ECOLOGICAL STUDIES OF A REGULATED STREAM: HUNTINGTON RIVER, EMERY COUNTY, UTAH

Robert N. Winget[1]

ABSTRACT.— A 36.9×10^6 m^3 reservoir constructed on Huntington River, Emery County, Utah, resulted in changes in physical habitat, water quality, temperature, and flow regime. The greatest changes in physical habitat resulted from: (1) sediment additions from dam and road construction plus erosion of reservoir basin during filling; and (2) changing stream flow from a spring high runoff regime to a moderated flow regime. Elimination of spring nutrient concentration peaks and overall reduction of total dissolved nutrient availability in the river plus moderate reductions in pH were the most apparent water quality changes below the reservoir. Water temperature changes were an increased diurnal and seasonal constancy, summer depression, and winter elevation, generally limited to a 10–12 km reach below the dam.

Physical and chemical changes altered macroinvertebrate community structure, with changes greatest near the dam and progessively less as distance downstream increased. Below the dam: (1) more environmentally tolerant taxa increased their dominance; (2) relative numbers of smaller sized individuals increased in relation to larger individuals; and (3) filter feeding, collector/gatherers, and scrapers gained an advantage over shredders. Insect taxa such as *Rhithrogena robusta*, *Pteronarcella badia*, and *Ephemerella doddsi* were eliminated from stream reaches near the dam, and other taxa such as *Arctopsyche grandis*, Chironomidae, and Simuliidae increased in numbers. Late spring to early summer egg hatch proved to be a disadvantage to *Brachycentrus occidentalis*, and *B. americanus*, with a fall hatch, was less impacted by altered river flow patterns. Macroinvertebrate taxa with small instar larvae present from late summer to early fall were negatively impacted by the unnaturally high July and August flows. The reservoir became a physical barrier to downstream larval drift and upcanyon and downcanyon immigration of adults, resulting in reduced numbers of several species above and below the reservoir.

Huntington Canyon, approximately 890 square km drainage, lies along the eastern slope of the Wasatch Plateau in Emery County, east central Utah (Fig. 1), and is part of the Colorado River drainage. Huntington River originates in the Manti–LaSal National Forest at an elevation of about 3000 m and flows 83 km to the southeast to its confluence with the San Rafael River. Precipitation in the upper canyon (75–100 cm annually) comes primarily from winter snows. In the lower regions of the canyon, precipitation (30 cm) mainly comes in the form of high-intensity summer thunderstorms.

Two 430-megawatt, coal-fired electric generating units have been built by Utah Power and Light Company near the mouth of Huntington Canyon. To provide water for the plant, a 36.9×10^6 m^3 (30,000 ac-ft) reservoir was constructed on Huntington River 32 km upstream (Fig. 1). The reservoir (Electric Lake) began to fill the fall of 1973. Since then, river flows and water temperature and quality have been altered below the dam. As stated by Ward and Stanford (1979), "the river continuum . . . is profoundly interrupted when dams are employed by man to impound or divert river flow." The resultant effects of these changes on Huntington River macroinvertebrates were the major concern of this study.

Most impoundment related impacts on receiving streams can be classified into seven basic types: (1) nutrients and fine sediments from reservoir basins being washed downstream (mainly in new impoundments), (2) addition of plankton to downstream reaches, (3) discharge of sediment-free water from the reservoir, (4) alteration of natural water temperature regimes, (5) alteration of natural flow regimes, (6) water chemistry changes created by the impoundment, and (7) obstacles to primary macroinvertebrate recolonization mechanisms.

Although an effort may be made to remove organic materials from new reservoir basins before filling (trees, brush, and grasses), soils still contain quantities of soluble and small

[1]Aquatic Ecology Laboratory, Department of Zoology, Brigham Young University, Provo, Utah 84602.

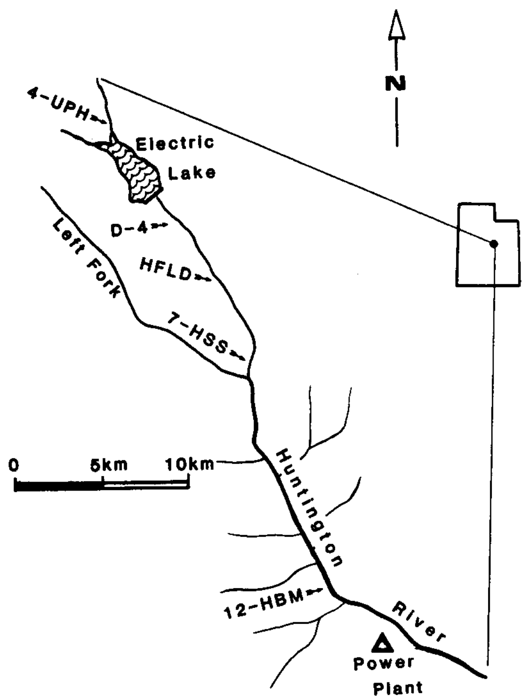

Fig. 1. Huntington River drainage showing location of Electric Lake Reservoir, the Huntington Power Generating Station, and study sampling stations.

particulate nutrients. These nutrients enter reservoir waters during filling and flow from the reservoir with release water. Silts produced during construction, in combination with nutrients from the impoundment in release waters, can cause increased algal growth below a dam (Mulligan and Baranowski 1969). Spence and Hynes (1971) noted that plankton from an impoundment often produced a macroinvertebrate community composition in the receiving stream like that found in streams affected by moderate organic enrichment. Increased epilithic algae below impoundments can result from clarifying effects of the reservoir, stabilization of substrates, increased nutrients, and higher water temperatures (Lowe 1979, Ward 1976a). Barber and Kevern (1973) found that increases in periphyton density decreased water current, with a corresponding deposition of fine sediments and detrital materials. These mats of algae can act as additional habitat, trapping detrital material and forming false bottoms (Pfitzer 1954), offering considerable shelter from the current and providing abundant food supply for some macroinvertebrates (Spence and Hynes 1971).

In a study on the North and South forks of the Anna River in Virginia, Kondratieff and Voshell (1981) indicated that low winter river water temperatures persisted longer into the summer, and warmer summer temperatures persisted longer into the fall in the impounded than in the unimpounded river. Ward (1976b) reported that some insects cannot lay eggs when temperatures are low, and eggs of others will not develop without cold temperatures. Eggs of some mayfly species must be subjected to near freezing temperatures before hatching (Lehmkuhl 1972). Altered temperatures can cause development and emergence to occur earlier or later than they would naturally (Coutant 1968, Nebeker 1971, Lillenammer 1975).

Rivers have distinct natural flow regimes depending on several factors, including the size of the area being drained, when and how much precipitation falls, and when and how fast snow melts, etc. Aquatic life is accustomed to, and even benefits from, natural flow regimes found in nature. Insects avoid natural spring runoff stresses by burrowing into the substrate, emerging as adults prior to runoff, or seeking slower portions of the river. They have adapted to the natural high and low flow patterns found in rivers. If, however, a large release was made "out of season" with high water velocity and accompanying sediment movements, fragile emerging adults could be killed before leaving the stream, early instar larvae could be covered with sediments and smothered, or sediments could interfer with feeding behavior. But if normal high flows are eliminated, sediments and algal growth would be allowed to build up from year to year, covering a major portion of available substrates (Ward 1974).

If macroinvertebrate species are eliminated from a stream reach by a short-term perturbation, recolonization is usually quick. This is accomplished by: (1) immatures drifting downstream from upstream unimpacted reaches, (2) adults immigrating to the impacted area and depositing eggs (adults could come from upstream or downstream), and (3) immatures crawling into the area from downstream. Drift recolonization is apparently the most important of the three recolonization mechanisms. Drift was shown by Gore (1979) to recolonize a newly openned river channel reach in 120 days. Bishop and Hynes (in Gore 1979) estimated that upstream migration accounts for only about 6.5% of the recolonization in a natural stream community. In a study made by Hilsenhoff (1971) of a newly dammed stream in Wisconsin, some insects did not appear in the community below the dam for two years after they were eliminated. Apparently, elimination of drift by an impoundment slows recolonization of the impoundment downstream. Large impoundments can interfer with downstream drift of immatures and adult immigration both up canyon and down.

METHODS

This report presents a summary of the results of studies at five stations on Huntington River, one above Electric Lake (Station 4-UPH) and four stations below the lake (Stations D-4, HFLD, 7-HSS, 12-HBM) (Fig. 1). Station 4-UPH is located between Swens and Burnout Canyons approximately 10 km above Electric Lake Dam at an elevation of 2620 m. This station was not affected by dam construction, but construction of a youth camp 5 km upstream added sedimentation and organic enrichment during 1976 to 1978. Station D-4 is located 2 km below Electric Lake Dam at an elevation of 2530 m. Station HFLD, located 7 km below Electric Lake Dam at an elevation of 2470 m, was established in 1978 to describe sediment movement downstream. Station 7-HSS is located 13 km downstream from Electric Lake Dam at an elevation of 2410 m. Station 12-HBM is located approximately 32 km downstream from Electric Lake Dam at an elevation of 2010 m and 1.7 km above the Huntington Canyon Generating Station.

Water quality data used in this report were obtained from: (1) water quality samples collected and analyzed by the Environmental Analysis Laboratory, Brigham Young University, (2) a water quality monitoring program conducted by Vaughn Hansen Associates, Salt Lake City, Utah, and (3) on-going water quality monitoring by the Bureau of Reclamation, USDI. Algal bioassays were conducted by Porcella and Merritt (1976). Bioassay test conditions were generally equivalent to EPA procedures (EPA 1971). Several constant temperature Ryan thermographs were placed in selected sites on Huntington River during the 1971–74 period. Temperatures were measured during winter, spring, and summer months. All stream discharge values were taken from USGS and UP&L gauging station records. Results are presented as daily and monthly mean cfs discharges.

Three to four sediment samples per station per date were taken from potential trout-spawning gravel beds using a 15.24 cm diameter steel cylinder sampler similar to the one described by McNeil and Ahnell (1964). Samples were generally taken during early spring, midsummer, amd late fall each year, with extra samples taken in relation to increased discharges from Electric Lake. Sediments were dried and then separated into specified size classes: gravel (>4.75 mm diameter), coarse sand (2.0–4.7 mm), medium sand (0.5–1.99 mm), fine sand (0.075–0.49 mm), and silt/clay (<0.074 mm) (Cummins 1962). The total amount <0.85 mm is referred to as total fines at each station.

Macroinvertebrate samples were taken with a Surber Sampler (Surber 1937) modified by Winget (Fig. 2). The modified sampler was designed with a larger collecting bag, to prevent backwash when collecting in deep water, and 280-um mesh netting to collect small instar larvae. Samples were taken using the stratified random method (Weber 1973) with rubble substrate in riffles as selected habitat. Four samples per station per date were collected, fulfilling guidelines given by Elliott (1971). In the field, each sample was washed into a plastic dish pan and covered with a saturated sodium chloride (NaCl) solution (specific gravity 1.19), which caused macroinvertebrates and organic debris to float above the inorganic sediments (Rees and Winget 1970). Floating organic material was poured off through a 250-um mesh sieve (Tyler equivalent 60 mesh), placed in a labeled bottle, and preserved in 10% formalin solution.

At the laboratory, samples were divided into eight equal parts using a subsampler (Waters, 1969). Two to four subsamples, depending on the estimated total number of

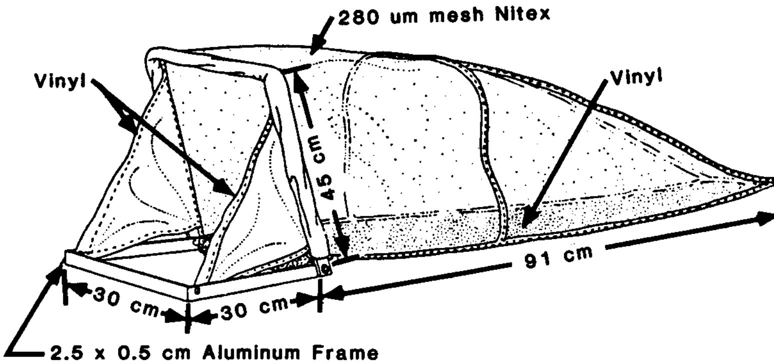

Fig. 2. Surber sampling device as modified by R. N. Winget in 1971.

insects in the sample, were randomly selected for processing. The remainder of the sample was preserved for later reference. Organisms were sorted to taxonomic groups, identified and counted, and body lengths of selected taxa were measured in mm, not counting antennae or cerci length (length measurements were used to define life histories). Organisms were dried for 8–10 hours at 80 C and then weighed to the nearest 0.1 mg. Data were analyzed for total, and by taxon densities and biomass, and community dominance diversity (H by Shannon and Weaver). Beginning in 1978, taxon (TQ) and community (CTQa and CTQd) tolerance quotients (Winget and Mangum 1979, and Winget 1984b) were calculated.

Results And Discussion

Water Quality

Before Electric Lake began filling, bicarbonate alkalinity in Huntington River generally had an annual cycle with values 175–250 mg/l from the first of August through the beginning of runoff in April or May; as runoff increased, alkalinity decreased until at peak runoff it was only 125–150 mg/l; and as runoff decreased through June and July, alkalinity gradually increased again. With Electric Lake and the moderated flows, alakalinity levels have had less seasonal fluctuation, with lows corresponding to high reservoir discharges rather than spring runoff. Bicarbonate alkalinity average concentrations during 1971–1973 (preimpoundment) and 1974–1979 (impoundment) were 145–179 and 154–216 mg/l, respectively.

The pH of Huntington River waters before Electric Lake generally ranged from 7.5 to 8.8, with lower values during winter/spring and higher values during summer/fall. Average pH for 1971–1973 was 8.3–8.5 at all stations. Huntington River is a bicarbonate-buffered stream accounting for the small pH changes recorded. After Electric Lake began to fill, pH of waters entering Huntington River from the reservoir were 7.0–8.3, with 7.0–7.6 being the most common. Moving downstream, pH soon increased to near preimpoundment values. For the period 1974–79, pH averaged 8.1 above Electric Lake (Station 4-UPH), 7.5 at the dam outfall, 7.8 at Station D-4 (2 km below the dam), 8.0 at Station 7-HSS (13 km below the dam), and 8.2 at Station 12-HBM (32 km below the dam).

Specific conductance was highly variable and increased downstream. Yearly average conductivities above Electric Lake ranged from 230 to 280 umhos/cm, 249 to 346 at the outlet, 317 to 470 at Station 7-HSS, and 334 to 519 at Station 12-HBM. Annual mean sulfate concentrations at Stations 4-UPH and 12-HBM were approximately 5 mg/l and 13.4 mg/l, respectively.

Nutrients in Huntington River, represented as nitrate nitrogen and ortho-phosphate, underwent significant changes in relation to Electric Lake. Before Electric Lake, both nitrate and ortho-phosphate concentrations increased with spring snowmelt. Dissolved nutrients from litter decomposition were

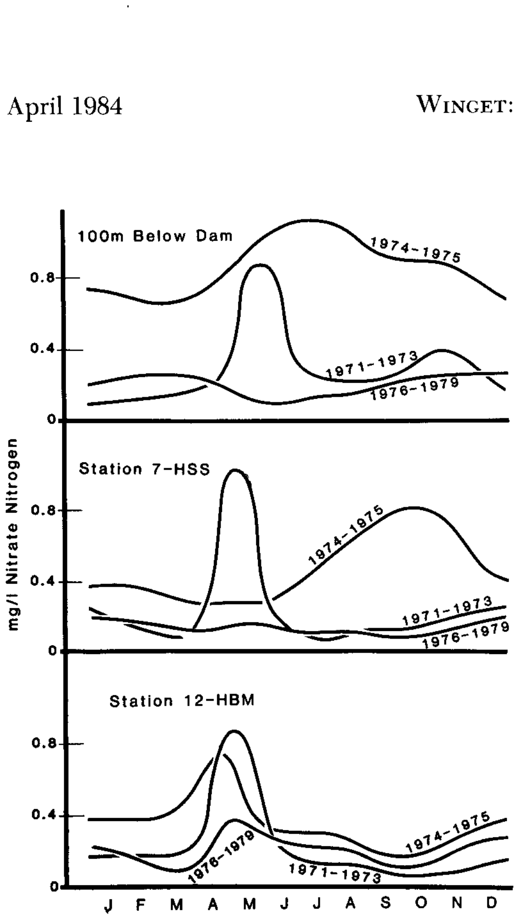

Fig. 3. Average nitrate concentrations for 1971–73 (preimpoundment), 1974–75 (initial filling period), and 1976–79 (impounded) at three stations on Huntington River.

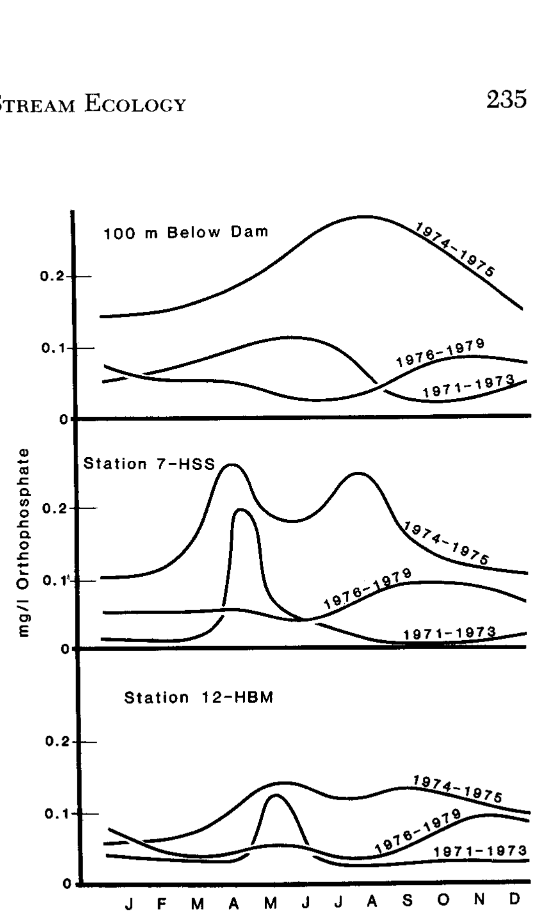

Fig. 4. Average ortho-phosphate concentrations for 1971–73 (preimpoundment), 1974–75 (initial reservoir filling period), and 1976–79 (impounded) at three stations on Huntington River.

carried into the stream with surface snowmelt, causing April–June peaks in concentration (Figs. 3 and 4). Borman and Likens (1979) found that plant communities accumulate nutrients and some salts in a plant-soil reservoir, and removal of the plant cover results in increases in concentration of nutrients and salts in surface runoff waters. During the 1974–75 period, following clear cutting of trees within the basin, waters began to cover exposed soils. Leaching of nutrients and salts was rapid, and increased ortho-phosphate and nitrate nitrogen levels were obvious below Electric Lake downstream to Station 7-HSS. Biological removal in the stream plus dilution with Left Fork waters lowered concentrations so that at Station 12-HBM increases were not evident.

Hannan (1979), in a review of chemical modifications in reservoir-regulated streams, reported that biological nutrient depletion within reservoirs is common. During the 1976–19 period nitrate nitrogen levels were lower than preimpoundment years at all stations below the reservoir (Fig. 3). Huntington River is nutrient poor, so biological activity within the reservoir readily captured most of the nutrients entering the system, resulting in low levels of dissolved nutrients in discharge waters. Ortho-phosphate concentration changes were similar to nitrate nitrogen, except ortho-phosphate showed a greater increase during fall overturn of Electric Lake than did nitrate nitrogen.

Results of a bioassay test of Huntington River and Electric Lake water illustrated the nutrient-poor nature of these waters. Samples for bioassay were taken from Huntington River at Station 4-UPH and from the reservoir surface near the dam in early August 1976. Chemical tests indicated phosphorus (P) levels in both samples at growth-limiting concentrations. Ratios of total inorganic nitrogen (N) to total P were 65 at inlet and 376 at site 1, indicating P strongly limiting relative to N (N/P>15 indicates P deficiency and $N/P<15$ indicates N deficiency). Bioassay results were essentially the same for the two samples. The samples responded to P alone and N plus P but not to N alone or trace elements (T.E.) alone. Essentially no growth occurred in either sample alone, thus verifying the low P levels measured chemically. Although nitrogen and phosphorus are generally considered the most important limiting nutrients for aquatic ecosystem primary productivity, based on biogeochemical reasoning (Hutchinson 1973), carbon dioxide is also often limiting. Carbon dioxide was not considered limiting because it can be taken from the abundant bicarbonates in Electric Lake and Huntington River. The geology of drainage basins in the Huntington Canyon area indicates that insolubility of trace elements might make them also limiting in some cases.

Dissolved oxygen (DO) in Huntington River most frequently ranges between 8 and 11 mg/l. Annual average DO for most stations was 8–10 mg/l. In 1974, the average DO measured above Electric Lake was 10.3 mg/l, compared with 7.8 at the dam outlet, and 9.8 at Station D-4. Dissolved oxygen concentrations react quickly to the turbulent flows in Huntington River and low water temperatures; thus concentrations were near saturation within a few km below the dam.

Water Temperature

Reservoirs can alter downstream water temperatures in several ways: (1) increased diurnal constancy, (2) increased seasonal constancy, (3) summer depression, (4) summer elevation, (5) winter elevation, and (6) thermal pattern changes (Ward and Stanford 1979). Thermal changes in Huntington River are of increased diurnal and seasonal constancy, summer depression, and winter elevation.

Changes in water temperature at the Electric Lake outlet were less dramatic compared with preimpoundment water temperatures, but in response to environmental stimuli, water temperatures returned to near preimpoundment ranges within a short distance downstream. Factors such as solar radiation, air temperature, water turbulance (channel morphology), amount of flow (reservoir discharge), turbidity, and TDS all affect a stream's rate of water temperature adjustment to "*normal*." *Normal* refers to the temperature the water would be without the reservoir, or under natural conditions.

Before Electric Lake (1971–1972), diurnal summer fluctuations often spanned 10 C, but in winter and during peak runoff, diurnal fluctuations seldom exceeded 3 C (Fig. 5). Before Electric Lake, seasonal fluctuations at the dam site were 18–20 C, but after dam completion (1974) they were only 4–5 C. Winter water temperatures (December) at the outlet were 4–5 C higher in 1974 than in 1972, compared with only 1–2 C 2 km downstream. Spring temperatures (June) were 5–7 C lower in 1974 than in 1972 at the outlet, compared with only 3–4 C 2 km downstream. The greatest difference was during the summer, when Electric Lake discharge waters were 3–14 C cooler than stream water temperatures before Electric Lake. This compares with a difference of 3–8 C 2 km downstream.

By the time Huntington River waters reached station 7-HSS, 13 km below Electric Lake, water temperatures had nearly equilibrated with environmental factors (Fig. 5). There were no noticeable differences between pre- and postimpoundment water temperatures. Direct thermal impacts to biota from Electric Lake are likely limited to a 3–5 km reach of stream below Electric Lake. Because of downstream drift behavior of macroinvertebrates, the actual impact may extend considerably further downstream. Evidence discussed later indicates that in Huntington River thermal impacts on stream biota are rather minor when compared to impacts from flow modification and sedimentation.

Sedimentation

No measurements of stream sediments in Huntington River were made prior to spring 1974. Because of this, some basic assumptions have been made: (1) measurements made at Station 4-UPH above Electric Lake represent a close approximation of sediment characteristics in the vicinity of Electric Lake Dam (Station D-4) before construction (1971); and (2) sediment composition during 1975 at Station 7-HSS represented relatively unimpacted conditions, reflecting preimpoundment sediment conditions below Electric Lake Dam.

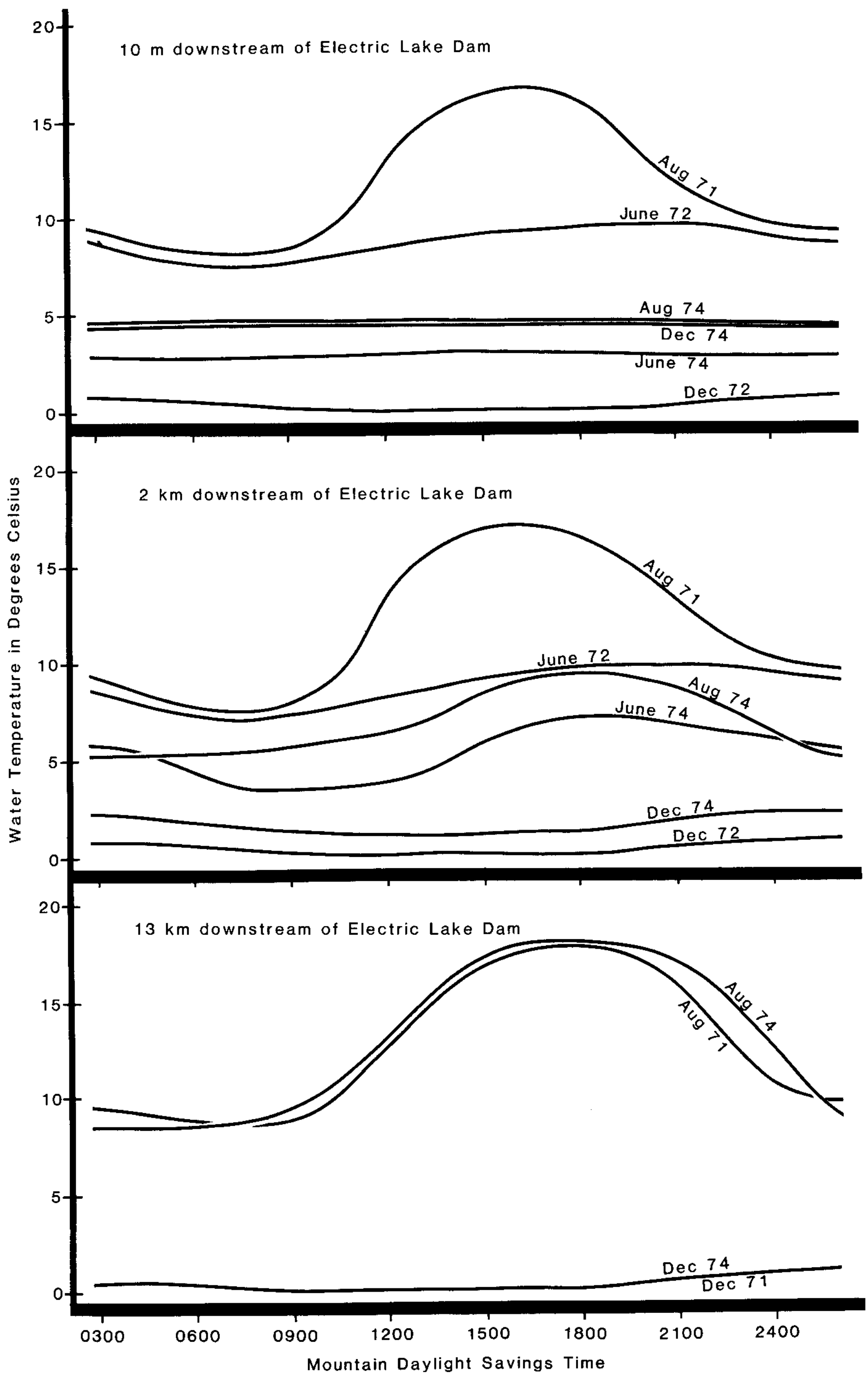

Fig. 5. Fifteen-day mean water temperatures by hour during June, August, and December of 1971 or 1972 (pre-impoundment) and 1974 (early impoundment) at 10 m (outfall), 2 km (Station D-4), and 13 km (Station 7-HSS) downstream from Electric Lake Dam.

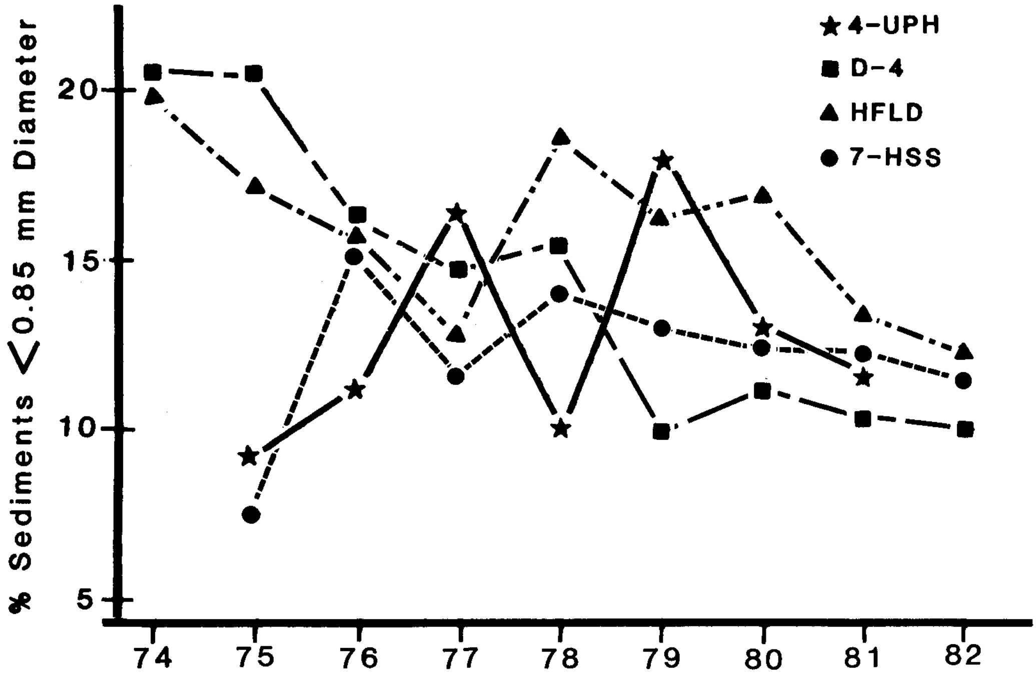

Fig. 6. Annual average percent by weight of sediments with diameter <0.85 mm at four stations on Huntington River 1974–82.

Before Electric Lake, Huntington River spawning gravel beds were composed of 75–90 % gravel, 7–12 % coarse sand, 2–7 % medium sand, and 6–15 % fine sand plus silt/clay. This compares closely to values reported for several California streams (Burns 1970) and the South Fork of the Salmon River (Platts and Megahan 1975). During construction and up through 1982, composition changed below Electric Lake to: 60–85 % gravel, 5–12 % coarse sand, 2–15 % medium sand, and 5–25 % fine sand plus silt/clay.

As in other studies (Cordone and Kelly 1961, McNeil and Ahnell 1964, Burns, 1970), sediment composition of spawning gravels was summarized as percent of the total sample passing through a 0.850-mm mesh screen (Fig. 6). It is assumed that, prior to construction of Electric Lake Dam, percent fines (<0.85mm) at all sampling stations was below 15. McNeil (1964) reported 15 % as the maximum acceptable level of fines for succesful trout spawning. Station 4-UPH, located upstream from reservoir construction activities, was to have been the control station, but construction and other land-use activities upstream resulted in increased loading of fine sediment from 1975 to 1977 (Fig. 6). The moderately low water year of 1976 and the drought of 1977 resulted in a decrease in percent gravels as medium and fine sand plus clay/silt accumulated (Fig. 7). The high water year of 1978 resulted in increased relative gravel content to 1975 levels. The low water year of 1979, in addition to upstream sedimentation, resulted in increased levels of fines. As construction activities ended upstream and stream banks became revegetated, levels of fines dropped from 1980 to 1982.

Following completion of Electric Lake Dam, reservoir gates were closed during the greater part of January and February 1974, reducing flows to 1 cfs (0.03 cms) and less below the reservoir, resulting in a covering of stream substrates with fine clay and silt particles. During periods of natural flows, these materials would have been kept in suspension or deposited in areas of low water velocity. Because of low flows and associated low water energy, even riffle areas were covered and interstitial spaces sealed with fines. Brown trout eggs, alevins, and fry were eliminated from a 10-km reach of stream immedi-

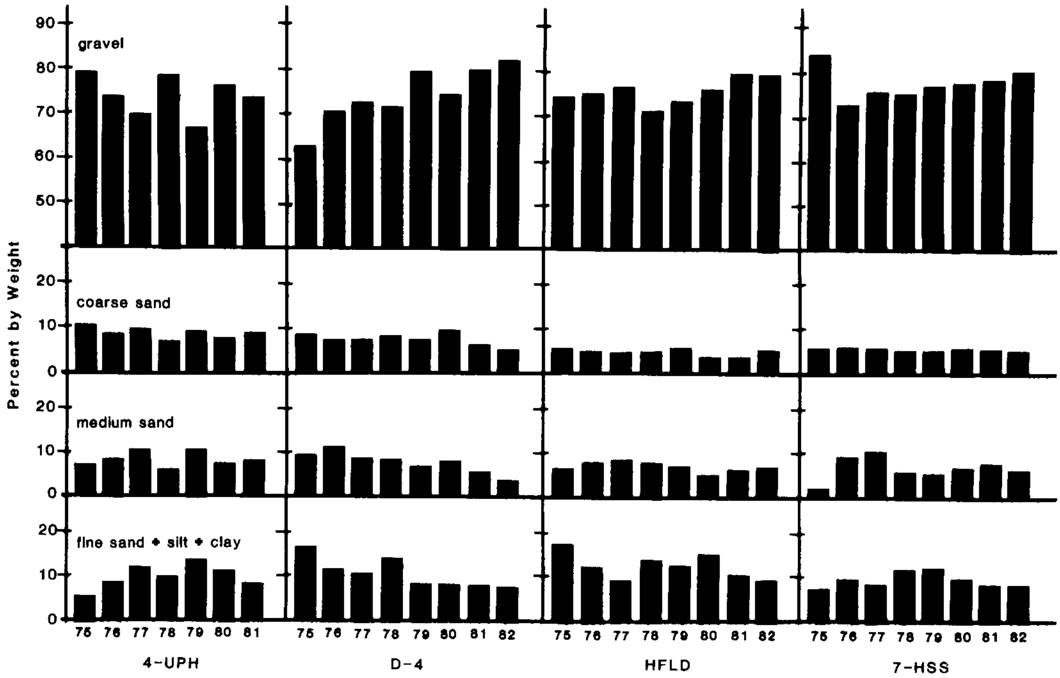

Fig. 7. Annual average by weight sediment composition as gravel, coarse sand, medium sand, and fine sand plus silt and clay for four stations on Huntington River 1975–82.

ately downstream from the dam (pers. comm with John Livesay, UDWR, Price Office; and Gervais 1975). Stoneflies (Plecoptera), mayflies (Ephemeroptera), and caddisflies (Trichoptera) were also largely eliminated from this same stream reach.

Knopp (1978) and Gervais (1975), both employed by the Manti–LaSal National Forest, reported (unpubl. management reports) sediment buildup in Huntington River, largely confined to an 8 km reach of channel immediately below Electric Lake Dam. They concluded that "a reduction in the reproductive potential [for fish] of the channel gravels" had occurred due to the accumulation of "large quantities of sediments over a prolonged period in Huntington River."

During an August 1978 flush, flows were increased from 15–20 cfs (0.4–0.6 cms) to 40–45 cfs (1.1–1.3 cms) and held there 2–3 hr; then increased to 155 cfs (4.4 cms) over a 16-hr period and held 3–4 hr; then flows were increased to 185 cfs (5.2 cms) and held 28–30 hr; then decreased back to 15–20 cfs (0.4–0.6 cms) over a 24-hr period. A total of 4 days were involved. Suspended solids showed a major increase (as mg/l) in immediate response to the first two flow increases, but then levels dropped off rapidly even though flows continued to increase. The flush resulted in a visible decrease in surface fines at Station D-4; but yearly average level of fines increased over 1977 (Fig. 6). At Stations H-FLD and 7-HSS, even though large amounts of fine sediments were put in suspension, considerable amounts remained in the channel. The flush was not of adequate duration or magnitude to transport the large load more than 3–6 km downstream. Thus, even though existing fines were removed from Stations HFLD and 7-HSS, fines from upstream reaches were apparently redeposited, resulting in increased levels. Knopp (1978) concluded that the flush was not adequate to physically move exisiting gravels—that would require flows over 300 cfs (8.5 cms).

Hansen (1970) reported that even at low discharges a stream can move some sand-size material, and the amount of sand in the total sediment load varies considerably between rising and falling stream discharges. When particle-size distribution was determined during floods, suspended sediment concentration (less than 0.063 mm) always peaked at or be-

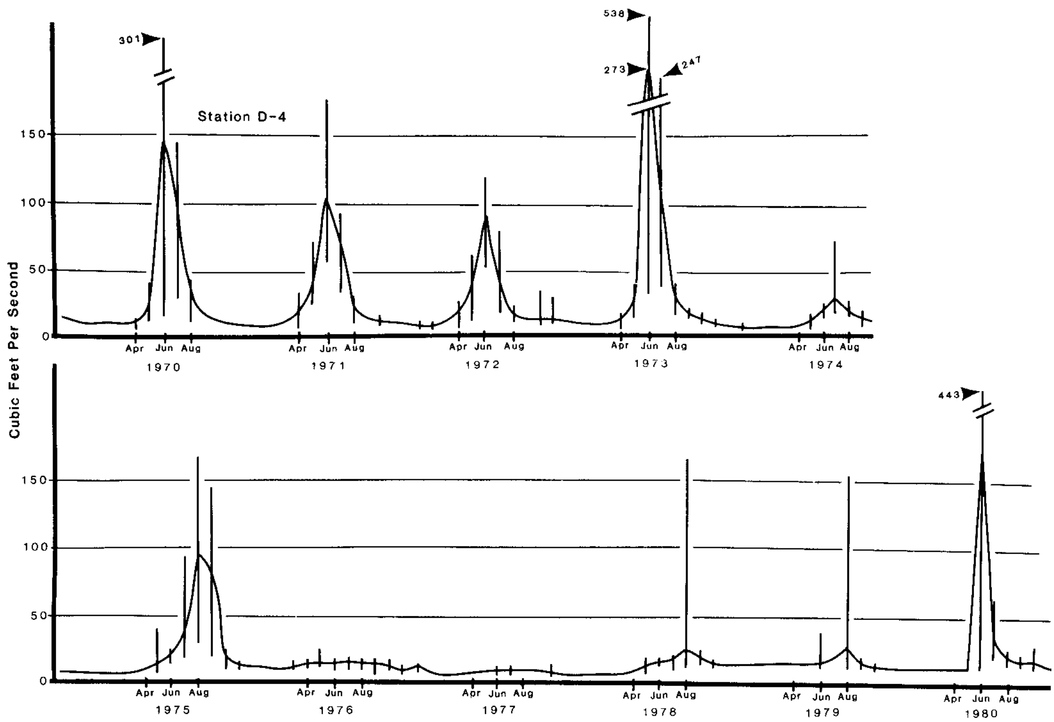

Fig. 8. Monthly average stream flows (cfs), with maximum and minimum daily average flows per month (vertical lines), at Station D-4 (2 km below Electric Lake Dam) for the period 1970–80.

fore the flood peak. However, material greater than 0.062 mm peaked later and displayed an increasing lag as it moved downstream. This lag was apparently due to the natural tendency of coarse bedload material to move at a slower mean velocity than the average stream velocity. The lag may also be related to an increase in channel sediment storage during high flow.

Station D-4, 2 km downstream from Electric Lake Dam, received a heavy load of fines during construction and early reservoir filling (1972–75), but levels of fines decreased each year, 1976 through 1979, and remained low through 1982 (Fig. 6). Reduction in fines was due to a loss of silt, clay and fine and medium sand, with a corresponding increase in gravels (Fig. 7).

At Station HFLD, levels of fines decreased yearly, from 1975 through 1977 (Fig. 6). In 1978 a large load of fines, mainly fine sand, silt, and clay (Fig. 7), was deposited at Station HFLD, probably the result of the August flush bringing accumulated fines from upstream areas. Levels of fines decreased from 1978 through 1982, but still remained higher than at the other stations.

Sediments at Station 7-HSS showed no impacts from upstream construction until 1976 – levels of fines during 1975 averaged only 8 % (Fig. 6) with gravels accounting for 86 % of the total (Fig. 7). Levels of fines nearly doubled in 1976 (15 %) and gravels dropped to only 75 %. The August 1978 flush resulted in a reduction in medium sands and an increase in silt, medium, and fine sand. From 1978 to 1982 the trend, although weak, was an increase in gravels and a decrease in fine sands, silts, and clays.

Stream Discharge

Prior to 1974, stream flows in Huntington River above Left Fork were similar to most natural mountain streams – low, nearly constant flows at 4–25 cfs (0.1–0.7 cms) from August through March; a rapid increase during spring snow-melt occurring somewhere from April through June, with monthly means between 75–200 cfs (2.1–5.7 cms); and a gradual decline through June and July (Fig. 8).

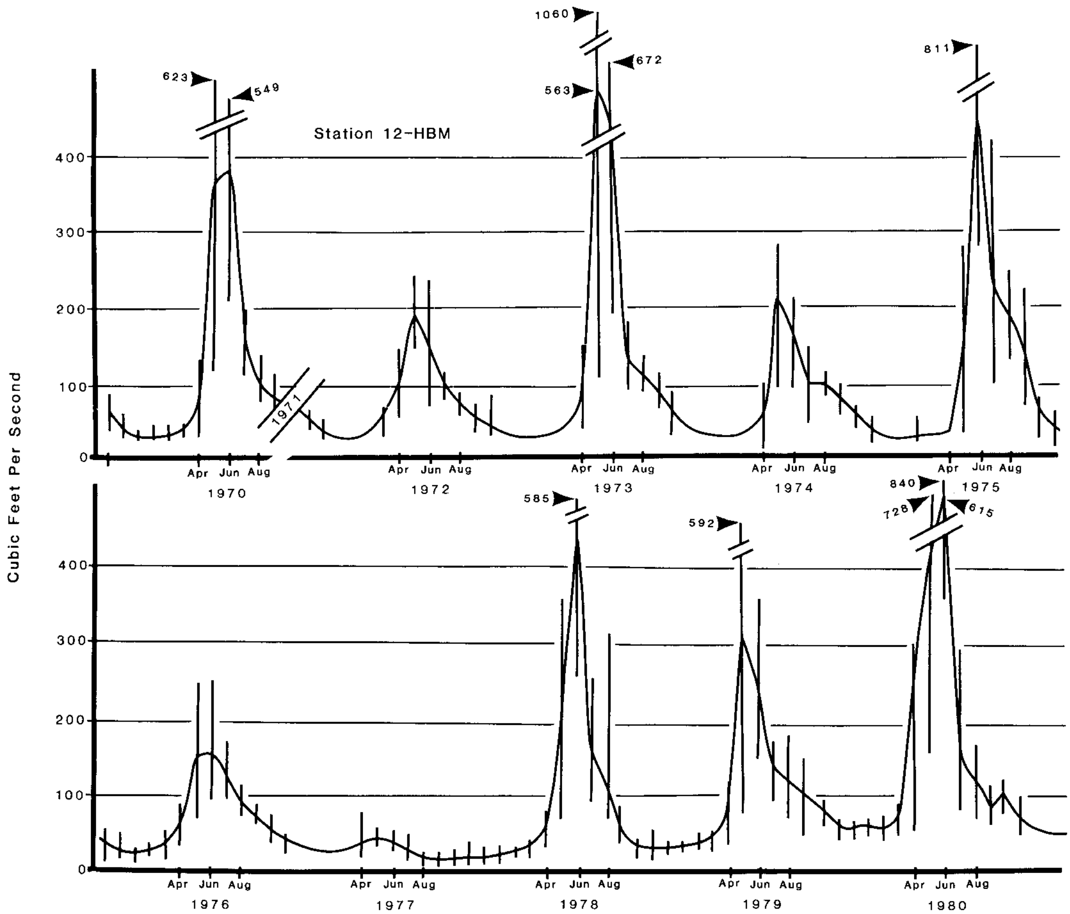

Fig. 9. Monthly average stream flows (cfs), with maximum and minimum daily average flows per month (vertical lines), at Station 12-HBM (32 km below Electric Lake Dam) for the period 1970–80.

Following completion of Electric Lake Dam (fall of 1973), flows above the dam continued to reflect the natural hydrological cycle of the canyon, including low flows during 1976 and the 1977 drought. Below the dam flows were regulated. A drawdown of the reservoir in 1975 resulted in high flows from July through September, rather than from April through June. Flushing flows were released in August 1978 and 1979, with flows of 150–190 cfs (4.2–5.4 cms) and 160 cfs (4.5 cms) for 3 days each, respectively. In 1980, spring runoff filled Electric Lake completely and water spilled over the top of the spillway for the first time, resulting in flows over 400 cfs (11. 3cms) during the month of June.

Left Fork Huntington Creek doubles the flow of Huntington River, on the average, plus several other small tributaries enter the river above Station 12-HBM. Below Left Fork, stream flows reflected a near natural flow pattern, with the exception that increases were more gradual in the spring and peak flows were extended into June and July (Fig. 9). This was the result of prerunoff and summer irrigation releases from upstream Left Fork reservoirs.

Macroinvertebrate Communities

The macroinvertebrate community of Huntington River is diverse, containing representatives inhabiting all major stream habitats, exhibiting all general stream organism habits, and exploiting all available energy types (Table 1). There are taxa considered intolerant (TQs < 36) to environmental changes as well as those classified as extremely tolerant (TQs > 90). The high quality of

TABLE 1. List of taxa collected within the Huntington River system, with habitat[a], habit[b], trophic relationships[c] and tolerance quotients for selected taxa, plus the percent frequency in which each was collected in quantitative samples. Habitat, habit and trophic relationships were largely taken from Merritt and Cummins (1978).

	Habitat	Habit	Trophic	TQ	Frequency
Nematoda	1,2	1,2,5	1,det	108	80.6
Gastropoda	1,2	1,2,3	1,2,3,5	108	5.0
Lymnaeidae					
Lymnaea	1,2	1,2,3	1,2,3,5	108	8.8
Physidae					
Physa	1,2	1,2,3	1,2,3,5	108	10.6
Planorbidae				108	10.6
Pelecypoda	1,2	1,5	4	108	35.0
Clitellata					
Oligochaeta	2	2,5	1,2	108	98.8
Hirudinea	1	1	6,8	108	2.5
Turbellaria				108	11.9
Planaria	2	2	1,2,3	108	0.6
Tardigrada					
Hydracarina	1,2	1	7,8	108	87.5
Crustacea					
Amphipoda	1,2	3,4	1,2		13.1
Gammaridae				108	0.6
Cladocera				108	2.5
Daphnia	2	3,4	1,3,4		18.7
Copepoda	2	3,4	1,3,4,det,inv	108	50.0
Cyclops					
Diaptomis					
Ostracoda	1,2	3,5	1,2,4	108	53.8
Insecta					
Ephemeroptera					
Siphlonuridae				72	0.6
Ameletus	1,2	3,4	1,2,det,dia	72	4.4
Siphlonurus occidentalis	1,2	3,4	1,2,3,6,inv,det	72	
Baetidae					
Baetis	1,2	1,3,4	1,2,3,det,dia	72	93.1
tricaudatus					
alexanderi					
bicaudatus					
intermedius					
parvus					
Callibaetis coloradensis	2	2,4	1,2,3,det	72	
Heptageniidae				48	4.4
Heptagenia	1	1,4	1,2,3	54	45.0
Cinygmula	1,2	1	1,2,3,det,dia	30	68.1
Rhithrogena robusta	1	3	1,2,det,dia	21	45.0
Epeorus longimanus	1	1	1,2,3,det,dia	21	28.1
Leptophlebiidae					
Paraleptophlebia heteronea	1,2	1,2,4	1,2,5,det,dia	24	24.4

[a]Habitat
1 = erosional
2 = depositional

[b]Habit
1 = clingers
2 = sprawlers
3 = climbers
4 = swimmers
5 = burrowers
6 = net spinners
7 = tube makers
8 = case makers
9 = divers
10 = skaters

[c]Trophic relationship
1 = collectors
2 = gatherers
3 = scrapers
4 = filterers
5 = shredders
6– engulfers
7 = piercers
8 = parasitic

det = detritus
dia = diatoms
alg = algae
inv = invertebrates
ani = animals

Table 1 continued.

	Habitat	Habit	Trophic	TQ	Frequency
Ephemerellidae				48	2.5
Ephemerella	1,2	1,2,4	1,2,det,dia	48	25.6
grandis	1,2	1,2	1,2,det,dia	24	65.6
doddsi	1	1,2	1,2,3,det,dia	2	15.6
coloradensis	1	1,2	1,2,det,dia	18	8.8
inermis	1,2	1,2	1,2,det,dia	48	73.1
tibialis	1	1,2	1,2,det,dia	24	16.2
Caenidae					
Caenis	2	2	1,2,3,det	72	0.6
simulans					
Tricorythidae					
Tricorythodes	1	1,2	1,2,3,det	108	12.5
minutus					
Odonata					
Libellulidae					
Libellula	2	2	6,inv,ani	72	
quadrimaculata					
Gomphidae					
Erpetogomphus	2	5	6,inv,ani	72	0.6
compositus					
Ophiogomphus	1,2	5	6,inv,ani	108	11.2
severus					
Coenagrionidae				108	0.6
Argia	1,2	1,2,3	6,inv,ani	108	13.1
Agrion	1,2	1,2,3	6,inv,ani	108	
Agrionidae					
Hetaerina	1,2	1,3	6,inv,ani	108	1.2
americana					
Plecoptera					
Nemouridae				24	6.9
Amphinemura	1,2	1,2	1,2,5,det	6	1.2
mogollonica					
Malenka	1,2	1,2	1,2,5,det	36	
californica					
Prostoia	1,2	1,2	3,5,det	24	20.6
besametsa					
Podmosta	1,2	1,2	5,det	12	0.6
delicatula					
Zapada	1	1,2	5,det	16	12.5
cinctipes				16	6.2
haysi					
Nemoura	1,2	1,2	1,2,5,det	24	3.8
Capniidae	1,2	1,2	5,det	32	28.1
Capnia	1,2	1,2	5,det	32	
confusa					
gracilaria					
nana wasatchae					
Eucapnopsis	1,2	1,2	5,det	18	
brevicauda	1,2	1,2	5,det	24	
Isocapnia					
crinita					
vedderensis					
Utacapnia	1,2	1,2	5,det	18	
logana					
Taeniopterygidae					
Taenionema	1,2	1,2	1,2,3,5,det	48	8.1
nigripenne					
Pteronarcyidae					
Pteronarcella	1,2	1,2	3,5,6	24	50.6
badia					
Pteronarcys	1,2	1,2	3,5,6,det	18	20.6
californica					

Table 1 continued.

	Habitat	Habit	Trophic	TQ	Frequency
Perlodidae				48	29.4
Cultus	1	1	6	12	1.2
aestivalis					
Isogenoides	1,2	1	6,inv	24	38.8
zionensis					
Diura	1	1	3,6	24	1.9
knowltoni				24	2.5
Isoperla	1,2	1,2	1,2,6,inv	48	33.1
fulva				48	30.0
ebria				24	0.6
patricia					
petersoni					
quinquepunctata					
Megarcys	1	1	6,3	24	8.8
signata					
Skwala	1	1	6,inv	18	5.0
parallela					
Chloroperlidae	1	1	1,2,3,6,det,inv	24	50.6
Alloperla					
severa					
Sweltsa					
coloradensis					
Suwallia					
pallidula					
Triznaka					
diversa					
signata					
Leuctridae					
Perlomyia	1	1,2	5,det	18	
utahensis					
Perlidae				24	0.6
Hesperoperla	1	1	6,inv,ani	18	9.4
pacifica					
Peltoperlidae					
Yoraperla	1,2	1,2	3,5,det	24	1.2
Hemiptera					
Saldidae	2	3	7,inv,ani	90	0.6
Notonectidae					
Notonecta	1,2	4	7,inv,ani	108	
Corixidae	1,2	4	7,6,alg,inv,det	108	
Gerridae					
Gerris	1,2	10	7,inv,det	72	
Mesoveliidae					
Mesovelia	1,2	10,2,3	7	108	
Veliidae					
Rhagovelia	1	10	7,inv	104	
Megaloptera					
Sialidae					
Sialis	1,2	1,3,5	inv,ani	72	1.2
Trichoptera					
Rhyacophilidae					
Rhyacophila	1	1	1,2,3,5,6	18	56.9
coloradensis					
Hydropsychidae					6.2
Hydropsyche	1	1,6	1,4,det,inv	108	67.5
Arctopsyche	1	1,6	1,4,det,inv	18	41.2
grandis					
inermis					
Cheumatopsyche	1	1,6	1,4,det,inv	108	2.5

Table 1 continued.

	Habitat	Habit	Trophic	TQ	Frequency
Psychomyiidae					
Psychomyia flavida	1,2	1,6	1,2,det,inv	108	
Hydroptilidae				108	3.8
Hydroptila	1,2	1,8	3,7,det,alg	108	14.4
Ochrotrichia	1,2	1,8	1,2,7,alg,dia	108	3.8
Stactobiella	1,2	1,8		108	0.6
Limnephilidae					7.5
Asynarchus nigriculis	1,2	1,2,3,8	1,2	108	
Limnephilus castor	1,2	1,2,3,8	1,2,5,det	108	1.2
Dicosmoecus atripes	1	2	3	24	5.6
Hesperophylax consimilis	1,2	2	5,det	108	6.2
Oligophlebodes minutus	1	1	1,2,3	24	24.4
Grammotaulius loerttae	1,2	3	1,2,3	108	0.6
Neothremma	1	1	1,2,3	8	1.9
Onocosmoecus	2	2	5	18	0.6
Leptoceridae					
Oecetis	1,2	1,2,3	5,6	54	1.2
Lepidostomatidae					
Lepidostoma	1,2	1,2,3	5,det	18	11.9
Brachycentridae					
Brachycentrus americanus occidentalis	1	1,8	1,4,3,det,dia	24	63.1
Micrasema	1	2,8	1,2,5,det	24	8.1
Oligoplectrum	1	1	1,2,3,det,dia	24	0.6
Glossosomatidae					
Glossosoma	1	1	1,2,3,det,alg	24	0.6
Protoptila	1	1	1,2,3,dia,det	32	1.2
Philopotamidae					
Chimmara	1	1	1,4	24	0.6
Lepidoptera					
Pyralidae					
Paragyractus kearfottalis	2	3,4,5	5	72	1.9
Coleoptera					1.2
Haliplidae					
Halipus	1	3	5,7,alg	54	3.1
Brychius	1,2	1	3,7,alg	54	
Dytiscidae	2	3,4	6,7,inv,ani	72	4.4
Deronectus dolerosus	1,2	3,4	7,inv,ani	72	
Agabus	1,2	4,9	7,inv,ani	72	
Acilius semiguleatus	1,2	4,9	7,inv,ani	72	
Oreodytes	1,2	3,4	7,inv,ani	72	
Rhantus	1,2	4,9	7,inv,ani	72	
Hydrophilidae	2	3	1,2,6,7	72	2.5
Helophorus	1,2	3	7,det	72	
Crenitis	1,2	5		72	
Ametor	1,2	1	1,2	72	
Elmidae	1,2	1,3	1,2,3,det,dia	104	84.4
Cleptelmis					
Heterlimnius					
Narpus					
Optioservus					

Table 1 continued.

	Habitat	Habit	Trophic	TQ	Frequency
Hydraenidae					
Hydraena	1	3,4	6,inv,ani	72	
Dryopidae					
Helichus	1,2	3	5,det	72	5.6
Amphizoidae					
Amphizoa	1,2	1	6,inv	24	
Diptera					
Tipulidae				108	1.9
Antocha monticola	1	1	1,2	72	24.4
Dicranota	1,2	2,5	1,5,6,inv,det	24	51.2
Tipula	1,2	5(det)	1,2,3,5,6	72	2.5
G (formerly called *Holorusia grandis*)				72	24.4
Eriocera	1,2	1,2,5	5,6,det,inv	72	48.1
Limnophila	1,2	5	6,inv	72	
Pseudolimnophila	1,2	5	6,inv	72	
Psychodidae					
Pericoma	2	5	1,2	36	16.9
Deuterophlebiidae					
Deuterophlebia coloradensis	1	1	3	4	1.9
Culicidae					
Aedes hexodontus	2	4	1,4	108	3.1
Chaoboridae					
Chaoborus	2	2,4	6,7,inv	104	
Dixidae	1	3,4	1,2	108	2.5
Dixa					
Simuliidae	1	1	1,4,det,alg	108	93.1
Simulium					
articum					
aureum					
canadense					
vittatum					
Prosimulium					
onychodactylum					
Cnephia					
Chironomidae	1,2	2,5,7	1,2,4,6,7	108	100.0
Ceratopogonidae	2	2,5	1,2,6,inv,det	108	41.2
Culicoides	2	1,2	1,2,6,det,inv	108	
Forcipomyia	1,2	1,2	1,2,3,det,alg	90	
Stratiomyidae					
Euparyphus	1	2	1,2,3	108	8.1
Tabanidae	2	2,5	7,inv,ani	108	2.5
Chrysops	2	2,5	1,2	100	
Tabanus	2	2,5	7	108	
Rhagionidae					
Atherix pachypus	1,2	2,5	7	24	50.6
Dolichopodidae	2	2,5	6	108	1.2
Empididae					
Hemerodromia	1,2	2,5	1,2,6,inv,ani	95	80.0
Muscidae					
Limnophora	1	5	6,inv	108	10.0
Ptychopteridae	2	5	1,2	48	2.5
Ptychoptera					
Tanyderidae	1	2	5	72	2.5
Ephydridae	1,2	2,4	1,2,5	108	

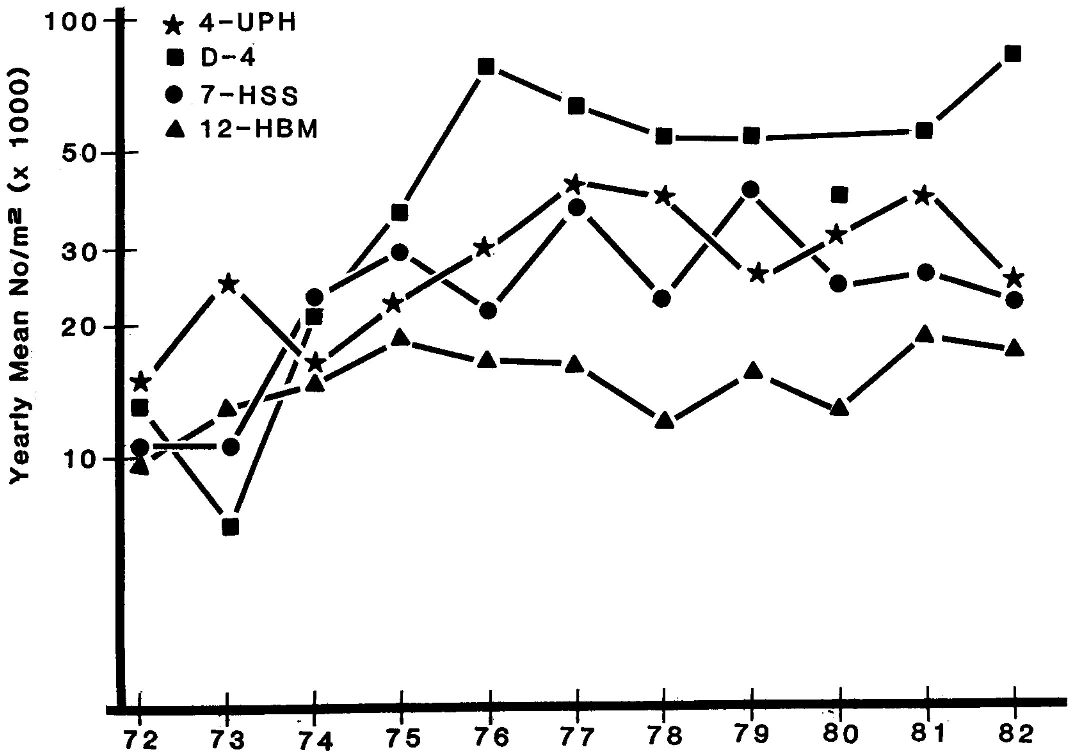

Fig. 10. Yearly average number of macroinvertebrates per square meter per sampling date at four stations on Huntington River for the period 1972–82.

Huntington River is attested to by the high percent frequency in quantitative samples of taxa with low TQ values.

At Station 4-UPH, from 1976 to 1977, a trend developed of increasing numbers but decreasing weight (Figs .10 and 11). This reflects a reduction in averge size per individual (Fig. 12) – numbers of larger-sized individuals decreased in relation to numbers of smaller individuals. Stress often has this effect on aquatic macroinvertebrate communities. Construction upstream during the 1973–77 period added sediment and organic enrichment to the upper section of Huntington River. The drainage was also receiving heavy recreational and grazing use, adding additional organic enrichment and sedimentation. The moderate water year of 1976 and the 1977 drought amplified the impacts of these environmental stresses. Conditions began to improve in 1978, as shown by an increase in dry weight associated with a decrease in numbers. Numbers in 1981, a low water year, had increased to 1977 levels, but dry weight was more than double that of 1977. High biomass continued through 1982, showing a marked improvement in the community.

Numbers and weights at Station D-4 were nearly the same as those at Station 4-UPH during 1972, even though highway bridge construction was in progress 0.8 km upstream. In June 1973 a spring flood washed out footings of the bridge, adding sands and silts that scoured the substrates at Station D-4 and eliminated most macroinvertebrates. In January 1974 reservoir release gates were almost closed, with flows less than 1 cfs (0.03 cms) for several days, eliminating most invertebrate taxa from this station. During the summer of 1974 numbers increased dramatically (Fig. 10), but with only a slight increase in weight (Fig. 11). In 1975, 1976, and 1977 the difference between numbers and weights continued to increase yearly, as shown by decreasing mean weight per individual (Fig. 12). Benthic communities below reservoirs have been noted to dramatically increase in numbers, with an increase in relative number of small larvae, following completion of dam construction (Williams and Winget 1979).

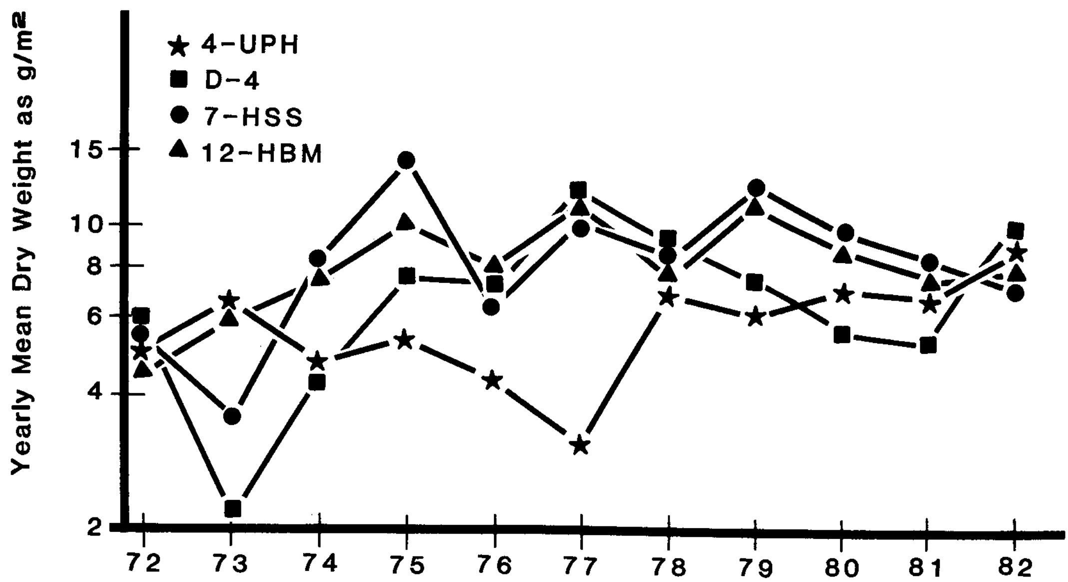

Fig. 11. Yearly average dry weight of macroinvertebrates per square meter per sampling date for four stations on Huntington River for the period 1972–82.

From 1977 to 1981, annual mean weight continued to decrease each year while numbers remained high. During 1982 there was an increase in both numbers and weight, but mean weight per organism remained low.

At Station 7-HSS the macroinvertebrate community showed an increase in numbers from 1973 to 1977 (Fig. 10), but not as dramatic as at Station D-4. From 1977 to 1982 numbers seemed to oscillate around a rather stable mean. Biomass was higher from 1974 to 1982 than in 1972 or 1973 (Fig. 11). At Station D-4 large larvae were largely eliminated and replaced by species with smaller larvae, but at Station 7-HSS it appears that reduction in large larvae was insignificant (Fig. 12). This represents a reduced impact on the aquatic community at Station 7-HSS compared to Station D-4.

The macroinvertebrate community at Station 12-HBM showed a slight increase in annual mean numbers from 1972 to 1975, a decreasing density trend from 1975 to 1978, and then an oscillation around a stable mean slightly higher than preimpoundment numbers (Fig. 10). Biomass increased from 1972 to 1975 and then seemed to stabilize at an increased level from 1975 through 1982 (Fig. 11). Mean size of community members, as average weight per organism, remained high through 1972 to 1982, with a high in 1979 and a low in 1981 (Fig. 12).

Stations 4-UPH, 7-HSS, and 12-HBM had approximately the same number of taxa per sample date (Table 2). Numbers of taxa were lower at Station D-4 but increased each year from 1978 to 1981, with a drop again in 1982.

Community Tolerance Quotients (CTQa) were similar at Stations 4-UPH, 7-HSS, and 12-HBM, indicating similar relative environmental tolerances of community members (Table 2). CTQa values were slightly lower at Stations 7-HSS and 12-HBM than at 4-UPH, a natural occurrence in a high quality stream — community diversity and quality increasing downstream until water quality or habitat deterioration begins, usually near the mouth of the canyon. Then the opposite occurs. Station D-4 had CTQa values considerably higher than the other stations, but note the yearly decrease from 1978 to 1981, a definite improvement trend below the dam. Biotic Condition Index (BCI) values showed a yearly improvement at Station D-4 and also illustrated the stresses of organic enrichment and sedimentation above Electric Lake at Station 4-UPH, showing the poorest condition during the low water year of 1981.

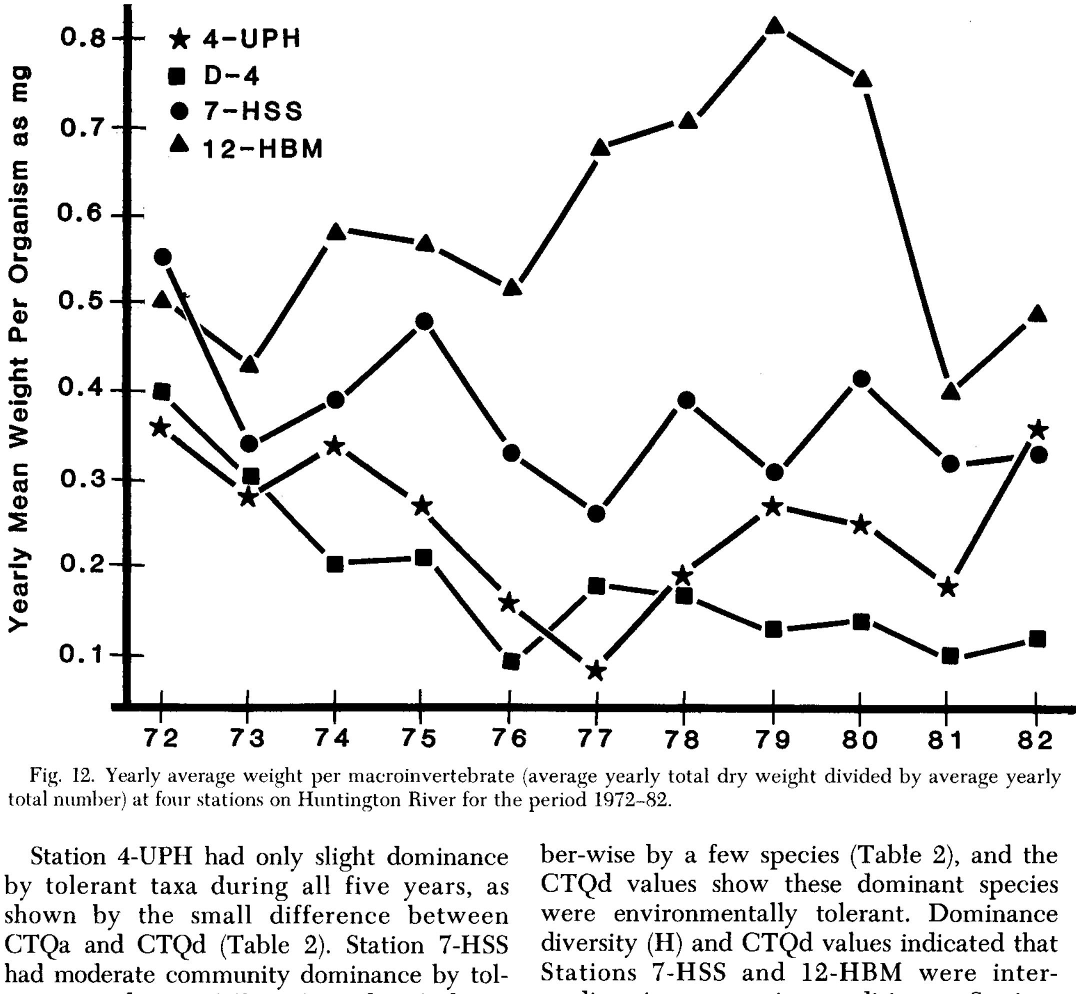

Fig. 12. Yearly average weight per macroinvertebrate (average yearly total dry weight divided by average yearly total number) at four stations on Huntington River for the period 1972–82.

Station 4-UPH had only slight dominance by tolerant taxa during all five years, as shown by the small difference between CTQa and CTQd (Table 2). Station 7-HSS had moderate community dominance by tolerant taxa during 1978, 1979, and, 1980 but a noticeable improvement occurred by 1981 and continued through 1982. Station 12-HBM macroinvertebrate community had a higher proportion of environmentally fragile taxa than Station 4-UPH (lower CTQa), but they were dominated number-wise by more environmentally tolerant species (CTQa-CTQd was greater). The community at Station 12-HBM represents a transition between the high canyon community and the lower canyon or valley communities. At Station D-4, CTQa-CTQd had a large difference (-5.5 average for all five years), indicating an unstable community structure under strong influence toward a more environmentally tolerant species composition.

The average H (Shannon-Weaver) dominance diversity index value of 1.90 at Station D-4 indicated a community dominated number-wise by a few species (Table 2), and the CTQd values show these dominant species were environmentally tolerant. Dominance diversity (H) and CTQd values indicated that Stations 7-HSS and 12-HBM were intermediate in community condition to Stations 4-UPH and D-4, illustrating moderate impact from Electric Lake compared with Station D-4. All three stations below Electric Lake showed a general recovery trend from 1978 through 1981.

Cinygmula, usually found on the surface of stable subtrates such as rubble or larger sized rocks, require at least some substrates clean of fine sediments or excessive algal growth. Species of *Cinygmula* are among the more sediment-tolerant of the family Heptageniidae. *Cinygmula* nymphs in Huntington River hatch from eggs in late fall to early winter, develop during the winter and spring, and emerge as adults in late spring through early summer following peak spring runoff. Eggs hatch approximately one month after being laid. *Cinygmula* were either in the adult or egg stages during August flushes.

At Station 4-UPH, numbers of *Cinygmula* dipped slightly from 1975 though 1977 as silt and organic enrichment entered the stream from construction and recreation upstream (Table 3). From 1978 to 1982, numbers of *Cinygmula* increased as land-use impacts decreased and increased runoff cleaned substrates of fine sediments. Below Electric Lake at Station D-4, numbers dropped during construction of Electric Lake Dam and remained low through 1978. Flushing of accumulated fine sediments from the substrates from 1975 to 1979 resulted in increasing numbers from 1978 through 1981. Numbers also increased at Stations 7-HSS and 12-HBM, probably due to moderated flows, decreased turbidity, and increased diatom growths.

The mayfly *Rhithrogena robusta* looks much like the mayfly *Cinygmula*, but gills of *Cinygmula* project dorso-laterally from the abdomen and gills of *R. robusta* extend from the ventral surface of the abdomen and overlap in such a as way to appear and function almost like a suction cup pressed against the rock. This aids *Rhithrogena* in maintaining position on rock surfaces in swift currents found in areas of clean, smooth, and angular substrates (Gore 1978), common to Huntington River. Gore (1977) reported that high water releases from a reservoir (over 120 cfs in his study) caused *Rhithrogena* to drift downstream. *Rhithrogena robusta* were present either as emerging adults or early instar larvae during August flushes, making it vulnerable to sediment movements and increased velocities associated with these flushes.

At Stations 7-HSS and 12-HBM, *R. robusta* increased in numbers from 1972 through 1982 (Table 3). At Station D-4, *R. robusta* were present before impoundment (1972), but were not found from 1973 through 1980. A few were collected in 1981 but were absent again in 1982. According to Humpesch and Elliot (1980), many species of *Rhithrogena* have temperature requirements for egg hatch. It is possible that at Station D-4 water temperatures may not have provided the proper stimulus. But, since Station D-4 is almost 2 km below the dam and water temperatures had responsed noticeabley to physical environment at this point (Fig. 5), it is probable that increases in siltation and algal growth plus regulated flows were responsible for eliminating *R. robusta*.

TABLE 2. Summary of aquatic macroinvertebrate community conditions at stations 4-UPH, D-4, 7-HSS, and 12-HBM from 1978 through 1982.

	4-UPH	D-4	7-HSS	12-HBM	4-UPH	D-4	7-HSS	12-HBM
	Number of taxa				H (Shannon-Weaver)			
1978	29.8	19.4	27.0	26.0	2.63	1.93	2.52	2.81
1979	33.3	22.6	30.4	29.8	2.94	1.78	2.53	3.12
1980	24.0	22.6	28.0	29.2	2.85	2.08	3.02	3.13
1981	30.0	28.5	32.7	32.2	3.27	2.20	3.45	3.23
1982	35.0	23.2	31.8	31.8	3.70	1.50	3.27	2.96
MEAN	30.4	23.3	30.0	29.8	3.08	1.90	2.96	3.05
	CTQa				CTQd			
1978	62.0	80.8	60.3	58.8	63.0	87.8	63.9	65.3
1979	56.7	67.4	56.6	58.0	59.3	74.2	61.4	62.2
1980	61.7	66.0	59.0	56.3	63.7	72.6	62.3	60.5
1981	65.5	64.5	57.0	60.7	64.5	68.2	56.8	64.5
1982	60.0	67.6	59.4	59.8	62.0	71.4	59.0	64.4
MEAN	61.2	69.3	58.5	58.7	62.5	74.8	60.7	63.4
	BCI				CTQa minus CTQd			
1978	88.6	68.0	92.0	95.3	-1.0	-7.0	-3.6	-6.5
1979	97.0	81.0	98.4	95.7	-2.6	-6.8	-4.8	-4.2
1980	89.3	83.6	94.0	98.5	-2.0	-6.6	-3.3	-4.2
1981	84.0	85.3	96.5	90.7	1.0	-3.7	0.2	-3.8
1982	91.7	81.4	92.6	92.0	-2.0	-3.8	0.4	-4.6
MEAN	90.1	79.9	94.7	94.4	-1.3	-5.5	-2.2	-4.7

TABLE 3. Mean number per square meter and standard error of mean (in parentheses) for several taxa at four stations on Huntington River, Utah.

Year	4-UPH	D-4	7-HSS	12-HBM	4-UPH	D-4	7-HSS	12-HBM
	Cinygmula				*Rhithrogena robusta*			
1972	1493	222	111	150	0	42	39	159
	(1355)	(62)	(13)	(96)		(20)	(12)	(51)
1973	2930	62	53	133	0	0	8	96
	(2061)	(39)	(18)	(49)			(4)	(32)
1974	3438	29	102	434	0	0	45	206
	(2039)	(11)	(45)	(178)			(13)	(56)
1975	542	42	302	1292	0	0	40	168
	(139)	(10)	(69)	(149)			(13)	(51)
1976	1108	21	78	348	0	0	220	168
	(407)	(21)	(37)	(332)			(136)	(101)
1977	1238	40	370	1324	0	0	319	453
	(1237)	(31)	(218)	(698)			(131)	(168)
1978	3728	42	202	383	0	0	32	233
	(1601)	(17)	(56)	(209)			(8)	(92)
1979	1697	131	666	384	0	0	100	304
	(576)	(37)	(280)	(216)			(70)	(282)
1980	1965	492	944	1266	0	0	53	208
	(641)	(415)	(440)	(903)			(23)	(78)
1981	4939	963	2322	1712	0	11	212	149
	(75)	(355)	(578)	(840)		(7)	(156)	(63)
1982	2066	234	1181	161	0	0	196	137
	-	(96)	(226)	(56)			(89)	(86)
	Ephemerella grandis				*Ephemerella doddsi*			
1972	32	474	458	36	209	107	1	0
	(12)	(145)	(107)	(7)	(126)	(56)	(1)	
1973	333	347	350	115	683	133	2	0
	(208)	(68)	(149)	(37)	(285)	(46)	(1)	
1974	19	1482	282	27	232	4	3	0
	(13)	(322)	(35)	(5)	(53)	(2)	(2)	
1975	4	591	317	17	359	0	0	0
	(4)	(257)	(49)	(3)	(359)			
1976	36	270	593	46	174	0	1	0
	(6)	(158)	(175)	(34)	(83)		(1)	
1977	40	1082	732	22	15	0	0	0
	(25)	(744)	(62)	(12)	(14)			
1978	53	142	236	38	108	0	0	0
	(22)	(63)	(46)	(18)	(42)			
1979	11	74	279	86	60	0	0	0
	(11)	(45)	(127)	(33)	(45)			
1980	0	7	266	57	131	3	4	0
		(7)	(85)	(26)	(72)	(3)	(4)	
1981	0	388	834	69	302	0	9	0
		(244)	(518)	(30)	(236)		(9)	
1982	43	152	582	71	560	9	6	0
	-	(60)	(234)	(28)	-	(6)	(4)	
	Pteronarcella badia				*Brachycentrus*			
1972	0	15	181	227	0	98	445	39
		(6)	(20)	(39)		(46)	(197)	(23)
1973	0	14	117	222	0	38	328	37
		(7)	(40)	(37)		(10)	(99)	(9)
1974	0	37	465	519	0	7	1023	44
		(11)	(72)	(107)		(2)	(219)	(8)
1975	0	20	464	473	0	5	566	127
		(9)	(33)	(56)		(2)	(133)	(30)
1976	0	2	158	526	0	0	180	14
		(2)	(64)	(141)			(55)	(7)

Table 3 continued.

Year	4-UPH	D-4	7-HSS	12-HBM	4-UPH	D-4	7-HSS	12-HBM
	Pteronarcella badia				*Brachycentrus*			
1977	0	22	112	193	0	164	639	48
		(15)	(46)	(46)		(164)	(238)	(30)
1978	0	0	80	230	0	186	701	80
			(26)	(113)		(81)	(193)	(17)
1979	0	0	58	304	0	54	1475	138
			(26)	(48)		(46)	(528)	(85)
1980	0	1	25	259	0	90	491	138
		(1)	(21)	(118)		(58)	(104)	(52)
1981	0	0	257	237	0	135	841	82
			(90)	(67)		(57)	(244)	(29)
1982	0	1	41	129	0	48	274	29
		(1)	(18)	(53)		(28)	(81)	(10)
	Arctopsyche grandis				*Chironomidae*			
1972	0	45	127	109	4382	3173	1434	1653
		(19)	(23)	(36)	(1296)	(458)	(260)	(491)
1973	0	103	145	169	4712	2307	2059	1764
		(55)	(65)	(66)	(1503)	(739)	(291)	(341)
1974	0	27	122	37	1759	15745	7355	2092
		(9)	(39)	(8)	(712)	(2798)	(1049)	(350)
1975	0	22	119	33	5181	21420	12390	2501
		(11)	(8)	(10)	(2055)	(4402)	(3494)	(322)
1976	0	4	167	234	10310	58107	5740	4162
		(4)	(96)	(140)	(1114)	(27716)	(2535)	(2424)
1977	0	92	125	76	21594	26782	14031	1154
		(92)	(57)	(23)	(4521)	(2464)	(6004)	(278)
1978	0	40	44	35	11914	26007	8844	2067
		(34)	(13)	(8)	(1321)	(5676)	(1872)	(454)
1979	0	23	29	80	5472	37200	8229	2057
		(16)	(9)	(50)	(2375)	(16389)	(2529)	(719)
1980	0	24	168	73	5832	11760	5475	1959
		(20)	(74)	(35)	(1857)	(4810)	(1655)	(542)
1981	0	24	255	124	8092	18608	4369	1936
		(11)	(88)	(75)	(2087)	(3432)	(808)	(366)
1982	0	14	144	107	3658	44475	2849	1467
		(9)	(59)	(41)	-	(8961)	(428)	(402)
	Simuliidae							
1972	492	133	166	73				
	(278)	(84)	(145)	(49)				
1973	97	5	51	99				
	(45)	(3)	(20)	(59)				
1974	372	4	283	218				
	(318)	(2)	(94)	(99)				
1975	234	17	510	303				
	(153)	(11)	(150)	(250)				
1976	3646	38	232	452				
	(2395)	(10)	(134)	(405)				
1977	1332	646	125	37				
	(1192)	(590)	(67)	(23)				
1978	2250	1701	277	267				
	(1077)	(763)	(147)	(155)				
1979	1253	729	1406	102				
	(970)	(156)	(821)	(89)				
1980	11394	5808	1837	1317				
	(11331)	(2201)	(1124)	(298)				
1981	1173	796	568	690				
	(484)	(401)	(149)	(332)				
1982	495	1207	770	185				
	-	(631)	(643)	(177)				

Ephemerella doddsi, intolerant of sedimentation, are found in fast-flowing streams with high-quality water and clean substrates. Adults emerge May–July and early instar larvae appear July–September. Before construction of Electric Lake, this species was commonly found at Stations 4-UPH and D-4, but only rarely at Station 7-HSS and never at Station 12-HBM (Table 3). At Station 4-UPH, the *E. doddsi* population has shown no definite trend over the 11-year study period. Numbers dropped in 1977 due to low flows plus silts from upstream land use, but numbers in 1981 and 1982 were similar to those of 1972–1975. Sedimentation and low flows nearly eliminated *E. doddsi* from Station D-4 in 1974. Numbers were even lower in 1975 and no *E. doddsi* were collected at Station D-4 from 1976 to 1979. A few individuals were found in 1980 and 1982, but not in 1981. This may represent a gradual upstream migration, or some adults may be flying down canyon past Electric Lake and depositing their eggs at this station.

Ephemerella grandis larvae are crawlers/sprawlers inhabiting detritous and sand/gravel interstitial materials between larger rock substrates. Excessive amounts of sedimentation or algal growth can reduce population levels by clogging these interstices. Early instar larvae appear July–September and adults emerge June–August.

Ephemerella grandis was commonly found throughout the study area prior to 1974 (Table 3). At Stations 7-HSS and 12-HBM, numbers of *E. grandis* remained relatively stable during the study period. Numbers declined at Stations 4-UPH and D-4, both above and below the reservoir. Since Station 4-UPH is located near the top of the *E. grandis* elevational range, the population at Station 4-UPH was probably able to remain stable as long as adults could immigrate from downstream to lay their eggs. After Electric Lake filled, upstream movement of adults was largely blocked (Electric Lake is over 8 km long), and maintenance of population numbers is now mainly dependent upon success of local emergence, mating, and egg laying. Elimination of drift from upstream sites and reduction of habitat quality hampered recovery of *E. grandis* and kept numbers low at Station D-4 through 1980. Increased numbers in 1981 and 1982 could be in response to nearly normal spring flows in 1980 and 1982.

Pteronarcella badia are omnivorous, moss and detritous composing a major part of their diet, although macroinvertebrates are also eaten (Fuller and Stewart 1977). This species is a clinger or sprawler, common in streams below 2600 m elevation, and larvae are moderately tolerant to siltation and organic enrichment. Adults emerge and early instar larvae appear in spring and early summer with rapid larval growth immediately following hatching through fall. They overwinter as medium to large larvae.

Prior to impoundment, *P. badia* was found at every station below the dam site, but not at Station 4-UPH (Table 3). Numbers were higher and fluctuated less at Station 12-HBM than at the other stations. At Stations D-4 and 7-HSS, numbers have decreased since construction of Electric Lake Dam, probably the result of increased fine sediments and algal growth and decreased detrital matter in the stream. Night time oxygen demands of macrophytes, coupled with possible low DO water released from the dam, may have also stressed *P. badia*. Although *P. badia* are relatively tolerant to warm water temperatures and low DO when compared with other stoneflies, low DO levels, even if not lethal, could cause drift out of the area (Spence and Hynes 1971).

Two species of *Brachycentrus* are found in Huntington River: *B. americanus* and *B. occidentalis*. The two species are similar in appearance during larval stages, but can be differentiated by stages of development on date of collection.

Numbers of *Brachycentrus* fluctuated at each station in response to a variety of impacts. In 1976 numbers dropped, with the greatest reduction near the dam at Station D-4 (Table 3). Numbers remained low at Station D-4 through most of 1977, but increased by October and remained high through 1978 and into 1979. In July and August 1979, when *B. occidentalis* early instar larvae should have appeared in large numbers, no *Brachycentrus* were collected. In October, when *B. americanus* should have appeared, only 11 larvae were collected at Station D-4. Low numbers continued through 1980 until a new *B. americanus* hatch showed up in the November samples. Increased numbers were collected through June 1981, but no new larvae were collected in September, and numbers remained low throughout 1982. Total numbers of *Brachycentrus* at Station 7-HSS had noticable fluctuations, but remained high in comparison with Stations D-4 or 12-HBM.

As reported by Winget (1984b), both *B. americanus* and *B. occidentalis* have adaptations to help survive natural environmental extremes. *Brachycentrus americanus* adults emerge following spring high runoff. New instar larvae appear during late summer to early fall, and by spring, larvae are large enough to cope with high water velocities and associated sediment movements of runoff. *Brachycentrus occidentalis* emerge as adults in early spring so they are out of the stream during runoff, and larvae hatch from eggs beginning in July, just after runoff and at the start of a normally stable growing season.

Short-term flushing flows were released from Electric Lake between late July and the end of August, when early instar *B. occidentalis* larvae were present (Fig. 9). Small inorganic suspended sediments could have interfered with feeding and respiration, and small larvae were probably scoured off substrates by the moving sediments. It appears that, because of the July to August flushes, the summer hatching of *B. occidentalis* has proved a disadvantage in Huntington River below Electric Lake.

Widespread and common in cold, running, high-quality waters, *Arctopsyche grandis* live on tops and sides of rocks exposed to stream current (Wallace 1975). Using pieces of debris plus silk produced in glands near their mouths, larvae construct small shelters or "retreats." Nets adjoining their retreats have mesh sizes coinciding with water currents and age of the larvae (Merritt and Wallace 1981). Small animals and debris floating in the water are caught in these nets. Larvae will at times, especially in June, July, and August, become "agressive predators," leaving retreats to attack other macroinvertebrates (Mecom 1972).

A flood in June 1973 at Station D-4 caused severe scouring of the stream and eliminated larval *A. grandis*. During August and September of the same year, early instar *A. grandis* appeared in the samples. *Arctopsyche* are generally intolerant of sedimentation, but in this study numbers do not appear to correlate with measured levels of fine sediments. The probable explanation is that *Arctopsyche* build their nets in areas of swift currents where surfaces of substrates are kept relatively clean; and as Benke and Wallace (1980) reported, the numbers of *Arctopsyche* vary according to available food quantities in stream drift. Since completion of Electric Lake, numbers of chironomid midge larvae and *Baetis* mayflies, both active drifters and common prey of *A. grandis*, have increased dramatically. More food in the stream could help offset the negative effects of increased fine sediments, helping to maintain high numbers of *A. grandis* below Electric Lake. Benke and Wallace (1980) also reported that *Arctopsyche* are common in high numbers below impoundments.

Chironomidae as a family contain some of the most tolerant of aquatic insect species. Commonly called "midge flies," chironomids are found almost anywhere there is fresh water. Chironomids are tolerant to sedimentation, and increases in amounts of fine sediments often result in increased numbers of chironomids, especially if the fines are organically rich. In Huntington River, emergence of adults and subsequent laying of eggs appeared to occur almost year round, with major peaks in March to April and September to October.

Chironomid population densities at Station 4-UPH remained stable from 1972 to 1975, but, due to heavy watershed use and upstream construction (1975 to 1978), silt and nutrient levels increased with an associated increase in number of chironomids (Table 3). From 1978 to 1982 levels of fine sediments decreased (Fig. 6), as did chironomid densities. At Station D-4, below the dam, numbers increased beginning in 1974 and remained high throughout the remainder of the study. At Station 7HSS chironomid densities slowly increased through 1974 and remained high throughout 1981. Numbers dropped in 1982, possibly in response to increased spring flows removing accumulated fine sediments. Numbers of chironomids at Station 12-HBM appeared stable throughout the 11-year study period.

Simuliidae commonly appeared at every station. Simuliid larvae cling to the silken nets spun on substrate surfaces by the larvae and, using tiny featherlike appendages near their mouths, filter organic materials, including plankton, from passing water. Some species of Simuliidae are tolerant of organic enrichment and only slightly less tolerant of sedimentation. Simuliid larvae thrive where there is a steady supply of plankton or suspended organic detritus in the stream. Early instar simuliid larvae appeared in Huntington River from late spring throughout the summer, and adults emerged from July through October.

Following impoundment of Huntington River, simuliids increased in numbers at each of the stations sampled (Table 3). As a result of heavy sedimentation from construction and scouring affects from a flood, numbers at Station D-4 dropped in 1973 and remained low through 1976. Numbers increased in 1977 and remained high through 1982. At Station 7-HSS, numbers dropped in 1973, but have been high since, especially from 1979 to 1982, with numbers noticeably higher than in preimpoundment years.

Acknowledgements

Utah Power & Light Company provided funding for the majority of this project from 1971 to 1982. Michael K. Reichert, now an environmental specialist with the Utah Division of Environmental Health, and Raymond Layton provided valuable assistance while students of the Department of Zoology, Brigham Young University. Several faculty, staff, and students of the Zoology, Botany and Range Science, Civil Engineering, and Chemistry departments of Brigham Young University provided advice, field and laboratory assistance, and use of equipment. Dr. C. Selby Herrin, Museum Computer Services, Monte L. Bean Life Science Museum, Brigham Young University, was responsible for computer storage and retrieval of data.

Literature Cited

BARBER, W. E., AND N. R. KEVERN. 1973. Ecological factors influencing macroinvertebrate standing crop distribution. Hydrobiologia 43:53–75.

BENKE, A. C., AND J. B. WALLACE. 1980. Trophic basis of production among net spinning caddisflies in a southern Appalachian stream. Ecology 61:108–118.

BORMANN, F. H., AND G. E. LIKENS. 1979. Pattern and process in a forested ecosystem. Springer-Vertag, New York, Inc. 253 pp.

BURNS, J. W. 1970. Spawning bed sedimentation studies in northern California streams. California Fish and Game. 56:253–270.

CORDONE, A. J., AND D. W. KELLEY. 1961. The influences of inorganic sediment on the aquatic life of streams. California Fish and Game 47:189–228.

COUTANT, C. C. 1968. Effects of temperature on the development rate of bottom organisms. Pages 9.13–9.14 *in* Annual Report for 1967, USAEC Div. Biol. and Med. Batelle-Northwest, Richland, Washington.

CUMMINS, K. W. 1962. An evaluation of some techniques for the collection and ananlysis of benthic samples with special emphasis on lotic waters. Amer. Midl. Nat. 67:4774–504.

ELLIOTT, J. M. 1971. Some methods for statistical analysis of samples of benthic invertebrates. Freshwater Biol. Assoc. Sci. Publ. 25. 144 pp.

ENVIRONMENTAL PROTECTION AGENCY. 1971. Algal assay procedures: bottle test. EPA, National Eutroph. Research Prog. Corvalis, Oregon.

FULLER, R. L., AND K. W. STEWART. 1977. The food habits of stoneflies (Plecoptera) in the upper Gunnison River, Colorado. Environ. Ent. 6:293–302.

GERVAIS, B. 1975. Aquatic habitat studies of Huntington Creek. Manti–LaSal National For. (est. 1975), unpubl. rept.

GORE, J. A. 1977. Reservoir manipulations in a prairie river. Hydrobiol. 55:113–123.

_____. 1978. A technique for predicting in-stream flow requirements of benthic macroinvertebrates. Freshwater Biol. 8:141–151.

_____. 1979. Patterns of initial benthic recolonization of a reclaimed coal strip mined river channel. Canadian J. Zool. 57:2429–2439.

HANNAN, H. H. 1979. Chemical modifications in reservoir-regulated streams. Pages 75–94 *in* J. V. Ward and J. A. Stanford, eds. The ecology of regulated streams. Plenum Publ. Corp.

HANSEN, E. A. 1970. Sediment movement in a pool and riffle stream. IASH-UNESCO-Symposium on the Results of Research on Representative and Experimental Basins. [Wellington, New Zealand, December, 1970] Mimeograph, U. S. For. Ser.

HILSENHOFF, W. L. 1971. Change in the downstream insect and amphipod fauna caused by an impoundment with a hypolimnion dam. Ann. Ent. Soc. Amer. 64:743–746.

HUMPESCH, U. H., AND J. M. ELLIOT. 1980. Effect of temperature on the hatching time of eggs of three *Rhithrogena* spp. (Ephemeroptera) from Austrian streams and an English stream and river. J. Anim. Ecol. 49:643–661.

HUTCHINSON, G. E. 1973. Eutrophication. Amer. Sci. 61:269–279.

KNOPP, C. 1978. Huntington Creek flushing flows. Manti–LaSal National For., Unpubl. rept.

KONDRATRIEFF, B. C., AND J. R. VOSHELL, JR. 1981. Influence of a reservoir with surface release on the life history of the Mayfly *Heterocleon curiosum* (McDonnough) (Ephemeroptera: Baetidae). Can. J. Zool 59:305–314.

LEHMKUHL, D. M. 1972. Change in thermal regime as a cause of reduction of benthic fauna downstream of a reservoir. J. Fish. Res. Bd. Canada. 29:1329–1332.

LILLENAMMER, A. 1975. Norwegian stoneflies. IV. Laboratory studies on ecological factors influencing distribution. Norwegian J. Entomol. 22:99–108.

LOWE, R. L. 1979. Phytobenthic ecology and regulated streams. Pages 25–34 *in* J. V Ward and J. A. Stanford, eds., The ecology of regulated streams. Plenum Publish. Corp.

MCNEIL, W. J. 1964. A method of measuring of pink salmon eggs and larvae. U.S. Fish & Wildl. Ser. Fish. Bull. 63, 3:575–588.

MCNEIL, W. J., AND W. H. AHNELL. 1964. Success of pink salmon spawning relative to size of spawning bed materials. U.S. Fish and Wildl. Ser. Spec. Sci. Rept.— Fish. No. 469. 15 pp.

MECOM, J. O. 1972. Feeding habits of Trichoptera in a mountain stream. Oikos 23:401–407.

MERRITT, R. W., AND K. W. CUMMINS. 1978. An introduction to the aquatic insects of North America. Kendall Hunt Publ. Co. 441 pp.

MERRITT, R. W., AND J. B. WALLACE, 1981. Filter feeding insects. Sci. Amer. 244:132–144.

MULLIGAN, H. F., AND A. BARANOWSKI. 1969. Growth of phytoplankton and vascular aquatic plants at different nutrient levels. Verh. Int. Ver. Limn. 17:802–810.

NEBEKER, A. V. 1971. Effect of high winter water temperatures on adult emergence of aquatic insects. Water Res. 5:777–783.

PFITZER, D. W. 1954. Investigations of waters below storage reservoirs in Tennessee. Trans. N. Amer. Wildl. Conf. 19:271–282.

PLATTS, W. S., AND W. F. MEGAHAN. 1975. Time trends in riverbed sediment composition in salmon and steelhead spawning areas: South Fork Salmon River, Idaho. 40th N. Amer. Wildl. and Natural Resources Conf. pp 229–239.

PORCELLA, D. B., AND L. B. MERRITT. 1976. Algal bioassay results on selected waters in the MAG Area. B Y U Environ. Anal. Lab., unpubl. rept., Brigham Young Univ., Provo, Utah. 5 pp.

REES, D. M., AND R. N. WINGET. 1970. Current investigations in Utah of the biting gnat *Leptoconops kerteszi*. Mosq. News 30:121–127.

SOLORZANO, L. 1969. Determination of ammonia in natural waters by the phenolhypochlorite method. Limnol & Ocean. 14:799–801.

SPENCE, J. A., AND H. B. N. HYNES. 1971. Differences in benthos upstream and downstream of an impoundment. J. Fish. Res. Bd. Canada. 28:35–43.

SURBER, E. W. 1937. Rainbow trout and bottom fauna production in one mile of stream. Trans. Amer. Fish. Soc. 66:193–202.

VAUGHN HANSEN ASSOCIATES. 1980. Studies of natural waters in the Huntington Creek and Rock Canyon Creek basins. Unpubl. repts. Salt Lake City, Utah.

WALLACE, J. B. 1975. The larval retreat and food of *Arctopsyche* with phylogenetic notes on feeding adaptations in Hydropsychidae larvae (Trichoptera). Ann. Ent. Soc. Amer. 68:167–173.

WARD, J. V. 1974. A temperature stressed stream ecosystem below a hypolimnial release mountain reservoir. Arch. Hydrobiol. 74:247–275.

———. 1976a. Comparative limnology of differentially regulated sections of a Colorado mountain river. Arch. Hydrobiol. 78:314–342.

———. 1976b. The effects of thermal constancy and seasonal temperature displacement on community structure of stream macroinvertebrates. Pages 302–307 *in* G. W. Esch and R. W. McFarlane, eds., Thermal ecology II., ERDA Symposium Series (CONF–750425).

WARD, J. V., AND J. A. STANFORD. 1979. Ecological factors controlling stream zoobenthos with emphasis on thermal modifications of regulated streams. Pages 35–36 *in* J. V. Ward, and J. A. Stanford, eds., The ecology of regulated streams. Plenum Publ. Corp.

WATERS, T. F. 1969. Subsampler for dividing large samples of stream invertebrate drift. Limnol. and Oceanogr. 14:813–815.

WEBER, C. I. 1973. Biological field and laboratory methods for measuring the quality of surface waters and effluents. National Environmental Research Center, Office of Research and Develop. U.S. E P A. Cincinnati, Ohio. 176 pp.

WILLIAMS, R. D., AND R. N. WINGET. 1979. Macroinvertebrate response to flow manipulation in the Strawberry River, Utah (U.S.A.). Pages 365–376 *in* J. V. Ward, and J. A. Stanford, eds., The ecology of regulated streams. Plenum Publ. Corp. 1980.

WINGET, R. N. 1984a. Methods for determining successful reclamation of stream ecosystems. *In* J. E Gore, ed., Restoration of rivers and streams. Butterworth Pub. In press.

———. 1984b. *Brachycentrus americanus* and *B. occidentalis* (Trichoptera) in a regulated stream. J. Freshwater Ecol. 2:373–381.

WINGET, R. N., AND F. A. MANGUM. 1979. Biotic condition index: integrated biological, physical, and chemical stream parameters for management. U.S. Dept. of Agric. Intermntn. Reg. For. Ser., Oct. 1979. 51 pp.