods. He analyzed data from several months of the same year, while my conclusions regarding species changes are based on a comparison of selected months for three different years. Also, Peters did not have a study site at my Site II, while I did not take samples at his Sites 1 and 4.

My biomass data differs from that of Peters. Peters found that biomass was similar at the 30 and 45 cm depths but much less at 15 cm, while I found that biomass was similar at 15 and 45 cm and somewhat less at 30 cm. Both studies agreed that biomass was greatest at 45 cm. I can see no logical reason for these differences other than chance variation or some undetected habitat deficiency. These differences are based on samples taken on stable habitat (all Peters' sites and my Site I), and do not reflect the effects of daily flow fluctuations.

The decrease in diversity with increasing depth found by Peters under stable flow conditions is neither supported nor rejected by my data. Half the samples from my shoreline control site showed this trend, while half showed an increase in diversity with depth. On the average, diversity was the same (2.8) at both the 15 and 45 cm depths. Again, I can see no logical reason for the differences in our findings other than chance variation. Considering the small magnitude of Peters' diversity difference with depth (approximately 0.2) and the fact that the diversity values reported by both studies are indicative of healthy, dynamic insect communities, these differences have little meaning as far as insect community structure is concerned.

SUMMARY

A study to determine the post-impoundment effects of Dworshak Dam on aquatic insects in northern Idaho's Clearwater River was carried out from August, 1973, to September, 1976. The dam is located on the North Fork of the Clearwater at Orofino. The study area included approximately eight kilometers of the main river above the dam and thirty kilometers below the dam.

Three sampling methods were used during the study. Three shoreline sites (one control and two test sites) were sampled once a month at water depths of 15, 30, and 45 cm using a cylindrical bottom sampler. Mid-channel areas of 1 m and 2 m deep were sampled using rock-filled wire baskets left in the river for one-month periods to allow time for insect colonization to occur. Basket samplers were used only in 1974 and 1975 at two control sites and one test site. Insect drift was sampled at two shoreline sites in August, 1974, and August, 1976, for intermittent one-hour periods in order to reflect daily drift cycles.

Both laboratory and in-stream simulation tests were conducted in order to provide an understanding of insect habitat preferences and colonization behavior. Selected insect species were tested in an artificial plexiglass stream using two levels of current velocity and periphyton development. In-stream colonization tests were conducted in the Clearwater River using both clean and algae-covered rocks arranged in rectangular plots on a stream riffle. Samples were taken after colonization periods of 3, 7, 14, and 21 days.

Dworshak Dam has had little appreciable effect on yearly maximum or minimum flows in the main Clearwater River during most years. Low regional water supplies in 1973, however, caused the dam to release above-normal amounts of water on a non-fluctuating basis in order to meet regional power demands. During other years, daily water-level fluctuations of up to 60 vertical centimeters have occurred on a regular basis during power-generating activities at the dam. By maintaining a minimum North Fork flow of at least 1000 cfs at all times, Dworshak Dam has assured that the amount of usable stream habitat below Orofino equals or exceeds what was available prior to impoundment. The dam has thus had a stabilizing effect on river benthos during low-water years.

River temperatures below Orofino are approximately 3°C colder in late summer and 3°C warmer in winter compared to pre-impoundment conditions, but these temperature changes appear to have had little effect on river benthos. Oxygen concentrations in the main Clearwater below the dam have remained well within the tolerance range of most aquatic organisms during the post-impoundment period.

Dworshak Dam has had few detrimental effects on river benthos during the post-impoundment period. Daily flow changes cause a temporary increase in aquatic habitat during daylight hours, but few aquatic insects (which are normally nocturnal) colonize this temporary habitat. Entrapment and subsequent dessication of insects in this habitat are thus minimal. Although insect density was lower at the shoreline test sites than at the control site, this occurred because test sites were often sampled on substrate that was subjected to daily dewatering. Insect density increased with increasing depth at all shoreline sites, indicating insect avoidance of very-shallow areas even under natural flow conditions. Insect density was even higher at basket sites than at shoreline sites, indicating that mid-channel areas up to 2 m deep may support more insects than do shoreline riffles. Basket data also supports the idea that Dworshak Dam has not decreased insect density below Orofino. Diversity and evenness have remained high, indicating that the dam has not damaged community stability by favoring only a few insect species. Insect communities in the Clearwater River remained healthy and well balanced. Although insect density declined at all sites during the study period, this was probably due to natural conditions rather than to the operation of Dworshak Dam.

Laboratory and in-stream colonization tests confirmed the importance of food in habitat selection by immature aquatic insects. Under natural conditions, colonization time was found to be more important than periphyton development in determining insect density on cobble substrate. Although midge larvae (Diptera; Chironomidae) were closely associated with periphyton development, it took between two and three weeks for colonization by most species to be statistically equal on newly-watered and permanently-watered substrate. Two to three weeks were required for periphyton to develop to detectable levels in the Clearwater River in late summer. Submerged substrate without periphyton was watered for less than this period, making the algal line useful for determining the extent of daily flow fluctuations.

Drift studies revealed that, although the highest total number of insects per hour drifted at the 45 cm depth, the largest number per m^3 of flow drifted at the 15 cm depth. This supports the idea that, even under natural conditions, habitat quality is reduced near the water's edge. Although insect density and water velocity were less at 15 cm, a larger percentage of the insect community drifted at this depth than at 30 and 45 cm (assuming equal flow volumes at all three depths).

REFERENCES CITED

Anderson, N.H. and D.M. Lehmkuhl. 1968. Catastrophic drift of insects in a woodland stream. Ecology 49:198-206.

Briggs, J.C. 1948. The quantitative effects of a dam upon the bottom fauna of a small California stream. Trans. American Fish. Soc. 78: 70-81.

Brusven, M.A. 1973. A closed system plexiglass stream for studying insect-fish-substrate relationships. Progr. Fish. Cult. 35(2): 87-89.

_______________, Craig MacPhee and Russell Biggam. 1974. Effects of water fluctuation on benthic insects. IN: Anatomy Of A River. Pacific Northwest River Basins Commission, Vancouver, Washington. pp. 67-79.

_______________, R.C. Biggam and K.D. Black. 1976. Ecological Strategies For Assessing Impact of Water Fluctuations on Fish-Food Organisms. Project completion report submitted to National Marine Fisheries Service, contract no. 03-4-208-243. Dept. of Entomology, University of Idaho. 69 p.

Edmundson, W.T. (ed.). 1959. Freshwater Biology. 2nd edition. John Wiley & Sons, New York. 1248 p.

Edwards, G.S., W.H. Funk and G.C. Bailey. 1974. Benthic organisms of the Lower Granite Pool area. U.S. Army Corps of Engineers report, Walla Walla, Washington. Contract no. DACW 68-74-C-0001. 57 p.

Falter, C.M., W.H. Funk, D.L. Johnstone and S.K. Bhagat. 1973. Water quality of the lower Snake River, especially the Lower Granite Pool area, Washington-Idaho. University of Idaho-Washington State University joint research report to the U.S. Army Corps of Engineers, Walla Walla District. 257 p.

Falter, C.M. 1976. Limnology of Dworshak Reservoir in the first three years after filling. Northwest Science Terrestrial & Aquatic Ecosystems Symposium (April, 1976). In Press.

Fisher, S.G. and A. LaVoy. 1972. Differences in littoral fauna due to fluctuating water levels below a hydroelectric dam. Journ. Fish Res. Bd. of Canada 29: 1472-1476.

Geen, G.H. 1974. Effects of hydroelectric development in western Canada on aquatic ecosystems. Jour. Fish. Research Board of Canada 31: 913-927.

Gilpin, B.R. and M.A. Brusven. 1970. Food habits and ecology of mayflies of the St. Maries River in Idaho. Melanderia (published by the Washington State Entomological Society, Washington State University, Pullman, Wa.) 4: 19-40.

Hynes, H.B.N. 1970. The Ecology of Running Waters. University of Toronto Press. 555 p.

Idaho Dept. of Environmental & Community Services. 1973. Idaho Water Quality Standards and Wastewater Treatment Requirements. 32 p.

Jensen, S.L. 1966. The mayflies of Idaho (Ephemeroptera). Unpubl. M.S. thesis. University of Utah. 365 p.

Jewett, S.G. 1959. The Stoneflies (Plecoptera) Of The Pacific Northwest. Oregon State University Press, Corvallis, Oregon. 95 p.

Kroger, R.L. 1973. Biological effects of fluctuating water levels in the Snake River, Grand Teton National Park, Wyoming. American Midland Nat. 80: 478-481.

Margalef, D.R. 1957. Information theory in ecology. (Transl. from Spanish). Yearbook of the Soc. of General Syst. Res. (1958) 3: 36-71.

Mason, William T. Jr., Cornelius I. Weber, Philip A. Lewis and Elmo C. Julian. 1973. Factors affecting the performance of basket and multiplate macroinvertebrate samplers. Freshwater Biol. 3: 409-436.

Minshall, G.W. and P.V. Winger. 1968. The effects of reduction in stream flow on invertebrate drift. Ecology 49: 580-582.

Needham, P R. 1934. Quantitative studies of stream bottom foods. Trans. Amer. Fish. Soc., 64: 238-247.

Pate, V.S.L. 1931. Studies on the fish food supply in selected areas. IN: A Biological Survey Of The Oswegatchie And Black River Systems (supplement to 21st Ann. Rept. N.Y. State Conservation Dept., p. 133-149.

Pate, V.S.L. 1932. Studies of fish food in selected areas. IN: Biological Survey of the Upper Hudson Watershed (suppl. to 22nd Ann. Rept. N.Y. State Conservation Dept., p. 130-156.

Patten, B.C. 1962. Species diversity in net phytoplankton at Raritan Bay. Jour. Marine Res. 20: 57-75.

Pearson, W.D. and D.R. Franklin. 1968. Some factors affecting drift rates of Baetis and Simuliidae in a large river. Ecology 49: 75-81.

Peters, D.J. 1973. Littoral distribution and drift of selected riffle insects. Unpubl. M.S. thesis. University of Idaho. 50 p.

Pielou, E.C. 1967. The use of information theory in the study of the diversity of biological populations. Proc. 5th Berkeley Symp. on Math., Statistics, and Probability. Univ. of Calif. Press, 4: 163-178.

Poole, Robert W. 1974. An Introduction To Quantitative Ecology. McGraw-Hill, New York.

Powell, G.C. 1958. Evaluation of the effects of a power dam water release pattern upon the downstream fishery. Colorado Coop. Fishery Unit Quarterly Report 4: 31-37.

Radford, D.S. and R. Hartland-Rowe. 1971. A preliminary investigation of bottom fauna and invertebrate drift in an unregulated and a regulated stream in Alberta. Jour. of Applied Ecol. 8: 883-903.

Richardson, J.W. 1965. The food habits of Plecoptera. Unpubl. M.S. thesis. Univ. of Utah. 93 p.

Ruttner, F. 1963. Fundamentals of Limnology. Univ. of Toronto Press. 295 p.

Smith, S.D. 1964. Ecological studies of the caddisflies of the upper Palouse River, Idaho (Trichoptera). Unpubl. M.S. thesis. University of Idaho. 178 p.

Spence, J.A. and H.B.N. Hynes. 1971. Differences in benthos upstream and downstream of an impoundment. Jour. Fish. Res. Bd. Canada 28: 35-43.

Stalnaker, C.B. and J.L. Arnette (ed.). 1976. Methodologies For The Determination Of Stream Resource Flow Requirements: An Assessment. U.S. Fish & Wildlife Service Office of Biological Sciences (Western Water Allocation). University of Utah publ. 199 p.

Steele, R.G.D. and J.H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill, New York. 481 p.

Ward, James V. 1976. Effects of flow patterns below large dams on stream benthos: a review. IN: Proceedings of the Symposium and Specialty Conference on Instream Flow Needs, Volume II. American Fisheries Soc. publication. p. 235-253.

Wene, G. and E.L. Wickliff. 1940. Modification of a stream bottom and its effect on the insect fauna. Canadian Ent. 72: 131-135.

APPENDICES

APPENDIX A. Distribution and relative abundance of aquatic insects in the main Clearwater River, 1973-75. R = Rare (1-10 insects per m^2); S = Sparse (11-100 insects per m^2); C = Common (101-1000 insects per m^2); V = Very Common (over 1,000 insects per m^2). Represents the highest density recorded in each year based on the total number of insects collected from all depths on one sampling date at a given site in a given year. * = a given species, if present, included in genus listing that year.

ORDER: EPHEMEROPTERA	Basket Site IA (R.K. 80.5): 1975	Basket Site IB (R.K. 72.9): 1974	Basket Site IB (R.K. 72.9): 1975	Shore Site I (R.K. 72.4): 1973	Shore Site I (R.K. 72.4): 1974	Shore Site I (R.K. 72.4): 1975	Basket Site HB (R.K. 57.9): 1974	Basket Site HB (R.K. 57.9): 1975	Shore Site II (R.K. 50.1): 1973	Shore Site II (R.K. 50.1): 1974	Shore Site II (R.K. 50.1): 1975	Shore Site III (R.K. 38.0): 1973	Shore Site III (R.K. 38.0): 1974	Shore Site III (R.K. 38.0): 1975
Ameletus spp. (mainly A. cooki McDunnough)	C	C	C	R	S	S	C	C		S	S		R	S
Baetis bicaudatus Dodds	V	V	C	R	C	S	V	V	S	C	S	S	S	C
Baetis parvus Dodds	V	C	C	*	*	C	V	C	*	*	C	*	*	S
Baetis tricaudatus Dodds	C	V		*	*	R	V	C	*	*		*	*	R
Baetis spp. (parvus & tricaudatus)	V	V	C	S	S	C	V	C	S	C	C	S	S	S
Centroptilum sp. A	S	C	C	R	S	S	C		S	S	S	R	R	S
Centroptilum sp. B		C			R		C			R				
Cinygmula sp.	C		C		S	S		C	R	R	S		R	R
Epeorus albertae (McDunnough)	C	C	C	S	C	C	C	S	S	C	S	S	C	C
Ephemerella doddsi Needham				S	C	C				R	R	R	S	R
Ephemerella edmundsi Allen						R								
Ephemerella flavilinea McDunnough					R	S				S	S		R	S
Ephemerella grandis Eaton	C	V	C	S	S	S	V	V		S	S	R	S	R
Ephemerella hecuba (Eaton)										R	R			R
Ephemerella hystrix Traver					R					R				
Ephemerella heterocaudata McDunnough														R
Ephemerella inermis - infrequens complex	V	V	V	S	S	C	V	V	C	S	C	C	C	C
Ephemerella margarita Needham	C	V	C	S	C	S	V	C	S	C	C	C	C	R
Ephemerella spinifera Needham										R				
Ephemerella tibialis McDunnough	S		S		R	S				R	R			R
Heptagenia criddlei McDunnough	S	C	C	R	S	S			C	S	S	S	S	S
Heptagenia solitaria McDunnough	S	S	S	S	S	S	C	S	R	R	R	S	R	R
Paraleptophlebia bicornuta (McDunnough)	C	C	C	S	S	R	V	C	C	C	S	S	R	R
Paraleptophlebia heteronea (McDunnough)	V		V	S	S	C	S	C	C	S	S	C	R	S

APPENDIX A. (continued)

ORDER: EPHEMEROPTERA (continued)	Basket Site IA (R.K. 80.5): 1975	Basket Site IB (R.K. 72.9): 1974	Basket Site IB (R.K. 72.9): 1975	Shore Site I (R.K. 72.4): 1973	Shore Site I (R.K. 72.4): 1974	Shore Site I (R.K. 72.4): 1975	Basket Site HB (R.K. 57.9): 1974	Basket Site HB (R.K. 57.9): 1975	Shore Site II (R.K. 50.1): 1973	Shore Site II (R.K. 50.1): 1974	Shore Site II (R.K. 50.1): 1975	Shore Site III (R.K. 38.0): 1973	Shore Site III (R.K. 38.0): 1974	Shore Site III (R.K. 38.0): 1975
Parameletus sp.					R									
Rithrogena hageni Eaton	V	C	C	C	C	C	C	C	C	C	R	C	C	C
Rithrogena robusta Dodds										R				
Rithrogena morrisoni (Banks)				S	R									
Siphlonurus columbianus McDunnough										R	R			
Tricorythodes minutus Traver	S	V	C	R	R	R	C	C		S	R			R
ORDER: PLECOPTERA														
Acroneuria californica (Banks)		S		*	*	S	C	S	*	*	R	*	*	R
Acroneuria pacifica Banks				*	*	R			*	*		*	*	R
Acroneuria spp. (californica & pacifica)				S	S	S	C	S	S	S	R	R	S	R
Alloperla spp.		S	C		S	S			R	S	S			R
Arcynopteryx spp.	C	C	C	S	S	S		S	C	S	R	S	R	
Brachyptera sp.	C	C	C	S	S	R	C	C	S	S	R	R	S	
Capnia spp.			S	C		R	R	S			R	R		R
Claassenia sabulosa (Banks)				S	R	S			R	R	R	S		S
Isogenus spp.	V	S	C	R	S	R	C	C	R	S	R	S	S	R
Isoperla spp.				R	R	R			R	S	R	S	R	R
Nemoura spp.	S	S	C			R	C	C	R	R	R		R	
Peltoperla brevis Banks					R									
Pteronarcella badia (Hagen)											R			
Pteronarcys californica Newport		R	S	R	R			S	R	R			R	
ORDER: TRICHOPTERA														
Agapetus sp.						R								
Athripsodes sp.		S	S	R		R		S	R		R	R		
Brachycentrus sp.	V	V	V	V	C	C	V	V	C	C	S	C	V	C
Cheumatopsyche sp.	V	V	V	C	C	C	V	V	C	S	S	C	C	S
Chimarra sp.				S	R		C							
Dicosmoecus sp.	R		S		R	R				R				
Dolophilodes sp.													R	
Drusinus sp.											R			R

APPENDIX A. (continued)

ORDER: TRICHOPTERA (continued)	Basket Site IA (R.K. 80.5): 1975	Basket Site IB (R.K. 72.9): 1974	Basket Site IB (R.K. 72.9): 1975	Shore Site I (R.K. 72.4): 1973	Shore Site I (R.K. 72.4): 1974	Shore Site I (R.K. 72.4): 1975	Basket Site HB (R.K. 57.9): 1974	Basket Site HB (R.K. 57.9): 1975	Shore Site II (R.K. 50.1): 1973	Shore Site II (R.K. 50.1): 1974	Shore Site II (R.K. 50.1): 1975	Shore Site III (R.K. 38.0): 1973	Shore Site III (R.K. 38.0): 1974	Shore Site III (R.K. 38.0): 1975
Glossosoma sp.	S	S		C	S	C	R		C	S	S	V	S	S
Helicopsyche borealis (Hagen)			R	S	R	R	S		R		R			
Hydropsyche sp. A	V	*	*	*	*	S	*	V	*	*	R	*	*	R
Hydropsyche sp. B	C	*	C	*	*	S	*	C	*	*	S	*	*	S
Hydropsyche spp. (A & B)	V	V	V	C	C	C	V	V	C	S	S	C	S	S
Hydroptila sp. A		C	S	C	R		V	C	S	C	S	S	R	R
Hydroptila sp. B				S										
Lepidostoma sp. A	V	C	V	V	C	C	C	C	C	C	S	C	C	S
Lepidostoma sp. B	S		S		R	R			R	R	R		R	
Lepidostoma sp. C										R				
Leptocera sp.														R
Leucotrichia sp.				S	R	R				R			R	
Micrasema sp.				R	R	R	R							
Mystacides alafimbriata Hill-Griffin									R					
Neophylax sp.											R			
Neothremma sp.		R			R		S							
Neotrichia sp.						R			S		S	R		R
Oecetis. sp.	S	C	C	S	R	R		C	R	S	S	R	R	R
Parapsyche elsis Milne					R								R	
Polycentropus sp.				R	R	R			R		R		R	R
Psychoglypha sp.					R					R			R	
Psychomyia sp.				R					R	R	R			
Rhyacophila hyalinata Banks						R								
Rhyacophila verrula Milne														R
Wormaldia sp.				S	S	S			S	R	R	R	R	R
ORDER: COLEOPTERA														
Ampumixis sp.						R					R			R
Brychius sp.			R											
Cleptelmis sp.	R		R										R	
Heterlimnius sp.					R		S			S	S		R	
Hydroporous sp.				S	S	S			R	S	R	S	S	R
Narpus sp.		S		S	R	R			S	R	R	R	R	
Optioservus sp.				R	S	R			S	S	R	R		R

APPENDIX A. (continued)

ORDER: COLEOPTERA (continued)	Basket Site IA (R.K. 80.5): 1975	Basket Site IB (R.K. 72.9): 1974	Basket Site IB (R.K. 72.9): 1975	Shore Site I (R.K. 72.4): 1973	Shore Site I (R.K. 72.4): 1974	Shore Site I (R.K. 72.4): 1975	Basket Site HB (R.K. 57.9): 1974	Basket Site HB (R.K. 57.9): 1975	Shore Site II (R.K. 50.1): 1973	Shore Site II (R.K. 50.1): 1974	Shore Site II (R.K. 50.1): 1975	Shore Site III (R.K. 38.0): 1973	Shore Site III (R.K. 38.0): 1974	Shore Site III (R.K. 38.0): 1975
Psephenus sp.				S	R	R	R		R	R	S	R	R	R
Zaitzevia sp.	S	S	S	C	S	S	S	S	C	S	S	S	R	S
ORDER: DIPTERA														
Antocha sp.				C	S			S	R	S	R		R	
Atherix variagata Walker				R	R	R			R	R	R		R	
Blepheroceridae (sp.)					R					R		R		
Chironomidae (spp.)	V	V	V	V	C	C	V	V	C	C	C	V	C	C
Deuterophlebia coloradensis Pennack											R			
Dicranota sp.	R				R					R				
Dolichopodidae (sp.)						R				R	R		R	R
Empididae (sp.)					R	R	C			R	R		R	R
Ephydridae (sp.)					R					R				
Forcipomyia sp.			S											
Hemerodromia sp.				R										
Hexatoma sp.			S	S	S	R			S	S	S	S	S	R
Limonia sp.										R				
Ormosia sp.										R				
Palpomyia sp.	R											R		R
Philorus sp.					R					R				
Protanyderus margarita Alexander				R		R			R	R	R	R		R
Simulium sp.	C	C	C		R	S	V	C	R	S	S	R	R	R
Stratiomyidae (sp.)						R								
Tabanidae (sp.)											R			
Tipula sp.										R				
ORDER: HEMIPTERA														
Sigara sp.		S			R									
ORDER: LEPIDOPTERA														
Parargyractis sp.				C	R	S		S	S	R	R	R	R	R
ORDER: ODONATA														
Enallagma sp.										R				
Ophiogomphus severus montanus (Selys)	S			R	R	R			R	R	R		R	

Appendix B. Shannon-Weaver diversity, evenness, number of species, and number of insects per 0.28 m^2 (3 ft^2) at shoreline study sites, Clearwater River, 1973-76. All numbers exclude Chironomidae (Diptera). *No samples taken.

Shore Site I (R.K. 72.4)

Date	Diversity/Depth			Evenness/Depth			Species/Depth			Insects/Depth		
	15 cm	30 cm	45 cm	15 cm	30 cm	45 cm	15 cm	30cm	45cm	15cm	30cm	45cm
VIII-2-73	2.36	2.75	2.53	.47	.56	.54	29	28	24	1241	914	1219
X-25-73	2.79	3.45	2.93	.60	.69	.61	23	30	28	744	772	985
I-28-74	3.26	3.02	2.61	.82	.74	.63	11	12	14	19	32	93
II-13-74	3.50	3.25	3.26	.87	.73	.71	16	21	21	80	213	222
VII-9-74	3.11	3.12	2.73	.73	.78	.72	15	13	12	53	30	52
VII-27-74	2.85	3.04	3.26	.72	.72	.87	12	13	13	42	36	26
VIII-13-74	3.29	3.19	2.20	.68	.68	.45	25	24	27	444	418	762
VIII-29-74	2.61	2.76	2.08	.57	.64	.48	18	18	19	159	554	970
IX-20-74	2.87	2.97	3.03	.63	.63	.63	21	26	25	499	496	414
XI-8-74	2.81	3.58	3.14	.62	.71	.63	22	30	29	287	436	740
III-14-75	1.57	2.13	2.82	.64	.81	.78	4	6	8	10	18	15
V-23-75	2.01	2.31	2.60	.44	.52	.65	20	20	15	518	424	291
VII-14-75	2.99	3.30	2.21	.80	.74	.48	12	20	23	76	145	509
VIII-12-75	3.54	3.41	2.78	.79	.69	.63	20	26	19	187	278	429
IX-10-75	3.76	3.30	2.97	.77	.67	.62	29	27	25	293	395	333
X-15-75	2.14	1.93	3.41	.60	.43	.71	9	21	24	51	443	229
VII-1-76	2.03	1.92	3.03	.78	.45	.65	5	13	21	54	88	201

Appendix B. (continued)

Date	Diversity/Depth 15 cm	30cm	45cm	Evenness/Depth 15cm	30cm	45cm	Species/Depth 15cm	30cm	45cm	Insects/Depth 15cm	30cm	45cm
	Shore Site II (R.K. 50.1)											
VIII-2-73	3.60	3.70	*	.73	.74	*	28	29	*	541	443	*
X-25-73	3.17	3.00	3.04	.63	.60	.62	31	29	30	410	837	1478
I-28-74	0.00	2.16	2.00	.00	.77	.70	1	5	5	1	8	8
II-13-74	3.02	3.14	2.56	.70	.69	.64	15	18	15	53	120	169
VII-9-74	3.71	3.73	3.19	.71	.77	.69	27	24	24	161	231	433
VII-27-74	3.43	3.62	3.78	.78	.80	.77	18	20	26	78	107	222
VIII-13-74	3.84	3.75	2.39	.76	.76	.49	32	26	28	259	223	588
VIII-29-74	3.49	2.79	2.05	.75	.58	.50	21	25	16	114	461	258
IX-20-74	2.25	2.26	2.80	.89	.79	.77	5	6	11	6	14	58
XI-8-74	3.71	3.29	3.65	.78	.67	.83	26	26	20	264	540	265
III-14-75	1.65	1.52	1.81	.69	.46	.53	5	8	9	25	50	56
V-23-75	1.96	1.81	2.02	.50	.50	.56	14	11	11	782	145	305
VII-14-75	3.03	3.30	*	.76	.70	*	14	25	*	59	227	*
VIII-12-75	3.52	3.76	3.91	.69	.77	.76	27	24	32	180	159	302
IX-10-75	0.00	0.00	2.50	.00	.00	.87	1	1	6	1	1	8
X-15-75	0.00	1.63	2.53	.00	.54	.56	1	5	21	1	14	193
VII-1-76	2.35	2.45	2.29	.81	.94	.71	6	6	6	14	12	11

Appendix B. (continued)

Date	Diversity/Depth			Evenness/Depth			Species/Depth			Insects/Depth		
	Shore Site III (R.K. 38.0)											
	15cm	30cm	45cm	15cm	30cm	45cm	15cm	30cm	45cm	15cm	30cm	45cm
VIII-2-73	2.61	2.43	1.98	.57	.51	.47	22	26	18	691	1069	1342
X-25-73	2.54	3.05	3.29	.57	.68	.72	21	21	23	590	871	928
I-28-74	1.79	0.00	1.79	.73	.00	.73	4	5	4	6	5	6
II-13-74	2.41	2.58	2.63	.64	.65	.75	10	12	11	58	119	89
VII-9-74	2.70	3.41	2.70	.79	.74	.59	10	19	18	51	67	102
VII-27-74	2.52	2.90	1.93	.77	.72	.72	9	13	6	37	45	43
VIII-13-74	2.68	1.88	2.10	.60	.44	.47	22	18	20	286	489	407
VIII-29-74	1.54	1.24	2.03	.34	.31	.48	20	14	17	306	380	618
IX-20-74	0.00	0.00	0.00	.00	.00	.00	1	1	2	1	1	2
XI-8-74	2.40	2.78	2.18	.65	.63	.54	12	19	16	207	391	497
III-14-75	0.00	0.81	0.00	.00	.77	.00	2	2	2	2	4	2
V-23-75	2.25	2.53	2.76	.56	.63	.58	14	15	21	131	304	208
VII-14-75	2.98	2.91	2.68	.69	.66	.54	19	18	27	134	155	425
VIII-12-75	3.47	3.45	3.19	.82	.81	.78	17	15	15	89	102	96
IX-10-75		0.00	1.50		.00	.78	0	1	3	0	1	4
X-15-75	0.00	1.55	2.50	.00	.74	.80	1	4	8	1	8	25
VII-1-76	1.50	0.91	2.52	.71	.61	.75	3	2	7	8	3	12

Appendix C. Shannon-Weaver diversity, evenness, number of species, and number of insects per basket at basket sites on the Clearwater River, 1974-75. All numbers exclude Chironomidae (Diptera).

Date	Diversity 1m	Diversity 2m	Evenness 1m	Evenness 2m	No. Species 1m	No. Species 2m	No. Insects 1m	No. Insects 2m
Basket Site IA (R.K. 80.5)								
IX-17-75	2.38	2.76	.58	.69	17	16	7088	5056
X-29-75	3.50	3.28	.77	.72	23	23	2430	1995
Basket Site IB (R.K. 72.9)								
VIII-28-74	2.97	2.34	.65	.57	24	17	6080	2816
IX-30-74	3.03	3.48	.74	.90	16	14	776	156
XII-23-74	3.58	2.93	.80	.73	21	14	237	321
II-11-75	1.94	1.85	.57	.53	10	11	472	848
IX-17-75	2.44	2.99	.65	.70	13	19	1712	2520
XI-17-75	2.56	2.39	.65	.61	15	15	1232	2040
Basket Site HB (R.K. 57.9)								
VIII-28-74	2.71	2.79	.64	.70	19	16	8015	4560
IX-30-74	2.78	2.82	.69	.68	16	17	1504	2832
XII-23-74	2.27	2.78	.50	.66	22	18	1473	728
II-11-75	2.50	1.37	.75	.39	10	11	552	1512
IX-17-75	2.41	2.28	.55	.52	20	20	3875	6728
X-29-75	2.41	2.22	.53	.56	22	15	1268	984