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Aquatic Assemblages and Their Relation to Temperature Variables of Least-Disturbed Streams in the Salmon River Basin, Central Idaho, 2001

Water-Resources Investigations Report 03–4076

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COVER: *Center*, Middle Fork Salmon River; *left*, collecting benthic invertebrates; *right*, bull trout

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
centimeter (cm)	0.3937	inch (in.)
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
kilometer (km)	0.6214	mile (mi)
meter (m)	3.281	foot (ft)
millimeter (mm)	0.03937	inch (in.)
square kilometer (km^2)	0.3861	square mile (mi^2)
square meter (m^2)	10.76	square foot (ft^2)

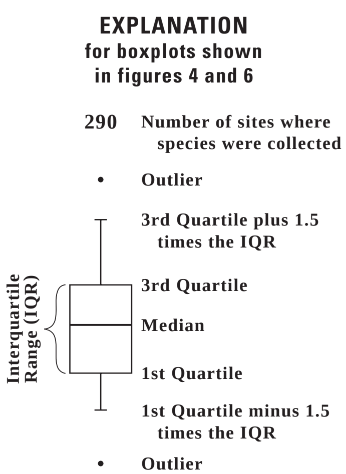
Temperature in degrees Celsius (ºC) can be converted to degrees Fahrenheit (ºF) as follows:

$$ºF=(1.8)(ºC) + 32$$

Other abbreviated units:

µm micrometer
µS/cm microsiemens per centimeter
mg/L milligram per liter

Sea Level: In this report “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.



Aquatic Assemblages and Their Relation to Temperature Variables of Least-Disturbed Streams in the Salmon River Basin, Central Idaho, 2001

By Douglas S. Ott *and* Terry R. Maret

Abstract

In the late 1990s, Idaho's established stream temperature criteria for the protection of coldwater biota and salmonid spawning were considered inadequate because the criteria did not agree with observed biological conditions in many instances and did not allow for variability in environmental condition or species diversity across a broad area such as the entire State of Idaho.

In 2001, benthic invertebrate and fish assemblages in 34 least-disturbed streams in the Salmon River Basin, central Idaho, were evaluated in relation to stream temperature and other environmental variables. The Salmon River Basin retains watersheds that are minimally affected by human activities. These "natural" stream conditions provide a basis for deriving attainable stream temperatures that can be used to set new, and revise existing, water-quality criteria for stream habitats affected by human activities.

During July through September 2001, data were collected to document the thermal regime of least-disturbed streams, characterize the distribution of aquatic biota at streams representing a gradient of temperature, and describe the relations between environmental variables and benthic invertebrate and fish assemblages. Nine stream temperature metrics were compared with the U.S. Environmental Protection Agency's criterion of 10°C (degrees Celsius) for bull trout spawning and juvenile rearing. The maximum weekly-maximum temperature at all 33 sites where temperature data were available exceeded this criterion. The maximum daily-maximum temperature (MDMT) at 30 of the sites exceeded the Idaho Department of Environmental Quality (IDEQ) criterion of 13.0°C for the protection of salmonid spawning; and the maximum daily-average temperature at all 33 sites exceeded the 9.0°C criterion for the protection of salmonid spawning. The thermal regime at most sites did not exceed the IDEQ criteria for the protection of coldwater biota. Nine environmental variables—water-surface gradient, discharge, wetted channel width, width:depth ratio, aspect, total seasonal thermal input, open canopy, riparian canopy density, and elevation were selected for correlation with the nine stream temperature metrics. Elevation showed the strongest inverse correlation with the stream temperature metrics.

Two hundred and one benthic invertebrate taxa from the 34 sampling sites were identified. The most abundant taxa were *Baetis tricaudatus*, Oligochaeta, *Tvetenia bavarica* gr., Acari, *Rhithrogena*, *Cinygmula*, *Heterlimnius*, *Micropsectra*, *Eukiefferiella devonica* gr., *Drunella doddsi*, and *Cricotopus*. Of the 201 benthic invertebrate taxa collected during this study, 57 taxa (present at a minimum of 5 sampling sites) were significantly correlated with one or more of the stream temperature metrics. Among the invertebrate taxa collected, 32 were identified as coldwater taxa. Of the coldwater taxa collected, *Zapada oregonensis* gr. showed the strongest inverse correlation with the stream temperature metrics and was collected at sites where maximum weekly-maximum temperature (based on date of sample and 6 days prior) ranged from 11.3° to 18.5°C.

Ten species of fish in the families Salmonidae, Cottidae, and Cyprinidae were collected. Two species (bull trout and chinook salmon) listed as threatened under the U.S. Fish and Wildlife Service Endangered Species Act were collected. Among all species, bull trout showed the strongest inverse correlation between relative fish abundance and stream temperature. Bull trout and juvenile bull trout densities were inversely correlated

with stream temperature. The probability of occurrence of juvenile bull trout was significantly correlated with MDMT on the basis of results from a logistic regression model developed during this study. However, this model differed from a similar model developed by the U.S. Forest Service on the basis of regional data collected in the Pacific Northwest. The regression model based on data collected during this study showed higher probabilities of occurrence of bull trout at colder stream temperatures (10° to 15°C) and lower probabilities of occurrence at warmer stream temperatures (16° to 21°C) than did the model based on regional data. The model comparisons suggest that regional or local differences need to be considered when deriving stream temperature criteria.

INTRODUCTION

Throughout the United States, watersheds have been altered by various forms of human disturbance. As a result, the distribution and structure of aquatic assemblages in rivers and streams within these watersheds have changed. Many endemic fish species of the Western United States are endangered, threatened, or of special concern as a result of human activities (Warren and Burr, 1994). Documenting these spatial and temporal changes in aquatic assemblages among streams can provide important information on water-resource quality and the biotic integrity of freshwater systems (Karr, 1991). However, before the effects of human alteration of streams can be evaluated, biological information is required from least-disturbed or "reference" streams, or by using suitable historical data (Hughes and others, 1986).

Unlike many areas of the United States, Idaho still retains watersheds that are minimally affected by human disturbance. It is assumed that these wilderness and roadless watersheds are without human sources of pollution and, thus, represent *a priori* natural background conditions (Grafe and others, 2002). Because the habitat structure and associated aquatic assemblages of a stream are determined by climate, geology, vegetation, and other features of the surrounding watershed (Frissell and others, 1986), streams within these watersheds are assumed to approximate historical conditions. The assessment of aquatic assemblages and environmental variables in relation to least-disturbed landscape characteristics is important for documenting resource potential (Hughes and others, 1986; Maret and others, 1997). In addition, this type of information provides the basis for deriving attainable conditions that can be used to set new and revise existing criteria within water-quality standards for stream habitats affected by human activities.

According to Karr (1991), criteria are those conditions that are presumed to support or protect the designated uses. In Idaho, the Idaho Department of Environmental Quality (IDEQ) is responsible for establishing and enforcing water-quality standards as mandated by Section 303 of the Clean Water Act. Idaho water-quality standard IDAP 58.01.02 (see **http://www2.state.id.us/deq/rules/waterrul.htm**) defines the goal of a water body by designating the use or uses of the water, setting criteria to protect those uses, and preventing degradation of water quality (Grafe and others, 2002).

Idaho water-quality standards WQS 3.35 and 100.01 to 100.05 designate four beneficial uses which all water bodies must meet: (1) aquatic life support—coldwater biota, seasonal coldwater biota, warm-water biota, and salmonid spawning; (2) contact recreation—primary (swimming) and secondary (boating); (3) water supply—domestic, agricultural, and industrial; and (4) wildlife habitat and esthetics.

In the early 1990s, Idaho WQS adopted the criteria of a 22.0°C maximum daily-maximum temperature (MDMT) and a 19.0°C maximum daily-average temperature (MDAT) for the protection of coldwater biota, and a 13.0°C MDMT and a 9.0°C MDAT for the protection of salmonid spawning, within the aquatic life support beneficial use (Grafe and others, 2002).

In addition to the Idaho WQS stream temperature criteria, the U.S. Environmental Protection Agency (USEPA) imposed a site-specific rule on those water bodies where bull trout (*Salvelinus confluentus*) are present (40 CFR 131.E.1.i.d, 1997). This rule set a 10.0°C maximum weekly-maximum temperature (MWMT) during June through September for the protection of bull trout spawning and juvenile rearing in natal streams.

At the time the criteria were adopted, little was known about the thermal regime of most Idaho streams. This lack of information led to the acceptance of stream temperature criteria that, in part, were established on the basis of laboratory studies of temperature tolerances of various species of aquatic life (Beitinger and others, 2000; Selong and others, 2001). While useful, laboratory studies of this type have limitations when applied to actual environmental conditions because laboratory studies don't take into account the ecologically diverse conditions in natural environments. By 1998, IDEQ had concluded that the established temperature criteria for Idaho streams were not adequate because they did not agree with observed biological conditions in many instances and did not allow for variability in environmental condition or species diversity (Essig, 1998).

Significant study of Idaho stream temperatures and their relation to established criteria had not been undertaken until recently, when exceedances were found to be common. During the summer of 2000, Donato (2002) studied the temperature regime of 183 minimally disturbed streams in the Salmon and Clearwater River Basins. Her results showed that temperatures in 100 percent (183 of 183) of the streams failed to meet the IDEQ 9.0°C MDAT and the 13.0°C MDMT criteria for the protection of salmonid spawning. Her results also showed that temperature in 35 percent (64 of 183) of the streams exceeded the IDEQ 19.0°C MDAT criterion, and temperatures in 40 percent (73 of 183) exceeded the 22.0°C MDMT criterion for the protection of coldwater biota. Results from this study underscore the fact that exceedances of temperature criteria are likely in many or most Idaho streams. In fact, Maret and others (2001), who studied sites across Idaho as part of the Idaho statewide surface-water quality monitoring program during 1996–98, identified 62 percent (25 of 40) of their sites where temperatures exceeded the Idaho WQS criterion of 22.0°C MDMT for protection of coldwater biota.

Within Idaho, most rivers and streams are presumed or explicitly designated such that their water quality supports coldwater biota (Grafe, 2002). Essig (1998) and Hillman and Essig (1998), on the basis of their reviews of several studies within Idaho, concluded that, although temperatures in many streams exceed criteria, these same streams are supporting populations of coldwater indicator species. Bugosh (1999), who looked at temperature regimes of streams and rivers draining wilderness or minimally disturbed watersheds in the Lochsa River Basin, concluded that, although summer stream temperatures naturally exceed the current criteria, the streams continue to support their beneficial uses.

Results of studies such as these support the fact that a single stream temperature standard is difficult to apply across a broad area such as the entire State of Idaho because streams differ in environmental complexity and biological diversity.

In 2001, the U.S. Geological Survey (USGS), in cooperation with IDEQ, began a study of 34 least-disturbed streams in the Salmon River Basin to document the environmental complexity and biological diversity of sites that are minimally affected by human activities. Objectives of the study were to provide a basis for defining attainable thermal conditions for stream habitats affected by human activities and to provide water-quality managers, policymakers, and the public with an improved scientific basis which would aid in establishing new, and revising current, life-stage temperature criteria for streams throughout Idaho.

Purpose and Scope

This report characterizes selected environmental variables, with a focus on stream temperature, and benthic invertebrate and fish assemblages for 34 wadeable (primarily second- through fourth-order), least-disturbed stream sites in the Salmon River Basin. Environmental and aquatic biota data were collected during the summer of 2001. Purposes of this report are to (1) document the thermal regime of least-disturbed streams; (2) characterize the distribution of aquatic biota in streams that represent a gradient of temperature; and (3) describe relations between environmental variables and benthic invertebrate and fish assemblages. Study results will assist resource managers in the development of applicable criteria that will protect coldwater biota and salmonid spawning and take into account natural environmental diversity.

Description of Study Area

The Salmon River Basin (fig. 1) is located in central Idaho and extends 684 km from its headwaters on the east side of the Sawtooth Range to the confluence with the Snake River, draining an area of approximately 36,324 km^2 (Lipscomb, 1998). The basin contains large areas that have been designated as wilderness, several national forests, and a national recreation area. Certain reaches of the Salmon River and its tributaries are designated as wild and scenic rivers. These features make the basin a popular destination for hiking, whitewater rafting, and other outdoor activities.

Elevation above sea level ranges from 3,852 m at Borah Peak, the highest point in Idaho, to 310 m at the

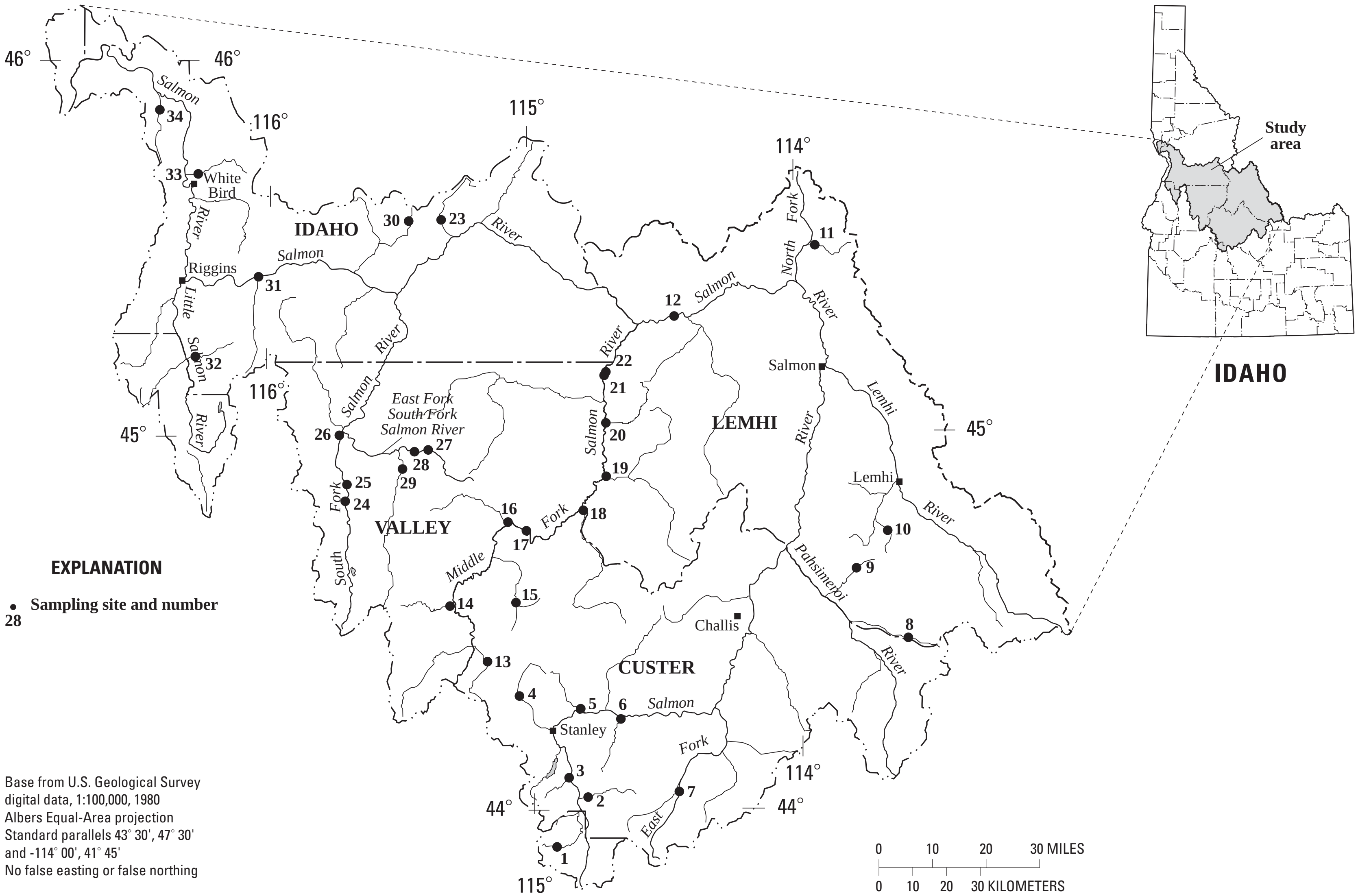


Figure 1. Location of sample sites in the Salmon River Basin, central Idaho. (Site names and characteristics shown in table 1)

confluence of the Salmon and Snake Rivers. Mean elevation of the basin is 2,014 m. Climate in most of the basin is semiarid and annual precipitation ranges from less than 10 to 50 cm; at higher elevations in the southwestern part of the basin, annual precipitation can average more than 50 cm (Lipscomb, 1998). Precipitation is primarily snow, and peak flows in streams generally result from spring snowmelt.

The Salmon River Basin is located in the Blue Mountains, Idaho Batholith, and Middle Rockies ecoregions (McGrath and others, 2001), which consist primarily of coniferous forests in upper elevations and sagebrush and grasslands in the valleys. Pine and fir predominate, covering 67 percent of the basin; rangeland and agricultural land cover 30 and 3 percent, respectively.

Geologically, the basin consists primarily of metamorphic and sedimentary rocks, granite, volcanic rocks, and alluvium (King and Beikman, 1974). The most noticeable geological feature within the basin is the Mesozoic Idaho batholith, which makes up the central mountains. Much of the basin is characterized by stream channels deeply incised in bedrock and bordered by steep terrain. Two major exceptions are the Lemhi and Pahsimeroi River Basins in the eastern part of the basin. Both of these basins have broad, alluvial valleys bounded by steep mountains (Lipscomb, 1998).

Mean annual streamflow of the Salmon River at the USGS streamflow gaging station near White Bird, Idaho, is 316 m^3/s for the period of record. The drainage area of the basin upstream from this gaging station is 35,095 km^2, or 97 percent of the entire basin area. Streamflow conditions for the study period were below the long-term average. The mean streamflow for 2001 was 55 percent of the mean annual streamflow for the Salmon River near White Bird (O'Dell and others, 2002).

Streams in the upper parts of watersheds in the basin typically have high water clarity, coarse-grained substrates (cobble and boulders), high stream gradients (>0.5 percent), well-defined riffles and pools, and very sparse macrophyte growth. Streams in these areas show few signs of human activities. Where present, most noticeable are the effects from historical logging, mining, and cattle grazing activities.

In contrast, streams in the lower parts of watersheds typically have lower water clarity, more fine-grained sediments, lower stream gradients, abundant run habitat, and generally denser macrophyte growth. These lower parts frequently are subjected to channelization, loss of riparian habitat by cattle grazing, and diversion of water for irrigation.

Invertebrates and fish in the Salmon River and its tributaries consist primarily of coldwater species. The most common benthic invertebrate orders are Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies), and Diptera (true flies); the most common fish families are Salmonidae (trout), Cottidae (sculpins), Cyprinidae (minnows), and Catostomidae (suckers).

Acknowledgments

Numerous individuals assisted in collecting and processing data during the course of this study, including Mike A. Beckwith, Ross G. Dickinson, Mary M. Donato, Dorene E. MacCoy, Marcia Medford, William H. Mullins, and Kenneth D. Skinner, all from the USGS. Several individuals from IDEQ also contributed significantly to the study: Don W. Zaroban, who assisted with data collection and logistics; Christopher A. Mebane and Don A. Essig, who contributed to the study design and facilitated its support; and Nick Gerhardt, who assisted with site selection. Craig Johnson, Bureau of Land Management, also assisted with site selection. Jason B. Dunham, U.S. Forest Service (USFS), Intermountain Research Station, provided regional data and assistance with the logistic regression model. Les Bechtal of Canyons, Inc., provided professional guide service to access tributary sites along the Middle Fork Salmon River. Funding for this study was provided by the USGS and IDEQ.

DATA COLLECTION METHODS

Site Selection

Sampling sites in the Salmon River Basin were selected to represent least-disturbed conditions with an emphasis on sites minimally affected by prior logging or mining activities within their watersheds. Criteria outlined by Hughes and others (1986) guided the selection of sample sites representing minimal human disturbance. These criteria included determining the level of human disturbance, quantifying stream size, characterizing stream channels, locating refuges, and determining migration barriers.

Other methods used to select least-disturbed sites included examination of existing data, review of previous qualifications of levels of disturbance of Idaho streams reported by Overton and others (1995), and consultation with local land management agencies familiar with streams in the area. Sites also were selected to represent a gradient of temperature as indicated by a previous study of least-disturbed streams in the basin (Donato, 2002). Final selection of sampling sites was made only after a thorough field reconnaissance of candidate sites to verify their lack of human disturbance.

In all, 34 sites were selected (table 1, fig. 1). Each site consisted of a representative reach generally containing repeating geomorphic channel units (riffles, runs, and pools). The length of a reach was determined as a function of stream width (Fitzpatrick and others, 1998). Reach lengths sampled during this study ranged from 130 to 280 m and usually exceeded 20 times the wetted channel width. The stream sites represented second- through fifth-order streams (Strahler, 1957), and all were wadeable. At two sites, Valley Creek (site 4) and Big Creek (site 30), three spatially disjunct stream reaches were sampled to evaluate spatial variability in the invertebrate and fish assemblages along a stream segment.

Environmental Variables

Several environmental variables, including basin and reach characteristics (table 1), physical habitat characteristics (tables A and B, back of report), and water physicochemistry (table C, back of report), were evaluated for each site. Several sources were used to construct geographic data layers. Basin characteristics, including basin size, stream elevation, stream order, and land cover, were determined using Arc Macro Language programs written for ArcInfo (Environmental Systems Research Institute, Inc., 1999). Basin boundaries were determined from the National Elevation Dataset (NED), which is based on a 30-m-resolution digital elevation dataset (**http://gisdata.usgs.gov/ned**). Hydrologic derivatives of the NED, including stream elevation and order, were developed using procedures similar to those in Stage 1 processing, using a custom projection for Idaho (**http://edcnts12.cr.usgs.gov/ned-h/about/Stage1.html**). Percent land cover (agricultural, barren, forest/upland, herbaceous upland, and range/shrub land) also was determined for each basin by using the National Land Cover Dataset (Vogelmann and others, 1998). Hydrologic unit code was determined from the Hydrologic Unit Map of Idaho (U.S. Geological Survey, 1975). Stream type was determined onsite following guidelines outlined by Rosgen (1994). Stream latitude and longitude were determined onsite by handheld Global Positioning System receivers.

STREAM TEMPERATURE

Temperature data collection and data logger deployment followed procedures outlined by Stevens and others (1975) and Zaroban (2000). The two digital data loggers used in this study (StowAway TidbiT and Optic StowAway; Onset Computer Corporation, Pocasset, Mass.) measure temperature to within ±0.4°C and record temperature within a range of – 0.5° to 37°C.

Prior to deployment of the data loggers, a calibration audit was conducted using an ice water and ambient temperature bath. Results of the audit showed that all data loggers recorded temperature to within ±0.4°C of the audit temperatures as determined by a thermometer calibrated by the American Society of Testing and Materials.

Data loggers were deployed in mid-June 2001 at most sites and programmed to record stream temperature hourly. Sites 16 through 22, located on tributaries to the Middle Fork Salmon River in the Frank Church River of No Return Wilderness Area, have limited access; an extensive, multiday trip by whitewater raft was required to reach these sampling sites. Data loggers were deployed at these sites in September 2000 during a raft trip conducted by IDEQ. Data loggers at these sampling sites varied in their collection intervals and recording time ranged from 30 to 72 minutes.

With the exception of sites 16 through 22, two data loggers were deployed at each site. Upon selection of a representative stream reach, data loggers were installed near both the upper and lower reach boundaries. At each boundary, cross-sectional measurements of stream temperature and specific conductance were made to verify stream mixing and lack of ground-water influence. Once a location near a reach boundary was determined to be well mixed, a data logger (wrapped in aluminum foil to reduce the effects of solar radiation) was attached to a steel rod that was driven into the streambed in the thalweg. Data loggers were placed at mid-depth and out of direct sunlight when possible. In addition, physical measurements of stream depth, stream aspect, percent open canopy, and riparian canopy density were made.

Table 1. Basin and site characteristics for all sample sites in the Salmon River Basin, central Idaho, 2001

[Site locations shown in figure 1; No., number; latitude and longitude in degrees, minutes, and seconds; HUC, hydrologic unit code; km², square kilometers]

Site No.	Site name	Latitude	Longitude	HUC	Rosgen (1994) stream type	Stream order	Basin area (km²)	Elevation (meters above sea level)	Percent land use					
									Forest/ upland	Range/ shrub-land	Herb-aceous upland	Agri-cultural land	Barren land	Other
1	Alpine Creek	435351	1145439	17060201	C	3	24.8	2,146	39.5	3.1	3.0	0	53.1	1.3
2	Fourth of July Creek	440148	1144802	17060201	B	3	44.6	2,182	69.8	5.1	5.9	0	17.6	1.6
3	Huckleberry Creek	440452	1145214	17060201	C	2	20.2	2,030	79.6	6.7	4.3	0	7.9	1.5
4	Valley Creek	441823	1150312	17060201	C	3	115	2,036	76.9	5.2	7.2	.2	8.6	1.9
5	Basin Creek	441609	1144944	17060201	B	3	129	1,865	74.6	6.0	9.8	0	9.1	.5
6	Warm Springs Creek	441436	1144046	17060201	B	3	208	1,829	68.6	7.0	8.3	0	15.2	.9
7	Germania Creek	440219	1142745	17060201	B	3	130	1,950	60.5	8.1	8.1	0	22.8	.5
8	Big Creek, South Fork	442629	1133558	17060202	B	2	67.0	2,006	62.8	17.0	11.2	0	9.0	0
9	Morse Creek	443756	1134717	17060202	B	3	33.5	1,908	44.1	25.7	22.6	0	7.4	.2
10	Hayden Creek, East Fork	444345	1134017	17060204	C	2	20.4	2,286	63.5	12.3	12.8	0	11.3	.1
11	Sheep Creek	452955	1135528	17060203	B	3	87.5	1,341	78.6	9.8	10.6	0	.8	.2
12	Owl Creek	451916	1142660	17060203	B	3	139	975	60.4	15.8	22.8	0	.7	.3
13	Cape Horn Creek	442322	1151030	17060205	C	3	64.1	1,996	71.4	7.1	4.5	0	15.5	1.5
14	Sulphur Creek	443227	1151844	17060205	C	4	132.7	1,731	70.3	9.9	7.8	.2	10.5	1.3
15	Vanity Creek	443247	1150344	17060205	B	3	46	1,853	70.0	5.7	4.8	0	19.2	.3
16	Indian Creek	444609	1150533	17060205	B	3	215.3	1,450	69.2	10.5	8.9	0	11.1	.3
17	Marble Creek	444440	1150102	17060205	B	4	338	1,355	68.6	11.5	12.1	0	7.7	.1
18	Loon Creek	444755	1144819	17060205	B	5	887	1,225	65.9	9.0	14.1	0	10.8	.2
19	Camas Creek	445331	1144313	17060206	B	4	1,029	1,160	76.7	7.5	9.0	0	6.5	.3

Table 1. Basin and site characteristics for all sample sites in the Salmon River Basin, central Idaho, 2001—Continued

Site No.	Site name	Latitude	Longitude	HUC	Rosgen (1994) stream type	Stream order	Basin area (km^2)	Elevation (meters above sea level)	Percent land use					
									Forest/ upland	Range/ shrub-land	Herb-aceous upland	Agri-cultural land	Barren land	Other
20	Wilson Creek	450201	1144326	17060206	B	3	97.8	1,116	58.6	10.5	12.2	0	18.2	0.5
21	Papoose Creek	451027	1144319	17060206	A	3	76.2	1,040	61.7	12.3	9.5	0	16.2	.3
22	Ship Island Creek	451035	1144312	17060206	A	2	31.8	975	64.2	10.0	5.1	0	18.8	1.9
23	Big Mallard Creek	453446	1151833	17060207	B	3	100.8	1,561	97.2	.9	.9	0	.4	.6
24	Blackmare Creek	444920	1154218	17060208	B	3	45.8	1,332	72.8	12.3	11.5	0	3.4	0
25	Fourmile Creek	445147	1154124	17060208	A	3	39.1	1,276	91.3	3.1	3.6	0	2.0	0
26	Fitsum Creek	450003	1154323	17060208	A	3	80.6	1,188	74.0	11.0	12.4	0	2.6	0
27	Tamarack Creek	445735	1152322	17060208	B	3	47.5	1,700	68.6	8.1	6.0	0	17.1	.2
28	Profile Creek	445729	1152544	17060208	B	3	50.4	1,615	76.4	4.4	3.8	0	15.1	.3
29	Riordan Creek	445424	1152907	17060208	B	3	58.2	1,494	90.1	3.0	1.7	0	4.7	.5
30	Big Creek	453509	1153128	17060207	C	3	42.1	1,859	96.5	1.0	1.0	0	.1	1.4
31	French Creek	452523	1160138	17060209	A	3	194	624	81.3	8.2	8.0	0	2.4	.1
32	Hazard Creek	451058	1161657	17060210	A	3	109	719	74.7	12.0	9.8	0	3.4	.1
33	Skookumchuck Creek	454207	1161553	17060209	C	3	77.5	451	65.6	20.4	10.3	0	3.4	.3
34	Rice Creek	455226	1162412	17060209	B	3	93	419	33.8	45.0	14.5	6.7	0	0

ONSITE WATER QUALITY

Water-quality samples were collected at each site by using methods described by Wilde and others (1999) for analysis of selected nutrients. A portion of each sample was filtered through a 0.45-μm filter; analytes in this portion hereafter are referred to as dissolved. Samples were shipped on ice to the USGS National Water Quality Laboratory in Arvada, Colorado, for analysis (Fishman, 1993). Onsite measurements of water temperature, dissolved oxygen, pH, and specific conductance also were recorded (Wilde and Radtke, 1998).

Onsite quality assurance (QA) consisted of water-quality blank samples and replicates. Laboratory QA consisted of routine blank analyses and replicates for water samples (Fishman, 1993). All analysis results for QA laboratory samples were within acceptable USGS method standards.

PHYSICAL HABITAT

Physical habitat measurements followed procedures as outlined in Fitzpatrick and others (1998). The reach length, lengths of geomorphic channel units (riffle, run, and pool) within the reach, and the water-surface gradient were measured. Six habitat transects were placed perpendicular to streamflow, equidistant throughout the reach. At each transect, wetted channel width, bankfull width, percent open canopy, percent riparian canopy density, and stream aspect were measured. In addition, along each transect at the thalweg and two intermediate locations, depth, velocity, bottom substrate size, percent substrate embeddedness, and instream habitat cover types were measured. Velocities were measured at 0.6 of the stream depth. Bottom substrate size, percent substrate embeddedness, instream habitat cover, and bank features were categorized visually.

Instream habitat cover was determined visually within a 1-m strip along each transect at the three instream locations and the left and right banks. Instream habitat cover is expressed as percent woody debris, overhanging vegetation, undercut banks, boulders, aquatic macrophytes, and artificial structures (such as tires and riprap). For data analysis, a mean value for each habitat variable was calculated to represent a reach.

Flow, channel, and bank conditions were characterized using combinations of easily measurable, but representative, descriptors. Discharge was calculated on the basis of width, depth, and velocity measured at the time of sampling. Width:depth ratio was determined as a relative measure of channel cross-sectional shape. Three measures of habitat complexity were calculated: the coefficients of variation (CV) for width, depth, and velocity (Gorman and Karr, 1978; Rahel and Hubert, 1991). A flow stability index was calculated as the ratio between low flow depth and estimated bankfull depth (Rosgen, 1994; Lammert and Allan, 1999). A flow stability index approaching 1.0 represents minimal flow fluctuation between low and bankfull flow and, therefore, higher stability. A bank stability index also was calculated on the basis of measures of bank angle, height, substrate type, and vegetative cover (Fitzpatrick and others, 1998). Scores were assigned to each measure and summed for a total bank stability score. The mean of all bank scores was used to represent the bank stability index score for the reach. Scores of 4 to 7 represent stable banks; 8 to 10 represent banks at risk of erosion; and 16 to 22 represent unstable banks.

Total seasonal thermal input for the months of June through September was determined using a Solar Pathfinder. This measure of the amount of incident solar radiation striking the surface of the water was determined at mid-channel at the upper, lower, and middle transects of each stream reach following procedures outlined by Platts and others (1987).

At each riffle location where invertebrates where sampled, microhabitat data were collected following procedures outlined by Cuffney and others (1993). Depth, velocity, percent substrate fines (<2 mm), bottom substrate size, percent substrate embeddedness, and percent open canopy were measured. Bottom substrate particle size was measured quantitatively across each riffle following procedures outlined by Wolman (1954). As stated previously, for the purpose of data analysis, a mean value for each habitat variable was calculated to characterize a riffle sample location.

Benthic Invertebrate Collection and Processing

Benthic invertebrates were collected once at all sites during low streamflow conditions from July through September 2001. Three riffle areas within the reach were selected and then sampled using a Slack rectangular kick net sampler equipped with a 425-μm mesh net (Cuffney and others, 1993). At each riffle, large gravel and cobbles within a 0.25-m^2 sample area in front of the net were brushed to dislodge organisms, after which the sample area was disturbed by kicking the loose gravel for 30 seconds.

Onsite processing consisted of elutriation of each sample by repeated washing with a 424-μm mesh sieve. After processing, the three riffle samples were composited (total sample area of 0.75 m^2) in a 1-L plastic jar, fixed with 10 percent buffered formalin, and shipped to EcoAnalysts in Moscow, Idaho, for taxonomic processing. At EcoAnalysts, samples were sorted and organisms were identified and counted to the lowest practical taxonomic level (genus or species for most taxa). Voucher specimens from this study were deposited in the Orma J. Smith Museum of Natural History, Albertson College of Idaho, Caldwell, Idaho.

Fish Collection and Processing

All sites but one were sampled during low streamflow conditions from July through September 2001. Fish were collected once at all sites except at Marble Creek (site 17). This site was not sampled because of high flow conditions and extreme turbidity. A scientific collection permit was obtained from the Idaho Department of Fish and Game (IDFG), and species data were provided to them as a provision of the permit. Fish sampling consisted of single-pass electrofishing. Single-pass electrofishing has been shown to be an effective method of sampling fish species richness, abundance, and assemblage structure in small streams (Simonson and Lyons, 1995; Kruse and others, 1998). Fish were collected using a backpack electrofisher (Smith-Root model 12) emitting pulsed direct current. Sampling was done in an upstream direction and included all available habitats within the reach. Sampling effort was measured as the total time that power was applied to the electrode, typically from 500 to 2,000 seconds.

Fish were anesthetized with a dilute solution of clove oil and ethanol, identified to species, measured for total length and weight, and examined for external anomalies following methods described by Meador and others (1993). After examination, the fish were returned to the stream. Specimens of selected species were retained for reference and verification of field identifications. Age class determinations for salmonids and cottids were based on length-frequency distributions and descriptions by Scott and Crossman (1973) and Wydoski and Whitney (1979).

In addition to fish, tailed frogs (*Ascaphus truei*) and salamanders, which have been shown to be effective indicators of stream conditions (Bennett and Fisher, 1989; Corkran and Thoms, 1996), also were identified and counted. A voucher collection from this study is located in the Orma J. Smith Museum of Natural History, Albertson College of Idaho, Caldwell, Idaho.

ANALYTICAL METHODS

General Approach

A variety of analytical methods were used to describe and evaluate aquatic communities and environmental variables. Initially, analysis focused on identifying general patterns and relations by data tabulation and graphical displays. Metrics then were calculated to quantify thermal regimes and to describe benthic invertebrate and fish assemblages. A metric is a biological or physical attribute which helps evaluate a stream's water-quality condition, or biotic integrity. According to Karr and others (1986), a metric is an enumeration representing an assemblage characteristic or combination of characteristics that change in a predictable way with disturbance. A metric score can be used as a single numeric index, such as MDMT, or combined into a comparative rating of multiple metrics, such as the Stream Fish Index (SFI) (Mebane, 2002) described in the section "Fish Assemblages and Metrics" later in this report. Once metrics were calculated, Spearman rank correlation matrices were developed to examine all possible combinations of responses and explanatory variables. As guided by the rank correlations, selected metrics were examined further using boxplots, scatterplots, and bar graphs. The latter analyses helped evaluate specific relations between fish and benthic invertebrate metrics and environmental variables and provided a visual description of variability among sample sites. All statistical analyses were performed using SYSTAT, version 9.0 (Wilkinson, 1999).

To evaluate spatial variability, community data collected among multiple reaches at a single sampling site were compared by calculating Jaccard's coefficient of community similarity (JC) index. The JC index is calculated for each site pair as the proportion of species out of the total list of species common to both sites: $JC = C/(A+B+C)$, where C is the number of species common to both sites, and A and B are the number of species unique to each of the two sites.

Finally, logistic regression (Hosmer and Lemeshow, 1989) was used to develop an algorithm that predicts the probability of occurrence of juvenile (<150 mm) bull trout as a function of maximum daily-maximum stream temperature. In logistic regression, the dependent variable (for this study, juvenile bull trout) is a binary variable. Unlike linear regression, logistic regression does not require normally distributed data. Model results were compared with a regional bull trout dataset compiled by the USFS (Dunham and others, 2001).

Environmental Variables

STREAM TEMPERATURE

Stream temperature data were inspected for obvious errors such as data logger malfunction and exposure to air temperature. Data collected prior to deployment and after retrieval were removed from the dataset. Time-series plots and other forms of graphical displays were used to visually inspect the data and to compare datasets. Quantitative summaries of the thermal regime, or metrics, were calculated for all sites and are described in table 2. Because most sites were equipped with two data loggers, the paired datasets were compared to evaluate spatial variability.

WATER QUALITY

Because the water-quality data in this study were collected to establish a baseline, extensive data analysis was not conducted. Primarily, data were collected to provide a more comprehensive understanding of environmental conditions during this study, to document water-quality conditions of least-disturbed streams, and to publish data for comparison with data from future studies.

Benthic Invertebrate Assemblages and Metrics

Benthic invertebrate assemblages were analyzed without accounting for ambiguous taxonomic groups. Ambiguities in the benthic invertebrate dataset arise when some specimens in a sample lack the characteris-

Table 2. Definition of stream temperature metrics

Stream temperature metric	Definition
MDMT	Maximum daily-maximum temperature, in degrees Celsius
MDAT	Maximum daily-average temperature, in degrees Celsius
MWMT	Maximum weekly-maximum temperature. Derived from 7-day moving average of daily maximum temperatures, in degrees Celsius
MWAT	Maximum weekly-average temperature. Derived from 7-day moving average of daily average temperatures, in degrees Celsius
MWMTS	Maximum weekly-maximum temperature for date of sample collection. Derived from 7-day moving average of daily maximum temperatures on sample date and 6 days prior, in degrees Celsius
MWATS	Maximum weekly-average temperature for date of sample collection. Derived from 7-day moving average of daily average temperatures on sample date and 6 days prior, in degrees Celsius
MAXΔT	Maximum of the maximum daily temperature minus minimum daily temperature (diurnal fluctuation) for deployment period, in degrees Celsius
BIGΔT	Maximum daily-maximum temperature minus minimum daily-minimum temperature for deployment period, in degrees Celsius
DEGDAY	Seasonal degree-days. Derived as sum of differences between daily average temperature and base temperature of 0 degrees Celsius for period July 1 through August 31, 2001

tics that allow identification to the targeted level of taxonomic resolution. Slight variations in the results of the benthic invertebrate data can occur if ambiguous taxonomic groups are accounted for prior to analysis.

Benthic invertebrate assemblages were analyzed using relative abundance data, density data, and the Stream Macroinvertebrate Index (SMI) (Jessup and Gerritsen, 2002). The SMI is a multimetric index that uses a bioregional scheme based on a grouping of ecoregions. These bioregions include the Northern Mountains, Central and Southern Mountains, and Basins. All sample sites in this study were located in the Central and Southern Mountains bioregion. Six metric categories—richness, composition, pollution tolerance, diversity, feeding group, and habitat—were used to identify assemblage attributes. The richness category consists of metrics for total number of taxa and total number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) taxa. The composition category consists of the metric percent Plecoptera, or percent of sample that includes stonefly nymphs. The pollution tolerance category derives a metric using the Hilsenhoff Biotic Index (HBI) that determines the abundance-weighted average tolerance of organisms to pollution (Hilsenhoff, 1987). According to Hilsenhoff (1987), an HBI value between 0 and 3.50 indicates “excellent” water quality with no apparent organic pollution. An HBI value between 3.51 and 4.50 indicates “very good” water quality with slight organic pollution. An HBI value between 4.51 and 5.50 indicates “good” water quality with some organic pollution. An HBI value above 5.51 indicates “fair” to “very poor” water quality with varying degrees of organic pollution from fairly significant to severe. The diversity category consists of the metric percent five dominant taxa, or percent of sample including the five most abundant taxa. The feeding group category consists of one metric, scraper taxa, or number of taxa that scrape periphyton from substrates. The final category, habitat, consists of the metric clinger taxa. This metric is the number of taxa that have fixed retreats or adaptations that allow them to attach to substrate in flowing water.

The multimetric index value (SMI score) for a sample site is the sum of the individual metric scores. Once an SMI score for a sample site is determined, comparisons are made with conditions at least-disturbed sites within the same bioregion. This comparison allows assignments of a narrative rating for the sample site ranging from “very good” to “very poor.” According to Jessup and Gerritsen (2002), SMI scores between 79 and 100 are considered “very good,” scores between 58 and 78 are considered “good,” scores between 39 and 57 are considered “fair,” and scores below 38 are considered “poor” to “very poor.”

Fish Assemblages and Metrics

Fish assemblages were analyzed using relative abundance data, density data, and the SFI (Mebane, 2002). Like the SMI just described, the SFI is a multimetric index. The SFI was developed for use on two separate site classes, montane-forested and desert basin-rangeland, on the basis of a grouping of ecoregions. All sites in this study were located in the Northern Rockies ecoregion, which is one of four ecoregions that make up the montane-forested classification grouping. Hence, the montane-forested classification was used for all sites in this study. Three metric categories—species richness and composition, reproductive function, and abundance—were used to identify fish assemblage attributes. The richness and composition category consists of the metrics number of coldwater native species, percent coldwater individuals, and percent sensitive native individuals. The reproductive function category consists of the metrics number of cottid age classes and number of salmonid age classes. The abundance category consists of one metric, catch per unit effort (CPUE, fish caught per minute of electrofishing). The presence of amphibians also was included as part of the SFI as a qualitative presence metric only. Supplemental points are added to the final index scores when amphibians are present. Absence of amphibians, however, is not considered a negative factor.

As with the SMI, the SFI score for a sample site is the sum of the individual metric scores. The higher the SFI score, the more closely a sample site represents least-disturbed conditions within its ecoregion. According to Mebane (2002), scores above 81 would place a sample site above the median of reference condition. A narrative rating of “very good” could be inferred for scores above 81, and a rating of “good” to “very poor” could be inferred for scores less than 81 to 0.

RESULTS OF TEMPERATURE DATA AND METRICS

Temperature data loggers were retrieved from all sites during late September and early October

2001. The raw temperature data can be accessed at **http://idaho.usgs.gov/public/studies.html**. Of the 68 data loggers deployed, 64 were retrieved. Both data loggers at Skookumchuck Creek (site 33) and French Creek (site 31) were missing. Of the 64 retrieved, three data loggers either were damaged or malfunctioned, and no stream temperature record was obtained. These included one of two data loggers at both Valley Creek (site 4) and Fourth of July Creek (site 2) and the only data logger at Marble Creek (site 17).

After the data loggers were downloaded, July 1 through September 30 (92 days) was selected as the period used to calculate the stream temperature metrics for most sites. Stream temperature records for Skookumchuck Creek and French Creek were available for 2000 from Donato's (2002) work in the basin and were used for calculations of the metrics at both sites. However, the deployment period in 2000 did not span the entire 92-day period as in 2001. The stream temperature record at Skookumchuck Creek in 2000 comprised a 76-day period from July 11 through September 24. The stream temperature record at French Creek in 2000 comprised a 77-day period from July 13 through September 27. No alternate stream temperature record was available for Marble Creek.

Other inconsistencies in the stream temperature records for sites 16 and 18 through 22 were evident. Data loggers were removed from these sites, which were located on tributaries to the Middle Fork Salmon River, on the day the sampling crew visited the site. Ending dates for the temperature record at these sites ranged from September 13 to September 20.

Because two data loggers were deployed at most sites, the variability between these paired data loggers was determined. Analysis of the stream temperature record of 24 paired data loggers indicated that the maximum difference in temperatures between any paired data logger was 1.4°C, and 96 percent of all temperatures recorded by paired data loggers were within 1.0°C.

Stream Temperature Metrics

Comparison of the nine stream temperature metrics for the 33 sites where data were available (table 3) indicated that water temperature varied substantially among sites within the basin, and that the range of observed temperatures varied over a broad gradient. Spearman rank correlations among the nine stream temperature metrics indicated that all were significantly correlated (all p-values <0.01); correlation coefficients ranged from 0.70 to 0.99. MDMT ranged from 12.0°C at Morse Creek (site 9) to 23.6°C at Indian Creek and Skookumchuck Creek (sites 16 and 33, respectively). MDAT ranged from 10.2°C at Morse Creek to 21.1°C at Skookumchuck Creek. MWMT ranged from 11.5°C at Morse Creek to 23.2°C at Skookumchuck Creek. The maximum weekly-average temperature (MWAT) ranged from 9.7°C at Morse Creek and East Fork Hayden Creek (site 10) to 20.7°C at Skookumchuck Creek. Maximum weekly-maximum temperature for date of sample (MWMTS) ranged from 11.3°C at Morse Creek to 22.9°C at Skookumchuck Creek. Maximum weekly-average temperature for date of sample (MWATS) ranged from 9.4°C at East Fork Hayden Creek to 20.4°C at Skookumchuck Creek. The maximum diurnal fluctuation (MAXΔT) ranged from 3.0°C at Ship Island Creek (site 22) to 12.2°C at Valley Creek (site 4). The maximum fluctuation for period of deployment (BIGΔT) ranged from 7.0°C at Morse Creek to 18.6°C at Basin Creek (site 5). The number of seasonal degree-days (DEGDAY) ranged from 550 at East Fork Hayden Creek to 1,070 at Rice Creek (site 34).

Comparison of Stream Temperature Metrics with Life-Stage Stream Temperature Criteria

Stream temperatures exceeded criteria for bull trout and chinook salmon spawning at all sites. A comparison of stream temperatures with life-stage stream temperature criteria is presented in table 4. Criteria established by USEPA (40 CFR 131.E.1.i.d, 1997) for the protection of bull trout spawning and juvenile rearing in natal streams are applicable during the months of June through September. Criteria established by IDEQ (Grafe and others, 2002) for the protection of salmonid spawning are specific to species and their spawning/egg incubation period. These criteria are intended to be applicable only during the period when a species is present and actually spawning.

During this study, the stream temperature record overlapped the core period for spring/summer run chinook salmon (*Oncorhynchus tshawytscha*) spawning and egg incubation, which extends from August 15 to June 1 (Grafe and others, 2002). Consequently, the criteria were applicable for this species during this period of time. To determine exceedances, the salmo-

Table 3. Stream temperature metrics for selected sample sites in the Salmon River Basin, central Idaho, July through September 2001

[Site locations shown in figure 1; site names and characteristics shown in table 1; description of temperature metrics shown in table 2; No., number; med, median; min, minimum; max, maximum; —, data unavailable; no temperature record available for site 17 because of missing data logger]

Site No.	MDMT	MDAT	MWMT	MWAT	MWMTS	MWATS	MAXΔT	BIGΔT	DEGDAY
1	15.6	12.4	14.4	11.5	13.9	10.6	7.2	11.4	649
2	15.0	11.2	13.9	10.4	13.2	9.6	8.2	13.6	580
3	18.4	13.5	16.7	12.4	16.4	11.1	10.8	15.5	677
4	22.1	16.1	20.1	15.0	18.6	13.9	12.2	18.3	838
5	21.7	16.5	20.2	15.5	18.4	14.1	12.1	18.6	863
6	16.2	13.0	15.2	12.3	14.1	10.9	7.0	11.8	688
7	16.3	12.3	15.5	11.6	15.3	11.0	8.7	13.9	660
8	15.0	11.9	14.0	11.2	13.5	11.0	7.5	10.9	627
9	12.0	10.2	11.5	9.7	11.3	9.6	4.2	7.0	556
10	13.9	10.3	13.2	9.7	12.7	9.4	7.5	13.4	550
11	13.3	10.8	12.5	10.3	12.4	10.2	4.8	8.3	595
12	20.1	17.9	18.9	16.8	18.5	16.5	5.5	11.5	980
13	19.9	14.0	18.7	12.9	18.5	12.1	12.1	16.9	732
14	21.0	16.8	19.9	16.0	18.8	14.9	9.2	14.9	923
15	13.8	11.4	13.2	10.7	12.6	9.7	5.9	10.1	604
16	23.6	17.3	22.1	16.5	16.3	11.7	11.7	17.3	956
18	21.6	18.4	20.3	18.0	16.3	14.4	5.7	12.8	1,045
19	20.3	17.7	19.1	17.1	14.9	13.6	5.5	12.1	1,001
20	17.6	15.4	16.8	15.0	13.8	12.7	4.9	9.2	—
21	18.2	16.0	17.3	15.6	14.2	13.1	4.4	8.8	908
22	16.0	15.0	15.5	14.5	12.4	11.8	3.0	7.2	840
23	19.6	16.5	18.7	15.7	18.7	15.7	6.8	13.9	850
24	16.3	14.4	15.4	13.5	14.6	12.7	5.0	11.1	766
25	16.3	14.7	15.4	14.1	14.9	13.4	3.9	10.6	795
26	19.5	16.2	18.1	15.3	18.0	15.3	6.9	13.2	875
27	17.6	12.5	16.8	12.2	14.9	11.5	8.9	12.7	703

Table 3. Stream temperature metrics for selected sample sites in the Salmon River Basin, central Idaho, July through September 2001—Continued

Site No.	MDMT	MDAT	MWMT	MWAT	MWMTS	MWATS	MAXΔT	BIGΔT	DEGDAY
28	15.5	12.2	14.8	11.8	13.5	11.3	6.2	10.6	674
29	17.4	15.4	16.6	14.5	16.2	14.3	6.1	12.0	806
30	19.4	13.8	18.3	12.9	18.3	12.9	11.1	17.0	703
31	21.5	19.7	20.9	19.1	20.0	18.1	4.0	15.3	—
32	20.5	17.6	19.9	17.2	19.9	17.1	6.3	13.0	963
33	23.6	21.1	23.2	20.7	22.9	20.4	6.1	14.4	—
34	21.9	19.4	21.1	19.0	20.9	18.8	5.4	12.8	1,070
Med	18.2	15.0	16.8	14.5	15.3	12.7	6.3	12.8	781
Mean	18.2	14.9	17.2	14.2	16.0	13.1	7.1	12.7	783
Max	23.6	21.1	23.2	20.7	22.9	20.4	12.2	18.6	1,070
Min	12.0	10.2	11.5	9.7	11.3	9.4	3.0	7.0	550

nid spawning criteria were applied from August 15 to the end of the stream temperature record (September 30, in most cases). Criteria established by IDEQ for the protection of coldwater biota apply year round, but the warmest period (July through August) was the time of focus. To determine exceedances, the coldwater biota criteria were applied from July 1 to the end of the stream temperature record (September 30, in most cases).

Comparison of the stream temperature metrics with the stream temperature criterion showed that temperatures at all 33 sites exceeded USEPA's 10.0°C MWMT criterion for bull trout spawning and juvenile rearing. The percentage of total days that the temperatures exceeded the criterion ranged from 58 to 100. Temperatures at 20 of 33 (58 percent) sites exceeded the criterion 100 percent of the time. Although this criterion is applicable only to those streams where bull trout are present, and bull trout were collected at only 19 of the 33 sites, it is notable that temperatures at none of these least-disturbed sites met this criterion during this study.

Temperatures at 91 percent (30 of 33) of the sites exceeded the IDEQ 13.0°C MDMT criterion for the protection of salmonid spawning; temperatures at all sites exceeded the 9.0°C MDAT criterion. The percentage of total hours that temperatures exceeded the 13.0°C MDMT criterion ranged from 0.4 to 91. Those sites where temperatures did not exceed the 13.0°C MDMT criterion were Morse Creek, Sheep Creek, and Vanity Creek (sites 9, 11, and 15, respectively). Temperatures at all 15 sites where chinook salmon were collected exceeded IDEQ criteria for the protection of salmonid spawning. The percentage of total hours that temperatures at these sites exceeded the 13.0°C MDMT criterion ranged from 5.9 to 87. The MDAT ranged from 9.8° to 19.2°C.

Thermal regime at most sites did not exceed the IDEQ criteria for the protection of coldwater biota. Thermal regime exceeded the criteria at Valley Creek, Indian Creek, and Skookumchuck Creek (sites 4, 16, and 33, respectively), where temperatures exceeded the 22.0°C MDMT criterion; and French Creek (site 31), Skookumchuck Creek, and Rice Creek (site 34), where temperatures exceeded the 19.0°C MDAT criterion. The percentage of total hours that temperatures exceeded the 22.0°C MDMT criterion ranged from 1.4 to 4.8. The MDAT ranged from 10.2° to 21.1°C.

Table 4. Relations between stream temperature metrics and life-stage stream temperature criteria for selected sample sites in the Salmon River Basin, central Idaho, July through September 2001

[Idaho Department of Environmental Quality salmonid spawning criteria exceedances based on summer chinook salmon spawning period beginning August 15 to end of temperature record (September 30, most cases); site locations shown in figure 1; site names and characteristics shown in table 1; °C, degrees Celsius; MWMT, maximum weekly-maximum temperature; MDMT, maximum daily-maximum temperature; MDAT, maximum daily-average temperature; No., number; no temperature record available for site 17 because of missing data logger]

	U.S. Environmental Protection Agency bull trout spawning and juvenile rearing criterion of 10.0°C MWMT June 1 through September 30 (most cases)			Idaho Department of Environmental Quality							
				Salmonid spawning criteria of 13.0°C MDMT and 9.0°C MDAT August 15 through September 30 (most cases)				Coldwater biota criteria of 22.0°C MDMT and 19.0°C MDAT July 1 through September 30 (most cases)			
	MWMT			MDMT 13.0°C			MDAT 9.0°C	MDMT 22.0°C			MDAT 19.0°C
Site No.	No. days above 10.0°C[1]	Percent days above 10.0°C	Consecutive days above 10.0°C	No. hours above 13.0°C[2]	Percent hours above 13.0°C	Consecutive hours above 13.0°C	MDAT[2]	No. hours above 22.0°C[1]	Percent hours above 22.0°C	Consecutive hours above 22.0°C	MDAT[1]
1	71	77	71	17	1.5	6	11.2	0	0	0	12.4
2	70	76	70	16	1.4	3	9.9	0	0	0	11.2
3	92	100	92	141	13	8	11.2	0	0	0	13.5
4	92	100	92	306	27	13	14.0	2	0	2	16.1
5	92	100	92	302	27	16	14.4	0	0	0	16.5
6	91	99	91	75	6.6	7	11.6	0	0	0	13.0
7	90	98	90	99	8.8	8	11.3	0	0	0	12.3
8	75	82	64	18	1.6	5	11.2	0	0	0	11.9
9	53	58	45	0	0	0	9.8	0	0	0	10.2
10	69	75	69	5	.4	2	9.8	0	0	0	10.3
11	71	77	62	0	0	0	10.4	0	0	0	10.8
12	92	100	92	696	62	530	16.6	0	0	0	17.9
13	92	100	92	206	18	10	12.1	0	0	0	14.0
14	92	100	92	416	37	18	15.6	0	0	0	16.8
15	68	74	68	0	0	0	10.2	0	0	0	11.4
16	[3]75	100	75	[4]326	54	17	[4]16.3	[3]21	1.4	4	[3]17.3
18	[5]78	100	78	[6]572	87	444	[6]17.7	[5]0	0	0	[5]18.4
19	[7]79	100	79	[8]541	80	199	[8]16.7	[7]0	0	0	[7]17.7
20	[9]72	100	72	[10]492	59	125	[10]14.8	[9]0	0	0	[9]15.4
21	[11]82	100	82	[12]519	70	440	[12]15.3	[11]0	0	0	[11]16.0

Table 4. Relations between stream temperature metrics and life-stage stream temperature criteria for selected sample sites in the Salmon River Basin, central Idaho, July through September 2001—Continued

	U.S. Environmental Protection Agency bull trout spawning and juvenile rearing criterion of 10.0°C MWMT June 1 through September 30 (most cases)			Idaho Department of Environmental Quality								
				Salmonid spawning criteria of 13.0°C MDMT and 9.0°C MDAT August 15 through September 30 (most cases)				Coldwater biota criteria of 22.0°C MDMT and 19.0°C MDAT July 1 through September 30 (most cases)				
	MWMT			MDMT 13.0°C			MDAT 9.0°C	MDMT 22.0°C			MDAT 19.0°C	
Site No.	No. days above 10.0°C[1]	Percent days above 10.0°C	Consecutive days above 10.0°C	No. hours above 13.0°C[2]	Percent hours above 13.0°C	Consecutive hours above 13.0°C	MDAT[2]	No. hours above 22.0°C[1]	Percent hours above 22.0°C	Consecutive hours above 22.0°C	MDAT[1]
22	[11]82	100	82	[12]245	33	25	[12]13.8	[11]0	0	0	[11]15.0
23	92	100	92	341	30	20	15.3	0	0	0	16.5
24	78	85	71	67	5.9	15	13.9	0	0	0	14.4
25	81	88	72	127	11	30	14.4	0	0	0	14.7
26	92	100	92	275	24	25	15.5	0	0	0	16.2
27	92	100	92	162	14	9	12.2	0	0	0	12.5
28	91	99	91	66	5.9	7	11.9	0	0	0	12.2
29	85	92	85	110	9.8	16	14.0	0	0	0	15.4
30	92	100	92	165	15	11	12.7	0	0	0	13.8
31	[13]77	100	77	[14]594	56	161	[14]16.3	[13]0	0	0	[13]19.7
32	92	100	92	610	54	126	17.1	0	0	0	17.6
33	[15]76	100	76	[16]898	91	461	[16]18.3	[15]88	4.8	8	[15]21.1
34	92	100	92	946	84	285	19.2	0	0	0	19.4

[1] days, n=92; hours, n=2,208
[2] days, n=47; hours, n=1,128
[3] days, n=75; hours, n=1,500
[4] days, n=30; hours, n=600
[5] days, n=78; hours, n=1,560
[6] days, n=33; hours, n=660
[7] days, n=79; hours, n=1,580
[8] days, n=34; hours, n=680
[9] days, n=72; hours, n=1,728
[10] days, n=35; hours, n=840
[11] days, n=82; hours, n=1,640
[12] days, n=37; hours, n=740
[13] days, n=77; hours, n=1,848
[14] days, n=44; hours, n=1,056
[15] days, n=76; hours, n=1,824
[16] days, n=41; hours, n=984

RESULTS OF WATER-QUALITY DATA

The analytical results (table C) indicate that water quality at sites sampled during this study is representative of least-disturbed conditions. Although samples from most sites did contain some form of a nutrient (nitrogen or phosphorus), many nutrient concentrations were at or near the method detection limit (MDL). Under ideal sample and analytical conditions, a few of the nutrient compounds in table C were positively identified at or below the determined MDL. However, concentrations reported below the MDL are considered qualitative. Nutrient concentrations were highest at sites in areas of recent forest fires. It is assumed that these high nutrient concentrations are a result of these fires. Dissolved oxygen concentrations ranged from 7.3 mg/L at Marble Creek (site 17) to 10.0 mg/L at Ship Island Creek (site 22). pH values at most sampling sites were near neutral and ranged from 6.9 at Morse Creek (site 9) to 8.4 at several sites. Specific conductance values ranged from 27 μS/cm at Big Creek (site 30) to 162 μS/cm at Fourth of July Creek (site 2). Dissolved nitrogen concentrations ranged from less than detection to 0.018 mg/L as N at Marble Creek. Total nitrogen concentrations ranged from less than detection to 0.647 mg/L as N at Marble Creek. Dissolved nitrite plus nitrate concentrations ranged from less than detection at Sulphur Creek (site 14) to 0.225 mg/L as N at Rice Creek (site 34). Total phosphorus concentrations ranged from less than detection at several sites to 0.2470 mg/L as P at Marble Creek (site 17). Orthophosphorus concentrations ranged from less than detection at several sites to 0.073 mg/L as P at Rice Creek.

RESULTS OF BENTHIC INVERTEBRATE TAXA AND METRICS

Two hundred and one benthic invertebrate taxa from the 34 sampling sites were identified. The raw invertebrate data can be accessed at **http://idaho.usgs.gov/public/studies.html**. The most abundant taxa (greater than 1 percent of total abundance and identified in 75 percent or more of the samples) were *Baetis tricaudatus*, Oligochaeta, *Tvetenia bavarica* gr., Acari, *Rhithrogena*, *Cinygmula*, *Heterlimnius*, *Micropsectra*, *Eukiefferiella devonica* gr., *Drunella doddsi*, and *Cricotopus*. Fifty-eight rare taxa (composing less than 0.005 percent total abundance and identified in less than 5 percent of the samples) were collected.

Total abundance (density expressed as individuals/m^2) varied greatly and ranged from 1,331 to 27,040 individuals/m^2 at Alpine Creek (site 1) and Basin Creek (site 5), respectively. The high abundance at site 5 resulted from large numbers of *Simulium* (blackflies) and *Cricotopus* (midges).

Comparison of Benthic Invertebrate Assemblages at Multiple-Reach Sites

The JC index was used to compare spatial variability in the benthic invertebrate assemblages at multiple-reach sites (Valley Creek and Big Creek). Differences among reaches in similarity of community structure (taxonomic composition), as determined by the JC index, provide an indication of how well a single sampling reach represents the biological conditions within that stream segment. Values for this index range from 0 (no species in common) to 1 (species composition is identical). Gauch (1982) suggested that, because biological community samples can be highly variable, JC values for replicate samples from a community often are less than 1 and typically range from 0.60 to 0.90.

During this study, JC values ranged from 0.54 to 0.63 at Valley Creek (site 4), and from 0.54 to 0.66 at Big Creek (site 30). JC values in the lower end of the typical range, such as these, indicate a greater degree of spatial variability in taxa occurrence between the multiple reaches.

Coldwater Taxa

According to Grafe and others (2002), coldwater obligates are taxa which have less than a 10-percent chance of occurrence in streams where the temperature exceeds 19.0°C. To determine obligate coldwater taxa in streams throughout Idaho, the IDEQ analyzed stream temperature and macroinvertebrate community data from more than 1,000 sampling locations (Grafe and others, 2002). From this information, a list of 64 coldwater obligate taxa was empirically derived.

Of the designated 64 coldwater obligates, 32 taxa (present at a minimum of 5 sampling sites) were collected during this study (table 5). Coldwater taxa represented 16 percent (32 of 201) of all taxa collected. The most frequently collected coldwater taxon was the mayfly *Drunella doddsi*, which was collected at 28 sampling sites. The most abundant coldwater taxon was *Oligophlebodes*, a caddisfly typically associated with mountain streams in the West. The number of individual coldwater taxa collected ranged from 4 at Skookumchuck Creek (site 33) to 29 at Big Creek (site 30). The percentage of coldwater taxa collected ranged from 1 at Camas Creek, Skookumchuck Creek, and Rice Creek (sites 19, 33, and 34, respectively) to 74 at East Fork Hayden Creek (site 10) (fig. 2).

Coldwater taxa were collected at all five sites (sites 4, 16, 31, 33, 34) where temperatures exceeded the IDEQ criteria for the protection of coldwater biota. The number of taxa at these sites ranged from 2 at Skookumchuck Creek (site 33) to 12 at Valley Creek (site 4).

Nine additional taxa, not classified by Grafe and others (2002) as coldwater obligates, were significantly ($p<0.05$) inversely correlated with one or more of the stream temperature metrics (table 5). Of these taxa, *Rhithrogena*, a mayfly typically associated with high velocity streams, was the most frequently collected at 30 sampling sites.

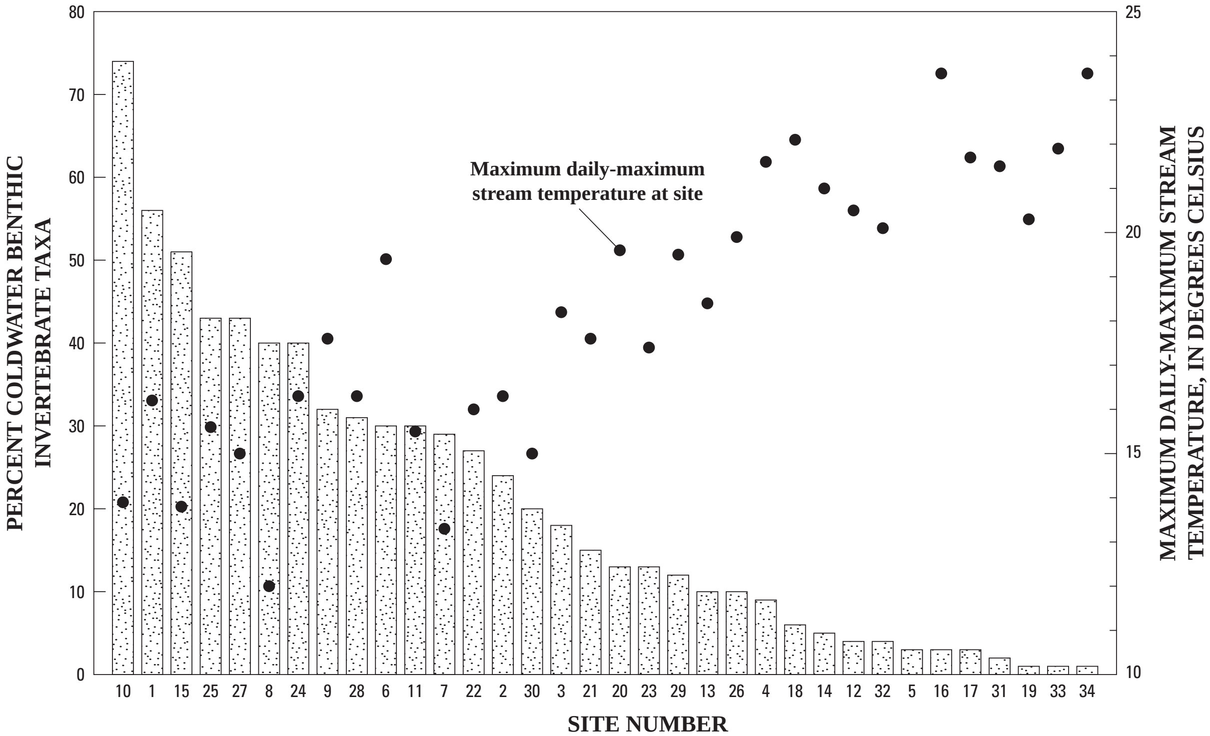


Figure 2. Percent coldwater benthic invertebrate taxa in relation to maximum daily-maximum stream temperature at all sample sites in the Salmon River Basin, central Idaho, July through September 2001. (Site locations shown in figure 1; site names and characteristics shown in table 1)

Stream Macroinvertebrate Index Scores and Metrics

In general, invertebrate metrics describe expected conditions for least-disturbed sites with SMI scores ranging from 69 (Marble Creek, site 17) to 100 (table 6). SMI scores for 85 percent (29 of 34) of the sample sites were above 79, which places these sites in the “very good” category when compared with other sites in the same bioregion.

Within the richness category (number of species), the total number of taxa ranged from 38 at Hazard Creek (site 32) to 68 at Fitsum Creek (site 26). Hazard Creek is a high-gradient stream with large boulder substrate and plunge-pool habitat conditions that may limit the diversity of taxa at this location. The total number of EPT taxa ranged from 17 at Marble Creek, Camas Creek, and Skookumchuck Creek (sites 17, 19, and 33, respectively) to 39 at Fourmile Creek (site 25).

The low diversity of EPT taxa at some locations may have been the result of severe forest fires in the summer of 2000 in parts of many drainages in the Middle Fork of the Salmon River Basin, including Marble Creek and Camas Creek. These fires caused large amounts of silt and sediment to be transported to the streams by overland runoff during localized rainstorms. According to Minshall and others (2001), “blowouts” in the headwaters of Marble Creek continue to send large amounts of silt and sediment into this creek following local rainstorms. The effect of continued high sediment transport is the destruction of the benthic habitat by sediment deposition (Minshall and others, 2001). On the day of sampling, Marble Creek and Camas Creek both were transporting large amounts of silt and sediment as a result of a recent rainstorm. In addition, high flow conditions made sampling these two sites extremely difficult. Either of these conditions may help to explain the low diversity of EPT taxa at these locations.

Within the composition category, percent Plecoptera ranged from 0.4 to 25.2. The HBI scores within the pollution tolerance category ranged from 1.91 to 4.97. HBI scores for 82 percent (28 of 34) of the sample sites were below 4.50, which indicates “very good” water

Table 5. Spearman rank correlation coefficients for relative abundance of coldwater benthic invertebrate taxa and selected stream temperature metrics for selected sample sites in the Salmon River Basin, central Idaho, July through September 2001

[Number of sites sampled, 33; taxa shown were collected at five or more sample sites; **bold** denotes significance ($p<0.05$); see table 2 for description of stream temperature metrics; No., number]

Taxon	No. of sites where collected	MDMT	MDAT	MWMT	MWAT	MWMTS	MWATS	DEGDAY[1]
Coldwater taxa[2]								
Baetis bicaudatus	8	-0.34	**-0.38**	-0.30	-0.35	-0.30	-0.27	-0.32
Cinygmula sp.	26	**-.49**	**-.43**	**-.47**	**-.41**	**-.54**	**-.53**	**-.39**
Drunella coloradensis/flavilinea	14	**-.52**	**-.61**	**-.55**	**-.61**	**-.42**	**-.53**	**-.59**
Drunella doddsi	28	**-.72**	**-.68**	**-.71**	**-.67**	**-.61**	**-.60**	**-.65**
Drunella spinifera	10	**-.38**	**-.39**	**-.38**	**-.38**	-.23	-.23	**-.38**
Epeorus deceptivus	12	**-.61**	**-.61**	**-.64**	**-.61**	**-.52**	**-.65**	**-.63**
Epeorus grandis	14	**-.59**	**-.61**	**-.56**	**-.61**	**-.44**	**-.48**	**-.60**
Epeorus sp.	22	0	-.06	.01	-.08	.05	-.01	-.04
Ephemerellidae	7	-.35	**-.39**	-.33	**-.40**	-.33	**-.40**	**-.39**
Cultus sp.	5	**.48**	**.37**	**.46**	.35	.25	.25	.36
Leuctridae	18	**-.59**	**-.68**	**-.59**	**-.70**	**-.55**	**-.68**	**-.67**
Megarcys sp.	15	**-.67**	**-.74**	**-.67**	**-.74**	**-.56**	**-.68**	**-.71**
Perlidae	7	.06	.15	.04	.11	.19	.23	.11
Sweltsa sp.	25	-.29	**-.44**	-.33	**-.45**	-.21	**-.43**	**-.48**
Taeniopterygidae	8	**-.54**	**-.42**	**-.51**	**-.39**	**-.61**	**-.40**	-.36
Visoka cataractae	5	-.33	-.25	-.29	-.25	-.32	-.24	-.25
Yoroperla sp.	5	-.23	-.22	-.23	-.20	-.09	-.06	-.23
Zapada columbiana	17	**-.66**	**-.57**	**-.62**	**-.53**	**-.62**	**-.41**	**-.48**
Zapada oregonensis gr.	13	**-.70**	**-.76**	**-.70**	**-.77**	**-.59**	**-.76**	**-.75**
Heterlimnius sp.	26	-.10	-.29	-.18	-.33	.07	-.19	-.36
Lara sp.	7	.02	.15	.02	.17	-.08	.22	.20
Narpus sp.	5	.33	**.47**	.36	**.48**	.35	**.47**	**.46**
Apatania sp.	10	-.20	-.35	-.25	**-.38**	-.09	-.22	**-.38**
Oligophlebodes sp.	10	-.34	-.11	-.35	-.14	-.29	.01	-.10

Table 5. Spearman rank correlation coefficients for relative abundance of coldwater benthic invertebrate taxa and selected stream temperature metrics for selected sample sites in the Salmon River Basin, central Idaho, July through September 2001—Continued

Taxon	No. of sites where collected	MDMT	MDAT	MWMT	MWAT	MWMTS	MWATS	DEGDAY[1]
Coldwater taxa[2]								
Parapsyche elsis	13	**-0.69**	**-0.62**	**-0.68**	**-0.61**	**-0.65**	**-0.60**	**-0.61**
Rhyacophila betteni gr.	16	**-.74**	**-.68**	**-.70**	**-.66**	**-.63**	**-.61**	**-.66**
Rhyacophila brunnea gr.	19	-.30	**-.39**	-.34	**-.42**	-.24	-.35	**-.43**
Rhyacophila hyalinata gr.	12	-.29	-.27	-.29	-.23	-.16	-.15	-.25
Rhyacophila narvae	14	**-.45**	**-.45**	**-.50**	**-.47**	-.30	**-.39**	**-.51**
Rhyacophila pellisa/valuma	6	**-.38**	**-.40**	**-.41**	**-.41**	-.31	**-.44**	**-.42**
Rhyacophila vagrita gr.	5	-.25	-.28	-.25	-.28	-.18	-.28	-.26
Glutops sp.	5	-.10	-.17	-.13	-.16	.02	-.13	-.17
Other taxa[3]								
Rhithrogena sp.	30	**-.49**	**-.45**	**-.47**	**-.45**	**-.45**	**-.41**	**-.44**
Serratella tibialis	18	-.23	**-.45**	-.27	**-.46**	-.08	-.30	**-.45**
Chloroperlidae	9	**-.38**	-.36	-.33	**-.39**	-.29	-.32	**-.40**
Perlodidae	18	-.20	**-.37**	-.26	**-.37**	-.12	-.25	-.36
Glossosoma sp.	20	-.33	-.32	-.31	-.31	**-.56**	**-.48**	-.30
Pericoma sp.	5	**-.38**	**-.39**	**-.37**	**-.39**	-.32	**-.37**	**-.40**
Parametriocnemus sp.	12	-.34	**-.38**	-.28	**-.38**	-.28	-.34	-.34
Ostracoda	19	**-.49**	**-.43**	**-.46**	**-.39**	**-.54**	**-.37**	-.36
Polycelis sp.	21	**-.52**	**-.69**	**-.57**	**-.69**	**-.47**	**-.66**	**-.69**

[1]Sites 20, 31, and 33 not included (n=30).
[2]Coldwater taxa from Grafe and others (2002).
[3]Taxa significantly correlated with one or more temperature metrics.

quality with slight organic pollution. The highest HBI score (5.20), was for Riordan Creek (site 29). Within the diversity category, the percent five dominant taxa ranged from 38.9 to 76.4. The number of scraper taxa in the feeding group category ranged from 4 to 12, and the number of clinger taxa in the habitat category ranged from 19 to 35.

RESULTS OF FISH TAXA AND METRICS

Ten species of fish in the families Salmonidae, Cottidae, and Cyprinidae were collected. The raw fish data can be accessed at **http://idaho.usgs.gov/public/studies.html**. A total of 4,199 fish were collected from the 33 sites sampled during

Table 6. Relations between benthic invertebrate metrics and Stream Macroinvertebrate Index scores for selected sample sites in the Salmon River Basin, central Idaho, 2001

[Total SMI scores were calculated from the metric values reported by Jessup and Gerritsen (2002); site locations shown in figure 1; site names and characteristics shown in table 1; No., number, SMI, Stream Macroinvertebrate Index]

Site No.	No. species	No. Ephemeroptera taxa	No. Plecoptera taxa	No. Trichoptera taxa	Percent Plecoptera	Hilsenhoff Biotic Index	Percent five dominant taxa	No. scraper taxa	No. clinger taxa	Total SMI score
1	56	17	7	10	13.0	2.87	46.5	11	23	100
2	53	11	7	17	9.5	2.67	50.4	10	27	100
3	49	14	6	10	5.9	4.35	58.2	6	21	91
[1]4	61	14	6	10	4.9	4.02	41.6	8	27	95
5	48	14	5	9	.9	4.97	68.8	7	25	86
6	48	11	8	12	4.6	1.91	59.0	10	25	100
7	60	15	11	8	11.1	3.35	41.7	10	27	100
8	57	10	11	14	15.2	2.62	49.4	10	30	100
9	51	14	9	10	13.5	3.21	44.9	10	24	100
10	42	9	10	7	25.2	2.71	63.3	9	19	98
11	60	13	11	11	7.8	3.08	55.3	12	31	100
12	48	10	3	9	1.3	4.64	67.2	7	26	81
13	55	16	6	7	7.0	3.84	53.0	8	25	99
14	53	10	7	9	5.6	4.33	38.9	4	25	92
15	53	11	10	11	13.1	3.32	49.0	7	25	100
16	44	8	4	10	1.9	4.65	68.0	7	23	78
17	41	6	5	6	3.4	3.69	74.0	6	20	69
18	51	10	6	9	3.8	3.79	59.9	11	30	98
19	43	7	2	8	.9	3.73	66.0	8	21	73
20	43	8	7	6	13.6	3.98	53.9	8	23	88
21	43	7	7	6	10.7	4.51	57.3	6	26	83
22	51	8	9	11	15.1	4.42	50.0	8	30	100
23	53	12	9	8	8.8	3.66	42.0	7	29	100
24	49	13	5	14	2.4	2.32	64.7	9	26	100
25	59	13	11	15	7.8	2.42	53.6	7	32	100

Table 6. Relations between benthic invertebrate metrics and Stream Macroinvertebrate Index scores for selected sample sites in the Salmon River Basin, central Idaho, 2001—Continued

Site No.	No. species	No. Ephemeroptera taxa	No. Plecoptera taxa	No. Trichoptera taxa	Percent Plecoptera	Hilsenhoff Biotic Index	Percent five dominant taxa	No. scraper taxa	No. clinger taxa	Total SMI score
26	68	17	9	12	7.4	4.15	45.5	11	35	100
27	59	15	8	7	8.9	3.08	39.4	9	23	100
28	59	13	8	13	5.0	4.20	46.2	9	32	100
29	53	9	3	11	.8	5.20	39.6	7	24	88
[1]30	54	12	8	10	11.4	4.08	42.1	6	27	99
31	44	6	4	13	2.5	4.02	76.4	11	27	87
32	38	10	2	7	.4	4.18	57.5	7	22	74
33	45	7	3	7	5.2	4.95	42.2	5	23	76
34	47	6	5	8	14.9	4.28	52.4	5	22	82

[1] Average of three multiple reaches.

this study. Fish collected at all sites appeared in good health with few external anomalies. The number of species collected at a site ranged from 1 at East Fork Hayden Creek (site 10) to 8 at Indian Creek (site 16).

Six salmonid species, composing 54 percent of the total number of fish collected, were collected during the study. Two species listed as threatened under the U.S. Fish and Wildlife Service Endangered Species Act (ESA) were collected—bull trout and chinook salmon—at 58 and 45 percent of the sampling sites, respectively. Rainbow trout (*Oncorhynchus mykiss*), which are considered native in the Salmon River Basin (Simpson and Wallace, 1982), were collected at 82 percent of the sampling sites, composing 33 percent of the total number of fish collected. According to the IDFG, rainbow trout are stocked in streams and rivers in the Salmon River Basin. However, less than 1 percent (6 of 1,381) of the rainbow trout collected showed signs such as eroded fins, deformities, and scars typically associated with hatchery fish. Cutthroat trout (*Oncorhynchus clarki*) were collected at 55 percent of the sampling sites; however, they composed only 2.6 percent of the total number of fish collected. Mountain whitefish (*Prosopium williamsoni*) were collected at 21 percent of the sampling sites. One introduced species, brook trout (*Salvelinus fontinalis*), was collected at 21 percent of the sampling sites.

Two cottid species were collected during the study. Shorthead sculpin (*Cottus confusus*) were collected at 85 percent of the sampling sites and was the most abundant species, composing 43 percent of the total number of fish collected. Torrent sculpin (*Cottus rhotheus*) were collected at 12 percent of the sampling sites.

Although common to the basin, suckers (*Catostomus* sp.) were not collected at any of the sampling sites. In addition to fish, tailed frogs and salamanders were collected at 48 percent and 18 percent of the sampling sites, respectively.

Comparison of Fish Assemblages at Multiple-Reach Sites

The JC index was used to compare spatial variability in the benthic invertebrate assemblages at multiple-reach sites (Valley Creek and Big Creek). The lower range of JC values for the multiple reaches sampled at Valley Creek (site 4) ranged from 0.29 to 0.57,

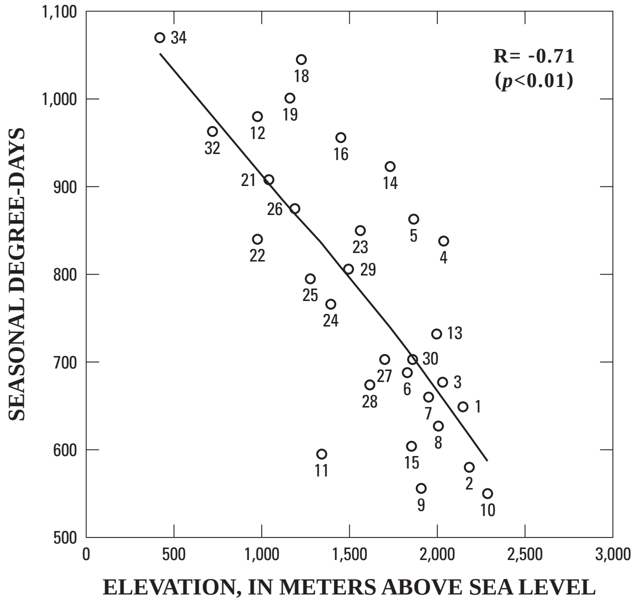


Figure 3. Elevation in relation to seasonal degree-days (July through August, above 0 degrees Celsius) for selected sample sites in the Salmon River Basin, central Idaho, 2001. [Trend line based on LOWESS smoothing technique (Helsel and Hirsch, 2002); site locations shown in figure 1; site names and characteristics shown in table 1]

indicating that the fish species were taxonomically dissimilar among multiple reaches. In other words, species composition varied substantially among the individual reaches. This variability is not easily explained. Typically, low JC values can be explained by low capture efficiency when sampling large rivers or streams with complex habitat. Valley Creek is neither large nor complex. This third-order, meandering, meadow stream can be sampled easily and contains little habitat variability.

The JC values for the multiple reaches sampled at Big Creek (site 30) ranged from 0.50 to 1.0 and were more typical of values for a small, wadeable stream. This range indicates that fish species were generally taxonomically similar and that fish collected at a single reach at this site are representative of the fish community assemblage.

Stream Fish Index Scores and Metrics

Similar to invertebrate metrics, the fish metrics describe expected conditions for least-disturbed sites; SFI scores ranged from 74 (Big Mallard Creek, site 23) to 100 at several sites (table 7). SFI scores for 91 percent (30 of 33) of the sample sites were above 81, which places these sites above the median of reference conditions for their ecoregion.

Within the richness and composition categories, the number of coldwater native species ranged from 1 at East Fork Hayden Creek (site 10) to 7 at Indian Creek and Camas Creek (sites 16 and 19, respectively); percent coldwater individuals ranged from 76 at Hazard Creek (site 32) to 100; and percent sensitive native individuals ranged from 25 at Big Mallard Creek (site 23) to 100. Within the reproductive function category, the number of cottid age classes ranged from 0 to 5. The number of salmonid age classes ranged from 2 to 5. Within the abundance category, CPUE ranged from 2.3 at Fourth of July Creek (site 2) to 21.9 at Skookumchuck Creek (site 33).

CORRELATIONS BETWEEN STREAM TEMPERATURE AND ENVIRONMENTAL VARIABLES

Representative environmental variables consisting of basin, site, and habitat characteristics (tables 1, A, and B) were analyzed in relation to the stream temperature metrics by using Spearman rank correlation analysis. Nine environmental variables—water-surface gradient, discharge, wetted channel width, width:depth ratio, aspect, total seasonal thermal input, open canopy, riparian canopy density, and elevation were selected for correlation with the nine stream temperature metrics.

Analysis of Spearman rank correlation coefficients for pairwise comparisons between the selected variables (table 8) determined that elevation showed the strongest inverse correlation with the stream temperature metrics, especially those metrics associated with mean temperature. Seasonal degree-days for July through August exhibited the strongest inverse correlation with elevation ($r=-0.71$) (fig. 3). Donato (2002) also reported that elevation showed a strong negative correlation with stream temperature in the Salmon River Basin. Riparian canopy density showed a strong inverse correlation with stream temperature metrics associated with maximum temperature. Wetted channel width and width:depth ratio were positively correlated with all stream temperature metrics. Donato (2002) also reported that these two variables showed a significant positive correlation with temperature in the Salmon River Basin. Discharge was positively corre-

Table 7. Relations between fish metrics and Stream Fish Index scores for selected sample sites in the Salmon River Basin, central Idaho, 2001

[Site locations shown in figure 1; site names and characteristics shown in table 1; No., number; CPUE, catch per unit effort; electrofishing not conducted at site 17]

Site No.	No. cold-water native species	Percent coldwater individuals	Percent sensitive native individuals	No. cottid age classes	No. salmonid age classes	CPUE (No. coldwater individuals per minute electro-fishing)	Stream Fish Index (forest)	Site No.	No. cold-water native species	Percent coldwater individuals	Percent sensitive native individuals	No. cottid age classes	No. salmonid age classes	CPUE (No. coldwater individuals per minute electro-fishing)	Stream Fish Index (forest)
1	3	100	75	4	5	4.3	95	19	7	100	52	4	4	4.2	94
2	4	100	96	5	2	2.3	80	20	2	99	99	5	3	5.1	97
3	2	100	80	3	2	10.1	87	21	5	100	100	5	3	7.0	100
4	3	100	84	4	3	10.9	97	22	2	100	100	0	3	4.5	100
5	4	99	99	4	2	9.1	90	23	2	100	25	0	2	3.6	74
6	5	100	96	5	4	2.6	89	24	5	99	99	4	2	16.1	100
7	4	100	91	5	5	6.9	99	25	3	100	100	0	3	4.1	100
8	4	100	100	5	3	4.5	96	26	3	97	97	4	3	6.6	100
9	3	100	100	5	4	4.6	97	27	3	100	100	5	3	3.2	100
10	1	100	100	0	5	5.4	75	28	4	100	98	5	3	2.7	99
11	3	100	100	5	3	8.5	98	29	4	100	100	5	3	6.8	100
12	5	98	72	5	3	9.2	98	30	2	100	100	0	3	5.5	89
13	4	100	90	4	2	10.4	100	31	5	94	93	5	3	4.7	96
14	3	100	99	4	2	5.0	90	32	4	76	76	4	3	7.5	100
15	3	100	98	4	3	4.2	100	33	2	93	93	4	3	21.9	97
16	7	100	94	4	5	7.7	100	34	2	97	97	3	3	13.1	95
18	6	96	68	3	3	3.0									

Table 8. Spearman rank correlation coefficients for selected habitat variables and selected stream temperature metrics for selected sample sites in the Salmon River Basin, central Idaho, July through September 2001

[Number of sample sites, 33; **bold** denotes significance ($p<0.05$); see table 2 for description of stream temperature metrics; m^3/s, cubic meters per second; m, meters; $BTUs/m^2/d$, British thermal units per square meter per day]

Habitat parameter	MDMT	MDAT	MWMT	MWAT	MWMTS	MWATS	DEGDAY[1]
Water-surface gradient (percent)	-0.25	-0.01	-0.21	0.04	-0.26	0.11	0.10
Discharge (m^3/s)	**.37**	**.40**	**.40**	**.43**	.20	.24	**.46**
Wetted channel width (m)	**.58**	**.64**	**.62**	**.66**	**.46**	**.49**	**.66**
Wetted stream width:depth ratio	**.52**	**.48**	**.54**	**.49**	**.51**	**.44**	**.47**
Stream aspect	.01	-.14	-.05	-.15	.20	-.13	-.18
Total seasonal thermal input, June through September 2001 ($BTUs/m^2/d$)	**.60**	**.41**	**.60**	**.40**	**.45**	.29	**.43**
Open canopy (percent)	**.48**	.22	**.46**	.19	.36	.10	.24
Riparian canopy density (percent)	**-.59**	-.30	**-.57**	-.27	**-.52**	-.19	-.29
Elevation (m above sea level)	-.29	**-.62**	-.35	**-.66**	-.13	**-.60**	**-.71**

[1] Sites 20, 31, and 33 not included (n = 30).

lated with all stream temperature metrics except those associated with the date of sample and 6 days prior (MWMTS and MWATS). Total seasonal thermal input was positively correlated ($p<0.05$) with all stream temperature metrics except MWATS. Open canopy was positively correlated with MDMT and MWMT. Neither water-surface gradient nor aspect was correlated with the stream temperature metrics.

CORRELATIONS BETWEEN STREAM TEMPERATURE AND BENTHIC INVERTEBRATE VARIABLES

Of the 201 benthic invertebrate taxa collected during this study, 57 taxa (present at a minimum of 5 sampling sites) were significantly correlated with one or more of the stream temperature metrics. Spearman rank correlation coefficients for pairwise comparisons of relative benthic invertebrate abundance and stream temperature metrics are shown in tables 5 and 9.

Of the 32 coldwater taxa collected, only 20 taxa showed a significant inverse correlation with one or more of the stream temperature metrics at the <0.05 probability level (table 5). Two of the designated coldwater obligates, *Cultus* and *Narpus*, showed a significant positive correlation with one or more of the stream temperature metrics. Of the coldwater taxa collected, *Zapada oregonensis* gr. showed the strongest inverse correlation with the stream temperature metrics and was collected at sites where MWMTS ranged from 11.3° to 18.5°C. Of the nine additional taxa not classified by Grafe and others (2002) as coldwater obligates, *Polycelis* showed the strongest inverse correlation with all stream temperature metrics and was collected at sites where MWMTS ranged from 11.3° to 18.6°C.

As expected, the percentage of coldwater taxa showed a strong inverse correlation (-0.73 to -0.87) with all stream temperature metrics. Figure 2 illustrates this correlation and indicates that, as MDMT increases, percent coldwater taxa decreases.

In contrast to coldwater taxa, 26 invertebrate taxa (present at a minimum of 5 sampling sites) showed a significant ($p<0.05$) positive correlation with one or more of the stream temperature metrics (table 9). These results suggest that these taxa may be tolerant of warmer water temperatures. These taxa represented 13 percent (26 of 201) of the total number of invertebrate taxa collected. Of the 26, the most frequently collected

Table 9. Spearman rank correlation coefficients for relative abundance of benthic invertebrate taxa and selected stream temperature metrics for selected sample sites in the Salmon River Basin, central Idaho, July through September 2001

[Number of sample sites, 33; taxa shown were collected at five or more sample sites; No., number; **bold** denotes significance (p<0.05); see table 2 for description of stream temperature metrics]

Taxon	No. of sites where collected	MDMT	MDAT	MWMT	MWAT	MWMTS	MWATS	DEGDAY[1]
Acentrella turbida	10	**0.58**	**0.51**	**0.57**	**0.50**	**0.57**	**0.54**	**0.50**
Baetis tricaudatus	33	.30	**.49**	.30	**.48**	**.40**	**.56**	**.49**
Diphetor hageni	14	**.53**	**.38**	**.54**	**.38**	**.52**	.37	**.39**
Hesperoperla pacifica	14	**.46**	.34	**.45**	.33	**.50**	.32	.31
Pteronarcys californica	7	**.46**	**.57**	**.49**	**.57**	**.44**	**.51**	**.55**
Pteronarcys sp.	6	**.54**	**.55**	**.54**	**.54**	**.40**	**.44**	**.54**
Skwala sp.	6	**.44**	**.40**	**.45**	**.44**	.29	.37	**.42**
Cleptelmis addenda	12	**.40**	.28	**.39**	.30	**.52**	**.40**	.24
Optioservus sp.	17	**.57**	**.74**	**.61**	**.74**	**.40**	**.61**	**.73**
Zaitzevia sp.	16	.29	**.48**	.35	**.49**	.14	**.37**	**.51**
Brachycentrus americanus	19	**.47**	.30	**.41**	.27	**.41**	.24	.24
Hydropsyche sp.	19	**.67**	**.81**	**.69**	**.82**	**.50**	**.66**	**.81**
Lepidostoma sp.	12	**.53**	**.53**	**.53**	**.51**	.31	.31	**.51**
Micrasema sp.	13	**.41**	.36	**.38**	**.37**	**.61**	**.51**	.31
Neophylax rickeri	5	**.38**	.30	.34	.27	.33	.31	.26
Antocha sp.	20	**.62**	**.74**	**.65**	**.78**	**.41**	**.65**	**.80**
Atherix sp.	8	**.53**	**.45**	**.51**	**.45**	**.47**	**.40**	**.44**
Cricotopus (Nostococladius) sp.	17	**.39**	.25	**.38**	.24	**.36**	.28	.22
Cricotopus sp.	26	**.50**	**.50**	**.49**	**.52**	.42	**.49**	**.52**
Orthocladius Complex	22	.36	.25	.32	.22	**.46**	**.40**	.20
Orthocladius sp.	24	**.44**	**.47**	**.49**	**.50**	.26	**.44**	**.53**
Polypedilum sp.	6	**.34**	.29	.34	.28	**.47**	**.43**	.23
Rheotanytarsus sp.	21	**.55**	**.47**	**.55**	**.44**	**.59**	**.54**	**.43**
Sublettea sp.	5	**.48**	**.43**	**.51**	**.45**	**.39**	.32	**.42**
Thienemanniella sp.	8	.33	**.28**	.33	.30	**.41**	**.39**	.30
Acari (=Acarina)	32	**.59**	**.62**	**.61**	**.63**	**.47**	**.59**	**.66**

[1] Sites 20, 31, and 33 not included (n=30).

was *Baetis tricaudatus*, which was collected at 33 of the 34 sampling sites. The caddisfly *Hydropsyche* showed the strongest positive correlation with the stream temperature metrics.

CORRELATIONS BETWEEN STREAM TEMPERATURE AND FISH VARIABLES

Spearman rank correlation coefficients for pairwise comparisons of relative fish abundance and stream temperature metrics are shown in table 10. Results of this comparison indicate that bull trout showed the strongest inverse correlation with stream temperature. According to Selong and others (2001), of salmonids in North America, bull trout are regarded as having one of the lowest thermal tolerances and typically do not live where maximum temperatures exceed 15°C. In this study, bull trout were collected at sites where MWMTS ranged from 11.3° to 20.0°C (fig. 4).

In contrast, rainbow trout were positively correlated with all stream temperature metrics except MDMT and MWMTS. Chinook salmon also showed a weak positive correlation with all stream temperature metrics except MWAT and MWATS. These two species were collected at sites where MWMTS ranged from 12.4° to 22.9°C and 14.2° to 20.0°C, respectively (fig. 4).

Two additional species were positively correlated with the stream temperature metrics. Longnose dace (*Rhinichthys cataractae*) showed a strong positive correlation with stream temperature, and torrent sculpin, although less pronounced, also showed a positive correlation with all stream temperature metrics except MWAT, MWMTS, and MWATS. The correlation between brook trout, cutthroat trout, speckled dace (*Rhinichthys osculus*), shorthead sculpin, mountain whitefish, or tailed frogs and the stream temperature metrics was not significant (p>0.05).

Correlations between SFI metrics, selected fish densities, and the stream temperature metrics are presented in table 11. As expected, percent coldwater individuals showed a strong inverse correlation with stream temperature. Percent sensitive native individu-

Table 10. Spearman rank correlation coefficients for relative abundance of fish species and selected stream temperature metrics for selected sample sites in the Salmon River Basin, central Idaho, July through September 2001

[Number of sample sites, 33; No., number; **bold** denotes significance (p<0.05); see table 2 for description of stream temperature metrics]

Fish species	No. of sites where collected	MDMT	MDAT	MWMT	MWAT	MWMTS	MWATS	DEGDAY[1]
Brook trout	7	-0.01	-0.16	-0.07	-0.19	0.11	-0.16	-0.25
Bull trout	19	**-.64**	**-.54**	**-.63**	**-.51**	**-.63**	**-.53**	**-.52**
Chinook salmon	15	**.45**	**.37**	**.40**	.34	**.38**	.32	**.41**
Cutthroat trout	18	-.21	-.20	-.23	-.20	-.29	-.25	-.11
Longnose dace	11	**.64**	**.66**	**.65**	**.66**	**.53**	**.61**	**.55**
Rainbow trout	27	.36	**.53**	**.44**	**.56**	.30	**.54**	**.55**
Speckled dace	2	.22	.36	.26	.34	.30	.35	.25
Shorthead sculpin	27	-.06	-.31	-.10	-.33	-.07	-.32	-.31
Torrent sculpin	4	**.45**	**.37**	**.42**	.35	.12	.13	**.44**
Mountain whitefish	11	.30	.32	.30	.31	.16	.14	.35
Tailed frog	14	-.05	-.08	-.02	-.04	-.02	.04	.07

[1] Sites 20, 31, and 33 not included (n=30).

als showed a weak inverse correlation with all stream temperature metrics except MWATS. Catch per unit effort showed a weak positive correlation with stream temperature metrics associated with maximum temperatures (MDMT, MWMT, MWMTS); all other stream temperature metrics were not correlated with this fish metric. No significant ($p>0.05$) correlation was evident between any of the stream temperature metrics and number of coldwater native species, number of sculpin and salmonid age classes, or percent sculpins.

Results of the fish density and stream temperature metric comparison were similar to the comparisons of relative fish abundance and stream temperature metrics; bull trout and juvenile bull trout (<150 mm) density showed strong inverse correlations with stream temperature (table 11 and fig. 5). Bull trout densities ranged from 0.001 fish/m^2 at Hazard Creek (site 32) to 0.094 fish/m^2 at Morse Creek (site 9). Juvenile bull trout densities ranged from 0 to 0.049 fish/m^2 at the 19 sites where bull trout were collected. Morse Creek and East Fork Hayden Creek (site 10) contained exceptionally high densities of bull trout relative to densities at other sites (fig. 5). MDMT at these sites was 12.0° and 13.9°C, respectively. Neither salmonid nor sculpin density was correlated with the stream temperature metrics.

Because bull trout are listed as threatened under the ESA and are believed to be among the most thermally sensitive species in coldwater habitats (Selong and others, 2001), regional models have been developed to predict their occurrence at various stream temperatures. These predictive tools also have been used to develop stream temperature water-quality criteria to protect bull trout. Dunham and others (2001) developed a univariate logistic regression model predicting the probability of occurrence of juvenile bull trout using MDMT as the predictor variable for 643 stream sites throughout the Western United States (fig. 6). They selected MDMT because it was significantly correlated with other stream temperature metrics

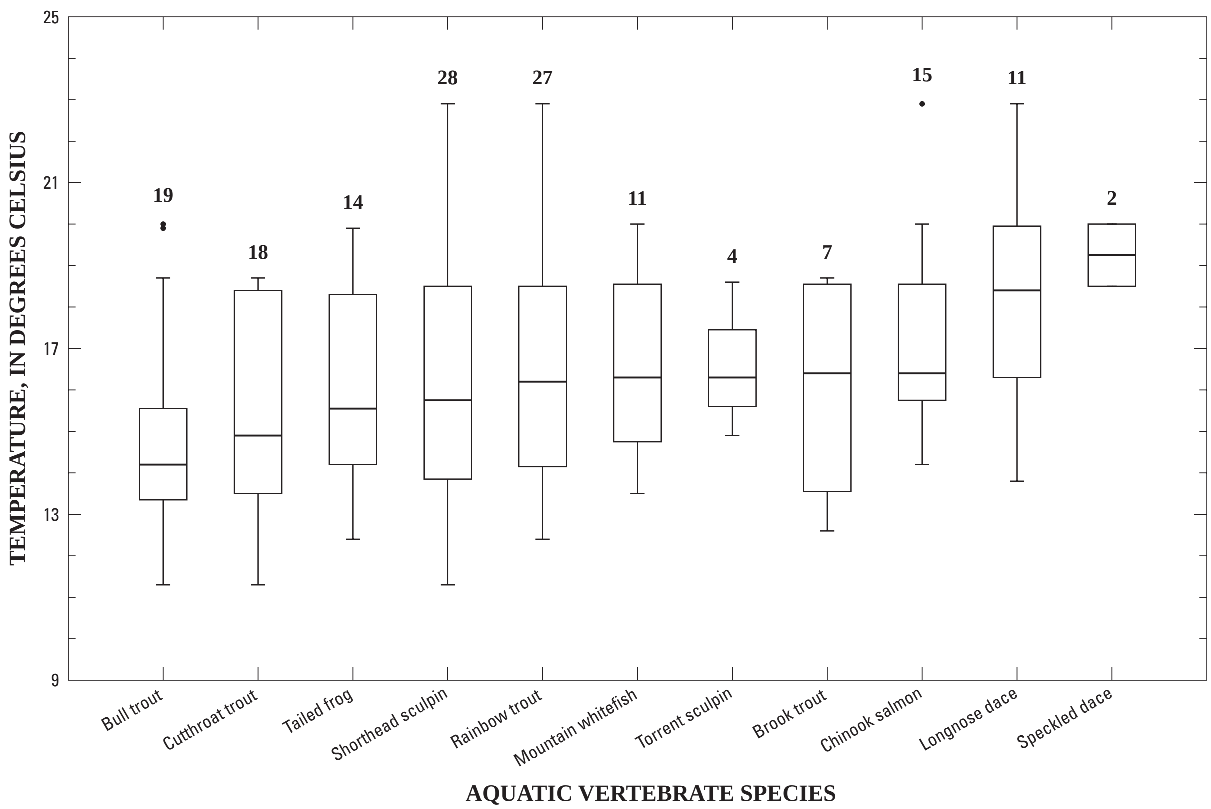


Figure 4. Range of maximum weekly-maximum stream temperatures (based on date of sample collection and 6 days prior) at which fish and tailed frogs were collected in the Salmon River Basin, central Idaho, 2001. [Species are ranked by median water temperatures at all sites where collected; site locations shown in figure 1; site names and characteristics shown in table 1]

Table 11. Spearman rank correlation coefficients for selected fish and stream temperature metrics for selected sample sites in the Salmon River Basin, central Idaho, July through September 2001

[Number of sample sites, 33; No., number; **bold** denotes significance ($p<0.05$); see table 2 for description of stream temperature metrics; m^2, square meters; <, less than; mm, millimeters]

Metric	MDMT	MDAT	MWMT	MWAT	MWMTS	MWATS	DEGDAY[1]
Stream Fish Index (forested)							
No. of coldwater native species	0.22	0.27	0.22	0.27	0.05	0.11	0.33
Percent coldwater individuals	**-.52**	**-.64**	**-.55**	**-.63**	**-.42**	**-.58**	**-.63**
Percent sensitive native individuals	**-.48**	**-.46**	**-.45**	**-.43**	**-.48**	-.31	**-.39**
No. of cottid age classes	-.32	-.31	-.32	-.30	-.33	-.29	-.27
No. of salmonid age classes	-.22	-.18	-.20	-.18	-.35	-.34	-.15
Catch per unit effort (No. of coldwater individuals per minute electrofishing)	**.41**	.28	**.36**	.26	**.44**	.31	.25
Density (No. fish/m^2)							
Salmonid	.06	.15	.05	.15	.11	.24	.14
Bull trout	**-.61**	**-.52**	**-.60**	**-.49**	**-.58**	**-.51**	**-.51**
Juvenile bull trout (<150 mm in length)	**-.66**	**-.62**	**-.67**	**-.61**	**-.52**	**-.54**	**-.63**
Sculpin	.19	-.04	.14	-.08	.16	-.09	-.08

[1] Sites 20, 31, and 33 not included (n=30).

and is an easily understood metric with strong biological implications for acute exposure. Juvenile fish were used because they represent resident (nonmigratory) individuals that are present for at least an entire annual thermal regime within the stream. Model predictions for the regional data set showed that the probability of occurrence is relatively low (<0.50) until MDMT declines to approximately 14° to 16°C, and the probability of occurrence is not high (>0.75) until MDMT declines to approximately 11° to 12°C.

To determine the probability of occurrence of bull trout in Salmon River Basin streams, a univariate logistic regression model was developed using MDMT from 33 sites in this study. The model developed during this study describes a significant ($p<0.001$) correlation between the probability of occurrence of juvenile bull trout and MDMT. However, this model differed from the regional model developed by Dunham and others (2001) in that the range of observed stream temperatures for the Salmon River Basin dataset is narrower than for the regional dataset. Perhaps this is because sites in the Salmon River Basin represent only minimally disturbed reference sites and constitute a much smaller sample size.

The regression model for this study showed higher probabilities of occurrence of bull trout at colder stream temperatures (10° to 15°C) and lower probabilities of occurrence at warmer stream temperatures (16° to 21°C) than the regional model showed. Most importantly, the regional model likely would overpredict the probability of bull trout occurrence at warmer stream temperatures if applied to streams in the Salmon River Basin. The boxplots comparing the predicted probabilities for both datasets (fig. 6) show that, for sites where no bull trout were present, the regional model predicts a median probability of occurrence of about 40 percent, whereas the model developed during this study predicts the median probability of bull trout occurrence at about 10 percent. A Mann-Whitney test for both datasets shows a significant ($p<0.001$) difference in predicted probability between cases where bull trout are absent and cases where they are present. Regression model results using all bull trout and MDMT did not perform as well as the model using juveniles only; the significance level was $p=0.01$. McFadden's rho, a measure of model performance (goodness of fit), was 0.40 and 0.15 for the model using juvenile bull trout and all bull trout, respectively. Values between 0.2 and 0.4 suggest a good fit to the model (Hosmer and Lemeshow, 1989).

As suggested in the preceding discussion, the model developed in this study probably would be a better predictor of bull trout occurrence for Salmon River Basin streams than would a model based on regional data for the entire Pacific Northwest, possibly because of other limiting factors that may not be present at least-disturbed sites sampled in this study. Additionally, the regional dataset was composed of a wide variety of data sources and varying collection methods that may have influenced model results, whereas during the Salmon River Basin study, consistent electrofishing effort was applied at each study site to standardize fish capture efficiency. The model comparisons suggest that regional or local differences need to be considered when deriving stream temperature criteria. These comparisons should be viewed with caution because of sample size differences—the regional dataset contained an order-of-magnitude more observations than those modeled in this study.

SUMMARY

Environmental variables, with a focus on stream temperature, and benthic invertebrate and fish assemblages were evaluated for 34 least-disturbed, wadeable, second- through fifth-order streams in the Salmon River Basin, Idaho. Data were collected to document the thermal regime of least-disturbed streams, characterize the distribution of aquatic biota in streams representing a gradient of temperature, and describe relations between environmental variables and benthic invertebrate and fish assemblages.

The Salmon River Basin is located within the Blue Mountains, Idaho Batholith, and Middle Rockies

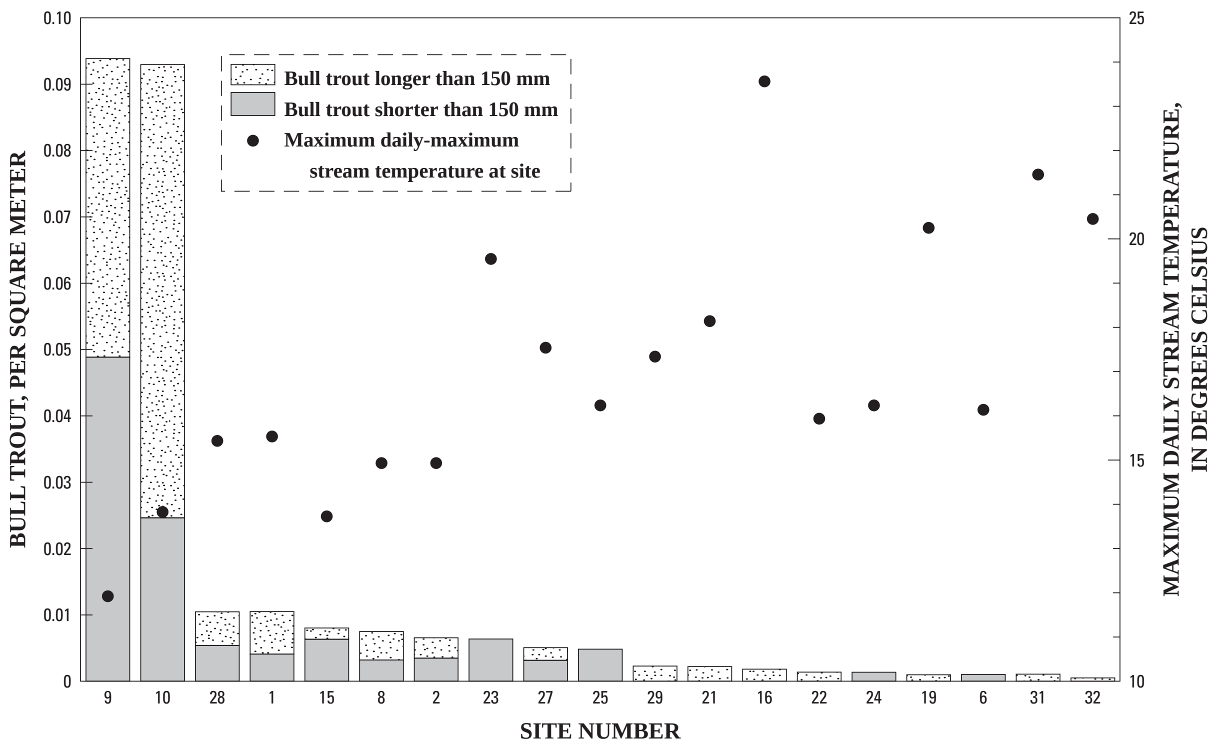


Figure 5. Bull trout densities in relation to maximum daily-maximum stream temperature at selected sample sites in the Salmon River Basin, central Idaho, 2001. [mm, millimeter; site locations shown in figure 1; site names and characteristics shown in table 1]

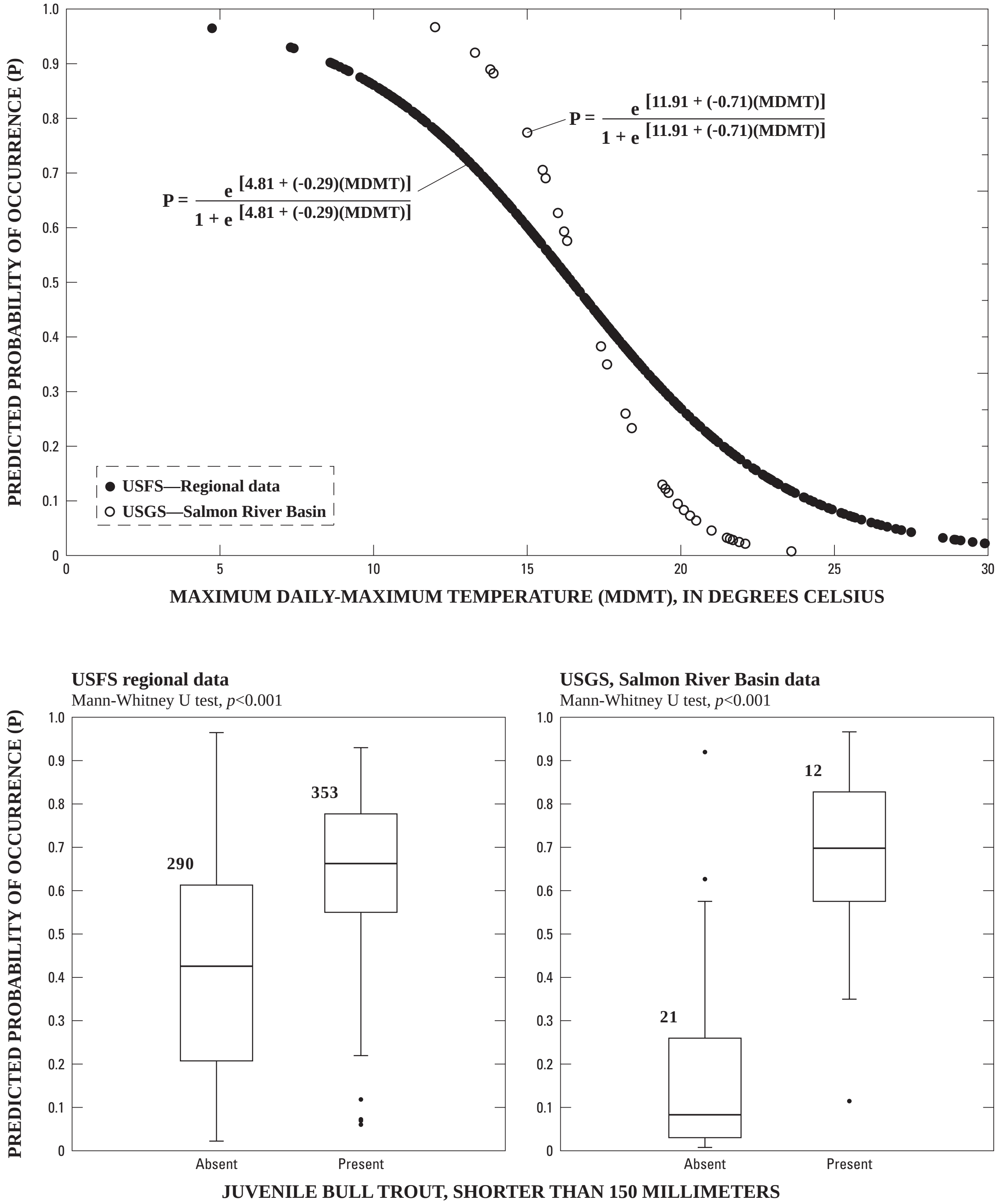


Figure 6. Model-predicted probabilities of occurrence of juvenile bull trout in relation to maximum daily-maximum stream temperature, based on regional and Salmon River Basin datasets. [Boxplots show predicted probabilities of occurrence for both models; regional data from U.S. Forest Service (Dunham and others, 2001); Salmon River Basin data from U.S. Geological Survey (this study); USFS, U.S. Forest Service; USGS, U.S. Geological Survey]

ecoregions, which consist primarily of coniferous forests. Land use in the basin comprises 67 percent forest, 30 percent rangeland, and 3 percent agricultural land. Large areas of the basin are designated as wilderness, and parts of the Salmon River and its tributaries are designated as wild and scenic rivers.

Sampling sites were selected to represent least-disturbed conditions with an emphasis on sites minimally affected by historical logging or mining activities within their watersheds. Several environmental variables, including basin and reach characteristics, physical habitat characteristics, and water physicochemistry, were examined and relations with benthic invertebrate and fish assemblages were evaluated.

Nine different stream temperature metrics were calculated for the 33 sites where stream temperature data were available. Stream temperature metrics indicated that water temperature varied substantially among sites within the basin and that the range of observed temperatures varied over a broad gradient. A comparison of stream temperature metrics with current stream temperature criteria showed that temperatures at all 33 sites where data were available exceeded the U.S. Environmental Protection Agency 10.0°C maximum weekly-maximum temperature criterion for bull trout spawning and juvenile rearing. Temperatures exceeded the Idaho Department of Environmental Quality 13.0°C maximum daily-maximum temperature criterion for the protection of salmonid spawning at 30 sites and exceeded the 9.0°C maximum daily-average temperature criterion for the protection of salmonid spawning at all 33 sites. Thermal regimes at most sites did not exceed the Idaho Department of Environmental Quality criteria for the protection of coldwater biota.

Nine environmental variables—water-surface gradient, discharge, wetted channel width, width:depth ratio, aspect, total seasonal thermal input, open canopy, riparian canopy density, and elevation were selected for correlation with the nine stream temperature metrics. Results of this analysis indicated that seasonal degree-days for July through August exhibited the strongest inverse correlation with elevation.

Two hundred and one benthic invertebrate taxa from the 34 sampling sites were identified. The most abundant taxa were *Baetis tricaudatus*, Oligochaeta, *Tvetenia bavarica* gr., Acari, *Rhithrogena*, *Cinygmula*, *Heterlimnius*, *Micropsectra*, *Eukiefferiella devonica* gr., *Drunella doddsi*, and *Cricotopus*. Thirty-two coldwater taxa, representing 16 percent of the total number of invertebrate taxa collected, were collected during this study. Coldwater taxa were collected at all sites where temperatures exceeded the Idaho Department of Environmental Quality criteria for the protection of coldwater biota. Stream Macroinvertebrate Index scores ranged from 69 to 100 and, in general, describe expected conditions for least-disturbed sites. Of the 201 benthic invertebrate taxa collected during this study, 57 taxa were significantly correlated with one or more of the stream temperature metrics. Of the 32 coldwater taxa collected, only 20 taxa showed a significant inverse correlation with one or more of the stream temperature metrics. In contrast to coldwater taxa, 26 invertebrate taxa showed a significant positive correlation with one or more of the stream temperature metrics.

A total of 4,199 fish were collected from the 33 sites sampled during this study. Ten species of fish in the families Salmonidae, Cottidae, and Cyprinidae were collected. Bull trout and chinook salmon, two species listed as threatened under the U.S. Fish and Wildlife Service Endangered Species Act, were collected. In addition to fish, tailed frogs and salamanders also were collected. Stream Fish Index scores ranged from 74 to 100 and, in general, describe expected conditions for least-disturbed sites.

Correlation between relative fish abundance and the stream temperature metrics indicated that bull trout showed the strongest inverse correlation with stream temperature and were collected at sites where the maximum weekly-maximum temperature (based on date of sample and 6 days prior) ranged from 11.3° to 20.0°C. Correlations between the Stream Fish Index metrics, selected fish densities, and the stream temperature metrics indicated that percent coldwater individuals showed the strongest inverse correlation with stream temperature metrics. Results of the fish density and stream temperature metric comparison were similar to the comparisons of relative fish abundance and stream temperature metrics. Bull trout and juvenile bull trout density showed strong inverse correlations with stream temperature.

A univariate logistic regression model developed during this study predicts the probability of occurrence of juvenile bull trout on the basis of the maximum daily-maximum temperature. Compared with a regional model, the regression model for the Salmon River Basin predicted higher probabilities of occurrence of bull trout at colder stream temperatures (10° to 15°C) and lower probabilities of occurrence at warmer stream temperatures (16° to 21°C). The model developed in this study appeared to be more effective at predicting the probability of bull trout for Salmon River Basin streams than did the regional model. The model comparison suggests that regional or local differences need to be considered when deriving stream temperature criteria.

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SUPPLEMENTAL INFORMATION

Table A. Habitat characteristics for selected sample sites in the Salmon River Basin, central Idaho, 2001

[Site locations shown in figure 1; site names and characteristics shown in table 1; No., number; m, meter; m/s, meters per second; mm, millimeters; m^3/s, cubic meters per second; CV, coefficient of variation; $BTUs/m^2/d$, British thermal units per square meter per day; no data available for site 17]

Site No.	Reach length (m)	Riffle area (percent)	Run area (percent)	Pool area (percent)	Water-surface gradient (percent)	Wetted channel width[1] (m)	Bankfull width[1] (m)	Open canopy[1] percent)	Riparian canopy (percent)	Stream aspect[1]	Stream depth[1] (m)	Thalweg depth[1] (m)	Bankfull thalweg depth[1]
1	150	39	29	32	1.0	7.3	9.3	27	71	92	0.28	0.35	0.67
2	150	57	28	15	3.8	4.3	4.9	3	93	220	.25	.31	.71
3	150	27	60	13	1.0	4.3	4.9	21	59	360	.19	.30	.55
[2]4	150	36	59	7	1.0	5.6	6.9	86	6	148	.20	.28	.72
5	150	60	27	13	2.1	7.4	10.6	32	39	120	.27	.36	1.00
6	280	69	31	0	3.5	11.5	13.4	32	43	360	.39	.51	.94
7	150	73	27	0	2.7	7.8	8.5	27	57	159	.28	.39	.68
8	155	85	6	9	1.8	4.5	6.2	16	80	275	.21	.24	.77
9	150	77	13	10	3.5	3.7	5.4	26	78	253	.15	.17	.65
10	150	20	57	23	1.0	4.1	6.0	36	45	360	.27	.35	.55
11	150	85	13	2	2.2	5.4	7.0	16	87	275	.25	.31	.70
12	150	77	10	13	3.4	6.8	8.3	14	88	140	.27	.34	.75
13	150	60	40	0	1.0	10.0	11.0	61	25	360	.23	.36	.79
14	200	62	38	0	1.8	12.0	14.1	34	33	117	.27	.32	.81
15	150	77	20	3	2.4	7.9	8.7	20	61	360	.25	.36	.61
16	200	54	37	9	1.9	12.1	15.9	43	11	127	.30	.4	.89
18	200	100	0	0	1.0	23.2	26.7	48	12	276	.42	.50	1.12
19	200	100	0	0	1.8	15.1	21.7	52	[2]37	316	0.60	0.69	1.37
20	150	75	3	22	3.5	8.0	9.7	14	90	262	.30	.41	.82

Table A. Habitat characteristics for selected sites in the Salmon River Basin, 2001—Continued

Site No.	Reach length (m)	Riffle area (percent)	Run area (percent)	Pool area (percent)	Water-surface gradient (percent)	Wetted channel width[1] (m)	Bankfull width[1] (m)	Open canopy[1] percent)	Riparian canopy (percent)	Stream aspect[1]	Stream depth[1] (m)	Thalweg depth[1] (m)	Bankfull thalweg depth[1]
21	150	66	3	31	14.0	7.5	9.2	26	84	98	0.35	0.50	1.43
22	150	74	0	26	21.5	6.2	10.7	13	90	268	.23	.33	1.19
23	150	20	57	23	1.7	8.8	11.3	18	63	195	.29	.41	.97
24	150	92	0	8	3.1	6.5	7.9	31	60	30	.28	.37	.68
25	130	58	19	23	5.7	5.8	6.3	16	92	296	.23	.35	.65
26	150	62	29	9	5.9	8.7	10.9	24	69	51	.27	.38	.92
27	150	28	2	70	4.5	7.3	10.2	38	37	234	.34	.40	1.14
28	150	60	37	3	4.5	7.8	9.1	24	77	238	.24	.32	.77
29	150	82	18	0	6.3	6.3	7.6	25	58	314	.29	.37	.90
[2]30	150	57	38	6	1.7	6.5	7.5	46	28	226	.22	.30	.64
31	150	80	0	20	4.5	11.8	16.8	22	89	233	.35	.54	1.52
32	150	80	0	20	5.9	14.6	16.8	24	69	235	.29	.45	1.09
34	130	33	14	53	4.5	2.5	8.9	0	100	360	.20	.25	1.01

Table A. Habitat characteristics for selected sites in the Salmon River Basin, 2001—Continued

Site No.	Stream velocity[1] (m/s)	Bottom substrate size (mm)	Percent substrate embeddedness[1]	Percent instream habitat cover	Percent large woody debris	Discharge (m^3/s)	Wetted width/depth ratio	Width CV (percent)	Stream depth CV (percent)	Velocity CV (percent)	Bank stability index	Flow stability index	Total seasonal thermal input ($BTUs/m^2/d$)
1	0.31	9	80	18.8	9.4	0.18	26	72	68	81	10	0.52	31,501
2	.42	384	0	17.8	1.7	.32	17	27	39	71	8	.44	8,077
3	.48	48	37	6.1	0.6	.29	23	27	75	46	10	.55	19,760
[2]4	.29	72	26	6.5	.2	.23	29	22	53	58	10	.39	95,627
5	.48	192	19	8.9	1.6	.64	27	20	52	69	8	.36	42,448
6	.70	192	19	20.0	5.0	2.25	29	28	30	43	8	.54	57,979
7	.59	192	38	8.9	3.3	1.25	28	21	38	51	11	.57	22,506
8	.55	96	0	10.0	4.4	.40	22	16	24	43	8	.31	17,564
9	.39	96	18	8.8	2.7	.15	25	16	28	63	7	.26	19,702
10	.24	24	86	12.0	5.0	.13	15	36	67	78	10	.64	35,632
11	.60	96	15	6.1	3.3	.60	22	24	32	51	10	.44	8,836
12	.37	192	18	20.0	5.0	.48	25	10	35	72	9	.45	17,084
13	.53	96	27	7.7	0	1.03	43	17	57	45	10	.46	78,384
14	.32	192	38	6.0	1.6	.78	44	29	34	43	7	.40	67,798
15	.60	192	28	20.0	4.0	1.07	32	12	42	47	10	.59	44,008
16	.43	96	19	5.6	1.1	1.11	40	21	42	55	9	.45	79,592
18	.52	192	19	6.7	0	3.76	55	8	27	26	10	.45	85,718
19	.50	768	0	17.0	0	3.68	25	16	29	41	10	.50	76,403

Table A. Habitat characteristics for selected sites in the Salmon River Basin, 2001—Continued

Site No.	Stream velocity[1] (m/s)	Bottom substrate size (mm)	Percent substrate embeddedness[1]	Percent instream habitat cover	Percent large woody debris	Discharge (m^3/s)	Wetted width/depth ratio	Width CV (percent)	Stream depth CV (percent)	Velocity CV (percent)	Bank stability index	Flow stability index	Total seasonal thermal input (BTUs/m^2/d)
20	0.53	96	16	13.3	1.7	1.16	27	22	41	53	8	0.50	30,297
21	.30	192	7	12.0	2.2	.91	22	45	48	92	12	.35	39,645
22	.25	192	4	19.4	3.3	.24	27	52	50	97	10	.28	10,088
23	.32	48	79	18.9	6.1	.55	30	26	61	50	10	.42	17,058
24	.48	192	11	13.8	2.7	.70	23	30	43	75	8	.54	40,498
25	.23	192	22	12.7	2.7	.20	25	29	48	73	8	.54	8,739
26	.40	192	32	12.0	1.7	.77	32	16	37	62	8	.41	33,989
27	.49	96	17	18.9	4.4	.90	21	22	26	38	9	.35	60,065
28	.49	144	14	16.1	1.7	.74	32	13	42	54	8	.42	40,234
29	.45	192	22	17.0	1.6	.68	22	20	37	62	9	.41	59,389
[2]30	.35	80	47	17.4	1.7	.36	29	24	39	47	10	.47	64,131
31	.63	384	0	12.7	0	2.39	34	26	51	61	10	.36	26,835
32	.31	768	0	18.3	0	1.03	50	16	56	55	10	.41	47,872
34	.14	96	0	8.3	1.1	.04	12	38	104	67	10	.25	29,453

[1] Average measurements taken at six transects.
[2] Multiple-reach site. Average measurements taken at 18 transects.

Table B. Microhabitat characteristics for all sample sites in the Salmon River Basin, central Idaho, 2001

[Values represent average of measurements taken at riffle collection sites within each reach; site locations shown in figure 1; site names and characteristics shown in table 1; No., number; m, meters; m/s, meters per second; <, less than; mm, millimeters; —, data unavailable]

Site No.	Stream depth (m)	Stream velocity (m/s)	Percent substrate fines (<2mm)	Bottom substrate size (mm)	Substrate embeddedness (percent)	Wolman bottom substrate size (mm)	Wolman fines, <6mm (percent)	Open canopy (percent)
1	0.13	0.65	18	64	23	31	33	13
2	.19	.67	0	96	15	31	13	26
3	.10	.59	5	48	23	48	23	24
4	.22	.44	5	64	7	64	11	80
5	.19	.47	0	96	15	96	11	23
6	.17	.57	5	96	15	96	12	27
7	.12	.71	3	64	38	96	20	34
8	.15	.52	0	96	12	96	13	25
9	.28	.35	3	96	15	96	15	29
10	.09	.79	20	23	100	23	42	37
11	.23	.61	0	128	8	96	16	19
12	.17	.76	3	256	8	384	22	18
13	.17	.48	0	64	38	96	18	68
14	.20	.38	7	192	15	192	31	30
15	.15	.45	13	96	23	48	20	20
16	.25	.49	7	96	38	96	14	44
17	.30	.65	10	64	46	192	13	43
18	.20	.61	3	64	15	—	—	25
19	.31	.41	3	256	15	—	—	49
20	.20	.48	3	64	23	192	17	18
21	.22	.53	3	192	8	192	2	23
22	.18	.39	3	96	15	1,536	8	6
23	.13	.59	3	64	23	48	32	12
24	.25	.51	13	96	23	96	22	24
25	.14	.29	10	192	23	192	28	10
26	.11	.32	0	192	30	192	19	19
27	.23	.49	0	96	15	96	9	50
28	.19	.62	0	192	15	192	5	25
29	.13	.52	0	192	46	192	11	46
30	.12	.45	5	75	28	64	24	46
31	.25	.59	0	768	15	384	9	28
32	.22	.13	0	768	23	384	4	16
33	.19	.19	0	192	5	—	—	31
34	.14	.23	0	192	38	96	3	0

Table C. Water-quality and nutrient data for all sample sites in the Salmon River Basin, central Idaho, 2001

[Site locations shown figure 1; site names and characteristics shown in table 1; No., number; sample date, month/day/year; sample time, 24-hour; °C, degrees Celsius; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; N, nitrogen; P, phosphorus; —, data unavailable; <, less than; E, estimated value reported by laboratory]

Site No.	Sample date	Sample time	Water temperature °C	Dissolved oxygen (mg/L)	Dissolved oxygen saturation (percent)	pH (standard units)	Specific conductance (µS/cm)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia + organic, total (mg/L as N)	Nitrite + nitrate, dissolved (mg/L as N)	Phosphorus total (mg/L as P)	Ortho-phosphorus, dissolved (mg/L as P)
1	8/2/01	0830	8.0	8.7	97	7.8	55	<0.002	<0.080	0.011	<0.0040	<0.007
2	8/23/01	1420	12.2	7.9	—	8.1	162	.014	E.054	.010	.0096	E.004
3	7/26/01	0900	6.8	9.5	100	8.1	37	.002	E.049	.013	E.0025	<.007
4	7/23/01	1630	18.3	7.6	102	8.4	95	<.002	E.052	.009	E.0032	<.007
5	7/24/01	0800	9.0	9.1	99	7.9	97	<.002	E.058	.008	.0046	<.007
6	7/25/01	0900	9.5	9.6	105	8.4	148	<.002	E.068	.016	.0041	<.007
7	7/31/01	1000	6.5	9.7	100	8.2	155	<.002	E.054	.006	.0278	<.007
8	8/23/01	1000	8.6	9.5	—	7.6	77	.006	E.077	.029	.0329	.023
9	8/24/01	0900	7.9	8.9	—	6.9	33	.006	E.064	.049	.0192	.012
10	8/24/01	1000	5.9	9.1	96	8.0	60	.005	E.076	.037	.0175	.009
11	8/22/01	1400	10.9	8.7	92	7.9	64	<.002	E.051	.015	.0160	.007
12	8/23/01	1200	14.3	8.8	98	8.0	81	.004	E.067	.007	.0098	<.007
13	7/30/01	1200	8.5	9.2	101	8.2	67	<.002	E.042	.006	.0039	<.007
14	8/7/01	1000	12.8	8.3	—	8.0	82	<.002	<.080	<.005	.0040	<.007
15	8/1/01	1000	6.4	9.7	99	8.2	108	<.002	E.059	.007	E.0028	<.007
16	9/14/01	1700	17.9	8.0	—	7.8	118	.002	.376	.009	.1506	.014
17	9/15/01	1600	15.8	7.3	—	8.0	98	.018	.647	.087	.2470	E.005
18	9/17/01	1300	13.8	8.6	—	8.1	126	.003	.128	.009	.0133	<.007
19	9/18/01	1600	13.5	8.7	—	8.0	129	.005	.453	.010	.1844	<.007

Table C. Water-quality and nutrient data for all sites in the Salmon River Basin, central Idaho, 2001—Continued

Site No.	Sample date	Sample time	Water temperature °C	Dissolved oxygen (mg/L)	Dissolved oxygen saturation (percent)	pH (standard units)	Specific conductance (µS/cm)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia + organic, total (mg/L as N)	Nitrite + nitrate, dissolved (mg/L as N)	Phosphorus total (mg/L as P)	Ortho-phosphorus, dissolved (mg/L as P)
20	9/19/01	1645	12.3	9.2	—	7.7	84	0.006	0.084	0.024	0.0048	<0.007
21	9/21/01	1000	12.0	9.8	—	7.8	78	.005	.087	.020	.0104	<.007
22	9/21/01	1600	10.1	10.0	—	7.0	50	<.002	.080	.113	.0110	<.007
23	8/15/01	1230	13.8	8.7	102	7.9	32	<.002	.098	.005	.0179	.011
24	8/8/01	1000	11.9	9.0	—	7.4	45	<.002	<.080	.009	.0061	<.007
25	8/8/01	1200	13.1	8.7	98	8.0	47	.002	E.044	.032	.0244	.014
26	7/19/01	0800	10.7	9.7	103	7.8	43	<.002	E.069	.005	.0045	<.007
27	7/16/01	1400	10.7	8.5	94	8.3	111	<.002	.130	.006	E.0029	<.007
28	7/17/01	1230	9.2	9.3	99	8.4	113	.005	<.080	.007	<.0040	<.007
29	7/18/01	0800	9.6	9.3	99	8.1	73	<.002	E.075	.006	.0047	<.007
30	8/14/01	0800	8.5	9.0	97	7.5	27	.009	.097	.006	.0093	E.004
31	8/15/01	1030	17.0	8.8	—	7.7	82	.007	.108	.011	.0069	<.007
32	8/13/01	1210	16.5	8.6	—	7.6	50	.009	.089	.014	.0099	E.005
33	8/16/01	0900	15.8	9.0	—	7.7	72	.003	.162	.030	.0609	.044
34	8/14/01	0900	17.3	8.6	—	7.9	118	.010	.195	.225	.0854	.073

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