Frontcountry Fishery Inventories


NPS/DAN MAHONY

Yellowstone cutthroat trout from Soda Butte Creek.

Soda Butte Creek Long-term Monitoring

Soda Butte Creek has historically been sampled regularly in the park. Since the mid-1960s, park fishery personnel have collected information about the resident fish and macroinvertebrates there to monitor responses, if any, to reduction in water quality arising from ongoing inputs of mining-associated pollutants. With few exceptions, annual monitoring has occurred at a site near the park's northeast boundary since 1984.

Cutthroat trout abundance in Soda Butte Creek has varied considerably from year to year, and length-frequency data suggest that at least three size/age groups have consistently been caught. Average size of captured trout was typically between 160 and 175 mm; few individuals were longer than 300 mm (Figure 13). Although the cutthroat trout in Soda Butte Creek have been protected from harvest since 1996, with the adoption of total catch-and-release regulations, few fish longer than 330 mm have been caught in recent years. Comparison of population length structure prior to 1996 with the most recent five-year sampling period suggests that the trout's response to the catch-and-release regulation in this stream has been minimal. Similar findings for rainbow trout were found in Great Smoky Mountains National Park and suggested that factors other than angler harvest (particularly, stream productivity) might be most important in regulating fish populations (Kulp and Moore 2005). Estimated abundance of cutthroat trout in Soda Butte Creek has increased since 2002, but most of the increase appears to be occurring in younger age classes that were previously not affected by the allowable harvest regulation.

A shift in stream channel location further confounds interpretation of long-term population responses in Soda Butte Creek. Downcutting, and the creation of a new stream channel after the record-high stream flows in 1997, resulted in the loss of approximately half of the old monitoring section. The new channel has undercut numerous trees that have been incorporated into the stream. This large woody debris appears to be a preferred habitat of young cutthroat trout during the colonization of the new stream channel area.

Although non-native brook trout had previously been known to reside in the headwater portions of Soda Butte Creek (Shuler 1995), they were not found in the park until 2003. Montana Fish, Wildlife and Parks chemically removed the source population of brook trout from a small upstream tributary in 2004, and re-treated it again in 2005. Although suppression by electrofishing within the park since 2003 has yielded brook trout each year (Figure 13), evidence of a widespread, robust population is lacking. The upstream chemical removal project appears to have reduced the brook trout population to where only an


NPS/DAN MAHONY

Fisheries crew electrofishing Soda Butte Creek in 2005.

occasional individual is now found in the park.

Cutthroat trout collected during brook trout electrofishing suppression were sampled for genetics analysis. Initial results indicate that the cutthroat trout have been recently hybridized with rainbow trout (Olson 2005). In 2005, NPS biologists also collected fin clips from 40 cutthroat trout upstream from Icebox Canyon to obtain the current genetic status of the population there. Although these fish have not yet been analyzed, at least one had the physical appearance of a hybrid.

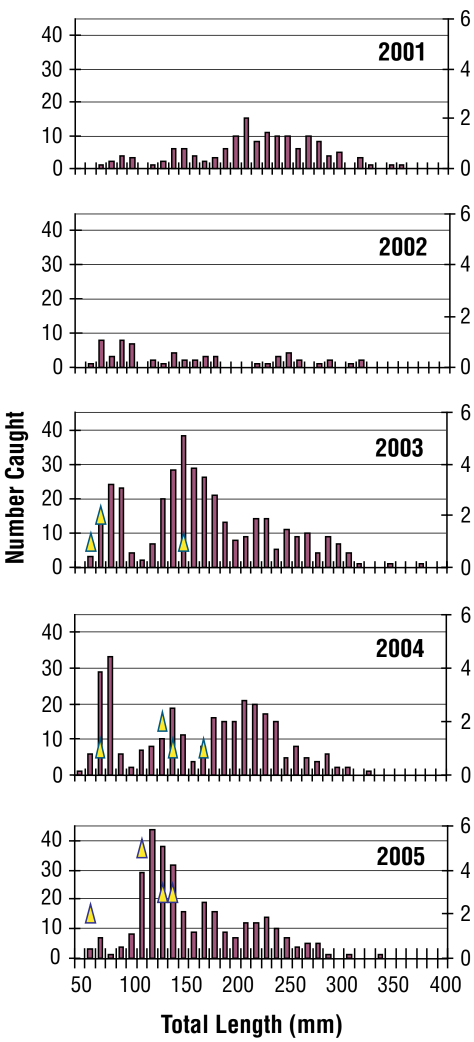


Figure 13. Number of Yellowstone cutthroat trout and brook trout captured in the Northeast Entrance sample section of Soda Butte Creek, 2001–2005. Solid bars denote 10-mm length groups for cutthroat trout. Triangular markers denote number of brook trout captured by length group and year.

Monitoring Associated with Road Reconstruction

Because large sections of many park roads were intentionally located adjacent to stream corridors, road reconstruction projects can potentially impact fish populations. In 2005, we continued to monitor these activities. Most of the projects were at the mid-construction or completion phase; thus, monitoring was restricted to areas sampled in previous years. In 2005, electrofishing surveys were conducted at several sites in Hayden Valley, in the tributary of Cascade Creek at the south end of the Canyon-to-Chittenden road, and at three sites in Antelope Creek. As in previous years, few of the captured cutthroat trout were longer than 250 mm, suggesting that the streams are used primarily as spawning and rearing areas for fish from the Yellowstone River mainstem. However, in Antelope Creek, consistent capture of multiple size-groups and the presence of potential barriers indicate that the population may be comprised of fluvial residents.

Sampling at the two sites of Middle Creek on the east side of Sylvan Pass again revealed a predominance of brook trout over cutthroat trout. Relative abundance of both species was smaller in 2005 than on other sampling occasions, but this may have been due, in part, to reduced capture efficiencies associated with the difficulty of sampling during higher stream flows. This year, in consultation with NPS

Sampling at the two sites of Middle Creek on the east side of Sylvan Pass again revealed a predominance of brook trout over cutthroat trout.

JOANN VOIGT

Non-native brook trout are being removed from upper Soda Butte Creek by electrofishing each year.

One long-term effect of upgraded roads is increased access and usage.

geologists and Federal Highway Administration staff, Aquatics Section staff sampled the upper portions of Middle Creek as a result of water quality concerns arising from the gravel-washing operation at the top of the Sylvan Pass divide. In September 2005, sampling of Middle Creek near the input source of the fine materials failed to capture any fish. Additional electrofishing upstream from the affected area also yielded no fish. This brief initial survey suggests that the localized area was historically fishless and remains so today. A more extensive survey of the watershed could reveal the presence of barriers, upstream distribution of cutthroat trout in the stream, and amount of risk to the cutthroat trout population based on its proximity to the input source. Intensive water quality and macroinvertebrate surveys have also been completed to document the potential impacts of sediment from the gravel-washing operation (described below).

Typically, road projects are a concern to resource managers because they can potentially impact fish populations if excessive sediment is generated during construction or improperly designed or placed road culverts impede fish passage after completion of the project. As such, most monitoring efforts have been focused at local sites where those types of impacts might occur. However, a broader temporal and spatial examination is required for all effects of road projects to be considered (Angermeier et al. 2004). One long-term effect of upgraded roads is increased access and usage. Wider roads and larger parking areas may lead to increased numbers of anglers at streams that are close to a road, but not close enough to be directly affected by the actual construction activities, for instance, at Obsidian Creek, where angler use may increase due to improved access to the stream with an upgraded road or removal of size limits in 2006. This stream was historically fishless, but brook trout were stocked there in the early days of the park. As brook trout have a high catch rate, Obsidian Creek has an unusual status as a park stream where children are allowed to use bait to catch non-native trout. Four years of sampling near the Indian Creek campground area have revealed that small brook trout are abundant in Obsidian Creek. Population data obtained during the pre-construction phase of the Mammoth-to-Norris road project will be useful for examination of longer-term changes.

The close proximity of Middle Creek to the East Entrance Road is a concern to fisheries biologists.

An upper reach of Middle Creek sampled in 2005.

NPS/DAN MAHONY

Status of Cutthroat Trout in the Upper Snake River

The Snake River watershed is the third largest in Yellowstone National Park. Historically, Yellowstone cutthroat trout, Snake River finespotted cutthroat trout, and several other native fish species occupied the mainstem river and its tributaries. Much of this basin has not been previously surveyed because of its remote location and difficult access to pre-selected study areas. In 2005, the Aquatics Section continued its native fish inventory of the Snake River in order to describe the distribution of cutthroat trout subspecies in the remote headwaters region within the park. A primary objective of the survey is detection of areas where the two cutthroat trout subspecies may coexist. Equally important is documenting the relative abundance and distribution of other native fishes and potentially harmful non-native species, including brown trout, brook trout, and lake trout in this watershed.

As the mainstem river survey was completed in 2004, our sampling in 2005 was primarily focused on tributary streams. Fish sampling techniques were similar among years and followed the methods of Novak et al. (2005) where each stream was subdivided into ten sections and the lower 100 meters of each section were sampled in an upstream direction. Surveys of two of the most remote tributaries (Forest Creek and Sickle Creek) were completed. As neither of these streams has an established trail access, logistic considerations were an important part of completing the inventory. Surveyed sample sections in these two tributary

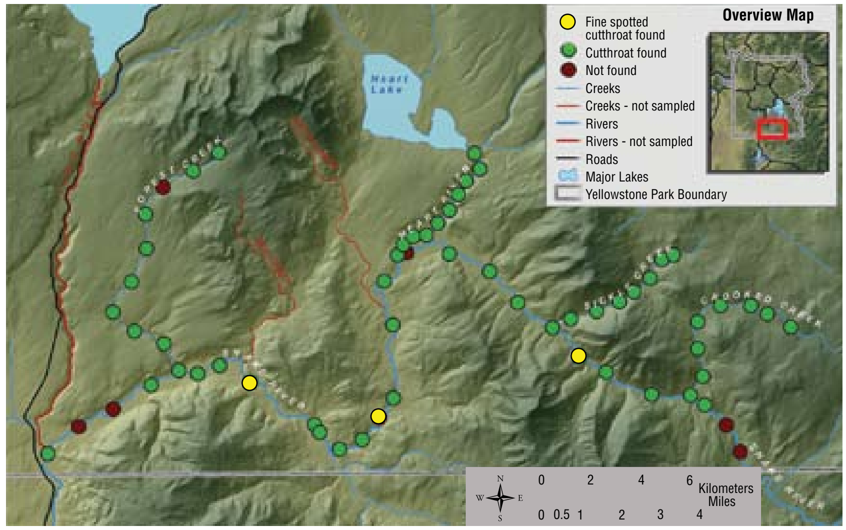


Figure 14. The upper Snake River watershed where fishes were sampled by electrofishing in 2004 and 2005, and Snake River finespotted cutthroat trout were found, Yellowstone cutthroat trout (large spotted) were found ("Cutthroat found" in the legend), or none were found.

streams were approximately 1 km apart (Figure 14). Forest Creek watershed was most likely historically fishless due to the presence of a large waterfall (>20 feet high) located about 1 km upstream from the confluence with the Snake River mainstem. According to historical records, about 100,000 eyed Yellowstone cutthroat trout eggs from the Yellowstone Lake hatchery were stocked annually into Forest Creek between 1939 and 1943 (Varley 1981). The relatively high abundance and widespread distribution of cutthroat trout there now suggests that these early stockings were highly successful. Much of the Forest Creek watershed was intensely burned during the 1988 wildfires. The stream channel now contains abundant deadfall and other woody debris from the riparian areas and adjacent uplands. The cutthroat trout population sampled contains numerous size groups representing several year classes. Abundance,

NPS/CHRIS ROMANKIEWICZ

Forest Creek was one of several remote Snake River tributaries surveyed for fishes in 2005.

NPS/CHRIS ROMANKIEWICZ

Forest Creek Yellowstone cutthroat trout.

distribution, and utilization of a variety of habitat types by the cutthroat trout all suggest that wildfire effects on this isolated population were negligible.

Sickle Creek, which contains large, low-gradient meadows in its headwater sections, flows out of a steep canyon into the Snake River approximately halfway between the headwaters of the river and the South Entrance of the park. In 2004, two sections near the confluence with the Snake River were sampled. All but one of the cutthroat trout caught in the high-gradient areas, characterized by bedrock pools and unstable stream channels, were small (<150 mm total length). The electrofishing survey of Sickle Creek was completed in 2005. Only cutthroat trout were caught, but their abundance in the upper reaches was one of the highest of any section sampled in the Snake River watershed. Most of the sampled trout had typical Yellowstone cutthroat trout spotting patterns; however, several fish had small- to intermediate-size spots distributed in a pattern characteristic of finespotted cutthroat trout. Several size classes of cutthroat trout were captured throughout the stream, and young-of-the-year were abundant. The largest cutthroat was captured in the headwater section.

The upper Yellowstone River (upstream of Yellowstone Lake) is the largest of 126 tributaries to Yellowstone Lake.

This year, we initiated an inventory of a large, unnamed tributary that flows north from Big Game Ridge into the Snake River just slightly upstream from the Crooked Creek-Snake River confluence. This tributary appears to comprise a substantial amount of the total mainstem flow. The cutthroat trout captured here were typically smaller than those caught in the nearby mainstem section in 2004. This tributary is the only location where mottled sculpins were collected in 2005.

A secondary objective of the survey was to collect additional cutthroat trout from previously sampled streams in order to obtain an adequate number of tissue samples for stream-specific genetic analyses. Enough genetic samples now have been collected for subspecific differences (if any) among the Heart River, Sickle Creek, Crooked Creek, and Forest Creek populations to be examined (Janetski 2007). Only Red Creek (which may have permanent barriers located near its mouth) and Basin Creek (which does have an occasional angler report of cutthroat trout) remain to be surveyed. Although these latter two streams have good trail access for much of their length, limited information is available and angler use appears to be minimal.

NPS/CHRIS DIXON

Sickle Creek near confluence with Snake River.

Status of Cutthroat Trout in the Upper Yellowstone River

The upper Yellowstone River (upstream of Yellowstone Lake) is the largest of 126 tributaries to Yellowstone Lake. More than one third of the water that enters Yellowstone Lake through tributary streams originates from this system. Its mainstem flows more than 84 river km from its source on Younts Peak in the Bridger-Teton Wilderness to its mouth within the Southeast Arm of Yellowstone Lake. The watershed contains more than 200 km of tributary streams and covers an area greater than 1,244 square km.

The year 2005 was the third year of the upper Yellowstone River fisheries assessment. The project, initiated in 2003 by the National Park Service, is now a joint effort between the NPS and the Wyoming Game and Fish Department. Through this coordinated effort, nearly the entire drainage has been surveyed. Until this survey, a comprehensive fishery assessment had not been performed in this region. When completed, the study will help answer questions regarding life-history strategies, movements, and distributional patterns of Yellowstone cutthroat trout in the most remote wilderness remaining in the continental United States.

To monitor movement patterns of adult

Yellowstone cutthroat trout, 151 fish were tagged with radio transmitters from June 2003 through July 2005, in various locations in the upper Yellowstone River basin (Figure 15). Due to the large size of the Yellowstone River and Thorofare Creek, angling was the most effective technique in capturing fish. All fish captured were examined for gender and spawning stage, and were measured for total length and weight. Scale samples for age and growth analysis, and fin clips for genetic testing were collected from a subsample of fish during each tagging trip.

Fish were radio-tagged during the spawn and post-spawn period to increase the likelihood of studying both the lacustrine-adfluvial and fluvial-adfluvial life history types (if they were present in the system). However, lack of fish within the mainstem or lower reaches of large tributaries late in the season (after August 1) prevented us from tagging equal numbers of fish in the spawning and post-spawning periods. Tracking surveys were conducted with a fixed-wing aircraft flying over the river system and portions of Yellowstone Lake (Figure 16). Monitoring flights took place weekly from May through August, twice each month in September and October, and monthly from November through April. Tracking flights were supplemented with walking surveys of the rivers and streams, and boat surveys on Yellowstone Lake as time permitted. Boat surveys proved unsuccessful, and they were discontinued after the first season of the study.

The majority of tagged fish migrated into Yellowstone Lake following the spawning period each year. Of the 109 fish that were relocated, 64% moved downstream to Yellowstone Lake and 14% moved downstream toward the lake before their signals were lost. We were unable to relocate 42 fish after their initial tagging, possibly because several of the fish migrated over large distances in relatively short periods of time. One fish actually migrated more than 40 river and lake miles in just 16 days. Fish also may have migrated to Yellowstone Lake and resided in locations outside of our tracking surveys. Increased coverage of Yellowstone Lake during tracking flights in 2005 showed that fish implanted with transmitters in the upper river system were found in several locations throughout Yellowstone Lake and also in locations within the Yellowstone River downstream of the lake outlet at Fishing Bridge. Similar results have been found in other tracking studies in the Yellowstone Lake basin (Koel et al. 2003). There is also the possibility of tag failure or of a predator eating the fish and moving out of the system.

To assess distribution of cutthroat trout of all ages in the basin, electrofishing surveys (100-m sections for every km of stream) were conducted in tributaries of the Yellowstone River and Thorofare Creek. Surveys were conducted after August 1, when it is likely that adfluvial

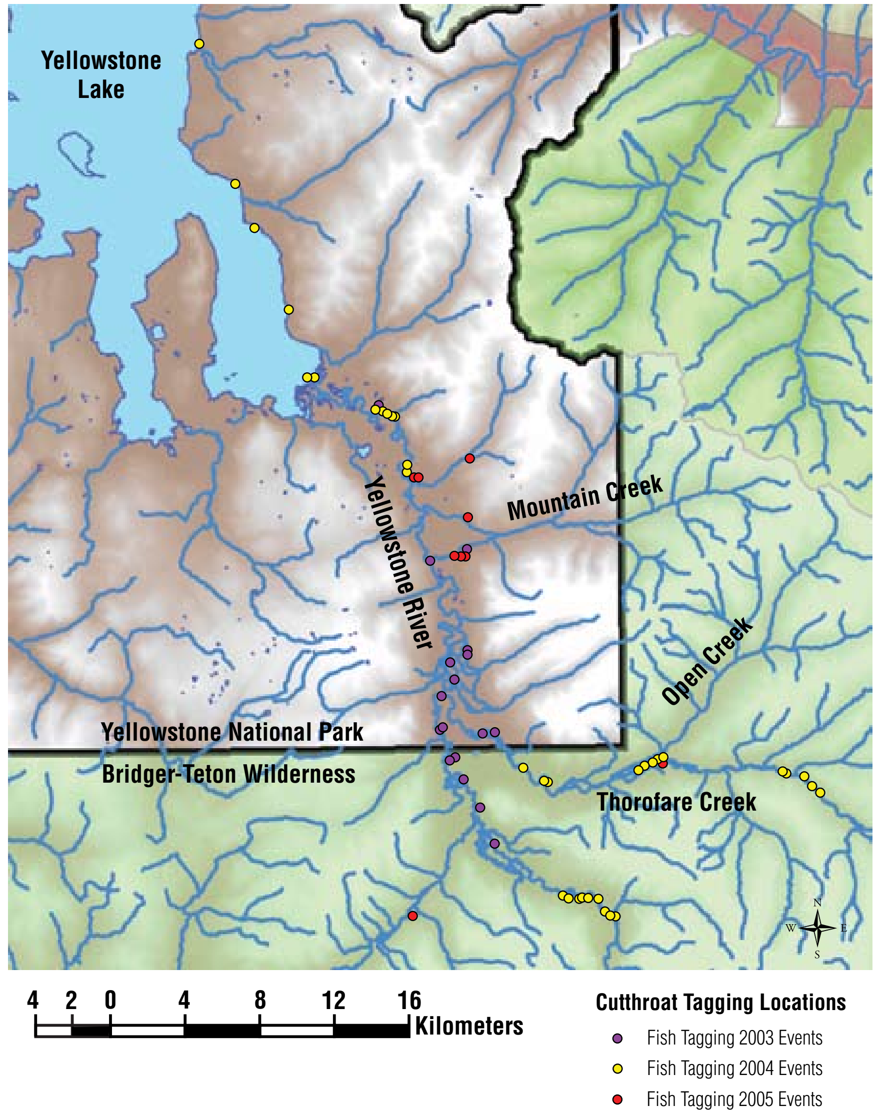


Figure 15. Locations where cutthroat trout were implanted with radio-tags in the upper Yellowstone River watershed, 2003–2005.

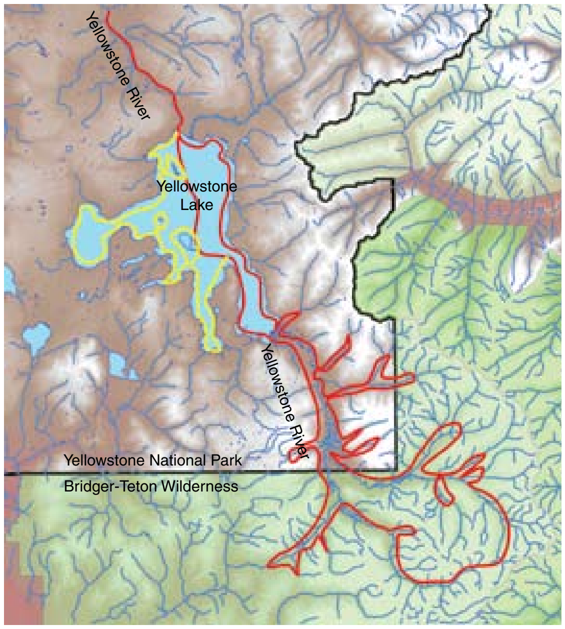


Figure 16. Yellowstone River watershed upstream of Yellowstone Lake and path of flights used to track radio-tagged cutthroat trout, 2003–2005.

It remains unknown if fish remain as year-round residents and survive to be adults within the upper Yellowstone River watershed.

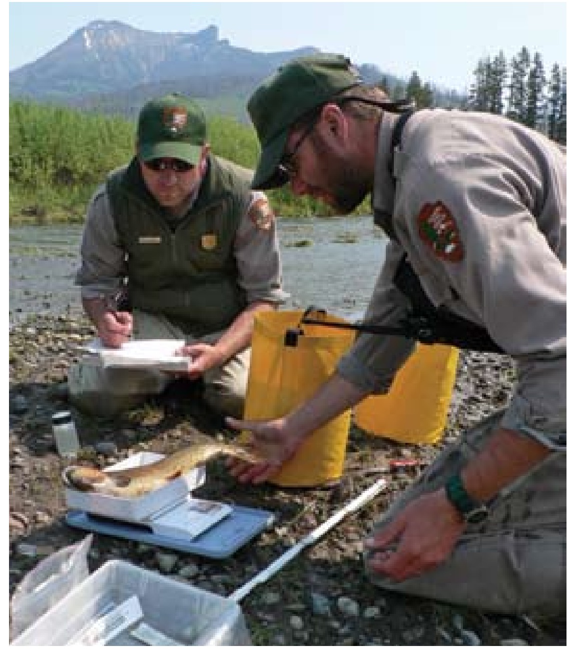
fish migrating upstream from Yellowstone Lake would have returned to the lake. To date, surveys have been conducted on Trappers, Mountain, Howell, Cliff, and Phlox creeks within the park boundary, and Open, Dell, Butte, Coyote, Hidden, Castle, and Atlantic creeks south of the park. All fish collected were measured and weighed. Scale samples for age and growth analysis, and fin clips for genetic analysis, were taken from a subsample of fish in each section.

Small cutthroat trout were captured below barriers to fish migration (e.g., waterfalls) during the electrofishing surveys within park boundaries. These fish ranged from 26 mm to 182 mm in length, and analysis of scales showed them to be 0–2 years of age. This indicates that some extended rearing may occur in the river system. It remains unknown if fish remain as year-round residents and survive to be adults within the upper Yellowstone River watershed.

Data collected during movement and distribution surveys (2003–2005) indicate that Yellowstone cutthroat trout in the upper Yellowstone River system primarily exhibit a lacustrine-adfluvial life history strategy, and spend the majority of their lives in Yellowstone Lake, migrating into the river system to spawn. This is similar to what has been observed in the other, much smaller tributaries of Yellowstone Lake. Completion of our surveys and detailed analyses planned during the next 1–2 years should result in a better understanding of movement patterns, habitat use, and life history strategies represented. Overall, through collaboration with our partners in the Wyoming Game and Fish Department, we will have documented the status of this subspecies in a very remote and logistically challenging watershed.

NPS/JEFF ARNOLD

Radio-tagged Yellowstone cutthroat trout from the upper Yellowstone River.



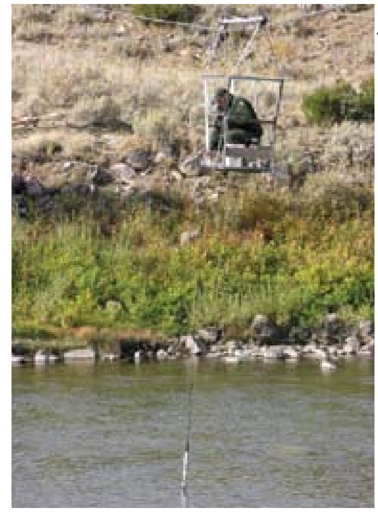
Fisheries technicians Brad Olszewski and Brian Ertel processing fish samples.

Aquatic Invasive Species Program

Yellowstone's world-class fisheries are threatened by introductions of aquatic invasive species (AIS). These harmful non-native and exotic invading species displace precious native species, such as cutthroat trout and many native macroinvertebrates, upon which Yellowstone fishes depend for growth and survival. AIS also have the potential to impact important trout consumers such as eagles, ospreys, and grizzly bears, causing a disruption of the Greater Yellowstone Ecosystem.

The New Zealand mudsnail (*Potamopyrgus antipodarum*; Richards 2002; Hall et al. 2003; Kerans et al. 2005) and the parasite that causes whirling disease in trout (*M. cerebralis*; Koel et al. 2006) are examples of exotic AIS that are already present in park waters. The zebra mussel and Eurasian watermilfoil are examples of AIS that are quickly approaching the park from elsewhere in the United States, and there are more than 300 others now in North America—often so small they are difficult to see (http://nas.er.usgs.gov). Because AIS are often hidden, they frequently "hitchhike" from one lake or stream to another within the water of a boat bilge or livewell, or in mud, dirt, sand, and plant fragments attached to boats, fishing equipment, or clothing. Prevention is key, because once introduced and established in park waters, AIS are virtually impossible to get rid of. The following measures have been taken in the park to help prevent additional AIS introductions:

- A brochure has been developed to provide information on how to conduct boat inspections and clean angling gear (available online at www.nps.gov/yell/planyourvisit/fishingexotics.htm).
- Boat ramp signs have been developed and installed at Yellowstone Lake and Lewis Lake ramps.
- Anyone purchasing a boating permit in the park is now informed about AIS and how to conduct boat inspections.
- Collaboration with partner agencies and non-governmental organizations and development of an Aquatic Nuisance Species Management Plan for the Greater Yellowstone Area.



NPS/JEFF ARNOLD

Water quality technician Jeremy Erickson collecting data at the Lamar River site.

Yellowstone National Park is a partner in the "Stop Aquatic Hitchhikers" campaign, led by the Aquatic Nuisance Species Task Force and sponsored by the U.S. Fish and Wildlife Service and U.S. Coast Guard (http://www.protectyourwaters.net). Whenever possible, images and other educational materials common to the campaign are used for purposes of AIS prevention within the park. Additional information can be obtained at www.protectyourwaters.net and several other websites.

Aquatic invasive species have the potential to impact important trout consumers such as eagles, ospreys, and grizzly bears.

Long-term Water Quality Monitoring

All water bodies in Yellowstone National Park are classified as outstanding natural resource waters and designated as Class I waters by the states of Montana and Wyoming. Class I waters are afforded the highest protection possible and, as a result, long-term degradation of these waters is prohibited (WDEQ 2001). Chemical and physical attributes of streams and lakes are a direct reflection of the land use that occurs within a watershed. Consequently, these attributes directly affect the organisms that live within those aquatic systems. For this reason, water quality monitoring is a necessary tool for tracking natural and anthropogenic changes as well as providing an overall evaluation of ecosystem health in Yellowstone National Park. By collecting chemical, physical, and biological properties of aquatic systems, staff can not only evaluate the overall health of those water bodies, but also assess the overall condition of the watershed and the surrounding environment. The Aquatics Section's long-term water quality monitoring program is comprised of two main components: (1) long-term water quality monitoring of major streams and Yellowstone

NPS/JEFF ARNOLD

Water quality technicians Jeremy Erickson and Hunter Hutchinson processing samples for total suspended solids analysis.

Lake, and (2) using aquatic benthic macroinvertebrates as health indicators of aquatic systems.

During 2005, the Aquatics Section continued to conduct routine water quality monitoring at the 12 established sites on major river basins throughout Yellowstone National Park (Figure 1). Sites were sampled once every two weeks (once each month during winter), with sample days randomly selected within a sample week. A multiparameter probe was used to collect *in situ* water quality measurements including water temperature, dissolved oxygen, pH, and conductivity. A portable turbidity meter was used to collect turbidity measurements as a way to quantify water clarity. In addition, water samples were collected during each site visit and filtered and dried for total suspended solids (TSS) analysis. These water quality parameters are important because they directly affect the types and distribution of organisms (plants, invertebrates, and fish) living in aquatic systems.

The park experienced a fairly dry winter in 2005, followed by a relatively wet spring. Temporal and spatial features of individual streams contributed to the wide variation of water quality parameters recorded from individual sites. Examples of environmental factors that affect water quality include diurnal cycles, higher flows during spring snowmelt, rain events, seasonal temperature changes, altitude differences, and the geothermal influences that affect many streams in YNP. The highest mean water temperature (15.6°C, range 6.0–25.1°C) occurred in the Firehole River, a thermally influenced stream. Lowest mean water temperature (4.9°C, range –0.1 to 13.7°C) occurred on upper Soda Butte Creek.

Most organisms become stressed when dissolved oxygen (DO) concentrations fall below 5.0 milligrams/Liter (mg/L-1). Low DO concentrations are not usually a problem in YNP because the water is constantly aerated by downhill movement. However, low DO concentrations may be a concern in some slow-moving and thermal streams. Highest mean DO concentration (11.1 mg/L-1, range 8.6–15.4 mg/L-1) was recorded for the Yellowstone River at Corwin Springs; lowest mean DO concentration (8.1 mg/L-1, range 6.5–9.7 mg/L-1) was recorded for Firehole River (Figure 17). High daily temperatures on the Firehole River probably played an important role in the low DO concentrations recorded.

Within-site variation of pH was quite low, with most differences occurring between sites (Figure 17). Mean pH for the thermally influenced Firehole River was 8.3 standard units (SU) (range 7.7–8.7). This was the highest mean value for all sites sampled, with the exception of the Gardner River, which also had a mean pH value of 8.3 (range 7.9–8.7). The Gibbon River had a mean pH value of 6.9 (range 6.6–7.2). This river receives considerable amounts of water from the Norris Geyser Basin, which is typically more acidic than other geyser basins within the park. The Yellowstone River at Artist Point had the lowest mean pH of all water quality sites, with a value of 6.8 (range 6.3–8.3).

Specific conductance, turbidity, and TSS were highly seasonal, and appeared to be correlated with river discharge (Figure 17). These parameters directly reflect changes in vegetative cover or other patterns that may occur within a watershed. In general, specific conductivity is a measure of the amount of ionic material dissolved in water. While a majority of ions found in water are derived from the weathering of rock material, small amounts of ions originate from atmospheric deposition and precipitation. Higher ion concentrations per volume of water result in higher specific conductivity values. On average, specific conductivity tended to be lowest during spring snowmelt and highest during the base flow period of fall and winter. Higher specific conductivity values were generally found at sample sites with thermal contributions. For example, the highest mean specific conductivity recorded for all sites were from the Gardner, Firehole, Madison, and Gibbon rivers, with 593, 489, 464, and 429 µSeimens per centimeter (µS/cm-1) respectively. All of those waterways receive considerable amounts of thermal contributions. Specific conductance was least variable at the Yellowstone River near Fishing Bridge, and had the lowest mean value of 94 µS/cm-1 (range

85–98 µS/cm-1) (Figure 17). The lowest specific conductivity for all sites sampled was 68 µS/cm-1, recorded at the Lamar River water quality station during a high-flow period on May 20, 2005.

Turbidity and TSS both measure the amount of inorganic (clay, silt, and sand) and organic (detritus and plankton) material suspended in the water column. Typically, turbidity and TSS values increase with increased discharge, which usually occurs during snowmelt and after rain events. Values for these parameters can also increase with an increase in algal production, which is a common occurrence on lakes during the warmer summer months. Turbidity is a measure of water clarity, with higher values reflecting a more turbid condition (i.e., less-clear water). Increases in turbidity can negatively affect aquatic plants (reduce photosynthesis) and animals (influence feeding behavior of visual predators). Most sites had mean turbidity measurements below 10 nephlometric turbidity units (NTU), with the exception of Pelican Creek and the Yellowstone River at Corwin Springs, which had mean NTU values of 18.5 NTU (range 7–118 NTU) and 12.3 NTU (range 0.9–160 NTU) respectively (Figure 17). The lowest mean turbidity measurement of 1.1 NTU (range 0.5–2.2 NTU) was recorded for the Yellowstone River at Fishing Bridge, which is located just downstream of Yellowstone Lake.

TSS is a quantitative measure of the total fraction of inorganic and organic material suspended in the water column. Increases in TSS, primarily in silt and sand, can lead to sediment deposition in the streambed, increasing stream embeddedness and resulting in a decrease of benthic productivity and loss of fish habitat. Concentrations of TSS at stream sites mirrored turbidity readings (Figure 17). The three highest averages for TSS occurred within the Yellowstone River drainage. The highest mean TSS of 23.21 mg/L was recorded for the Yellowstone River at Corwin Springs (range 1.49–337.00 mg/L),

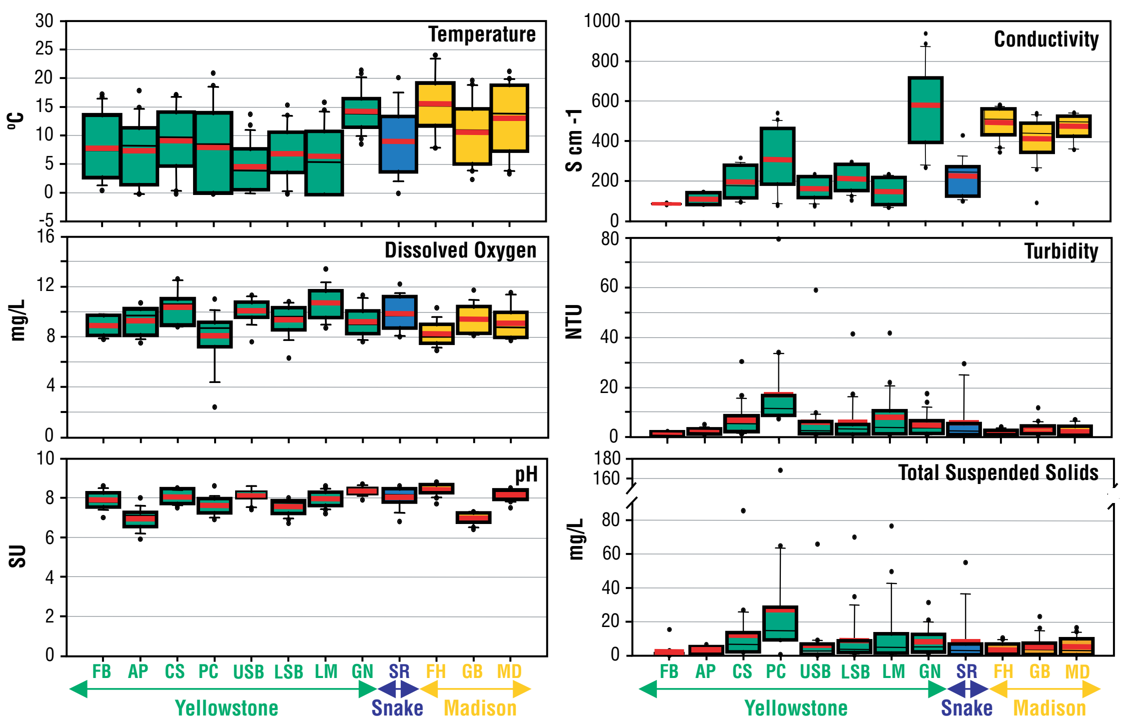


Figure 17. Box and whisker plot illustrating annual variation for selected parameters at each stream water quality location in 2005. Lower and upper portions of boxes represent the 25th and 75th percentile, respectively; lower and upper black horizontal bars represent 10th and 90th percentile, respectively. Outlying values are represented by black dots; means are indicated by solid red lines. Green, blue, and orange represent the Yellowstone, Snake, and Madison river basins, respectively. FB = Fishing Bridge, AP = Artist Point, CS = Corwin Springs, PC = Pelican Creek, USB = upper Soda Butte, LSB = lower Soda Butte, LM = Lamar River, GN = Gardner River, SR = Snake River, FH = Firehole River, GB = Gibbon River, and MD = Madison River.

followed by the Pelican Creek and Lamar River sites, with mean TSS of 20.71 and 16.79 mg/L, respectively. The lowest mean TSS, 1.06 mg/L, was recorded for the Yellowstone River at Fishing Bridge (range 0.048–2.92 mg/L).

Water Quality Monitoring Goals

Future goals for the water quality program are to continue monitoring at the 12 established sites on major river basins to acquire baseline information and determine inter- and intra-annual variation of water quality core parameters. In addition, through collaboration with the NPS Inventory & Monitoring (I&M) Program, monitoring of the park's state 303(d)-listed streams (Soda Butte Creek and Reese Creek) will continue. (Section 303(d) of the Clean Water Act requires state departments of environmental quality to prepare a list of water bodies that do not meet water quality standards and where Total Maximum Daily Loads will be developed.) Water quality monitoring is also expected to occur relative to piscicide treatment of streams and lakes as a part of the restoration program for fluvial populations of native trout. Samples would be obtained prior to chemical treatment, concurrent with treatment, and post-treatment both within and downstream of the treatment areas. Specifically, analyses would be conducted to detect volatile organic compounds, semi-volatile organic compounds, and rotenone. Antimycin, at concentrations used to remove fish, cannot be detected in water analytically, but the solvents used to disperse antimycin in water (acetone, diethyl phthalate, and nonoxynol-9) would be monitored as a portion of the volatile organic compounds and semi-volatile organic compounds described above.

Sampling aquatic invertebrate communities continues to be a practical method of evaluating stream health in YNP.

Yellowstone Lake Limnology

Water quality sampling was conducted at seven fixed locations on Yellowstone Lake between May and October (Figure 4). Basic water quality parameters (water temperature, DO, pH, specific conductance, turbidity, and secchi transparency readings) were collected from each site. Surface water samples were collected and analyzed for total and volatile suspended solids. Surface water quality parameters were similar among all sites; for reporting purposes, only the sites at West Thumb and the South Arm of Yellowstone Lake will be described. Surface water temperatures and DO concentrations are closely linked, and vary greatly with season. As expected, lower water temperatures were recorded during spring, and higher temperatures were recorded during the summer months (range 3.3–16.2°C and 4.2–17.4°C, respectively, for West Thumb and the South Arm). Conversely, higher DO concentrations were recorded during spring, and lower DO concentrations were recorded during the summer months (range 8.1–10.1 mg/L and 7.9–10.7 mg/L, respectively, for West Thumb and the South Arm). Values for pH and specific conductivity were less dependent on seasonal changes and relatively more constant throughout the sample period. Ranges for pH were between 7.1 and 7.9 for West Thumb and between 7.5 and 8.1 for the South Arm. Ranges for specific conductivity were between 84 and 100 µS/cm-1 for both sample locations.

In addition to surface water parameters, temperature profiles were collected from the same two locations to give fisheries biologists a better understanding of seasonal temperature changes throughout the water column and of fish movement patterns throughout the lake. In general, water temperatures remain at about 4°C throughout the water column until mid-June (Figure 18). Water temperatures begin to increase rapidly during the last week of June with the development of a thermocline, an area in the water column with noticeable temperature change, becoming prominent from July through mid-September. The thermocline remains at about 15 and 20 meters for the West Thumb and South Arm locations, respectively.

Macroinvertebrates as Health Indicators

Successful water quality monitoring requires a combination of physical, chemical, and biological measurements to effectively evaluate the health of aquatic systems. Physical and chemical measurements directly measure

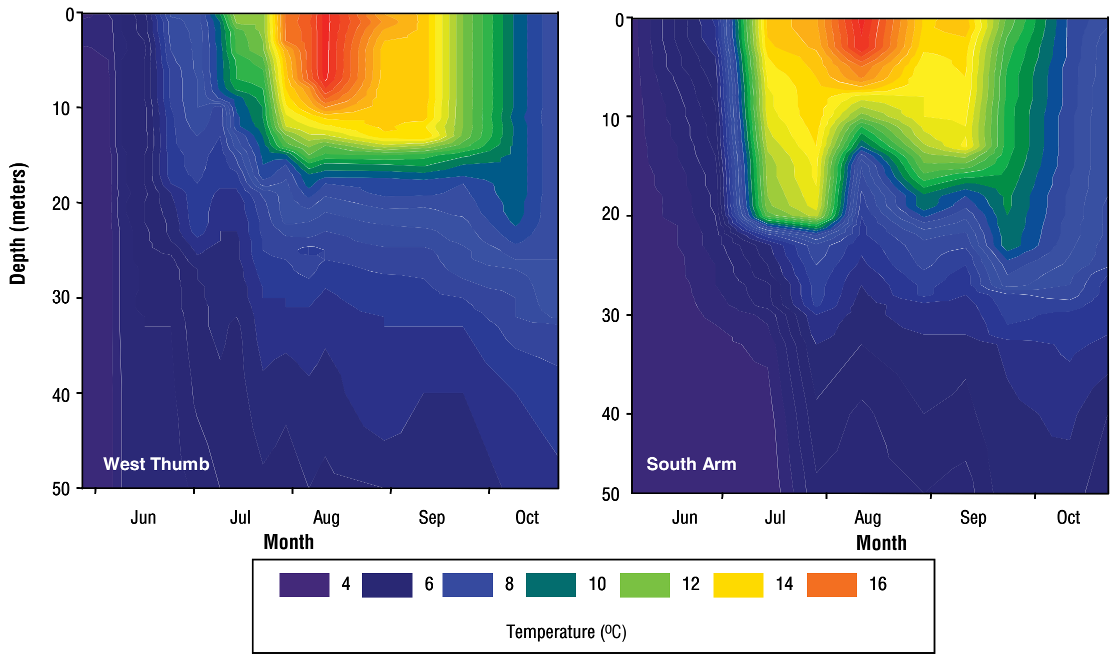


Figure 18. Isopleth of water temperature in West Thumb and the South Arm of Yellowstone Lake during summer 2005. Contour lines represent one-degree intervals. For comparison and greater resolution of surface temperatures, only data from the first 50 meters is displayed for the West Thumb location. Note that the shallow water depth of the South Arm contributes to surface waters that warm more quickly than surface waters associated with deeper portions of the lake.

parameters within the stream channel and water column; biological measurements evaluate the response of organisms (e.g., periphyton, aquatic invertebrates, and fish) to changes within their environments. Sampling aquatic invertebrate communities continues to be a practical method of evaluating stream health in YNP. These organisms are excellent indicators of aquatic health because they are long-lived, relatively immobile, sensitive to changes in the environment, and important food for resident fishes. By studying aquatic macroinvertebrate communities within a given stream segment, we can assess the current water quality condition of that stream. For each sample, total numbers of invertebrates were tallied for individual taxa and tolerance values (percent tolerant and intolerant taxa) were calculated. In addition, EPT (*Ephemeroptera*, *Plecoptera*, and *Trichoptera* taxa) Richness Index values and modified Hilsenhoff's Biotic Index (HBI) values, which are known water quality indicators, were also calculated for each site (Lenz 1997).

EPT Richness Index is calculated by tallying distinct invertebrate taxa belonging to the insect orders *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), and *Trichoptera* (caddisflies). EPT taxa are pollution-sensitive and respond readily to environmental changes. Generally, numbers of EPT taxa increase with lower water temperatures, increased DO concentrations, and little organic pollution, and decrease with higher water temperatures, decreased DO concentrations, and increased organic pollution. By contrast, organisms that are least sensitive to water pollution are in the non-insect orders *Oligochaeta* (segmented worms) and *Hirudinea* (leeches), and in the insect orders *Odonata* (dragonflies/damselflies), and *Diptera* (true flies).

Modified HBI values are obtained by evaluating the number of benthic invertebrates in the phylum *Arthropoda* at a site and their tolerance to pollution to ascertain the degree to which organic compounds, elevated temperatures, low DO, and other stressors are likely to be present (Hilsenoff 1987; 1988; USGS 1999). Each benthic invertebrate is assigned a tolerance value from 0 to 10, with 0 assigned to invertebrates least tolerant to pollution and 10 assigned to invertebrates most tolerant of pollution. A low HBI value indicates excellent water quality with no pollution; a high HBI value indicates poor water quality with high amounts of pollution.

During 2005, sample site selection was based primarily on location, accessibility, water depth, and a minimum riffle or riffle-run stretch of at least 15 meters. Basic water quality measurements collected at each site included water temperature, DO, pH, specific conductance, turbidity, and stream discharge. A Surber net sampler (0.09-m^2 plot and 500-micron mesh) was used to quantitatively sample riffle habitats within the sample reach; an Eckman dredge (0.02-m^2 plot and 500-micron mesh screen) was used for invertebrate sampling in deeper, slow-moving streams. Individual plot areas were characterized by percent coverage of substrate, silt, and vegetation (i.e., aquatic macrophytes and algae) by using a 20-cm^2 piece of Plexiglas to view underwater benthic habitat. Following substrate characterization, aquatic benthic macroinvertebrates were collected by gently rubbing the surface area of cobble and coarse gravel by hand and thoroughly scrubbing the plot area with a soft bristle brush.

Generally, macroinvertebrate collection in the park is focused on aquatic systems threatened by anthropogenic sources. For example, ongoing road construction projects are a continual concern to park resource managers. Many roads within the park are decades old, and in various stages of disrepair. These roads often parallel stream and river corridors. Renovation of these roads poses potential risks to aquatic systems through sedimentation and stream channel alteration. Between 2002 and 2005, the Aquatics Section sampled 21 sites from 13 streams in response to ongoing or proposed road construction projects in YNP. Streams (and number of sites) sampled were: Alum Creek (1), Antelope Creek (1), Elk Antler Creek (1), Gardner River (1), Gibbon River (5), Glen Creek (1), Middle Creek (2) and an associated unnamed tributary (1), Mammoth Crystal Spring (1), Obsidian Creek (4), Otter Creek (1), Pelican Creek (1), and Trout Creek (1) (Figure 1). Soda Butte Creek was also sampled at the park boundary in collaboration with the NPS I&M program. In 2002, the


NPS/JEFF ARNOLD

Stonefly collected from the Gibbon River.

Montana Department of Environmental Quality determined a 4.2-mile segment of Soda Butte Creek, from the McLaren mine tailings near Cooke City, Montana, to the YNP boundary, to be only partially supporting aquatic life and coldwater fisheries due to metals contamination from the McLaren mine tailings (MDEQ 2002). The designation places this section of Soda Butte Creek on Montana's impaired 303(d) list. Soda Butte Creek is not listed as impaired after it enters YNP, but remains at risk from metals contamination during spring snowmelt and after extreme rain events. In addition to invertebrate collections on Soda Butte Creek, Aquatics staff sampled for total and dissolved metals (arsenic, copper, iron, and selenium) in the water column, and for sediment during the spring and fall.

Yellowstone River Between Tower and Yellowstone Lake

This sample area encompasses streams that enter the upper Yellowstone River between Tower Junction and Yellowstone Lake. In fall 2003, reconstruction and resurfacing activities began on two road segments between Lake Village and Tower Junction: (1) the road from Canyon Village to Tower Junction, and (2) the road between Pelican Creek and Canyon Village. In response to these activities, Aquatics Section staff sampled Antelope Creek near Tower Junction (2002–2005) and five streams in Hayden and Pelican valleys (Otter, Alum, Trout, Elk Antler, and Pelican creeks, 2003–2004). Hydrology, flow characteristics, and thermal contributions vary considerably between these two sample areas. Antelope Creek, which

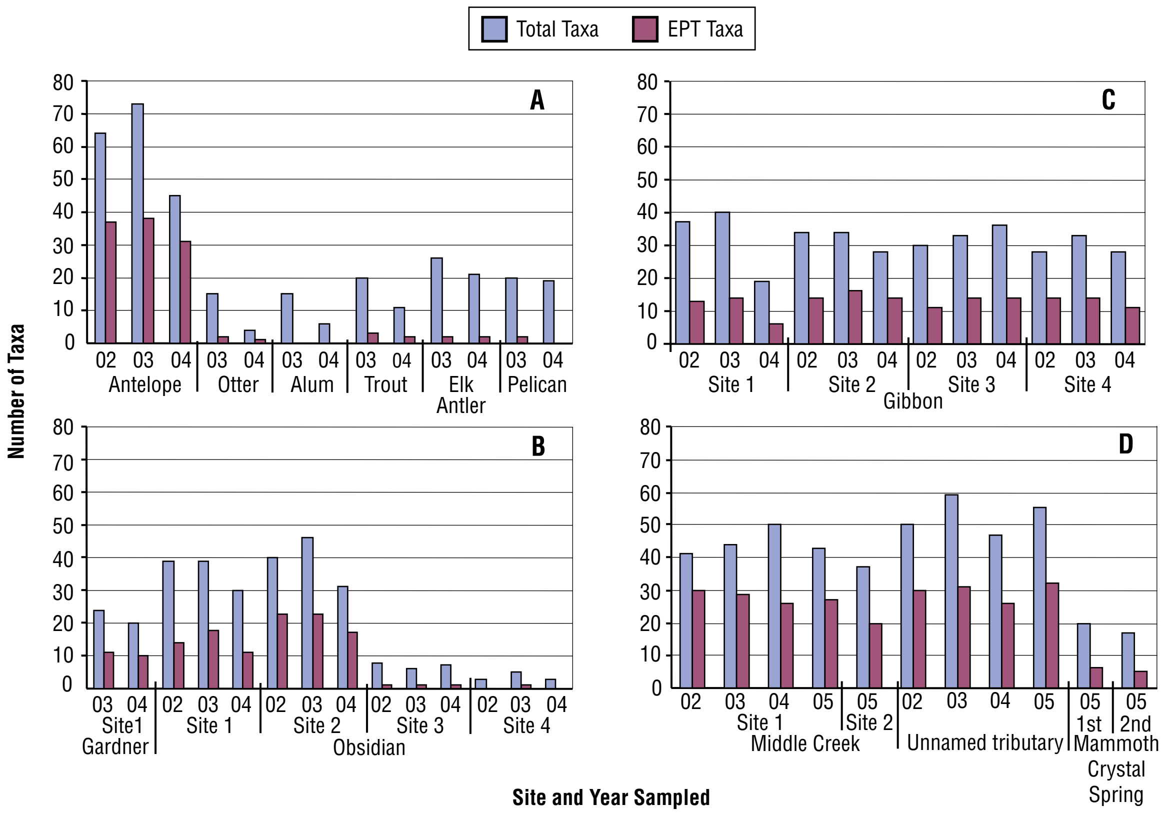


Figure 19. Total aquatic invertebrate taxa and EPT taxa for streams sampled in conjunction with road reconstruction activities in Yellowstone National Park, 2002–2005. Data represents streams sampled within the Yellowstone River drainage (A and B); the Madison River drainage (C); and Middle Creek drainage (D).

parallels the road near Tower Junction, has a moderately steep gradient, considerable canopy cover, and substrates composed almost entirely of large boulders, cobble, and coarse gravel. Thermal areas are absent from this drainage. Streams sampled in Hayden and Pelican valleys have low gradients, little canopy cover, and fine sediments primarily composed of sand and silt. Thermal areas found in the upper reaches of all five watersheds can dramatically alter chemical and physical characteristics of the water, thus affecting aquatic biota. In addition, these sites are inundated by the Yellowstone River (Yellowstone Lake in the case of Pelican Creek) during the spring and summer high-flow periods.

The aquatic invertebrate community on Antelope Creek is quite diverse, with 94 taxa collected over a three-year period (2002–2004). Seventy-three of these taxa were represented in the 2003 sample—the highest number of taxa collected from all sites in YNP since the surveys began in 2002 (Figure 19a). Numbers of EPT taxa were also high for the three sample years, ranging between 31 and 38 taxa. The high diversity of aquatic invertebrates on Antelope Creek can be attributed to the wide range of in-stream habitat, including a mixed variety of substrate sizes (boulders, cobble, gravel, and sand) and abundant coarse woody debris that is present throughout the stream reach. The shaded stream and moderately high gradient provide the lower temperatures and higher DO favored by EPT taxa. This stream ranked from very good to excellent on the HBI for the three-year period (2002–2004).

Invertebrate communities found within the five streams sampled between Lake and Canyon villages represented a stark contrast to those within Antelope Creek. Water temperature and DO varied considerably among all sites depending on time of day sampled. During both sample years, Alum Creek, which has the greatest contribution of thermal activity, had the highest

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Water quality technician Hunter Hutchinson filtering water for chloride analysis.

pH (range 8.3–8.9) and specific conductance (range 1,055–1,101 µScm-1) of the five streams sampled. Trout and Elk Antler creeks, located near the south end of Hayden Valley, had comparable pH (range 7.3–7.7) and specific conductance values (range 170–236 µScm-1) for both years sampled. A total of 56 taxa were collected from the five streams, with most invertebrate taxa obtained from Elk Antler Creek (Figure 19a), which also had the most diverse in-stream habitat (i.e., greater variety of substrate) than the other four sites. Numbers of EPT taxa were low among all sites; three was the highest number, collected from Trout Creek in 2003. Although the numbers and types of aquatic invertebrates found in this section of the park are not typical of most coldwater streams, they are characteristic of streams that exhibit low gradient and very little in-stream habitat. The lower numbers of invertebrates encountered during the second year of sampling can likely be attributed to annual variation of aquatic communities rather than effects of road construction activities.

Impacts of Roads on the Gardner River

The Gardner River, located in the north-central portion of YNP, is a major tributary to the Yellowstone River. Sampling in this area primarily focused on the road segment between Norris Junction and the North Entrance (Figure 1). Road improvement activities here have been sporadic over the past five years, mainly consisting of localized repair work and a resurfacing project between Norris Junction and Golden Gate in summer 2003. Streams (and number of sites sampled), included the Gardner River (1), Obsidian Creek (4), and Glen Creek (1). Sampling on the Gardner River was conducted near the main road just south of the park boundary. This area is several miles downstream of Boiling River (a thermal feature), and has a high gradient, low canopy cover, and a high percent of large substrates. Twenty-eight taxa were collected from this site between 2003 and 2004, of which 24 were collected during the 2003 sample year. The number of EPT was relatively low, with 11 and 10 EPT taxa collected, respectively, in 2003 and 2004. HBI indices for both sample years rated this stream from fair (2004) to fairly poor (2003). The lower HBI rating for this stream is most likely attributed to the high volume of thermal waters entering from the Boiling River.

Beginning in 2002, macroinvertebrates have been collected annually from four sites on Obsidian Creek to obtain baseline information from this stream with heavy geothermal contributions. Eighty-three taxa were collected from four sites on Obsidian Creek between 2002 and 2004. The greatest number of taxa collected during a sampling event was 46, occurring at site 2 during 2003 (Figure 19b). Sites 3 and 4 had the fewest numbers of taxa (range 3–8) during the three-year sample period. These two sites receive waters from various geothermal sources and, as a result, typically exhibit low DO and high temperatures. They are also very acidic. These features contribute to a benthic macroinvertebrate community with low diversity and a tolerance for extreme environmental conditions. Typically, invertebrates collected from these two stream sections belong to the insect orders *Diptera* (true flies) and *Odonata* (dragonflies/damselflies).

Road Re-route in the Gibbon River Canyon

The Gibbon River is located in the west-central portion of YNP, and is a major tributary to the Madison River. During the summer of 2001, major reconstruction and widening activities began on the road segment between Norris and Madison junctions, a large portion of which parallels the Gibbon River. Aquatics Section staff began to monitor aquatic macroinvertebrates and other water quality parameters here in 2002 (Figure 1). In general, all sites on the Gibbon River exhibited similar patterns for total numbers of taxa and EPT taxa for all sample years (Figure 19c). The greatest number of total taxa (40) and least number of total taxa (19) were collected from site 1 during 2003 and 2004, respectively. Generally, HBI values rated this stream between fair and fairly poor. This is likely a result of thermal activity rather than road construction. In addition, the New Zealand mudsnail, an exotic species that competes with native invertebrates for food and habitat, was collected from the first three sites on the Gibbon River, and is now documented to occur above Gibbon Falls. During 2002, this species alone comprised between 38 and 60% of the total invertebrates collected from these three sites. However, through subsequent sampling, it appears that this nuisance species has been declining within the sampling areas (Figure 20).

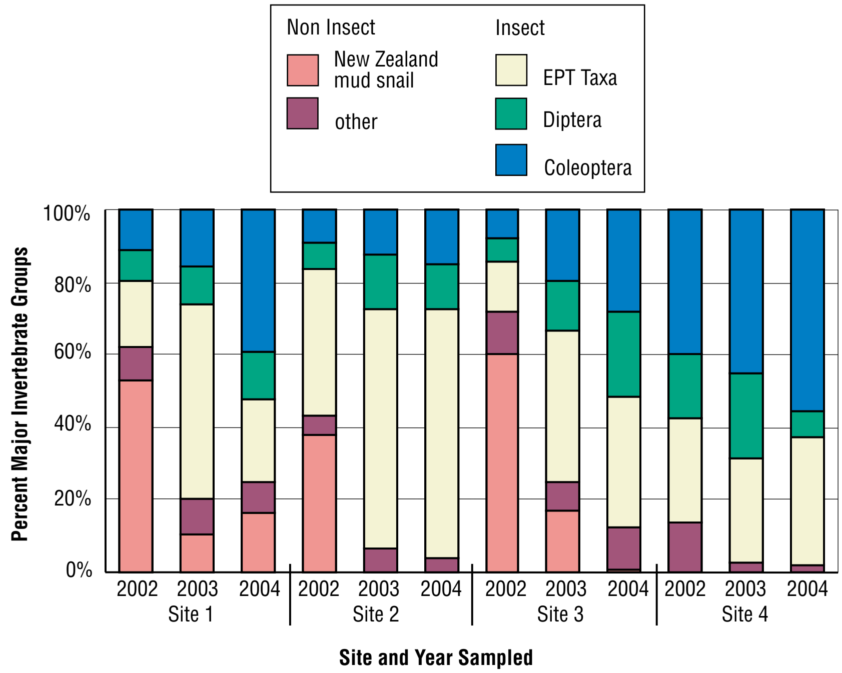

Figure 20. Percentage of major invertebrate groups collected from four sites on the Gibbon River, 2002–2004.

Water Quality Monitoring at Mammoth Crystal Spring

Middle Creek is located in the east-central portion of YNP; its headwaters are near the base of Top Notch Peak of the Absaroka Mountain Range. The mainstem of Middle Creek flows in an easterly direction for approximately 12 km before leaving the park. Within YNP, the lower 10 km of the creek parallel the East Entrance road, with the last three km flowing directly adjacent to the road. The watershed of Middle Creek is relatively small, with a total catchment area of approximately 8,414 hectares contained within the borders of YNP. Middle Creek exits YNP near the East Entrance and flows another three km before it merges with the North Fork Shoshone River.

Benthic macroinvertebrate sampling began within the Middle Creek drainage during late August 2002 (Arnold and Koel 2006). Two sites were established: one on the mainstem of Middle Creek near the East Entrance, another on an unnamed tributary at a location directly downstream from the East Entrance road crossing (Figure 1). Between 2002 and 2005, both sites were sampled once each year during late August or early September. Because of recent concerns about road construction activity within the Middle Creek drainage, two additional stream sites were sampled during late August 2005, near the vicinity of Mammoth Crystal Spring. Mammoth Crystal Spring is a small tributary of Middle Creek whose headwaters originate near Sylvan Pass. The geology of the Sylvan Pass area is dominated by talus generated by adjacent mountains. A large gravel mine and rock-crushing operation is the primary land use in the vicinity, and there is concern that increased turbidity and sediment loads from the operation could threaten the aquatic biotic

NPS/JEFF ARNOLD

Mammoth Crystal Spring.

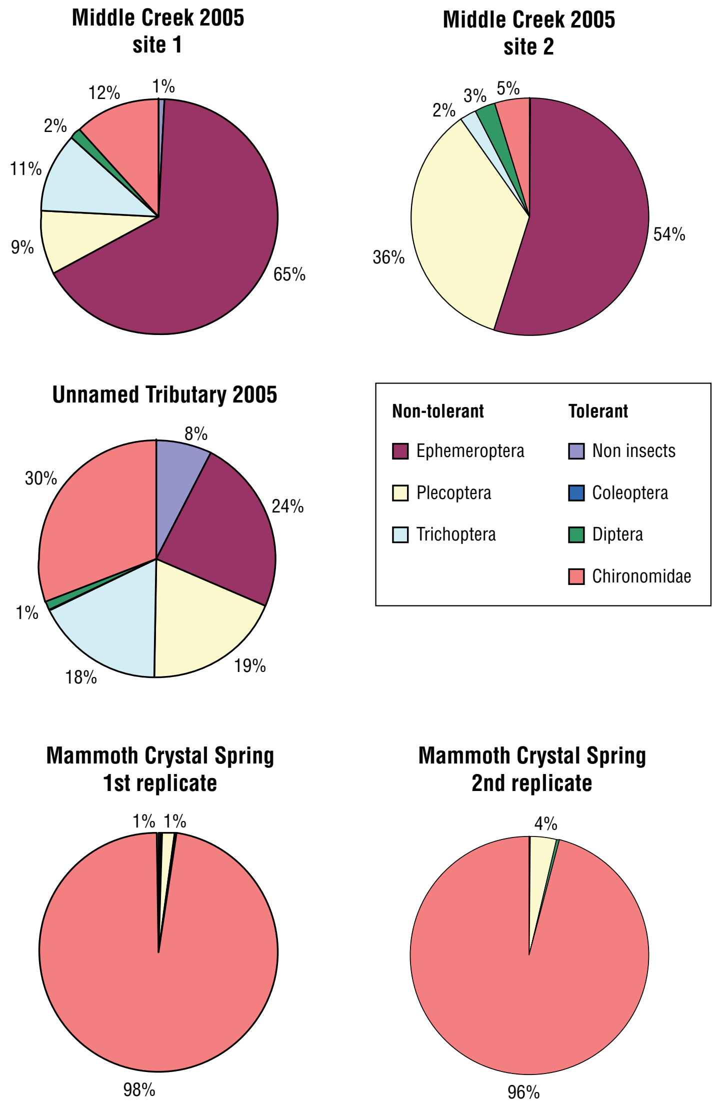

Figure 21. Percentage of major invertebrate groups collected from the Middle Creek drainage during 2005.

community and the overall health of Middle Creek.

A total of 113 unique invertebrate taxa were collected from the Middle Creek drainage from 2002 to 2005. Distinct benthic invertebrate taxa from individual locations ranged from 23 at the Mammoth Crystal Spring site (one year of collection) to 82 at the unnamed tributary (four years of collection). Chironomids (midges), a group of aquatic insects that are generally tolerant of adverse environmental conditions, dominated the invertebrate community at Mammoth Crystal Spring. The high abundance of chironomids is one indication that this stream reach is under severe environmental stress, most likely caused by increases in turbidity and stream embeddedness.

EPT taxa were most abundant on the unnamed tributary (range 26–32) and least abundant at the Mammoth Crystal Spring site (range 5–6). By comparison, 20 EPT taxa were collected from the Middle Creek site adjacent to Mammoth Crystal Spring. Middle Creek near the park boundary also had a high number of EPT taxa for all years combined (range 27–30) (Figure 19d).

As a group, EPT taxa dominated the mainstem of Middle Creek and the unnamed tributary segment. Total percent of EPT taxa combined for Middle Creek near the park boundary had a range between 74 and 86%, with the lowest percentage occurring during the 2004 sample year. Total percent of EPT taxa combined for the unnamed tributary was between 29 and 62%, with the lowest percentage also occurring during the 2004 sample year. The upstream site on Middle Creek exhibited the highest percent of EPT taxa for all sites and all years combined (92%), while the invertebrates collected at Mammoth Crystal Spring had the lowest percent of EPT for all sites and combined years, with <2% EPT taxa for the first replicate sample and <4% EPT taxa for the second replicate sample. Dipterans, primarily chironomids, made up the remainder of the invertebrate taxa collected from each sample location (Figure 21).

Regulatory Monitoring on Soda Butte Creek

During 2005, field parameters including water temperature, dissolved oxygen, pH, specific conductivity, and turbidity were collected from this site once every two weeks as part of YNP's long-term water quality and ecosystem health program. Water samples were also brought back to the Aquatics Section's field laboratory for total suspended solid analysis (TSS). Water and sediment samples were analyzed for metals (arsenic, copper, iron, and selenium) in conjunction with the NPS I&M program during June and September (Table 2). To better assess the overall health of Soda

Butte Creek at the park boundary, benthic macroinvertebrate samples were also collected on August 16, 2005. These samples were sent to an independent laboratory for processing and analysis.

All required field parameters were within ranges expected of high-elevation, coldwater streams. Natural variations were observed depending upon the time of day and month sampled. Mean water temperature was 5°C (range –0.1 to 13.7°C). Dissolved oxygen concentrations (range 7.7–10.5 mg/L) tended to correspond with changes in water temperature, with high concentrations recorded during the cold winter months and lower concentrations recorded during July and August. The pH of Soda Butte Creek was neutral to slightly basic (range 7.3–8.4), and considerably higher than pH values consistent with acid mine drainage. Values for specific conductance, turbidity, and TSS tended to be directly related to flow. In general, specific conductance tended to be lower during the spring high-flow period, turbidity and TSS higher. During the low-flow fall and winter periods, the opposite seemed to be true, with higher specific conductance values and lower turbidity and TSS values.

During June and September 2005, arsenic and selenium were below the specified laboratory reporting limits for both aqueous and sediment samples collected. Both dissolved and total copper concentrations were detected in water samples collected on the evening of June 17, 2005 (Table 2). Dissolved copper concentration (3 µg/L) was below the Montana aquatic life standards for acute and chronic levels (5.2 µg/L @ 50mg/L hardness for acute and 7.3 µg/L @ 50mg/L hardness for chronic aquatic life standards); however, total copper concentrations

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Water quality technician Hunter Hutchinson collecting water for heavy metal analysis on Soda Butte Creek.

Table 2. Concentrations for select metal concentrations on Soda Butte Creek at the park boundary during June and September 2005.

				Measured Analyte			
Date	Matrix	Analysis	Time	Arsenic	Copper	Iron	Selenium
June 17	Aqueous*	Dissolved metals	0904	<8	<3	112	<20
			1846	<8	<3	85	<20
		Total metals	0904	<8	3	658	<20
			1846	<8	11	3,270	<20
September 22	Aqueous*	Dissolved metals	0917	<8	<3	55	<20
			1809	<8	<3	51	<20
		Total metals	0917	<8	<3	219	<20
			1809	<8	<3	237	<20
September 22	Sediment**	Total metals	1809	<5	17	14,000	<5

*Aqueous measurement units are in µg/L.
**Sediment measurement units are in mg/kg.

(11 µg/L) were above the specified chronic levels of copper in water. Although copper did exceed Montana's chronic aquatic life standard, the data may not be comparable because water hardness was not measured at the time of sample collection. Copper in sediment was recorded at 17 mg/kg, which is below the 33 mg/kg listed by Montana's aquatic life standards. Samples analyzed for dissolved iron did not exceed the Montana aquatic life standard of 1,000 µg/L. However, samples analyzed for total iron exceeded this standard on the evening of June 17, 2005. During September 2005, total iron concentration was 14,000 mg/kg; there are no recognized standards for iron in sediments.

Specimen Creek Prior to Cutthroat Trout Restoration

During August 2004 and 2005, the Aquatics Section sampled the Specimen Creek drainage as part of the proposed westslope cutthroat trout restoration project.

Specimen Creek, a tributary of the Gallatin River, is located in the northwest corner of YNP, near the northwestern boundary. Specimen Creek exhibits geophysical, hydrological, and chemical characteristics that are common for high-elevation, coldwater systems of the northern Rocky Mountains. The drainage is generally covered by snow during the first part of the year, with snowmelt usually beginning in May. Snowmelt contributes to the low water temperatures and high streamflow during May and June. These high-flow conditions ultimately lead to higher turbidity and lower conductivity values. During July and August, water temperatures and specific conductivity values generally increase while turbidity values decrease. Substrate within Specimen Creek is primarily composed of cobble and coarse gravel, which is ideal for aquatic invertebrates and larval fishes. Submersed aquatic vegetation is sporadically dense in some stream segments and primarily consists of rooted aquatic bryophytes.

During August 2004 and 2005, the Aquatics Section sampled the Specimen Creek drainage as part of the proposed westslope cutthroat trout restoration project. Chemical, physical, and biological parameters were sampled at six stream locations during 2004, and at three stream locations (East Fork Specimen Creek only) during 2005 (Figure 22). High Lake, which forms the headwaters of East Fork Specimen Creek (EFSC), was also sampled for basic water quality parameters and aquatic invertebrates

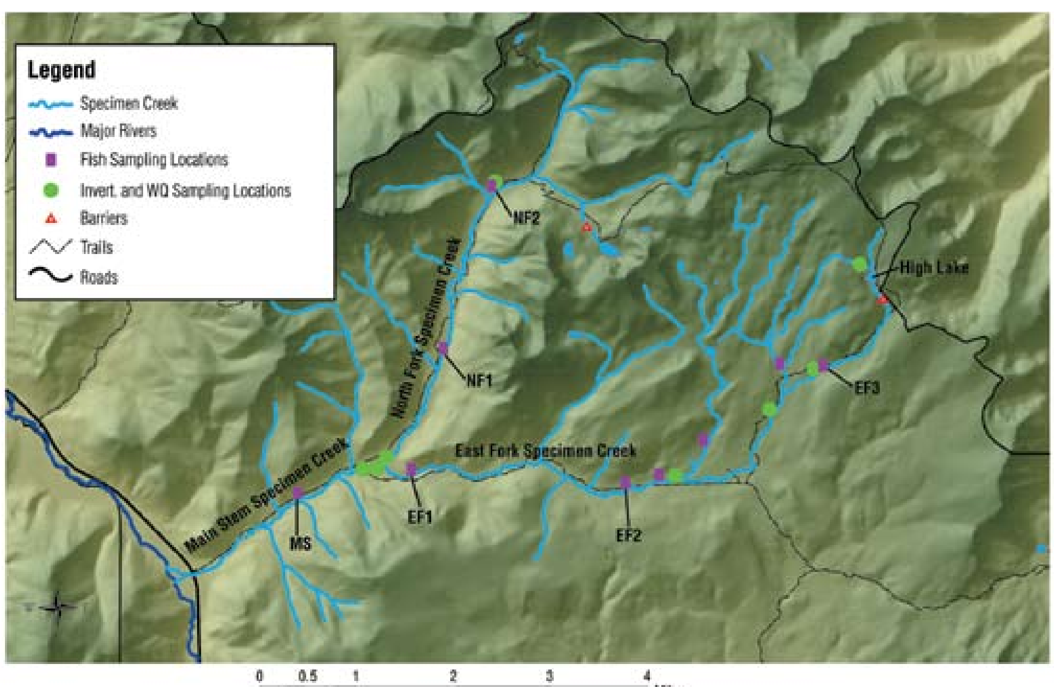

Figure 22. Sites where pre-treatment surveys were conducted for fish, macroinvertebrates (Invert.), and water quality (WQ) in the East Fork (EF), North Fork (NF), and mainstem (MS) Specimen Creek.

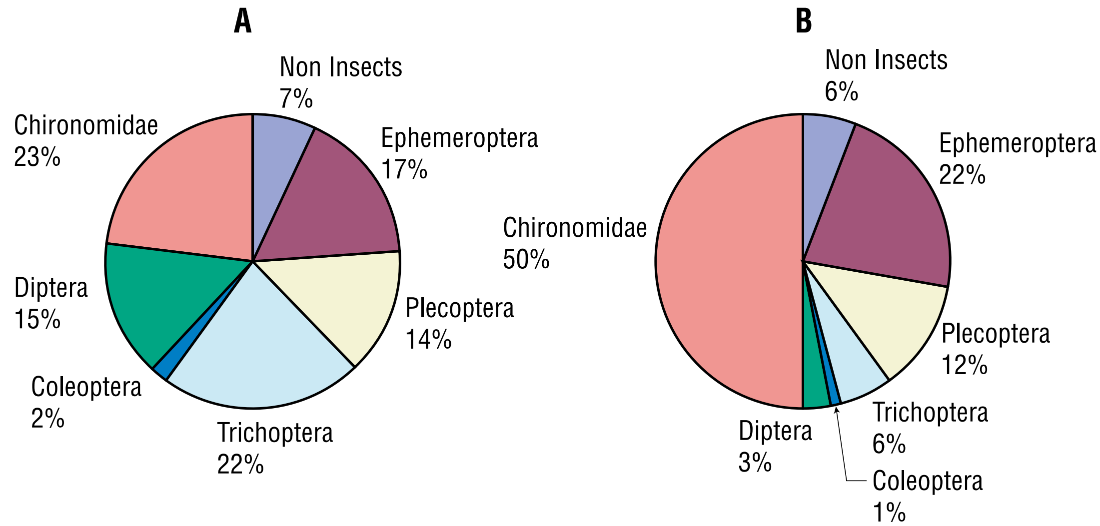

Figure 23. Percentage of major invertebrate taxa (A) and percent invertebrate abundance (B) belonging to major taxonomic groups collected from the Specimen Creek watershed, August 2004.

during August 2005. Water quality parameters collected at each site included temperature, DO, pH, specific conductivity, turbidity, and stream discharge. Aquatic invertebrates were collected to gain supplementary information regarding their presence and distribution throughout the watershed and because they are relatively long-lived, immobile, and sensitive to environmental changes.

During August 2004, 87 invertebrate taxa were collected in the Specimen Creek drainage. The least number of taxa (39) identified was collected from the mainstem of Specimen Creek; the greatest number (51) was collected from the uppermost site on EFSC. Ten taxa were found at all six locations: water mites (*Acari* spp.), two mayflies (*Baetis bicaudatus* and *Cinygmula* spp.), three stoneflies (*Sweltsa* spp., *Zapada columbiana*, and *Zapada oregonensis*), and four midge taxa (*Cricotopus nostococladius*, *Eukiefferiella* spp., *Orthocladius* spp., and *Pagastia* spp.). EPT taxa comprised 53% of the total taxa identified from all sites combined (Figure 23), while midges (order *Diptera*, family *Chironomidae*) comprised 51% of total invertebrate abundance within the Specimen Creek drainage.

During August 2005, additional benthic invertebrate samples were collected from three sites on EFSC. In addition, both benthic and plankton samples were collected from several locations on High Lake. A D-frame net was used to collect supplementary information regarding invertebrate and larval frogs from the littoral zone surrounding High Lake. Generally, sediments in High Lake are composed of fine silt and organic material. Benthic invertebrate fauna consisted of midge larvae in the deeper portions of the lake, and abundant midge larvae and fingernail clams (family *Sphaeriidae*) in shallow portions of the lake. Amphipods, fingernail clams, and dragonfly larvae were collected within the littoral zone. Open-water areas were dominated by several species of Cladocerans and Copepods, both of which are planktonic crustaceans. No larval amphibians were collected during the lake survey; however, one adult frog was collected on a subsequent trip in September 2005.

Monitoring for potential impacts of the piscicides antimycin and rotenone and/or KMnO4 (potassium permanganate, used to detoxify the piscicides) on aquatic macroinvertebrate communities and amphibian species would be conducted immediately following treatment and for several years thereafter. Impacts would be judged by comparing post-treatment data to that collected during pre-surveys at sites throughout the EFSC watershed (both treated and untreated streams) and in High Lake.

During August 2004, 87 invertebrate taxa were collected in the Specimen Creek drainage.