Henry R. LaVigne[1,2], **Robert M. Hughes**, and **Alan T. Herlihy**. Department of Fisheries and Wildlife, Oregon State University, 200 SW 35th Street, Corvallis, Oregon 97333

Bioassessments to Detect Changes in Pacific Northwest River Fish Assemblages: A Malheur River Case Study

Abstract

The EPA's Environmental Monitoring and Assessment Program large-river assessment protocol was applied to assess the ecological condition, major stressors, and likely human disturbances of the mainstem Malheur River, OR. We used inflatable rafts to allow launching and retrieving from difficult access points and to sample river reaches inaccessible to most other boat types or wading crews, including areas with river obstacles such as rapids and small dams. Electrofishing twenty-four 1-2 km long reaches within the lower 150 km of the river during the summers of 2006 and 2007 revealed: (1) the absence of native mountain whitefish *Prosopium williamsoni*; (2) the presence of previously undocumented endemics, mountain sucker *Catostomus platyrhynchus* and leopard dace *Rhinichthys falcatus*; (3) the existence of previously undocumented aliens, flathead catfish *Pylodictis olivaris,* tadpole madtom *Noturus gyrinus,* pumpkinseed *Lepomis gibbosus,* fathead minnow *Pimephales promelas*, and western mosquitofish *Gambusia affinis*; (4) possible range extensions into the main river by two alien basin-reservoir inhabitants, largemouth bass *Micropterus salmoides* and yellow perch *Perca flavescens*; and (5) index of biological integrity scores that declined from a high of 53 for an upstream site to 0.5 for a site 6 km from the river mouth. Regular standardized direct assessments of large-river fish assemblages can provide important information used to update river-basin management plans and inform water-resource managers.

Introduction

Direct assessments of large-river fish assemblages are an important monitoring tool that fisheries managers can use to determine the biological condition of individual rivers (Hughes and Gammon 1987, Mebane et al. 2003). Just as state water resource agencies monitor water quality along rivers to determine trends and set water quality goals (ODEQ 2005), regular monitoring of river fish assemblages could inform fisheries management decisions (ODFW 2005).

The EPA's Environmental Monitoring and Assessment Program (EMAP) large-river sampling protocol was designed to assess the ecological condition, major stressors, and likely human disturbances of entire mainstem rivers of the western US. The protocol includes the use of inflatable rafts that enable crews to launch and retrieve from difficult access points and sample reaches inaccessible to most other boat types or wading crews, including areas with river obstacles such as rapids, small dams and diverted flows.

The objective of this paper is to illustrate the usefulness of this sampling protocol for detecting changes in the distribution and assemblage structure of fishes inhabiting large western rivers during summer base-flow conditions. We describe a portion of our work conducted along the lower 150 km of the Malheur River, OR, (Figure 1) during the summers of 2006 and 2007. Prior to our research, the Oregon Department of Fish and Wildlife (ODFW) conducted the last extensive fish survey of the lower Malheur River from Namorf, OR, to the river mouth during the summer of 1978 (ODFW 1978, NPCC 2004).

Methods

The EMAP large-river assessment protocol (Peck et al. *In Press*) includes probability selection of river sampling reaches to allow rigorous statistical analyses (Stevens and Olsen 2004). Twenty-four mid-reach points and associated GPS coordinates were marked on 1:24000 scale USGS topographic maps and provided to the crew leader to facilitate logistics. We gained access to sites (Figure 1) either by private landowner permission or from public lands including bridge easements. Isolated canyon sites were reached after a full-day float. We electrofished 20 reaches between Juntura and Vale, OR, during August 2006, and the remaining

[1]Author to whom correspondence should be addressed.
E-mail address: lavigne@fs.fed.us.

[2]Current address: Bureau of Land Management, 4077 SW Research Way, Corvallis, Oregon 97333

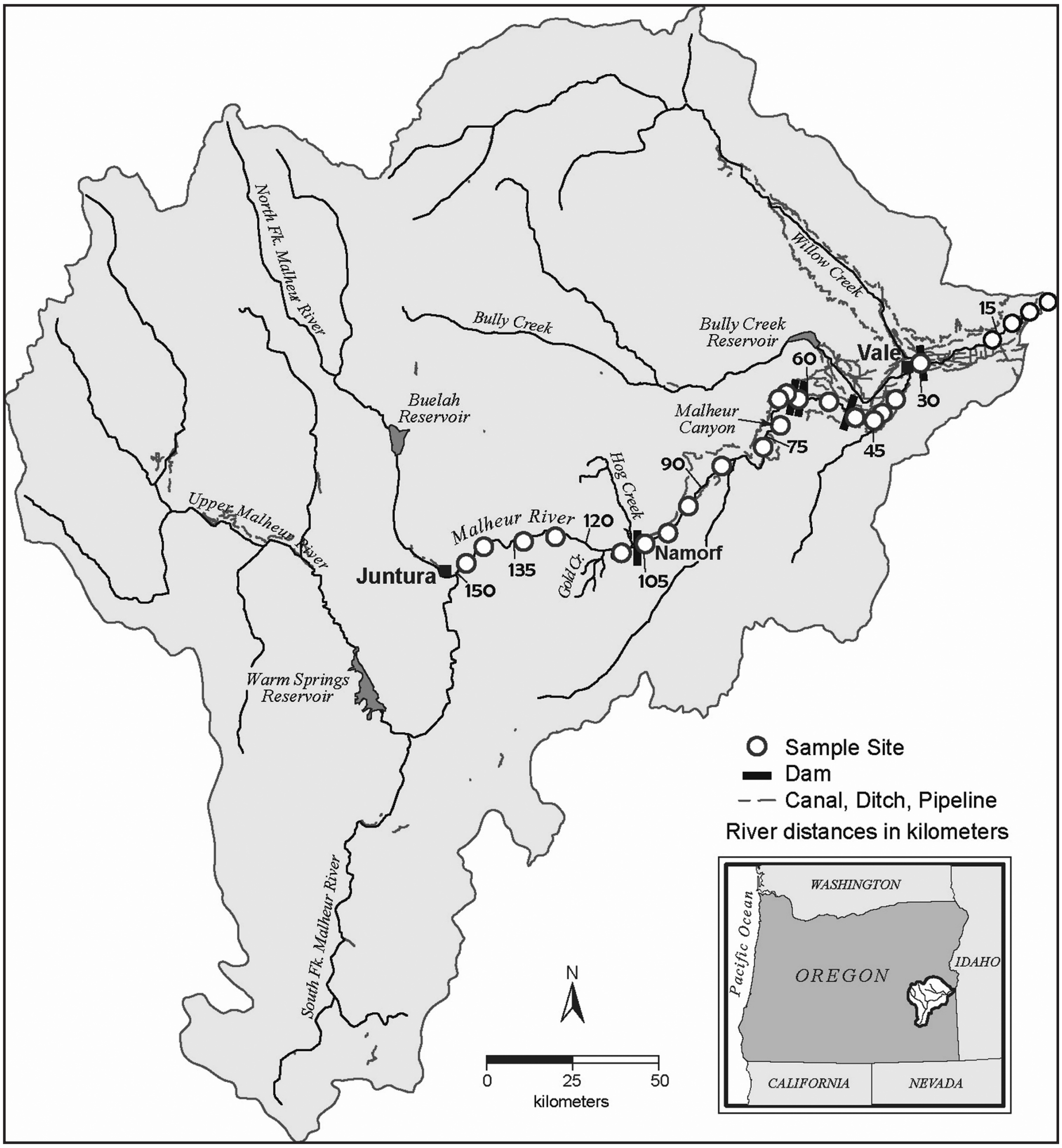

Figure 1. Sampling reaches and dams located within the lower Malheur River sub-basin. Numbers represent river-kilometer locations; dashed lines show diversions, siphons and canals for irrigated agriculture.

four reaches downstream of Vale during early September 2007.

Reach set-up and length determination followed EMAP standardized protocols as did the electrofishing of 10 subreaches, along alternating banks, within each reach (Peck et al. *In Press*). Reach length was set at 50 times the mean wetted width of the channel at the time of sampling based on the work of Hughes and Herlihy (2007) and Maret et al. (2007). We identified fish to species, with any unknown or questionable fishes either photographed or preserved for later identification. A GPS location was recorded at each of 11 transects bracketing the fish subreaches to allow future repeat sampling.

We compared observed fish distributions to those listed in the Malheur River Subbasin

Management Plan for Fish and Wildlife Mitigation (MRSMP; NPCC 2004) which contained fish data obtained from regional ODFW biologists and ODFW (1978).

We calculated an index of biological integrity (IBI) score for each site sampled in the present study through use of Mebane et al. (2003). Although their IBI may not be ideal for the Malheur River because much of the river is likely a warm-water system naturally, their IBI does offer a means to quantify longitudinal changes in the entire fish assemblage. We were unable to calculate IBI scores for sites fished by ODFW in 1978 because of a lack of data.

We used fish nomenclature from Nelson et al. (2004) and confirmed our species identifications with Professor Douglas Markle (Department of Fisheries and Wildlife, Oregon State University, Corvallis, personal communication).

Water quality was sampled as described in Peck et al. (*In Press*). Conductivity was measured by electronic field meter, and water samples were taken at the end of each reach, iced, and analyzed at our laboratory. Chloride was measured by ion chromatography, nitrate by cadmium reduction and colorimetry, and total N and total P through persulfate oxidation and colorimetry (U.S.EPA 1987).

Results

The capture of 4592 fish from 24, 1100-1850 m sampling reaches (Figure 1) revealed many changes in the summer distribution and assemblage structure of fishes inhabiting the lower Malheur River (Table 1) compared with the older MRSMP information (ODFW 1978; NPCC 2004). We captured nine native fish species, two of which were not listed in the MRSMP as river inhabitants. Newly documented endemic mountain sucker and leopard dace were captured at 11 and 3 sites, respectively, the latter set downstream of Vale, OR (Figure 1; Table 1). The seven MSRMP-listed native species we collected displayed no changes in distribution. In contrast, mountain whitefish, a ubiquitous main-river fish of the Columbia River drainage, was listed as a lower-river species in the MRSMP, yet was absent from our catch and that of ODFW (1978). No sculpin species were listed as historical main-river inhabitants in the MRSMP and none were captured by either survey.

Discrepancies were found between the alien lower-river fish species listed in the MRSMP and those captured by ODFW in the summer of 1978. The MRSMP listed 3 species, hatchery rainbow trout, common carp, and channel catfish, as alien lower-river residents (Table 1). However, ODFW captured 4 alien species, including the two latter fishes, and observed three others (Table 1).

Our catch of 13 alien species (Table 1) included all 3 MRSMP-listed species, 8 fish species not listed as lower-river inhabitants, and 2 aliens, flathead catfish and pumpkinseed, that were MRSMP-listed as subbasin inhabitants without distribution information. ODFW did not capture the latter two species in 1978, but did observe one flathead catfish.

Index of biological integrity scores (Mebane et al. 2003) declined from 53 at rkm 143 to 0.5 at rkm 6 (Table 2; Figure 1) and were associated with declining water quality and the presence or absence of salmonids. Conductivity increased in a downstream direction from 150 to >1000 µS/cm, chloride increased from 70 to >750 µeq/L, total phosphorus doubled, and total nitrogen increased tenfold (Table 2). These water quality changes were associated with marked increases in irrigated agriculture conducted on an old flood terrace located along the lower river (Figure 1). We captured hatchery rainbow trout within 3 sampling reaches affected by the discharge of the North Fork Malheur River (Figure 1); these sites had the highest IBI scores (Table 2).

Discussion

The two probable endemic species we collected, mountain sucker and leopard dace, were probably misidentified in previous surveys. Mountain sucker, a widespread species of the Pacific Northwest, was first identified as a Willamette River native in 1951 (Noble 1952), although previous surveys had collected mountain sucker specimens that were misidentified and reported as largescale sucker(Dimick and Merryfield 1945). We speculate that leopard dace, another Pacific Northwest endemic, was misidentified as speckled dace until now (Douglas Markle, Department of Fisheries and Wildlife, Oregon State University, Corvallis, personal communication).

The contrast between our alien species total (13) and the 3 alien lower-river fishes listed in the MRSMP was artificially enhanced by the fact that 5 alien species recorded as captured or observed in the 1978 ODFW report were not listed

TABLE 1. Fishes captured or observed on the lower Malheur River in 1978 by ODFW and in 2006-2007 during the present study. The former survey was conducted from approximately rkm 0-105 and the latter from rkm 2-150. MRSMP denotes the Malheur River Subbasin Management Plan for Fish and Wildlife Mitigation (MRSMP; 2004). Dashes (---) represent no specimens collected or observed.

Family, common name, *species*	Survey year(s) 1978	2006-2007	Range MRSMP	Present (rkm)
Salmonidae				
Hatchery rainbow trout[1] *Oncorhynchus mykiss*	---	X[2]	Gold Creek to Warm Springs Dam	No change
Mountain whitefish *Prosopium williamsoni*	---	---	Lower Malheur River	Not observed
Cyprinidae				
Chiselmouth *Acrocheilus alutaceus*	X	X	Lower Malheur River	No change
Common carp[1] *Cyprinus carpio*	X	X	Lower Malheur River	No change
Fathead minnow[1] *Pimephales promelas*	---	X	Not listed	2-15
Leopard dace *Rhinichthys falcatus*	X[3]	X	Not listed	6-15
Longnose dace *Rhinichthys cataractae*	X[3]	X	Lower Malheur River	No change
Northern pikeminnow *Ptychocheilus oregonensis*	X	X	Lower Malheur River	No change
Redside shiner *Richardsonius balteatus*	X	X	Lower Malheur River	No change
Speckled dace *Rhinichthys osculus*	X[3]	X	Lower Malheur River	No change
Catostomidae				
Bridgelip sucker *Catostomus columbianus*	X	X	Lower Malheur River	No change
Largescale sucker *Catostomus macrocheilus*	X[4]	X	Lower Malheur River	No change
Mountain sucker *Catostomus platyrhynchus*	X[4]	X	Not listed	2-113
Centrarchidae				
Bluegill[1] *Lepomis macrochirus*	X[5]	---	Not listed	Not observed
Largemouth bass[1] *Micropterus salmoides*	---	X	Warm Springs and Bully Creek Res.	30-49
Pumpkinseed[1] *Lepomis gibbosus*	---	X	Listed; no range given	15-61
Smallmouth bass[1] *Micropterus dolomieui*	X[5]	X	Warm Springs and Bully Creek Res.	15-105
White crappie[1] *Pomoxis annularis*	X	X	Warm Springs, Beulah and Bully Creek Res.	2-30
Ictaluridae				
Brown bullhead[1] *Ameiurus nebulosus*	X	X	Warm Springs and Bully Creek Res.	30-71

continued, next page

TABLE 1. Continued.

Family, common name, *species*	Survey year(s) 1978	2006-2007	Range MRSMP	Present (rkm)
Channel catfish[1] *Ictalurus punctatus*	X	X	Lower Malheur River	No change
Flathead catfish[1] *Pylodictus olivaris*	X	X	Listed; no range given	30
Tadpole madtom[1] *Notorus gyrinus*	---	X	Not listed	2-30
Percidae				
Yellow perch[1] *Perca flavescens*	---	X[5]	Warm Springs and Bully Creek Res.	30
Poeciliidae				
Western mosquitofish[1] *Gambusia affinis*	---	X	Not listed	2-6

[1]Alien species; [2]captured upstream of ODFW survey; [3]probable, dace not separated to species; [4]probable, only bridgelip sucker separated to species; [5]one captured; [6]one observed.

TABLE 2. Fish IBI scores and total nitrogen, total phosphorus, chloride and conductivity values for sample sites along the lower Malheur River. Sites located at rkm 2-15 were sampled in summer 2007, all other sites in summer 2006.

Site rkm	IBI Score[1]	Total N (ug/L)	Total P (ug/L)	Chloride (ueq/L)	Conductivity (uS/cm)
149	51.1	350	231	74	151
143	53.1	360	225	69	131
134	36.5	350	223	69	145
127	39.6	360	229	67	138
113	35.6	330	235	78	147
105	18.1	300	239	80	146
100	25.9	300	242	74	147
95	32.7	270	233	78	149
85	29.6	360	270	100	184
77	22.8	370	279	124	256
71	19.8	850	282	142	252
66	17.4	460	285	143	264
63	13.5	480	278	143	275
61	14.3	460	292	140	282
56	15.3	470	289	162	335
49	17.0	820	458	283	427
45	13.3	930	379	328	507
43	21.4	1090	394	258	420
41	17.9	2390	445	266	419
30	13.6	3890	398	379	595
15	6.5	4830	368	726	1100
11	12.1	4480	361	787	1120
6	0.5	4550	371	709	975
2	3.5	4360	342	760	955

[1]IBI scores were calculated as described in Mebane et al. (2003).

in the MRSMP, perhaps due to their rarity in that survey (Table 1).

The previously undocumented alien fishes we collected probably colonized the lower Malheur River in various ways. Flathead catfish and tadpole madtom are documented inhabitants of the adjoining Snake River (USGS 2007). Flathead catfish was listed in the MRSMP with an unknown distribution because it inhabits the adjoining Snake River and is known to be highly invasive (Raymond Perkins, ODFW, Vale, personal communication). Largemouth bass, pumpkinseed, and yellow perch were listed as basin reservoir residents in the MRSMP (Table 1). Western mosquitofish was released into Columbia and Willamette river sloughs for mosquito control in the early 1930s (McHugh et al. 1964), and probably into the Malheur River basin around the same time. The USGS (2007) documented fathead minnow as an established lower Malheur River irrigation ditch resident in 1995 and listed stocking for forage or released bait as possible introduction pathways.

The number of range expansions by alien fishes within and into the lower Malheur River was not surprising given that the river had not been thoroughly surveyed since 1978 and because of its extensive network of irrigation and drainage channels (Figure 1). The slower, warmer, enriched waters of the diversion network provide conditions favorable to tolerant alien fishes (Zaroban et al. 1999, Mebane et al. 2003). The results of an extensive fish survey performed by Hughes and Gammon (1987) on the mainstem Willamette River in 1983 were equally dramatic when compared to a previous survey performed in 1944 (Dimick and Merryfield 1945). These studies illustrate the need for regular assessments of large-river fish assemblages to detect and monitor invasive alien species and implement adaptive management actions.

Two species, flathead catfish and mountain whitefish, deserve special consideration from fisheries managers. The former is an invasive predator that can reach 56 kg and ingest adults of most native species. While this primarily piscivorous fish (Pine et al. 2005) can be highly mobile (Bringolf et al. 2005), we collected flathead catfish at just one site downstream of the channel-spanning diversion dam at Vale, OR, which may block upstream movement.

Mountain whitefish, a ubiquitous main-river species of the Columbia River drainage, has also been affected by dams and may be extirpated from the lower Malheur River. This salmonid was absent from the ODFW catch of 1978 and our survey in 2006-7. Ineffective sampling (Lapointe et al. 2006, LaVigne et al. 2008) may explain the absence of mountain whitefish from our catch, but we consider it unlikely because we captured hundreds of mountain whitefish from the Willamette River, OR, and the Okanogan River, WA, two other Columbia River basin rivers, during the same season in 2006. The latter river drains a semi-arid region similar to the Malheur River basin. The entire mainstem Willamette River and the lower 124 km of the Okanogan River contain no dams that could impede the summer spawning migrations of mountain whitefish to upper basin tributaries (Pettit and Wallace 1975, Thompson and Davies 1976). None of the five, 1.5 to 3.7 m high channel-spanning dams we encountered in our study area had fish passage structures, although most had boards that could be added or removed to adjust water levels.

The results of the lower Malheur River bioassessment were dependent on many factors. High water during 2006 probably affected summer water temperatures and fish distributions. Low-water summer distributions could be very different. Sampling inefficiencies (Lapointe et al. 2006, LaVigne et al. 2008) add uncertainty to our data. Differing methods can affect the catch composition of otherwise similar river electrofishing surveys (Hughes et al. 2002, Dauwalter and Pert 2003, Meador 2005, Hughes and Herlihy 2007). Multiple gears are superior for estimating fish species richness in large rivers (Lapointe et al. 2006), but even the use of multiple gears cannot prove the absence of a fish species from a given area (Bayley and Peterson 2001).

Our fish distribution results represent a snapshot in time best compared to the results of future repeat surveys performed under similar conditions.

Index of biological integrity scores decreased in a downstream direction and were associated with declining water quality (Table 2) and with covarying changes in soils and land use, hindering clear assessments of causal stressors. However, it is probable that some of the increased nutrients were derived from fertilizer additions and irrigation return flows, and it is likely that the water withdrawals and dams altered fish migrations and physical habitat quality.

The broader purpose of this research is to document the feasibility, logistics, and costs to managers of using EPA EMAP indicators and designs to assess the ecological condition, major stressors, and likely human disturbances of entire mainstem rivers. Our four-person field team, using two rafts, one trailer, and two four-wheel-drive pickup trucks, sampled 20 reaches on each of 3 Oregon/Washington mainstem rivers during the summers of 2006 and 2007. Each reach was randomly selected and 50 channel-widths long, thereby varying from 1-5 km each. A state, university or contractor crew could also thoroughly sample three large rivers each summer and all major rivers in Oregon within a 5-6 year cycle as part of a long-term monitoring program. Once the gear is acquired, the major costs are labor and transportation. States implementing such a program could rapidly evaluate and respond to detrimental changes in fish assemblages (Scott and Helfman 2001, Hughes et al. 2005) with adaptive management actions. Excellent examples of the value of such annual long-term monitoring programs for pollution regulation and biological assessment of large rivers at the state scale are given by Yoder et al. (2005).

Acknowledgements

We thank J. Adams, J. Correra, R. Emig, A. Farmer, W. Freese, and E. Hughes for their work in the field, Don and Evelyn Winslow for access to the river from their Little Valley farm, Joy and Vern Montgomery for river access from their Ontario farm, and S.M. Pierson and C. Johnson for creating Figure 1. The EPA funded this research through cooperative agreement RM832827-01 to Oregon State University.

Analytical data were provided by the Cooperative Chemical Analytical Laboratory established by memorandum of understanding no. PNW-82-187 between USDA Forest Service and the Department of Forest Science, Oregon State University.

Literature Cited

Bayley, P. B., and J. T. Peterson. 2001. An approach to estimate probability of presence and richness of fish species. Transactions of the American Fisheries Society 130:620-633.

Bringolf, R. B., T. J. Kwak, W. G. Cope, and M. S. Larimore. 2005. Salinity tolerance of flathead catfish: implications for dispersal of introduced populations. Transactions of the American Fisheries Society 134:927-936.

Dauwalter, D. C., and E. J. Pert. 2003. Effect of electrofishing effort on an index of biotic integrity. North American Journal of Fisheries Management. 23:1247-1252.

Dimick, R. E., and F. Merryfield. 1945. The fishes of the Willamette River system in relation to pollution. Engineering Experiment Station Bulletin Series 20:7-55. Oregon State College, Corvallis, OR.

Hughes R. M., and J. R. Gammon. 1987. Longitudinal changes in fish assemblages and water quality in the Willamette River, Oregon. Transactions of the American Fisheries Society. 116:196-209.

Hughes, R. M., P. R. Kaufmann, A. T. Herlihy, S. S. Intelmann, S. C. Corbett, M. C. Arbogast, and R. C. Hjort. 2002. Electrofishing distance needed to estimate fish species richness in raftable Oregon rivers. North American Journal of Fisheries Management 22:1229-1240.

Hughes, R. M., J. N. Rinne, and B. Calamusso. 2005. Historical changes in large river fish assemblages of the Americas: a synthesis. *In* J.N. Rinne, R.M. Hughes, and B. Calamusso (editors), Historical Changes in Large River Fish Assemblages of the Americas. American Fisheries Society, Symposium 45, Bethesda, MD. Pp. 603-612.

Hughes, R. M., and A. T. Herlihy. 2007. Electrofishing distance needed to estimate consistent IBI scores in raftable Oregon rivers. Transactions of the American Fisheries Society 136:135-141.

Lapointe, N. W. R., L. D. Corkum, and N. E. Mandrak. 2006. A comparison of methods for sampling fish diversity in shallow off-shore waters of large rivers. North American Journal of Fisheries Management 26:503-513.

Lavigne, H. R., R. M. Hughes, R. C. Wildman, S. V. Gregory, and A. T. Herlihy. 2008. Summer distribution and diversity of non-native fishes in the mainstem Willamette River, Oregon, 1944-2006. Northwest Science 82:83-93.

Maret, T. R., D. S. Ott, and A. T. Herlihy. 2007. Electrofishing effort required to estimate biotic condition in southern Idaho Rivers. North American Journal of Fisheries Management 27:1041-1042.

McHugh, R. A., L. S. Miller, and T. E. Olson. 1964. The ecology and naturalistic control of log pond mosquitoes in the Pacific Northwest. Oregon State Board of Health, Portland, OR.

Meador, M. R. 2005. Single-pass versus two-pass boat electrofishing for characterizing river fish assemblages: species richness estimates and sampling distance. Transactions of the American Fisheries Society 134:59-67.

Mebane C. A., T. R. Maret, and R. M. Hughes. 2003. An index of biological integrity (IBI) for Pacific Northwest rivers. Transactions of the American Fisheries Society 132:239-261.

Nelson, J. S., E. J. Crossman, H. Espinosa-Pérez, L. T. Findley, C. R. Gilbert, R. N. Lea, and J. D. Williams. 2004. Common and Scientific Names of Fishes from the United States Canada and Mexico, 6th Edition.

Special Publication 29. American Fisheries Society, Bethesda, MD.
Noble, R. E., 1952. The Willamette River fishes as biological indicators of pollution. M.S. Thesis, Oregon State University, Corvallis.
Northwest Power and Conservation Council (NPCC). 2004. Malheur River subbasin assessment and management plan for fish and wildlife mitigation, Appendix A, Part 2—Aquatic Assessment. Available online at http://www.nwcouncil.org/fw/subbasin-planning/malheur/plan/Malheur03_App_A2_Aquatic_2004-05-28.pdf (accessed 4 October 2007).
Oregon Department of Environmental Quality (ODEQ). 2005. Oregon water quality index summary report water years 1999-2005. Available online at http://www.deq.state.or.us/lab/wqm/docs/OWQISummary05.pdf (accessed 5 October 2007).
Oregon Department of Fish and Wildlife (ODFW). 1978. Fish populations in the lower Malheur and Owyhee rivers. Unpublished report on file at Oregon Department of Fish and Wildlife, Vale, OR.
Oregon Department of Fish and Wildlife (ODFW). 2005. Oregon native fish status report: volume II—assessment methods and population results. Available online at http://www.dfw.state.or.us/fish/ONFSR/volume-2-final.pdf (accessed 6 October 2007).
Peck, D. V., A. T. Herlihy, B. H. Hill, R. M. Hughes, P. R. Kaufmann, D. J. Klemm, J. M. Lazorchak, F. H. McCormick, S. A. Peterson, P. L. Ringold, T. Magee, and M. R. Cappaert. *In Press*. Environmental Monitoring and Assessment Program-Surface Waters: Western Pilot Study field operations manual for non-wadeable streams and rivers. USEPA. Corvallis, OR.
Pettit, S. W., and R. L. Wallace. 1975. Age, growth, and movement of mountain whitefish, *Prosopium williamsoni* (Girard), in the North Fork Clearwater River, Idaho. Transactions of the American Fisheries Society 104:68-76.
Pine, W. E., III, T. J. Kwak, D. S. Scott, and J. A. Rice. 2005. Diet selectivity of introduced flathead catfish in coastal rivers. Transactions of the American Fisheries Society 134:901-909.
Scott, M. C., and G. S. Helfman. 2001. Native invasions, homogenization, and the mismeasure of integrity of fish assemblages. Fisheries. 26(11):6-15.
Stevens, D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99:262-278.
Thompson, G. E., and R. W. Davies. 1976. Observations on the age, growth, reproduction, and feeding of mountain whitefish (*Prosopium williamsoni*) in the Sheep River, Alberta. Transactions of the American Fisheries Society. 105:208-219.
U S.EPA. 1987. Handbook of methods for acid deposition studies: laboratory analyses for surface water chemistry. EPA/600/4-87/026. Washington, DC.
USGS. 2007. NAS—nonindigenous aquatic species. Available online at http://nas.er.usgs.gov/ (accessed 5 October 2007).
Yoder, C. O., E. T. Rankin, M. A. Smith, B. C. Alsdorf, D. J. Altfater, C. E. Boucher, R. J. Miltner, D. E. Mishne, R. E. Sanders, and R. F. Thoma. 2005. Changes in fish assemblage status in Ohio's nonwadeable rivers and streams over two decades. *In* J. N. Rinne, R. M. Hughes, and B. Calamusso (editors), Historical Changes in Large Fiver Fish Assemblages of the Americas. American Fisheries Society, Symposium 45, Bethesda, MD. Pp. 399-429.
Zaroban, D. W., M. P. Mulvey, T. R. Maret, R. M. Hughes, and G. D. Merritt. 1999. Classification of species attributes for Pacific Northwest freshwater fishes. Northwest Science 73:81-93.

Received 3 March 2008
Accepted for publication 15 August 2008