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Impacts of Land-Use Changes and Hydrologic Modification on the Lower Boise River, Idaho, USA

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Abstract.—In less than two centuries, the lower Boise River below 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 also provides irrigation water to more than 1,300 km^2 of land. The construction of three large dams in the upper basin dramatically altered the flow regime and sediment supply to the lower river. Flows are no longer sufficient to mobilize bed sediments and have allowed cottonwood trees and alien hardwoods to stabilize parafluvial surfaces, thereby narrowing sections of the river channel. Cadastral survey notes of 1867 and 1868 were used to recreate features associated with the lower Boise River Valley and identify characteristics of the river channel prior to dam construction and urbanization. Gravel and sand bars, historically present throughout the river, which are necessary to maintain biodiversity and productivity, are currently scarce. Sloughs were a dominant feature on the floodplain of the late 1800s, but today have been converted to irrigation canals, drains, or residential and commercial land uses. Flow alterations, water quality degradation, and habitat loss due to urbanization near the lower Boise River have resulted in macroinvertebrate and fish assemblages dominated by tolerant and alien species.

Introduction

The influence of human development on streams and rivers has been dramatic. In the United States, dams, locks, or diversions alter nearly every river in the lower 48 states (Collier et al. 1996). 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 et al. 1996; Bravard et al. 1999; Schick et al. 1999; 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 et al. 1996). These changes can have a dramatic impact on many aspects of aquatic ecosystems, including habitat structure and water quality. To fully comprehend and appreciate changes to aquatic ecosystems and to develop appropriate restoration plans, the current 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. Failure to recognize changes in natural ecosystems is due in part to the limited spatial and temporal scales with which they are measured (Sisk 1998).

The impact of urbanization on streams is not a recent phenomenon and, in some cases, can be persistent and severe. In the case of the rivers Tay and Tummel in Scotland, Gilvear (1993) and Winterbottom (2000) reported that the channels were transformed from braided to a confined, incised, single channel beginning in the late 1700s with levee construction, impoundment, decreased flood magnitude and frequency, and alterations in sediment supply. In many rivers, the impact of urbanization and development began centuries ago, and the environment prior to development is not well understood. When available, historical data are useful for understanding the ecological changes in urban watersheds.

Several authors have used data from cadastral sur-

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veys to recreate historical conditions of ecosystems. Nelson et al. (1998) described the presettlement vegetation on part of the upper Mississippi River using data from cadastral surveys of the general land office. Delcourt and Delcourt (1996) described presettlement vegetation in Michigan, also using data from cadastral surveys. In this paper, we use cadastral survey notes to explore the history of the lower Boise River and to assess changes to its structure and function since the late 1800s.

Study Area

The lower Boise River extends from the confluence with the Snake River to river kilometer 103 at Lucky Peak Dam (Figure 1). The study area is confined to the valley bottom, determined to be approximately 8 km wide, based on the 1867 and 1868 cadastral survey (Figure 2).

The lower Boise River is in the northern part of the western Snake River Plain ecoregion and has a semiarid climate with cool, wet winters and warm, dry summers. The river lies in a broad, alluvium-filled valley with several step-like terraces, or benches, which are more pronounced and continuous on the south side of the river. The valley upstream from Lucky Peak Dam is mountainous and sparsely populated with an average gradient of 2%. Downstream from Lucky Peak Dam, the valley floor slopes northwestward at a gradient of about 0.2%. The altitude of the river near Lucky Peak Dam is about 850 m above sea level, declining to 670 m near its mouth (Thomas and Dion 1974).

Indians camped and fished along the lower Boise River prior to and during the early 1800s. There are several historical references to large groups of Indians salmon and trout fishing in the lower Boise River (Pratt et al. 2001). Trappers and traders were among the first European inhabitants of the lower Boise Valley (Bird 1971), arriving in 1813, and by 1850, many beaver had been removed. The importance of beaver in shaping the river is unknown, but they were certainly a factor influencing the hydrology and riparian zone. Parts of the upper Boise River water-

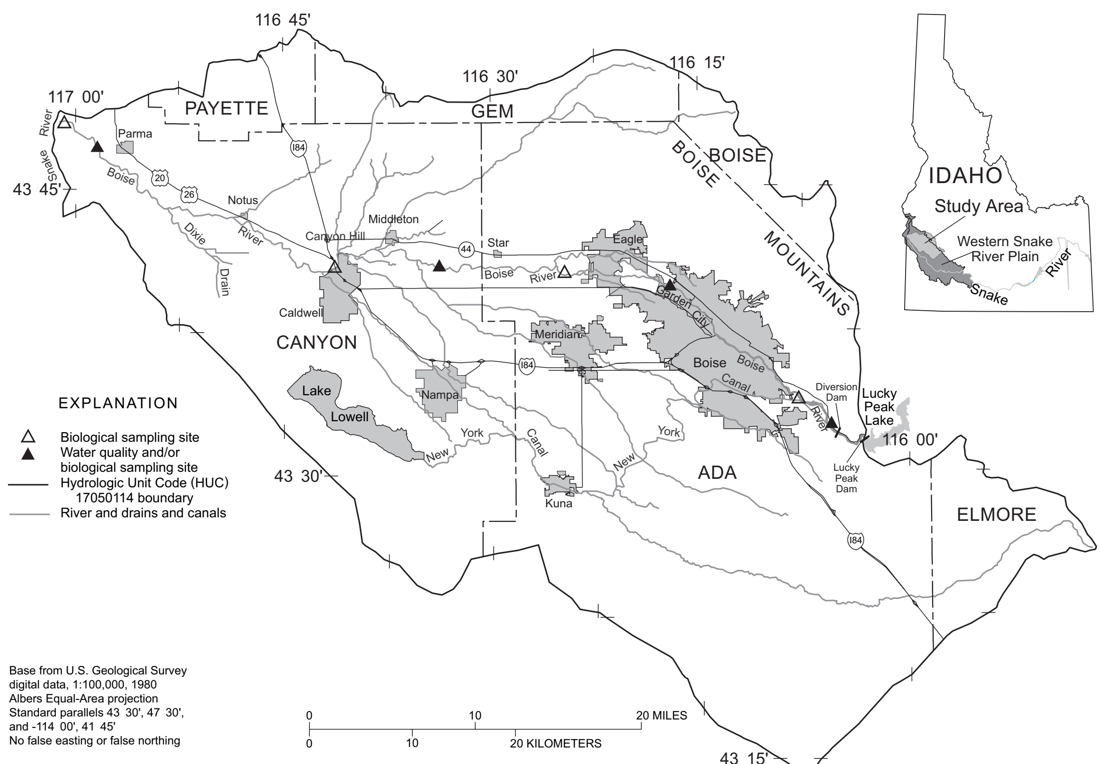


FIGURE 1. Lower Boise River Valley and USGS sampling locations, 1994–2002.

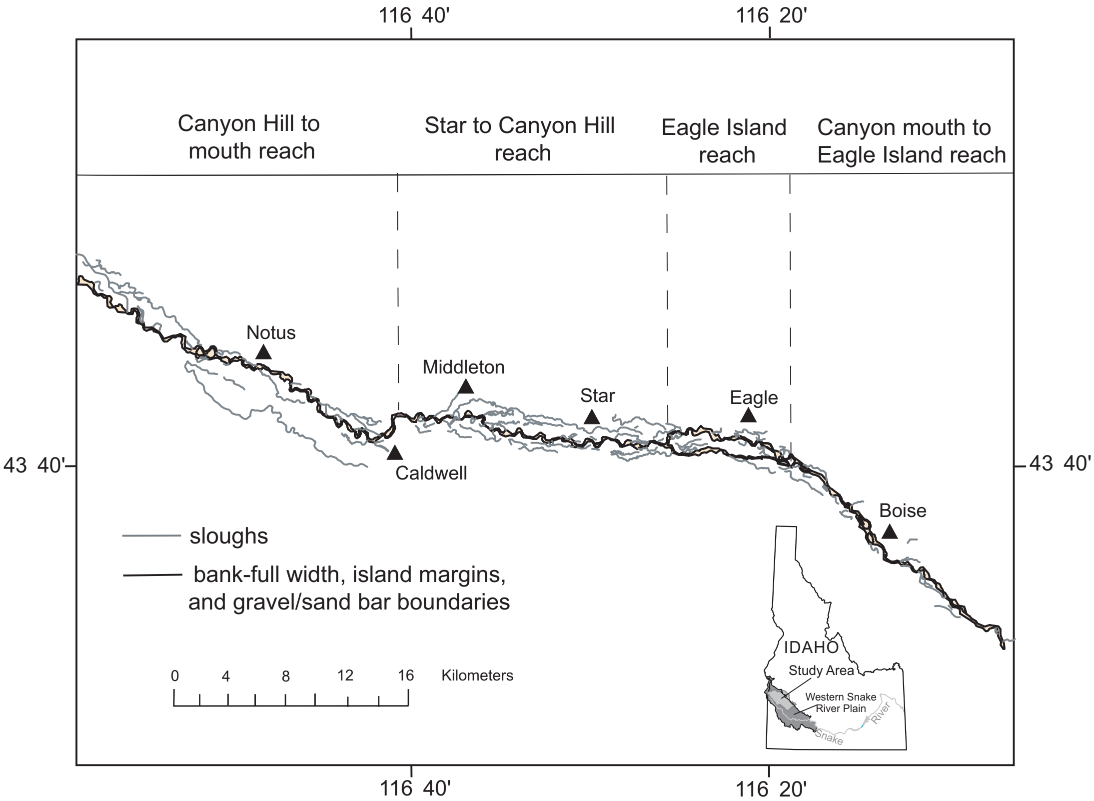


FIGURE 2. Historic map of the lower Boise River with sampling reaches recreated from cadastral survey notes of 1867 and 1868.

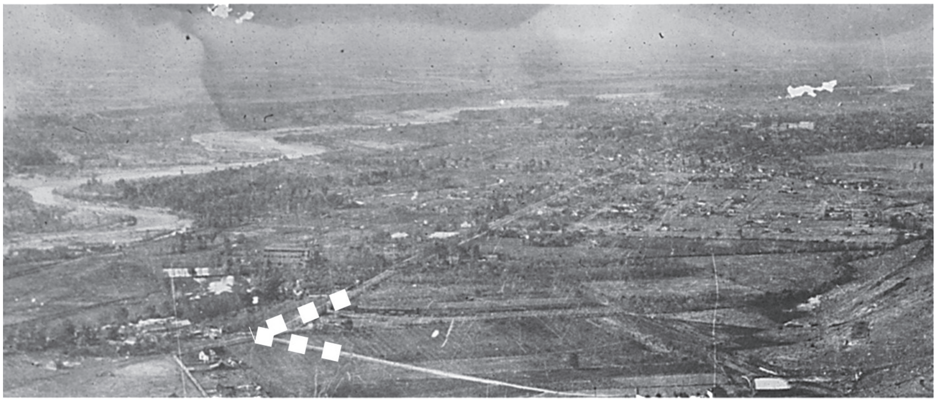
shed were heavily mined for gold using shaft and placer methods (Stacy 1993). Beginning in 1862, the discovery of gold in the upper basin encouraged agricultural development in the valley (Bird 1934). Early settlers also harvested timber along the river and, by 1863, were diverting water from the lower Boise River to irrigate crops. By 1867, agriculture was widespread throughout the lower Boise River Valley. Some irrigation canals and ditches had been constructed, but they were generally small. Irrigation was mainly accomplished by diverting water from the numerous sloughs already present on the floodplain. Farmers soon 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 Reclamation Service (now known as the Bureau of Reclamation, BOR) (Stacy 1993). By 1906, the New York Canal and several small irrigation projects had been built and Arrowrock Dam was built in 1915 on the main-stem Boise River, 10.5 km upstream from Boise. The U.S. Army Corps of Engineers (Corps) built Anderson Ranch Dam in 1950 on the south fork of the Boise River (Stacy 1993). In 1957, the Corps built a third dam, Lucky Peak, less than 6 km upstream from Boise (Stacy 1993).

The construction of a sewage treatment facility downstream from Boise in the early 1950s helped disinfect wastewater entering the river, but the plant was overloaded and toxic concentrations of chlorine 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 (Osborne 1959; Chandler and Chapman 2001). In 1986, a second outlet was constructed for Lucky Peak Dam in order to provide additional flow during the winter, which helped dilute sewage effluent. Flows in the lower Boise River varied with allocations of water for urban and agricultural use (IDEQ 1999). Cleanup efforts have continued in the lower Boise River, such as wastewater treatment upgrades and implementation of best management practices for urban and agricultural runoff.

The Boise River provides irrigation water to more than 1,300 km^2 of agricultural land (Sisco 2001) in the lower Boise River valley. The lower Boise River also has a history of water quality problems related to urbanization, including raw sewage, wastewater treatment outfall, storm drainage, industrial runoff, and bacterial contamination (BOR 1977; Clark and Bauer 1983; Frenzel 1988, 1990; Stacy 1993; Mullins 1998b; Parliman and Spinazola 1998; Boyle 2001; Fox et al. 2002). Many of these urban contaminants have been eliminated through improvements to wastewater treatment and the City of Boise storm water program (Robbin Finch, City of Boise, personal communication).

In 1994, land use and land cover in the lower Boise River Valley included rangeland (50%), irrigated cropland (29%), and urban and rural areas (9%); the remaining land use is unclassified or in transition (Kramber et al. 1997). Recently, large tracts of farmland have been converted to subdivisions and commercial facilities, while older residential areas have become businesses, shopping centers, and parking lots. The major crops in the basin are alfalfa, wheat, sugar beets, barley, and potatoes. Land use in the upper Boise River basin is primarily logging and recreation. Photographs taken in 1910 and 1995 (Figure 3) show the urbanization that has occurred in the valley and the narrowing of the river channel.

In the early 1800s, the lower Boise River fishery was described as the most renowned fishing place in the country, with large numbers of salmon (Pratt et al. 2001). The Idaho Power Company (IPC) has documented evidence of Chinook salmon *Onchorhynchus tshawytscha* spawning in the lower reaches of the lower Boise River until the early 1860s, when mining and irrigation projects began (Chandler and Chapman



1910

1995

FIGURE 3. Photographs of the lower Boise Valley looking west toward the city of Boise in 1910 (Idaho State Historical Society, picture no. 81–88.3) and 1995 (dashed white lines show common location on both photographs).

2001). The IPC also reported steelhead *O. mykiss* runs in the lower Boise River, as well as the presence of Pacific lamprey *Lampetra tridentata* near Caldwell.

Within the last century, the lower reaches of the lower Boise River changed from a thriving, coldwater salmon and trout assemblage to a coolwater assemblage. Alien warmwater fish such as common carp *Cyprinus carpio*, warmouth *Lepomis gulosus* (also known as *Chaenobryttus gulosus*), crappie *Pomoxis* spp., northern pike *Esox lucius*, largemouth bass *Micropterus salmoides*, smallmouth bass *M. dolomieu,* bluegill *L. macrochirus*, pumpkinseed *L. gibbosus*, channel catfish *Ictalurus punctatus*, tadpole madtom *Noturus gyrinus*, and oriental weatherfish *Misgurnus anguillicaudatus* were introduced into the lower Boise River since the turn of the 20th century (Mullins 1999; Chandler and Chapman 2001). Hells Canyon Dam, built in 1967, prevented anadromous fish from entering the lower Boise River (Chandler and Chapman 2001). The IPC concluded that the lower Boise River is no longer suitable to support salmonid spawning due to high water temperatures in the late summer and early fall (Chandler and Chapman 2001).

Methods

We compared morphology of the lower Boise River before and after urbanization using cadastral survey notes and photo interpretation. Unfortunately, few preurbanization biological data are available. Instead, personal accounts of species in the river were compared with current water quality and biological data.

We divided the lower Boise River into four reaches with similar physical features (Figure 2): the canyon mouth to the upstream end of Eagle Island (Canyon Mouth to Eagle Island Reach), Eagle Island north and south channels (Eagle Island Reach), the downstream end of Eagle Island at Star to Canyon Hill (Star to Canyon Hill Reach), and Canyon Hill to the river mouth (Canyon Hill to Mouth Reach).

Historical Geomorphology

Land cover data from 1867 and 1868 cadastral survey notes obtained from the Bureau of Land Management (BLM) for the lower Boise Valley were used to recreate the "historical" lower Boise River. The lands were surveyed during late summer and fall when river flows were lowest. After surveyors established township boundaries, section lines were surveyed to establish section corners and quarter corners. Surveyors also noted other geographical and cultural features located on or near section lines. Meander surveys were then conducted along the river to determine the location and extent of the river margins. Bearing trees were recorded with distance and bearing of each tree to the section, quarter, or meander corner.

Data from 250 km of survey transects were entered into a database, including qualitative notes on various attributes of the lower Boise River Valley. Survey coordinates were converted to latitude and longitude and verified with recent geographic data using algorithms to convert distance in meters to directional movement in minutes. A geospatial dataset was created on the basis of the geographic coordinates created. These data were projected into the Idaho Transverse Mercator projection to correspond with other datasets being used. The data were then adjusted to the Geographic Coordinate Data Base (GCDB).

Surveyors documented slough widths and azimuths in their notes. Azimuths and back azimuths were mapped for each slough and buffered to the appropriate width; these azimuths extended 100 m from the central data point at the section line. To verify the slough location, the buffered sloughs and azimuths were layered over 1939 aerial photographs. Between 1868 and 1939, many sloughs were converted to agricultural drains or canals so their historical locations were easily determined. Many sloughs along the river corridor were obliterated due to the movement of the river. In these cases, the sloughs were only partially drawn using the meander surveys indicating the "head" or the "tail" of a slough.

Meanders of the lower Boise River were surveyed after the completion of the section line surveys in each township. Meander survey methods can be found at URL: http://www.ca.blm.gov/webmanual/id156_m.htm (accessed March 2001). Survey data were given as an azimuth and distance for each meander. Meanders were typically measured at the mean high water mark and were typically used to indicate land remaining for development or farming (Brown 1962). In this study, the surveyed meander lines are assumed to approximate bank-full width.

On the basis of azimuth and distance in the survey notes, trigonometric functions of sine and cosine were used to determine the north and west movement of each succeeding meander point. The distance was then converted to latitude and longitude as previously described and verified using the GCDB based on the original 1867 and 1868 survey notes. There were only minor deviations between the converted meander notes and the GCDB; therefore, the GCDB was adopted for the river meanders.

Current Ecological Data

Recent measurements of bank-full 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 1999). Flow records from the water quality and biological sampling sites were obtained from the National Water Information System Web site (NWIS WEB). To compare historical and current flow conditions, discharge data were obtained from USGS gauge number 13202000. This gauge had the longest record on the lower Boise River, from 1895 to 2002 (USGS NWIS WEB: http://waterdata.usgs.gov/id/nwis/qwdata). Two metrics were used to evaluate the magnitude of change in the natural flow regime in the lower Boise River following dam construction: the magnitude and variation of mean monthly flows and the average monthly flows for December and August. For sites not equipped with continuous water stage recorders or stage-discharge ratings, instantaneous stream discharge was measured at the time of sample collection using methods described by Rantz (1982).

Water quality data were collected monthly, bimonthly, or seasonally between 1994 and 2002 by the USGS at four main-stem sites (Mullins 1998a; MacCoy 2004) (Figure 1). These sites were located at USGS gaging stations below Diversion Dam (Diversion Dam; Canyon Mouth to Eagle Island Reach), above Glenwood Bridge (Glenwood; Eagle Island Reach), above Middleton (Middleton; Star to Canyon Hill Reach), and near Parma (Parma; Canyon Hill to Mouth Reach). Biological samples associated with these sites were not always at the same location due to the lack of riffle habitat and were located upstream or downstream from the water quality sites but were within the same reach (Figure 1). Water quality data were not collected at Caldwell, but this was an important biological sampling site within the Canyon Hill to Mouth Reach.

Water quality data included instantaneous measurements of temperature, dissolved oxygen, pH, and specific conductance. Depth- and width-integrated water samples were collected, processed, and preserved according to Wilde et al. (1999) for analyses of suspended sediment and nutrients. Nutrients were analyzed by the USGS National Water-Quality Laboratory using methods described by Fishman (1993) and quality-assurance/quality-control protocols as described by Pritt and Raese (1995). Suspended sediment was analyzed by the USGS Cascades Volcano Observatory Sediment Laboratory using methods described by Guy (1969).

Water samples for bacterial analysis were collected near the center of the stream. Fecal coliform bacteria concentrations were measured using membrane-filter methods and are reported as colonies per 100 mL (Wilde et al. 1999). In 2000, the state water quality standard for bacteria changed from fecal coliform to *Escherichia coliform* (*E. coli*); beginning in 1999, the USGS began monitoring for both fecal and *E. coli*. *Escherichia coliform* concentrations were measured using the Colilert Quantitray method by Idaho Department of Health and Welfare and reported as most probable number (MPN) per 100 mL (Eaton et al. 1999). The MPN is considered equivalent to colonies per 100 mL.

Since 1995, periphyton and macroinvertebrate samples have been collected from riffle areas by the USGS (Mullins 1998b, 1999; MacCoy 2004). Periphyton samples were collected and processed using protocols developed by Porter et al. (1993). A measured sample of periphyton was collected from five areas within a riffle and composited. A subsample of the composite was passed through a glass-fiber filter, which was wrapped in foil, placed on dry ice, and delivered to the laboratory. Chlorophyll-a and ash-free dry weight were analyzed by the BOR Pacific Northwest Regional Laboratory, using spectrophotometry (standard method 10200H, Eaton et al. 1999).

Benthic macroinvertebrates were collected using protocols developed by Cuffney et al. (1993). A modified Surber sampler with a 425-mm-mesh net was used to collect a composite of invertebrates from cobble substrates near the five periphyton sampling locations. Microhabitat measures of depth, velocity, substrate, and embeddedness were measured at each macroinvertebrate sampling site. Large or rare taxa were isolated from the main sample to ensure that they were not lost or damaged during laboratory processing. Samples were fixed in 10% buffered formalin and shipped to Aquatic Biology Associates, Inc. for analysis. Periphyton chlorophyll-a, macroinvertebrate assemblage summaries, and associated habitat data were reported in Mullins (1999) and MacCoy (2004).

Fish assemblages were assessed by electrofishing a representative reach (1,700–2,100 m) using protocols developed by Meador et al. (1993). Shallow riffle areas were sampled using backpack electrofishers (700 V for an average of 10 min), and deepwater areas were sampled from a drift boat (using a 5,000-W, 240-V generator for an average of 25 min). Data collected included numbers of each species, total lengths, weights, and types and numbers of anomalies. Fish were collected annually between 1995 and 2001 (Table 1), and vouchers are located in the Orma J.

TABLE 1. Number and fish species collected at select sites in the lower Boise River between 1995 and 2001 (Mullins 1998b, 1999; MacCoy 2004). Fish attributes from Zaroban et al. (1999).

				Canyon Mouth to Eagle Island Reach	Eagle Island Reach					Star to Canyon Hill Reach		Canyon Hill to Mouth Reach		
Scientific name	Common name	Origin[a]	Temperature preference	Below diversion	Above Glenwood	Above Glenwood	Above Glenwood	South channel Eagle Island	South channel Eagle Island	Below Middleton	Below Middleton	Caldwell	Below Parma	Below Parma
				Dec-96	Feb-95	Dec-96	Sep-01	Mar-95	Dec-96	Dec-96	Aug-97	Aug-97	Dec-96	Aug-97
Salmo trutta	Brown trout	I	Cold	3	1	2	4		7					
Prosopium williamsoni	Mountain whitefish	N	Cold	94	93	68	251	125	238	110	19	5	10	4
Onchorhynchus mykiss	Wild rainbow trout	N	Cold	17	5	2	5	29	46	1				
Cottus bairdi	Mottled sculpin	N	Cold	65		2	24							
C. confusus	Shorthead sculpin	N	Cold	53		3	5							
Catostomus columbianus	Bridgelip sucker	N	Cool		36	30	18	1	7	12	99	18	59	69
C. macrocheilus	Largescale sucker	N	Cool		166	85	37	66	30	76	120	34	33	74
C. platyrhynchus	Mountain sucker	N	Cool		2	2	2	10	0	8				
Cyprinus carpio	Common carp	I	Warm							34	3	5	3	7
Acrocheilus alutaceus	Chiselmouth	N	Cool	1		1		2		2	370	20		14

TABLE 1. Continued.

Scientific name	Common name	Origin[a]	Temperature preference	Canyon Mouth to Eagle Island Reach	Eagle Island Reach					Star to Canyon Hill Reach		Canyon Hill to Mouth Reach		
				Below diversion	Above Glenwood	Above Glenwood	Above Glenwood	South channel Eagle Island	South channel Eagle Island	Below Middleton	Below Middleton	Caldwell	Below Parma	Below Parma
				Dec-96	Feb-95	Dec-96	Sep-01	Mar-95	Dec-96	Dec-96	Aug-97	Aug-97	Dec-96	Aug-97
Ptychocheilus oregonensis	Northern pikeminnow	N	Cool			2		1	2		86			13
Richardsonius balteatus	Redside shinner	N	Cool		3	16		24	9		66	120		1
Rhinichthys cataractae	Longnose dace	N	Cool		20	26	19	37	5	33	145		13	
R. osculus umatilla	Umatilla dace	N	Cool	3	60	7	5	46	10	150	61		1	
Gila bicolor	Tui chub	N	Warm											24
Lepomis macrochirus	Bluegill	I	Warm								1			
Micropterus salmoides	Largemouth bass	I	Warm				3			1	9		3	2
M. dolomieui	Smallmouth bass	I	Cool						1		1			9
Ictalurus punctatus	Channel catfish	I	Warm									1		4
			IBI score	89	46	52	68	66	60	39	27	23	11	7

[a] I = Introduced; N = Native.

Smith Museum of Natural History, Albertson College, Caldwell, Idaho.

Macroinvertebrate and fish assemblages were used to assess biotic integrity in the lower Boise River. Biological condition of the macroinvertebrate assemblages was assessed with metrics such as taxa richness, Ephemeroptera, Plecoptera, and Trichoptera (EPT) richness, percent dominant taxon, percent Elmidae, percent predators, and percent tolerant species. The biological condition of the fish assemblages was evaluated using an index of biological integrity (IBI; Mebane et al. 2003), which consists of 10 metrics: number of coldwater native species, percent sculpin (cottids), percent coldwater species, percent sensitive native individuals, percent tolerant individuals, number of alien species, CPUE of coldwater fish, percent of fish with DELT (deformities, eroded fins, lesions, or tumors) anomalies, number of trout age-classes, and percent common carp. These 10 metrics were standardized by scoring them continuously from 0 to 1 and weighted to produce a score ranging from 0 to 100. According to Mebane et al. (2003), sites with scores between 75 and 100 exhibit high biotic integrity with minimal disturbance and possess an abundant and diverse assemblage of native coldwater species; sites with scores between 50 and 74 are somewhat lower quality where alien species occur more frequently and the assemblage is dominated by coldwater, native species; and sites with scores less than 50 have poor biotic integrity where coldwater and sensitive species are rare or absent and where tolerant fish predominate.

Results and Interpretation

Canyon Mouth to Eagle Island Reach

The historical bank-full widths identified by the cadastral survey in the Canyon Mouth to Eagle Island Reach averaged 275 m and ranged between 92 and 675 m (Table 2). Historically, the river through this reach had extensive parafluvial surfaces (coarse sediments within the active channel, outside the wetted stream) with extensive gravel bars and islands. The valley gradient for this reach was approximately 0.29%. In describing a portion of this reach, the surveyor wrote, “the River is here divided by a large low gravely bar into two main channels, the bar island is entirely worthless.” Based on the data in the cadastral survey the island measured 340 m wide. The surveyor goes on to say that there are “barren river bars subject to frequent inundation.” At one point, the surveyor described the river as “wide and shallow” and gravels “washed nearly clean of soil by the overflow of the river at every freshet.” The meander survey notes described some gravel bars in backwater areas that contained “fine, rich alluvial soils” and “along the left bank of (the) Boise River (there are) low and generally very fertile (soils) with a dense undergrowth of willow and wildrose bushes.” The river channel today contains very few gravel bars, and the bed substrate is mainly cobble embedded by fine sediments up to 50% (Mullins 1999; MacCoy 2004).

Cottonwood stands are considered essential components to large gravel-bed alluvial systems (Poff et al. 1997; Merigliano 1996) and are native to the lower Boise River. Cottonwood did occur in the canyon mouth to Eagle Island Reach prior to dam construction but were not extensive (see 1910 photo in Figure 3; Table 2). The surveyor noted, “land along the right bank of the Boise River (is) low, subject to frequent inundation (with) scattering clumps of cottonwood (and) dense undergrowth willow.” The surveyor indicated that willow and wildrose were the dominant vegetation in this reach. Cottonwood stands and woody vegetation appeared to be confined to a narrow corridor at the stream margins.

Today, due to the lack of extreme flows to recruit and move instream and riparian substrate, there is a lack of parafluvial surfaces and limited recruitment of new cottonwood or willow trees. Using regression equations to determine unregulated basin flow in the lower Boise River calculated from basin characteristics (Hortness and Berenbrock 2001; USGS StreamStats at http://streamstats.usgs.gov/idstreamstats/) the annual mean flow for Diversion Dam in the Canyon Mouth to Eagle Island reach would be 53 m^3/s, while the actual regulated annual mean flow is 24 m^3/s. Presently, the average bank-full width (43 m) is less than one quarter of the historical width (Table 2; Mullins 1999). The average instantaneous temperature measured at the Diversion Dam from 1994 to 2002 was 10°C (Table 3) and ranged between 1.6°C and 19°C (MacCoy 2004). The water at the canyon mouth comes from the hypolimnion of Lucky Peak Lake and has an average temperature of 8.5°C at USGS gauge 13202000 (USGS NWIS WEB: http://waterdata.usgs.gov/id/nwis/qwdata). The river flows through the city of Boise in this reach and receives effluent from sewage treatment facilities. There is an increase in total phosphorus and bacteria between Diversion Dam and Glenwood, approximately 8 km upstream above Eagle Island, attributable to urban

TABLE 2. Features of the historic (1867–1868) and current (1994–2002) lower Boise River.

Parameter		Canyon Mouth to Eagle Island Reach	Eagle Island Reach	Star to Canyon Hill Reach	Canyon Hill to Mouth Reach
Embeddedness	Historic				
	Current	50%	75%	75%	50%
Dominant substrate	Historic				
	Current	cobble	cobble	cobble	gravel
Average bank-full width	Historic	275 m	North channel 240 m South channel 120 m	160 m	190 m
	Current	43 m	North channel 121 m South channel 47 m	87 m	76 m
Channel forms, parafluvial surfaces	Historic	Midchannel islands, gravel	gravel and sand bars	some islands, sand bars	some islands, sand bars, split channel at the mouth
	Current	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
	Current	none		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
	Current	some stands of native cottonwood	alien species dominate	alien species dominate	alien species dominate
Gradient	Current	0.29%	0.30%	0.02%	0.18%

sources. Total phosphorus increased slightly from Diversion Dam (median 0.04 mg/L) to Glenwood (median 0.09 mg/L), and median *E. coli* concentrations increased from 1 to 23 colonies/100 mL between these sites (Table 3; MacCoy 2004).

An average of only 22 macroinvertebrate taxa were found below Diversion Dam in the Canyon Mouth to Eagle Island Reach that included an average of 12 EPT taxa and 1 stonefly taxa (MacCoy, 2004). Coldwater native fish species, including mountain whitefish *Prosopium williamsoni*, shorthead sculpin *Cottus confusus*, and mottled sculpin *C. bairdii*, are abundant in this reach (Table 1; Mullins 1999; MacCoy 2004). Rainbow trout (nonanadromous *Onchorhynchus mykiss*) and brown trout *Salmo trutta* have been stocked in the lower Boise River. There is some salmonid spawning in tributaries of this reach, such as in Loggers Creek (Jeff Dillon, Idaho Fish and Game, personal communication). The fish IBI score calculated for this reach is 89, indicat-

Table 3. Median and range of instantaneous water quality values and select constituent concentrations from sites on the lower Boise River, 1994–2002 (MacCoy 2004).

	Diversion		Glenwood		Middleton		Parma	
	Mouth to Eagle Island Reach		Eagle Island Reach		Star to Canyon Hill Reach		Canyon Hill to Mouth Reach	
	median	range	median	range	median	range	median	range
Dissolved oxygen, mg/L	11.6	9.1–14.6	11.4	8.4–15.8	11.7	8.8–15.7	10.2	6.7–16.2
pH, standard units	7.6	6.6–8.5	8.0	7.8–8.9	8.0	6.7–9.1	8.0	7.3–8.9
Specific conductance, μS/cm	75	51–107	90	52–197	136	74–314	343	128–585
Temperature, °C	9.2	1.6–18.8	11.5	2.8–23.0	12	2.7–22.5	12.1	3.4–31.5
Total nitrogen, mg/L as N	0.26	0.15–0.51	0.45	0.18–1.90	0.89	0.38–3.51	2.17	0.62–5.33
Total phosphorus, mg/L as P	0.04	0.01–0.09	0.09	0.02–0.38	0.15	0.03–0.85	0.3	0.08–0.55
Suspended sediment, mg/L	4	1–38	5	1–107	6	2–211	45	8–245
Fecal coliform, colonies per 100 mL	1	1–29	43	4–1,030	73	3–3,950	440	44–3,600
*Escherichia coli*form, colonies per 100 mL	1	1–8	23	2–150	42	3–4,800	79	21–1,000
Periphyton average Chlorophyll-a, mg/m^2	6	<1–21	108	22–267	271	23–477	173	13–300

ing that it supports coldwater biota (Table 1; MacCoy 2004).

Eagle Island Reach

The Eagle Island reach gradient of 0.30% is similar to that of the Canyon Mouth to Eagle Island Reach; however, a decrease in gradient at the head of the island is evident (Hortness and Werner 1999). Historically, the north channel was dominant with an average bank-full width of 240 m, while the south channel averaged 120 m wide (Table 2). The south channel was shallow and the surveyor noted at one point no triangulations were needed to determine stream width, stating, "The stream being shallow I measured across." Several notes by the surveyor indicate that many areas along the north channel of Eagle Island were "low and subject to flooding or frequent inundation from 1 to 3 ft."

The surveyor notes indicated a change in the character of parafluvial surfaces from gravel to sand from the head of Eagle Island to its terminus. Near the head of the island, the surveyor writes "I now measure across gravel bars 7.75 chains to a slough too deep to wade." This is the last parafluvial surface specifically described as a "gravel bar." From this point downstream, the surveyor describes the parafluvial surfaces as "beaches," "sandy beaches," or "sand bars." At one point, the surveyor described the river as "divided into a number of channels by very low sandy islands covered with willows." Current photographic evidence at the top of Eagle Island Reach near Glenwood shows that most parafluvial surfaces have been stabilized by woody vegetation or covered by residential development (Figure 4).

The Eagle Island Reach was the first section of the lower Boise River to receive extensive natural development of side channels and sloughs, according to the cadastral survey. There are numerous notes on the presence of sloughs that ranged between 4 and 56 m wide with an average width of 16 m. Sloughs had subsurface hydrologic connections with the river, and in meander survey notes, the surveyor recorded numerous surface connections between sloughs and the main channel.

The pre-dam vegetation through this reach was similar to that of the Canyon Mouth to Eagle Island Reach, with differences occurring toward the terminus of the island. The surveyor described Eagle Island as having rich soil and dense willows along the stream

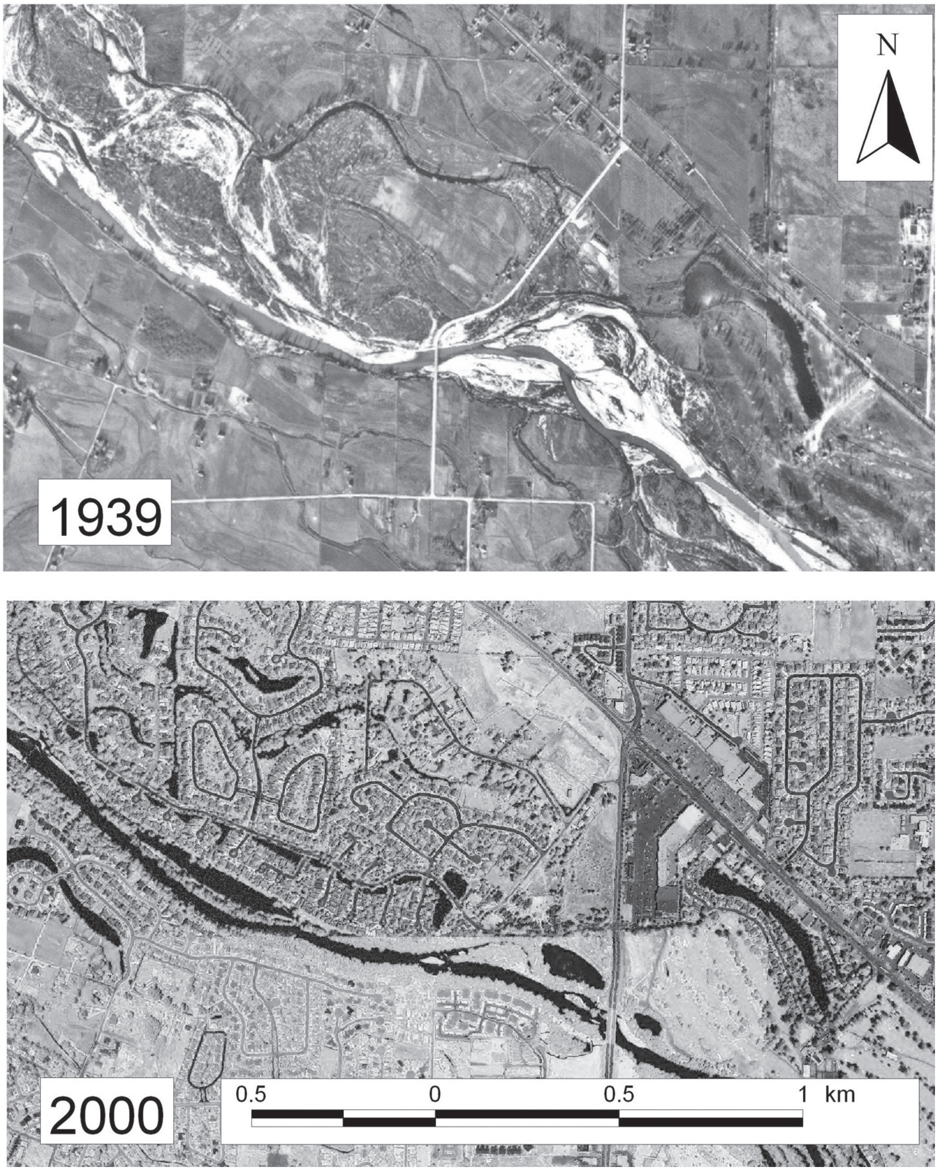


FIGURE 4. Aerial photographs from 1939 and 2000 of the lower Boise River near Glenwood Bridge (Eagle Island Reach) indicating the loss of parafluvial surfaces.

corridor with scattered cottonwoods. At the terminus of the island, the surveyor measured a cottonwood stand approximately 900 m wide. Throughout the notes, the surveyor describes the island as being populated by settlers.

Today, Eagle Island has changed both physically (Table 2) and ecologically. Many sloughs have been filled or converted to irrigation canals. The island is used mainly for residential housing with some agriculture and gravel mining. Flows are currently managed in both channels to meet flood management objectives and ensure delivery of irrigation water. The annual mean flow at the south channel USGS gauge 13206305 in 2002 was approximately 10 m^3/s with a wetted channel width of approximately 25 m (USGS NWIS WEB: http://waterdata.usgs.gov/id/nwis/qwdata). The average bank-full width from three surveyed transects in the north and south channels are 121 and 47 m, respectively (Table 2; Hortness and Werner 1999), approximately half the width of the historical river. Parafluvial surfaces are stabilized by trees and shrubs as seen in the photo of the north channel of Eagle Island near the town of Eagle (Figure 5).

At some locations in the Eagle Island Reach, embeddedness was as much as 75%, providing little opportunity for macroinvertebrate and small fish colonization (Mullins 1998a). The abundance of macroinvertebrates in this reach is similar to samples taken in the Canyon Mouth to Eagle Island Reach with few stoneflies but a higher percent tolerant species (10% compared to 3%) (Mullins 1998b). The Eagle Island Reach supports alien brown trout and rainbow trout, but no sculpins *Cottus* spp. (Table 1;

FIGURE 5. Aerial photographs from 1939 and 2000 of the south channel of the lower Boise River at Eagle Island (Eagle Island Reach) showing riparian vegetation stabilizing parafluvial surfaces.

Mullins 1999). A variety of other cold- and coolwater species were also present.

Star to Canyon Hill Reach

The historical bank-full width of the river in the Star to Canyon Hill Reach averaged 160 m (Table 2). The surveyor described the parafluvial surfaces as sand with descriptions such as beaches or sandy islands. In the spring of 1876, Judge Milton Kelly toured the lower Boise River Valley and described the river near Middleton (within the Star to Canyon Hill Reach) as "always high from springtime through July, so a ferry was a necessity. However, the sandy approaches kept washing out, the channel changing a little and the banks of the river shifting so that a ferry was not successful" (Bird 1934; p. 240). This statement suggests that nearshore deposits at Middleton were dominated by sand. There was no mention in the cadastral survey notes of multiple channels (braiding) as described in the upstream reaches. At one point, the surveyor does note "the river here is divided into two channels by a low sandy & gravelly Island about 10 chains long E & W." This is the only mid-channel island in this reach described by the survey and may be a further indication of a change in sediment characteristics. The reach gradient is 0.02%, considerably lower than that of the upstream reaches. This could be one reason for development of numerous side channels and sloughs in this reach. Through the approximately 21 km of river surveyed in this reach, the surveyors crossed sloughs 81 times with sloughs averaging 10 m wide, ranging between 3 and 60 m. Meander surveys noted that many sloughs had surface water connections with the river.

The width of the hyporheic zone through this reach is unknown, but some of the sloughs were located as far as 1.5 km from the main channel. During the September and October cadastral surveys, a period of declining flow in the basin, the surveyor indicated that sloughs were watered. Recharge of the hyporheic zone occurred during periods of high flow. Wagon roads located on the north side of the river and situated on a low ridge about 1.5 km from the river also indicate a wetted floodplain (large hyporheic zone) that would be difficult to traverse by wagon or horseback.

Cottonwood stands were well developed in the Star to Canyon Hill Reach. From surveyor notes, the cottonwood stands ranged from 500 m to 1 km and the surveyor described most of the vegetation as being "timber scattering of cottonwood." Willows were recorded in only a few areas.

Today, the Star to Canyon Hill reach contains few exposed parafluvial surfaces and there is a reduction in natural slough formation (Table 2). Aerial photographs from 1939 and 2000 of a section of the river near Middleton (Figure 6) show parafluvial surfaces colonized by woody vegetation and no longer a part of the active channel.

High flows exceeding 113 m^3/s were measured at the Middleton gauge in 1993 and 1995 (USGS NWIS WEB: http://waterdata.usgs.gov/id/nwis/qwdata). Similar high flows may have caused the river to incise and increase erosion potential and riverbank sloughing. Currently, islands and backwater in this reach provide fish habitat (Mullins 1999). The average bank-full width from three surveyed transects between the terminus of Eagle Island and the Ada County line was 87 m (Table 2, Hortness and Werner 1999), almost half the historical width.

The median instantaneous temperature collected from 1994 to 2004 at the Middleton biological sampling site was 12°C with a range between 2.7°C in winter months to 22.5°C in summer months (Table 3; MacCoy 2004). The Idaho State standard temperatures of not to exceed 13°C during the salmonid spawning period between October 15 and March 15, and not to exceed 22°C to support coldwater aquatic life, were exceeded at this site (MacCoy 2004). At Middleton, total nitrogen (median 0.89 mg/L), total phosphorus (median 0.15 mg/L), and suspended sediment (median 6 mg/L) were higher than in the canyon mouth reach (Table 3).

The macroinvertebrate assemblages below Middleton between 1995 and 2000 consisted of up to 30% tolerant species such as *Tricorythodes minutus*, a sediment-tolerant mayfly, and the New Zealand mudsnail *Potamopyrgus antipodarum* (Mullins 1999; MacCoy 2004). Both species have increased since sampling began in 1995, and no stoneflies were found in the 2000 sample (MacCoy 2004). Mountain whitefish was the predominant salmonid found at Middleton, and no sculpin were found. Bridgelip sucker *Catostomus columbianus*, largescale sucker *C. macrocheilus*, chiselmouth *Acrocheilus alutaceus*, and two dace species, longnosedace *Rhinichthys cataractae* and Umatilla dace *Rhinichthys umatilla*, were the most abundant species at this site (Table 1; Mullins 1999; MacCoy 2004). These fish were collected from fast runs and are considered coolwater species (Zaroban et al. 1999). The IBI score for the Middleton fish assemblage in 1996 was less than 40, below the minimum threshold associated with coldwater biota (Table 1, MacCoy 2004).

Canyon Hill to Mouth Reach

The Canyon Hill to Mouth Reach is approximately 15 km long (Figure 2) with pre-dam average bank-full width of 190 m, ranging between 20 and 890 m (Table 2). The surveyor used "sand beach," "beach," or "sandy island" to describe the parafluvial surfaces. These sandy bars were extensive, as the surveyor described one being 74 m wide. Near the end of the reach, the surveyor described the river as divided into "a number of channels by low sandy islands and bars." The surveyor described areas "subject to frequent inundation" above the meander lines in the lower part of this reach. The valley gradient is 0.18%, which is greater than that of the Star to Canyon Hill Reach (Table 2). Judge Milton Kelly, in 1876, described the river dividing near the mouth and forming an island with the north channel approximately 5 km from the south channel (Bird 1934). This change occurred sometime between the completion of the cadastral survey in 1868 and Kelly's tour in 1876. A 1939 aerial photograph shows the north channel and the remnants of the south channel described by Kelly. The 2000 photo shows the decrease in parafluvial surfaces from 1939 (Figure 7).

Sloughs were a prominent feature in the historical Canyon Hill to Mouth Reach, averaging 15 m wide and ranging between 3 and 45 m. Some sloughs were used for irrigation and several irrigation ditches were described in the surveyor notes. One of the main sloughs, Dixie Slough, originates approximately 2 km south of the lower Boise River and runs parallel to the river for approximately 16.7 km west to its confluence with the river. The historical water source for Dixie Slough is unknown, but it is now principally fed by irrigation return flow. Sagebrush *Artemisia* sp. and greasewood *Sarcobatus* sp. were noted in the surveyor's notes between the slough and the lower Boise River. This plant association commonly grows on saline sodic-soils generally created by an accumulation of salts in the upper soil profile from evaporation of large amounts of water at the soil surface. Current soils in the area are mapped as Letha soils, which are still considered saline-sodic (USDA 1972). The cause of the saline-sodic soils between Dixie Slough and the lower Boise River is unknown.

Cottonwoods were the dominant trees in this reach. The surveyor frequently refers to the vegetation as "timber scattering of cottonwood." These stands of cottonwood were probably extensive as the surveyor provides descriptions such as "enter timber" and "leave timber" at nearly every section line. On the basis of these data, the width of the cottonwood stand was between 700 m and 1 km. These cottonwood stands do not appear to be dense, on the basis of the small number of trees marked as bearing trees. The surveyor also describes a few dispersed willow trees, not as extensive as in upstream reaches.

Today, the Canyon Hill to Mouth reach is confined to the main channel and sloughs have been converted to irrigation canals and drains (Table 2). Parafluvial surfaces are absent, and the river is mainly a deep run and the river channel is incised (Figure 7). In 1998, the average bank-full width near the mouth was 76 m (Table 3; Mullins 1999), less than half the historical width. Average instantaneous temperature measured at Parma between 1994 and 2002 was 12.1°C, ranging between 3.4°C and 31.5°C (Table 3; MacCoy 2004). Prior to urbanization, temperatures were likely colder to support the number of salmon indicated in historical documents. Nutrients, bacteria, and suspended sediment increase at Parma compared to the upstream sites, mainly from agricultural sources. Total phosphorus (median 0.3 mg/L), *E. coli* (median of 79 organisms/100 mL), and suspended sediment (median of 45 mg/L) increased from Middleton to Parma by 50%, 50%, and 30%, respectively (Table 3; MacCoy 2004). Today, there is minimal fish habitat and very few riffles for macroinvertebrate colonization (Mullins 1999). The macroinvertebrate assemblage measured below the Parma water quality site was composed mainly of the tolerant mayfly, *Tricorythodes minutus* (50%), and no stoneflies were found. The fish species that occurred in this reach were mainly coolwater suckers and minnows (Table 1; Mullins 1999; MacCoy 2004). The fish assemblage assessed near the mouth in 1996 had the lowest IBI score (under 20) of all the sites in the lower Boise River (MacCoy 2004).

General River Conditions

The magnitude and variability of seasonal flow changed on the lower Boise River following the construction of Lucky Peak Dam. Seasonal flows were similar prior to dam construction (pre-1917) at the Boise River near Boise gauge (USGS 1202000) just downstream from Lucky Peak Dam. Prior to 1917, average flows for December and August were 31 and 34 m^3/s, respectively, each with a standard deviation of 13 m^3/s. Average flows after dam construction (post-1957) for December and August were 10 and 114 m^3/s, respectively; and standard deviations were 10 and 18 m^3/s, respectively (USGS NWIS WEB: http://waterdata.usgs.gov/id/nwis/qwdata). In fact, the flow

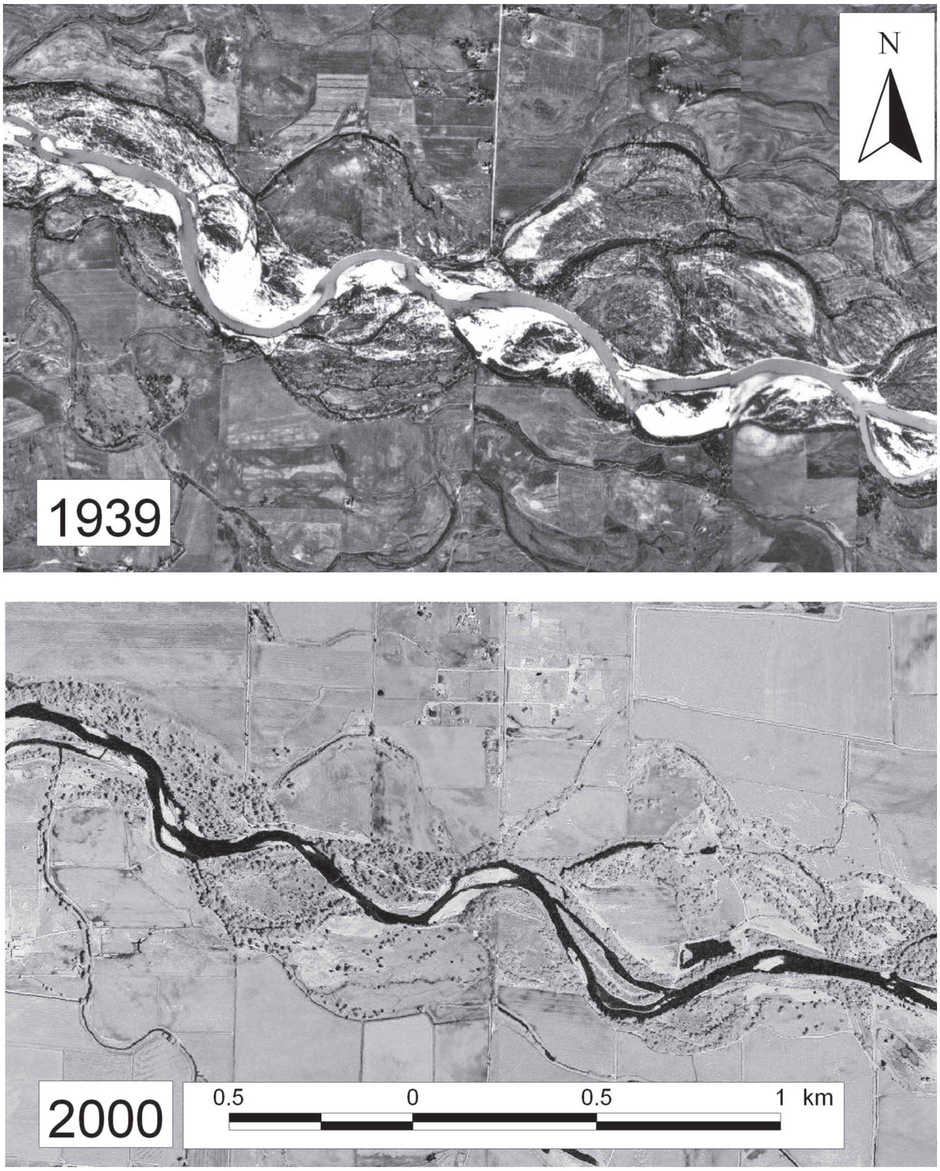


FIGURE 6. Aerial photographs from 1939 and 2000 of a section of the lower Boise River near Middleton (Star to Canyon Hill Reach) showing the stabilization of parafluvial surfaces.

regime was the opposite of pre-dam flows in December and August (Figure 8). The average December post-dam flows are significantly lower ($P < 0.001$, Wilcoxon rank sum test) than during pre-dam years, and the average August post-dam flows are significantly ($P < 0.001$) higher than during pre-dam years.

Recent water quality data revealed increases in constituent concentrations in the lower Boise River in a downstream direction (Mullins 1998b; MacCoy 2004). At four sampling locations between Diversion Dam and Parma, nitrogen, phosphorus, suspended sediment, and fecal coliform bacteria increased more than 8, 7, 11, and 400 times, respectively (Table 3). Chlorophyll-a concentrations also increased in a downstream direction and were highest at Middleton and Parma (Table 3), but there was no indication of nuisance algae (MacCoy 2004).

The state's temperature standards of 22°C and

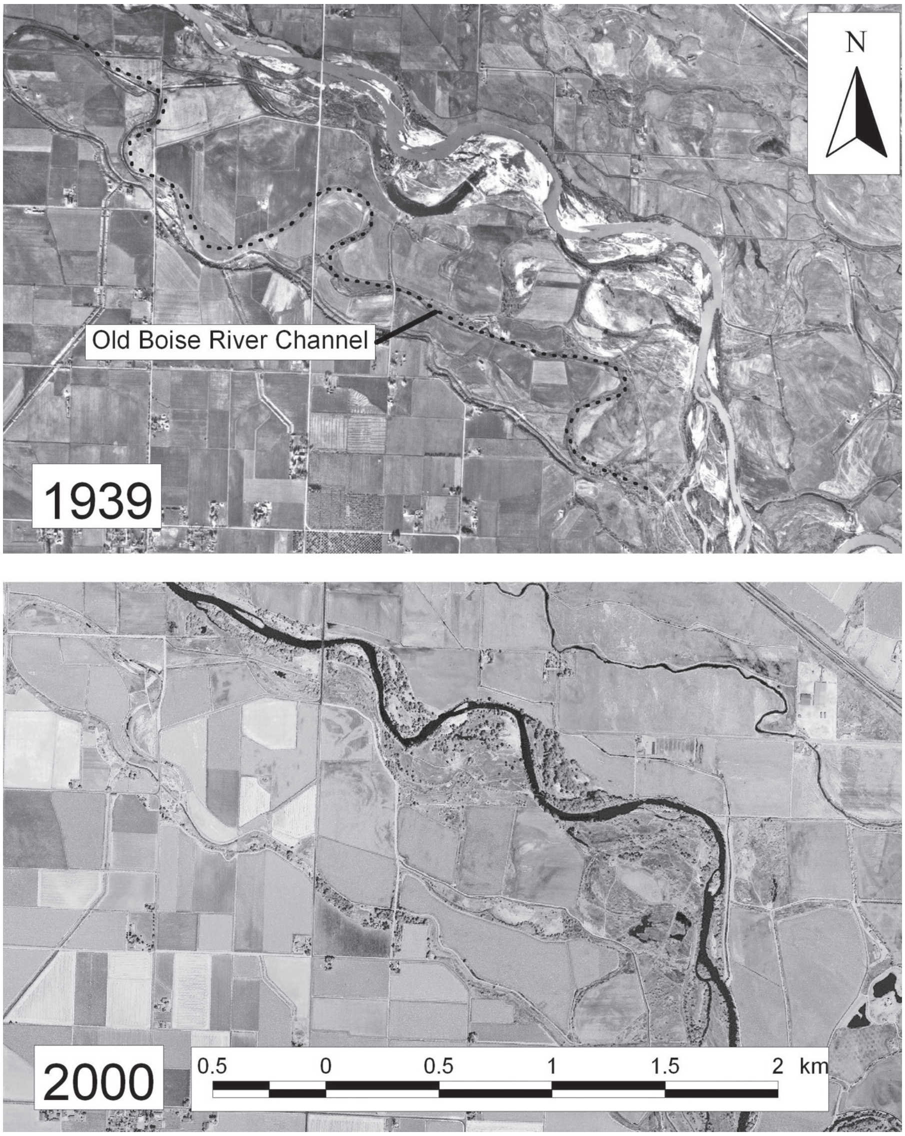


FIGURE 7. Aerial photographs from 1939 and 2000 of the lower Boise River near Parma (Canyon Hill to Mouth Reach) showing historic divided channel and stabilization of parafluvial surfaces.

13°C (IDEQ 2001) to protect coldwater biota and salmonid spawning, respectively, were exceeded most frequently at Middleton and Parma (MacCoy, 2004). The suspended sediment criterion of 80 mg/L for no more than 14 d (Rowe et al. 1999) was exceeded most frequently at Parma (Table 3). Total nitrogen concentrations at Glenwood, Middleton, and Parma exceeded national background levels of 1.0 mg/L (USGS 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 et al. 2000). Glenwood, Middleton, and Parma also exceeded the flow-adjusted total phosphorus concentrations for undeveloped basins (0.02 mg/L; Clark et al. 2000). The Idaho standard for *E. coli* in recreational waters (406 organisms/100 mL; IDEQ 2001) was exceeded at Middleton and Parma between 1994 and 2002.

The lower Boise River channel form and function change in a downstream direction. The gradient

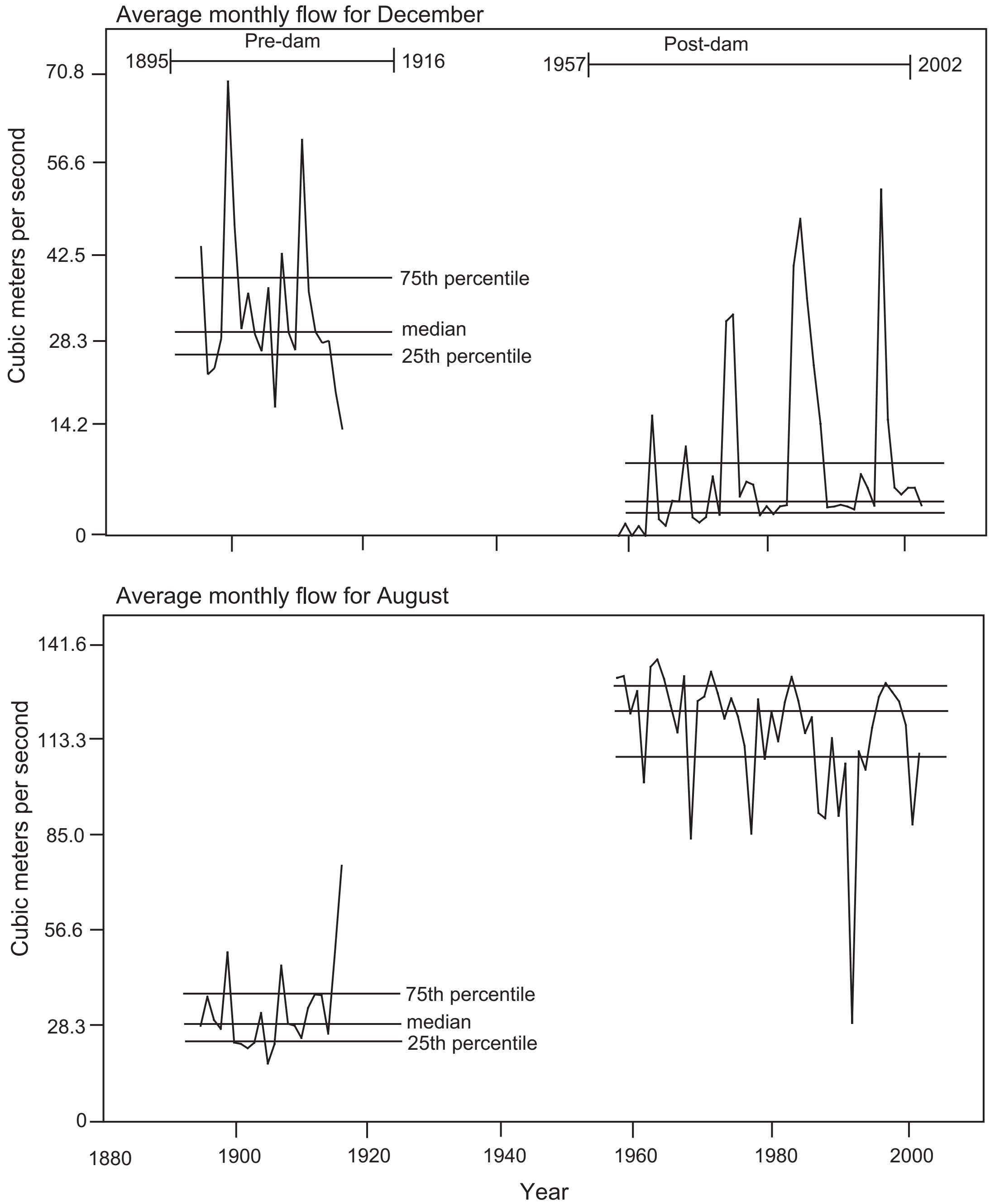


FIGURE 8. Monthly average flows for December and August pre-dam (1885–1916) and post-dam (1957–2002) in the lower Boise River at USGS gauge 13202000.

decreased from near 0.30% to 0.02% from the Canyon Mouth to Eagle Island Reach to the Star to Canyon Hill Reach (Table 2). The formation of sloughs and side channels historically dominated the Star to Canyon Hill Reach and would have provided important habitat for fish and invertebrates. In the Canyon Hill to Mouth Reach, the gradient increased to 0.18% forming a more centralized channel but still provided slough and side channel habitat. Historically river bottom substrate above the Eagle Island Reach was dominated by cobble and gravel. Below the Eagle Island Reach, substrate was dominated by sand. Currently, there is little movement of substrate in the river due to regulated flows and embeddedness of greater than 50% is common. Throughout the river, there has been extensive loss of parafluvial surfaces, and average bankfull width, in some cases, has decreased to less than half the historical measure (Table 2).

Regulated flow, poor habitat, and water quality have affected the biological communities in the lower Boise River. Biological condition throughout the river was poor compared to other Idaho rivers not impacted by urbanization and agriculture (Maret et al. 2001; MacCoy 2004). The macroinvertebrate assemblages at each site remained similar over the 8-year USGS study; however, there were decreases in density during extremely high and low flows. The number of EPT taxa ranged between 5 and 16 and was lowest at the downstream sites (MacCoy 2004). The number of tolerant taxa increased in a downstream direction, and up to 50% of the macroinvertebrate assemblage near the mouth of the lower Boise River was composed of tolerant species (MacCoy 2004).

Discussion

Urbanization and agriculture have affected water quality and decreased aquatic habitat and parafluvial surfaces in the lower Boise River. The construction of three large dams in the upper basin dramatically altered the flow regime and sediment supply to the river. Stream regulation by dams eliminates natural variations in flow (Waters 1995). Natural seasonal patterns, timing of extreme flows, frequency of high and low flows, and droughts and floods contribute to the biodiversity of a river ecosystem (Richter et al. 1996; Stanford et al. 1996; Poff et al. 1997) and are sensitive to human impact (Olden and Poff 2003). Dams and other hydrologic alterations have decreased the natural disturbance regime and biodiversity of the lower Boise River. Phosphorus from wastewater treatment facilities and increased nutrients, bacteria, and sediment from agriculture lowered water quality. The increased abundance of tolerant and alien species has lowered the quality of natural aquatic assemblages.

Currently, alien plant species occur in all reaches of the lower Boise River. Jones (2001) reported alien hardwoods have replaced the native cottonwood stands along Eagle Island. Purple loosestrife *Lythrum salicaria* and reed canarygrass *Phalaris arundinacea* are present along most of the lower Boise River.

The number of macroinvertebrate taxa is diminished in all reaches of the lower Boise River. There are very few stoneflies found compared to the numbers found in most rivers in Idaho (Maret et al. 2001). Most macroinvertebrates in the lower Boise River are tolerant to sediment and excess nutrients, and the percent tolerant species increases in a downstream direction. The embedded substrates restrict the colonization of macroinvertebrates and fish that require coarse sediments. Alien fish are present throughout the lower Boise River, especially in the lower reaches, and there is a lack of refuge for native species. There are no quantitative biological data prior to dam construction that would help us estimate biological conditions in the lower Boise River, but historical accounts of salmon throughout the system indicate it supported large anadromous fish populations.

Canyon Mouth to Eagle Island and the Eagle Island Reaches

The historical river channel between the canyon mouth and Eagle Island was more dynamic than the current channel. The gravel bars historically present in this reach represented part of the “shifting habitat mosaic” necessary to maintain biodiversity and productivity (Poff et al. 1997). The completion of Lucky Peak Dam exacerbated the armoring of bottom substrate by reducing sediment supply to reaches just downstream from the dam. Sediment starvation is a common occurrence on many large gravel-bed rivers (Poff et al. 1997). The maintenance of parafluvial surfaces is dependent upon an adequate supply of sediment and high flows to create sufficient shear stress to mobilize coarse streambed material. Currently, flows do not produce adequate shear stress to mobilize bed material on a regular basis. Dredging, aggregate mining, and stream channelization also reduced parafluvial surfaces in this reach. Today, with the river flowing through the city of Boise, the major land uses in this reach are urban and residential to the river’s edge, necessitating channelization and bank stabilization in several sections. Regulated flows and colder than normal temperatures also affect the aquatic assemblages in these reaches.

The sloughs and side channels beginning in the Eagle Island Reach indicate an extensive hyporheic zone, a key to the functioning and productivity of gravel-bed alluvial systems (Stanford et al. 1996). The conversion of sloughs to irrigation canals and drains resulted in the loss of some of the most important habitat in the river. Stanford et al. (1996) described the importance of side channels and sloughs in maintaining fisheries and their importance for certain life stages of native salmonids.

Star to Canyon Hill Reach

The lack of extreme flows has caused the bottom substrate to be embedded as much as 75% in this reach, reducing interstitial habitat used by macroinvertebrates and fish. The apparent reduction in the size and amount of bedload through the Star to Canyon Hill Reach may have prevented the braiding and islands that were seen historically in upstream reaches. Streams and rivers with large amounts of coarse bedloads are often associated with braided or divided channels (Knighton 1998; Bravard et al. 1999). Two factors identified in the literature as affecting the width of rivers are the reduction in sediment transport and reduction of flow (Schumm 1972). We suspect that both factors are responsible for the narrowing of the channel in this reach compared to upstream reaches. The decrease in gradient aided formation of side channels and sloughs as described in the surveyor notes. At channel-forming flows, these sloughs would have reduced flow in the main channel and the capacity of the main channel to transport sediment. According to Lane (1972), reduction in flow would reduce both size and quantity of the sediment transported. This may explain why there was extensive deposition of sand in this reach. Many of the historical sloughs in the Star to Canyon Hill Reach were converted to drains or irrigation canals and no longer provide high quality aquatic habitat. Prior to construction of dams, levees, and extensive irrigation, sections of the lower Boise River had a large (up to 1.5 km wide) hyporheic zone that provided side channels for refuge and salmon spawning and rearing (Boulton et al. 1998). Many authors have described the importance of the hyporheic zone in alluvial systems (Boulton et al. 1998; Stanford and Ward 1993; Wondzell and Swanson 1999). The Boise River dams 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 construction of levees are associated with incision of the lower Boise River and reduction of depositional areas and wetlands associated with the hyporheic zone. A reduced hyporheic zone along with the potential cooling effect of its groundwater discharge to the river may have increased temperature in this reach. The elevated nutrients and sediment from agricultural practices produced poor water quality conditions. These factors and the loss of important habitats for sensitive macroinvertebrates and fish aided colonization of alien and tolerant macroinvertebrates and fish in the Star to Canyon Hill reach.

Canyon Hill to Mouth Reach

The Canyon Hill to Mouth Reach had many areas described by the surveyor as being low and subject to frequent inundation, with numerous side channels and sloughs, indicating an extensive hyporheic zone. Historically, this increased the reach's susceptibity to channel avulsions and may have caused the main channel shifting north 5 km between 1867 and 1876. However, saline-resistant vegetation on parts of the floodplain indicate changes in subsurface flow patterns that resulted in the accumulation of salts in the soil profile.

Changes in flow regime and sediment supply have altered the geomorphologic characteristics of this reach; parafluvial surfaces are nearly gone, with many stabilized by woody vegetation. The lack of parafluvial surfaces necessary to maintain high quality aquatic habitat is one reason why tolerant species dominate this reach. Another reason for abundant tolerant species is the high concentrations of nutrients and sediment associated with agriculture. High stream temperatures and poor physical habitat have resulted in a poor fish assemblage near the mouth.

Conclusion

The lower Boise River needs to be viewed as the result of a complex history of alterations. The physical features of the lower Boise River in 1867 and 1868 indicate that the river was wider and more dynamic than the present river, but there were alterations prior to the cadastral surveys. Historical information helped us to identify changes within the river ecosystem, to understand the complex connectivity between the main channel and sloughs, and to identify physical processes of the river. These processes and the river's connectivity have been lost in the current urbanized system. Restoration of chemical, physical, and biological condition is dependent upon reconnecting these fragmented components.

Restoration efforts, such as agricultural best management practices to reduce sediment and nutrient runoff, and efforts to reduce urban storm water runoff have begun to improve the water quality in the lower Boise River. Sediment, nutrient and bacteria TMDLs have been or are in the process of being written to help develop additional plans to restore beneficial uses (fishable and swimable) of the river. Currently, there are no efforts to restore the coldwater fishery in the lower reaches of the river. An archeological study of fish species utilized by Native Americans might help to understand the historical distribution and the rich biodiversity that once typified the lower Boise River. Such data would provide a benchmark for efforts to restore those resources.

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