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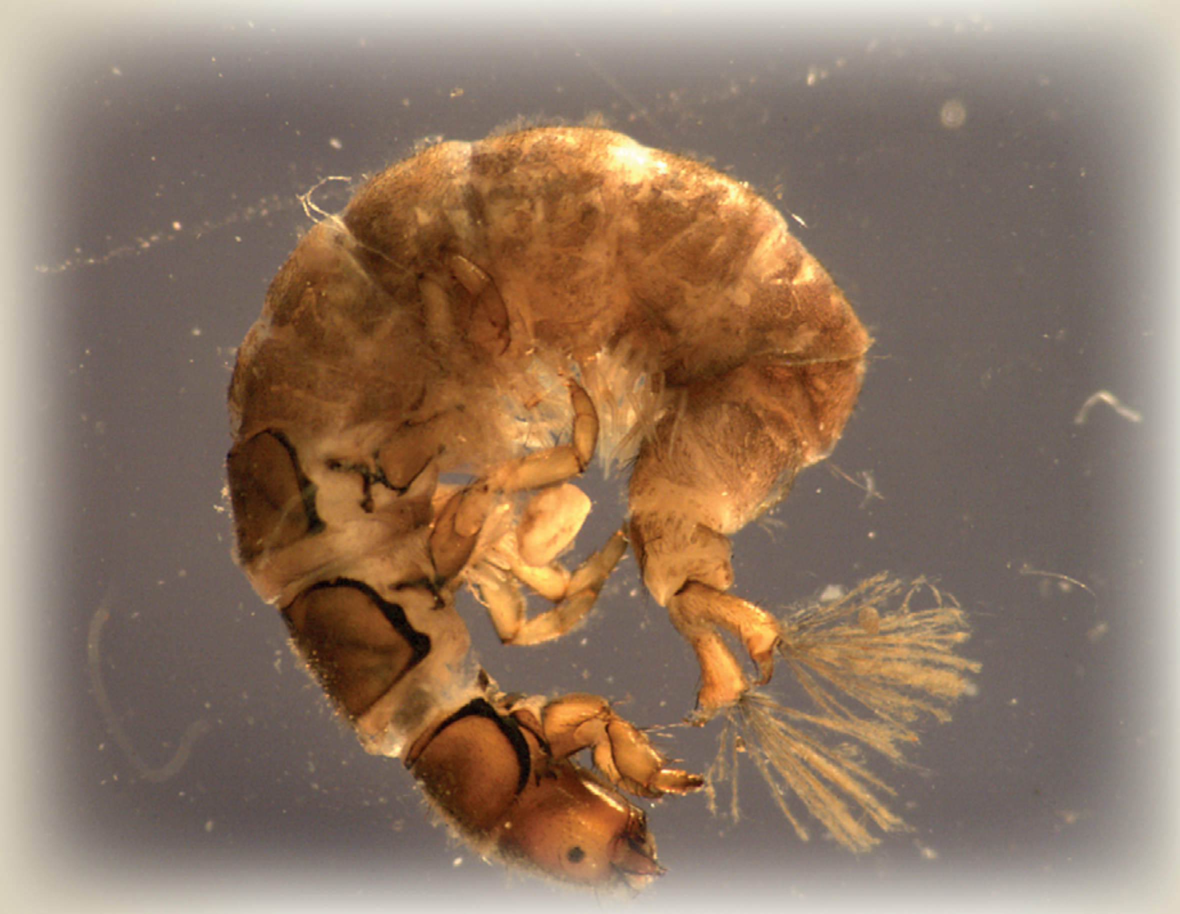
Macroinvertebrate Communities Evaluated Prior to and Following a Channel Restoration Project in Silver Creek, Blaine County, Idaho, 2001–16



Scientific Investigations Report 2017–5126

U.S. Department of the Interior
U.S. Geological Survey

COVER: Photograph of *Hydropsyche* sp. from Silver Creek near Picabo, Idaho. Photograph used with permission by John Pfeiffer, EcoAnalysts, Inc., December 2007.

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Contents

Figures

Tables

Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square meter (m^2)	10.76	square foot (ft^2)
	Flow rate	
meter per second (m/s)	3.281	foot per second (ft/s)
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as:

$$°F = (1.8 \times °C) + 32.$$

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

Supplemental Information

A water year is the 12-month period from October 1 of any given calendar year through September 30 of the following calendar year. The water year is designated by the calendar year in which it ends. For example, water year 2013 is the period from October 1, 2012, through September 30, 2013.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given in either milligrams per liter (mg/L) or micrograms per liter (µg/L).

Abbreviations

CI	confidence interval
CV	coefficient of variation
D	diversity
EPT	Ephemeroptera, Plecoptera, and Trichoptera
IDFG	Idaho Department of Fish and Game
IDWSC	Idaho Water Science Center
TNC	The Nature Conservancy
USGS	U.S. Geological Survey
WY	water year

Macroinvertebrate Communities Evaluated Prior to and Following a Channel Restoration Project in Silver Creek, Blaine County, Idaho 2001–16

By Dorene E. MacCoy and Terry M. Short

Abstract

The U.S. Geological Survey, in cooperation with Blaine County and The Nature Conservancy, evaluated the status of macroinvertebrate[1] communities prior to and following a channel restoration project in Silver Creek, Blaine County, Idaho. The objective of the evaluation was to determine whether 2014 remediation efforts to restore natural channel conditions in an impounded area of Silver Creek caused declines in local macroinvertebrate communities. Starting in 2001 and ending in 2016, macroinvertebrates were sampled every 3 years at two long-term trend sites and sampled seasonally (spring, summer, and autumn) in 2013, 2015, and 2016 at seven synoptic sites. Trend-site communities were collected from natural stream-bottom substrates to represent locally established macroinvertebrate assemblages. Synoptic site communities were sampled using artificial (multi-plate) substrates to represent recently colonized (4–6 weeks) assemblages. Statistical summaries of spatial and temporal patterns in macroinvertebrate taxonomic composition at both trend and synoptic sites were completed.

The potential effect of the restoration project on resident macroinvertebrate populations was determined by comparing the following community assemblage metrics:

1. Total taxonomic richness (taxa richness);
2. Total macroinvertebrate abundance (total abundance);
3. Ephemeroptera, Plecoptera, Trichoptera (EPT) richness;
4. EPT abundance;
5. Simpson's diversity; and
6. Simpson's evenness for periods prior to and following restoration.

A significant decrease in one or more metric values in the period following stream channel restoration was the basis for determining impairment to the macroinvertebrate communities in Silver Creek.

Comparison of pre-restoration (2001–13) and post-restoration (2016) macroinvertebrate community composition at trend sites determined that no significant decreases occurred in any metric parameter for communities sampled in 2016. Taxa and EPT richness of colonized assemblages at synoptic sites increased significantly from pre-restoration in 2013 to post-restoration in 2015 and 2016. Similarly, total and EPT abundances at synoptic sites showed non-significant increases from 2013 to 2015 and 2016. Significant seasonal differences in macroinvertebrate assemblages were apparent at synoptic site locations and likely reflected typical life-history patterns of increased insect emergence and development in the late spring and early summer months. Taxa and EPT richness were each significantly higher in spring and summer than in autumn, and total abundances were significantly higher in spring than in summer and autumn. No significant differences in community diversity or evenness of colonized communities were noted at synoptic site locations between pre- and post-restoration years or among seasons. Select community-metric results from the trend- and synoptic-site sampling indicated that the Silver Creek restoration effort in 2014 did not result in a significant decline in resident macroinvertebrate communities.

Introduction

Silver Creek is a predominantly spring-fed stream and a tributary to the Little Wood River located in the lower Wood River Valley in Blaine County, Idaho (fig. 1). The creek is a locally important recreational and economic resource owing to cold groundwater inflows that support a healthy aquatic ecosystem and a highly productive trout fishery; however, past land-use practices, including removal of native vegetation and flood irrigation, increased sediment loading to the system (Perrigo, 2006). The completion of Purdy Dam in 1882 further contributed to increased sediment accumulation in areas of Silver Creek upstream of the dam due to aggradation and flow-mediated settling of suspended particulates (Perrigo, 2006; Gillilan, 2007).

[1]Macroinvertebrates are invertebrate fauna that can be captured by a 500 micron net or sieve.

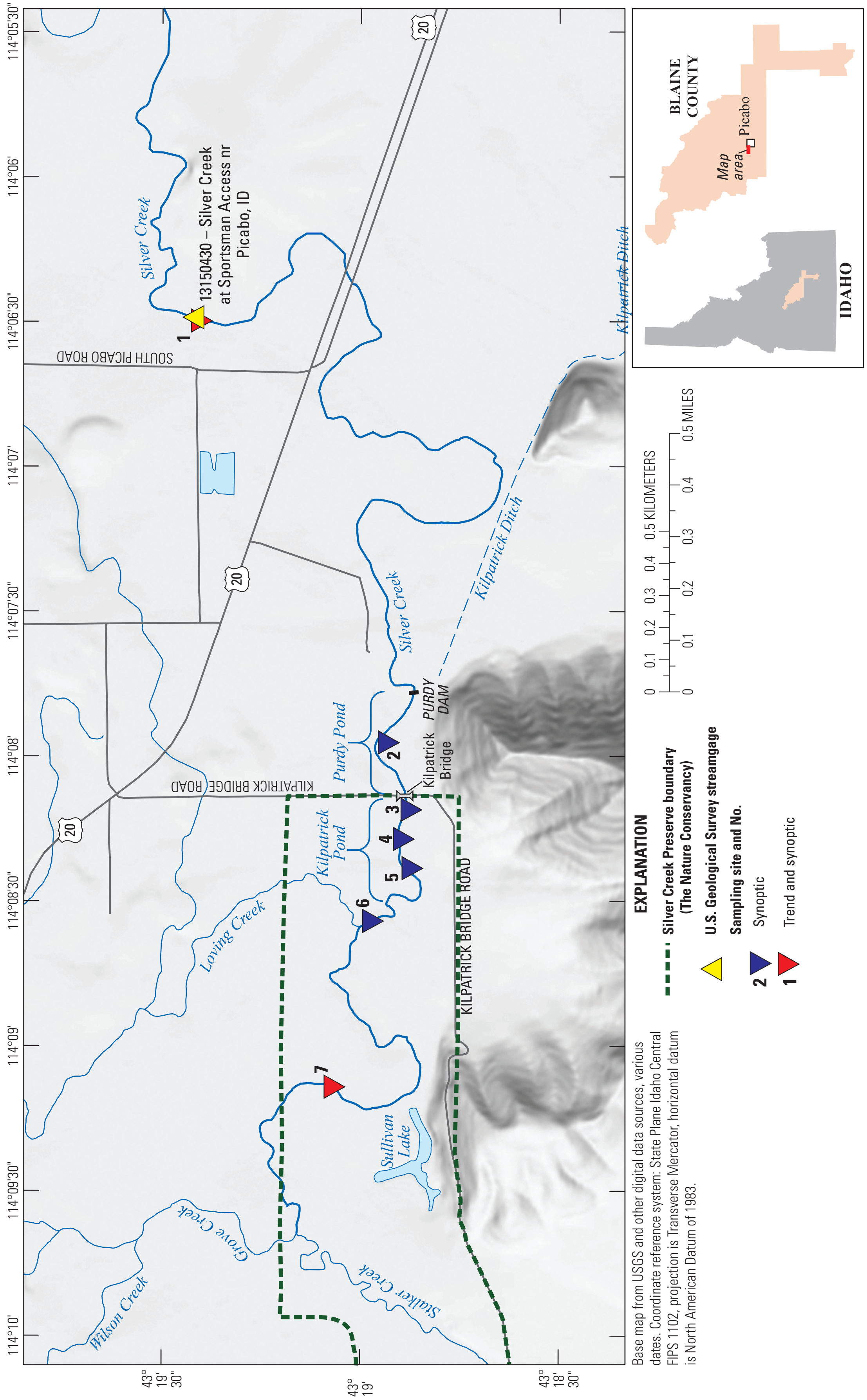

Figure 1. Macroinvertebrate study area, Silver Creek, Blaine County, Idaho.

In 1976, The Nature Conservancy (TNC) purchased land in the Wood River Valley and established the Silver Creek Preserve, which now includes more than 10,000 acres of the Silver Creek watershed. Since 2001, the U.S. Geological Survey (USGS) has provided TNC with water-quality and biological monitoring information to assess the long-term health of Silver Creek in and just downstream of the preserve. In 2011, TNC worked with area landowners and the Ecosystem Enhancement Foundation to develop an ecological enhancement strategy for Silver Creek. The strategy identified the impounded reach of Silver Creek (known as Purdy Pond and Kilpatrick Pond; fig. 1) as the top priority due to increased sedimentation and elevated water temperatures (Ecosystem Science Foundation, 2011). Additionally, the strategy noted that Purdy Dam[2], located at the downstream end of Purdy Pond (fig. 1), blocked fish passage in this area of Silver Creek. The strategy document called for replacing Purdy Dam and dredging the impounded reach. Additional documents included a feasibility study for restoring Kilpatrick Pond and removing Purdy Dam (Gillilan Associates, 2007), and an engineering plan for the restoration effort (GeoEngineers, 2012). TNC concluded that the preferred approach was to replace Purdy Dam and dredge the channel to improve habitat conditions.

During public meetings on the proposed stream-channel restoration project, concerns were raised about how the channel modification might affect the short-term and long-term health of resident macroinvertebrate communities and the fishery (Dayna Gross, TNC, written commun., April 26, 2013). In response to these concerns, and in cooperation with Blaine County and TNC, the USGS proposed a study to evaluate macroinvertebrate communities before and after the channel restoration project.

The goal of the study was to evaluate macroinvertebrate samples collected from the impounded reach upstream of Purdy Dam and in reaches upstream and downstream of this location to identify potential changes in benthic and colonizing communities that could be attributed to channel restoration. Negative effects on macroinvertebrate community composition, such as a decrease in species diversity, might indicate potential impairment of water-quality conditions and a decline in general stream health. In addition, macroinvertebrates are an important food source for Silver Creek trout and other resident fish species, and a decline in diversity and abundance of macroinvertebrates could threaten the health of the fishery. Trend monitoring data collected between 2001 and 2016 and seasonal synoptic monitoring data collected prior to channel restoration (2013) and following channel restoration (2015 and 2016) were used to evaluate the long- and short-term effects to resident macroinvertebrate communities.

[2]Referred to as Kilpatrick Dam in the strategy document.

Purpose and Scope

This report presents findings of the macroinvertebrate community analysis before and after a stream-channel restoration project completed in 2014 on an impounded section of Silver Creek. Two types of community data were used in the study: (1) trend-site benthic macroinvertebrates collected every 3 years from natural substrates from 2001 to 2016, and (2) synoptic site macroinvertebrates collected seasonally from artificial substrates in 2013, 2015, and 2016. Metrics based on macroinvertebrate community composition are used to identify community condition at both trend and synoptic sites. Hydrology and water quality measures are also reported for the trend and synoptic site locations.

Description of Study Area

Silver Creek is a meandering, low gradient (<1 percent) stream that originates primarily from springs and seeps of the Wood River Valley aquifer system, with some contribution to flow from surface-water irrigation return (Hopkins and Bartolino, 2013). Bartolino (2009) estimated that between 1995 and 2004, 40 percent of the outflow from the Big Wood aquifer system discharged to Silver Creek. Stalker Creek, Grove Creek, and Loving Creek contribute most of the surface-water flow and sediment load to Silver Creek. Discharges from these systems are highly influenced by fluctuations in artificial recharge from local irrigation practices (Ecosystem Sciences Foundation, 2011).

The regional climate is mild and arid during the summer months and cold and wet in the winter months. About 60 percent of the total annual precipitation in the area falls between the first of November and the end of March, mostly as snow (Skinner and others, 2007). Silver Creek is at an elevation of approximately 1,500 meters (m), with average air temperatures greater than 30 °Celsius (°C) during summer and less than 0 °C during winter (U.S. Climate Data, 2017).

Silver Creek supports a productive rainbow and brown trout fishery that TNC manages within the preserve boundaries for catch-and-release during summer months. The Silver Creek Preserve works closely with Idaho Department of Fish and Game to minimize potential effects on the resident fishery from elevated summer water temperatures. To avoid stress to resident trout species, TNC can restrict fishing in the preserve when water temperature exceeds 25 °C (information on critical temperatures for trout can be found at Idaho Department of Environmental Quality [2017a]).

The impounded reaches of Silver Creek are locally identified as Purdy Pond and Kilpatrick Pond. Purdy Pond extends from just upstream of Purdy Dam to the Kilpatrick Bridge (fig. 1); Kilpatrick Pond includes the remainder of the impounded reach upstream of Kilpatrick Bridge.

Increased sedimentation in the impounded reach of Silver Creek has reduced water depth and significantly widened the stream channel. These changes resulted in proliferation of aquatic plants and increased summer water temperatures (Sunny Healey, Silver Creek TNC manager, oral commun., May 2013). To mitigate sedimentation effects and to improve stream habitat conditions in parts of Kilpatrick and Purdy Ponds, TNC proposed a stream-channel restoration project. Project objectives were to replace Purdy Dam with a structure to improve fish passage, remove bottom sediment upstream of the dam, and amend island and riparian vegetation. A joint study was designed by the USGS and TNC to quantitatively evaluate the effects of channel restoration on macroinvertebrate communities in a 7.5-kilometer (km) study reach that extends from the upstream boundary of the Silver Creek Preserve downstream to the Idaho Fish and Game Sportsman Access (fig. 1).

Silver Creek Stream Channel Restoration

A channel enhancement strategy was prepared for TNC with input from local landowners, anglers, and other public interest groups, with the goal of improving fish habitat in the Kilpatrick Pond section of Silver Creek (fig. 2; Ecosystem Sciences Foundation, 2011). Among the priorities outlined in the enhancement strategy were:

1. Increasing rearing habitat for juvenile trout by narrowing the stream channel through the impounded section of Silver Creek;
2. Increasing side-channel habitat; and
3. Creating island wetlands that could provide refugia from predators.

These improvements have the added benefit of potentially augmenting invertebrate productivity by increasing habitat availability and complexity for resident macroinvertebrate fauna.

The initial plan to dredge sediment from the entire impounded area (fig. 3*A*) and to replace Purdy Dam to improve fish passage (GeoEngineers, 2012) was revised after the dam was removed. Following dam removal (the first stage of the restoration effort), increased streamflow velocity and sediment transport deepened the stream channel, thereby eliminating the need for channel dredging upstream of Kilpatrick Bridge. Parts of Purdy Pond were dredged during dam reconstruction to remove fine sediment (fig. 3*B*). The impounded reach upstream of Kilpatrick Bridge was narrowed when the dam was removed, and the creek was allowed to flow naturally. The narrowing of the channel allowed for enhancement of the riparian area through the Kilpatrick Pond area of the creek (fig 3*C*). In 2015, dam construction was completed and riparian vegetation was restored to parts of the creek (fig. 3*D* prior to dam reconstruction and fig. 3*E* after dam reconstruction).

Figure 2. Kilpatrick Pond at synoptic sampling site 3 prior to channel restoration, Blaine County, Idaho, 2013.

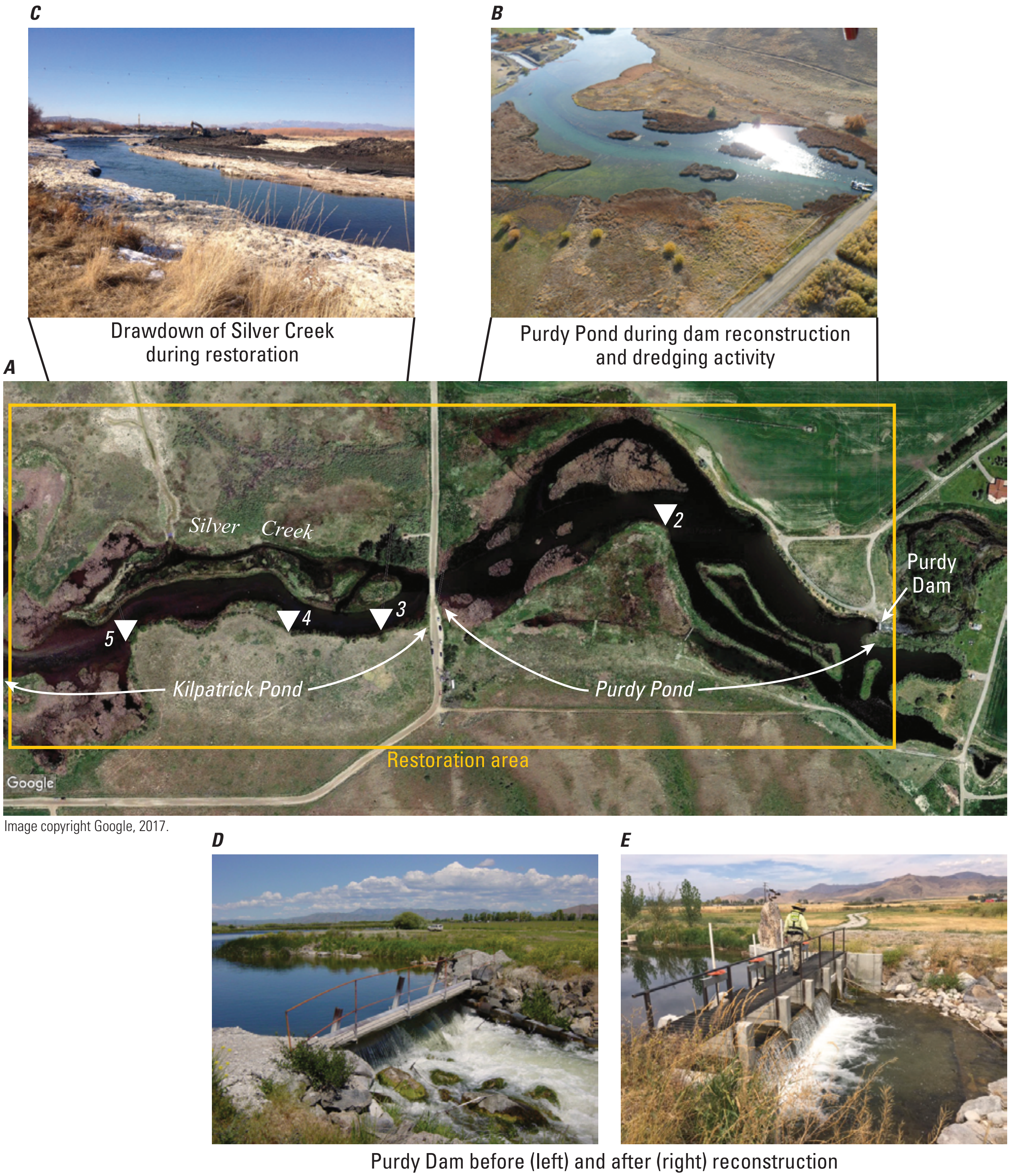

Figure 3. Photographs showing locations of restoration area and synoptic sampling sites, Silver Creek, Blaine County, Idaho. (*A*) Aerial view of Silver Creek restoration area and synoptic sampling sites. (*B*) Purdy Pond during dam reconstruction and dredging activity. (*C*) Kilpatrick Pond area of Silver Creek during drawdown restoration. (*D*) Purdy Dam before and (*E*) after reconstruction. Photograph *B* taken by Nick Purdy, Picabo resident. Photograph 3*C* by Sunny Healey, Silver Creek Preserve manager, The Nature Conservancy. Photographs *D* and *E* taken by Dorene MacCoy, U.S. Geological Survey.

Hydrology, Water Quality, and Macroinvertebrates at Trend and Synoptic Sites

Sampling Sites

Information from two types of study sites are included: (1) trend sites that provide long-term monitoring data (2001–16) of macroinvertebrate assemblages from natural benthic habitats, and (2) synoptic sites that use macroinvertebrate colonization of artificial substrates as indicators of stream health prior to (2013) and following (2015 and 2016) channel restoration (table 1). Each of these sampling methods provides different but complementary data on responses of macroinvertebrate communities to environmental conditions.

Trend Sites

Two trend sites were established in 2001 to provide TNC with long-term monitoring data on the ecological health of Silver Creek. One of the sites, Silver Creek at The Nature Conservancy (SC TNC, fig. 4), is located at the upstream end of the study area near the northwestern boundary of the preserve. The second trend site, Silver Creek at Sportsman Access near Picabo (SC Sportsman), is colocated with a USGS streamgage that provides continuous stream discharge and water temperature data approximately 5 km downstream of the preserve boundary (figs. 5 and 6). Fish and macroinvertebrate communities and measurements of select hydrologic and water-quality parameters are assessed periodically (every 3 years) at both sites. By integrating water-quality conditions from parts of Silver Creek upstream of, in, and downstream of the preserve boundaries, macroinvertebrates collected at these sites provide valuable information on extrinsic and intrinsic environmental factors that affect the long-term health of the TNC part of Silver Creek.

Table 1. Macroinvertebrate sampling sites, Silver Creek, Blaine County, Idaho.

[See figure 1 for site locations. Sampling sites include trend site locations (data collected once every 3 years from autumn 2001 through 2016 from natural substrates) and synoptic site locations (data collected seasonally in spring, summer, and autumn from artificial substrates in 2013, 2015 and 2016). **Abbreviations:** SC, Silver Creek; TNC, The Nature Conservancy; USGS, U.S. Geological Survey]

Site No.	Site name	Site short name	USGS site identification No.	Latitude	Longitude	Site type
1	Silver Creek at Sportsman Access near Picabo, ID	SC Sportsman	13150430	43.323	-114.108	Trend and synoptic
2	Purdy Pond above Dam near Picabo, ID	SC above Dam	431855114075800	43.315	-114.133	Synoptic
3	Silver Creek at Kilpatrick Bridge near Picabo, ID	SC at Bridge	431852114081100	43.314	-114.136	Synoptic
4	Silver Creek above Kilpatrick Bridge near Picabo, ID	SC at monument	431853114081700	43.315	-114.138	Synoptic
5	Silver Creek above Kilpatrick Pond near Picabo, ID	SC below S turns	431852114082300	43.314	-114.140	Synoptic
6	Silver Creek above Pond at S turns near Picabo, ID	SC above pond	431858114083400	43.316	-114.143	Synoptic
7	Silver Creek at the Nature Conservancy Preserve	SC TNC	431854114091200	43.315	-114.153	Trend and synoptic

Figure 4. Trend sampling site on Silver Creek at The Nature Conservancy preserve (SC TNC), Blaine County, Idaho, 2014. Photograph taken at the top of the study reach looking downstream. Photograph by Terry Maret, U.S. Geological Survey (retired).

Figure 5. Silver Creek at Sportsman Access near Picabo, Idaho streamgage (13150430), 2014. Photograph taken at streamgage at upstream end of trend study reach. Photographs by Dorene MacCoy, U.S. Geological Survey.

Figure 6. Trend sampling site downstream of U.S. Geological streamgage Silver Creek at Sportsman Access near Picabo (13150430), Blaine County, Idaho. Photograph taken just downstream of streamgage by Dorene MacCoy, U.S. Geological Survey.

Synoptic Sites

Synoptic sites were distributed along Silver Creek at locations upstream, within, and downstream of the restoration project area (fig. 1). Two of the seven synoptic sites (sites 7 and 1) were colocated with trend sites at SC TNC and SC Sportsman, respectively (figs. 7 and 8). Site 2 was located 260 m upstream of Purdy Dam and in Purdy Pond. Synoptic sites 3, 4, and 5 were located approximately 150 meters apart in Kilpatrick Pond. Site 6 is upstream of Kilpatrick Pond in a free-flowing stretch of Silver Creek.

Figure 7. Scientists taking depth and flow measurements at synoptic site 7 on the Silver Creek at The Nature Conservancy preserve, Blaine County, Idaho, 2014. Photograph taken by Terry Maret, U.S. Geological Survey (retired).

Figure 8. Photograph showing synoptic site 1 upstream of U.S. Geological Survey streamgage Silver Creek at Sportsman Access near Picabo (13150430), Blaine County, Idaho, 2014. Photograph taken by Dorene MacCoy, U.S. Geological Survey.

Trend Site Hydrology and Water Quality

Continuous discharge is monitored at the USGS streamgage located at the SC Sportsman site (fig. 1 and fig. 5). Daily stream stage recordings were used to estimate continuous discharge using a stage-discharge relation described by Mueller and Wagner (2009) and by Turnipseed and Sauer (2010). Discharge records were computed according to methods described in Rantz and others (1982) and are available from the USGS National Water Information System (U.S. Geological Survey, 2017a). Daily average discharge values for water years 2013–16 and the long-term median daily discharge for the period of record for SC Sportsman are summarized.

Continuous water temperatures also collected at the SC Sportsman streamgage are summarized for water years (WYs) 2013–16. Temperature data were collected using a thermistor mounted on the streamgage orifice line and recorded at 15-minute intervals. Temperature calibration, monthly temperature checks, record compilation, and reporting of continuous temperature data followed USGS standard procedures (Wagner and others, 2006).

At both trend sites, water depth and flow velocity were measured at specific habitat locations (typically riffles) that were targeted for macroinvertebrate sampling. Water depths were measured using a graduated wading rod, and flow velocities were determined with an electronic flow meter (Hach® Marsh-McBirney Flo-Mate™).

Instantaneous measures of water temperature, pH, specific conductance, and dissolved oxygen were collected at each trend site prior to macroinvertebrate sampling. Water-quality parameters were determined in accordance with USGS procedures (Turnipseed and Sauer, 2010; U.S. Geological Survey, variously dated) using a calibrated six-series multiparameter water-quality sonde (Yellow Springs, Inc.). Instrument calibration was done using methods described in Wagner and others (2006).

Synoptic Site Hydrology and Water Quality

Hydrologic measures at synoptic sites were limited to factors affecting rates and extent of macroinvertebrate colonization (Meier and others, 1979; Ciborowski and Clifford, 1984) and included depth of the substrate sampler below water surface, wetted depth of stream channel at sampler location, and flow velocity approximately 0.5 m immediately upstream of each sampler. Determinations of sampler depth, water column depth, and flow velocity were made at the time of initial deployment and at the end of the prescribed colonization period prior to sampler removal.

Continuous temperature was recorded seasonally (spring, summer, and autumn) at sites 1, 4, 5, and 7 using Onset® Hobo® thermistors installed at the time of artificial substrate installation. The thermistors were checked prior to installation using U.S. Geological Survey (variously dated) protocols and compared to instantaneous temperature measurements made during substrate deployment and retrieval.

Trend Site Macroinvertebrates

Benthic macroinvertebrate communities at the two trend sites were sampled once every 3 years (2001–16) using standard protocols described by Moulton and others (2002). Sample collection, processing, and data management were done under the supervision of the lead scientist. Samples were collected in early- to mid-June from gravel- to cobble-sized rock substrates using a modified D-frame net fitted with a 500 micrometer (µm)-mesh net and a detachable collection receptacle. Macroinvertebrates were collected from a 0.25-square meter area immediately upstream of the sampler by systematically removing attached organisms from rocks and other substrate surfaces. Individual samples were collected from five locations distributed in riffle regions throughout each stream reach and composited into a single sample. Each sample was cleaned of extraneous inorganic and organic materials by elutriation, preserved in ethanol, and shipped to EcoAnalysts in Moscow, Idaho, for taxonomic identification and enumeration. The EcoStandard West procedure was used to identify macroinvertebrates to the lowest taxonomic level possible (usually genus or species; U.S Geological Survey, 2017b). The EcoStandard West laboratory procedure includes rinsing a sample through a 500 µm sieve and placing it in a Caton-style (gridded) subsampling tray. Sorting is done using a standard dissecting microscope with a minimum sorting target of 300 specimens, with no separate sort for large and rare specimens. Oligochaetes are identified to class, chironomidae are identified to family, and all other taxa are identified to the lowest practical level. At least 20 percent of the sorted material is checked for accuracy to make sure all specimens are counted. The sample is resorted if there is not a 90 percent match with the first sorting effort. All taxonomic data and associated sampling information were uploaded to the USGS BioData database (U.S. Geological Survey, 2017b). Macroinvertebrate assemblage data were summarized using USGS Invertebrate Data Analysis System software (Cuffney and Brightbill, 2011).

Synoptic Site Macroinvertebrates

Artificial substrates were used to sample macroinvertebrate communities at synoptic site locations and to provide information on the numbers and kinds of taxa colonizing the substrate surfaces. Seasonal differences in streamflow, water temperature, vegetation patterns, and macroinvertebrate life history stages can influence colonization rates and composition (Mackay, 1992; Tikkanen and others, 1994). To account for seasonal effects on colonization dynamics and to provide a more robust sampling strategy, assessments were done seasonally (spring, summer, and autumn) at all site locations in 2013, 2015, and 2016.

Although not intended to reproduce natural habitat conditions, artificial substrates, such as Hester-Dendy multi-plate samplers, can provide a degree of sampling replicability difficult to achieve when sampling natural habitats, particularly for situations where conventional techniques are impractical or inappropriate (Resh and McElravy, 1993; De Pauw and others, 2005). For example, the abundant macrophyte beds in Silver Creek support a rich variety of macroinvertebrate fauna; however, quantitative macroinvertebrate assessments of these habitats are problematic owing to difficulty in standardizing sampling area and minimizing loss of organisms during sample handling and processing. By minimizing habitat disruption during sampling and by standardizing habitat type, colonization time, and sampler placement, artificial substrate samplers have been effective for assessing stream health based on the composition of colonized macroinvertebrate fauna (Blockson and Flotemersch, 2005; Rinella and Feminella, 2005).

Duration of exposure, placement location in the stream channel, and placement depth are important factors affecting the number of individuals, taxonomic composition, and community diversity of macroinvertebrates on artificial substrates (Rosenberg and Resh, 1982). To account for spatial differences in colonization properties, three Hester-Dendy artificial substrates (fig. 9) were installed across the stream channel at each sampling location: one at the thalweg (deepest part of the channel) and one each approximately equidistant between the thalweg and the left and right edges of water. Substrates were suspended at mid-depth from steel posts with polyvinyl chloride (PVC) sleeves at each across-channel location. Average installation depths among sites ranged from 0.25 to 0.63 m, depending on depth of stream channel at the location. Colonization periods were 4 weeks for all samples collected in 2015 and 2016, 5 weeks for spring samples collected in 2013, and 6 weeks for summer and autumn samples collected in 2013. The longer periods for the 2013 samples compared to the 2015 and 2016 assessments were necessary to accommodate multiple field activities during the first year of sampling.

Sample processing followed procedures outlined in Moulton and others (2002). Each substrate was retrieved by carefully placing a D-Frame net under each sampler before removing the substrate from the water and placing it into a clean bucket. Attached organisms were removed from substrate surfaces by hand-picking and gentle washing, sieved through a 500 µm mesh, preserved in ethanol, placed in labeled jars, and shipped to EcoAnalysts, Inc., in Moscow, Idaho, for taxonomic identification and enumeration. Methods for taxonomic processing and data handling were as described for the trend-site macroinvertebrate samples. Prior to metric calculation and data analysis macroinvertebrate colonization results for individual substrates at each site were combined by summing individual assemblage results.

Figure 9. Hester-Dendy artificial substrate sampler with a temperature logger, 2013. Photograph taken by Terry Maret, U.S. Geological Survey (retired).

Macroinvertebrate Community Metrics

Evaluation of macroinvertebrate responses to potential disturbance from the stream channel restoration project was based on comparisons of six community metrics:

1. Total taxonomic richness (taxa richness);
2. Total macroinvertebrate abundance (total abundance);
3. Ephemeroptera, Plecoptera, and Trichoptera (EPT) richness;
4. EPT abundance;
5. Simpson's diversity; and
6. Simpson's evenness (Washington, 1984).

Taxa richness (number of unique taxa in a sample) and abundance (number of organisms in a sample) are fundamental properties of macroinvertebrate community structure, and alterations of these assemblage properties can signal the presence of water-quality alterations or other types of perturbations (Norris and Georges, 1993; Lenat and Barbour, 1994). For example, numerical dominance of macroinvertebrate assemblages by one or a few taxa, or reduced taxa richness, have been effective indicators of impaired water quality or generally degraded environmental conditions (Reice and Wohlenberg, 1993; Barbour and others, 1995). Richness and abundance of aquatic insect taxa represented by EPT are commonly used as indicators of water-quality and biological condition, with decreasing EPT richness and EPT abundance values indicating a loss of species that generally are sensitive to environmental degradation (Barbour and others, 1999). In their assessment of least-disturbed streams in Idaho, Maret and others (2001) determined that healthy cold-water streams to have consistently higher EPT richness, as well as higher taxa richness values. Diversity indices, such as Simpson's diversity, are based on information about the number of taxa in a community and the evenness of taxa abundances, such that community diversity is highest when all taxa in the community are equally abundant (Magurran, 1988). Taxa richness and abundance are generally low on colonized artificial substrates compared to natural substrates where communities have established over longer periods of time and have more resource options for supporting a greater variety and number of taxa. Accordingly, Simpson's diversity is preferable to other measures of diversity, such as Shannon-Wiener (Washington, 1984), for evaluating colonization-based assemblages, because Simpson's diversity is less sensitive to the abundance of rare species in the community (Attrill, 2002). Simpson's evenness is included as an indicator metric relevant to the use of artificial substrates because disturbance of water-quality and hydrologic conditions can result in decreased equitability in relative abundance of colonizing taxa (Mackay, 1992).

Hydrology, Water Quality, and Macroinvertebrate Evaluation

Trend-Site Hydrology and Water Quality

Silver Creek discharge was relatively uniform prior to and following the 2014 channel restoration. Daily average discharge at SC Sportsman for WY 2013–16 ranged from 1.5 to 5.5 cubic meters per second (m^3/s) (fig. 10; U.S. Geological Survey, 2017a). Highest flows occurred during late winter and early spring, typically in March, at the beginning of snow melt and prior to irrigation season (daily average discharge in March for WYs 2013–16 was 3.5 m^3/s). The lowest flows occurred during May through October (daily average discharge in July for WYs 2013–16 was 2.3 m^3/s). Water years 2013 through 2016 were drought years for the region (U.S. Geological Survey, 2017c), with daily average discharge at SC Sportsman approximately 0.90 m^3/s lower than the median long-term period of record (period of record = 42 years; fig. 10).

Daily water temperatures for WYs 2013–16 were lowest from November through January (daily temperatures < 0 °C) and highest during July (daily temperatures > 20 °C) (fig. 11). The State of Idaho water-quality criteria specifies a maximum temperature of 22 °C in cold water streams for the protection of aquatic life (Idaho Department of Environmental Quality, 2017b). Maximum temperature criteria was exceeded an average of 19 days at SC Sportsman during summer months (mainly July) during WYs 2013–16 (fig. 11).

Average depth and velocity at sampling locations where macroinvertebrates were collected are reported in table 2. Sampling location depths ranged from 0.18 to 0.57 m at SC Sportsman and 0.13 to 0.27 m at SC TNC; flow velocities ranged from 0.31 to 0.52 m/s at SC Sportsman and 0.36 to 0.42 m/s at SC TNC. Instantaneous water-quality parameters (temperature, specific conductance, pH, and dissolved oxygen) also are reported for select sampling dates (table 2). Instantaneous temperature measurements at the time of sampling varied between 8.6 and 18 °C, with an average of 13.4 °C. Specific conductance remained relatively consistent between years and sites (344–413 µS/cm), with an average of 379 µS/cm. pH was more variable at SC Sportsman (ranging between 6.5 and 8.3) compared to SC TNC (7.2 and 7.5). Instantaneous dissolved oxygen averaged 10.1 mg/L between years and sites, but concentrations varied in and between sites depending on the time of day and the water temperature when samples were collected.

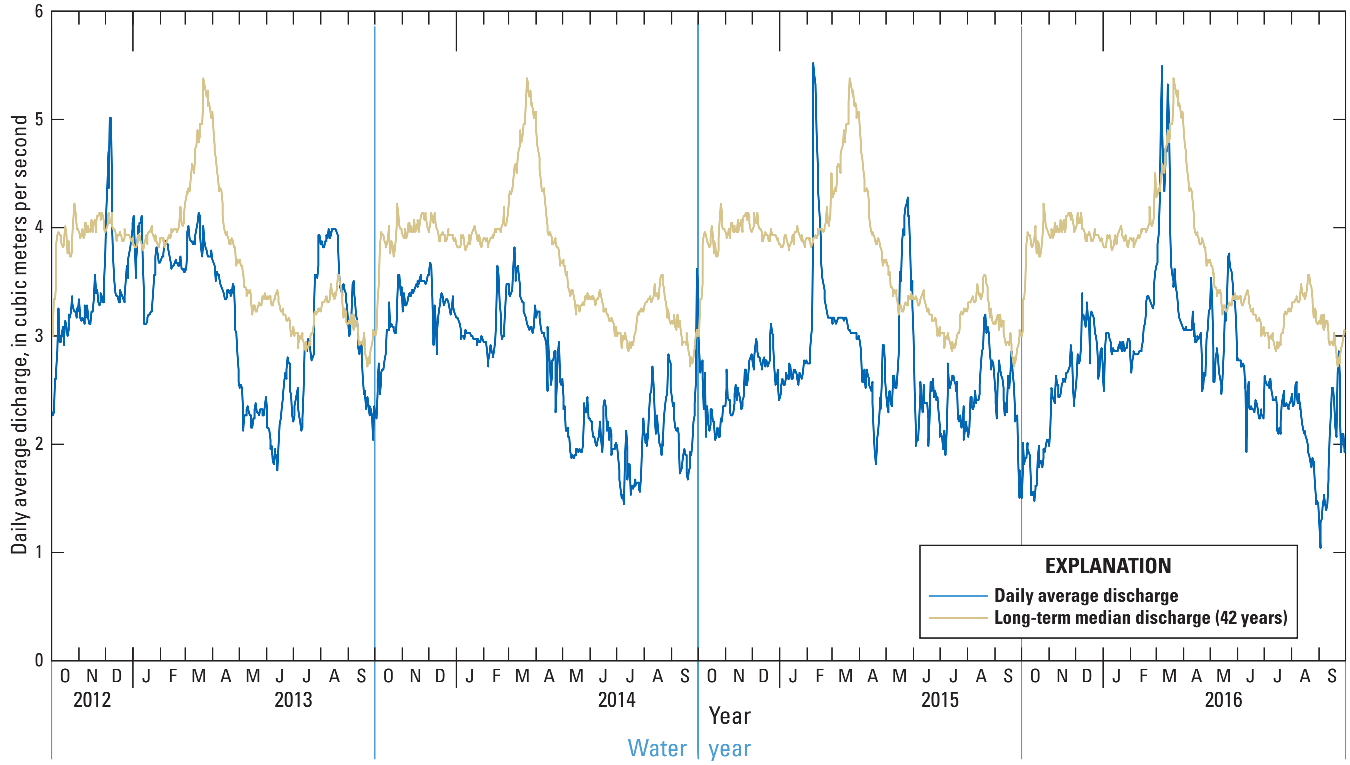

Figure 10. Daily average discharge and long-term median daily discharge for U.S. Geological Survey streamgage Silver Creek at Sportsman Access near Picabo, Idaho, water years 2013–16.

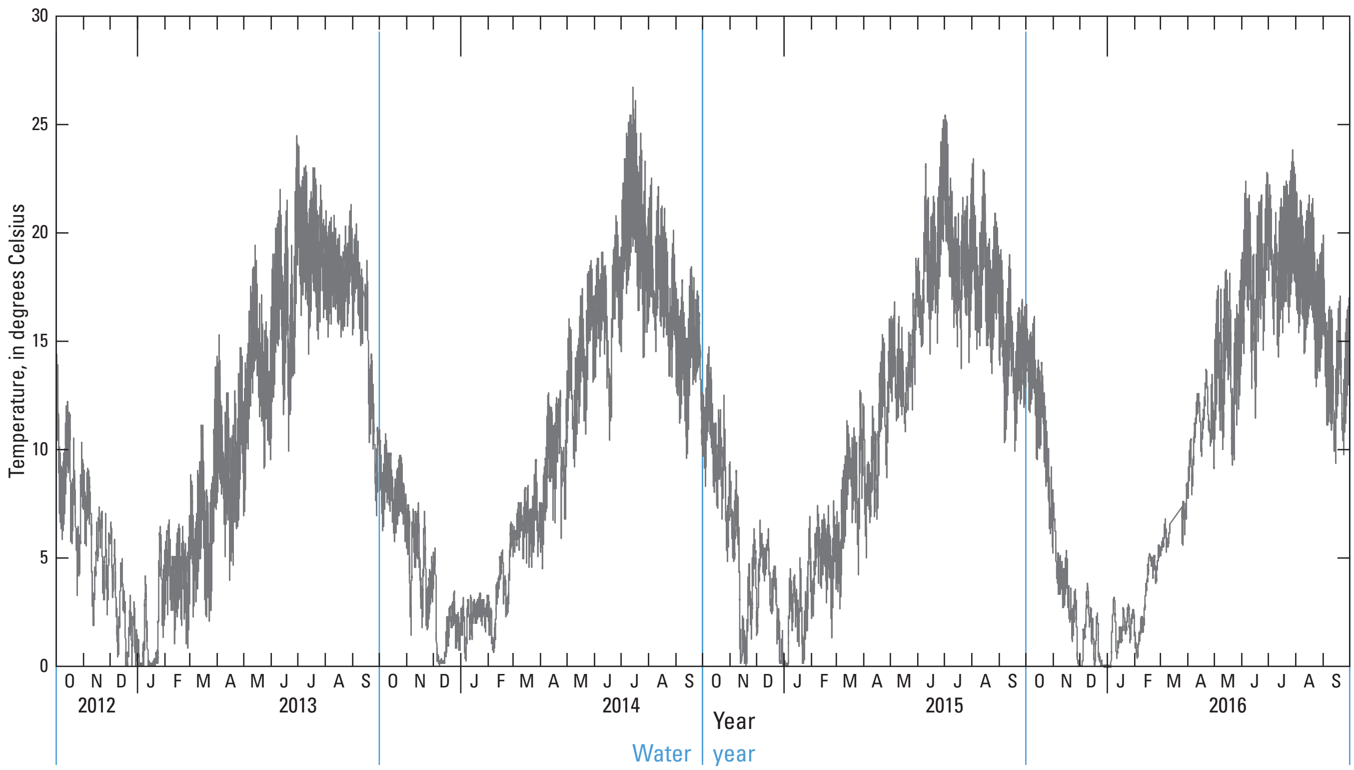

Figure 11. Continuous temperature collected from U.S. Geological Survey streamgage Silver Creek at Sportsman Access near Picabo, Idaho, water years 2013–16.

Table 2. Depth, velocity, and instantaneous water quality at trend site Silver Creek, Blaine County, Idaho, 2001–16.

[See table 1 for site description and figure 1 for site locations. Average water-column depth and velocity are from five individual macroinvertebrate sampling locations; instantaneous water-quality measurements were collected at the upstream end of each trend sampling reach prior to collecting macroinvertebrate samples; –, data not available; data can also be found at https://aquatic.biodata.usgs.gov. **Site short name:** SC Sportsman, Silver Creek at Sportsman Access near Picabo, ID; SC TNC, Silver Creek at The Nature Conservancy Preserve. **Abbreviations:** °C, degrees Celsius; m, meter; m/s, meter per second; µS/cm 25 °C, microsiemens per centemeter at 25 degrees Celsius; mg/L, milligram per liter; –, not available]

Site short name	Date	Average water column depth (m)	Average water column velocity (m/s)	Instantaneous water quality				
				Time	Water temperature (°C)	Specific conductance (µS/cm 25 °C)	pH (units)	Dissolved oxygen (mg/L)
SC Sportsman	06-05-01	0.28	0.37	1130	9.7	382	7.1	7.5
	06-15-04	0.57	0.48	1400	16.3	344	8.3	11.5
	06-05-07	0.24	0.52	1015	11.1	413	7.5	7.7
	06-14-10	0.36	0.48	1100	14.6	385	6.5	14.7
	06-10-13	0.39	0.31	–	–	–	–	–
	06-13-16	0.18	0.34	1500	18	380	–	–
SC TNC	06-04-01	0.27	0.36	1030	8.6	378	7.2	7.6
	06-14-04	0.18	0.42	–	–	–	–	–
	06-05-07	0.20	0.41	1000	12.0	358	7.5	10.4
	06-14-10	0.24	0.37	1415	17.4	385	7.3	11.5
	06-10-13	0.13	0.42	–	–	–	–	–
	06-13-16	0.17	0.39	0900	13	390	–	–

Synoptic-Site Hydrology and Water Quality

Artificial substrate installation and channel depths, and corresponding near-sampler flow velocities (based on in-site averages for individual substrates) for 2013, 2015, and 2016, are reported in table 3. Average water column depths at substrate locations were greatest at the Kilpatrick Pond sites (sites 3, 4, and 5; average annual depth range = 0.88–1.14 m) and lowest at site 7 (average annual depth = 0.56 m). Near-sampler flow velocities were typically lowest at the Kilpatrick Pond sites (3, 4, and 5), with average annual flow velocities ranging from 0.05 to 0.19 m/s. Flow velocities were highest at the upstream-most site (site 7), with an average annual velocity of 0.31 m/s.

Daily water temperatures were monitored at sites 1, 4, 5, and 7 during seasonal deployment periods in water years 2013, 2015, and 2016 (table 4). Average daily water temperatures tended to be highest in the spring and summer farthest downstream at site 1, but temperature differences among sites for any given season were not remarkable. Average seasonal water temperatures for 2013, 2015, and 2016 were highest among sites in summer (15.8–18.7 °C) and lowest in autumn (10.3–14.9 °C). Maximum seasonal water temperatures were highest in spring (20.8–23.9 °C) and summer (21.2–24.0 °C) and lowest in autumn (19.0–20.4 °C).

Table 3. Synoptic-site average and range of water column depth and velocity at Silver Creek and The Nature Conservancy sites, Blaine County, Idaho, water years 2013 and 2015–16.

[See table 1 for site description and figure 1 for site locations. Values represent the annual average and range of parameters for three seasons (spring, summer, and autumn) at each sampling site. **Abbreviations**: m, meter; m/s, meters per second]

Site No.	Year	Average depth from water surface to substrate (m)	Average water column depth at substrate (m)	Range of water column depth at substrate (m)	Average velocity at substrate (m/s)	Range of velocity at substrate (m/s)
1	2013	0.49	0.80	0.60–0.97	0.23	0.10–0.50
	2015	0.56	0.83	0.64–1.82	0.16	0.02–0.54
	2016	0.45	0.86	0.46-0.72	0.17	0.01–0.48
2	2013	0.50	0.82	0.42–1.1	0.21	0.06–0.30
	2015	0.55	0.88	0.80–2.50	0.15	0.00–0.14
	2016	0.45	0.88	0.82–1.34	0.17	0.00–0.32
3	2013	0.50	1.00	0.80–1.20	0.19	0.00–0.24
	2015	0.55	0.85	0.60–1.98	0.15	0.01–0.23
	2016	0.45	0.88	0.60-1.28	0.05	0.00–0.11
4	2013	0.50	1.13	1.0–1.30	0.09	0.00–0.17
	2015	0.55	1.09	0.74–1.58	0.13	0.02–0.24
	2016	0.63	1.14	0.82-1.50	0.11	0.01–0.26
5	2013	0.50	0.93	0.80–1.14	0.12	0.04–0.21
	2015	0.43	0.88	0.52–1.37	0.17	0.00–0.30
	2016	0.45	0.97	0.72-1.80	0.14	0.00–0.44
6	2013	0.50	0.75	0.60–0.84	0.20	0.03–0.40
	2015	0.38	0.71	0.58–1.16	0.16	0.00–0.45
	2016	0.41	0.82	0.62–1.10	0.31	0.00–0.36
7	2013	0.30	0.60	0.60–0.62	0.40	0.09–0.72
	2015	0.33	0.59	0.30-–1.12	0.25	0.00–0.69
	2016	0.25	0.49	0.43–0.54	0.29	0.00–0.68

Table 4. Seasonal temperature statistics from selected synoptic sites in Silver Creek, Blaine County, Idaho, 2013, 2015, and 2016.

[See table 1 for site description and figure 1 for site locations. Temperatures represent the minumum, average, and maximum daily average values during seasonal artificial substrate deployment in degrees Celsius. **Spring**: Mid-May to mid-June. **Summer**: Mid-July to mid-August. **Autumn**: Mid-September to mid-October]

Synoptic site No.	Year	Spring			Summer			Autumn		
		Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
1	2013	9.7	15.8	23.1	15.6	18.7	23.2	6.3	10.9	19.0
	2015	11.1	15.5	22.8	14.0	18.4	23.8	10.0	14.9	20.4
	2016	9.5	15.5	23.1	13.9	18.4	24.0	9.7	13.9	20.4
4	2013	10.0	15.6	20.8	13.7	17.2	21.8	5.9	10.6	19.3
	2015	6.7	14.5	23.0	11.5	16.8	22.9	8.4	13.8	19.6
	2016	7.9	14.5	23.6	11.1	16.8	22.4	8.5	12.9	19.3
5	2013	9.6	15.6	20.9	13.6	17.3	22.3	5.9	10.6	19.3
	2015	9.8	14.5	23.3	11.6	17.0	23.1	8.3	13.8	19.7
	2016	7.9	14.6	23.9	11.2	17.1	22.4	8.6	13.0	19.5
7	2013	8.8	14.8	21.0	12.4	16.2	21.2	5.8	10.3	19.0
	2015	8.9	13.6	22.0	7.9	15.8	22.2	7.8	13.3	19.9
	2016	7.6	13.6	22.8	10.0	15.9	22.3	8.1	12.5	19.8

Trend-Site Macroinvertebrates

Benthic macroinvertebrate community data for the two trend sites on Silver Creek (SC TNC and SC Sportsman) are summarized for each sampling year (2001, 2004, 2007, 2010, 2013, and 2016) in appendix A. Although macroinvertebrate community composition varied between sites and years, mayflies (Ephemeroptera) and caddisflies (Trichoptera) were the most numerically dominant taxonomic groups at both locations, and overall represented 71.0 and 58.5 percent of the total macroinvertebrate abundance at SC TNC and SC Sportsman, respectively. A notable difference in macroinvertebrate abundance between sites was determined for freshwater snails (Gastropoda), which comprised 13.5 percent of the total abundance at the SC Sportsman site but only 1.5 percent of the abundance at SC TNC. Of the gastropods, the pebble snail (*Fluminicola* sp.) was the most dominant. The invasive New Zealand mudsnail (*Potamopyrgus antipodarum*) comprised only 5 percent of the total number of freshwater snails collected at the trend sites.

Taxa richness among sampling years was similar between trend sites and ranged from 27 to 44 taxa at SC TNC and 25 to 42 at SC Sportsman (appendix A; fig. 12). EPT richness was also similar between sites and ranged from 9 to 13 taxa at SC TNC and 8 to 12 taxa at SC Sportsman. Simpson's diversity ranged from 0.603 to 0.918 at SC TNC and 0.753 to 0.918 at SC Sportsman. Simpson's diversity values take into account both the number of taxa and the relative abundance of each taxon, with values increasing with increasing equitability or evenness in abundances among taxa. The relatively low Simpson's diversity value of 0.603 at SC TNC occurred in 2007, and despite relatively high taxa richness (33 taxa), approximately 62 percent of the abundance that year was dominated by a single taxon—the mayfly (*Ephemerella* sp.). The numerical dominance of a single taxon reduced community evenness and resulted in a low diversity index value for 2007 compared to other sampling years.

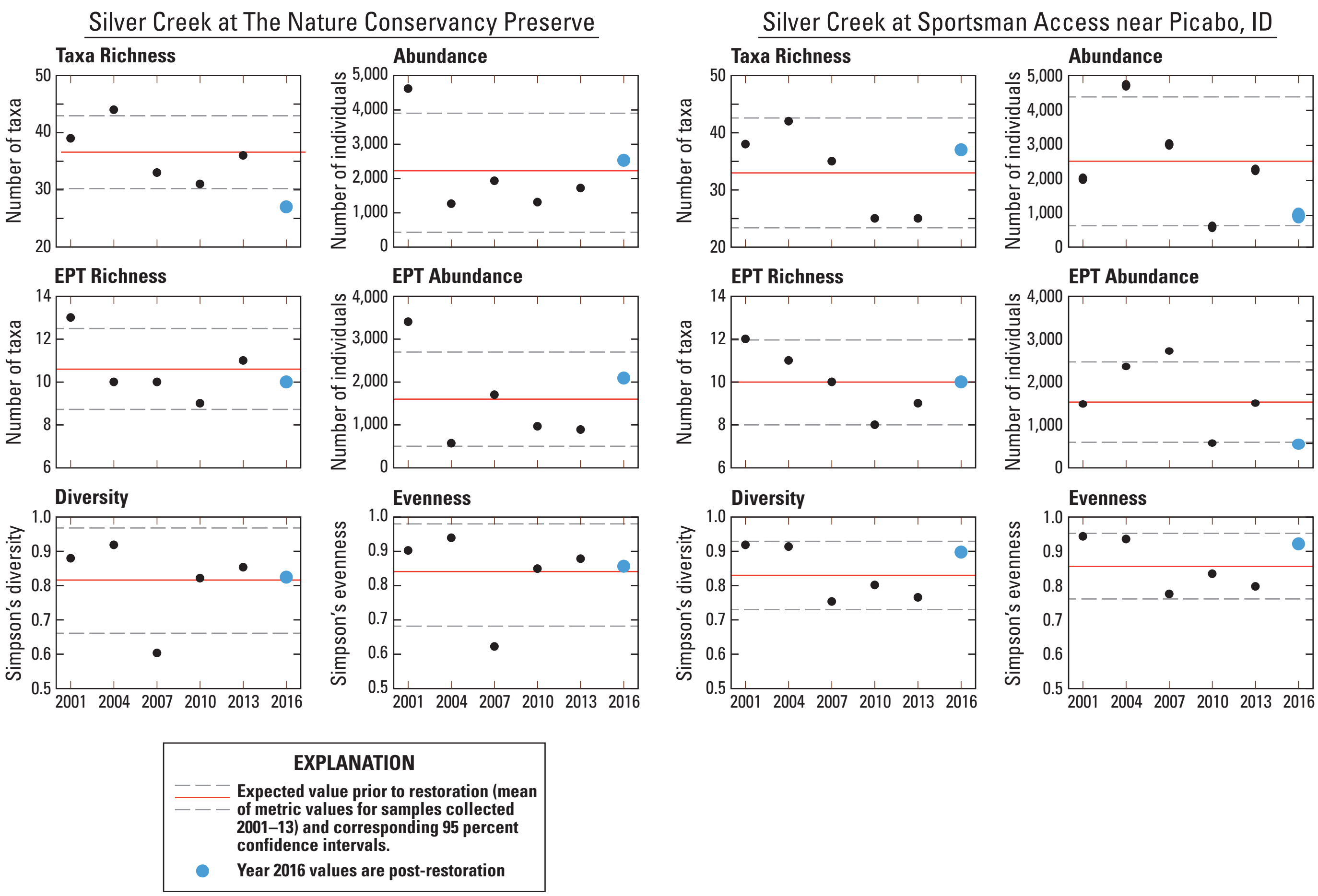

Figure 12. Invertebrate metrics from trend sites U.S. Geological Survey Silver Creek at the Nature Conservancy Preserve (431854114091200) and Silver Creek at Sportsman Access near Picabo, Blaine County, Idaho, 2001–16.

To determine if physical disturbance resulting from the restoration adversely affected macroinvertebrates on natural substrate in Silver Creek, community assemblages at SC TNC and SC Sportsman were evaluated for the years prior to (2001–13) and following restoration in 2016 (fig. 12). Metric means and corresponding confidence intervals (CI; ± 95 percent CI) for the pre-restoration period (2001–13) were compared to post-restoration (2016) metric values. Metric confidence intervals were used to determine ranges of expected macroinvertebrate community properties for evaluating potential post-restoration effects. Metric values for the 2016 macroinvertebrate communities that were in the range of expected values for a given metric (± 95 percent CI) were considered unchanged relative to pre-restoration conditions. Macroinvertebrate metric values for the 2016 samples outside of the 95 percent CI boundaries were compared to mean annual values for the pre-restoration period using a single-observation and mean comparison technique described in Sokal and Rohlf (2012).

Results of the 2016 macroinvertebrate assessment at SC TNC showed that total abundance, EPT richness, EPT abundance, Simpson's diversity, and Simpson's evenness were all within the expected range of values (fig. 12). Taxa richness in 2016 was less than the range of expected values for that metric but was not significantly different (P=0.17) than the annual mean metric value for the prior period (2001–13). At SC Sportsman, taxa richness, total abundance, EPT richness, Simpson's diversity, and Simpson's evenness were within the expected range of values. EPT abundance in 2016 was less than the expected range for that metric, but was not significantly different (P=0.23) than the mean metric value for previous sampling years.

Synoptic-Site Macroinvertebrates

Results of macroinvertebrate assessments for the synoptic sites are summarized in appendix B and reported by site (1–7), season (spring, summer, autumn), and year sampled (2013, 2015, and 2016). Colonization among individual substrates at a given site and among site locations can vary considerably because of local differences in the proximity to pools of potential upstream colonizers and to the variable accumulation of periphyton and other particulate organic materials that act as food and habitat (Boothroyd and Dickie, 1991; Smock, 1996). Within-site variability in macroinvertebrate colonization was examined by calculating the coefficient of variation (CV) of taxa richness for the three individual substrate samplers deployed at each site and was based on colonization results for all sites, seasons, and years of the study. The CV describes the amount of variability in taxa richness at a site relative to the average number of taxa among substrate samplers distributed across the stream channel and is expressed as a percentage. The average CV for all sites and years was low (27 percent) and ranged from 5 to 59 percent. To account for within-site variability in substrate colonization and to provide the best representation of macroinvertebrate assemblage properties, individual substrate datasets were combined for each site (appendix B).

Duration of substrate deployment also can affect colonization properties with longer periods of deployment, often resulting in increased numbers and kinds of colonizing organisms (Rosenberg and Resh, 1982). Colonization results for the 2013 synoptic study were examined to determine whether extended deployment periods (5 weeks for spring sampling and 6 weeks for summer and autumn sampling) might have significantly altered results relative to the 2015 and 2016 assessments, where all deployment periods were 4 weeks. Of particular concern was whether the longer deployment periods in 2013 resulted in higher taxa richness and abundances. Differences in colonized macroinvertebrate assemblages among deployment periods were tested for significance using a one-way ANOVA with Holm-Sidak pairwise multiple comparisons (Sokal and Rohlf, 2012). No significant differences (P>0.05) in abundance of colonized organisms were noted among assessment years for any of the seasonal sampling periods. There also were no significant differences in taxa richness between years for macroinvertebrate samples collected during the spring or summer sampling periods. Autumn 2013 taxa richness was lower than autumn 2015 (14 compared with 23 taxa, P =0.003) and autumn 2016 (14 compared 17 taxa; non-significant). The longer deployment periods for the 2013 assessments did not result in significant increases in taxa richness or abundances of colonized macroinvertebrates relative to the 2015 and 2016 assessments.

Overall, aquatic insects (class Insecta), the most numerically dominant macroinvertebrate fauna to colonize the artificial substrates, accounted for 83 percent of the total macroinvertebrate abundances among sites and years (appendix B, fig. 13). Snails (class gastropoda) represented 4 percent of the total abundance and were dominated by four taxa, *Fluminicola* sp., *Gyraulus* sp., *Planorbella* sp., and *Valvata* sp. Amphipods (class malacostraca, order amphipoda) represented 6 percent of the total macroinvertebrate abundance and consisted primarily of the amphipod *Hyalella*, an invertebrate common to spring-fed streams with abundant plant biomass (Thorp and Covich, 1991). Multi-plate samplers, such as the ones used in this study, primarily target drifting organisms, which in most streams are dominated by aquatic insects (Ward, 1992; Kirk and Perry, 1994). The numbers and kinds of aquatic insects that colonize these samplers are strongly dependent on the upstream macroinvertebrate density as a recruitment source (Mackay, 1992). Results of the trend site community assessments (appendix A) showed that aquatic insects were the most abundant macroinvertebrate group on natural substrate at the farthest upstream study sites (SC TNC and synoptic site 7), and presumably the greatest contributor to downstream colonization.

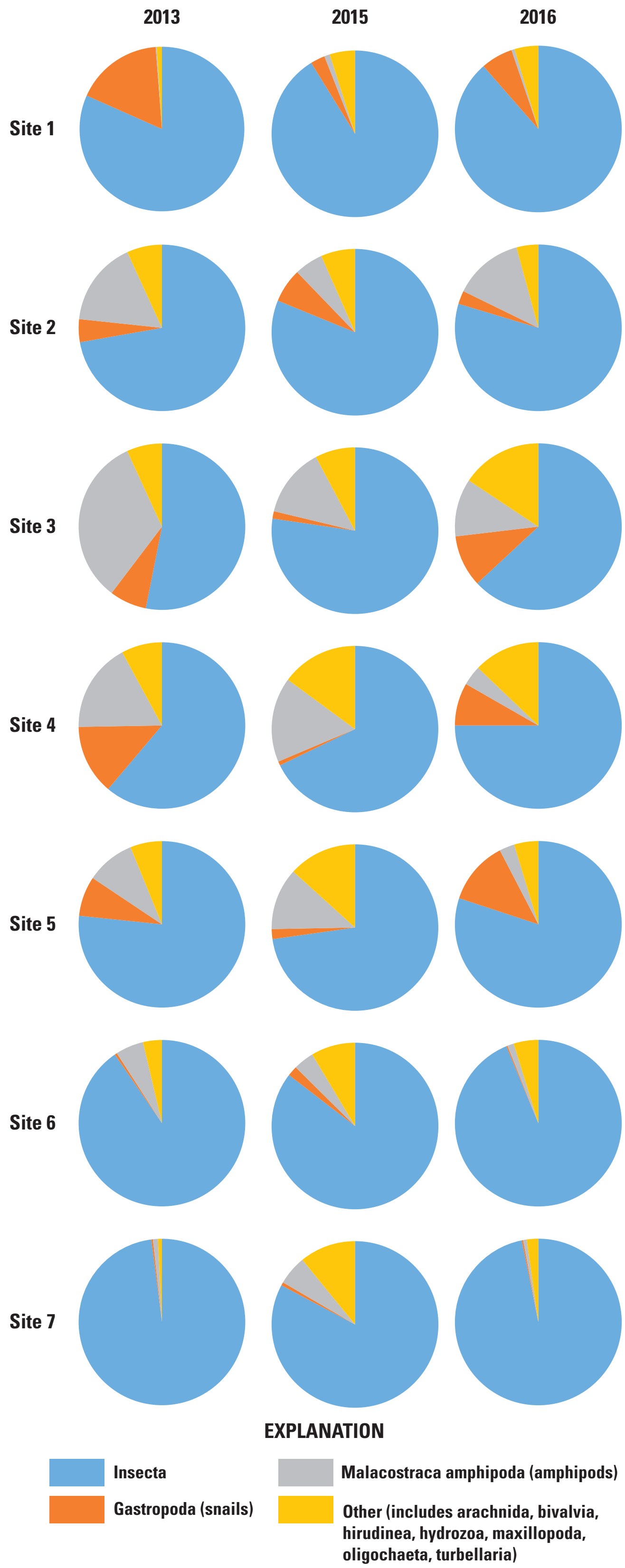

Figure 13. Macroinvertebrate classes collected from artificial substrates at Silver Creek synoptic sites, Blaine County, Idaho, 2013, 2015, and 2016.

Although contributions to total insect abundances varied among insect groups, overall the mayflies (Ephemeroptera) and true flies (Diptera) were the largest contributors to substrate colonization among synoptic sites (fig. 14) and collectively represented 70.2, 67.1, and 65.3 percent of the total insect abundance in 2013, 2015, and 2016, respectively. The mayflies were dominated by *Baetis tricaudatus*, with fewer numbers of *Diphetor hageni*, *Ephemerella* sp., Leptophlebiidae, and *Tricorythodes* sp. The true flies consisted nearly exclusively of midges (Chironomidae) and black flies (*Simulium* sp.). Caddisflies (Trichoptera) were the next most abundant insect group among sites and years but generally were present in lower numbers. Members of this group comprised 11.5, 13.2, and 19.4 percent of the total insect abundance in 2013, 2015, and 2016, respectively.

To determine whether disturbance from the channel restoration adversely affected colonizing macroinvertebrates, comparisons were made of annual and seasonal differences in select community metrics (fig. 15). The same community metrics used to evaluate the trend site macroinvertebrate data (taxa richness, total abundance, EPT richness, EPT abundance, Simpson's diversity, and Simpson's evenness) were used for the synoptic-site assessments. Because site-specific colonization processes are not independent but influenced by local and upstream conditions, among-year comparisons were based on colonization results averaged for all sites and seasons for a given year. Seasonal comparisons were based on colonization results averaged for all sites and years for a given season. Statistical comparisons were based on a general linear model two-way ANOVA with year and season as factors, and pairwise multiple comparisons using the Holm-Sidak method (Sokal and Rohlf, 2012). Data were checked for normality (Shapiro and Wilk, 1965) and equal variance (Brown and Forsythe, 1974) prior to analysis, and adjusted if needed using logarithmic transformations to meet normality and variance requirements.

Comparison of macroinvertebrate metrics among years showed a significant ($P<0.001$) increase in mean taxa richness from 17.3 in 2013 (pre-restoration) to 22.3 in 2015 and 19.8 in 2016 (post-restoration) (fig. 15). Similarly, annual mean EPT richness showed a significant increase ($P=0.002$) from 7.5 taxa in 2013 to 10.1 in 2015, and a non-significant increase ($P=0.090$) to 8.9 taxa in 2016, respectively. Neither total abundance nor EPT abundances were significantly different among years ($P=0.835$ and $P=0.235$, respectively). Comparison of macroinvertebrate community metrics among seasons showed that total taxa and EPT richness were each significantly higher ($P=0.024$ and $P<0.001$, respectively) in the spring and summer compared to autumn (fig. 15).

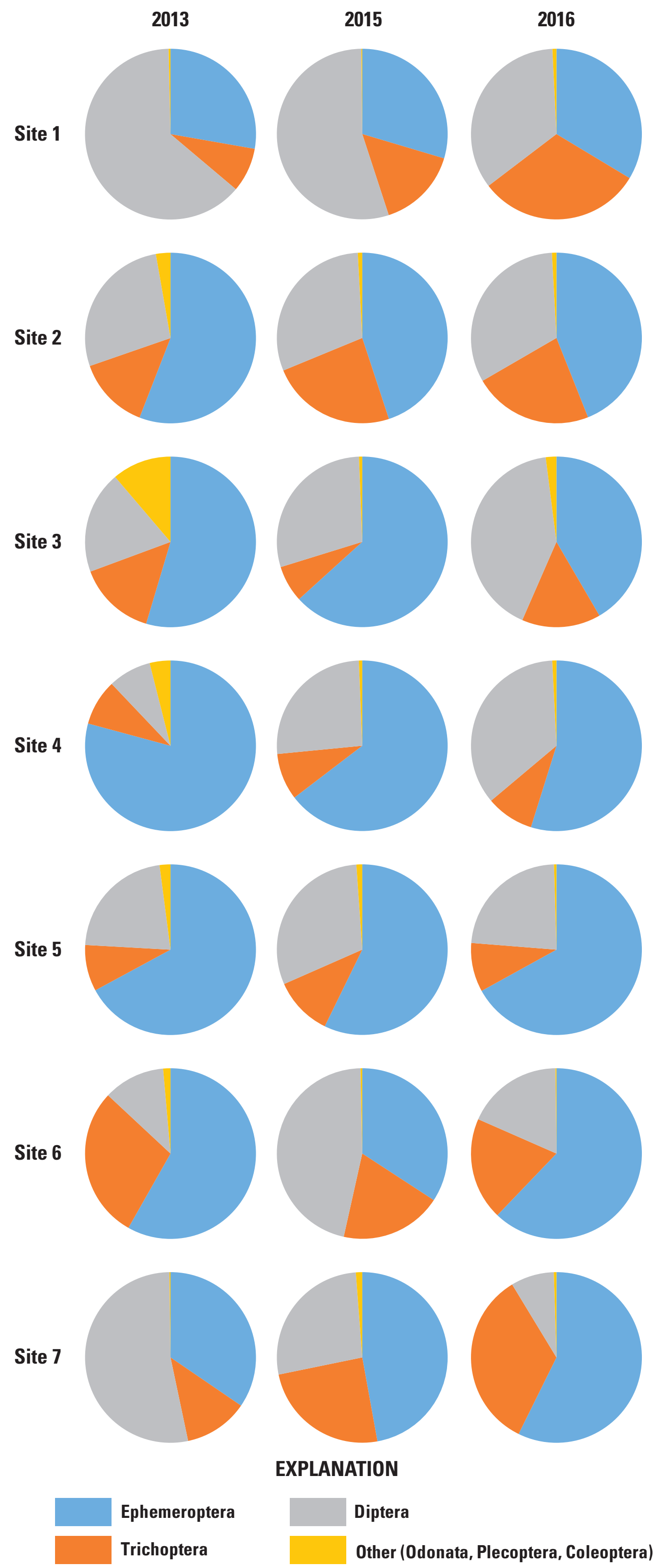

Figure 14. Macroinvertebrate insects collected from artificial substrates at Silver Creek synoptic sites, Blaine County, Idaho, 2013, 2015, and 2016.

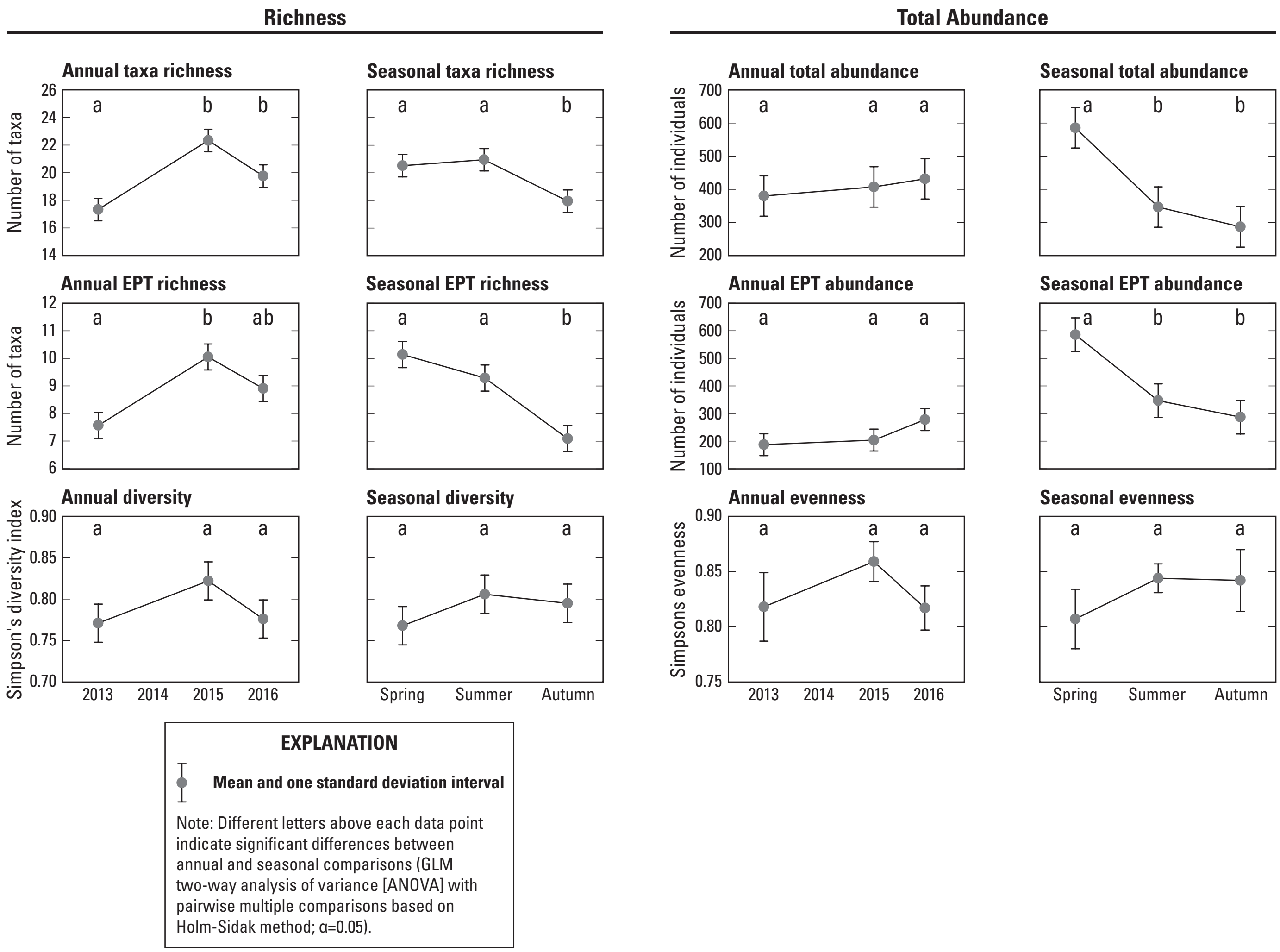

Figure 15. Statistical summaries of annual metrics calculated from macroinvertebrates collected from artificial substrates at Silver Creek synoptic sites, 2013, 2015, and 2016.

Total and EPT abundances were significantly higher in the spring than in the summer and autumn (*P*=0.002 and *P*<0.001, respectively). There were no significant differences in Simpson's diversity or Simpson's evenness among years (*P*=0.234 and *P*=0.373) or seasons (*P*=0.508 and *P*=0.493) for colonized macroinvertebrate communities at synoptic-site locations. Despite marked differences in seasonal richness and abundances, the absence of a seasonal effect on species diversity and evenness is attributed to the relatively consistent equitability of taxa abundances among seasons with average richness-density ratios for spring, summer, and autumn of 0.60, 0.64, and 0.63, respectively (based on log transformed data from appendix B).

Summary and Conclusions

The part of Silver Creek that flows in The Nature Conservancy's (TNC's) Silver Creek Nature Preserve in south-central Idaho supports a wide diversity of aquatic life and a highly productive trout fishery. Historical and current land use practices in the drainage contributed to sedimentation of the stream channel, decreasing depth and affecting stream habitat. A decline in habitat quality and availability threatened the health of the local fishery. To mitigate the potential adverse biological effects of sedimentation in the impounded parts of Silver Creek, TNC and local stakeholders initiated a channel restoration project. Project objectives included: (1) replacing Purdy Dam to improve fish passage and to restore natural flow regimes, (2) excavating deposited sediments from select regions, (3) stabilizing stream banks to reduce erosion potential, and (4) revegetating affected riparian areas.

Given the potential effect on resident biota from activities associated with the restoration project, scientists from the USGS, in cooperation with TNC and Blaine County, Idaho, were tasked with evaluating effects of the project on resident macroinvertebrate communities. Specifically, to evaluate the status of the macroinvertebrate communities in Silver Creek prior to and following the 2014 restoration project, and to determine whether disturbance resulting from physical modifications to the stream channel and riparian areas resulted in a decline in populations of resident macroinvertebrates. A decrease in the numbers and kinds of macroinvertebrate taxa could indicate potential impairment of water-quality conditions and a decline in stream health. Of concern was that macroinvertebrates represent an important food resource for Silver Creek trout and a decline in the quality and quantity of this resource could threaten the health of the fishery.

To determine potential effects of channel and riparian restoration on Silver Creek macroinvertebrate communities, macroinvertebrate sampling was conducted every 3 years (2001–16) at two long-term trend sites and seasonally (spring, summer, and autumn) in 2013, 2015, and 2016 at seven synoptic sites. Trend-site communities were collected from naturally occurring stream-bottom substrates and represent locally established macroinvertebrate assemblages. Synoptic-site communities were sampled using artificial (multi-plate) substrates and represent recently colonized (4–6 weeks) macroinvertebrate assemblages. Potential effect on resident macroinvertebrate populations from the restoration project was determined by comparing select community assemblage metrics (taxa richness, total abundance, EPT richness, EPT abundance, Simpson's diversity, Simpson's evenness) for periods prior to and following restoration. A significant decrease in one or more metric values in the period following stream channel restoration was the basis for determining impairment to macroinvertebrate populations in Silver Creek.

Temporal patterns in macroinvertebrate assemblage properties at trends sites in the years preceding restoration (2001–13) were used to identify impairment thresholds for communities sampled after restoration in 2016. A decrease in one or more of the community metrics that is significantly less than the respective pre-restoration range of metric values was considered evidence of impairment. Comparison of pre-restoration and post-restoration macroinvertebrate community composition at trend sites determined no significant decreases in any metric parameter for communities sampled in 2016. Because post-restoration macroinvertebrate assessments at trend sites were not done until 2 years following the restoration, it is uncertain if physical disturbance to the stream channel from restoration activities in 2014 resulted in significant impairment to macroinvertebrate communities in 2015, particularly at the most downstream trend-site location where disturbance effects likely would be most pronounced.

Artificial substrates were used to sample macroinvertebrate populations at synoptic-site locations where community composition is based on the numbers and kinds of taxa colonizing the substrate surfaces over a standard period. Statistical comparisons were made of community metrics determined from colonized assemblages collected the year prior to restoration (2013) and for the 2 years following restoration (2015 and 2016). There was no evidence of a post-restoration decline in community assemblage properties for macroinvertebrates colonizing artificial substrates. Taxa richness and EPT richness of colonized assemblages at synoptic sites increased significantly from 2013 to 2015 and 2016. Similarly, total and EPT abundances increased at synoptic sites, but the increase was not statistically significant. No significant differences were determined in Simpson's diversity or Simpson's evenness of colonized communities among pre- and post-restoration sampling years (2013, 2015, and 2016).

Significant seasonal differences in macroinvertebrate assemblages were apparent at synoptic-site locations and likely reflected typical life-history patterns of increased insect emergence and development in the late spring and early summer months. Taxa and EPT richness were each significantly higher in the spring and summer compared to autumn, and abundances were significantly higher in the spring than in the summer and autumn. Despite marked differences in seasonal richness and abundances, the absence of a seasonal effect on species diversity and evenness is attributed to the equitability of taxa abundances among seasons. The relatively constant taxa richness and abundance ratios among seasons are consistent with inherent seasonal changes in macroinvertebrate community composition, and generally characteristic of a relatively undisturbed system.

Results from the trend- and synoptic-site sampling indicate that the Silver Creek restoration effort in 2014 did not result in a significant decline in resident macroinvertebrate populations. The findings are based on evaluation of select macroinvertebrate community metrics and are intended to reflect system-wide biological responses indicative of conditions in Silver Creek and within the Silver Creek Nature Preserve boundaries. Results of this investigation are limited to data collected for the 2 years following restoration. Continued monitoring will provide additional insight into the potential long-term effects of the Silver Creek restoration project on resident macroinvertebrate communities.

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The sampling of macroinvertebrates during this study could not have been completed without the support of Blaine County and the help of The Nature Conservancy staff and interns, U.S. Geological Survey current and retired staff, local fishing guides, and other public volunteers who committed valuable time during this study. The authors would like to acknowledge Terry Maret, retired U.S. Geological Survey employee, and Bob Unnasch, TNC Director of Science and Stewarship who helped develop the study design and assisted in the field work, and Sunny Healey, Silver Creek TNC Manager, for logistical support and for providing information about the restoration project.

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Appendix A. Macroinvertebrate Density and Calculated Metrics from Samples Collected from Riffle Habitat at Trend Sampling Sites, Silver Creek at The Nature Conservancy, and Silver Creek at Sportsman Access near Picabo, Idaho, 2001–16

Appendix A is a Microsoft® Excel file and is available for download at https://doi.org/10.3133/sir20175126.

Appendix B. Macroinvertebrate Abundance and Select Metrics Calculated from Synoptic (Artificial Substrate) Sampling Sites in Silver Creek, Blaine County, Idaho, 2013, 2015 and 2016

Appendix B is a Microsoft® Excel file and is available for download at https://doi.org/10.3133/sir20175126.

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