Predicting the Effects of Dam Removal on Aquatic Communities in the Salmon River, New York

Phase 1 Baseline Data

Final Report Grant 671

Submitted to the Great Lakes Protection Fund by:

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Executive Summary

Dam removal has been used as a means of river restoration but few dam removal programs have included collecting comprehensive baseline data that could be used to evaluate the effect of dam removal on the aquatic habitat. Phase 1 of this study was designed to collect data on the aquatic community (defined here as sediment, macroinvertebrates, fish, and aquatic plants) of the Salmon and Little Salmon rivers to be used in predicting the effects of removing the Fort Covington Dam.

Sand comprised the highest mean weight of any fraction at all transects sampled, ranging from 58 to 98%. The center of each river was composed primarily of coarse sand with fine sand and silt along the river banks. Embeddedness in the riffles ranged from 20 to 40% in the riffles where the substrate was cobble, boulder, and bedrock mixed with coarse sand. Deposition of sediment behind the dam was minimal, equal to about 5% of the annual sediment production of the watershed, and was concentrated on the west side of the river.

Water level changes showed that both rivers responded rapidly to inputs of precipitation, particularly snowmelt and localized thunderstorms. Hydrographs were similar at locations upstream and downstream of the dam as well as in the Little Salmon River. There did not appear to be any measurable influence to water level from the St. Lawrence River, however, a sustained decrease in water level was noted in all the rivers in September, 2004, indicating that substantial water level changes may be correlated. Ice cover formed in late November and broke up in late March. The maximum ice thickness was 0.6 m. Water temperature reached a maximum of about 27ºC in late June or July. Water chemistry tests indicated that the river water could be classified as turbid, soft

water with moderate buffering capacity. None of the parameters tested exceeded any guidelines for drinking water supply and the results were similar to that found in previous studies.

A total of 102 macroinvertebrate taxa was collected from 15 transects. Six biotic indices were constructed using 88 families of macroinvertebrates to assess the effect from the dam. There was lower diversity in the run transects than in the riffle transects and was attributed to reduced flow velocity and limited habitat in the glides. The combined score from the indices indicated that the impact to water quality was ‘slight’. Chironomidae (midges) dominated the glides but no single family dominated the riffles: dominance alternated among Elmidae (riffle beetles), Hydropsychidae (net-spinning caddisflies), Baetidae (small minnow mayflies), and Chironomidae.

Six unionid mussel species were collected in the study area. The distribution of unionid mussel species does not seem to be affected by the dam since five of the six species were collected upstream and downstream of the dam. Fewer juvenile mussels were collected than expected and may indicate a low level of reproductive success but a more thorough study would be necessary to determine this.

Forty-three species of fishes were collected in the study area and the species composition was similar to that found in a 1930 survey. Three fish species that were present in 1930 were not collected in the present study: blacknose shiner, channel darter, and Johnny darter. Six species that were not collected in 1930 were collected in the present study: longnose gar, carp, central mudminnow, American eel, largemouth bass, and brook silverside. No sea lamprey was collected but silver lamprey and American brook lamprey were present in low abundance. The most abundant fish species was brown bullhead. The major predators were smallmouth bass, longnose gar, northern pike, and walleye. Mimic shiner and bluntnose minnow were the more abundant forage fish.

Eastern sand darter (a threatened species in New York) was ninth in relative abundance and was collected upstream and downstream of the dam, in the Little Salmon River, and at the confluence of the Salmon and Little Salmon rivers.

Scores from the fish index of biotic integrity suggest that the rivers are in good condition with relatively low effects from stressors such as pollution or sedimentation. There were few instances of fishes with body injuries (lesions, sores) that could be attributed to environmental contaminants.

The abundance and distribution of aquatic plants has not changed substantially since the 1930s. The abundant plant genera at that time were *Potamogeton*, *Elodea*, and *Vallisneria*, and these genera were also abundant in the present study. These plants provided the major nursery habitat for fish larvae and juveniles in both rivers. Two exotic species were present in small areas, the flowering rush *Butomus umbellatus* and the European frogbit *Hydrocharis morsus-ranae*.

The removal of the dam will open about 22 km of river to migrating fishes, primarily longnose gar, carp, American eel, smallmouth bass, and walleye, but will allow increased movements of other fish species as well. The arrival of new migrants, such as sea lamprey and lake sturgeon, is possible after the dam is removed. Neither species has been collected in the study area. The removal of the dam will increase flow velocity and habitat diversity primarily in the reservoir with the most effect occurring just upstream of the dam. This area retains some of the rocky substrate of the original river bed and will be colonized by lotic macroinvertebrates and fishes. The riffles downstream of the dam and those at the upstream end of the reservoir will expand in size with the most expansion occurring at the riffle downstream of the dam. The downstream riffle may expand upstream to well within the former reservoir. The increased flow velocity in the run transects within the reservoir area may increase the habitat of the eastern sand darter and, if so, would mitigate for any short-term loss of habitat downstream of the dam during the dam removal process. The choice of sediment management options will determine the downstream effects of dam removal.

Introduction

Dams have altered the natural cycle of water flow, sediment transport, and water temperature regimes in many streams in the United States (Ligon et al. 1995). The presence of dams has led to changes in land use and instream morphometry that were frequently deleterious to the stream as well as costly in lost property (Schroeder and Savonen 1997). Lotic system alterations from damming have led to changes in patterns of biodiversity and fish production as well as ecosystem function and have impaired the recreational uses of the aquatic system in some cases. Dams have also prevented the range expansion of some introduced species, such as carp, and the reduction in reproductive success of others, such as sea lamprey in Lake Ontario tributaries (Christie 1974).

More than 450 dams have been removed in the US but less than 5% of these have included published ecological studies (Hart et al. 2002). Studies of the major components of a community have been limited to assessments of fish (e.g. Kanehl et al. 1997) or macroinvertebrates (e.g. Stanley et al. 2002). The reasons for the lack of studies included not having a monitoring effort in the removal plan, lack of funding, and a perceived feeling of urgency for dam removal due to economic or ecological reasons (Bednarik 2001). The potential catastrophic failure of dams (e.g. the IVEX dam, Evans et al. 2000) may have added to the feeling of urgency.

There are nearly 3000 dams in New York State, primarily in the Susquehanna and Hudson River drainages. The remainder are scattered rather evenly across the state. The majority of these dams are small, run-of-river dams that do not affect moderate or high flow in downstream reaches (Heinz Center 2002), and, additionally, many are of private ownership where ecological monitoring is rare (Bednarik 2001). These run-of-river dams may have less impact since the reservoir area is limited, and the alteration of the flow regime is restricted to low-flow periods which affect only the pool area upstream of the dam. The pool areas formed behind the dams are generally lower in species diversity (Stanley et al. 2002) since there are fewer habitat types.

The objectives of this study were to characterize the aquatic community (sediment, macroinvertebrates, aquatic plants, and fish) prior to dam removal and to predict what could be expected to happen to the community after the dam is removed. This study can be used as a model for other dam removal projects in rivers that have similar physical and biotic characteristics if our predictions prove to be accurate.

The Salmon River drainage basin extends from the northwestern part of the Adirondack Park to the international border with Quebec, Canada (Figure 1), and covers 1456 km^2 with 1000 km of stream (NYSDEC 1998). There are six dams on the Salmon River and two dams on the Little Salmon River; these are a mixture of recreational, hydropower, and abandoned mill dams.

The Salmon River headwaters emerge near Elbow Ponds (north of Loon Lake) at an elevation of 548 m. The Little Salmon River headwaters arise near Twin Ponds at an elevation of 427 m (Figure 2). Both rivers have a steep gradient (approximately 11 m/rkm) until they reach the study area where the gradient ranges between 0.6 to 1.0 m/rkm. The rivers are 4th-order in the study area.

Study area

The Fort Covington dam is located on the first riffle of the Salmon River, approximately 8 km from the St. Lawrence River. The original dam was built in the late

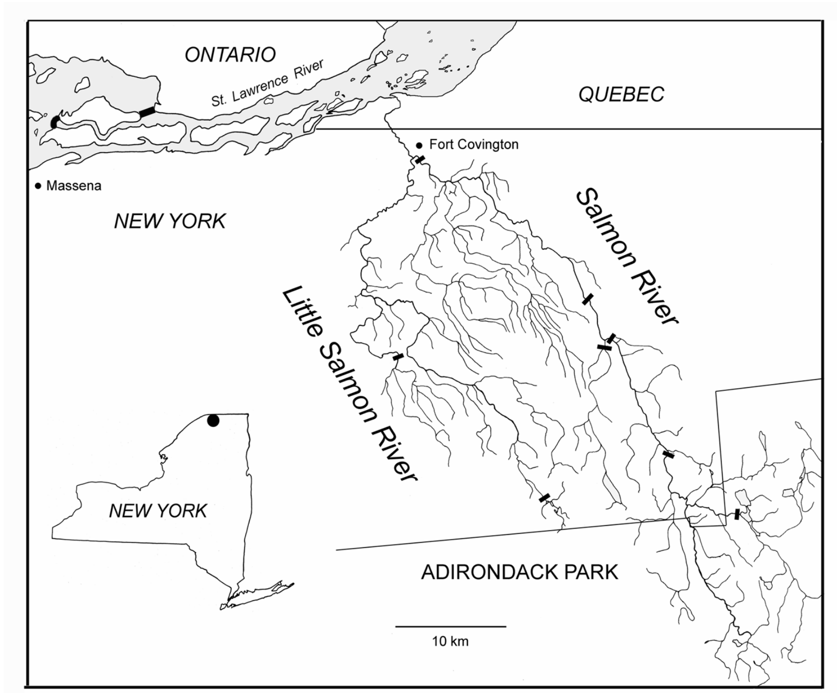


Figure 1. Location map of the Salmon and Little Salmon rivers, Franklin County, New York. The black boxes in the St. Lawrence River are the Robert Moses-Saunders Power Dam (right) and Long Sault Dam (left). The Fort Covington Dam is the most downstream dam in the Salmon River; the remaining boxes represent dams upstream from the study area.

1800s as a wood crib structure and was damaged in a freshet in 1912. It was rebuilt in 1913 as a concrete gravity, run-of-river, hydroelectric dam with a spillway that was 27 m in length, 1.2 m thick at the crest that was 2.7 m above the concrete apron. The apron extends about 6 m downstream of the spillway crest and rises about 0.3 m above the river bottom. The downstream face of the spillway is steep and the upstream face is nearly vertical. Concrete abutments are present at both ends of the dam which house ports; these are partially blocked with debris and the remains of the stop logs. There are many cracks and spalled areas in the abutments, spillway, and gate areas (Milone and MacBroom 2004). The dam created a reservoir extending approximately 1600 m upstream with a bankfull depth of 1.2 m (surface area of 4-5 ha). The river width ranges from 20 to 70 m in the Salmon River (mean = 30 m) and from 10 to 30 m (mean = 20 m) in the Little Salmon River. The channel bed is flat with a distinct thalweg at the outside of bends.

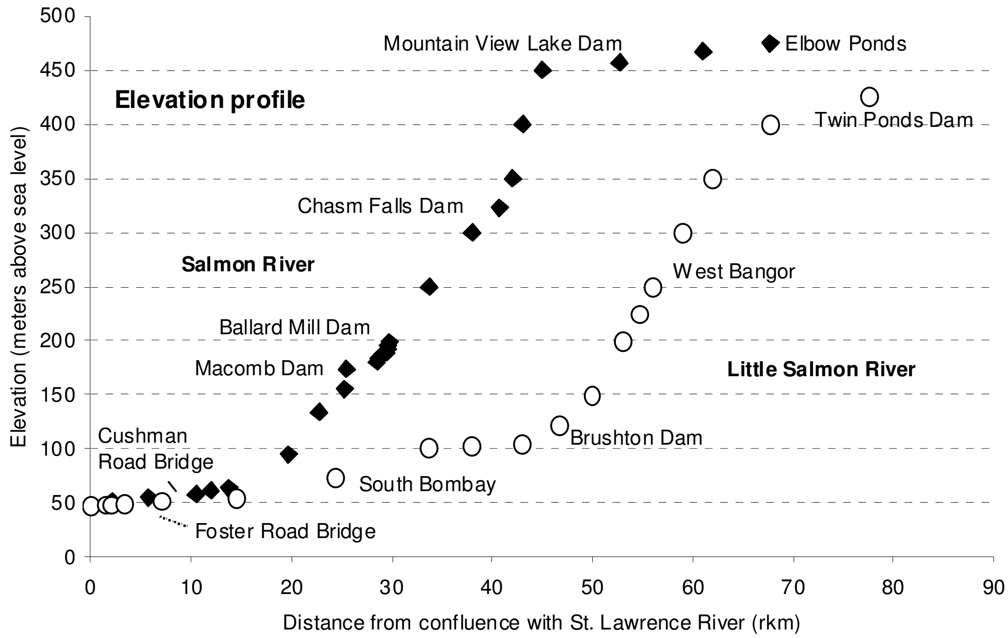


Figure 2. Elevation profile of the Salmon and Little Salmon rivers. The study area extends downstream from the Cushman Road and Foster Road bridges.

Flow characteristics. Water discharge in the Salmon and Little Salmon rivers is variable and responds rapidly to inputs of precipitation. Flooding can occur upstream of the dam particularly if ice floes collect at the dam. Mean daily streamflow can reach 3300 cubic feet per second (cfs) in the Salmon River and 2500 cfs in the Little Salmon River (Figure 3). Peak flow rates and their frequency of occurrence have been estimated at 5338 cfs every two years, 7346 cfs every 5 years, and 8754 cfs every 10 years (Milone and MacBroom 2004).

Land use. Agriculture was the primary land use (estimated within 300 m from each bank of each river), accounting for 75% of the land use (based on 1994 orthophotos,

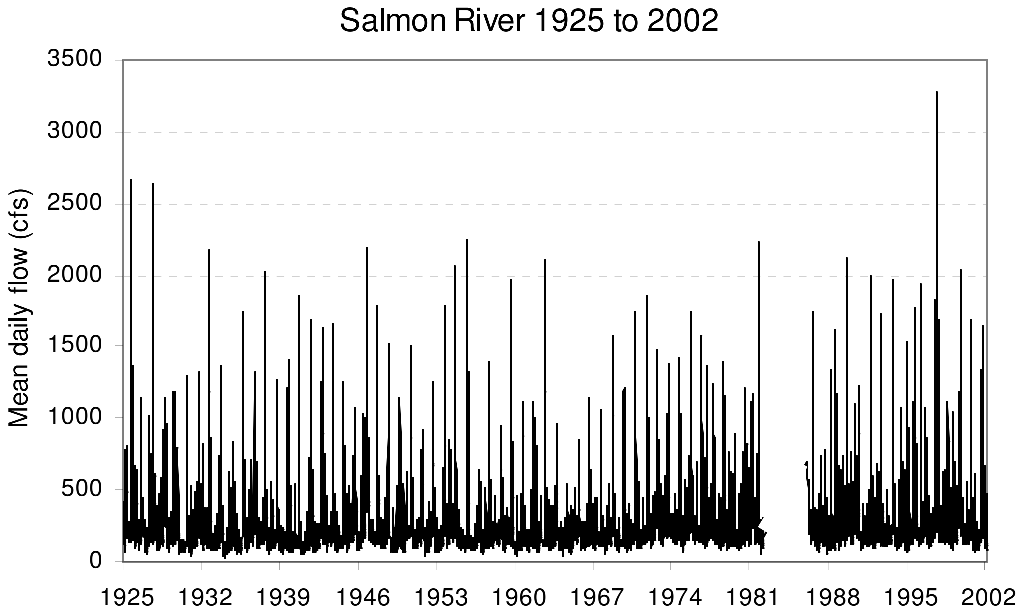


Figure 3. Mean daily flow of the Salmon River from 1925 to 2002 as measured by the USGS gage at Chasm Falls (gage 04270000). There is a break in the record from 1982 to 1986.

NYSGIS). Housing development (15%) and forest (10%) accounted for the remainder. The river banks downstream from the dam and upstream from the dam to about the extent of the first pond are bordered by residential and commercial buildings with a narrow band of trees along some areas. Wooded areas become wider upstream of the second pond and these are bordered by cultivated fields and pastures.

Geology. The Adirondack Mountains are part of a large expanse of Precambrian metamorphic rock called the Grenville Province. Uplift of this area has allowed the metamorphic sedimentary rock, which once covered the mountains, to erode into the St. Lawrence Lowland. The Salmon and Little Salmon rivers are now redistributing this sediment as well as sediment from a glacial moraine just north of Malone. The primary sediments are calcite, dolomite, and quartzite.

Methods

Sampling design. The Salmon River was considered as the experimental river and the Little Salmon River as a control: no effect was expected from dam removal on the Little Salmon River. Fifteen permanent transects were established, nine in the Salmon River and six in the Little Salmon River, divided between riffles (transects 3, 7, 9, 13, 15) and glides (transects 1, 2, 4-6, 8,10-12, 14). Transects were paired across rivers (riffle to riffle, glide to glide) with the exception of transects 1 through 3 — these three transects did not have analogous reaches in the Little Salmon River. The reservoir transects were used to detect changes in emigration from the ponds and the effects of lower water levels after dam removal. Each transect was subdivided into east, center, and west areas (when facing north). Riffle and glide areas were represented upstream and downstream of the Fort Covington Dam (Figure 4). The sampling period was from September, 2002, to October, 2004.

A brief description of transects: *Salmon River*: transects 1 and 4 were steep-sided, relatively deep (3 m), and bordered by a wooded buffer on one bank and residential housing on the other. Transect 1 was downstream of the dam and transect 4 was upstream of the dam. Transect 2 was bounded upstream by the Center Street Bridge and downstream by a railroad bridge, and was in a straight section of the river. It was bordered by residential housing with grass extending to the river banks and was relatively shallow (1.5 m) with a flat bottom. Transect 3 was the first riffle in the Salmon River. The riffle extended from upstream of the Center Street Bridge to near the base of the dam. Transects 5 and 6 were located in a straight section of the Salmon River that had a flat bottom with low, vegetated banks. Transect 5 was bordered by lawn grass on the east side and a narrow wooded buffer on the west side; transect 6 was bordered by a narrow wooded buffer on both sides and had deeper areas on both sides at the upstream end.

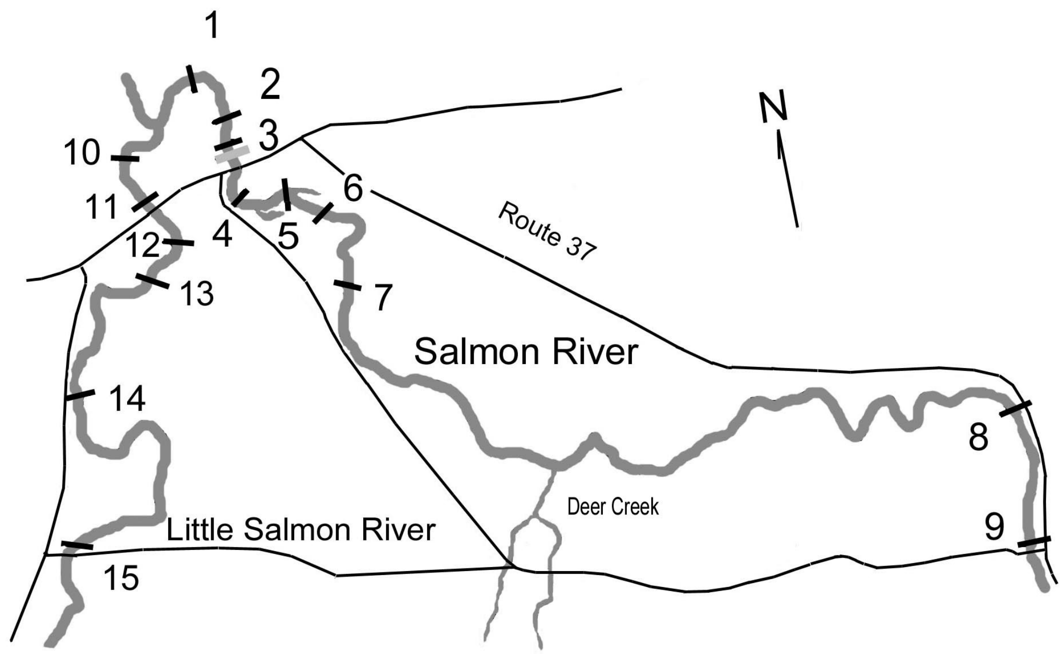


Figure 4. Location of transects sampled for sediments, macroinvertebrates, fish, unionid mussels, and aquatic plants. Horiba monitors were located near transects 2, 4, and 11. Water temperature recorders were located near transects 3, 7, 9, 10, 12, and 15. Water level recorders were located near transects 3, 6, and 10. The barometric pressure recorder was located near transect 10.

Transect 7 was the second riffle in the Salmon River and was the upstream limit of the reservoir. The riffle was bordered by pasture on the east side and forest on the west side. Transect 7 was the widest transect (Table 1) and had an extensive sand bar at the downstream end. Transect 8 was steep-sided with undercut banks with a wooded buffer, and had a soft bottom. The substrate on the east side was rocky and on the west side was sand/silt. Transect 9 was the longest riffle in the Salmon River study area with exposed bedrock at the upstream end of the riffle. The Cushman Road Bridge crosses the river at the upstream end of the riffle and marked the end of the study area. *Little Salmon River*: transect 10 was located just upstream from the Lewis Marina at a narrow, steep-sided section of the river. The river was bordered by open fields on both sides. Transect 11 was located in a shallow, straight section with low banks, a wooded buffer on the west side and residential grass and open field on the east side. Transect 12 was narrow, steep-sided, with a rocky area along the east side and sand/silt along the west side. Transect 13 was the first riffle in the Little Salmon River and was the most narrow transect (Table 1) in the study area. This riffle was bordered by residential grass on the west side and a wooded buffer with open fields on the east side. Transect 14 was bordered by fields with a steep bank on the east side and a low bank on the west side. Transect 15 was the second major riffle in the Little Salmon River and was bordered by fields on both sides. The upstream end of the study area was bounded by the Foster Road Bridge.

Table 1. Maximum width (m) and depth (m) of the transects.

Salmon River			Little Salmon River		
Transect	Width	Depth	Transect	Width	Depth
1, glide	25	3	10, glide	17	3
2, glide	50	2	11, glide	34	1
3, riffle	34	0.5	12, glide	21	2
4,glide	25	3	13, riffle	13	0.5
5, glide	30	2	14, glide	38	1
6, glide	50	1	15, riffle	30	0.5
7, riffle	70	0.5			
8, glide	34	2			
9, riffle	40	0.5			

Sediment. Three grabs taken with a 6 X 6 ponar dredge (0.02 m^2) were composited to make one sample from each subdivision in each glide transect (N = 30). Sediment composition was not determined in the riffle areas but was assumed to approximate that found in the glide transects. Samples were stored at 3.8° C until analyzed. Grain size was determined by the dispersal method (Folk 1980) resulting in sand (0.5 to 2 mm), silt (0.0039 to 0.031 mm), and clay (0.002 mm) fractions, and reported as the percent dry weight of the original sample. Organic content was estimated by loss-on-ignition (Wilde et al. 1972) and reported as a percentage of the dry weight of the original sample. Particle size (Cummins 1962) and estimates of embeddedness (Barbour et al. 1999) were made at five locations in the center of each riffle transect.

Water chemistry. Water temperature, dissolved oxygen, pH, conductivity, oxidation-reduction potential (ORP), and turbidity measurements were recorded by Horiba U-20 monitors at three locations programmed to record at 2 hr intervals. Water temperature was also recorded using Onset thermographs at five locations. Solinst Leveloggers recorded water level changes and water temperature at 1 hr intervals at three locations: one above the dam and two below the dam (Figure 4). A separate Levelogger was used to determine barometric pressure to correct the measured values of water level and to record air temperature. Alkalinity, ammonium, chloride, nitrate, and sulfate were estimated from grab samples.

Macroinvertebrates. Three methods were used to collect macroinvertebrates: rectangular kick net (0.44 m X 0.6 m; 500µ mesh), ponar dredge, and drift net. Seven kick net samples, each representing 0.26 m^2, were composited from each of the three areas of each riffle transect sampled (N = 3) in each sampling period. Four 6 X 6 ponar dredge samples were composited from three areas of each glide transect (N = 3). Nine transects (2-4, 6, 7, 9, 11, 13, 15) were sampled in October, 2002 (N = 27), and 15 transects (Figure 4) were sampled in June 2003 (N = 45), October 2003 (N = 45), and June 2004 (N = 45). Each sample was washed through a 500µ mesh screen before compositing. Macroinvertebrate drift was estimated by towing the rectangular net downstream for 2 minutes. This method was used instead of anchoring the drift net to avoid the potential loss of the net due to rapid water level increases, and to avoid stranding of the net due to decreasing water levels. All samples were preserved with 10% buffered formalin and returned to the laboratory for sorting and counting. No sub-sampling was used. Organisms were identified to the family level except for oligochaetes, nematodes, leeches, diptera pupae, diptera adults, and water mites.

Six indices were calculated for macroinvertebrates using 88 families out of the 102 taxa identified: *EPT* – the number of families in Ephemeroptera, Plecoptera, and Trichoptera; *richness* – the total number of families; *dominance* – sum percentage of the 5 more abundant families out of the total number of individuals; *percent Chironomidae* – the percentage of chironomids out of the total number of individuals; *Family Biotic Index* (formerly Hilsenhoff Biotic Index) - family tolerance value (Barbour et al. 1999) multiplied by abundance and divided by total number collected; and the *Percent Model Affinity* – a comparison of the percent similarity between seven taxonomic groups in the samples to the percent of the same taxonomic groups in a 'model' community (Novak and Bode 1992). The methods for Percent Model Affinity differed from that specified by Novak and Bode (1992) in that all organisms were used in the calculations rather than a 100-organism subsample. The Biological Assessment Profile (Bode et al. 1996) was not used in the present study as the macroinvertebrates were not identified to species. A series of sweep net samples was taken in the two pond areas in May, 2003, and April, 2004, to assess the macroinvertebrate species present and to determine if northern pike used the ponds for spawning.

Unionid mussels. A qualitative survey of unionid mussels was made during various sampling efforts, primarily at each transect but also in adjacent areas and in Deer

Creek, a primary tributary of the Salmon River (Figure 4). The assessment was to determine species presence and relative abundance but not density.

Fish. Collections of adult fish were made using hoop nets (1.2 m hoop, 6 m wings, 12 mm bar mesh), a 3 m X 1 m seine (3 mm mesh), and electroshocking (boat and backpack) in various locations representing the various habitat types upstream of the dam, downstream of the dam, and in the Little Salmon River. Collections corresponded to the permanent transects where possible. Hoop nets were set overnight and fished in the same order as deployed. The total fishing time for each net was recorded. Seining was done in representative habitats with each haul distance recorded. Boat electroshocking was done only in the lower portion of the rivers since access was not possible upstream of the dam with the electroshocking boat. Backpack electroshocking was done in representative riffle and glide areas in both rivers. All fish were identified to species, and the majority was measured for total length (mm) and wet weight (g) in the field and returned alive to the collection area. Some minnows were preserved in 10% buffered formalin to verify their identification. Samples of fish larvae were made using standard sweeps with the rectangular net along the shoreline and augmented with the towed net samples.

An index of biotic integrity was constructed for fish for each river based on 12 metrics following Daniels et al. (2002). These metrics were 1) total number of fish species (excluding carp, American eel, and stocked trout); 2) number of benthic insectivores; 3) number of water column species (excluding smallmouth and largemouth bass); 4) number of terete minnow species; 5) dominant species - 3 more abundant species as a percentage of the total number of species; 6) percentage of total individuals that were white sucker; 7) percentage of total individuals that were omnivores; 8) percentage of total individuals that were insectivores; 9) percentage of total individuals that were top carnivores - largemouth bass, smallmouth bass, northern pike, longnose gar, and walleye; 10) density as number/m^2 per river (these values were determined only from seining data since trap net data does not account for an area that is fished); 11) percentage of species that had two age classes (estimated from length frequency plots); and 12) the percentage of individuals that had tumors, lesions, or parasites. Each metric was then scored from 1 to 5 with 5 representing the least amount of impact. The index was the sum of scores for the metrics.

Aquatic plants. A qualitative survey was made of aquatic plants within the study area in September, 2003, and August, 2004. Plants were identified to genus, ranked by abundance, and locations noted. The primary objective was to locate areas that could function as spawning areas for fish.

Results

Sediment. Sand comprised the highest mean weight of any fraction at all run transects (Figure 5). The center of each river was composed primarily of coarse sand with fine sand and silt along the river banks. The percentage of sand at the river center (98.4%) was similar at transects upstream of the dam compared to those transects downstream of the dam (98.3%), as was the mean percentage of sand on the river banks upstream (81.9%) compared to downstream (88.8%). The mean percentage of silt at the river banks was higher upstream of the dam (15.4%) than downstream (8.2%). The percentage of clay at the center was similar at upstream transects (0.7%) compared to downstream transects (0.9%). The percentage of clay was similar on the east side of the river upstream (4.9%) and downstream (5.1%) of the dam, and similar, although lower, at the west side of upstream transects (0.5%) and downstream transects (0.6%). Three areas had high silt content: west side of transect 10 (67%), east side of transect 5 (55.5%), and west side of transect 4 (44%). Silt content was less than 22% at the remaining transects (mean = 5.5%; range = 0.09 to 21.5%). Clay deposits were present in three areas: the east side of transect 1 (8.5%), the east side of transect 5 (16.4%), and the west side of transect 10 (28.3%). These clay deposits may be contiguous under the overlying sediment. The mean clay content was 1% (range = 0.1 to 3.8%) at the remaining transects. The organic content was 1.1% or less in all samples (mean = 0.4 %; range = 0.07 to 1.1%) and came from leaf packs and woody debris. Embeddedness in the riffle transects ranged from 20% at transects 3, 13, and 15 to 40% at transects 7 and 9. The substrate at each riffle transect was cobble (64 to 256 mm), boulder (>256 mm) and bedrock mixed with coarse sand.

Deposition of sediment (silt/sand over a clay substrate) was minimal behind the dam (approximately 765 m^3 from the dam to the Route 37 Bridge; Milone and MacBroom 2004) and was limited to the west side. The substrate graded from coarse sand and gravel in the center of the river to gravel and cobble on the east side.

Discharge and water level. Discharge values were not available from the Salmon River for the study period but comparisons of historical discharge records from the USGS gage at Chasm Falls, Salmon River (gage 04270000), and the USGS gage at Bombay, Little Salmon River (gage 04270200), showed that the response to precipitation was similar in the two rivers, although the Salmon River discharged at a greater rate. Recent

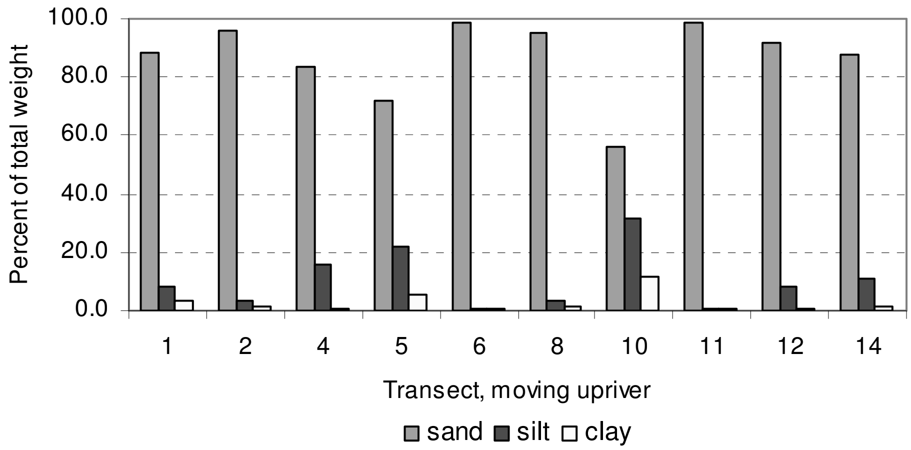


Figure 5. Sediment fractions from the run transects. Transects 1 through 8 were in the Salmon River, and transects 10 through 14 were in the Little Salmon River.

records of the Little Salmon River (Figure 6) showed a rapid response to precipitation events, particularly snowmelt and localized thunderstorms. Water level changes were rapid, although brief, at the three monitoring locations in both years and showed similar hydrographs (Figures 7 and 8) upstream and downstream of the dam as well as in the Little Salmon River. Changes in water level were frequently accompanied by changes in barometric pressure. The maximum change for a single event was about 120 cm in late June, 2003, which was also the maximum change in water level during the study period. A large, sustained, and nearly simultaneous decrease in water level of 60-80 cm occurred in early September, 2004 (Figure 8),that was accompanied by a 20 cm decrease in barometric pressure. The water level increased about 20 cm in the Little Salmon River after this event but did not increase in the Salmon River.

Water temperature. Ice cover formed in late November and broke up in late March in 2002 and 2003 (Figures 6 and 9). Water temperature increased from 3 ºC in April at about 5 ºC per month in May and June to a peak of 25 ºC in late June, 2003, and

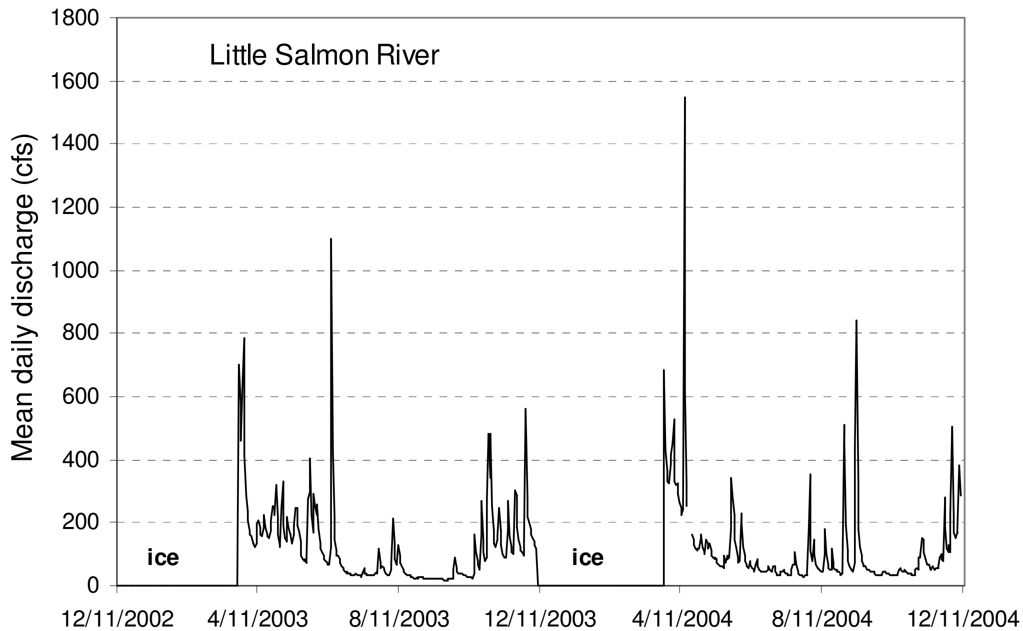


Figure 6. Mean daily discharge of the Little Salmon River during the study period as measured by the USGS gage at Bombay (gage 04270200).

in late July, 2004. Water temperature remained near or higher than 20 ºC until late August, 2003, and early September, 2004, and then decreased about 5 ºC per month until ice formation in early December (temperature recorders were removed in September, 2004). Water temperature was similar among all transects within each year (Figures 10-13). The water temperature recorder at Transect 15 was lost or vandalized on two occasions thus there was no useful data from that transect.

Dissolved oxygen ranged from 7.5 to 17 mg/L (52% to 200% saturation) during the study period and saturation was 78% or greater except for two days, 10 and 11 June, 2003, in the Little Salmon River when saturation was less than 53% for a 2 hr period on each day. There was more fluctuation in dissolved oxygen upstream of the dam, and in the Little Salmon River, than downstream of the dam in both years (Figures 14-19). pH values ranged from 5 to 8 during the study period with more fluctuation occurring in the

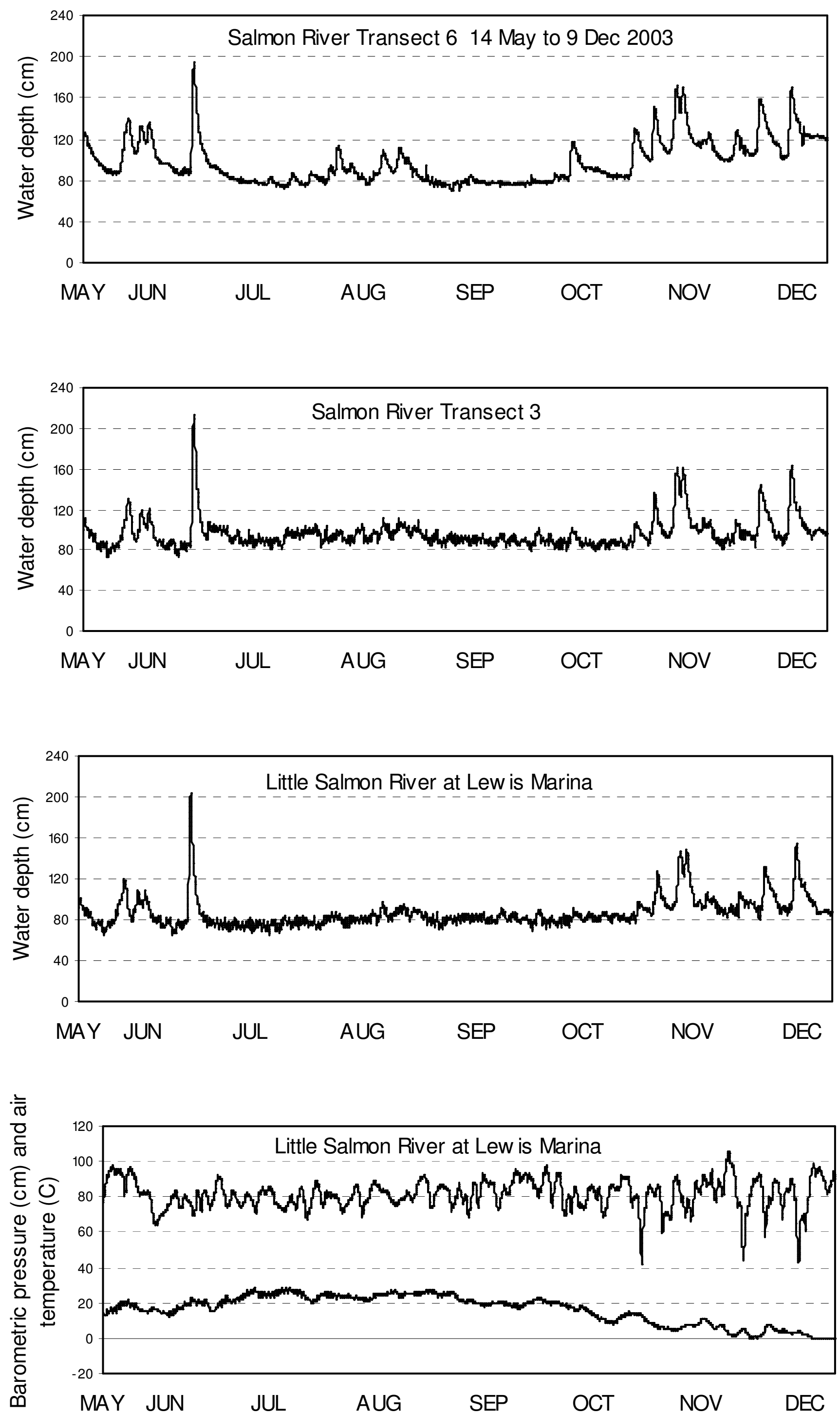


Figure 7. Water level changes recorded in 2003 upstream of the dam (transect 6), downstream of the dam (transect 3), and in the Little Salmon River (Lewis Marina), and barometric pressure and air temperature.

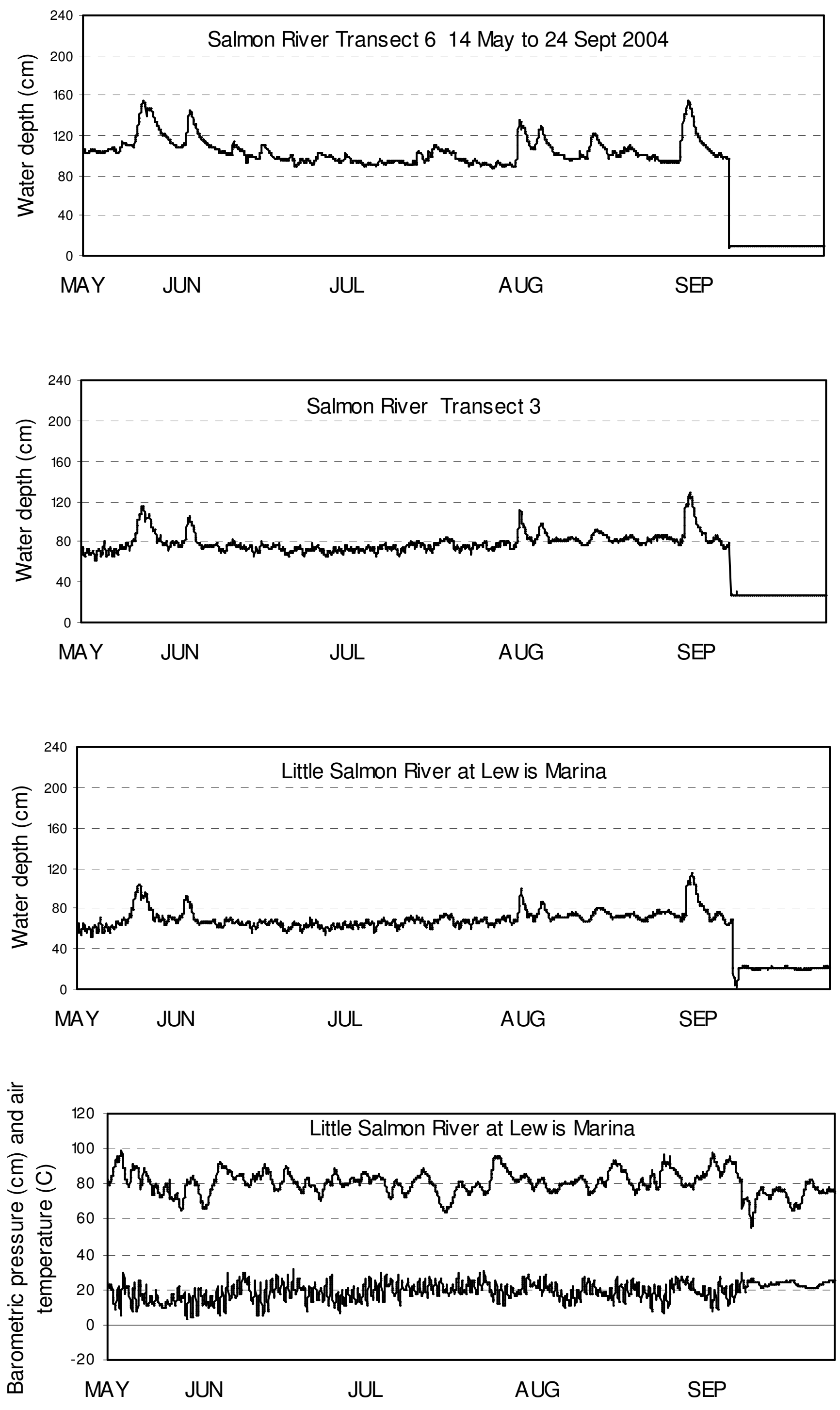


Figure 8. Water level changes recorded in 2004 upstream of the dam (transect 6), downstream of the dam (transect 3), and in the Little Salmon River (Lewis Marina), and barometric pressure and air temperature.

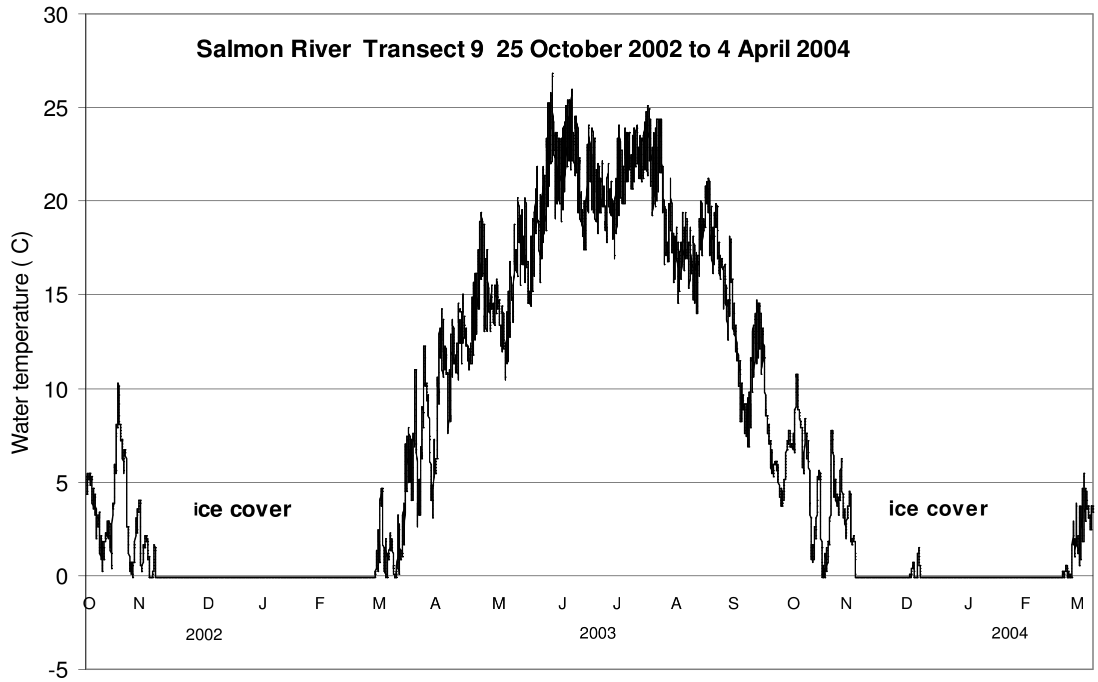
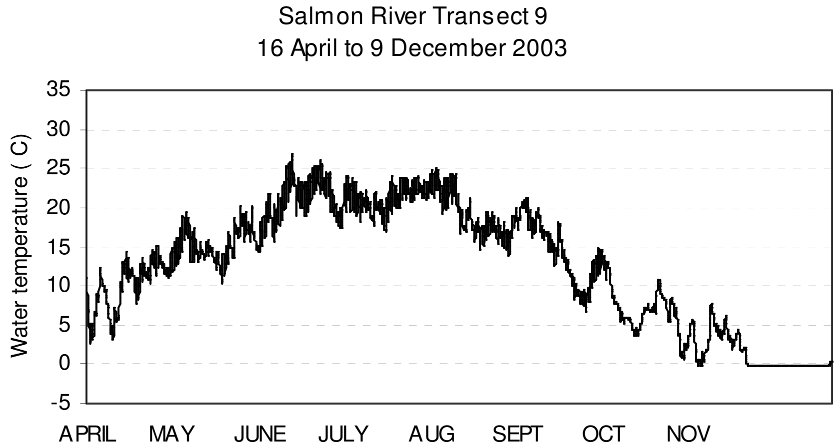
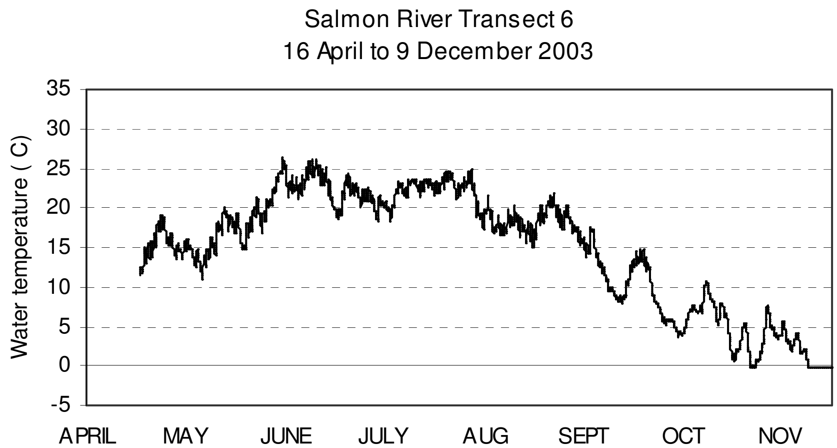


Figure 9. Water temperature at transect 9 (Cushman Bridge Road) in late 2002 to early 2004.

Little Salmon River than at the other two monitoring sites. Conductivity ranged from 0.01 to 0.022 S/m during the study period and followed a similar seasonal pattern among the monitoring transects. Total dissolved solids (derived from conductivity) ranged from 0.09 to 0.13 mg/L and showed less fluctuation in the Little Salmon River in 2004 than at the other sites in either year. Oxidation-reduction potential values ranged from 200 to 550 mV with daily fluctuations of 100 mV and frequent changes of 300 mV. Similar seasonal patterns were present at all monitoring sites during each year. Turbidity ranged from 3 to 245 NTUs (mean = 45) and was generally higher in 2003 than 2004 (Figure 20) as a result of increased precipitation. These values were taken from manual measurements and supplemented by readings from the water quality monitors. Periphyton fouling of the turbidity sensor in the programmable monitors produced unreliable readings except for a





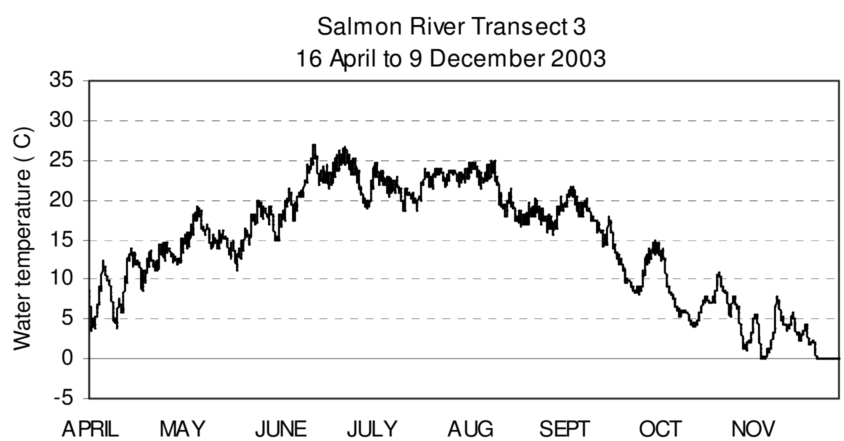


Figure 10. Water temperature (ºC) in the Salmon River from 16 April to 9 December, 2003. Transects 9 and 6 are upstream of the dam and transect 3 is downstream of the dam.

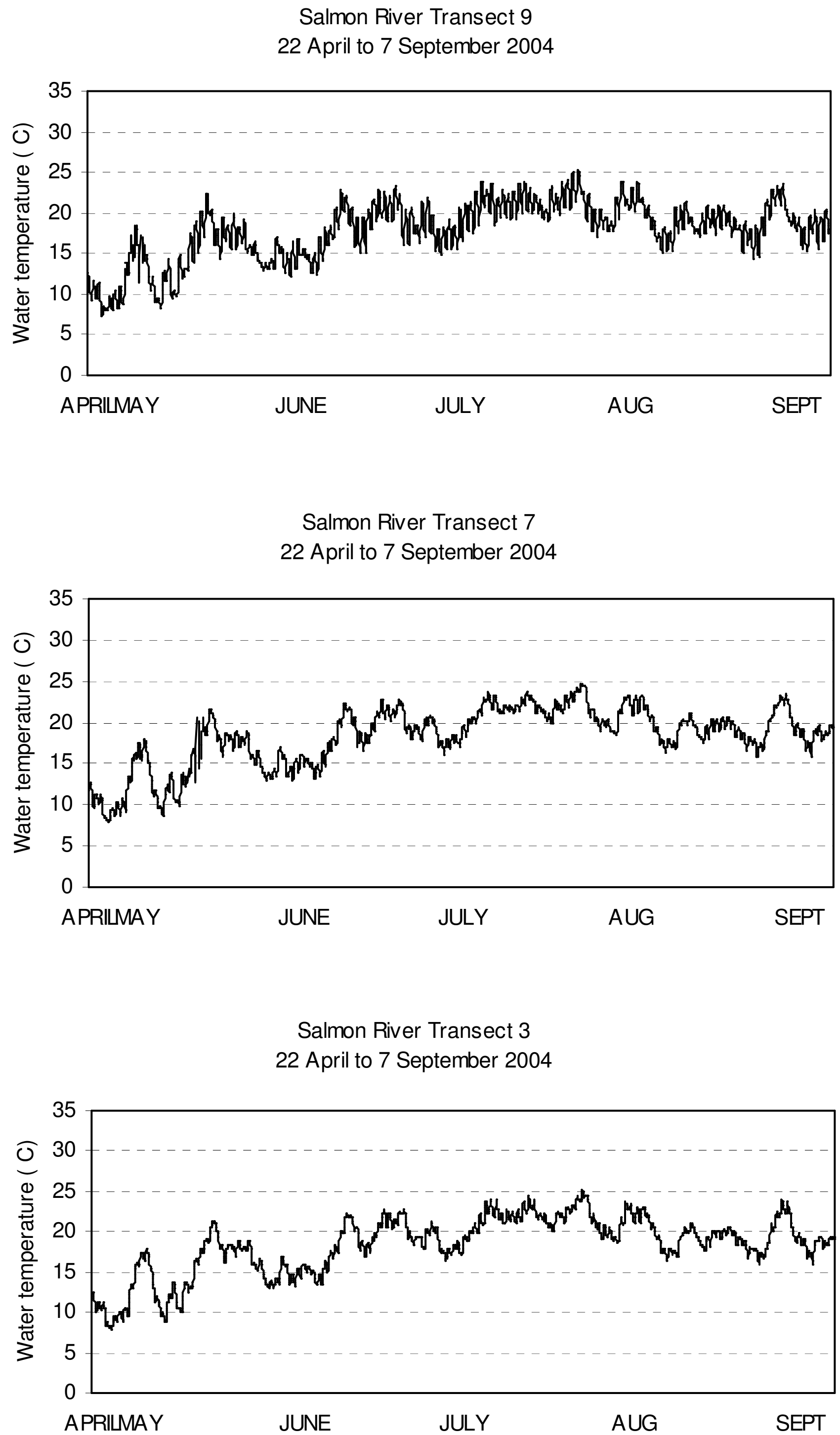
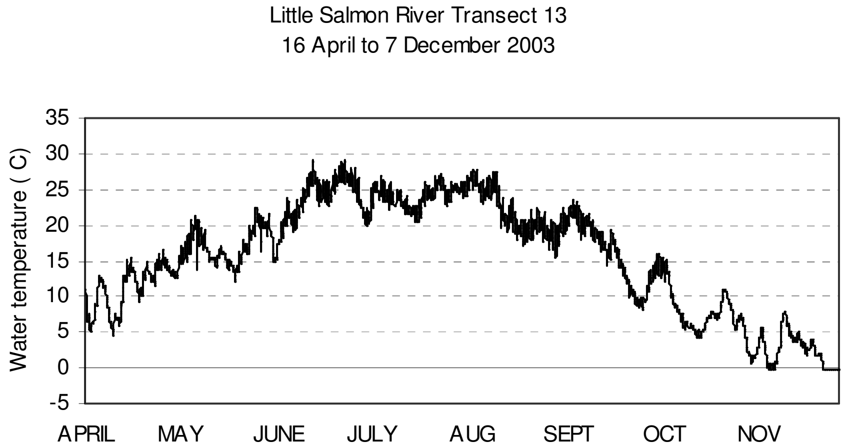
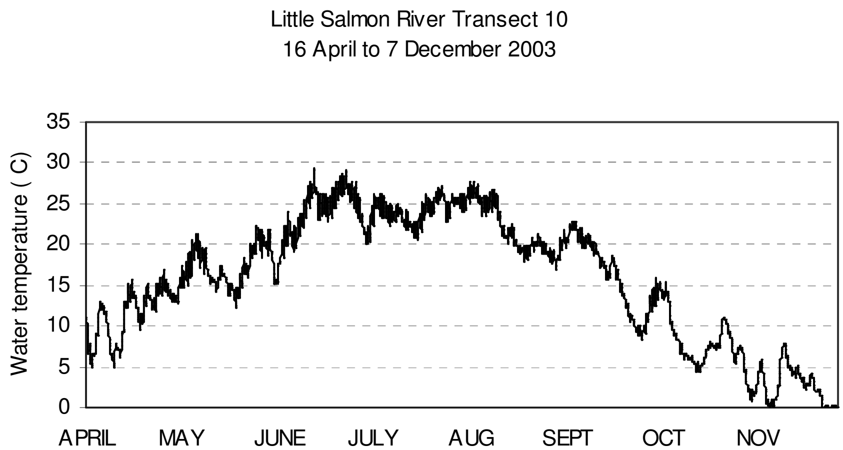


Figure 11. Water temperature in the Salmon River recorded in 2004 upstream of the dam (transects 9 and 7), and downstream of the dam (transect 3).





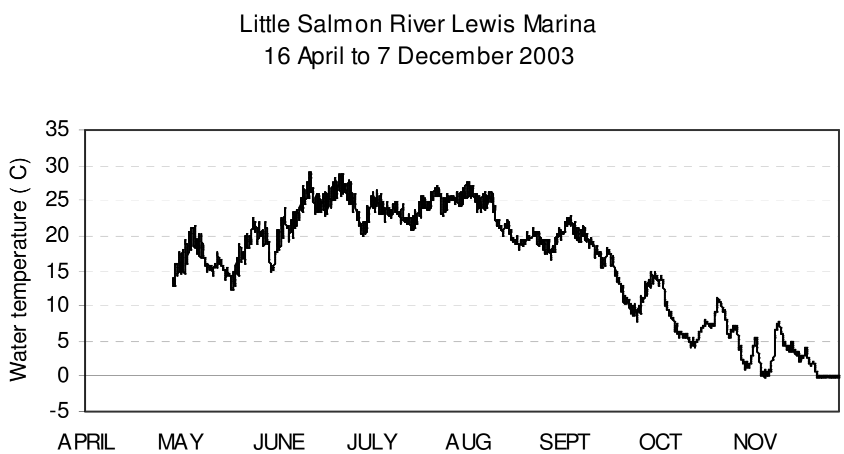
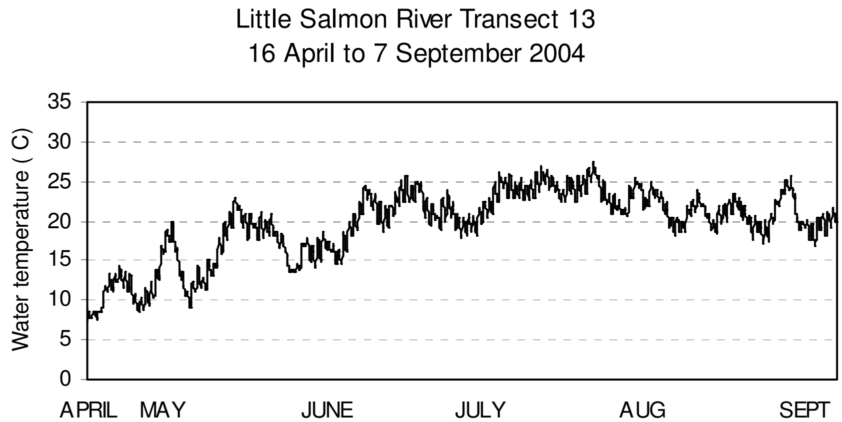
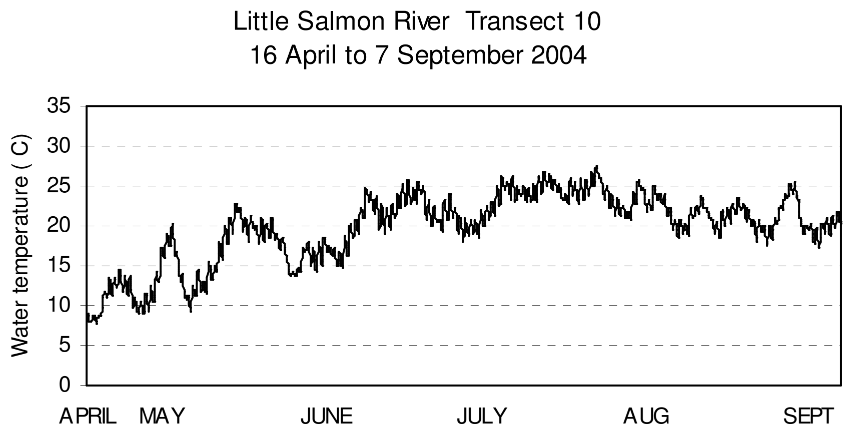


Figure 12. Water temperature in the Little Salmon River recorded in 2003.





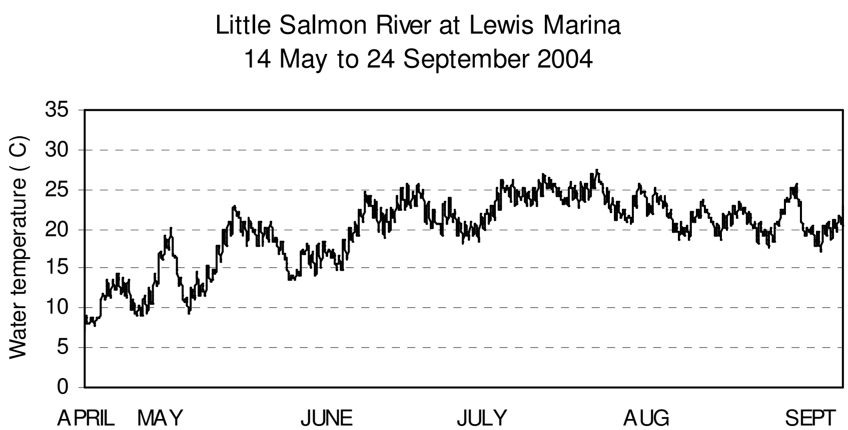


Figure 13. Water temperature recorded in the Little Salmon River in 2004.

few hours after the sensors were cleaned. Sensors were cleaned once per week.

Chloride and sulfate concentrations were similar in both rivers although chloride concentrations were elevated in December 2002 (Table 2). Nitrate and ammonia concentrations were higher near pastures (transects 7 and 15) and residential lawns (transects 2 and 10) than at the other transects. Alkalinity ranged from 40 to 136 mg/L (as $CaCO_3$; mean = 76.0, N = 117) but did not show any seasonal trends.

Table 2. Concentrations of five water chemistry parameters (mg/L) taken as grab samples.

	Salmon River			Little Salmon River		
Transect	2	7	9	10	13	15
Date			Chloride (Cl)			
Dec 2002	11.5	11.0	9.9	9.1	8.8	8.9
May 2003	8.3	8.2	7.8	8.4	8.7	9.7
			Nitrate (NO_3-N)			
Dec 2002	0.39	0.39	0.36	0.24	0.25	0.26
May 2003	0.08	0.13	0.13	0.07	0.07	0.10
			Sulfate (SO_4)			
Dec 2002	12.7	12.3	8.7	15.6	15.5	15.7
May 2003	8.0	8.1	7.2	7.9	7.8	7.6
			Ammonia (NH_4)			
Dec 2002	0.09	0.08	0.08	0.12	0.05	0.16
May 2003	0.03	0.07	0.01	0.02	0.02	0.01
			Alkalinity ($CaCO_3$)			
Oct 2002 to July 2004	76.8	75.0	68.8	79.5	84.8	80.1

Macroinvertebrates. A total of 102 taxa were identified during the study and 88 families were used in the construction of indices. The indices used various combinations of the collected taxa. Those taxa that were excluded were: water mite, hydra, nematode, diptera pupa and adult, nematomorpha, leech, springtail, planaria, spider, sponge, crayfish, and leafhopper. These taxa were either not identified to family level or were collected infrequently. The mean number of EPT families was lower in the reservoir transects (mean = 5.3) than at other run transects (mean = 7.9) and was lowest at transect 4 (mean = 4.5; Fig. 21) just upstream of the dam. The mean EPT values increased slightly

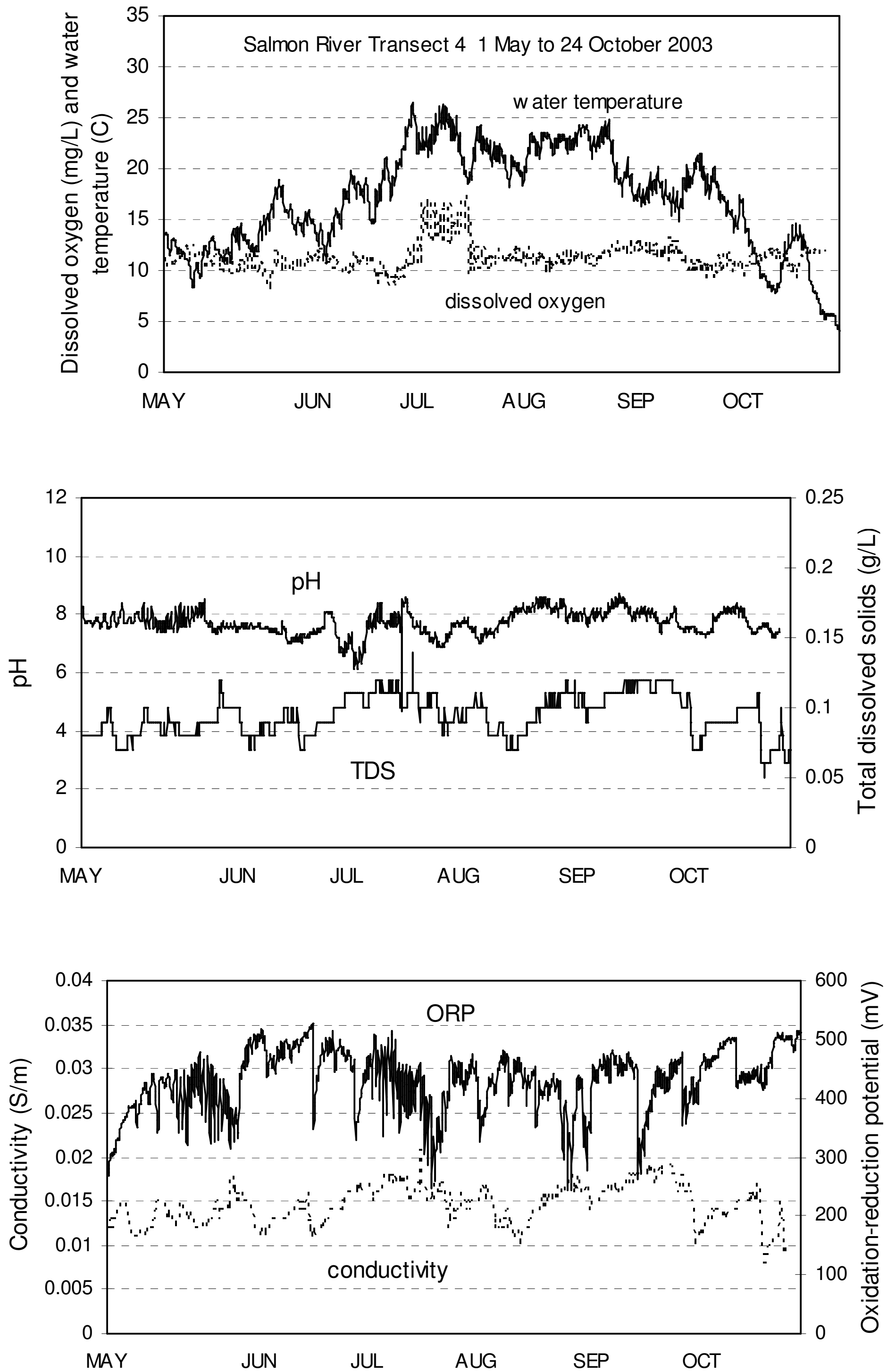


Figure 14. Water chemistry parameters recorded by Horiba monitors in the Salmon River in 2003 from upstream of the dam (transect 4). TDS = total dissolved solids and ORP = oxidation-reduction potential.

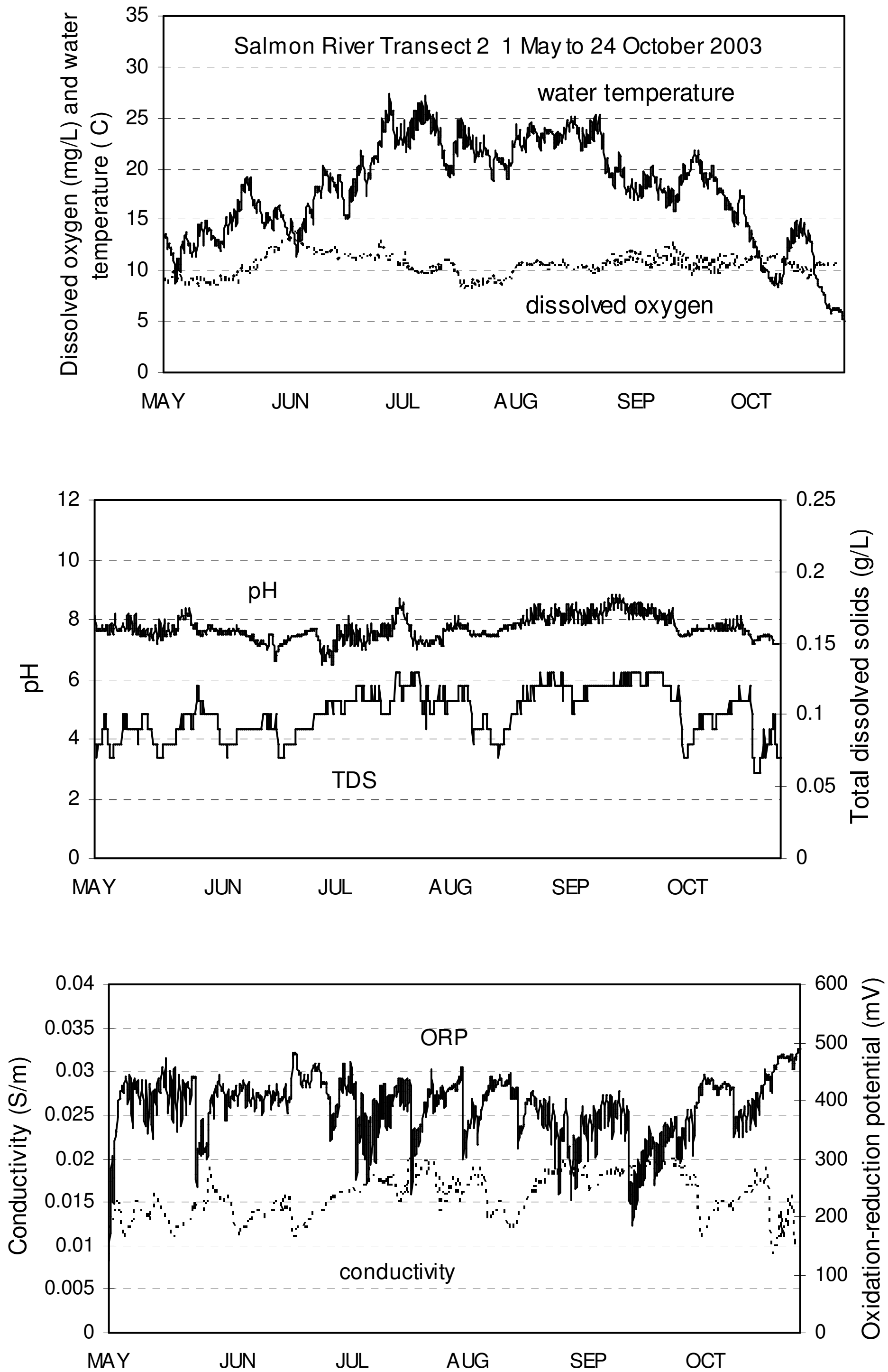
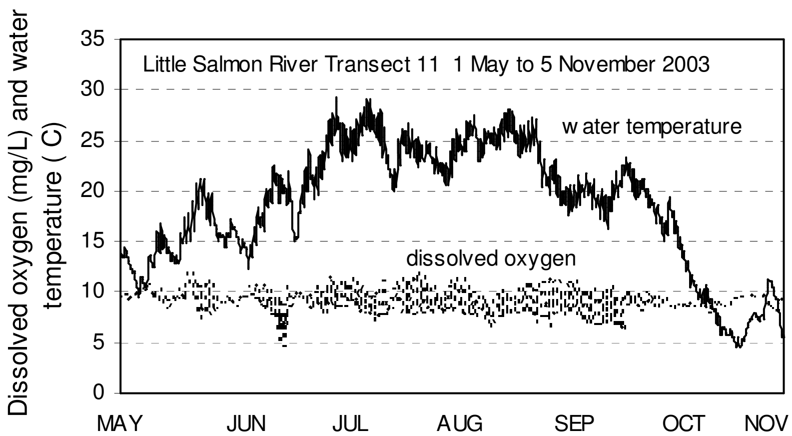
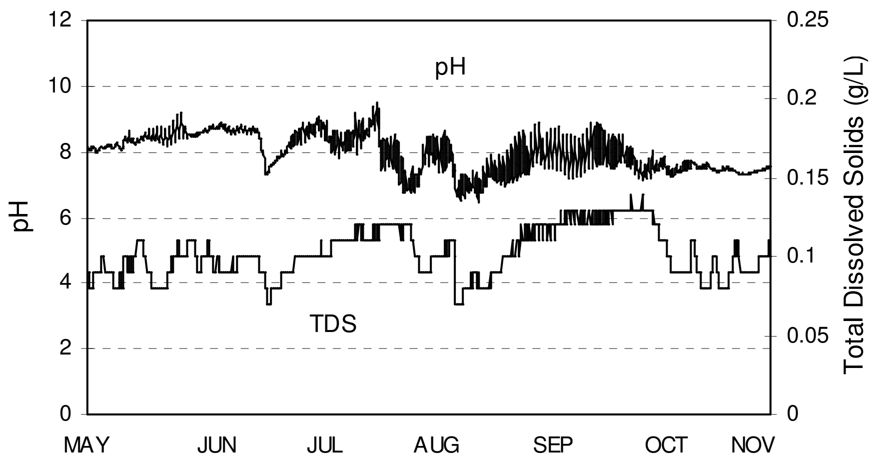


Figure 15. Water chemistry parameters recorded by Horiba monitor in the Salmon River in 2003 from downstream of the dam (transect 2). TDS = total dissolved solids and ORP = oxidation-reduction potential.





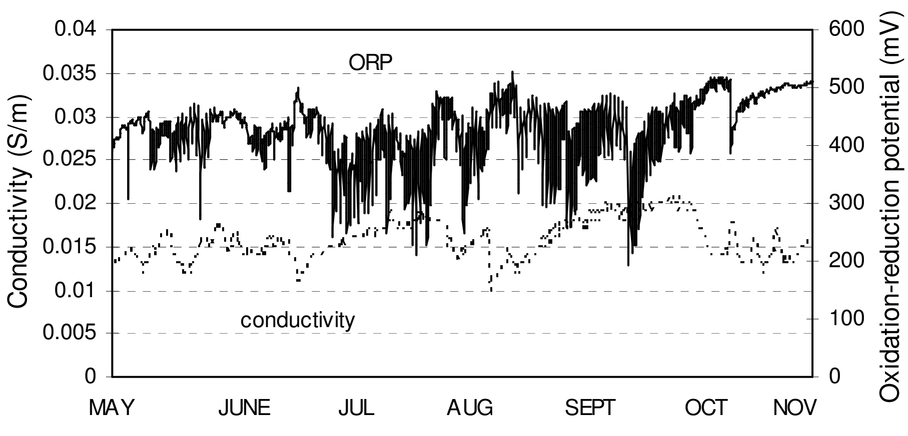


Figure 16. Water chemistry parameters recorded by Horiba monitor in the Little Salmon River in 2003. TDS = total dissolved solids and ORP = oxidation-reduction potential.

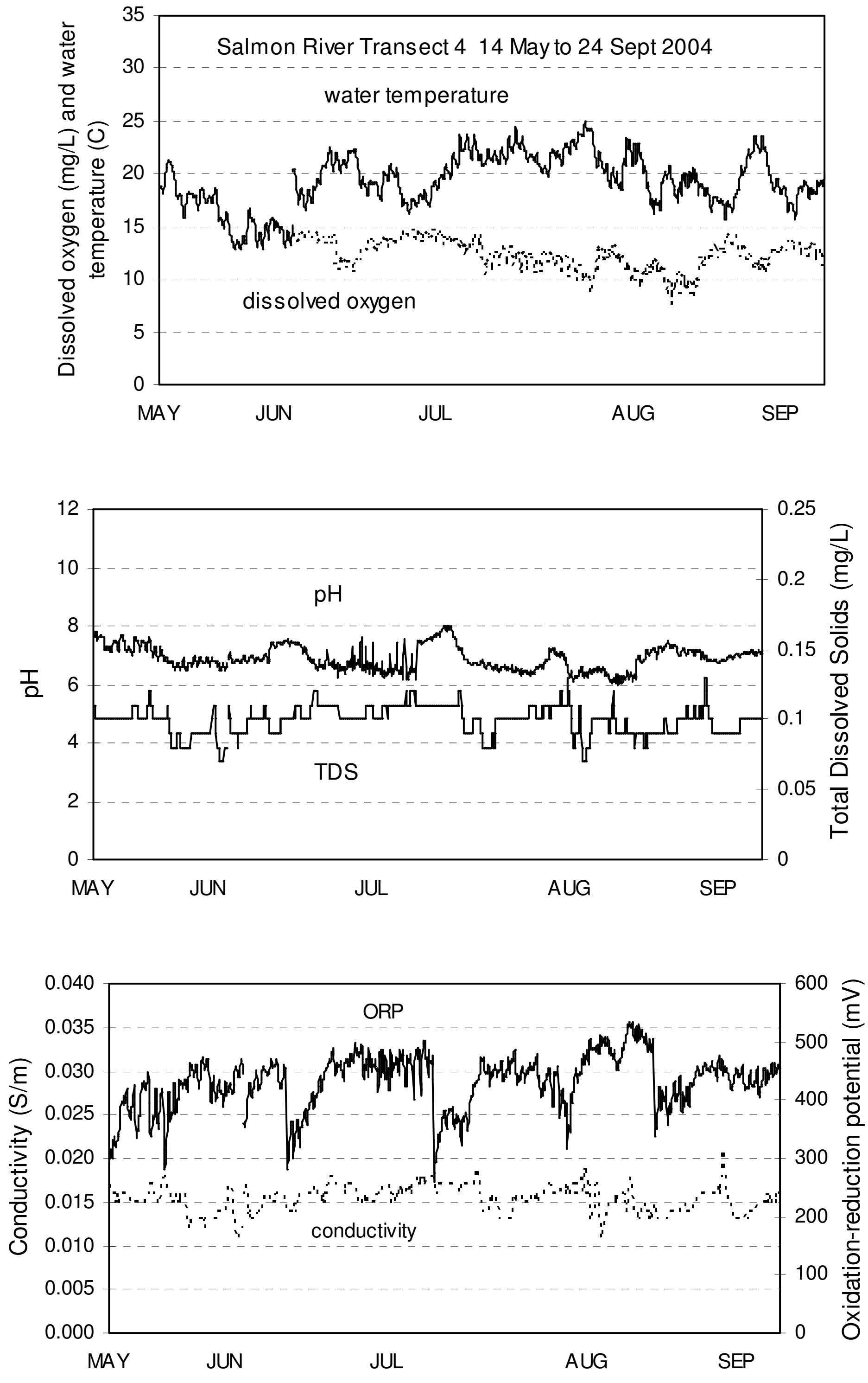


Figure 17. Water chemistry parameters recorded by Horiba monitor in the Salmon River in 2004 from upstream of the dam. TDS = total dissolved solids and ORP = oxidation-reduction potential.

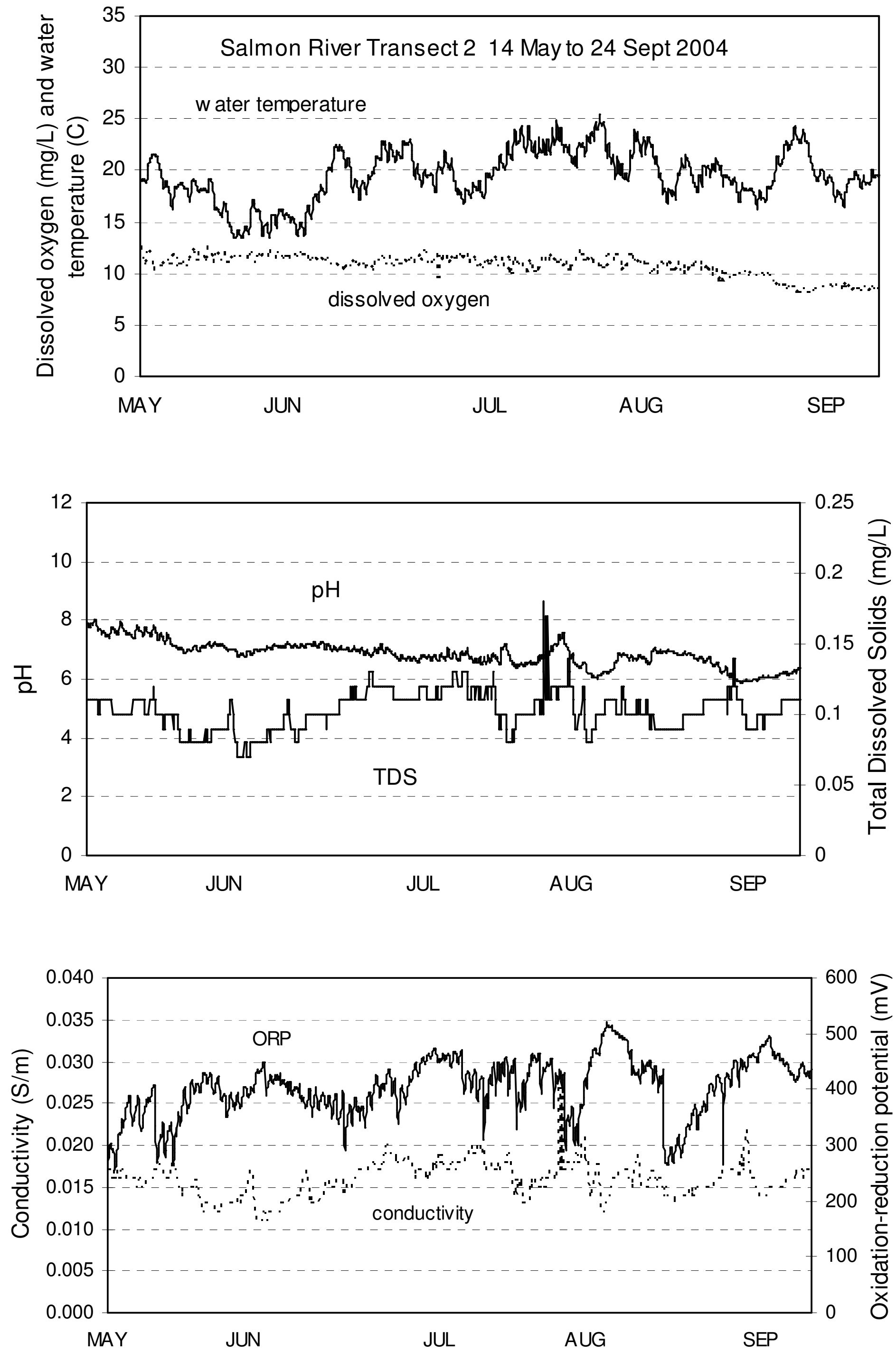


Figure 18. Water chemistry parameters recorded by Horiba monitor in the Salmon River in 2004 from downstream of the dam. TDS = total dissolved solids and ORP = oxidation-reduction potential.

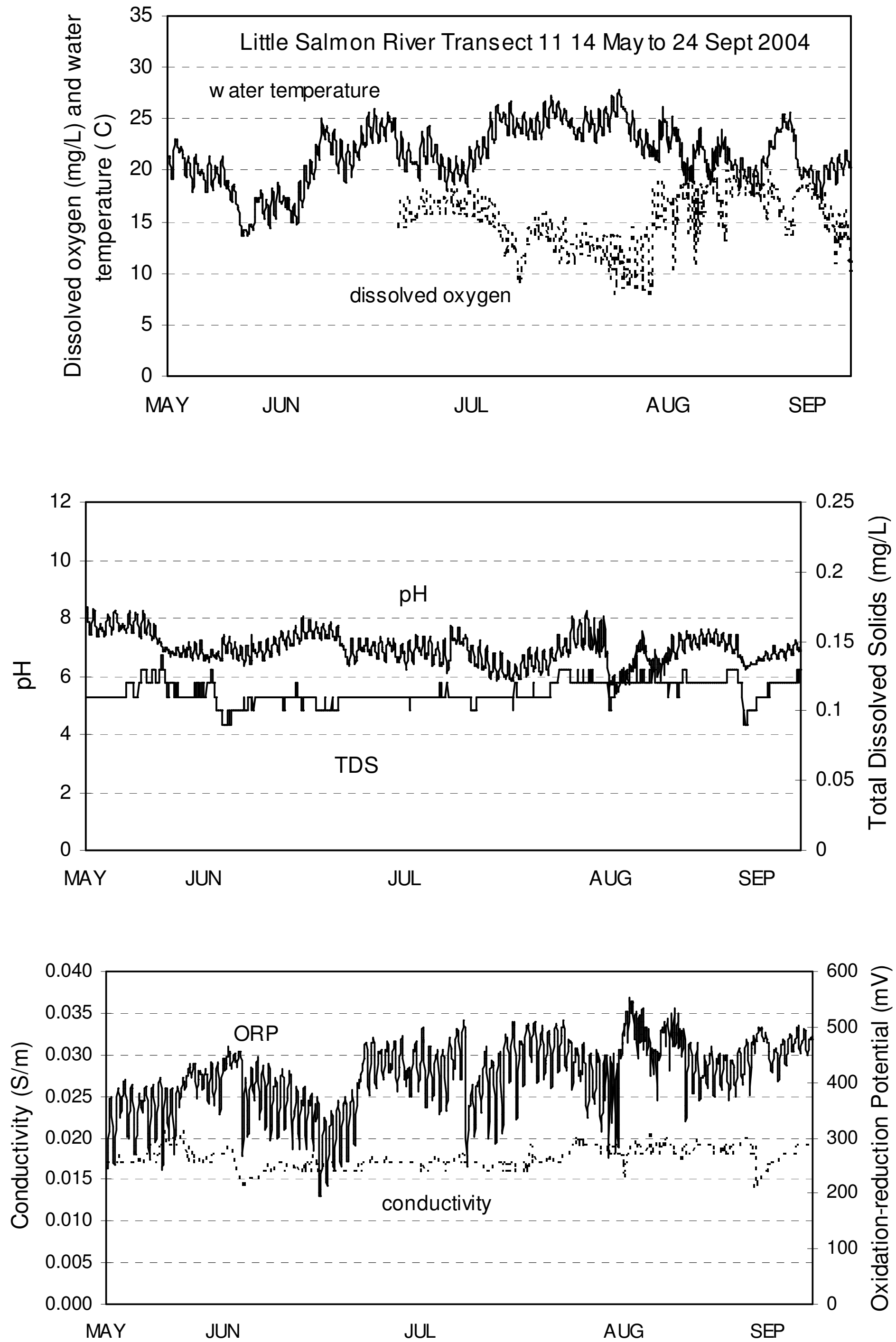


Figure 19. Water chemistry parameters recorded by Horiba monitor in the Little Salmon River in 2004. TDS = total dissolved solids and ORP = oxidation-reduction potential. Oxygen probe failed in May and was replaced on 16 June.

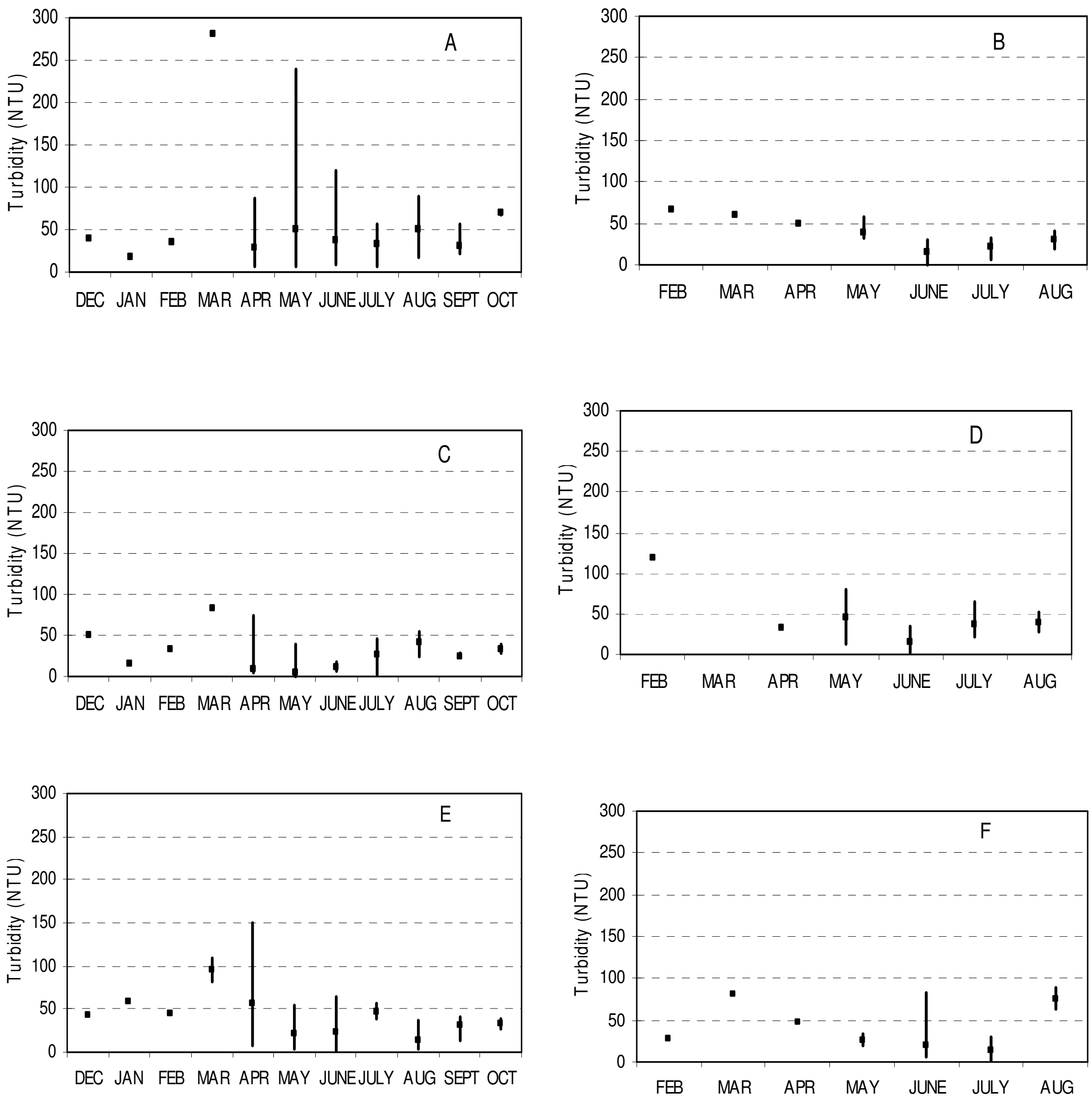


Figure 20. Turbidity values from the Salmon and Little Salmon rivers. Boxes are means and bars are ranges. A) Salmon River upstream from dam in 2002-2003, B) Salmon River upstream from dam in 2004, C) Salmon River downstream of dam in 2002-2003, D) Salmon River downstream of dam in 2004 , E) Little Salmon River in 2002-2003, and F) Little Salmon River in 2004.

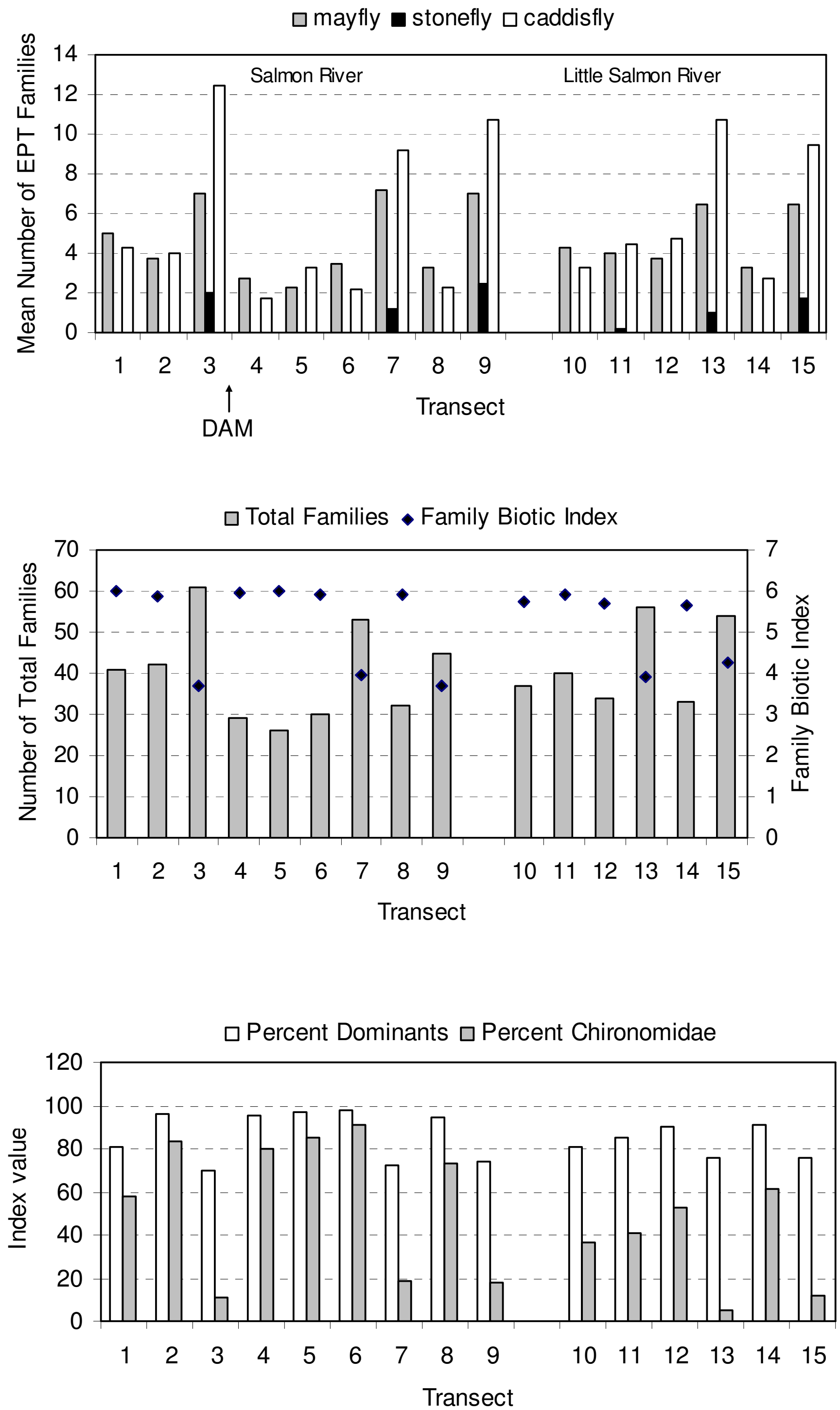


Figure 21. Macroinvertebrate indices for each transect and river calculated from 88 families. Top panel: Mean number of Ephemeroptera, Plecoptera, and Trichoptera families; center panel: Total number of families and Family Biotic Index; and lower panel: Percent dominants and percent Chironomidae.

in an upstream direction within the reservoir. Transect 3 had the highest mean EPT value; the other riffle transects were similar in mean EPT value. The four run transects (10, 11, 12, 14) in the Little Salmon River were similar to each other in the number of EPT families.

There was little difference in Total Families between the upstream riffle transects and the downstream riffle transects when comparing the October and June samples (Table 3), however, the number of families was slightly higher at transect 3 than at transects 7 and 9. The number of families at transect 3 was most similar to that at transect 13 (Little Salmon River). The mean number and number of Total Families was lower in the reservoir transects than at any of the other run transects.

Table 3. Number of Total Families of macroinvertebrates from riffle transects in the Salmon (transects 3, 7, and 9) and Little Salmon (transects 13 and 15) rivers, based on 84 samples per sampling period from each transect.

Transect	3	7	9	13	15	Mean
October 02	39	39	36	35	37	37.2
October 03	40	33	36	40	39	37.6
Mean	39.5	36.0	36.0	37.5	38.0	
June 03	35	34	35	40	37	36.2
June 04	46	33	33	40	36	37.6
Mean	40.5	33.5	34.0	40.0	36.5	

Family Biotic Index values ranged from 3.15 to 4.64 in the riffle transects (Table 4). Values were lower in October than in June due to fewer organisms collected in October: for example, 1130 Baetidae mayflies were collected in June 2003 compared to only 40 in October 2002, and only 72 in October 2003. Differences in the number of organisms collected was most evident at transect 3 (downstream of dam) and at transects 13 and 15. Family Biotic Index values were similar among glide transects, and higher than for the riffle transects (Figure 21).

The mean Percent Dominants value was lower at transect 3 than at the other riffle transects but within the seasonal range seen in the upstream transects and in the Little

Table 4. Values for the Family Biotic Index for riffle transects in the Salmon and Little Salmon rivers based on 84 samples per sampling period from each transect.

Transect	3	7	9	13	15
October 02	3.50	3.74	3.41	3.53	4.14
June 03	4.26	4.48	4.10	4.37	4.64
October 03	3.15	3.83	3.25	3.37	4.00
June 04	3.72	3.85	3.86	4.05	4.01
Mean	3.66	3.97	3.65	3.83	4.19

Salmon River (Table 5). Values from the June samples were higher generally than those from the October samples. Dominance alternated among Elmidae, Hydropsychidae, Baetidae, and Chironomidae in the riffle transects in each sample period. Values for the run transects were greater than 80 and were higher generally in the reservoir than at other transects (Figure 21).

Table 5. Values for Percent Dominants for riffle transects in the Salmon and Little Salmon rivers, based on 84 samples per sampling period from each transect

Transect	3	7	9	13	15
October 02	65.7	66.1	69.4	68.5	73.3
June 03	69.6	81.7	72.1	83.6	82.6
October 03	76.9	70.2	78.3	69.4	67.2
June 04	67.5	73.1	86.7	81.5	82.2
Mean	69.9	72.8	76.6	75.7	76.3

Values for Percent Chironomidae ranged from 3.2 to 28.1 and were greater generally in June 2003 samples than in all other samples. The mean value was lowest at transect 13 and highest at transect 7 (Table 6). Percent Chironomidae was much higher at the run transects than at riffle transects (Figure 21).

Table 6. Values for Percent Chironomidae for riffle transects in the Salmon and Little Salmon rivers, based on 84 samples per sampling period from each transect.

Transect	3	7	9	13	15
October 02	10.1	13.0	11.1	4.4	9.0
June 03	13.3	25.4	28.1	5.8	25.2
October 03	10.5	16.1	10.7	3.2	4.6
June 04	10.2	18.7	20.2	6.4	9.4
Mean	11.0	18.3	17.5	4.9	12.0

Values for Percent Model Affinity for riffle transects ranged from 70.4 (transect 13) to 76.9 (transect 7) and were similar upstream and downstream of the dam (transect 7; 76.9 and transect 3; 76.5). Percent Model Affinity was also applied to the run transects as a means of comparison, although this method was not specified by Novak and Bode (1992). Estimates of impact determined by Percent Model Affinity ranged from 'severe' (32%) at transect 6 to 'slight' (55-59%) or 'moderate' (39-46%) at other glide transects to 'none' (70-77%) at the riffle transects (scores by transect are given in the appendix).

Twenty-four macroinvertebrate taxa were collected in the towed net samples. Chironomidae, diptera adults, and diptera pupae were the more abundant taxa (Table 7).

The ponds were sampled with a sweep net on 8 May, 2003, and 23 and 30 April, 2004. Twenty-six macroinvertebrate families were collected dominated by Culicidae (*Culex* sp.) which accounted for 89.7% of all macroinvertebrates collected. Leptoceridae and Chironomidae were also abundant (4.4% and 2.2% of the total number). Culicidae density was estimated at 580,000/m^3 but occurred in only in the shallow end of the ponds. Siphlonuridae and Pleidae were collected in the downstream pond but not in any river transects. Northern pike eggs were collected in both ponds in 2004 but not in 2003, perhaps due to later sampling in 2003.

Table 7. Density of macroinvertebrate taxa estimated from 36 towed net samples from the Salmon and Little Salmon rivers. Each tow sampled 4.71 m^3.

Taxa	No./100m^3	Taxa	No./100m^3
Chironomidae	30.67	Ephemerellidae	0.59
diptera adult	21.23	Caenidae	0.59
diptera pupa	19.46	Chrysomelidae	0.59
Baetidae	8.85	Philopotamidae	0.59
Simuliidae	6.49	Pleuroceridae	0.59
Elmidae	5.31	Hydrobiidae	0.59
water mite	4.13	Thysanoptera	0.59
Mymaridae	3.54	springtail	0.59
Braconidae	1.77	spider	0.59
Hydroptilidae	1.18	ant	0.59
Leptoceridae	1.18	oligochaete	0.59
Heptageniidae	1.18	nematode	0.59

Unionid mussels. Six species of unionid mussels were collected during the study period (Table 8). *Elliptio complanata* was the most abundant and was collected at all transects. *Lampsilis cariosa* was represented by one empty shell. Five of the six species occurred upstream and downstream of the dam and three species were collected in Deer Creek. Only 34 juvenile unionid mussels (unidentified) were collected in the benthic samples, equivalent to about 4 juveniles per 100 benthic samples.

Table 8. Species of adult unionid mussels collected and their collection locations.

	Upstream of dam	Downstream of dam	Little Salmon River
Elliptio complanata	transects 4 - 9, Deer Creek	transects 1-3	transects 10, 11, 13-15
Lasmigona compressa	transect 7	transect 2	transect 14
Lampsilis ovata	Deer Creek		transect 11, 13
Pyganodon cataracta	Deer Creek		transect 11
Lampsilis radiata	transect 7		transect 10
Lampsilis cariosa			transect 11

Fish. Trap nets were fished for 41 net-nights (852 hr) at seven locations: 3 upstream of the dam, 3 downstream of the dam, and 2 in the Little Salmon River. Twenty species were collected with trap nets (N = 503). Brown bullhead was the most abundant in CPUE (Table 9) with rock bass second; these two species accounted for 71% of the total catch in trap nets.

Twenty-one seine hauls were made at 11 locations covering 609 m. Seine haul distance ranged from 9 m to 58.5 m; the results have been standardized to a 9 m haul. Mimic shiner and bluntnose minnow were the more abundant species out of the 26 species collected by seining (Table 9). Eastern sand darter was 12th in CPUE with the largest catch (N = 101) being made on a sand bar opposite the Lewis Marina (downstream of transect 10) in the Little Salmon River. Eastern sand darters were also collected at transects 2, 4, 5, and 6.

Forty species of fishes (N = 2265) were collected in the study area (all gear combined). Brown bullhead was the most abundant (Figure 22). The eastern sand darter (a threatened species in New York) was ninth in relative abundance and

Table 9. Catch-per-unit-effort of 10 more abundant fish species collected in trap nets and seine. One net-night represents 21 hr of fishing time by one net. Seine hauls were standardized to a distance of 9 m.

Species	Hoop net 41 net-nights	Species	Seine 67 standard hauls
Brown bullhead	6.54	Mimic shiner	3.42
Rock bass	2.24	Bluntnose minnow	2.39
Longnose gar	0.61	Spottail shiner	2.13
White sucker	0.58	Rosyface shiner	1.91
Greater redhorse	0.56	Rock bass	1.72
Pumpkinseed	0.56	Tessellated darter	1.64
Smallmouth bass	0.36	Fallfish	1.49
Shorthead redhorse	0.15	Pumpkinseed	0.74
Northern pike	0.12	Logperch	0.72
Black crappie	0.10	Spotfin shiner	0.66

was collected upstream and downstream of the dam, and in the Little Salmon River. Six species were not collected upstream of the dam: walleye, yellow perch, longnose gar, cutlips minnow, American eel, and carp.

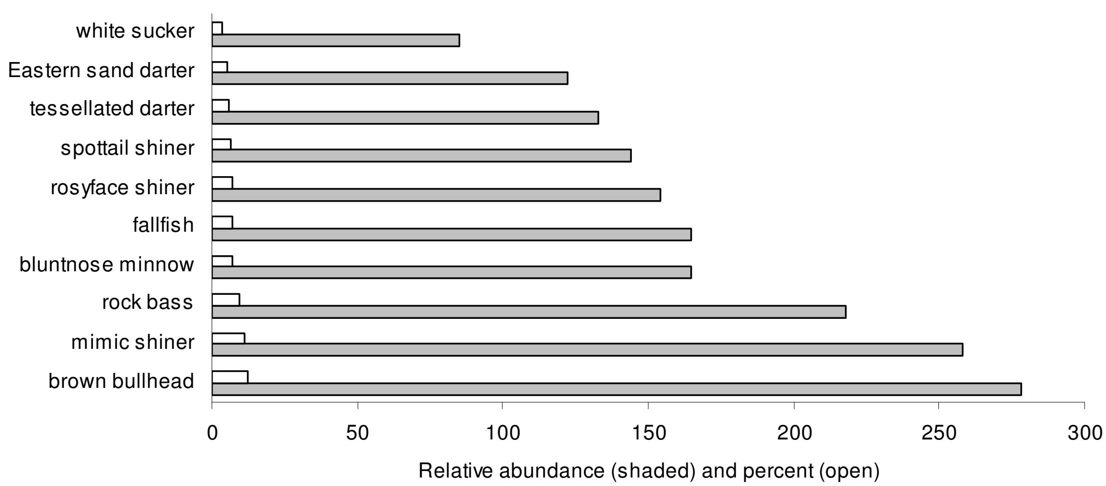


Figure 22. Relative abundance and percent abundance of the 10 more common fish species collected in the study area (all gear combined).

Predators were collected in lower relative abundance: smallmouth bass ranked 11th, largemouth bass ranked 26th, northern pike ranked 28th, and walleye ranked 34th. No sea lamprey was collected in the study area. The silver lamprey was the only parasitic lamprey collected (30th in relative abundance) and was collected only in the Little Salmon River. The non-parasitic American brook lamprey (23rd in relative abundance) was collected upstream and downstream of the dam, and in the Little Salmon River. A single muskellunge X northern pike hybrid (tiger muskie) was collected downstream of the dam in 2004 and was the largest predator collected (76 cm, 2.8 kg).

Logarithmic regressions of length and weight of seven more abundant species resulted in relationships with good predictive characteristics with the exception of longnose gar (Figure 23). Longnose gar were caught only during the spring spawning period (although they were observed at other times) and the catch most likely included individuals that had spawned which would affect the length-weight relationship. Length-weight plots discriminating between catches upstream and downstream of the dam showed that brown bullhead and greater redhorse sucker collected downstream of the dam were larger generally than those collected upstream of the dam but the sizes of rock bass collected in both areas were similar. There were not enough fish collected of other species at each site to make this comparison.

Length frequency plots of the more abundant fish species collected by seine showed a wide range of sizes (Figure 24) but the majority were young-of-year. Bluntnose minnow and spottail shiner exhibited a bimodal distribution. The distribution of length frequencies was similar between upstream and downstream populations of eastern sand darter, tessellated darter, rosyface shiner, fallfish, and bluntnose minnow.

Two species of lamprey were collected: American brook lamprey (non-parasitic) was collected at transects 2, 5, 6, 8, 9, and 14 as ammocoetes and adults and adult silver lamprey (parasitic) was collected at the confluence of the Salmon and Little Salmon rivers, and at transects 3 and 13. One silver lamprey was attached to a shorthead redhorse sucker in the present study. No sea lamprey was collected during the study although one tiger muskellunge had a putative lamprey scar. There were no exotic or invasive fish species collected (excluding carp) although the round goby (*Neogobius melanostomus*) has been collected in the St. Lawrence River at the Akwesasne Marsh (Jim McKenna, USGS, pers. comm.).

Twelve fish species (N= 207) were collected as larvae or juveniles in the towed and sweep nets (Table 10). Sweep nets collected 93% of the total catch which was composed primarily of white sucker, rosyface shiner, and fallfish. The majority of these fishes were collected near or in the vegetated areas over a variety of substrates.

Table 10. Fish larvae and juveniles collected in towed net and sweep net by transect.

Transects upstream of the dam				Transects downstream of the dam			
Transect	Species	Number caught	TL (mm) range	Transect	Species	Number caught	TL (mm) range
4	fallfish	14	17-20	2	fallfish	3	22-24
4	white sucker	12	20-26	2	white sucker	18	15-23
5	rosyface shiner	6	13-23	3	smallmouth bass	2	11-11.5
5	American brook lamprey	1	17	3	mimic shiner	1	5.5
6	American brook lamprey	1	205	10	fallfish	9	18-20.5
7	fallfish	34	11-22	10	shorthead redhorse	3	35-37
7	logperch	1	11.5	10	tessellated darter	1	24.5
7	rosyface shiner	24	21.5-25	10	white sucker	9	14-17.5
7	smallmouth bass	3	19-21	11	logperch	1	14.5
7	white sucker	7	13-28	13	rosyface shiner	1	30
8	spottail shiner	2	13.5-14.5	13	smallmouth bass	5	10-27.5
8	American brook lamprey	4	13.5-73	13	white sucker	15	13-16
8	tessellated darter	2	6.5-10	15	stonecat	16	16.5-20.5
Deer Creek	golden shiner	1	24				
Deer Creek	rosyface shiner	11	17-44				

Electrofishing was done with a boat-mounted unit for 60 min in the Salmon River downstream of the confluence upstream to transect 2, and upstream from the confluence to transect 10 in the Little Salmon River; and backpack electrofishing was done for 40 min at the confluence and transects 9, 10, and 15. Thirty fish species were collected by electrofishing (N = 165). Smallmouth bass (25% of total) and silver redhorse sucker (13%) were the more abundant species. All of these smallmouth bass were collected downstream of the dam.

Index of biotic integrity. Both rivers had high scores in the richness and composition metrics of total species, number of insectivore species, water column species, number of terete minnow species, percentage of dominant species, and the percentage of white suckers (Table 11). Scores were lower in two of the trophic

Table 11. Metric scores for fish index of biotic integrity following Daniels et al. (2002) based on a watershed of 2838 km^2.

		Scoring			Salmon River		Little Salmon River	
Metric	Description	5	3	1	value	score	value	score
	Resident fish species richness and composition							
1	Total number of species	>13	6 - 12	<6	31	5	33	5
2	Number of benthic insectivores	>4	2 - 4	<2	5	5	6	5
3	Water column species	>5	2.5 - 5	<2.5	6	5	8	5
4	Number of terete minnow species	>4.5	2 - 4.5	<2	9	5	9	5
5	% dominant species	<40%	40-55%	>55%	36.3	5	47.2	3
6	% total white sucker	<3%	3-15%	>15%	3.4	3	0.7	5
	Trophic composition							
7	% total omnivores	<20%	20-45%	>45%	53.4	1	61.8	1
8	% total insectivores	>50%	25-50%	<25%	28.7	3	32.9	3
9	% carnivores	>5%	1-5%	<1%	6.2	5	5.3	5
	Fish abundance and condition							
10	fish abundance (no./100m^2)	>10	5-10	<5	104	5	184	5
11	% with 2 age groups	>40%	15-40%	<15%	22.6	3	12.9	1
12	% with tumors, lesions, parasites	0%	>0<1%	>1%	0.5	3	2.2	1
	Total score					48		44

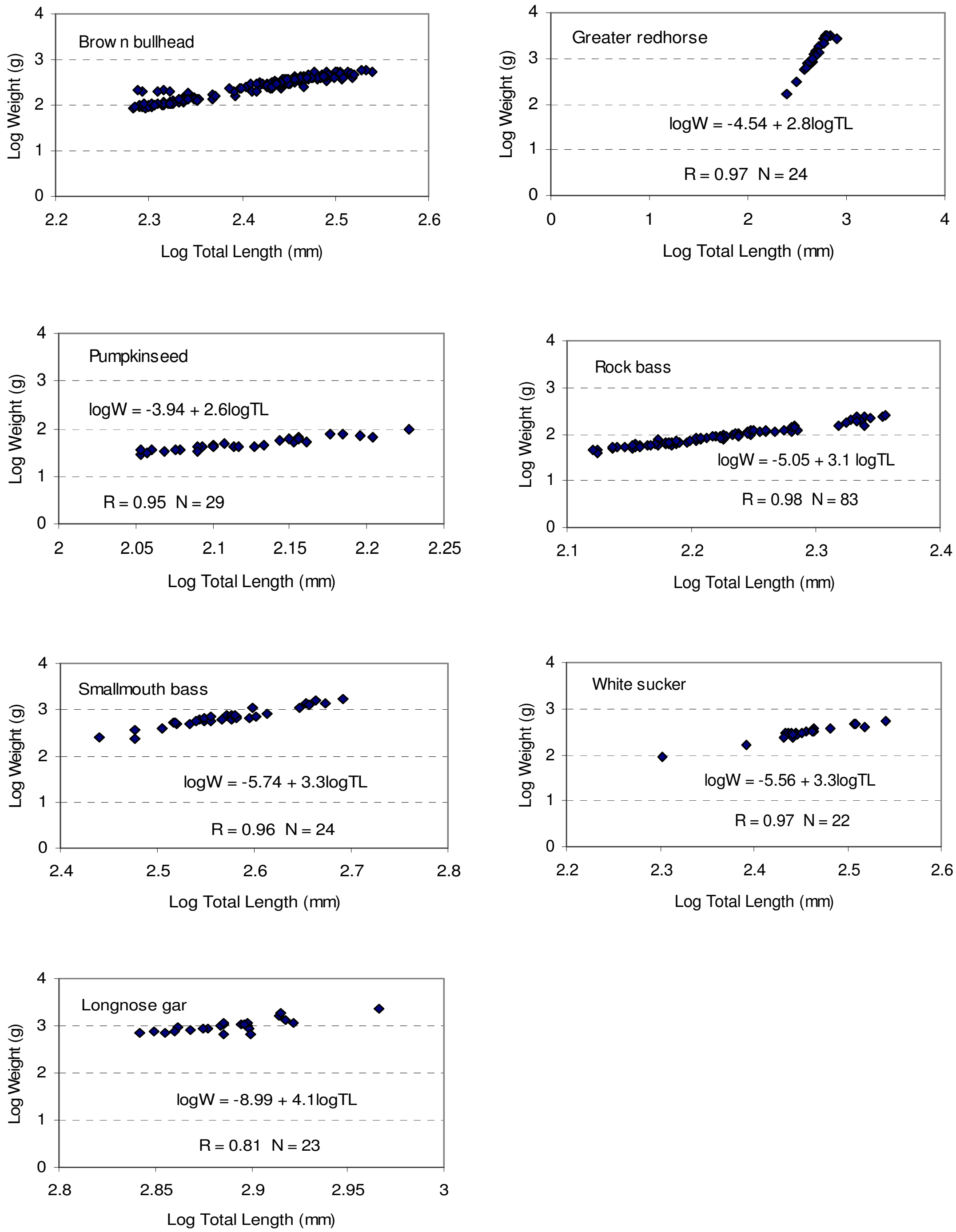


Figure 23. Length-weight relationships for seven more abundant fishes collected in trap nets in the Salmon and Little Salmon rivers.

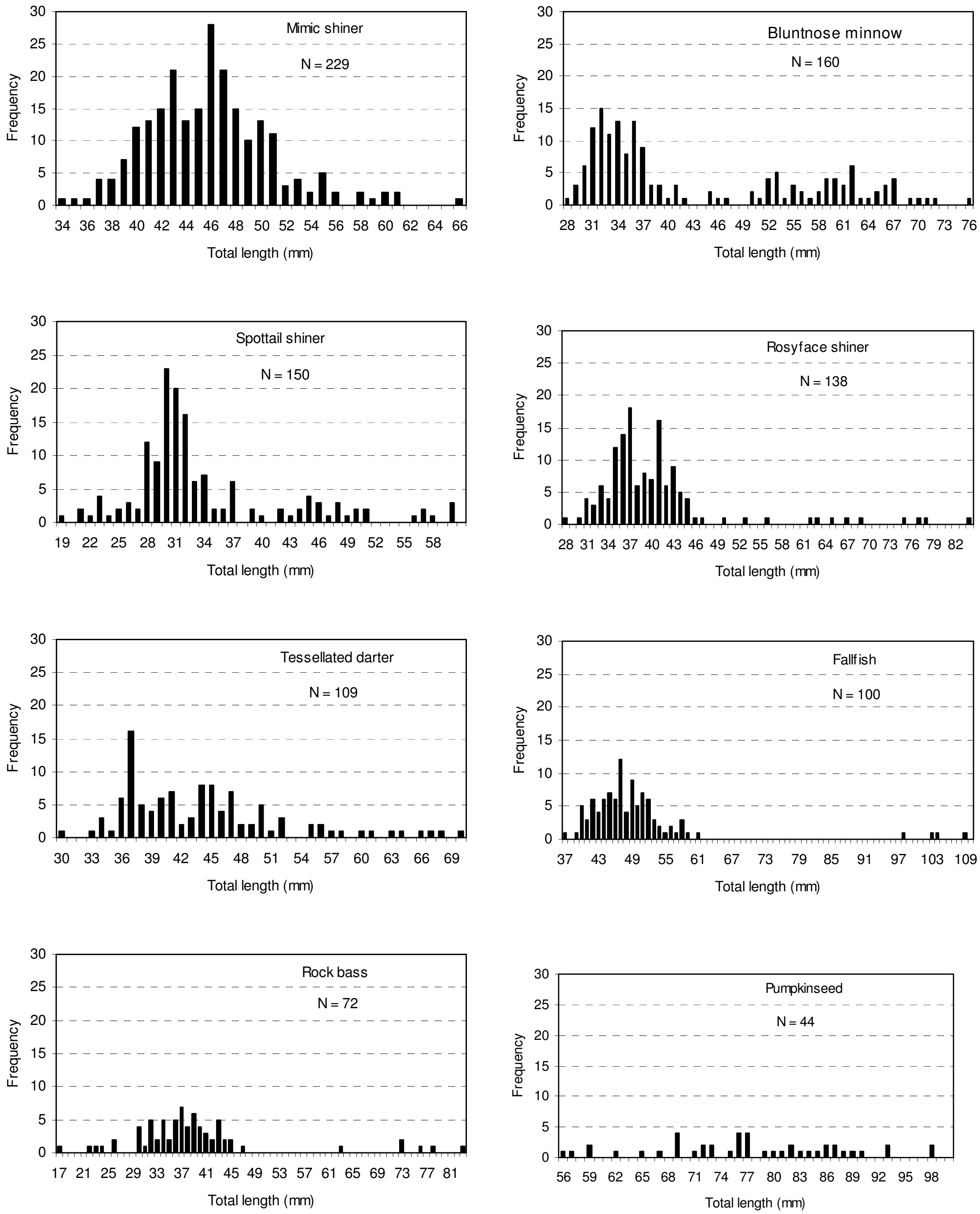


Figure 24. Length frequency plots of eight fish species collected by seining in the Salmon and Little Salmon Rivers.

composition metrics (percent omnivores and percent insectivores) but at the maximum for percent of top carnivores. Scores were mixed in the fish abundance and condition metrics of fish density, percent with at least 2 age groups, and percent with tumors, lesions or parasites. The overall score was high based on the watershed size.

Aquatic plants. Ten genera of aquatic plants were identified in the rivers (Figure 25; excluding the ponds above the dam) and occurred in small patches primarily along the banks. Three areas of channel-wide plant cover were found upstream of transects 1, 10, and 12. *Potamogeton* and *Elodea* were the dominant genera in these areas. *Elodea* dominated the plant cover at transect 8 (not shown) but the area covered was restricted to the east side. Northern wild rice (*Zizania palustris*) was found in one small area upstream of transect 1. The exotic flowering rush (*Butomus umbellatus*) was found along the banks of the Little Salmon River, and the exotic European frogbit (*Hydrocharis morsus-ranae*) was found in several colonies upstream of the dam.

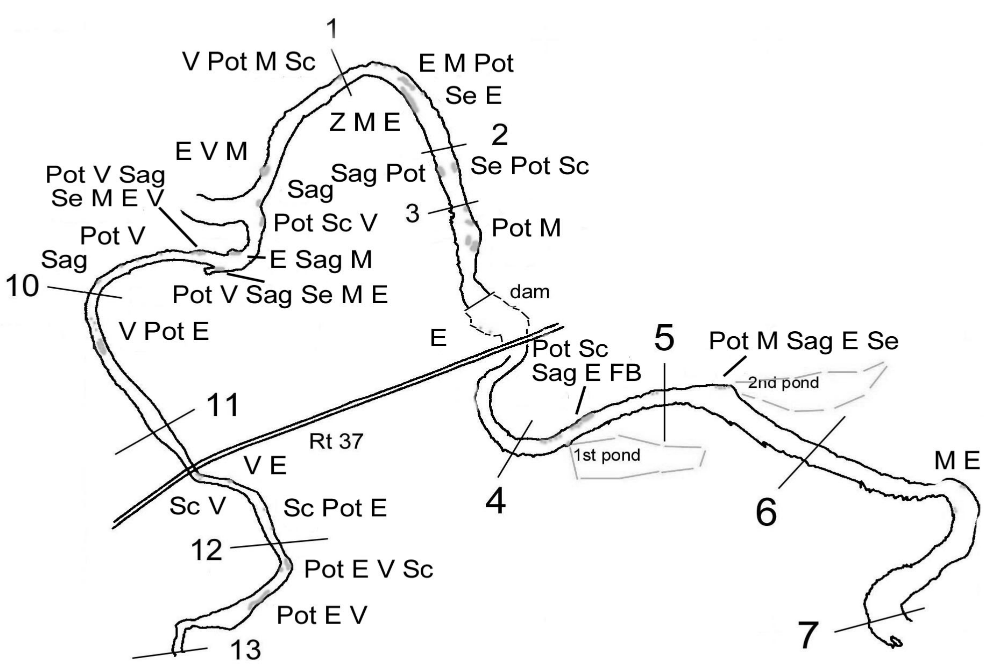


Figure 25. Aquatic plant genera identified in the study area in 2003 and 2004. The letter abbreviations for plants are: V =*Vallisneria*, Pot = *Potamogeton*, M = *Myriophyllum*, Sc = *Scirpus*, Z = *Zizania*, E = *Elodea*, Sag = *Sagitarria*, FB = European frogbit, and Se = sedges. Flowering rush *Butomus umbellatus* was collected along the north side of transect 10.

Discussion

The Salmon and Little Salmon rivers cut through a glacial moraine deposit of coarse sand on the north side of Malone. This sand has been deposited in the rivers and overlies the glacial lake bed silt and clay of the St. Lawrence River valley. The silt and clay deposits can be seen at some transects, especially at transect 10. The low gradient of the rivers and large particle size allows much of the sand to settle out and it is redistributed by ice movement and high water events. Ice thickness averages about 0.6 m for nearly four months of the year. Ice can form to the bottom of the river in some areas which scours the bottom during the spring breakup, reducing the amount of large woody debris and leaf packs, thereby reducing the organic material in the substrate. Ice scouring also occurs along the vegetated banks which removes some of the accumulated woody debris from the previous year. Ice scrapes along tree trunks can be seen as high as 2 m above the average summer water level.

The frequent high water events, seasonal ice movement, and large particle size of the sediment reduced the accumulation of sediment behind the Fort Covington Dam. The volume of sediment behind the dam represented about 5% of the annual estimated sediment production in the Salmon River watershed (Milone and MacBroom 2004). Most of the sediment production is kept in suspension and is carried over the dam. The downstream movement of sediment is of critical importance in assessing the risks of dam removal (Shuman 1995). Three conceptual models have been proposed for the transport of sediments (reviewed in Lisle et al. 1997) where the sediment can 1) move as a discrete mass with little change in shape, 2) move as a diffuse stream of particles over time, and 3) remain in place with only a small proportion moving downstream. Much of the sediment behind the Fort Covington dam is higher in elevation than the expected average water level after the dam is removed, and the sediment is concentrated one side of the river (Milone and MacBroom 2004). These factors would reduce the amount of sediment available to mobilization and thus sediment movement may not conform to any of the proposed models. The movement of the sediment in the Salmon River may depend as much on the dam removal procedure as on water flow events. Milone and MacBroom (2004) have outlined a series of options to manage the sediment ranging from leaving all the sediment in place (with or without stabilization) to dredging and relocation. The proposed options include a gradual drawdown of the reservoir water level that would also help to reduce the downstream movement of sediment. The volume of sediment behind the dam is not likely to cause any long-term deleterious effects to the downstream biota as most of the sediment is silt and clay which will remain in suspension and be carried, and dispersed, throughout much of the lower river with each subsequent high water event. The coarse sand sediment in the remainder of the river will not be mobilized easily and may move only with extreme water flow (Johnson et al. 2001) or with ice movement.

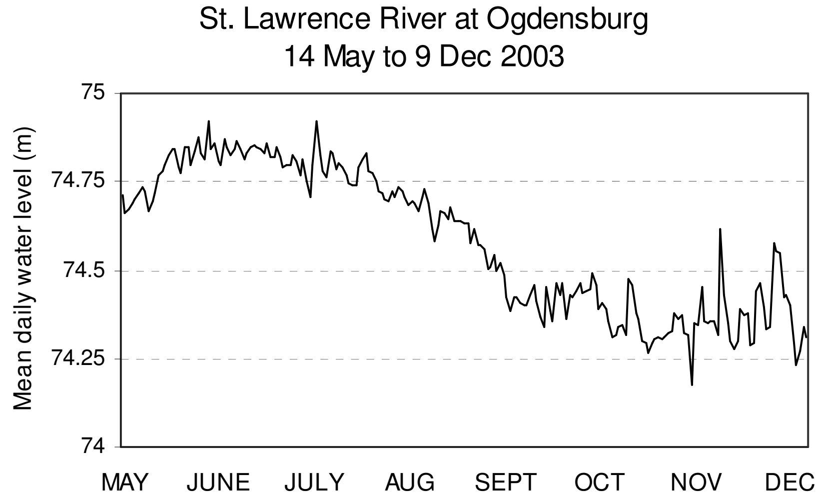
Several compounds typical of coal gasification processes were found in the sediment upstream and downstream of the dam in concentrations that exceed the NYSDEC guidelines for sediment (Milone and MacBroom 2004). Additional sampling of the sediment is expected to determine the extent of the contamination. This was similar to that found at the Manatawny Creek Dam in Pennsylvania (Johnson et al. 2001) where the hydrocarbon contaminants did not sorb readily to the coarse sand. There was little evidence found of physical injuries (lesions, sores) in fish in the present study that could be attributed to these contaminants although the occurrence of this type of injury has been of concern in the past (NYSDEC 1999).

Water level changes were the result of precipitation events with little apparent influence from the controlled discharge of the St. Lawrence River. The Salmon River, as a tributary, would be under some influence from the St. Lawrence River but comparisons of water level changes in the Salmon and Little Salmon rivers (Figures 7 and 8) with water level changes in the St. Lawrence River (Figure 26) did not reveal any correspondence. The sustained decrease in water level seen in September, 2004, in the study area, however, was evident in the St. Lawrence River. It is not known if the decrease in the St. Lawrence River is a function of the operation of the St. Lawrence Seaway or if it reflects changes in water level in the Oswegatchie River, just upstream from the water level gage.

The pattern of water level changes were similar among transects upstream and downstream of the dam and were similar to that in the Little Salmon River. These similarities suggest that there was no influence on water level from the dam other than the creation of the reservoir. The similarity of water level changes would be expected in a run-of-river dam (Heinz Center 2002).

Water chemistry tests indicate that the rivers can be classified as turbid soft water with moderate buffering capacity. Four constituents tested for in this study (chloride, nitrate, sulfate, ammonia) were determined to have levels that were at the low end that would be expected in natural freshwater and had similar levels to those determined in previous studies over the past 50 years (USGS). Nitrate and ammonia were elevated in some samples but these were localized. Dissolved oxygen was similar upstream and downstream of the dam indicating that there was little impact on the flow regime from the dam and was supported by the similarity in water level changes at upstream and downstream locations. A similar response in dissolved oxygen values was found in the Baraboo River, WI (Stanley et al. 2002).

The macroinvertebrate indices suggest that habitat diversity in the run areas was less than in the riffles, and was lowest in the reservoir. Run transects were dominated by midges (Chironomidae) while riffle transects were dominated by caddisflies, mayflies, riffle beetles, and midges. This was similar to that described by Stanley et al. (2002) in



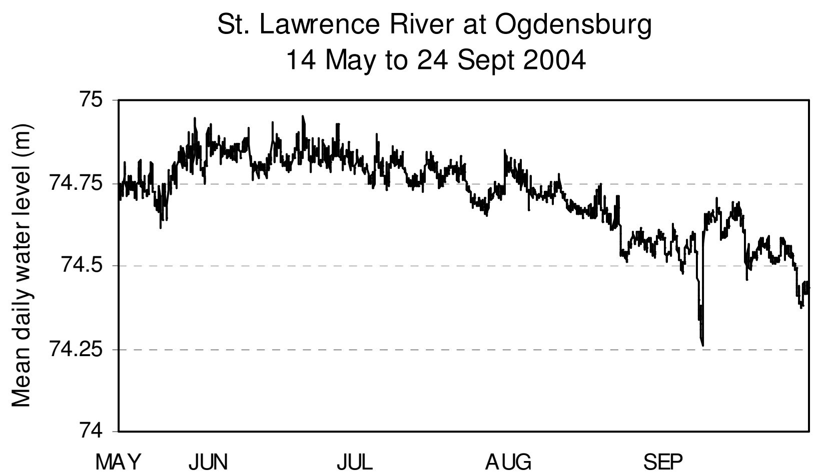


Figure 26. St. Lawrence River mean daily water level measured at the NOAA gage at Ogdensburg (gage 8311030).

the Baraboo River. The impact shown by the indices may be due to reduced flow velocity, especially in the reservoir transects, and the nearly uniform sand substrate, both of which would reduce habitat diversity (Hill et al. 1993). The sediment in the run areas was conducive to production of Chironomidae which is the preferred food of the eastern sand darter (Cooper 1983). Chironomidae also serves as prey for many of the minnow species that, in turn, support the larger predators such as smallmouth bass and northern pike.

A comparison of index values can be made using the data presented by Ichthyological Associates (IA 2005) collected at the Flat Rock Road Bridge (Table 12), approximately 5.5 miles upstream from transect 9 (Cushman Road Bridge). The greater values for EPT family richness and Total Family richness in the present study may be accounted for by the greater number of samples per site which would sample a wider variety of habitats and result in a greater number of taxa, including those that were uncommon or rare. Lower values for the Family Biotic Index would be expected as sampling proceeded downstream into lower gradient-higher temperature habitats.

Table 12. Comparison of metric values from the Flat Rock Road Bridge riffle (IA 2005) to the downstream riffles in the present study.

Metric	Transect					
	Flat Rock Road	3	7	9	13	15
EPT family richness	13	26	24	23	23	22
Family Biotic Index	4.35	3.66	3.97	3.65	3.83	4.19
Total Family richness	22.0	40.0	34.7	35.0	38.7	37.2
Percent Model Affinity	79.3	76.5	76.9	72.2	70.4	71.9

Similar values were obtained for Percent Model Affinity although the habitat for the two sampling areas differs in gradient and summer temperature maxima.

Only one exotic macroinvertebrate was collected, the Chinese mystery snail *Cipangopaludina chinensis malleata*, which was introduced from Asia. Two other exotic macroinvertebrates, *Echinogammarus ischnus* (amphipod) and *Dreissena polymorpha* (zebra mussel) were not collected in the study area although both occur in the St. Lawrence River.

The distribution of unionid species does not seem to have been influenced by the dam since five of the six species were found upstream and downstream of the dam. The low number of unionid juveniles suggests that there may be low reproduction since more juveniles would be expected to be collected in the benthic samples. Studies from other river systems have shown that dams can decrease or eliminate the upstream unionid population by preventing the unionid larvae from finding the proper fish host (Mathiak 1979) and conversely, that fish migration restoration (such as fish ladders) can increase unionid populations upstream (Smith 1985). Distribution studies of fish and unionid mussels do not always support these results (Strayer 1983, Gordon and Layzer 1993) but much of the life history of mussels is unknown and other factors, such as multiple fish hosts, may be involved.

The fish collections revealed an assemblage that was similar to that collected in 1930 (NY Cons. Dept. 1931). The 1930 survey covered a wider area, including the headwaters of the Salmon River and collected 12 species that were not collected in the present study. Nine of the 12 species were considered to be headwater species and would not be found in the present study area. Three fish species were collected in the 1930 survey in the present study area that were not collected in the present study: blacknose shiner, channel darter, and Johnny darter. Blacknose shiner was collected in the St. Regis River in 2004 (Dawn Dittman, USGS, pers. comm). Six fish species were not collected in the 1930 study that were collected in the present study: longnose gar, carp, central mudminnow, American eel, largemouth bass, and brook silverside. These six species were collected in adjacent rivers during the 1930 survey. Largemouth bass were collected in the study area in 1998 and 2001 (Morrill and Tyson 2001) and in the St. Regis River in 2004 (Dawn Dittman, USGS, pers. comm).

One sea lamprey was collected by the 1930 survey in the St. Regis River at Hogansburg but no sea lamprey was collected in the present study. One silver lamprey was attached to a shorthead redhorse sucker and one tiger muskellunge had a putative lamprey scar. Silver lamprey and American brook lamprey were collected in low abundance in the present study.

The major predators collected in both rivers were smallmouth bass, longnose gar, walleye, northern pike, and tiger muskellunge. Tiger muskellunge was stocked in the Salmon River upstream of the Cushman Road Bridge (transect 9) in 1994 and 1995 (Rich Preall, NYSDEC, pers. comm.). The tiger muskellunge that was caught downstream of the dam was not old enough to have come from this stocking program and we have considered this individual to be a natural hybrid. Other natural pike X muskellunge hybrids have been caught in the St. Lawrence River. Minnow and sucker species were abundant and formed the forage base for the predators. The exotic round goby has been collected from the St. Lawrence River near Massena (Jim McKenna, USGS, pers. comm.) but was not collected in the present study.

Eastern sand darter (a threatened species in New York) was ninth in relative abundance and was collected upstream (transects 4, 5, and 6) and downstream (transects 2 and 3) of the dam, in the Little Salmon River opposite Lewis Marina, and at the confluence of the Salmon and Little Salmon rivers. The percent of sand in the substrate was determined by Daniels (1993) to be the best predictor of sand darter abundance and each transect in the present study where sand darters were collected had a firm, clean sand bottom with moderate current.

The scores obtained from the fish index of biotic integrity suggest that these two rivers are in good condition with relatively low impacts from stressors such as pollution or sedimentation. This conclusion is supported by the high number of fish species and good body condition of the fish collected, and by the macroinvertebrate indices. These results suggest, but do not validate, that the metric scoring system of Daniels et al. (2002) is applicable to rivers in the St. Lawrence system, as those authors suggested. Validation of the metric used will require a larger sampling effort, or data from previous efforts, over a wider geographic area that would include the headwater communities. Our study represents only two sites which may not be indicative of an 'ideal' aquatic community.

The abundance and distribution of aquatic plants has not changed substantially since the 1930 survey which found three genera to be abundant: *Potamogeton*, *Elodea*, and *Vallisneria*. These genera were distributed along the river banks in small patches. The coarse sand substrate and frequent periods of high discharge would prevent most plant colonization except in those areas that were sheltered in some way, such as downstream of the supporting pylon for the railroad bridge, or in slack water areas more common in the Little Salmon River. Many submerged aquatic plants have shallow root systems and can be dislodged easily by strong currents (Wetzel 1983). Three larger areas of aquatic plants were found in the present study that served as spawning areas for fishes, as well as the two ponds above the dam. Towed net and sweep net samples showed that fish larvae and juveniles were present primarily along the river banks, generally near or in the vegetation, and were rare in open water.

Predicted changes. We expect that there will not be any effect upstream from transect 7 which is the upstream limit of the reservoir, and no substantial effect downstream of transect 2 since bed elevation is similar upstream and downstream of the dam (Milone and MacBroom 2004) and there is little accumulated sediment behind the dam. The riffle at transect 7 will expand downstream a short distance only since the gradient at the lower end of the transect is quite low. Transects 5 and 6 will remain as run-type habitats, similar to transect 8. It is possible that increased flow velocity in these transects could incise a deeper channel in the sand substrate. The lower water level will allow emergent and submergent plant colonization along the river banks which can serve as spawning and nursery areas for fish larvae and habitat for macroinvertebrates.

The first pond (Figure 25) will become shallower and narrower with increased vegetation along the edges. A channel may develop at the outlet if water flow can erode the sill that blocks the outlet at low water levels. If so, this may increase flow through the pond and will allow for fish access to the pond. The characteristics of the second pond will not be altered substantially with the exception of increased vegetation density along the edges. The aquatic plant and macroinvertebrate community in both ponds will remain similar to that at present. Transect 4 will experience the most change in flow velocity and community assemblage, particularly the macroinvertebrates, from a community dominated by lentic species to one dominated by lotic species. The sand bar present at the upstream end of this area will be dewatered and colonized by aquatic vegetation, depending upon ice scouring. The riffle at transect 3 will expand upstream, perhaps as far as transect 4 which has an extensive rocky area on the west side. This rocky area may represent the original river bed. Transects 1 and 2 will receive additional sediment during the dam removal period but this should be short-lived as high water events will suspend some of the silt and clay sediments from behind the dam and distribute them farther downstream in much the same way as happens at present. The expansion of the riffle areas and increased water velocity will allow for an increase in lotic species such as riffle beetles, caddisflies, mayflies, stoneflies, blackflies, and some species of midges. The run areas will continue to support lentic species of mayflies and midges and with increased vegetation along the river edges, the overall density and diversity of macroinvertebrates should increase. The increase in macroinvertebrate density should produce an increase in fish growth rates and an increase in the population of lotic species.

There should not be a substantial change in the unionid mussel population with the exception of the possibility of stranding in transects 5 and 6 as the water level of the reservoir is lowered. Sedimentation downstream should not be a factor if the reservoir drawdown is gradual and the sediments behind the dam are stabilized according to the options outlined by Milone and MacBroom (2004).

Fish migration upstream will be possible for American eel, walleye, longnose gar, yellow perch, and carp for the first time in 91 years, although the benefit to American eel and walleye may be limited due to their low population level in the river. Predation on forage fish by longnose gar and smallmouth bass may increase, particularly in the ponds if access is possible. Increased growth rate of smallmouth bass was seen in the Milwaukee River after dam removal (Kanehl et al. 1997) although that reservoir was more eutrophic than that in the Salmon River. The presence of carp may be disruptive to the sediment and vegetation in the ponds as well as in Deer Creek marsh, and may reduce spawning success of some forage fish (Roberts et al. 1995). The effect of carp activities will depend on water level and access to the ponds. The habitat areas for the eastern sand darter will not change appreciably; the only effect is likely to be a short-term increase in sediment at transect 2. The amount of suitable sand substrate at transect 5 may increase as water velocity increases after the dam is removed and could offset any decrease in habitat at transect 2. The density of midges may also increase at transect 5 and could offset any decrease in midge density at transect 4. New migrants, such as sea lamprey and lake sturgeon, are possible although sea lamprey have not been collected in the Salmon River. Lake sturgeon restoration through stocking appears to be successful in the St. Regis River (a tributary of the St. Lawrence River west of the Salmon River) and may lead to colonization of the Salmon River, or alternatively, a direct stocking program (Doug Carlson, NYSDEC, pers. comm.). Lake sturgeon are present downstream of the Moses-Saunders Power Dam at Massena and may colonize the Salmon River after the dam is removed.

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APPENDIX

Appendix table 1. Weight and percent of sediment fractions and percent organic matter by transect. E = east, C = center, and W = west areas of each transect.

Total weight (g)	SAND % Dry	SILT % Dry	CLAY % Dry	TOTAL % Dry	% organic	Transect
0.78230	78.51208	13.00013	8.48779	100	0.78	tr1 E
7.78168	98.27672	0.77490	0.94838	100	0.32	tr1 C
5.75915	88.26048	11.01063	0.72889	100	1.01	tr1 W
6.67126	91.06646	7.14243	1.79112	100	0.55	tr2 E
8.30382	98.36702	0.85021	0.78277	100	0.93	tr2 C
7.96770	97.53254	1.88009	0.58737	100	0.13	tr2 W
8.30385	98.30734	0.76526	0.92740	100	0.16	tr4 E
8.95853	98.03361	1.83066	0.13574	100	0.29	tr4 C
4.75333	55.33050	44.11511	0.55439	100	1.08	tr4 W
8.83065	28.02816	55.59978	16.37206	100	0.53	tr5 E
9.01381	98.96492	0.43822	0.59686	100	0.17	tr5 C
6.47412	89.36777	10.15115	0.48108	100	0.58	tr5 W
8.86023	99.19415	0.09368	0.71217	100	0.09	tr6 E
8.35855	98.83592	0.45702	0.70706	100	0.15	tr6 C
8.00847	97.52137	2.11901	0.35962	100	0.17	tr6 W
7.17939	92.23193	5.98770	1.78037	100	0.23	tr8E
9.75793	97.95756	0.70507	1.33737	100	0.11	tr8C
8.10935	95.06066	4.45155	0.48778	100	0.09	tr8W
9.04619	90.36427	6.49233	3.14340	100	0.16	tr10 E
5.73386	74.55117	21.56872	3.88011	100	0.99	tr10 C
9.96323	4.30814	67.34764	28.34422	100	0.31	tr10 W
8.17840	98.88242	0.66761	0.44997	100	0.47	tr11 E
9.41468	99.35358	0.09235	0.55407	100	0.13	tr11 C
7.96662	97.58994	2.25692	0.15314	100	0.83	tr11 W
8.97771	90.05537	8.92432	1.02030	100	0.45	tr12 E
8.41268	99.07045	0.17949	0.75006	100	0.10	tr12 C
6.37417	85.23118	14.69305	0.07577	100	0.75	tr12 W
7.82341	83.84081	12.82267	3.33652	100	0.40	tr14E
8.15675	98.86107	0.20106	0.93787	100	0.08	tr14C
5.60391	80.24716	19.18174	0.57110	100	0.85	tr14W

Appendix table 2. Total number (all months) of macroinvertebrates by transect. These families were used to construct the indices.

Transect		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**TOTAL**
caddisfly	Hydroptilidae	3	8	720	6	2	3	473	0	300	0	7	5	1460	1	2181	5169
	Philopotamidae	0	0	2422	0	1	0	507	0	1613	6	5	0	934	0	713	6201
	Hydropsychidae	3	7	6738	0	0	4	2958	3	4539	0	28	2	8332	12	8826	31452
	Molannidae	0	0	12	0	0	0	0	0	0	0	6	3	6	0	8	35
	Limnephilidae	21	0	18	4	0	0	41	8	34	1	7	1	310	0	97	542
	Phyrganeidae	1	7	1	0	0	1	0	0	0	2	7	3	0	1	1	24
	Helicopsychidae	0	0	207	0	0	0	9	1	93	0	0	1	222	0	640	1173
	Brachycentridae	1	2	976	0	0	1	837	0	1146	0	0	0	1915	0	451	5329
	Polycentropodidae	14	23	90	31	40	2	101	10	76	24	106	65	47	30	24	683
	Leptoceridae	5	22	6	2	6	4	37	0	8	21	22	7	197	8	350	695
	Glossosomatidae	0	1	92	0	0	0	1	0	52	0	0	0	72	0	6	224
	Rhyacophilidae	1	0	29	0	0	0	3	0	26	0	0	0	20	0	0	79
	Psychomyiidae	0	0	15	0	0	0	211	1	58	0	0	0	1	0	0	286
	Odontoceridae	0	0	11	0	0	0	7	0	0	0	0	0	125	0	117	260
	Lepidostomatidae	0	0	10	0	1	0	2	0	1	0	0	0	2	0	0	16
mayfly	Heptageniidae	77	0	1424	1	1	0	521	2	504	2	15	2	3918	1	2637	9105
	Baetidae	8	7	3494	2	0	7	1846	1	2333	2	4	3	9025	10	7494	24236
	Isonychiidae	1	2	3207	0	0	1	1681	0	1189	0	4	0	1268	0	658	8011
	Ephemeridae	2	11	0	17	13	16	0	2	0	30	15	23	0	7	0	136
	Polymitarcyidae	4	1	366	0	0	1	44	2	188	2	0	0	372	0	196	1176
	Ephemerellidae	6	1	4099	0	0	0	696	1	1881	0	10	0	2113	0	2389	11196
	Caenidae	15	103	30	92	44	22	181	3	3	62	74	77	123	33	75	937
	Baetiscidae	3	4	0	0	1	5	4	0	0	1	0	0	0	0	0	18
	Leptophlebiidae	0	0	250	0	0	1	44	0	125	0	0	1	1	0	0	422
	Tricorythidae	4	1	48	1	0	1	44	2	25	13	28	12	692	7	451	1329
stonefly	Perlidae	0	0	86	0	0	0	24	0	18	0	2	0	402	0	68	600
	Taeniopterygidae	0	0	140	0	0	0	89	0	39	0	0	0	0	0	74	342
	Nemouridae	0	0	7	0	0	0	0	0	4	0	0	0	0	0	1	12
beetles	Elmidae	65	417	3460	89	88	106	1377	78	2250	332	703	498	8529	401	7009	25402
	Psephenidae	39	3	489	1	0	0	52	0	48	0	0	0	370	0	275	1277
	Hydrophilidae	1	9	1	0	0	0	1	0	0	55	61	0	11	11	16	166

Appendix table 2 continued. Total number of macroinvertebrates by transect. These families were used to construct the indices.

Transect		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
	Dryopidae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
	Gyrinidae	0	1	0	0	0	0	2	3	1	1	4	1	15	0	70	98
	Dytiscidae	2	0	3	0	0	0	4	0	0	0	0	0	1	0	0	10
	Noteridae	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	6
	Staphylinidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
	Haliplidae	1	1	0	2	0	0	0	0	0	0	0	0	0	1	0	5
	Chrysomelidae	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
	Curculionidae	0	0	0	0	0	0	0	1	0	0	0	0	2	0	1	4
	Veliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
amphipods	Gammaridae	55	12	78	0	0	1	9	0	0	35	18	3	105	12	407	735
	Hyalellidae	80	5	8	6	0	0	6	0	0	113	44	1	241	5	53	562
snails	Viviparidae	0	0	0	4	3	1	0	13	2	0	0	0	0	0	0	23
	Pleuroceridae	0	5	33	0	0	0	0	0	0	5	50	10	0	0	2	105
	Valvatidae	4	0	0	0	1	0	0	0	0	0	2	3	0	0	0	10
	Physidae	10	2	14	1	0	1	2	1	2	6	40	5	137	2	274	497
	Hydrobiidae	80	62	2	27	107	17	6	2	0	66	942	95	87	67	1	1561
	Ancylidae	35	16	383	6	2	2	203	7	112	5	34	4	93	4	63	969
	Planorbidae	64	5	0	6	1	0	0	0	0	0	18	0	13	3	2	112
	Lymnaeidae	2	0	1	0	0	0	1	0	3	0	1	0	11	0	5	24
	Bithynidae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
	Sphaeriidae	61	40	80	17	26	5	79	30	7	92	147	94	330	42	1082	2132
diptera	Simuliidae	0	9	2382	0	0	0	181	4	431	0	0	2	2204	0	1235	6448
	Tipulidae	2	1	217	0	1	1	326	1	722	0	0	0	108	0	104	1483
	Tabanidae	3	2	0	13	13	5	2	13	0	8	2	6	0	15	0	82
	Ceratopogonidae	6	19	2	15	8	35	2	105	5	31	58	42	7	25	4	364
	Empididae	0	3	85	0	0	2	98	1	80	0	0	0	82	0	46	397
	Stratiomyidae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Athericidae	0	0	0	0	0	0	1	0	6	0	0	0	0	0	2	9
	Dolichopodidae	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	2
	Ephydridae	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	3
	Muscidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1

Appendix table 2 continued. Total number of macroinvertebrates by transect. These families were used to construct the indices.																	
Transect		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Total**
chironomids	Chironomidae	795	4521	4065	1808	1984	3046	2957	1002	4068	584	1549	1230	2438	1309	6395	37751
spongillafly	Sisyridae	0	0	1	0	0	0	8	0	0	6	0	0	0	0	2	17
damselfly	Protoneuridae	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	2
	Coenagrionidae	23	20	1	9	1	0	9	1	0	9	43	0	60	3	90	269
	Lestidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
	Calopterygidae	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
dragonfly	Libellulidae	0	1	1	0	1	0	0	0	0	1	0	0	0	0	0	4
	Gomphidae	5	9	0	5	4	5	0	2	0	8	5	2	0	7	0	52
	Aeshnidae	1	0	4	0	0	0	1	0	0	0	0	0	0	0	0	6
	Cordulidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
	Macromiidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
moths	Pyralidae	0	1	2	1	0	0	21	0	5	6	9	3	45	2	32	127
	Nepticulidae	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
isopod	Asellidae	6	6	77	2	3	0	473	10	93	31	3	19	19	8	160	910
megaloptera	Sialidae	0	0	0	4	3	1	0	1	0	14	13	3	2	2	0	43
	Corydalidae	0	0	17	0	0	0	7	0	12	0	0	0	4	0	1	41
bugs	Corixidae	1	42	1	47	4	17	1	3	1	2	1	1	4	8	8	141
	Belastomatidae	0	0	0	0	0	1	0	0	0	0	0	0	5	0	2	8
	Gerridae	0	0	3	0	0	0	0	0	0	0	0	0	2	0	13	18
	Aphididae	0	0	2	3	0	0	3	1	1	0	0	0	0	1	3	14
	Notonectidae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
	Nepidae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
	Saldidae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Hebridae	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2
wasp	Mymaridae	0	1	64	0	0	0	52	0	25	0	0	0	45	0	122	309
	Braconidae	0	0	10	0	0	0	8	0	1	0	0	0	8	0	5	32
TOTAL		1512	5416	35994	2226	2364	3321	16260	1323	22140	1590	4100	2240	46557	2056	44957	191936

Appendix table 3. Common and scientific names of fishes collected

American brook lamprey	*Lampetra appendix*
American eel	*Anguilla rostrata*
black bullhead	*Ameirus melas*
black crappie	*Pomoxis nigromaculatus*
bluegill	*Lepomis macrochirus*
bluntnose minnow	*Pimephales notatus*
bridle shiner	*Notropis bifrenatus*
brook silverside	*Labidesthes sicculus*
brown bullhead	*Ameirus nebulosus*
carp	*Cyprinus carpio*
central mudminnow	*Umbra limi*
common shiner	*Notropis cornutus*
cutlips minnow	*Exoglossum maxillingua*
eastern sand darter	*Ammocrypta pellucida*
fallfish	*Semotilus corporalis*
fantail darter	*Etheostoma flabellare*
fathead minnow	*Pimephales promelas*
golden shiner	*Notemigonus crysoleucas*
greater redhorse	*Moxostoma valenciennesi*
largemouth bass	*Micropterus salmoides*
logperch	*Percina caprodes*
longnose dace	*Rhinichthys cataractae*
longnose gar	*Lepisosteus osseus*
mimic shiner	*Notropis volucellus*
northern pike	*Esox lucius*
pumpkinseed	*Lepomis gibbosus*
rock bass	*Ambloplites rupestris*
rosyface shiner	*Notropis rubellus*
shorthead redhorse	*Moxostoma macrolepidotum*
silver lamprey	*Ichthyomyzon unicuspis*
silver redhorse	*Moxostoma anisurum*
smallmouth bass	*Micropterus dolomieui*
spotfin shiner	*Cyprinella spiloptera*
spottail shiner	*Notropis hudsonius*
stonecat	*Noturus flavus*
tessellated darter	*Etheostoma olmstedi*
tiger muskie	*hybrid of pike and muskellunge*
walleye	*Sander vitreus*
white sucker	*Catostomus commersoni*
yellow perch	*Perca flavescens*

Appendix table 4. Total catch of fishes by sampling gear.
These totals were used to construct the fish index of biotic integrity
Salmon River

Species	traps	seine	electrofishing	benthos	total
Am brook lamprey			1	1	2
American eel					0
black bullhead	1				1
black crappie					0
bluegill		1			1
bluntnose minnow		126	5		131
bridle shiner					0
brook silverside		8			8
brown bullhead	158		4		162
carp					0
central mudminnow					0
common shiner		14	4		18
cutlips minnow		3			3
eastern sand darter		21		2	23
fallfish	3	96	3		102
fantail darter				8	8
fathead minnow			3		3
golden shiner					0
greater redhorse	22	4	4		30
largemouth bass					0
logperch		14	2		16
longnose dace				3	3
longnose gar	11				11
mimic shiner		10	12		22
northern pike	2	1			3
pumpkinseed	13	19	4		36
rock bass	78	56	2		136
rosyface shiner		112	1		113
shorthead redhorse	3		2		5
silver lamprey	1		1		2
silver redhorse	3		8		11
smallmouth bass	11	9	37		57
spotfin shiner		16	1		17
spottail shiner		105			105
stonecat					0
tessellated darter		105	1		106
tiger muskellunge			1		1
walleye	1		1		2
white sucker	23	14	3		40
yellow perch	3		3		6
TOTAL					1184

Appendix table 4 continued. Total catch of fishes by sampling gear.
These totals were used to construct the fish index of biotic integrity

Little Salmon River

Species	traps	seine	electrofishing	benthos	total
Am brook lamprey		1		1	2
American eel			2		2
black bullhead					0
black crappie	4				4
bluegill		3			3
bluntnose minnow		38			38
bridle shiner		1			1
brook silverside		16			16
brook stickleback					0
brown bullhead	50		6		56
carp	1		1		2
central mudminnow		6	1		7
common shiner			1		1
cutlips minnow		2			2
eastern sand darter		100	1		101
fallfish		3			3
fantail darter				6	6
fathead minnow					0
golden shiner		2			2
greater redhorse	2		2		4
largemouth bass	2	6			8
logperch		28		1	29
longnose dace				1	1
longnose gar	14	1	2		17
mimic shiner		233	1		234
northern pike	3				3
pumpkinseed	18	31		2	51
rock bass	10	25	11	2	48
rosyface shiner		24			24
shorthead redhorse	3				3
silver lamprey					0
silver redhorse			13		13
smallmouth bass	5	5	4	2	16
spotfin shiner		23			23
spottail shiner		44		3	47
stonecat				4	4
tessellated darter		23	20		43
tiger muskellunge					0
walleye					0
white sucker	3	1	2		6
yellow perch	1	1	9		11
TOTAL					831

Appendix table 5. Values calculated for the Percent Model Affinity index (Novak and Bode 1992). Taxon listed as other includes Simuliidae, Gammaridae, Asellidae, Physidae, and Empididae. Levels of impact are 'none' = 65% or greater, 'slight' = 50-64%, 'moderate' = 35-49%, and 'severe' = <35%.

Percent abundance of each taxa for all samples combined

Taxa		Transect 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Trichoptera		2.63	1.17	30.31	1.71	1.91	0.40	29.51	1.34	34.76	3.04	3.90	3.13	28.50	2.20	28.14
Ephemeroptera		6.45	2.17	34.51	4.49	2.25	1.45	28.79	0.76	27.33	6.30	3.11	4.24	36.59	2.46	29.16
Plecoptera		0	0	0.62	0	0	0	0.64	0	0.27	0	0.04	0	0.84	0	0.30
Coleoptera		5.81	7.18	10.56	3.66	3.35	2.85	8.17	4.76	10.06	21.81	15.94	17.94	18.67	17.58	15.47
Oligochaeta		14.41	6.68	0.77	8.82	8.16	9.25	4.45	21.56	1.12	10.46	11.90	17.33	0.20	10.72	0.23
Chironomidae		42.74	75.34	10.86	71.83	75.64	81.90	16.82	58.22	17.79	32.83	32.16	44.23	5.09	55.47	13.42
other		3.82	0.53	7.04	0.12	0.11	0.11	4.34	0.93	2.65	4.05	1.27	1.04	5.32	0.93	4.45

Absolute difference between percent abundance and model percent

	Model percent	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Trichoptera	10	7.37	8.83	20.31	8.29	8.09	9.60	19.51	8.66	24.76	6.96	6.10	6.87	18.50	7.80	18.14
Ephemeroptera	40	33.55	37.83	5.49	35.51	37.75	38.55	11.21	39.24	12.67	33.70	36.89	35.76	3.41	37.54	10.84
Plecoptera	5	5.00	5.00	4.38	5.00	5.00	5.00	4.36	5.00	4.73	5.00	4.96	5.00	4.16	5.00	4.70
Coleoptera	10	4.19	2.82	0.56	6.34	6.65	7.15	1.83	5.24	0.06	11.81	5.94	7.94	8.67	7.58	5.47
Oligochaeta	5	9.41	1.68	4.23	3.82	3.16	4.25	0.55	16.56	3.88	5.46	6.90	12.33	4.80	5.72	4.77
Chironomidae	20	22.74	55.34	9.14	51.83	55.64	61.90	3.18	38.22	2.21	12.83	12.16	24.23	14.91	35.47	6.58
other	10	6.18	9.47	2.96	9.88	9.89	9.89	5.66	9.07	7.35	5.95	8.73	8.96	4.68	9.07	5.55
sum difference		88.44	120.97	47.07	120.68	126.17	136.34	46.28	121.99	55.66	81.71	81.67	101.09	59.12	108.18	56.05
sum diff X 0.5		44.22	60.49	23.54	60.34	63.09	68.17	23.14	61.00	27.83	40.86	40.84	50.54	29.56	54.09	28.02
100 - sum diff		55.78	39.51	76.46	39.66	36.91	31.83	76.86	39.00	72.17	59.14	59.16	49.46	70.44	45.91	71.98
impact		slight	moderate	none	moderate	moderate	severe	none	moderate	none	slight	slight	moderate	none	moderate	none