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Fish Communities and Related Environmental Conditions of the Lower Boise River, Southwestern Idaho, 1974-2004

Scientific Investigations Report 2006–5111

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

Cover: Photograph of shorthead sculpin (*Cottus confusus*) from lower Boise River in Barber Dam Reach, southwestern Idaho. (Photograph taken by Dorene MacCoy, U.S. Geological Survey, 2006.)

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By Dorene E. MacCoy

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Dirk A. Kempthorne, Secretary

U.S. Geological Survey
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Conversion Factors, Datums, and Abbreviations

Inch/Pound to SI

Multiply	By	To obtain
cubic foot (ft^3)	0.02832	cubic meter (m^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.189394	meter per km (m/km)
inch (in.)	2.54	centimeter (cm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

SI to Inch/Pound

gram (g)	0.03527	ounce, avoirdupois (oz)
meter (m)	1.094	yard (yd)
millimeter (mm)	0.03937	inch (in.)

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

$$°F=(1.8\times°C)+32.$$

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 either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

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).

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

Conversion Factors, Datums, and Abbreviations—Continued

Abbreviations

Abbreviation	Definition
BLM	Bureau of Land Managment
BMP	best management practice
BOR	Bureau of Reclamation
Corps	U.S. Army Corps or Engineers
CPUE	catch per unit effort
DEM	digital elevation model
DRG	digital raster graphic
EMAP	Environmental Monitoring and Assessment Program (EPA)
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System
IBI	Index of Biotic Integrity
IDEQ	Idaho Department of Environmental Quality
IDFG	Idaho Department of Fish and Game
IDWR	Idaho Department of Water Resources
IHA	Indicators of Hydrologic Alteration
IPC	Idaho Power Company
NAWQA	National Water Quality Assessment (USGS)
NMFS	National Marine Fisheries Service
NPDES	non-point discharges and elimination system
NWIS	National Water Information System (USGS)
TMDL	total daily maximum load
USGS	U.S. Geological Survey
WTF	wastewater-treatment facility

Fish Communities and Related Environmental Conditions of the Lower Boise River, Southwestern Idaho, 1974-2004

By Dorene E. MacCoy

Abstract

Within the last century, the lower Boise River has been transformed from a meandering, braided, gravel-bed river that supported large runs of salmon to a channelized, regulated, urban river that provides flood control and irrigation water to more than 1,200 square miles of land. An understanding of the current status of the river's fish communities and related environmental conditions is important to support the ongoing management of the Boise River. Therefore, fish community data from the U.S. Geological Survey and the Idaho Department of Fish and Game collected since 1974 were analyzed to describe the status of fish communities in the lower Boise River. Each set of data was collected to address different study objectives, but is combined here to provide an overall distribution of fish in the lower Boise River over the last 30 years. Twenty-two species of fish in 7 families have been identified in the lower Boise River—3 salmonidae, trout and whitefish; 2 cottidae, sculpins; 3 catostomidae, suckers; 7 cyprinidae, minnows; 4 centrarchidae, sunfish; 2 ictaluridae, catfish; and 1 cobitidae, loach.

Analysis of fish community data using an Index of Biotic Integrity (IBI) for Northwest rivers shows a decrease in the biotic integrity in a downstream direction, with the lowest IBI near the mouth of the Boise River. The number of tolerant and introduced fish were greater in the lower reaches of the river. Changes in land use, habitat, and water quality, as well as regulated streamflow have affected the lower Boise River fish community. IBI scores were negatively correlated with maximum instantaneous water temperature, specific conductance, and suspended sediment; as well as the basin land-use metrics, area of developed land, impervious surface area, and the number of major diversions upstream of a site. Fish communities in the upstream reaches were dominated by piscivorous fish, whereas the downstream reaches were dominated by tolerant, omnivorous fish. The percentage of sculpin in the river decreased in a downstream direction, and sculpin disappear completely at sites downstream of Glenwood Bridge. The sculpin population increased downstream of the Lander wastewater-treatment facility within the last decade, possibly as a result of improved wastewater treatment. The condition of the mountain whitefish (*Prosopium williamsoni*) throughout the lower Boise River was good and was similar both to the condition of mountain whitefish from least-disturbed rivers in southern Idaho and to the North American standard weight for mountain whitefish.

Introduction

Purpose and Scope

Fish community sampling has been included in some water-quality studies in the lower Boise River from 1974 to 2004. These sampling events have not been summerized in one report until now. These studies differed somewhat in objectives, sampling protocols, and findings. The data, however, can be compiled and summarized for selected reaches of the lower Boise River to further the understanding of the fish community and associated environmental conditions. The purposes of this report are to describe the occurrence and distribution of fish species of the lower Boise River using data collected by IDFG and USGS from 1974 to 2003 to describe temporal trends in fish-community structure and fish condition, and to identify environmental factors affecting occurrence, distribution, and community trends. Historic land and channel features from the late 1800s were used to compare fish habitat prior to and following hydrologic modification of the lower Boise River Basin.

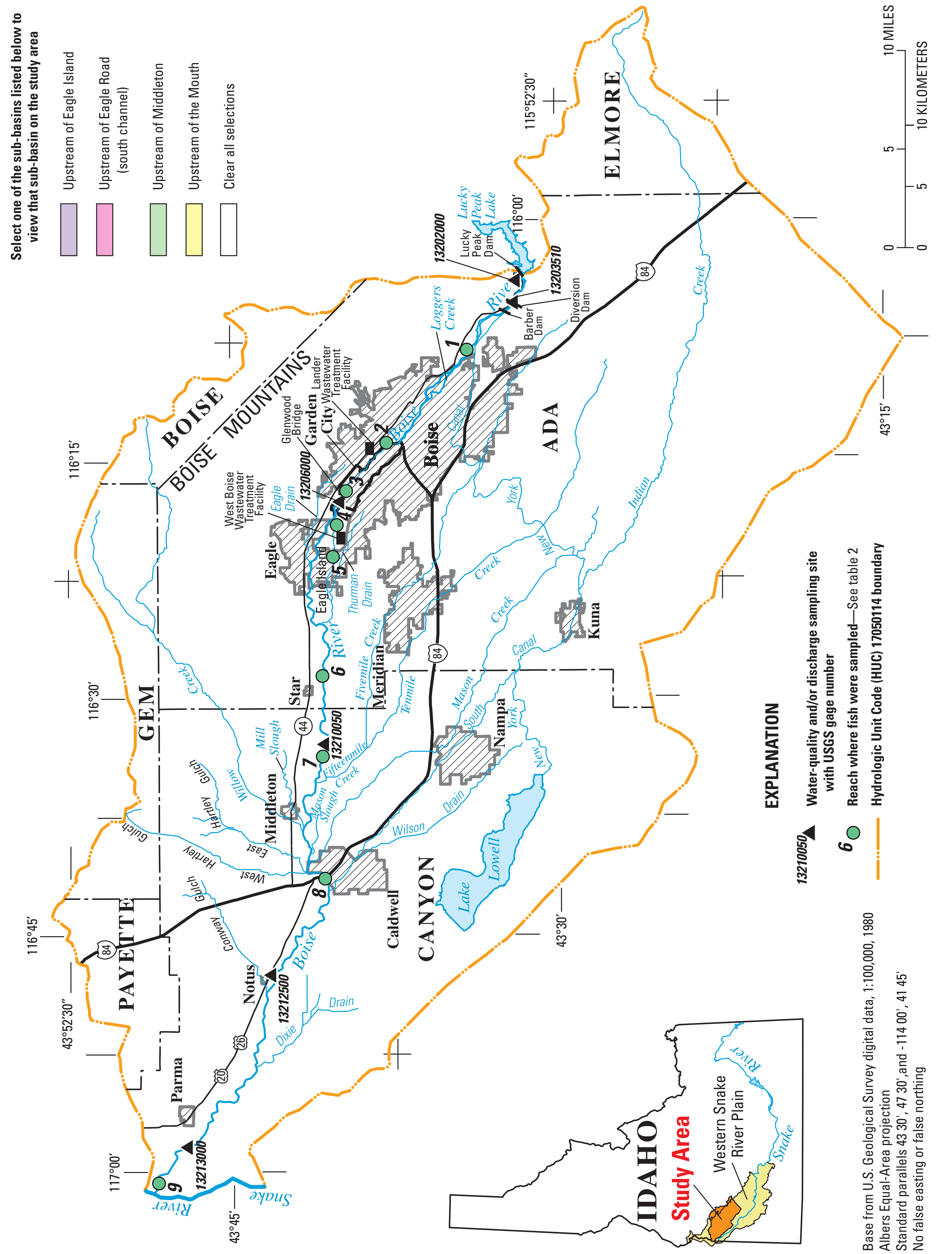

Figure 1. Location of study area in the lower Boise River Basin, southwestern Idaho.

Description of Lower Boise River Basin

The 1,290 mi^2 lower Boise River Basin is located in Ada and Canyon Counties in southwestern Idaho between Lucky Peak Dam (river mile 64) and the confluence of the Boise and Snake Rivers (river mile 395) (fig. 1). The basin contains the most industrialized and urbanized areas in Idaho. In 2000, the population in Ada and Canyon Counties was about 432,300 (U.S. Census Bureau, 2002), which is 33 percent of Idaho's population. Population in 2000 increased more than 46 percent over the 1990 population in these two counties.

The lower Boise River Basin is in the northern part of the western Snake River Plain (fig. 1), and it lies in a broad, alluvium-filled basin with several step-like terraces, or benches, which are more pronounced and continuous on the south side of the river. The upper basin, upstream of Lucky Peak Dam, is mountainous and sparsely populated. Downstream of Lucky Peak Dam, the basin floor slopes northwestward at a gradient of about 10 ft/mi. The altitude of the basin near Lucky Peak Dam is about 2,800 ft above sea level; the altitude near the river mouth is about 2,200 ft (Thomas and Dion, 1974). In addition to the lower Boise River, several tributaries are interconnected by a complex irrigation system of canals, laterals, and drains. Climate in the lower Boise River Basin is characterized as semiarid; winters are cool and wet, and summers are warm and dry. Some years considered to have normal to high amounts of precipitation are 1995 to 1998, and 2000; and some years categorized as severe drought are 1999, 2001, and 2002. Thomas and Dion (1974), Mullins (1998), and the lower Boise subbasin assessment conducted by the Idaho Department of Environmental Quality (1999) provide more information on the geography, geology, and climate of the lower Boise River Basin.

Flow in the lower Boise River between Lucky Peak Dam and the mouth is controlled primarily by reservoir regulation, irrigation withdrawals and return flows, and seepage of shallow ground water (Thomas and Dion, 1974). The three reservoirs upstream in the upper Boise River Basin have a combined storage capacity of about 1 million acre-ft. These reservoirs are managed primarily for irrigation and flood control, and secondarily for recreation and power generation (Mullins, 1998). Some storage is assigned to salmonid flow augmentation in Lucky Peak Lake as required by the National Marine Fisheries Service (NMFS) 1995 Biological Opinion for the Snake River Basin (Bureau of Reclamation, accessed March 2002, at http://www.usbr.gov/dataweb/html/boise.html).

Land use and land cover in 1994 within the lower Boise River Basin included urban activities (4 percent); irrigated agriculture, pasture, and other agriculture-related activities (47 percent); and rangeland, water, and unclassified land (49 percent) (Kramer and others, 1994). Crops in the basin consist of alfalfa hay and seed, corn and corn seed, wheat, potatoes, onions, sugar beets, barley, spearmint and peppermint, and dry edible beans (Koberg and Griswold, 2001). This land use contrasts with that in the upper Boise River Basin, which consists primarily of logging and recreation. Parts of the upper basin were heavily mined for gold during the late 1800s and early 1900s (Love and Benedict, 1940; Chandler and Chapman, 2001).

Land use in the lower Boise River Basin has undergone major changes since 1994; particularly conversions of large tracts of farmland to residential subdivisions and commercial facilities, and conversions of many residential areas in and near cities to businesses, shopping centers, and parking lots. These land-use changes typically cause a reduction in agricultural non-point runoff, and may increase urban stormwater runoff to the lower Boise River and its tributaries, depending on the development practices implemented. Under the Clean Water Act, numerous public and private entities in the lower Boise River Basin are required to seek non-point discharge and elimination system (NPDES) stormwater discharge permits. These permits require these entities to implement best management practices that reduce pollutant loads to the "maximum extent practicable" (Johanna Bell, City of Boise, written commun., April 17, 2006). U.S. Environmental Protection Agency (EPA) regulation guidance and requirements are available online at http://yosemite.epa.gov/r10/WATER.NSF/webpage/Storm+Water?OpenDocument (accessed June 15, 2006). State of Idaho guidance is available online at http://www.deq.state.id.us/water/permits_forms/permitting/catalog_bmps.cfm (accessed June 16, 2006). Boise municipal regulations and guidance are available online at the Partners for Clean Water web site at http://www.partnersforcleanwater.org (accessed June 16, 2006). The City of Boise stormwater program is implementing a plan to reduce the stormwater load of sediment (p. 61 of Lower Boise River total daily maximum load [TMDL] at http://www.lbrwqp.boise.id.us/tmdl/tmdl_4.pdf; accessed June 15, 2006) and total phosphorus. The stormwater sediment load reduction is a result of the development of a sediment TMDL (Idaho Department of Environmental Quality, 1999). Development of a total phosphorus TMDL and a temperature assessment are currently being done for the lower Boise River (Robbin Finch, City of Boise, written commun., November 2005).

Historical Changes in the Fishery

The fishery of the lower Boise has changed over time partly in response to multiple human impacts caused by development of the study area. Settlers began to divert water from the lower Boise for irrigation in the late 1800s and early 1900s; irrigation return flows were an early source of water-quality and stream habitat degradation. Also at that time, extensive mining began in the upper basin, and numerous lumber mills were operated east of Boise to supply timber for development (Stacy, 1993; Simonds, 1997). Temporal changes due to natural factors (climate change) in the lower Boise are unknown.

Soon after development began, farmers recognized the need for flood control and storage of irrigation water, which led to the 1902 "Boise Project," one of the earliest projects by the Bureau of Reclamation (Stacy, 1993; Simonds, 1997). By 1906, the New York Canal and several small irrigation projects had been built as part of the Boise Project. One of the Bureau of Reclamation's (BOR) "big dams," Arrowrock, was built in 1915 on the mainstem Boise River, about 17 mi upstream of the City of Boise. The U.S. Army Corps of Engineers (Corps) built Anderson Ranch Dam on the South Fork of the Boise River (the world's highest earthfill dam at the time of its completion in 1950). Anderson Ranch Dam is the uppermost storage facility on the Boise system located 42 mi upstream of Arrowrock Dam. Anderson Ranch Dam and Powerplant is a multiple-purpose structure that provides benefits in irrigation, power, and flood and silt control (accessed April 17, 2006, at: http://www.usbr.gov/power/data/sites/anderson/anderson.html). In 1957, the Corps built the third and final large dam, Lucky Peak, less than 10 mi upstream of the City of Boise, in response to concerns about potential flooding and to the need for additional irrigation water (Stacy, 1993). The construction of these dams affected the lower Boise fishery by blocking fish passage, changing the thermal regime and flow patterns of the river, modifying sediment transport and substrate size, and altering water quality and channel shape.

Progressive urbanization around the City of Boise increased the need to treat wastewater prior to discharge to the lower Boise River. The construction of wastewater-treatment facilities (WTFs) downstream of Boise in the early 1950s helped to disinfect wastewater entering the river, but introduced toxic concentrations of chlorine that resulted in frequent fish kills (Stacy, 1993). In the late 1950s, the lower Boise River was identified as one of the three most polluted waters in Idaho (Casey and Webb, 1996; Chandler and Chapman, 2001). In 1976, a second outlet was proposed for installation in Lucky Peak Dam to implement a minimum flow of about 150 ft^3/s during winter, which helped to dilute effluent. According to the IDEQ, minimum flow varied as a result of water allocations downstream (Idaho Department of Environmental Quality, 1999). Continuing cleanup efforts in the lower Boise River Basin include upgrading WTFs and implementing best management practices (BMPs) for urban and agricultural runoff.

Prior to construction of dams, levees, and extensive irrigation in the lower Boise River Basin, a large (as wide as 0.75 mi) hyporheic zone (an area beneath the main channel where surface water interacts with ground water) existed. The river's interaction with the hyporheic zone allowed the river to develop side channels and other habitat for refuge and areas ideal for salmon spawning and rearing (David Blew, Idaho Department of Water Resources, oral commun., 2002). Operation of the three Boise River dams for irrigation and flood control created a flow regime with higher than natural flows during the peak irrigation season (April through September) and lower than natural flows during the nonirrigation season (October through March). The change in hydraulic regime and the construction of levees has caused the lower reaches of the lower Boise River to incise to the point that depositional areas, backwater sloughs, and wetlands associated with the hyporheic zone have diminished (David Blew, Idaho Department of Water Resources, oral commun. 2002; MacCoy and Blew, 2005). For further information on the effect of dams on alluvial rivers please refer to Williams and Wolman (1984), Collier and others (1996), and the World Commission on Dams (2000).

The lower Boise fishery was described in the early 1800s as the "most renowned fishing place in the country," because of the large numbers of salmon caught there (Pratt and others, 2001). The lower reaches of the Snake and its adjoining tributaries, which include the lower Boise River, were highly productive fisheries in the early 1800s for the Shoshone-Bannock Tribes (accessed March 2005, at http://www.shoshonebannocktribes.com/fhbc.html). The historical distributions of Chinook salmon (*Onchorhynchus tshawytscha)* and steelhead (*Oncorhynchus mykiss)* were evaluated by Idaho Power Company (IPC) as part of an ongoing hydroelectric project relicensing effort for the Hells Canyon Complex on the Snake River. The Complex includes the lower Boise River as an important tributary. Chandler and Chapman (2001) documented evidence of Chinook salmon spawning in the lower reaches of the lower Boise River until the early 1860s, coincident with the time when mining and irrigation projects began. They also reported steelhead runs in the lower Boise River, as well as the presence of Pacific lamprey (*Lampetra tridentatus)* in the river near Caldwell.

Within the last century, the lower reaches of the lower Boise River changed from a thriving, cold water fish community with significant numbers of salmon and trout to a cool- and warm-water fish community. Nonindigenous warm-water fishes, including common carp (*Cyprinus carpio)*, largemouth bass (*Micropterus salmoides)*, smallmouth bass (*M. dolomieu),* bluegill (*Lepomis macrochirus)*, channel catfish (*Ictalurus punctatus)*, tadpole madtom (*Noturus gyrinus)*, and oriental weatherfish (*Misgurnus anguillicaudatus)* have been introduced into the lower Boise River since the turn of the 20th century (Mullins, 1999a; Chandler and Chapman, 2001). Some of these nonindigenous fish species are known to be detrimental to salmonid populations (Li and others, 1987; Fuller and others, 1999). The Hells Canyon Complex of dams (Brownlee, Oxbow, and Hells Canyon), built between 1959 and 1967, prevented salmonids from entering the lower Boise River (Chandler and Chapman, 2001). Chandler and Chapman (2001) concluded, following the 2001 study, that the lower Boise River was no longer suitable to support salmonid spawning because of high water temperatures (greater than 20ºC) in the late summer.

Benke (1992) designated all native rainbow trout (*Oncorhynchus mykiss*) in the Columbia River Basin east of the Cascade Mountains, which includes the lower Boise River Basin, as redband trout. The Idaho Department of Fish and Game (IDFG) has not verified that the wild rainbow trout in the lower Boise River are a genetically distinct species (Jeff Dillon, oral commun., November 2005). The American Fisheries Society has grouped redband trout and rainbow trout into one group but does recognize that with additional genetic data this could be revised (Nelson and others, 2004). The IDFG manages the lower Boise River as a "put and take" fishery through the City of Boise (Idaho Department of Fish and Game, 2000). IDFG has created a very popular urban fishery by stocking the river with hatchery-reared rainbow trout of catchable size (greater than 6 in. total length). For example, more than 56,000 rainbow trout were stocked in the lower Boise River in 2004 (accessed June 15, 2006, at http://fishandgame.idaho.gov/apps/stocking/year.cfm?region=3). In addition, IDFG has stocked Chinook salmon and steelhead in the lower Boise River.

Previous Fishery Investigations

The impairment of water quality and biological integrity in the lower Boise River and several of its tributaries has been evaluated as part of Federal and State monitoring programs, but only a few of those programs included an examination of fish communities (MacCoy, 2004). A summary of U.S. Geological Survey (USGS) and IDFG fish sampling in the lower Boise River since 1974 is shown in table 1, and the location of sampling reaches is shown in table 2.

Table 1. Summary of U.S. Geological Survey and Idaho Department of Fish and Game sampling of fish communities in the lower Boise River, southwestern Idaho, 1974 to 2004.

[**Abbreviations:** IDFG, Idaho Department of Fish and Game; USGS, U.S. Geological Survey; WAG, Lower Boise Watershed Advisory Group; WRI, Water Resources Investigation; WTF, wastewater-treatment facility]

Date	Project	Lead collection agency	Study objectives	Reference
March 1974 to February 1975	Snake River Fisheries Investigations	IDFG	Identify fish population, and habitat and water-quality characteristics	Idaho Department of Fish and Game, 1975
January 1988 to March 31, 1988	Regional Fishery Management Investigation	IDFG	Fish community assessment upstream and downstream of WTF	Frenzel and Hansen, 1988; Idaho Department of Fish and Game, 1988; Frenzel, 1990
March to April 1992	Regional Fishery Management Investigation	IDFG	Fish community assessment upstream and downstream of WTF	Idaho Department of Fish and Game, 2000
December 1993 to March 1994	Regional Fishery Management Investigation	IDFG	Characterize trout[1] and whitefish[2] population	Idaho Department of Fish and Game, 2000
February and March 1995, and October 1996	USGS WRI	USGS	Fish community assessment upstream and downstream of WTF	Mullins, 1998
December 1996 to August 1997	USGS WRI	USGS	Examine biological integrity of fish population as related to water quality	Mullins, 1999
December 2001	USGS Idaho Statewide Water Quality Network	USGS	Examine biological integrity of fish population as part of a long-term trend statewide water-quality study	MacCoy, 2004
November 2003	USGS WRI	USGS	Fish community assessment upstream and downstream of WTF	Data available on USGS web site at http://id.water.usgs.gov/projects/fish/index.html
December 2004	USGS Idaho Statewide Water Quality Network	USGS	Examine biological integrity of fish population as part of a long-term trend statewide water-quality study	Data available on USGS web site at http://id.water.usgs.gov/projects/fish/index.html

[1]Brown trout (*Salmo trutta*); rainbow trout (*Oncorhynchus mykiss*).

[2]Mountain whitefish (*Prosopium williamsoni*).

Table 2. Fish sampling reach locations, lower Boise River, southwestern Idaho, 1988–2004.

[Reach locations are shown in figure 1. Reach lengths varied according to project sampling protocol; upstream and downstream latitude and longitude given is for the maximum reach sampled using North American Datum of 1983 (NAD 83). **Abbreviations:** WTF, wastewater-treatment plant]

Reach No.	Reach name	Subbasin location	Upstream latitude/longitude	Downstream latitude/longitude
1	Barber Dam	Upstream of Eagle Island	116º08’03”W/43º34’07”N	116º09’34”W/43º34’58”N
2	Upstream of Lander WTF	Upstream of Eagle Island	116º13’53”W/43º37’02”N	116º14’05”W/43º37’23”N
3	Downstream of Lander WTF	Upstream of Eagle Island	116º15’02”W/43º38’30”N	116º16’46”W/43º39’38”N
4	Upstream of West Boise WTF	Upstream of Eagle Road	116º18’09”W/43º40’10”N	116º19’22”W/43º40’16”N
5	Downstream of WTF	Upstream of Eagle Road	116º20’23”W/43º40’30”N	116º21’15”W/43º40’29”N
6	Star	Upstream of Middleton	116º27’01”W/43º40’47”N	116º28”13”W/43º41’02”N
7	Middleton	Upstream of Middleton	116º33’34”W/43º40’55”N	116º34’17”W/43º41’03”N
8	Caldwell	Upstream of Mouth	116º41’19”W/43º40’45”N	116º41’40”W/43º40’40”N
9	Upstream of Mouth	Upstream of Mouth	116º27’03”W/43º67’41”N	116º58’16”W/43º46’41”N

Idaho Department of Fish and Game, 1974-75

The IDFG conducted a survey of fish populations and water quality in the lower Boise from its mouth upstream to Barber Dam during 1974 and 1975 (Idaho Department of Fish and Game, 1975). The 1974 sampling of 10 reaches (1 through 9 and a reach near Notus, fig. 1) of the lower Boise River was part of the Snake River Fisheries Investigation (a survey of the physical and biological information of the Snake River upstream of Brownlee Reservoir; Idaho Department of Fish and Game, 1975). The lower Boise River was included in the investigation because of its importance to the Snake River drainage. This study was the first extensive assessment of the fish community in the lower Boise River. The IDFG found abundant mountain whitefish populations in the Barber Dam to Star reach. The report concluded that these fish were competing with juvenile and adult trout, and it recommended cropping the population. The IDFG also recommended that this reach be managed as a cold water fishery. The Star to mouth reach was dominated by warm water species (mainly in the sloughs), and the IDFG recommended that the reach be managed as a warm water fishery. They also stated that minimum and maximum flow requirements should be established for the well being of aquatic life (Idaho Department of Fish and Game, 1975).

U.S. Geological Survey, 1988

In 1988, the USGS evaluated the effect of multiple wastewater discharges on water quality and aquatic communities in the lower Boise River (Frenzel, 1988; 1990). The study was designed primarily to assess trace-element effects on aquatic communities. Artificial substrates were used to assess macroinvertebrate communities, and IDFG assisted in the assessment of the fish community by electrofishing reaches 2 through 5 (fig. 1) upstream and downstream of the Lander and West Boise WTFs (reaches 2, 3, 4, and 5; fig. 1). Frenzel (1988) found no evidence of adverse affects of the effluent from these facilities on the macroinvertebrate and fish communities. Asbridge and Bjornn (1988) included information from the USGS study and additional data in a survey of potential and available salmonid habitat in the lower Boise River. They concluded that the lower Boise River was not ideally suited to trout due to high velocities in the upper reaches and high temperature in the lower reaches. Winter cover also was mentioned as affecting trout abundance.

Idaho Department of Fish and Game, 1992 and 1993-94

Population estimates of trout and mountain whitefish were conducted by IDFG during the spring of 1992 and the winter of 1993–94 at reach locations similar to those in 1988 through the City of Boise (Frenzel, 1988). Idaho Department of Fish and Game (2000) noted that sportfish populations continued to decrease, with the most likely cause being the low winter flows.

U.S. Geological Survey, 1995–96

As a follow-up study to the 1988 and 1992 studies, the USGS, in cooperation with the City of Boise, sampled fish communities upstream and downstream of the Lander and West Boise WTFs during the spring of 1995 and the autumn of 1996 (reaches 2 through 5, fig. 1). An IBI was calculated using percentages of sculpin, salmonids, pollution-tolerant species, invertivores, juvenile trout (assumed to be those less than 100 mm total length), juvenile mountain whitefish (assumed to be those less than 210 mm total length), and percentage of individuals with one or more anomalies (Mullins, 1999b). High flows in autumn of 1996 in the lower Boise River affected sampling efforts. Therefore, accurate species abundance estimates could not be made, and this data are not included in this report. The IBI scores were similar among the four sampling reaches, although Mullins (1999b) noted variability between riffles sampled within a reach. He suggested that more frequent sampling would help to determine any statistical differences between reaches. Sculpins were only found upstream of the Lander WTF, with shorthead sculpin (*Cottus confusus*) being the most abundant species (appendix A). Mullins (1996a) also noted the absence of juvenile trout at all locations, which may have been an indication of poor natural recruitment.

U.S. Geological Survey, 1996–97

The USGS conducted fish-community surveys at five locations (reaches 1, 3, 7, 8 and 9; fig. 1) during December 1996 and August 1997, as part of an ongoing water-quality and biological integrity study done in cooperation with IDEQ and the Lower Boise River Water Quality Plan (Mullins, 1999a). Representative reaches at each location were sampled with both boat and backpack electrofishing equipment. IBI for each reach using five metrics (percentages of sculpin, salmonids, pollution-tolerant species, invertivores, and individual anomalies) were summarized only for the data collected in 1996 (Mullins, 1999a). The 1997 data were of poor quality due to problems associated with high-flow sampling, and those data were not used in the assessment of biotic integrity. The IBI scores calculated for reaches 3, 7, and 9 (fig. 1) in 1996 indicated a longitudinal decrease in biological integrity, with the lowest score from reach 9 near the mouth (fig. 1). At reach 9, the fish community consisted of a high percentage of pollution-tolerant species, a reduced number of salmonids and invertivores, and a relatively high occurrence of anomalies. Mullins (1999a) concluded that the lower Boise River was moderately impaired in the upper reaches, and that river water quality decreased gradually downstream. He described a lack of well-developed pools, riffles, and fish cover, and he also noted extended low winter flow and high summer water temperatures in the lower reaches. Mullins (1999a) recommended monitoring the fish community and habitat in the lower Boise River on a 3- to 5-year cycle.

U.S. Geological Survey, 2001 and 2004

The USGS sampled the fish community at reach 3 (fig. 1) in 2001 and 2004, as part of the Idaho Statewide Water Quality Network. Data from 2001 were summarized in MacCoy (2004), but the data collected in 2004 have not been previously published. The IBI score calculated for reach 3 in 2001 (68) was higher than the score calculated for the 1996 data (57), indicating a possible improvement to the fish community.

U.S. Geological Survey and City of Boise, 2003

In November 2003, the USGS, in cooperation with the City of Boise, conducted another follow-up study of the fish community upstream and downstream of the WTFs. This evaluation included reaches 1 through 5 (fig. 1), and the sampling reaches were extended to 40 times the channel width (about 1 mi long) to capture the maximum fish diversity in each reach as described by Maret and Ott (2003). The 2003 data have not been previously published.

Data Compilation and Analysis

Subbasins, Sampling Reaches, and Water-Quality Sampling Locations

The lower Boise River Basin was divided into four subbasins to assess associations in land use, habitat, and fish community. The divisions were selected using both geomorphic channel features and water-quality aspects of the river. These divisions are described in more detail in MacCoy and Blew (2005). These subbasins include: upstream of Eagle Island to Lucky Peak Dam (upstream of Eagle Island); upstream of the south channel of the Boise River at Eagle Island downstream of West Boise WTF at Eagle Road (upstream of Eagle Road); upstream of Middleton (Middleton); and upstream of mouth (Mouth) (fig. 1). Each subbasin consists of one to three fish sampling reaches and one to two water-quality sampling locations (table 2). Beginning in 1994, the USGS sampled water quality at four lower Boise River sites: Boise River below Diversion Dam 13203510 (Diversion), Boise River above Glenwood Bridge 1320600 (Glenwood), Boise River near Middleton 13210050 (Middleton), and Boise River near Parma 13213000 (Parma) (fig. 1). Diversion and Glenwood are in the upstream of Eagle Island subbasin, Middleton is in the Middleton subbasin, and Parma is in the upstream of Mouth subbasin.

Data-Collection Methods

Habitat, Hydrology, and Water Quality

Data pertaining to recent land and channel features were obtained primarily from biological surveys done between 1994 and 2002 by the USGS (Mullins, 1999a). With the exception of measurements of channel width, most of the data collected were qualitative. Recent measurements of bankfull width were obtained from cross sections of the lower Boise River surveyed in 1997 and 1998 (Hortness and Werner, 1999) and from surveys at biological sampling sites (Mullins, 1999a).

Historic geomorphic data (1867 and 1868) are used to compare fish habitat prior to and following hydrologic modification in the lower Boise River Basin. Land-cover data from cadastral survey notes obtained from the Bureau of Land Management (BLM) for the lower Boise Valley were used to re-create the “historical” lower Boise River. These data were summarized by the Idaho Department of Water Resources (David Blew, written commun., 2003) and in the methods published by MacCoy and Blew (2005). In their notes, surveyors documented slough and meander widths and azimuths, which typically were measured at the mean high-water mark. Therefore, these measurements were used to indicate bankfull width of the river and tributaries. The surveyors also noted land features such as gravel or sand bars.

Flow records were obtained from the National Water Information System web site (NWIS). Historic and recent flow conditions were compared by analyzing discharge data from the USGS gaging station “Boise River at Boise,” (13202000), which has the longest record on the lower Boise River from 1895 to 2002 (U.S. Geological Survey National Water Information System web site, accessed October 1, 2005, at http://nwis.waterdata.usgs.gov/id/nwis/qwdata). The Indicators of Hydrologic Alteration (IHA) program was used to evaluate the magnitude of change in the natural flow regime following dam construction (The Nature Conservancy, 2001). The magnitude and variation of mean monthly discharges and the average monthly discharges for December and August were summarized for the Boise River at the Boise streamflow gaging station.

Water-quality collection methods and data on the lower Boise River from 1994 to 2002 presented in this report are published in MacCoy (2004). Temperature, dissolved oxygen, pH, and specific conductance data were based on instantaneous readings. Data on suspended sediment and nutrients were based on depth- and width-integrated water samples.

Fish Community

Fish-community data were compiled from studies conducted by the USGS and IDFG between 1974 and 2004 (table 1). U.S. Geological Survey fish sampling reaches were usually located near water-quality sampling locations in the lower Boise River (MacCoy, 2004). Fish communities were assessed by electrofishing a representative reach of river using protocols developed by the USGS National Water Quality Assessment (NAWQA) Program (Meador and others, 1993). Shallow riffle areas were sampled using backpack electrofishing equipment (Smith-Root models 12 and 12A), and deep-water areas were sampled using a drift boat or a pontoon boat carrying a Smith-Root model VI-A and a 5,000-watt, 240-volt generator with either multiple handheld or two bow-mounted electrodes. Netting crews consisted of four to six people and included personnel from IDFG, USGS, and the City of Boise. Usually two electrofishing passes were made through each reach, and an effort was made to sample all representative habitat types. Captured fish were held in livewells until they were processed and released. Fish were identified, counted, measured, weighed, and examined for types and numbers of anomalies. Fish were identified onsite by Dorene MacCoy and Terry Maret, USGS; Don Zoroban, IDEQ; and Dale Allen, IDFG using taxonomic names described in Nelson and others (2004). Voucher samples were taken of selected species, and those samples are in the collection of the Orma J. Smith Museum of Natural History, Albertson College, Caldwell, Idaho. The taxonomy of sculpin (*Cottus sp.*) and dace (*Rhinichthys sp.)* was verified by Dr. Carl E. Bond and Dr. Douglas F. Markel, Oregon State University, Corvallis, Oregon, and by Dr. Gordon Haas, University of British Columbia, Vancouver, Canada.

Sampling techniques in November 2003 and August 2004 changed slightly with the use of a raft-mounted electrofisher and techniques described in the U.S. Environmental Protection Agency’s Environmental Monitoring and Assessment Program (EMAP) fish sampling protocols (Peck and others, 2002). Each sampling reach was 40 times the mean channel width, or about 1 mi. A raft-mounted electrofisher was used to collect fish from near-shore habitats while floating downstream through the entire sampling reach. In addition, 100 m of riffle within each reach were sampled using a backpack electrofisher to capture small benthic species often missed by boat electrofishing. Sample data for these studies are summarized on the USGS Web site, accessed June 15, 2006, at http://id.water.usgs.gov/projects/fish/index.html. Increasing the reach length provided a larger sample of the population but the percentage of composition of each species would be similar.

General locations of IDFG sampling areas were predetermined by either the senior IDFG fishery research biologist or cooperators such as the USGS and the City of Boise. The IDFG used boat-mounted or shore-based electrofishing equipment for all fish community sampling. For the 1974 sampling, boats were powered upstream against the current while electrofishing (Idaho Department of Fish and Game, 1975). Boat-mounted electrofishing equipment using a variable voltage pulsator (0-600 watts DC) was powered by a 2,000 watt portable generator. This equipment was mounted on either an aluminum jet boat or on a smaller boat where maneuverability was limited. All species were counted, game fish were weighed and measured, and a summary of findings was produced (Idaho Department of Fish and Game, 1975).

In 1988, the City of Boise and the USGS worked with the IDFG to choose sampling locations in reaches 2 through 5 (fig. 1; table 2). A three-pass population depletion electrofishing technique (Zippin, 1958) was used at six 200-m reaches from Diversion Dam to Star. Crews in two drift electrofishing boats sampled from upstream to downstream in each reach using Coffelt model VVP 2-E electrofishers with direct current (600 volt) on a pulse frequency of 120 and a pulse width of 5 (Idaho Department of Fish and Game, 1988). Both game and nongame species were placed in livewells and counted separately. The game fish were weighed and measured for their total length. Nongame fish were counted, and all fish were returned to the river following the third pass. Attempts were made to use block nets at the upstream and downstream ends of each reach, but organic debris and higher streamflows made it difficult to keep the nets in place (Idaho Department of Fish and Game, 1988).

In 1992 and 1994, estimation techniques similar to the 1988 sampling were used (J. Dillon, Idaho Department of Fish and Game, written commun., 2004). In 1994, electrofishing efficiency was improved with new equipment. A new Coffelt VVP-15 electrofisher with a 5,000-watt, shore-based generator and five anodes was used (Idaho Department of Fish and Game, 2000). In 1994, the focus of the sampling was to better characterize the trout and mountain whitefish populations in the river. No nongame species were identified. The 1994 data are mentioned, but not used in statistical summaries in this report due to the lack of nongame species.

Analytical Methods

As a result of the Clean Water Act's objective to "restore and maintain the physical, chemical, and biological integrity of the Nation's waters," there has been a growing focus on the development of biocriteria in State water-quality standards. Increasingly, biological monitoring programs and biocriteria development have expanded to include large rivers. In the United States, the IBI is used by the EPA and many State agencies to assess fish assemblage structure because it serves as an indicator of the history and current health or condition of a stream system (Karr, 1991). The IDEQ has recently published monitoring protocols and an IBI to evaluate large rivers of Idaho using aquatic organisms and habitat measures (Grafe, 2002; Mebane and others, 2003). Zaroban and others (1999) classified Northwest fish species into various attributes to facilitate the evaluation of surface-water resource conditions.

The fish community was evaluated using an IBI (Mebane and others, 2003) that consists of: (1) number of cold water native species; (2) percentage of abundance of sculpin; (3) percentage of cold water species; (4) percentage of sensitive native individuals; (5) percentage of tolerant individuals; (6) number of nonindigenous species; (7) catch per unit effort (CPUE) of cold water fish; (8) percentage of fish with anomalies (deformities, eroded fins, lesions, or tumors); (9) number of trout age classes (determined by length distribution); and (10) percentage of individual species of common carp. Hatchery fish were not included in the IBI calculations. Each of these 10 metrics was standardized and weighted to produce a score ranging from 0 to 100. Within this range, three classifications of biotic integrity can be identified. According to Mebane and others (2003), sites with scores between 75 and 100 exhibit high biotic integrity with minimal disturbance, and they possess an abundant and diverse community of native cold water species (classification = high biotic integrity). Sites with scores between 50 and 74 are of somewhat lower quality. Nonindigenous species occur more frequently, and the community is dominated by cold water, native species (classification = intermediate biotic integrity). Finally, sites with scores less than 50 have poor biotic integrity. In these sites, cold water and sensitive species are rare or absent, and tolerant fish predominate (classification = poor biotic integrity). The relative abundance of each species by site and year, origin (native or introduced), tolerance to pollutants (tolerant, intermediate, or sensitive), and trophic guilds (percentage of invertivores and piscivores, and percentage of omnivores and herbivores) also are summarized.

Selected metrics and IBI scores were summarized for fish community data collected during low-flow periods (November through March) only. The sample effort was similar for each study: two or more netters using at least a 2,000 watt generator to sample at least 0.16 mi of the river (about six times the channel width). Maret and Ott (2003) found that a sample size of greater than 100 represented 85 percent of the species in a reach; therefore, IBI scores were calculated for samples of at least 120 individuals. Individual fish community metrics and IBI scores were compared spatially and temporally in the lower Boise River. They were then compared to one upstream site near Twin Springs (13185000) assumed to be unaffected by urban and agricultural activities, as well as to three least-disturbed sampling sites in southern Idaho (Maret and others, 2001; Terry Maret, U.S. Geological Survey, oral commun., April 2005). The least-disturbed sites were the Henry's Fork River near St. Anthony (13050500), South Fork Snake River near Heise (13037500), and South Fork Payette River near Lowman (13235000). These sites were sampled as part of the Statewide Water Quality Network. For more information on this network, see the web page at http://id.water.usgs.gov/public/wq/index.html. Land-use and water-quality parameters for these sites have been published in Clark (1994), Maret (1997), and Maret and others (2001). The least-disturbed sites were sampled during normal flow years but not always during the same years as the lower Boise River (mean monthly flows and long-term flows for the least-disturbed sites can be accessed at http://waterdata.usgs.gov/id/nwis/rt). These sites provide a comparison of the best available data from least-disturbed streams in Idaho.

Land-use derived metrics that include area of developed land, area of impervious surface, and number of major diversions calculated for each subbasin were compared with IBI scores. Subbasins were delineated upstream of the downstream end of a fish-sampling reach, and land-use metrics were derived from Geographic Information System (GIS) spatial datasets of the basin. Subbasin boundaries were delineated from 10-m digital elevation model (DEM) spatial data (accessed June 15, 2006, at http://ned.usgs.gov/) and visually compared with digital raster graphic (DRG) datasets to detect any delineation errors. Points of diversions within each subbasin were obtained from the Idaho Department of Water Resources (IDWR) web site, accessed June 16, 2006, at http://www.idwr.idaho.gov/gisdata/new%20data%20download/water_rights.htm), and impervious surface data were obtained from the NOAA-NESDIS National Geophysical Data Center's web site, accessed June 15, 2006, at http://dmsp.ngdc.noaa.gov/. Habitat features were summarized from both historic (1867 to 1868) and recent (1994 to 2002) qualitative and quantitative measurements. Spearman rank correlation coefficients (Zar, 1974) were used to determine significant correlation between land use and select water-quality parameters and IBI scores. A Spearman Rank coefficient is considered significant if it is greater than 0.5.

Condition indices were used to determine the 'health' or 'robustness' of individual fish by comparing length to weight. Mountain whitefish, a native, and the most abundant salmonid in the lower Boise River, was used to compare relative condition of this species to the North American standard weight equation (Rogers and others, 1996) and measurements of mountain whitefish from least-disturbed sites in southern Idaho. Because only a few mountain whitefish were sampled in the downstream reaches of the lower Boise River, mountain whitefish at sites upstream of Eagle Road of a length between 150 and 350 mm were used for comparison. To determine a linear relation between fish length and weight, data were $\log_{10}$ transformed prior to regression analysis. Exponential equations for the length and weight relation used the following equation described in Armour and others (1983):

$$W = aL^b \,, \quad (1)$$

where

W is weight, and
L is length.

The equation is a transformation of the log-linear equations where "a" is the antilog of the Y-intercept and "b" is the slope of the regression line.

Fish Communities and Related Environmental Conditions

Habitat

Human actions and their impacts on streams are well-documented by numerous authors (Heede and Rinne, 1990; Bayley, 1991; Gilvear and Winterbottom, 1992; Gilvear, 1993; Baker, 1994; Brookes, 1996; Stanford and others, 1996; Bravard and others, 1999; Schick and others, 1999; and McDowell, 2000). River alterations include the acute impacts of dams, channelization, water pollution, and long-term hydrologic and sediment modifications that result from these activities. The natural disturbance regimes that maintain habitats and biological communities are lost (Stanford and others, 1996). These changes can dramatically affect many aspects of aquatic ecosystems, including the habitat structure and the water quality necessary to maintain a viable fish population. To fully comprehend and appreciate changes to aquatic ecosystems, and to develop appropriate restoration plans, the condition of a river must be viewed as the result of a complex history of alterations and not just the result of current watershed conditions.

The habitat of the lower Boise River has changed dramatically over the past century, as indicated by comparison of recent (1994–2002) and historic (1867 and 1868) habitat features (MacCoy and Blew, 2005, table 3). Qualitative measures of embeddedness and substrate size collected by the USGS from 1994 to 2002, summarized in table 3, indicate an "armoring" of substrate throughout the lower Boise River. In its investigation of the availability of habitat for salmonid spawning in the lower Boise River, the IDFG also noted armoring of the bottom substrate and a lack of spawning-sized gravels (Asbridge and Bjornn, 1988). When gravels were suitable, the IDFG reported embeddedness from 25 to 49 percent (Asbridge and Bjornn, 1988). U.S. Geological Survey embeddeddness measures increased in a downstream direction with the highest embeddedness (75 percent) measured in reach 7, upstream of Middleton (Mullins, 1999a). Both historic and recent data were available for average bankfull width, channel forms, and number of sloughs in the basin

Table 3. Habitat features measured for each subbasin of the historic (1867–1868) and recent (1994–2002), lower Boise River, southwestern Idaho.

[Subbasin and reach locations are shown in figure 1. Derived from MacCoy and Blew (2005). **Abbreviations:** ft, foot; ºC, degrees Celsius; –, no data]

Habitat features		Subbasins: Upstream of Eagle Island	Upstream of Eagle Road	Middleton	Mouth
		Fish sampling reach numbers: 1, 2, and 3	4 and 5	7	9
Embeddedness	Historic	–	–	–	–
	Recent	50 percent	75 percent	75 percent	50 percent
Dominant substrate	Historic	–	–	–	–
	Recent	Cobble		Cobble	Gravel
Average bankfull width	Historic	900 ft	North channel 790 ft South channel 390 ft	520 ft	620 ft
	Recent	140 ft	North Channel 400 ft South channel 150 ft	280 ft	250 ft
Channel forms, parafluvial surfaces	Historic	Mid-channel Islands, gravel bars	Gravel and sand bars	Some islands, sand bars	Some islands, sand bars, split channel at the mouth
	Recent	Run, riffle, pool	Run, stabilized.	Run, exposed islands.	Deep run, few islands, no sand bars, single channel at the mouth
Sloughs	Historic	Few sloughs	Some development of sloughs	Abundant	Abundant
	Recent	None	Sloughs filled or converted to irrigation or drain ditches	Sloughs filled or converted to irrigation or drain ditches	Few natural sloughs, sloughs converted to irrigation or drain ditches
Vegetation	Historic	Willow and wildrose scattering of cottonwood	Willows and cottonwood	Cottonwood, some willow	Cottonwood, some willow
	Recent	Some stands of native cottonwood.	Alien species dominate	–	–
Mean temperature	Historic	–	–	–	–
	Recent[1]	16ºC	–	19ºC	21ºC
	Recent[2]	17ºC	–	19ºC	21ºC

[1]Mean temperature for July and August 1996 at U.S. Geological Survey water-quality sites at Glenwood, Middleton, and Parma (MacCoy, 2004).

[2]Mean daily average temperature for July and August 2004 at U.S. Geological Survey water-quality sites at Glenwood, Middleton, and Parma (City of Boise written commun., June 2005).

(table 3). The average bankfull widths measured in most reaches in recent years have decreased to less than one-half of the historic width. For example, the historic average bankfull width of 900 ft upstream of Eagle Island has decreased to 140 ft (table 3). Historic channel forms and parafluvial surfaces (coarse sediments within the active channel and outside the wetted stream) have almost disappeared from all reaches of the lower Boise River. Gravel and sand bars were dominant downstream of Eagle Island, but these habitat features either have been stabilized or have been exposed (table 3). Historically, sloughs were abundant in the lower Boise River downstream of Eagle Island. Recently, the sloughs either have been filled in or have been converted to irrigation drains (table 3).

Cottonwood stands are considered to be major components to large gravel-bed alluvial systems (Merigliano. 1996; Poff and others, 1997) and are native to the lower Boise River. Historically, the lower Boise River's riparian vegetation was dominated by willows and cottonwoods, owing to the dynamic flows and spring flooding that occurred. In 2002, cottonwood stands were confined to a narrow corridor at the river margins (table 3). Rood and Mahoney (1993) list several impacts on riparian cottonwood forests on dammed rivers in North America, including the lack of extreme flows that reduce forest abundance and seedling production. Today's (2002) absence of parafluvial surfaces and the limited recruitment of new cottonwood or willow trees are largely due to the lack of extreme flows to recruit and move instream and riparian substrate. The extent to which the lower Boise River's riparian vegetation has been affected by alteration in the natural flow regime is still unknown.

Hydrology

Higher than normal flows on the lower Boise River, resulting from flood-control releases and springtime irrigation returns, can last from January through June and persist all the way to the Snake River. The highest instantaneous discharge recorded between 1994 and 2002 was greater than 8,000 ft^3/s measured at Glenwood in the spring of 1998. In years of severe and (or) consecutive drought, late winter and spring discharge remains low. Irrigation releases typically begin in mid-April (or following flood releases from Lucky Peak Dam during high-flow years) and continue through mid-October. Recent annual and mean monthly discharges for the lower Boise River at Glenwood and Parma illustrate the wide variation between water years and the regulated monthly discharge in the river (fig. 2). Water is diverted from the lower Boise River at several locations, and 12 major irrigation tributary/drains discharge to the lower Boise River between Lucky Peak Lake and the mouth (fig. 3).

Recent annual mean flow in the lower Boise at Diversion is less than one-half of the calculated unregulated flow. Regression equations were used to estimate unregulated flow calculated from basin characteristics at Diversion (Hortness and Berenbrock, 2001; USGS Streamstats online report, accessed June 16, 2006, at http://streamstats.usgs.gov/html/idaho.html). The estimated annual mean flow for Diversion based on unregulated flow was about 1,870 ft^3/s (average standard error of 33 percent; Hortness and Berenbrock, 2001), and the regulated annual mean flow for the period of record (1987–1993) was about 830 ft^3/s (U.S. Geological Survey National Water Information System Web site, accessed August 30, 2005, at http://nwis.waterdata.usgs.gov/id/nwis/qwdata).

Examination of the long-term flow record from the Boise River near Boise gaging station (USGS station 13202000) just downstream of Lucky Peak Dam shows a change in the magnitude and variability of seasonal flow following dam construction (fig. 4). Median mean monthly discharge for December and August prior to 1915 were about 1,090 and 1,200 ft^3/s, respectively, with standard deviations near 460 ft^3/s. In comparison, median discharge after dam construction (post-1957) for December and August were 350 and 4,020 ft^3/s, respectively, with standard deviations of 350 and 640 ft^3/s, respectively (U.S. Geological Survey National Water Information System Web site, accessed August 30, 2005, at http://nwis.waterdata.usgs.gov/id/nwis/qwdata). In fact, the flow regime in 2002 is opposite of pre-dam flows in December and August (fig. 4). The mean December post-dam flows are significantly lower than those in pre-dam years (P<0.001, Wilcoxon rank sum test with α=0.05); and the mean August post-dam flows are significantly higher (P<0.001, Wilcoxon rank sum test with α=0.05) than those recorded during pre-dam years.

Little information is available on the effect of flow alteration on the lower Boise River fishery, although most of the lower Boise River fish investigations have indicated that low winter flows were the reason for the decrease in the fish community (Idaho Department of Fish and Game, 1975; 1988; 2000; Mullins, 1999a). Altering the flow regime affects not only the fish community, but the entire aquatic environment. Several studies have shown that altering the natural river flow regime affects fish community biodiversity, food availability, habitat complexity, life history patterns, and connectivity (the ability of an organism to move freely through the stream hierarchy) (Ward and Stanford, 1983; Collier and others, 1996; Poff and others, 1997; Bunn and Arthington, 2002; Postel and Richter, 2003).

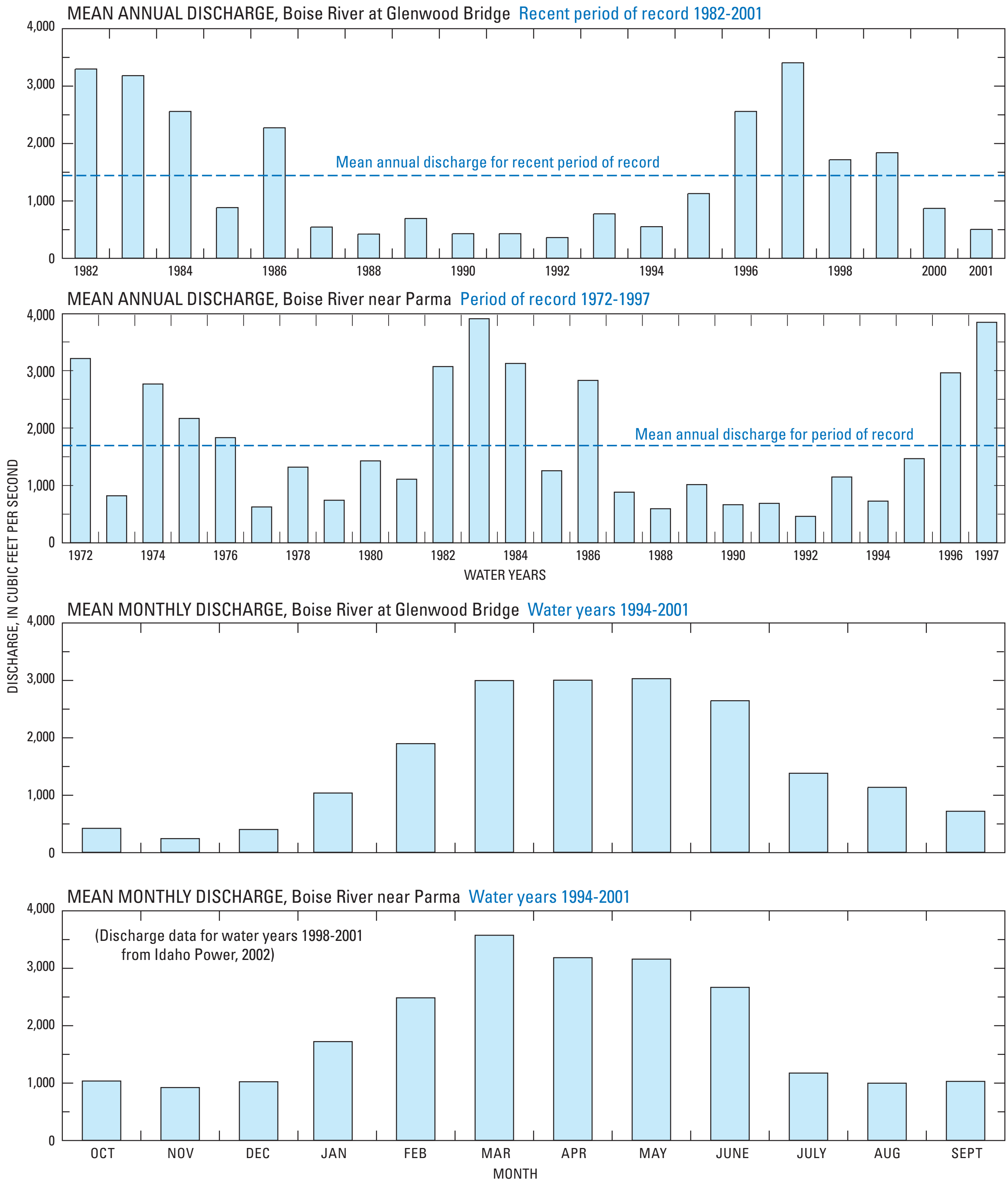

Figure 2. Mean annual and mean monthly discharge rates for the Boise River recorded at the U.S. Geological Survey Glenwood Bridge near Boise, Idaho (13206000) and near Parma, Idaho (13213000) gaging stations.

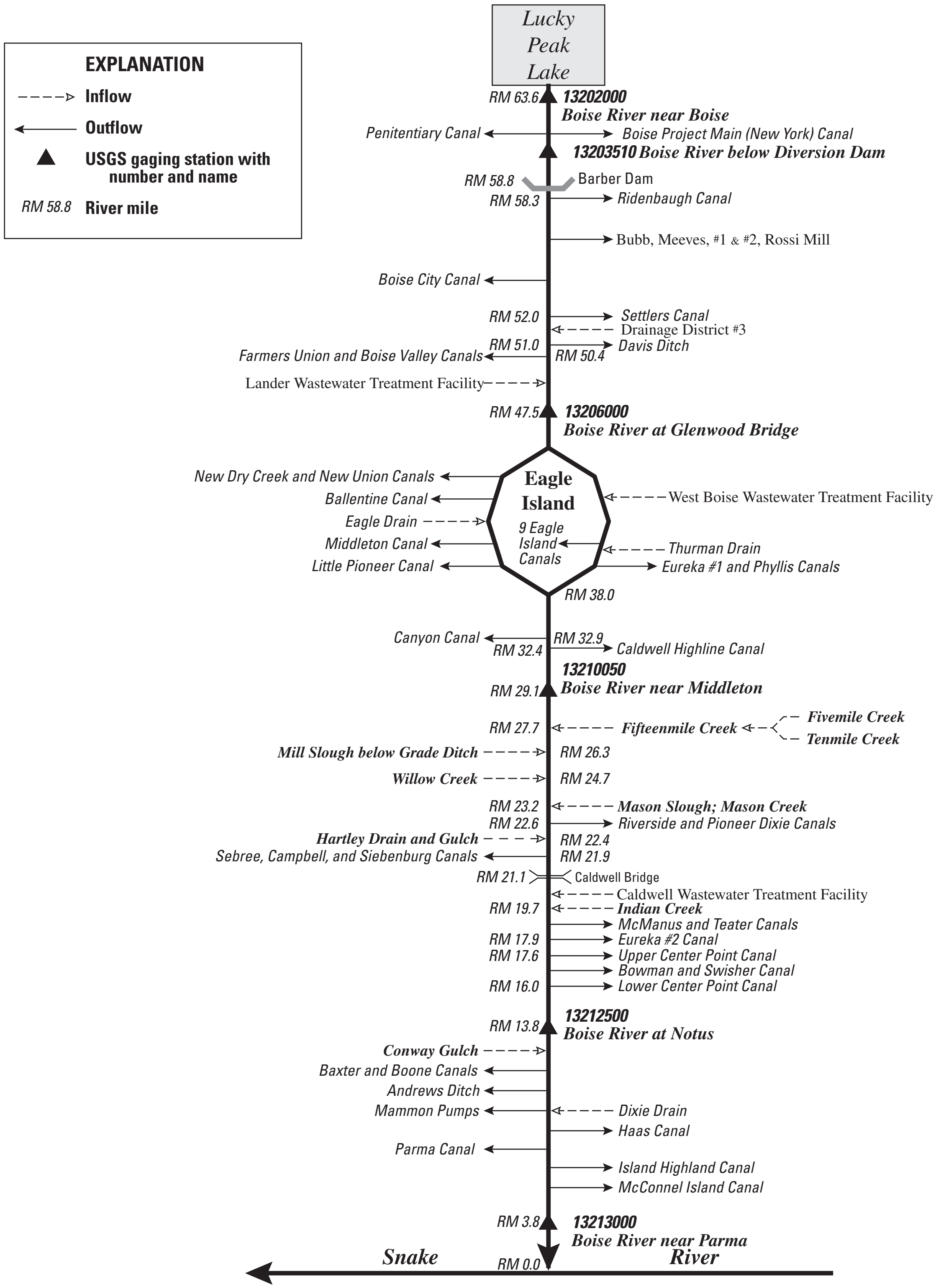

Figure 3. Diversions, drains, and tributaries along the Boise River from Lucky Peak Lake to the Snake River, southwestern Idaho. (Modified from Warnick and Brockway, 1974).

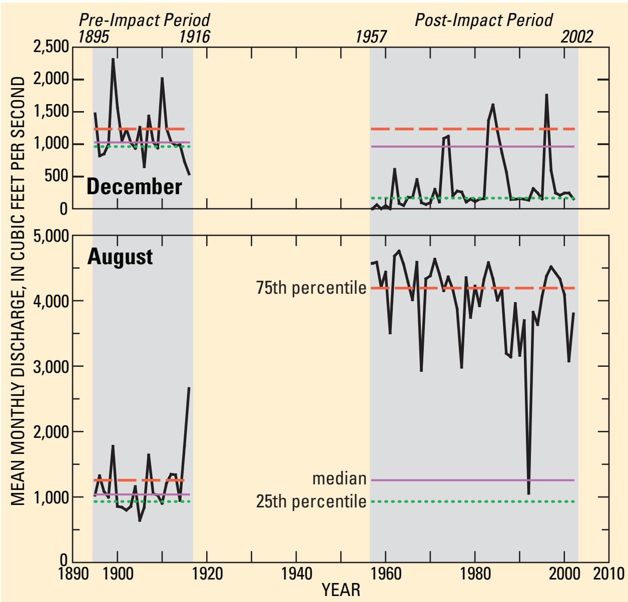

Figure 4. Mean monthly discharge for December and August recorded during pre- (1895–1916) and post-dam (1957–2002) periods at the U.S. Geological Survey Boise River near Boise gaging station (13202000), southwestern Idaho.

Water Quality

Recent water-quality data revealed longitudinal increases in constituent concentrations in the lower Boise (Mullins, 1998; MacCoy, 2004). Nitrogen, phosphorus, and suspended-sediment concentrations increased between Diversion and Parma (table 4). Increased agricultural activity in the lower basin appears to increase nutrient and sediment concentrations and is directly correlated with specific conductance. Urban land use also appears to increase nutrient concentrations in the lower Boise River. Maret (1997) found that specific conductance and percentage of fine sediment in streams and rivers of southern Idaho were highly correlated with agricultural land use. The suspended-sediment criterion of 80 mg/L for no more than 14 days (Rowe and others, 2003) was exceeded most frequently at the downstream-most site at Parma. Total nitrogen concentrations at Glenwood, Middleton, and Parma exceeded National background concentrations of 1.0 mg/L (U.S. Geological Survey, 1999). Middleton and Parma had more than twice the median flow-adjusted total nitrogen concentrations compared to undeveloped basins across the country (0.26 mg/L; Clark and others, 2000). Glenwood, Middleton, and Parma also exceeded the flow-adjusted total phosphorus concentrations for undeveloped basins (0.02 mg/L; Clark and others, 2000).

Table 4. Median, minimum, and maximum values of instantaneous water-quality measurements and select constituent concentrations from sites on the lower Boise River, southwestern Idaho, 1994–2002.

[Derived from MacCoy (2004). Subbasins shown in figure 1. Abbreviations: USGS, U.S. Geological Survey; ºC, degrees Celsius; mg/L, milligram per liter; µS/cm, microsiemen per centimeter; Min., minimum, Max., maximum]

Water-quality sampling site	USGS station No.	Subbasins	Temperature (ºC)	Dissolved oxygen (mg/L)	pH (standard units)	Specific conductance (µS/cm)	Suspended sediment (mg/L)	Total nitrogen (mg/L as N)	Total phosphorus (mg/L as P)
			Median (Min.-Max.)	Median (Min.-Max.)	Median (Min.-Max.)	Median (Min.-Max.)	Median (Min.-Max.)	Median (Min.-Max.)	Median (Min.-Max.)
Diversion	13203510	Upstream of Eagle Island Basin	9.2 (1.6 - 18.8)	11.6 (9.1 - 14.6)	7.6 (6.6 - 8.5)	75 (51 - 107)	4 (1 - 38)	0.26 (0.15 - 0.51)	0.04 (0.01 - 0.09)
Glenwood	13206000	Upstream of Eagle Road Basin	11.5 (2.8 - 23.0)	11.4 (8.4 - 15.8)	8.0 (7.8 - 8.9)	90 (52 - 197)	5 (1 - 107)	0.45 (0.18 - 1.90)	0.09 (0.02 - 0.38)
Middleton	13210050	Upstream of Middleton Basin	12 (2.7 - 22.5)	11.7 (8.8 - 15.7)	8.0 (6.7 - 9.1)	136 (74 - 314)	6 (2 - 211)	0.89 (0.38 - 3.51)	0.15 (0.03 - 0.85)
Parma	13213000	Upstream of Boise River Mouth Basin	12.1 (3.4 - 31.5)	10.2 (6.7 - 16.2)	8.0 (7.3 - 8.9)	343 (128 - 585)	45 (8 - 245)	2.17 (0.62 - 5.33)	0.3 (0.08 - 0.55)

In natural stream environments, the temperature regime varies longitudinally and can be modified by land-management activities that influence channel width, riparian canopy cover, pool volume, runoff timing, and instream flow. Temperature has been an influential parameter in determining fish community structure (Poole and Berman, 2001; Poole and others, 2004), and it is vital to the understanding of the fish community in the lower Boise River. The State's daily maximum temperature standards of 22°C and 13°C (Idaho Department of Environmental Quality, 2001) to protect cold water biota and salmonid spawning, respectively, were exceeded most frequently at Middleton and Parma (MacCoy, 2004). Continuous long-term monitoring of temperature is needed in the lower Boise River to monitor compliance with these standards. The City of Boise and the USGS began continuous temperature monitoring at selected sites on the lower Boise River in 2004 as part of a modeling effort; data from those monitoring efforts have not yet been published. For more information on the Idaho State water-quality standards for temperature refer to http://www.deq.idaho.gov/water/data_reports/surface_water/monitoring/temperature-index.cfm.

Occurrence and Status of Fish in the Lower Boise River

Occurrence

Fish species that have been collected in the lower Boise River from the studies listed in table 1 are summarized in appendix A. Table 5 summarizes the occurrence of each species by river mile from USGS and IDFG sampling events. All USGS data and only that from the first pass of the IDFG depletion sampling are summarized in appendix A and used in summary statistics. Water-quality and habitat conditions have changed in the basin since the first study was completed in 1974 by the IDFG. Therefore, the species listed for a given location in table 5 may not occur at that location today. For example, in 1988 and 1992, IDFG sampled common carp near Glenwood Bridge. Studies since that time have not found common carp at that site. The occurrence of fish species found near Middleton and near the mouth also is a result of only one sampling event at each USGS sampling site between 1995 and 1996 (table 1); a different community may occur at these sites today (2004).

Twenty-two species of fish distributed among 7 families have been identified in the lower Boise River: 3 Salmonidae (2 trout and 1 whitefish), 2 Cottidae (sculpins), 3 Catostomidae (suckers), 7 Cyprinidae (minnows), 4 Centrarchidae (sunfishes), 2 Ictaluridae (catfishes), and 1 Cobitidae (loach) (table 5).

Mountain whitefish (fig. 5) is the most widely distributed salmonid, having been collected from downstream of Barber Dam to the mouth. Brown trout (*Salmo trutta*, fig. 6) have been collected downstream of Barber Dam to Eagle Road Bridge; although rainbow trout (fig. 7) are the least distributed of the salmonids, having been collected downstream of Barber Dam to Middleton.

Figure 5. Mountain whitefish (Prosopium williamsoni).

Figure 6. Brown trout (Salmo trutta).

Figure 7. Rainbow trout (Oncorhynchus mykiss).

Table 5. Occurrence of fish species in the lower Boise River, southwestern Idaho, 1988–2004.

[Data for this chart from studies listed in table 1. Abbreviations; WTF, wastewater-treatment facility; HWY, highway]

Fish species		Major dams, drains, canals between each river mile		Diversion Dam, New York Canal, Barber Dam	Ridenbaugh Canal	City Canal, Settlers Canal diversion dam	Thurman Mill Canal, WTF input	Farmers Union Canal	Dry Creek Canal	WTF input, Thurman Drain	
		River mile	64	59	57.5	52	50	47.5	46.4	45	43
			Lucky Peak Dam	Barber Dam	Loggers Creek	Diversion above Americana Blvd	Lander WTF	Glenwood Bridge	Top of Eagle Island	West Boise WTF	Eagle Road
Salmonidae	*Salmo trutta*	Brown trout									
	Prosopium williamsoni	Mountain whitefish									
	Onchorhynchus mykiss	Wild rainbow trout									
Cottidae	*Cottus bairdi*	Mottled sculpin									
	Cottus confusus	Shorthead sculpin									
Catostomidae	*Catostomus columbianus*	Bridgelip sucker									
	Catostomus macrocheilus	Largescale sucker									
	Catostomus platyrhynchus	Mountain sucker									
Cyprinidae	*Cyprinus carpio*	Commom carp									
	Acrocheilus alutaceus	Chiselmouth									
	Ptychocheilus oregonensis	Northern pikeminnow									
	Richardsonius balteatus	Redside shinner									
	Rhinichthys cataractae	Longnose dace									
	Rhinichthys umatilla	Umatilla dace									
	Gila bicolor	Tui chub									
Centrarchidae	*Lepomis gibbosus*	Pumpkinseed									
	Leponis macrochirus	Bluegill									
	Micropterus salmoides	Largemouth bass									
	Micropterus dolomieui	Smallmouth bass									
Ictaluridae	*Ictalurus punctatus*	Channel catfish									
	Noturus gyrinus	Tadpole madtom									
Cobitidae	*Misgurnus anguillicaudatus*	Oriental weatherfish									

Table 5. Occurrence of fish species in the lower Boise River, southwestern Idaho, 1988–2004.—Continued

[Data for this chart from studies listed in table 1. Abbreviations; WTF, wastewater-treatment facility; HWY, highway]

Fish species		Major dams, drains, canals between each river mile	Dry Creek, Middleton Canal, Phyllis Canal, Warm Springs Canal	Phyllis Canal, Warm Springs Canal		Caldwell Highline Canal, Fifteenmile Creek, Mill Slough, Willow Creek, Mason Creek, Noble Drain, Notus Canal	Indian Creek, Conway Gulch, Eureka Canal, WTF input	Dixie Slough		
		River mile	38	34	31	21	14	5	3.8	2
			Bottom Eagle Island	Star	Middleton	HWY 95 at Caldwell	Notus	HWY 95 near Parma	Parma gage	Fort Boise National Wildlife Refuge
Salmonidae	*Salmo trutta*	Brown trout								
	Prosopium williamsoni	Mountain whitefish								
	Onchorhynchus mykiss??	Wild rainbow trout								
Cottidae	*Cottus bairdi*	Mottled sculpin								
	Cottus confusus	Shorthead sculpin								
Catostomidae	*Catostomus columbianus*	Bridgelip sucker								
	Catostomus macrocheilus	Largescale sucker								
	Catostomus platyrhynchus	Mountain sucker								
Cyprinidae	*Cyprinus carpio*	Commom carp								
	Acrocheilus alutaceus	Chiselmouth								
	Ptychocheilus oregonensis	Northern pikeminnow								
	Richardsonius balteatus	Redside shinner								
	Rhinichthys cataractae	Longnose dace								
	Rhinichthys umatilla	Umatilla dace								
	Gila bicolor	Tui chub								
Centrarchidae	*Lepomis gibbosus*	Pumpkinseed								
	Leponis macrochirus	Bluegill								
	Micropterus salmoides	Largemouth bass								
	Micropterus dolomieui	Smallmouth bass								
Ictaluridae	*Ictalurus punctatus*	Channel catfish								
	Noturus gyrinus	Tadpole madtom								
Cobitidae	*Misgurnus anguillicaudatus*	Oriental weatherfish								

Both mottled (*Cottus bairdi*) and shorthead (*Cottus confusus*) sculpin (fig. 8) have been found only downstream of Barber Dam to Glenwood Bridge. Both largescale sucker (*Catostomus macrocheilus*, fig. 9) and bridgelip sucker (*Catostomus columbianus*, fig. 10) were found at all locations sampled, whereas mountain suckers (*Catostomus platyrhynchus)* were collected only from Glenwood Bridge to Middleton.

Most minnow species were widely distributed. Common carp, northern pikeminnow (*Ptychocheilus oregonensis*, fig. 11), redside shiner (*Richardsonius balteatus)*, longnose dace (*Rhinichthys cataractae)* and Umatilla dace (*Rhinichthys Umatilla)* were found at all sampling sites from Glenwood Bridge to the mouth. One minnow, chiselmouth (*Acrocheilus alutaceus),* was collected at all sampling sites downstream of Barber Dam.

Of the sunfish, bluegill were found from Glenwood Bridge to Star, smallmouth bass (*Micropterus dolomieu*) (fig. 12) were found from Middleton to the mouth, and largemouth bass were found from Glenwood Bridge to the mouth. Catfish were found in the lower reaches: channel catfish from Caldwell to the mouth, and tadpole madtom (Noturus gyrinus) from Star to Middleton.

The oriental weather fish (loach) is an invasive species that probably was introduced in the drains of the lower Boise River from tropical fish aquariums; it has been found from Glenwood to Middleton. The species is native to northeastern Asia and central China. They prefer still or slow-moving shallow waters in which they can burrow into the mud. They are tolerant to a wide range of water temperatures and conditions. For example, their ability to absorb oxygen from the air allows them to survive in water that is low in oxygen content. Moreover, the species has few predators and high production rates (Gulf States Marine Fisheries Commission: accessed March 2005, at http://nis.gsmfc.org/nis_factsheet.php?toc_id=192).

Figure 8. Shorthead sculpin (*Cottus confusus*) and mottled sculpin (*Cottus bairdi*).

Figure 9. Largescale sucker (*Catostomus macrocheilus).*

Figure 10. Bridgelip sucker (*Catostomus columbianus*).

Figure 11. Northern pikeminnow (*Ptychocheilus oregonensis*).

Figure 12. Smallmouth bass (*Micropterus dolomieu*).

Status

Fish metrics and the associated IBI scores have been summarized in table 6 for reaches in the lower Boise River sampled during low-flow periods (November to April) and from least-disturbed rivers in southern Idaho. Sampling events for low-flow periods were chosen for IBI comparison to eliminate any sampling bias due to the inability to capture fish during high flows. Although all 10 metrics are similarly weighted, the occurrence of cold water species, sculpin, and common carp, or the occurrence of tolerant species, tended to drive the IBI scores either lower or higher. For example, the lack of sculpin species, as well as the decrease in cold water and sensitive species, decreased the overall IBI score. The occurrence of common carp at reach 3 in 1988 and 1992, and reaches 7 and 9 in 1996, also decreased the IBI scores. The percentage of anomalies also were highest at reach 3 in 2003, but this metric did not appear to have a profound effect on the IBI score.

IBI scores were higher for reaches 1 through 5 in 2003 (average IBI score of near 81) than in 1988 (average IBI score of near 62), which may indicate improved water-quality conditions in the upper reaches. The IBI scores from four least-disturbed sites ranged from 65 (intermediate biotic integrity) at the South Fork Snake River near Heise in 2003 to 99 (high biotic integrity) at the South Fork Payette River near Lowman in 2001. The median IBI score for all four least-disturbed sites was 81, indicating high biotic integrity (table 6). The dominant metrics driving the IBI scores at the least-disturbed sites were percentage of sculpin and cold water species. No carp were found at the least-disturbed sites, although tolerant individuals were found at all sites except the South Fork Payette River near Lowman.

Overall, the IBI scores for the lower Boise River (calculated since 1988, n=26, median of 67, intermediate biotic integrity) were lower than those for the least-disturbed sites. The IBI scores of 11 and 40 (indicating poor biotic integrity) at the Mouth and Middleton, respectively, were much lower than the scores at the least-disturbed sites. Additional sampling in the lower Boise River would be required to better characterize the biotic integrity of the system, particularly in the lower reaches where findings are based on a small number of samples.

Most IBI score classifications for sites with multiple years of data remained similar except for reach 3 (fig. 13). In this reach, IBI scores increased from 36 (poor biotic integrity) in 1988 to 73 (intermediate biotic integrity) in 2003. Median IBI scores calculated for reaches 1 and 2 sampled between 1988 and 2003 were greater than 75, indicating high biotic integrity, and for reaches 4 and 5 were near 60, indicating intermediate biotic integrity.

IBI scores were compared to some water-quality and habitat features measured between 1994 and 2002 (tables 3 and 4). Maximum instantaneous values of water temperature were negatively correlated with IBI scores (Spearman's rank correlation coefficient >0.5, n=10, α=0.1). A significantly negative correlation was found between IBI scores and maximum instantaneous values of specific conductance and suspended sediment (Spearman's rank correlation coefficient >0.80, n=10, α <0.5). Recent habitat measures such as embeddedness and bankful width were similar throughout the lower Boise River (table 3) and did not correlate well with IBI scores.

A dramatic longitudinal shift occurs in feeding groups from upstream to downstream in the lower Boise River (fig. 14, appendix A). Communities numerically dominated by piscivores (fish feeding on other fish) and invertivores (fish feeding on invertebrates), and those dominated by omnivores (fish feeding on both plant and animals) and herbivores (fish feeding on primarily plants) were compared between reaches for the samples collected in 1996. There was a decrease in piscivores and invertivores in reaches 3, 7, and 9. Only 20 percent of the fish species in reach 9 fed on macroinvertebrates or other fish. MacCoy (2004) found little difference in macroinvertebrate abundance from reach 1 to reach 9, but did identify differences in macroinvertebrate tolerance levels and feeding habits. In reach 1, the macroinvertebrate community consisted of only 2 percent tolerant species and was primarily filterers. Filterers spend most of their life cycle on the surface of coarse substrate, using specialized web and filtering mechanisms to feed on suspended detritus, and they are readily available for fish to consume (Voshell, 2002). The macroinvertebrate community in reach 9 consisted of near 50 percent tolerant species, and the community was primarily gatherers. Gatherers eat fine detritus that has fallen out of suspension and is located either on bottom sediment or between coarse substrate (Voshell, 2002). These species may not be readily available for fish to consume because they usually reside between course substrate or burrow into bottom sediment.

Subbasin areas were similar except for the upstream of Mouth subbasin that included an additional 1,000 mi^2 of land (table 7). No significant correlation was found between basin area and IBI scores. However, specific land-use metrics calculated for each lower Boise River subbasin appear to correlate with IBI scores. Area of developed land, impervious surface area, and number of major diversions increased in a downstream direction (table 7) and had a significant negative correlation with IBI scores (Spearman rank correlation coefficient >0.9, n=7, α<0.05). Additional fish-community data in the downstream reaches would help to test the relation between land use and fish community.

Table 6. Selected metrics and Index of Biological Integrity scores calculated for fish samples collected during low-flow periods (November to April) from the lower Boise River and least disturbed sites in southwestern Idaho.

[Reach locations are shown in figure 1 and table 2. Data for U.S. Geological Survey fish samples can be found online at http://id.water.usgs.gov/projects/fish/index.html. Reach: *, least-disturbed sites. **Abbreviations**: DELT, deformities, eroded fins, lesions, or tumors; ND, no data collected]

Reach No. or site name	Month	Year	Number of cold native species	Percentage of sculpin	Percentage of sensitive native individuals	Percentage of cold individuals	Percentage of tolerant individuals	Number of non-indiginous species	Percentage of carp	Salmonid age classes (no whitefish)	Cold individuals per minute	Percentage of DELT anomolies	Index of Biological Integrity
1	Jan.	1988	3	22	2	79	9	1	0	3	ND	ND	81
	Dec.	1996	4	50	30	98	0	1	0	3	ND	ND	89
	Nov.	2003	4	79	80	97	1	1	0	5	15	0	93
2	Jan.	1988	3	1	0	16	9	1	0	2	ND	ND	54
	Apr.	1992	3	45	2	56	13	1	0	2	5	ND	76
	Mar.	1995	4	28	21	59	11	0	0	ND	ND	ND	92
	Dec.	1996	4	45	14	74	16	2	0	2	12	0	78
	Nov.	2003	5	45	25	91	7	1	0	6	9	0	89
3	Jan.	1988	3	1	0	6	35	3	1	ND	ND	ND	36
	Mar.	1992	2	0	0	20	80	1	1	1	3	ND	33
	Feb.	1995	2	0	4	28	51	1	0	ND	4	ND	48
	Dec.	1996	4	2	2	31	48	1	0	2	2	0	57
	Dec.	2001	4	8	3	77	16	2	0	2	12	2	68
	Nov.	2003	5	15	4	69	26	2	0	3	4	3	73
4	Jan.	1988	3	1	5	67	31	1	0	6	ND	ND	70
	Mar.	1992	2	0	3	43	53	1	0	5	3	ND	55
	Mar.	1995	2	0	5	83	17	1	0	ND	ND	ND	62
	Dec.	1996	2	0	2	70	27	2	0	4	4	1	65
	Nov.	2003	3	0	9	90	8	2	0	4	6	1	72
5	Jan.	1988	3	4	4	38	37	1	0	7	ND	ND	67
	Mar.	1992	2	0	0	6	62	1	0	2	ND	ND	35
	Feb.	1995	2	0	6	44	20	0	0	2	5	1	67
	Dec.	1996	2	0	9	81	11	2	0	2	ND	1	60
	Nov.	2003	3	0	27	84	16	2	0	5	5	ND	77
7	Dec.	1996	2	0	0	26	28	2	8	ND	3	1	39
9	Dec.	1996	1	0	0	8	80	2	2	0	0	2	11
*Henry's Fork River near St. Anthony	Sept.	1999	3	7	0	78	1	3	0	6	10	1	78
*South Fork Snake River near Heise	Sept.	2003	3	2	10	83	13	3	0	3	3	2	65
*South Fork Payette River near Lowman	July	2001	3	73	91	92	0	0	0	4	3	0	99
*Boise River near Twin Springs	Sept.	2004	5	7	19	46	35	0	0	5	2	0	84

Table 7. Subbasin areas, selected land-use metrics, and fish Index of Biotic Integrity scores for selected sampling events on the lower Boise River, southwestern Idaho, 2000–03.

[Subbasins and reach locations are shown in figure 1 and table 2. Subbasin area: including 2,690 mi^2 upstream of Lucky Peak Dam. Abbreviations: WTF, wastewater- treatment facility; mi^2, square mile; IBI, Index of Biotic Integrity]

Fish sampling reach No.	Fish sampling reach name	Subbasin	Subbasin area (mi^2)	2001 developed land (mi^2)	2000-01 impervious surface (mi^2)	2001 number of major diversions	IBI score (year sampled)
1	Downstream of Barber Dam	Upstream of Eagle Island	2,710	0.12	1.70	5	93 (2003)
2	Upstream of Lander WTF	Upstream of Eagle Island	2,770	14.8	14.3	13	89 (2003)
3	Downstream of Lander WTF						73 (2003)
4	Upstream of West Boise WTF	Upstream of Eagle Road	2,777	17.6	16.5	19	72 (2003)
5	Downstream of West Boise WTF						77 (2003)
7	Middleton	Upstream of Middleton	2,894	27.5	25.8	31	39 (1996)
9	Mouth	Upstream of mouth	3,910	79.9	73.9	57	11 (1996)

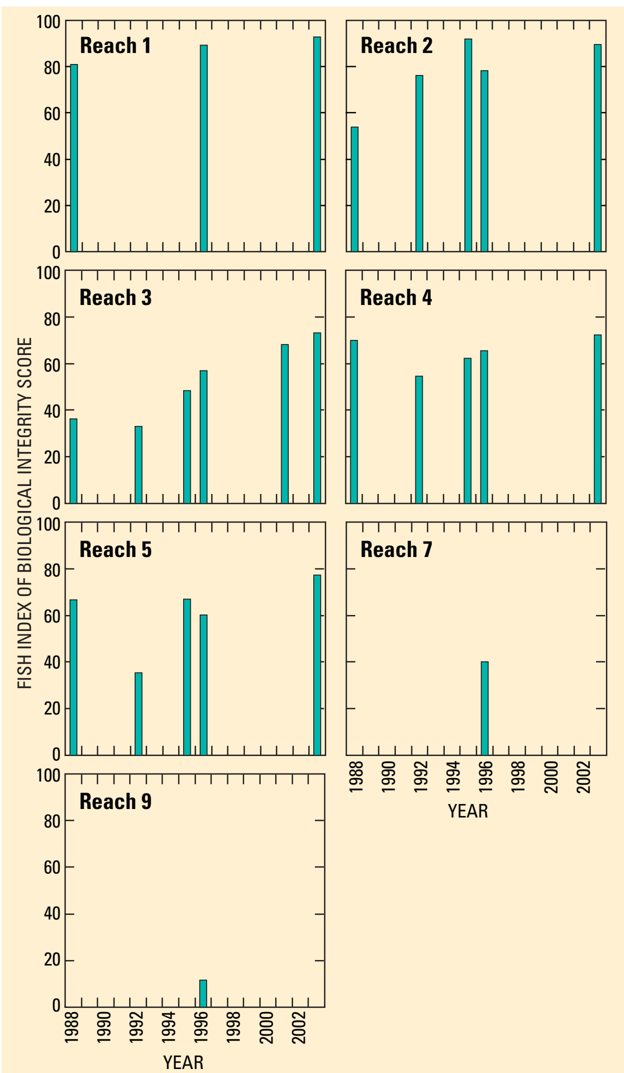

Figure 13. Fish index of biological integrity scores by year calculated for low-flow sampling events (November to April) in seven reaches of the lower Boise River, 1988–2003. (Reach numbers correspond to the reaches identified in figure 1 and table 2.)

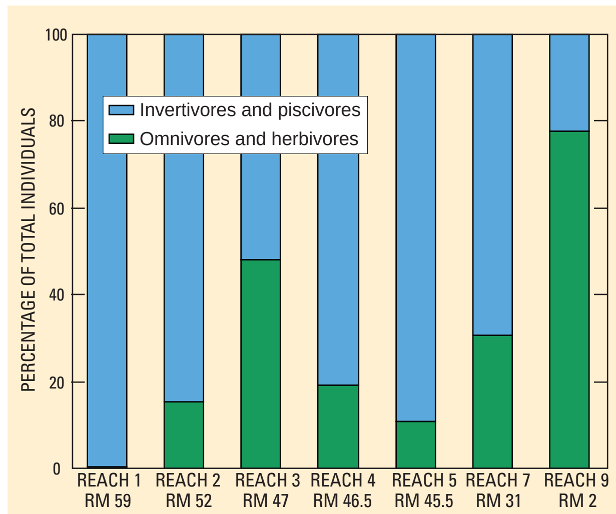

Figure 14. Percentages of invertivores and piscivores versus percentages of omnivores and herbivores derived from 1996 fish collections in the lower Boise River, southwestern Idaho.

Fish Communities Upstream and Downstream of Wastewater-Treatment Facilities

Most of the fish-community data have been collected upstream and downstream of the Lander and West Boise WTFs (reaches 2 through 5; fig. 1). Data available for reaches 1 through 5 allowed for a more in-depth analysis of fish-community responses to water-quality and habitat variables. Table 6 provides individual metrics and IBI scores for sites upstream and downstream of WTFs.

The median IBI scores calculated from 1988 through 2003 at reaches 3 and 5 downstream of WTFs (53 and 67, respectively) were lower than reaches 2 and 4 upstream of the WTFs (78 and 65, respectively). Of the sites upstream and downstream of WTFs, the average IBI score upstream of Lander WTF, reach 2, was the only site with high biotic integrity (fig. 13). More tolerant fish species were found downstream of WTFs, with the average percentage of tolerant species increasing from reaches 2 to 3 (11 to 43 percent), and reaches 4 to 5 (27 to 29 percent). The difference in tolerant species between reaches 4 and 5 was small and these sites are considered to support similar fish communities. The average percentage of cold water species decreased from reach 2 to 3 (from 59 to 38 percent) and from reach 4 to 5 (from 71 to 50 percent). Percentage of sculpin had the most dramatic longitudinal decrease for an individual metric. The average (1988–2003) percentage of sculpin in reach 1 was close to 50 percent of the fish community and decreased to an average of 33 percent in reach 2 and decreased even further to an average of 4 percent in reach 3. Sculpin have not been found since 1988 at reaches 4 and 5, and were found in very low numbers. The decrease in the sculpin population in the downstream reaches may be a factor of a combination of habitat loss, predation, and water-quality degradation. There was an increase in percentage of sculpin between 1988 and 2003 in reach 3 that suggests a slight improved water quality (fig. 15). There also was an increase in the IBI score in reach 3 from 36 (poor biotic integrity) in 1988 to 73 (intermediate biotic integrity) in 2003. The City of Boise changed from chlorination/declorination treatment of wastewater to ultraviolet treatment at the Lander WTF in 1995 (Robbin Finch, City of Boise, written commun., 2003), which may have had an impact on the sculpin population. Sculpin were not found in the downstream Lander WTF sample in August 2004 (appendix A). Previous samples from this reach were taken during low-flow periods (December to March) suggesting that sculpin may have flow or seasonal preferences in habitat. Although similar changes to wastewater treatment were made at the West Boise WTF in 2000, sculpin have not been found upstream or downstream of this facility.

Sculpin and other benthic small-bodied fish have been used as sentinel species for environmental monitoring because they may be sensitive to chemical or other stressors. They are not subject to fishing harvest and stocking which confound the analyses of game fish. Sculpin have a limited home range (less than 50 m and respond to local conditions (Brown and Downhower, 1982; Gray, 2004; Petty and Grossman, 2004). In contrast, the home range of large-bodied fish such as suckers or mountain whitefish can be more than 50 km making it difficult to relate exposure to responses (Pettit and Wallace, 1975; Baxter, 2002).

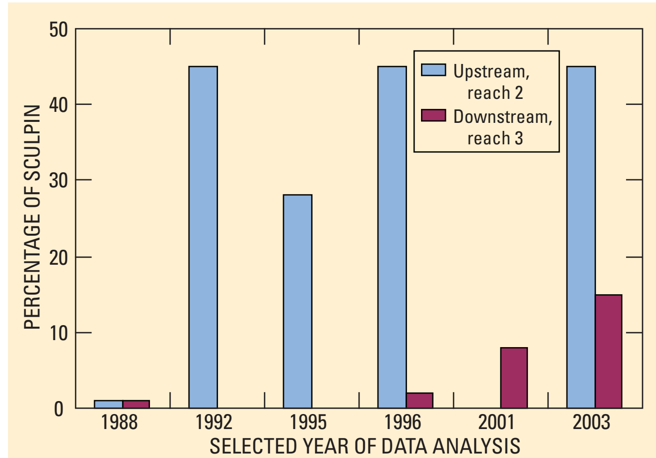

Figure 15. Changes in the occurrence of sculpin upstream and downstream of Lander Wastewater Treatment Facility, lower Boise River, southwestern Idaho, 1988–2003.

Analysis of Mountain Whitefish Condition

Mountain whitefish comprise a large portion of the fish biomass in the lower Boise River. The species has been classified as a cold water native, but it is intermediate in its sensitivity to degraded water-quality conditions such as siltation, elevated temperatures, and low dissolved-oxygen concentrations (Zaroban and others, 1999). Several studies have documented the adverse effects of elevated summer temperatures and suspended sediment on mountain whitefish. For example, in laboratory experiments with adult fish, increasing lethality was observed at temperatures greater than about 23ºC (Ihnat and Buckley, 1984). In July 2002, a large kill of mountain whitefish occurred in the Snake River near Waters Ferry, Idaho, following several days during which the maximum daily temperatures in the river exceeded 26ºC (Idaho Department of Environmental Quality, 2003). Mountain whitefish also showed avoidance behavior and gill damage following exposures to elevated suspended sediments during a sluicing operation in Wyoming in which sediment concentrations increased to 500 times the background concentration (Bergsted and Bergersen, 1997). In contrast, when exposed to elevated concentrations of suspended sediment that were within the natural range in an Alberta River, mountain whitefish showed no avoidance behavior (Reid and others, 2002).

Because lower Boise River mountain whitefish are somewhat sensitive to degraded water quality and account for a large portion of the fish biomass, additional analyses of length and weight data were made to determine the relative “health” of the population. The relation of mountain whitefish length and weight observed in the lower Boise River from sites upstream of Middleton is compared to those from least-disturbed rivers in southern Idaho and to mountain whitefish collected from throughout their natural range in the northern United States and Canada (Rogers and others, 1996) to give a relative “condition” of individual fish. Condition indexes or standard weight equations are considered most representative if they are developed by using a large portion of the population across the geographical range (Murphy and others, 1991). Rogers and others (1996) developed a North American standard weight equation for mountain whitefish using more than 13,000 fish from their range in the northern United States and two Canadian provinces. Condition equations were developed from the lower Boise River and least-disturbed rivers using regression analysis of log-transformed mountain whitefish total lengths and weights (fig. 16). The lower Boise River equation ($\log_{10} W = 5.624 + 3.229 \log_{10} L$)was very similar to both the North American standard equation ($\log_{10} W = 5.086 + 3.036 \log_{10} L$) and the least-disturbed site equation ($\log_{10} W = -4.057 + 2.623 \log_{10} L$). Lower Boise River mountain whitefish appear to be slightly smaller than those from the least-disturbed sites in southern Idaho (fig. 17). Based on their abundance and their relative weight, the general condition of the mountain whitefish in the lower Boise River appears to be high, although mountain whitefish are uncommon downstream of Middleton. Possible factors that may limit mountain whitefish populations in the downstream reaches include water-quality conditions such as high temperatures and increased siltation.

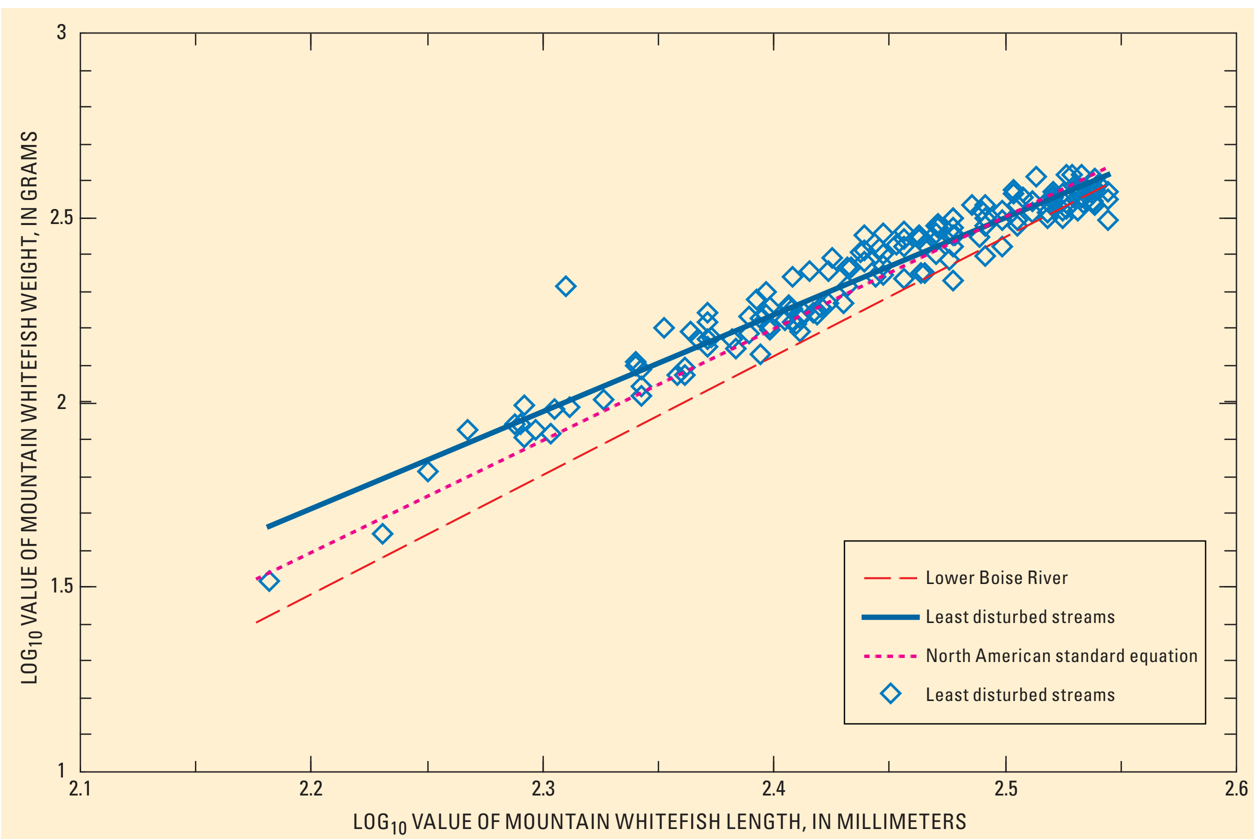

Figure 16. Comparison of relative weight equations calculated for mountain whitefish collected from the lower Boise River with the North American standard weight equation for mountain whitefish and measurements from least-disturbed rivers in southern Idaho.
North American standard weight equation for mountain whitefish from Rogers and others (1996).

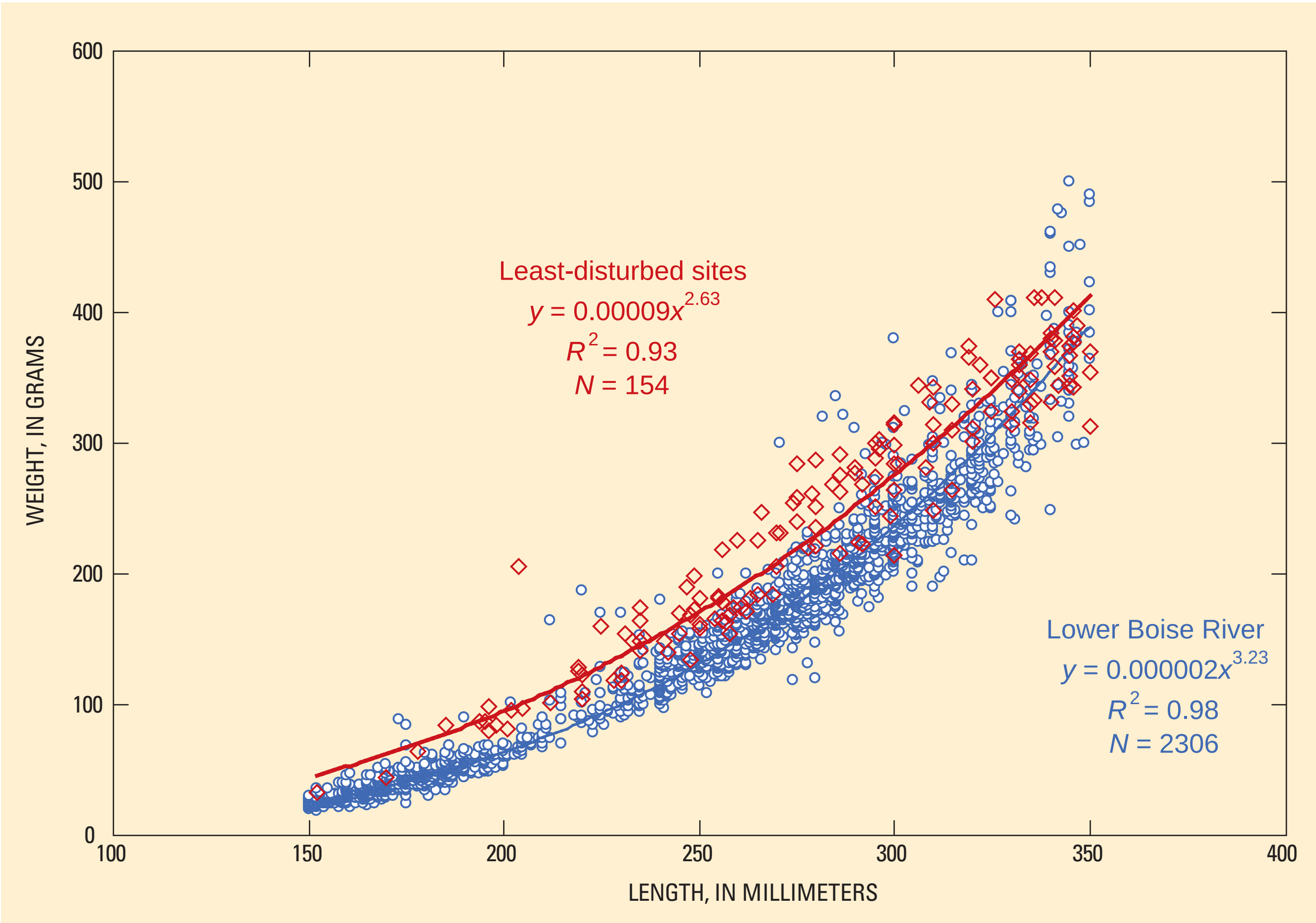

Figure 17. Mountain whitefish length and weight relations for the lower Boise River and least-disturbed sites in southern Idaho, 1988–2004.

Data Limitations and Potential Future Investigations

Based on several metrics and an overall IBI of the lower Boise River, the fish community upstream of the Lander WTF is similar to that of least-disturbed rivers in southern Idaho. Downstream of the Lander WTF, the apparent range expansion of sculpin over the last decade may indicate long-term improvements in water quality. However, important limitations apply to the analysis of this limited dataset. The main analytical tools, an IBI model to evaluate the overall fish community and relative weight equations to evaluate fish community "health," are useful but crude in their predictive power to asses the effect of pollutants on the fish population.

Future assessments of status or changes in fish community and health in the lower Boise River would benefit from more robust assessments of the distribution of benthic species such as sculpin and direct assessment of fish health. Measures related to energy expenditure, energy storage, and survival of fish populations can be obtained with little additional effort (Munkittrick and McMaster, 2000). Measures of bioaccumulation and biomarkers of chemical exposure can be important measures for waters that receive complex point and non-point discharges. These measures have been successfully used in the monitoring and assessment of fish health in rivers receiving organic effluents and in targeting similar species found in the lower Boise River (Kloepper-Sams and others, 1994a, 1994b; Swanson and others, 1994; Gibbons and others, 1998).

Recent studies have shown that rivers receiving urban and agricultural effluent, such as the lower Boise River, may be influenced by wastewater chemicals that include detergents, disinfectants, fragrances, fire retardants, nonprescription drugs, and pesticides (Barnes and others, 2002; Kolpin and others, 2002; Sprague and Battaglin, 2004). Some of these chemicals may mimic hormones, causing effects in fish that may not be obvious in conventional monitoring, such as reduced reproductive health or reduced defense against disease (Thorpe and others, 2001; van der Oost and others, 2003; Brown and others, 2004). Three sites on the lower Boise River (downstream of Diversion Dam, upstream of

Middleton, and downstream of Parma) were selected as part of a national assessment of wastewater chemicals (Barnes and others, 2002). Results of this study found no antibiotics or human pharmaceutical compounds at these sites in water but did detect hormones and other organic wastewater chemicals. Bioaccumulation of these chemicals is unknown in the lower Boise River. Preliminary results of a recent USGS study have identified these types of chemicals in Colorado streams (Sprague and Battaglin, 2004) and have indicated their potential endocrine disruption effects on fish. The USGS conducted a reconnaissance of endocrine-disrupting compounds in rivers across the United States and concluded that sites containing these compounds may affect the endocrine system of resident fish (Goodbred and others, 1997). In a survey of fish contamination in the Columbia River, mountain whitefish tended to have higher concentrations of mercury and some pesticides than did other fish (U.S. Environmental Protection Agency, 2002). This finding suggests that different species also may have different uptake rates and reactions to pollutants. Considering the above factors, a more comprehensive evaluation of fish health that includes both indicators of exposure and potential effects of endocrine-disrupting chemicals could provide important information about the effects of pollutants on fish populations in the lower Boise River.

Summary

Within the last century, the lower Boise River downstream of Lucky Peak Dam in southwestern Idaho has been transformed from a meandering, braided, gravel-bed river that supported large runs of salmon to a channelized, regulated, urban river that provides flood control and irrigation water to more than 1,200 square miles of land. In some places, the river is one-half the width it was before it was dammed. The lower Boise River fish communities are impacted by flow alterations, habitat loss, and poor water quality. As water demand increases for urban, domestic, and agricultural uses, so does the impact on the fish communities. The river's flow is regulated by upstream dams and downstream irrigation returns. In fact, the current flow in the lower Boise River is opposite to that of pre-dam era, with lower flows in the winter and higher flows in the summer. The lack of higher flows to recruit and move gravel for riffle habitat and to mobilize fine sediment has caused embeddedness throughout the river that measures between 50 and 75 percent. The quality of water decreases in a downstream direction with increasing temperatures and nutrient and sediment concentrations. Although rainbow trout are stocked at a rate of 56,000 fish per year in the lower Boise River, the lack of colder temperatures downstream has reduced natural spawning of this species.

Fish data from the U.S. Geological Survey (USGS) and Idaho Department of Fish and Game (IDFG) collected since 1974 were combined to report the status of fish communities in the lower Boise River. Twenty-two species representing 7 families of fish have been identified in the lower Boise River: 3 salmonids (trout and whitefish), 2 cottids (sculpins), 3 catostomids (suckers), 7 cyprinids (minnows), 4 centrarchids (sunfish), 2 ictalurids (catfish), and one cobitidae (loach). Of these, 13 are native species, 5 are cold water species, 9 are cool water species, and 8 are warm water species. Most of the warm water species are found in the lower reaches of the river. Of the salmonid species, mountain whitefish have been found throughout the lower Boise River, and rainbow and brown trout have been found upstream of Eagle Road. Sculpin, a cold water, bottom-feeding fish, has been found only in the upstream reaches upstream of Glenwood Bridge. Suckers have been found throughout the river, and tolerant species such as carp, northern pikeminnow, bass, and catfish have been found primarily in the lower reaches. Index of Biotic Integrity (IBI) scores calculated for USGS and IDFG sampling events between 1988 and 2004 decreased in a downstream direction, with two of the lowest scores (indicating poor biotic integrity) measured at Middleton (40) and near the mouth (11), respectively. IBI scores for each sampling reach remained similar over time except for the reach downstream of the Lander WTF. The IBI scores for the reach downstream of the Lander WTF (reach 5) increased from a score of 36 in 1988, indicating poor biotic integrity, to 73 in 2003, indicating intermediate biotic integrity. The increase in IBI score at this site may be an indication of increased water quality and reflects the increased number of sculpin found in 2003. IBI scores for all sites were negatively correlated with maximum instantaneous water temperature, specific conductance, and suspended sediment; as well as the basin land-use metrics of area of developed land, impervious surface area, and number of major diversions within a subbasin. Fish communities downstream of Middleton consisted primarily of tolerant species and omnivorous feeders, whereas fish communities in the upstream most reach downstream of Barber Dam consist of only 2 percent tolerant species and were piscivores and invertivores.

Fish communities downstream of the Lander WTF generally had lower IBI scores, an increase in tolerant species, and a decrease in percentage of cold water species. Sculpin were not found downstream of Glenwood Bridge in the lower Boise River, possibly due to decreases in habitat and water quality. Length-weight relations for mountain whitefish, an indicator used to determine the condition of the species' population in the lower Boise River, were similar to those found both in regional populations and in least-disturbed rivers in southern Idaho.

The fish communities in the lower Boise River have changed in response to changes in habitat, land use, and water quality. As the human population increases in the lower Boise River Basin, the demand for both high-quality water and recreation in and around the river will affect aquatic communities, especially fish communities. Frequent and comprehensive monitoring of the lower Boise River fish communities will help to identify impacts and to sustain this beneficial resource.

Land use in the lower Boise River Basin is changing rapidly from a rural/agricultural community to an urban/residential community, and these changes may affect the lower Boise River fish community. Future assessments of status or changes in fish community and health in the lower Boise River should focus on the distribution of benthic species such as sculpin and the direct assessment of fish health. A more comprehensive evaluation of fish health that includes both indicators of exposure and potential effects of endocrine-disrupting chemicals could provide important information about the effects of pollutants on fish populations in the lower Boise River.

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Appendix A. Relative percentage of abundance of fish species in the lower Boise River, Idaho.

[**Origin:** I, introduced; N, native. **Tolerance:** I, intermediate; S, sensitive; T, tolerant. **Adult trophic guild:** Classification of species from Zaroban and others, 1999; inv., invertivore, pisc, piscivore; omni, omnivore; herb, herbivore. **Abbreviations:** IFG, Idaho Fish and Game; USGS, U.S. Geological Survey; WTF, wastewater-treatment facility; –, no species found]

	Date	Collecting agency	Species					
			Brown trout (*Salmo trutta*)	Mountain whitefish (*Prosopium williamsoni*)	Wild rainbow trout (*Onchorhychus mykiss*)	Mottled sculpin (*Cottus bairdi*)	Shorthead sculpin (*Cottus confusus*)	Sculpin (*Cottus* sp.)
Origin			I	N	N	N	N	N
Tolerance			I	I	S	I	S	I
Temperature preference			Cold	Cold	Cold	Cold	Cold	Cold
Adult trophic guild			inv/pisc	inv	inv/pisc	inv	inv	inv
Site location								
Downstream Barber Dam	Jan. 1988	IDFG	1.3	72.7	2.7	–	–	12.7
Downstream Barber Dam	Dec. 1996	USGS	1.3	39.8	7.2	27.5	22.5	
Downstream Barber Dam	Nov. 2003	USGS	.2	11.9	5.4	4.4	74.8	–
Upstream Lander WTF	Jan. 1988	IDFG	.1	15.5	.3	–	–	.4
Upstream Lander WTF	Mar. 1992	IDFG	2.1	38.4	2.1	–	–	28.9
Upstream Lander WTF	Mar. 1995	USGS		29.9	1.8	8.8	18.8	–
Upstream Lander WTF	Dec. 1996	USGS	.4	28.4	.6	31.4	13.5	–
Upstream Lander WTF	Nov. 2003	USGS	2.3	38.1	6.0	15.8	19.1	9.7
Downstream Lander WTF	Jan. 1988	IFG	–	5.5	–	–	–	.5
Downstream Lander WTF	Mar. 1992	IFG	–	19.6	.2	–	–	–
Downstream Lander WTF	Feb. 1995	USGS	.3	24.2	1.3	–	–	–
Downstream Lander WTF	Dec. 1996	USGS	.8	27.6	.8	.8	1.2	–
Downstream Lander WTF	Dec. 2001	USGS	1.1	66.4	1.4	6.6	1.4	–
Downstream Lander WTF	Nov. 2003	USGS	1.8	48.6	3.5	10.6	.4	3.9
Downstream Lander WTF	Aug. 2004	USGS	5.3	17.2	2.4	–	–	–
Upstream West Boise WTF	Jan. 1988	IFG	.3	61.6	5.1	–	–	.3
Upstream West Boise WTF	Mar. 1992	IFG	.7	39.5	3.3	–	–	–
Upstream West Boise WTF	Mar. 1995	USGS	.4	77.3	5.2	–	–	–
Upstream West Boise WTF	Dec. 1996	USGS	.6	67.4	1.7	–	–	–
Upstream West Boise WTF	Nov. 2003	USGS	3.2	78.8	8.5	–	–	–
Downstream West Boise WTF	Jan. 1988	IFG	.3	32.0	2.7	–	–	3.7
Downstream West Boise WTF	Mar. 1992	IFG	–	5.3	.4	–	–	–
Downstream West Boise WTF	Mar. 1995	USGS	–	36.7	8.5	–	–	–
Downstream West Boise WTF	Dec. 1996	USGS	2.1	69.8	9.4	–	–	–
Downstream West Boise WTF	Nov. 2003	USGS	2.1	55.5	26.6	–	–	–
North channel Eagle Island	Jan. 1988	IFG	.2	.9	–	–	–	.9
Middleton	Dec. 1996	USGS	–	25.9	.2	–	–	–
Middleton	Aug. 1997	USGS	–	2.0	–	–	–	–
Above Star Road	Jan. 1988	IFG	–	6.6	.7	–	–	–
Caldwell	Aug. 1997	USGS	–	2.5	–	–	–	–
Near mouth	Dec. 1996	USGS	–	8.3	–	–	–	–
Near mouth	Aug. 1997	USGS	–	1.8	–	–	–	–
						–	–	–

Appendix A. Relative percentage of abundance of fish species in the lower Boise River, Idaho.—Continued

[**Origin:** I, introduced; N, native. **Tolerance:** I, intermediate; S, sensitive; T, tolerant. **Adult trophic guild:** Classification of species from Zaroban and others, 1999; inv., invertivore, pisc, piscivore; omni, omnivore; herb, herbivore. **Abbreviations:** IFG, Idaho Fish and Game; USGS, U.S. Geological Survey; WTF, wastewater treatment facility; –, no species found]

	Date	Species						
		Bridgelip sucker (*Catostomus columbianus*)	Largescale sucker (*Catostomus macrocheilus*)	Mountain sucker (*Catostomus platyrhynchus*)	Sucker (*Catostomus* sp.)	Common carp (*Cyprinus carpio*)	Chiselmouth (*Acrocheilus alutaceus*)	Longnose dace (*Rhinichthys cataractae*)
Origin		N	N	N	N	I	N	N
Tolerance		T	T	I	T	T	I	I
Temperature preference		Cool	Cool	Cool	Cool	Warm	Cool	Cool
Adult trophic guild		herb	omni	herb	herb/omni	omni	herb	inv
Site location								
Downstream Barber Dam	Jan. 1988	–	–	–	10.0	–	–	–
Downstream Barber Dam	Dec. 1996	–	–	–	–	–	0.4	–
Downstream Barber Dam	Nov. 2003	0.4	0.5	–	–	–	–	–
Upstream Lander WTF	Jan. 1988	–	–	–	9.1	–	.1	–
Upstream Lander WTF	Mar. 1992	–	–	–	16.3	–	–	–
Upstream Lander WTF	Mar. 1995	3.9	6.9	1.1	–	–	–	9.7
Upstream Lander WTF	Dec. 1996	5.7	9.4	–	–	0.1	–	4.0
Upstream Lander WTF	Nov. 2003	1.4	5.1	–	–	–	–	–
Downstream Lander WTF	Jan. 1988	–	–	–	28.1	1.1	.1	–
Downstream Lander WTF	Mar. 1992	–	–	–	79.0	.9	–	–
Downstream Lander WTF	Feb. 1995	9.4	42.9	.5	–	–	–	5.2
Downstream Lander WTF	Dec. 1996	12.2	34.6	.8	–	–	.4	10.6
Downstream Lander WTF	Dec. 2001	5.0	10.2	.6	–	–	–	5.2
Downstream Lander WTF	Nov. 2003	5.3	17.7	–	1.1	–	–	.7
Downstream Lander WTF	Aug. 2004	3.0	39.1	–	–	–	–	10.1
Upstream West Boise WTF	Jan. 1988	–	–	–	30.6	–	.7	–
Upstream West Boise WTF	Mar. 1992	–	–	–	52.6	–	–	–
Upstream West Boise WTF	Mar. 1995	3.3	13.3	–	–	–	–	.4
Upstream West Boise WTF	Dec. 1996	5.8	13.3	.3	–	–	–	.9
Upstream West Boise WTF	Nov. 2003	1.1	5.8	–	1.1	–	–	1.3
Downstream West Boise WTF	Jan. 1988	–	–	–	37.3	–	–	–
Downstream West Boise WTF	Mar. 1992	–	–	–	57.4	–	2.7	–
Downstream West Boise WTF	Mar. 1995	.3	19.4	2.9	–	–	.6	10.9
Downstream West Boise WTF	Dec. 1996	2.1	8.8	–	–	–		1.5
Downstream West Boise WTF	Nov. 2003	1.4	12.1	–	–	–	–	–
North channel Eagle Island	Jan. 1988	–	–	–	76.5	–	1.6	–
Middleton	Dec. 1996	2.8	17.9	1.9	–	7.5	.5	7.8
Middleton	Aug. 1997	10.2	12.3	–	–	.3	37.2	14.9
Above Star Road	Jan. 1988	–	–	–	14.5	–	17.5	–
Caldwell	Aug. 1997	8.9	16.7	–	–	2.5	9.9	–
Near mouth	Dec. 1996	48.8	26.4	–	–	2.5	–	10.7
Near mouth	Aug. 1997	31.2	33.5	–	–	3.2	6.3	–

Appendix A. Relative percentage of abundance of fish species in the lower Boise River, Idaho.—Continued

[**Origin:** I, introduced; N, native. **Tolerance:** I, intermediate; S, sensitive; T, tolerant. **Adult trophic guild:** Classification of species from Zaroban and others, 1999; inv., invertivore, pisc, piscivore; omni, omnivore; herb, herbivore. **Abbreviations:** IFG, Idaho Fish and Game; USGS, U.S. Geological Survey; WTF, wastewater treatment facility; –, no species found]

	Date	Species						
		Umatilla dace (*Rhinichthys umatilla*[1])	Dace (*Rhinichthys* sp.)	Northern pikeminnow (*Ptychocheilus oregonensis*)	Redside shiner (*Richardsonius balteatus*)	Tui chub (*Gila bicolor*)	Pumpkinseed (*Lepomis gibbosus*)	Bluegil (*Leponis macrochirus*)
Origin		N	N	N	N	N	I	I
Tolerance		I	I	T	I	T	T	T
Temperature preference		Cool	Cool	Cool	Cool	Warm	Warm	Warm
Adult trophic guild		inv	inv	inv/pisc	inv	omni	inv/pisc	inv/pisc
Site location								
Downstream Barber Dam	Jan. 1988	–	–	–	0.7	–	–	–
Downstream Barber Dam	Dec. 1996	1.3	–	–	.0	–	–	–
Downstream Barber Dam	Nov. 2003	1.1	–	0.5	.8	–	–	–
Upstream Lander WTF	Jan. 1988	–	–	.1	74.2	–	–	–
Upstream Lander WTF	Mar. 1992	1.6	–	–	10.5	–	–	–
Upstream Lander WTF	Mar. 1995	17.5	–	.2	1.4	–	–	–
Upstream Lander WTF	Dec. 1996	5.6	–	.9	–	–	–	–
Upstream Lander WTF	Nov. 2003	1.4	–	.6	.6	–	–	–
Downstream Lander WTF	Jan. 1988	–	–	1.1	58.7	–	–	4.8
Downstream Lander WTF	Mar. 1992	–	–	.3	–	–	–	–
Downstream Lander WTF	Feb. 1995	15.6	–	–	.8	–	–	–
Downstream Lander WTF	Dec. 1996	2.8	–	.8	6.5	–	–	–
Downstream Lander WTF	Dec. 2001	1.4	–	–	–	–	–	–
Downstream Lander WTF	Nov. 2003	4.3	–	1.8	–	–	–	–
Downstream Lander WTF	Aug. 2004	4.7	–	1.8	16.0	–	–	–
Upstream West Boise WTF	Jan. 1988	–	1.4	–	–	–	–	–
Upstream West Boise WTF	Mar. 1992	–	–	–	3.9	–	–	–
Upstream West Boise WTF	Mar. 1995	.0	–	.1	–	–	–	–
Upstream West Boise WTF	Dec. 1996	1.7	–	–	.3	–	–	–
Upstream West Boise WTF	Nov. 2003	–	–	–	–	–	–	–
Downstream West Boise WTF	Jan. 1988	–	1.2	1.1	21.7	–	–	–
Downstream West Boise WTF	Mar. 1992	–	1.5	3.8	28.3	–	–	–
Downstream West Boise WTF	Mar. 1995	13.5	–	.3	7.0	–	–	–
Downstream West Boise WTF	Dec. 1996	2.9	–	.6	2.6	–	–	–
Downstream West Boise WTF	Nov. 2003	–	–	1.4	–	–	–	–
North channel Eagle Island	Jan. 1988	–	3.2	2.3	14.5	–	–	–
Middleton	Dec. 1996	35.3	–	–	–	–	–	–
Middleton	Aug. 1997	6.3		8.8	6.8			.1
Above Star Road	Jan. 1988	–	4.6	5.1	51.1	–	–	–
Caldwell	Aug. 1997	.8	–	–	–	–	–	–
Near mouth	Dec. 1996	.8	–	–	–	–	–	–
Near mouth	Aug. 1997	–	–	5.9	–	10.9	0.5	–

Appendix A. Relative percentage of abundance of fish species in the lower Boise River, Idaho.—Continued

[**Origin:** I, introduced; N, native. **Tolerance:** I, intermediate; S, sensitive; T, tolerant. **Adult trophic guild:** Classification of species from Zaroban and others, 1999; inv., invertivore, pisc, piscivore; omni, omnivore; herb, herbivore. **Abbreviations:** IFG, Idaho Fish and Game; USGS, U.S. Geological Survey; WTF, wastewater treatment facility; –, no species found]

	Date	Species					Total abundance
		Largemouth bass (*Micropterus salmoides*)	Smallmouth bass (*Micropterus dolomieui*)	Channel catfish (*Ictalurus punctatus*)	Tadpole madtom (*Noturus gyrinus*)	Oriental weatherfish (*Misgurnus anguillicaudatus*)	
Origin		I	I	I	I	I	
Tolerance		T	I	T	T	T	
Temperature preference		Warm	Cool	Warm	Warm	Warm	
Adult trophic guild		pisc	pisc	inv/pisc	inv/pisc	omni	
Site location							
Downstream Barber Dam	Jan. 1988	–	–	–	–	–	150
Downstream Barber Dam	Dec. 1996	–	–	–	–	–	236
Downstream Barber Dam	Nov. 2003	–	–	–	–	–	826
Upstream Lander WTF	Jan. 1988	–	–	–	–	–	702
Upstream Lander WTF	Mar. 1992	–	–	–	–	–	190
Upstream Lander WTF	Mar. 1995	–	–	–	–	–	565
Upstream Lander WTF	Dec. 1996	–	–	–	–	–	806
Upstream Lander WTF	Nov. 2003	–	–	–	–	–	514
Downstream Lander WTF	Jan. 1988	–	–	–	–	–	2,929
Downstream Lander WTF	Mar. 1992	–	–	–	–	–	647
Downstream Lander WTF	Feb. 1995	–	–	–	–	–	385
Downstream Lander WTF	Dec. 1996	–	–	–	–	–	246
Downstream Lander WTF	Dec. 2001	0.8	–	–	–	–	363
Downstream Lander WTF	Nov. 2003	.4	–	–	–	–	282
Downstream Lander WTF	Aug. 2004	–	–	–	–	0.6	169
Upstream West Boise WTF	Jan. 1988	–	–	–	–	–	294
Upstream West Boise WTF	Mar. 1992	–	–	–	–	–	152
Upstream West Boise WTF	Mar. 1995	–	–	–	–	–	842
Upstream West Boise WTF	Dec. 1996	8.1	–	–	–	–	347
Upstream West Boise WTF	Nov. 2003	.3	–	–	–	–	378
Downstream West Boise WTF	Jan. 1988	.1	–	–	–	–	748
Downstream West Boise WTF	Mar. 1992	.6	–	–	–	–	714
Downstream West Boise WTF	Mar. 1995	–	–	–	–	–	341
Downstream West Boise WTF	Dec. 1996	–	0.3	–	–	–	341
Downstream West Boise WTF	Nov. 2003	1.0	–	–	–	–	290
North channel Eagle Island	Jan. 1988	–	–	–	–	–	442
Middleton	Dec. 1996	.2	–	–	–	–	425
Middleton	Aug. 1997	.9	.1		0.1	.1	974
Above Star Road	Jan. 1988	–	–	–	–	–	607
Caldwell	Aug. 1997	–	–	0.5	–	–	203
Near mouth	Dec. 1996	2.5	–	–	–	–	121
Near mouth	Aug. 1997	.9	4.1	1.8	–	–	221

[1] *Rhinichthys umatilla* is not classified in Zaroban and other (1999), classified in Wydoski and Whitney (2003).

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Fish Communities and Related Environmental Conditions of the Lower Boise River, Southwestern Idaho, 1974-2004

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