An Evaluation of Wilderness and Aquatic Biointegrity in Western Montana

Nathaniel P. Hitt
Christopher A. Frissell

Abstract—Although the Wilderness Act of 1964 was justified in part by the importance of aquatic conservation, implementation of the Act has primarily focused on protecting terrestrial ecosystems. In this paper, we investigated the role of Congressionally-designated wilderness towards conservation of aquatic biointegrity in western Montana. To evaluate trends between 6th code watersheds ("subwatersheds") with and without wilderness, we applied a previous Aquatic Diversity Areas (ADA) analysis which scored subwatersheds for indicators of aquatic biointegrity and conservation significance: road density, native/exotic fish ratio, fish stocking and occurrence of sensitive and endangered species. Wilderness-containing subwatersheds scored disproportionately higher for aquatic biointegrity indicators than subwatersheds with other land uses (X^2=115.71, P<0.001) but were not consistent in this regard.

Since the passage of the Wilderness Act in 1964, millions of acres of wilderness have been established on federal lands to protect the resources and values recognized in the Act. However, although the cultural and economic values of wilderness are well known (Nash 1967; Rudzitis and Johansen 1991), the biological significance of wilderness for aquatic ecosystems has not been systematically evaluated. Given that, compared to terrestrial taxa, aquatic species are disproportionately listed under the Endangered Species Act (Allan and Flecker 1992) and that aquatic biodiversity is being lost more rapidly than terrestrial biodiversity (Moyle and Yoshiyama 1994), evaluations of the aquatic features of conservation reserves are of immediate importance. In this paper, we investigate the role of Congressionally-designated wilderness in conservation of aquatic biointegrity within western Montana.

The concept of "aquatic biointegrity" arose from recognition that purely physical or chemical evaluations may not accurately reflect the biological function or conservation significance of aquatic species or ecosystems. In response, Karr (1981) developed a technique to evaluate aquatic biointegrity by focusing on fish community structure. Known as the Index of Biotic Integrity (IBI), Karr's (1981) methodology has been subsequently adapted to research of aquatic ecosystems in California (Moyle and Randall 1998; Moyle and Marchetti 1999), Michigan (Allan and others 1997), New York (Harig and Bain 1998) and Montana (Frissell and others 1995, Frissell and others 1996; Rothrock and others 1998).

Although the indicators of aquatic biointegrity analyses vary according to the scope of each investigation, they converge at Karr and Dudley's (1981) basic definition of biotic integrity as "the ability [of an ecosystem] to support and maintain a balanced, integrated, and functional organization comparable to that of the natural habitat of the region" (Karr and Dudley 1981). Although investigations of biointegrity may focus on various spatial and temporal features (such as stream macroinvertebrate community structure, nutrient cycling patterns and/or road densities), the ultimate utility of any biointegrity index relies on the ability of that metric to describe the natural patterns and processes of an ecosystem.

Over the last decade, the concept of "ecosystem management" has been endorsed by federal land management agencies in an effort, among other purposes, to consider aquatic biointegrity in management decisions (McCormick 1999; Salwasser 1991, 1992; Slocombe 1998). In principal, ecosystem management informs land use decisions with scientific evaluations of natural ecosystems (Noss 1999). Although the practice of ecosystem management has been applied with various results (Frissell and Bayles 1996), the concept of ecosystem management offers significant improvements from historical management philosophies in the acknowledgements that 1) management for biodiversity and biointegrity cannot be relegated to within the bounds of protected areas and 2) an understanding of ecosystems requires multivariate evaluations of biointegrity.

The conservation of freshwater species and ecosystems presents a special challenge for land managers and biologists. Due to the cumulative nature of flowing water (Vannote and others 1980), the dynamic watershed-stream relationships (Davies and Walker 1986; Doppelt and others 1993; Hynes 1970; Frissell and others 1986) and the particular importance of surface water-groundwater interactions (Stanford and Ward 1988), conservation of aquatic ecosystems requires ecological considerations at various spatial and temporal scales. Moreover, although the importance of refugia for native fish communities has been thoroughly described (Lee and others 1997; Moyle and Sato 1991; Reeves and others 1995; Schlosser 1991; Sedell and others 1990), the contributions of Congressionally-designated wilderness areas as aquatic refugia remain largely undetermined.

Using data from a previous Aquatic Diversity Areas (ADA) assessment (Frissell and others 1996), here we evaluate the role of Congressionally-designated wilderness towards conservation of aquatic biointegrity in western Montana by asking two related questions: 1) To what extent do wilderness-containing subwatersheds contribute to aquatic

In: McCool, Stephen F.; Cole, David N.; Borrie, William T.; O'Loughlin, Jennifer, comps. 2000. Wilderness science in a time of change conference—Volume 2: Wilderness within the context of larger systems; 1999 May 23–27; Missoula, MT. Proceedings RMRS-P-15-VOL-2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.
Nathaniel P. Hitt, Division of Biological Sciences, University of Montana, Missoula, MT 59812 U.S.A., e-mail: than@wildrockies.org. Christopher A. Frissell, Flathead Lake Biological Station, University of Montana, 311 Bio Station Lane, Polson, MT 59860-9659 U.S.A., e-mail: frissell@selway.umt.edu

biointegrity in western Montana? 2) How well does the presence of wilderness predict the relative aquatic biointegrity between subwatersheds? We hope that this analysis helps scientists, conservationists, and land managers better understand the importance of wilderness within a landscape context as well as the importance of aquatic ecosystem conservation.

Methods

In 1995, researchers at The University of Montana's Flathead Lake Biological Station and the Sierra Biodiversity Institute initiated an Aquatic Diversity Areas (ADA) assessment to prioritize 6th code watersheds ("subwatersheds") for their aquatic biointegrity and contribution to regional ecosystem conservation (Frissell and others 1996). Building on efforts in Oregon by the American Fisheries Society (Henjum 1994) and in California by Moyle and Ellison (1991) and Moyle and Sato (1991), the study calculated and ranked ADA scores for subwatersheds in western Montana. Four indices were used to rank each subwatershed for its aquatic biointegrity: road density (data source: Sierra Biodiversity Institute), fish stocking history (data source: Montana Department of Fish, Wildlife and Parks), native/exotic fish ratio (data source: Montana Rivers Information System, MDFWP) and sensitive species occurrences (data source: Montana Natural Heritage Program). All data layers were analyzed with an ARCINFO™ Geographic Information System.

Data from each category of information were integrated into an algorithm to calculate an ADA score for each subwatershed (figure 1). In this formula, the presence of roadless areas, native fish and sensitive species contributed positively to the ADA score; stocking of hatchery and exotic fish contributed negatively to the score. The study ranked subwatershed into one of four categories, from lowest to highest, based on a total possible 40.0 points: low-scoring (<15.0 points), lower mid-range (15.1-20.0 points), upper mid-range (20.1-25.0) and high-scoring (>25 points).

Many observational and experimental field investigations have documented direct and indirect impacts of road networks on aquatic systems (for a review, see USDA Forest Service 1997). Accordingly, the ADA methodology used road densities as a proxy for land use intensity and watershed condition, assuming that increasing road densities indicate increasingly degraded aquatic habitat. This assumption is supported by several recent studies that correlated increasing road densities and land use intensity with aquatic

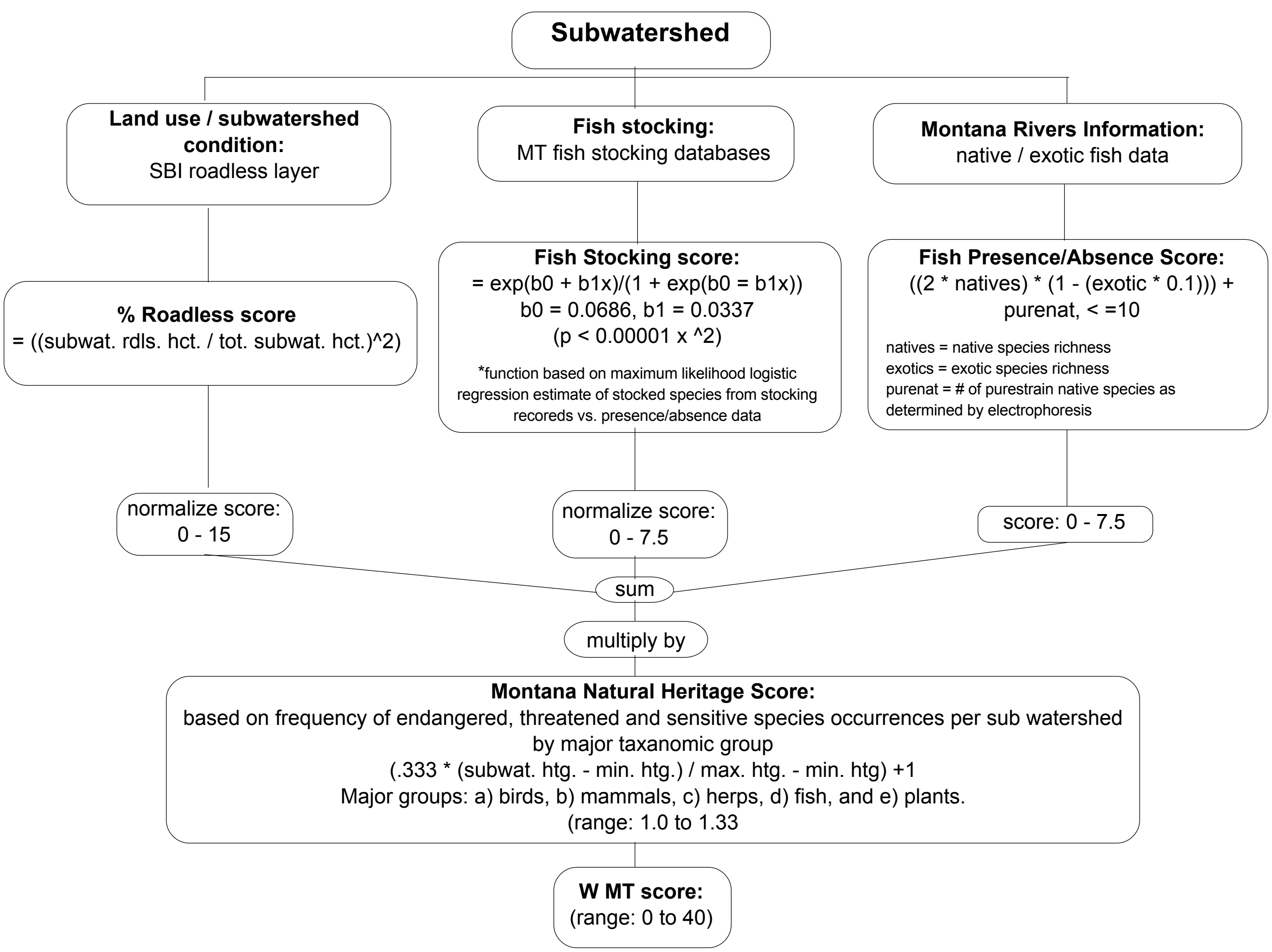

Figure 1—Aquatic Diversity Areas (ADA) scoring algorithm (from Frissell and others 1996).

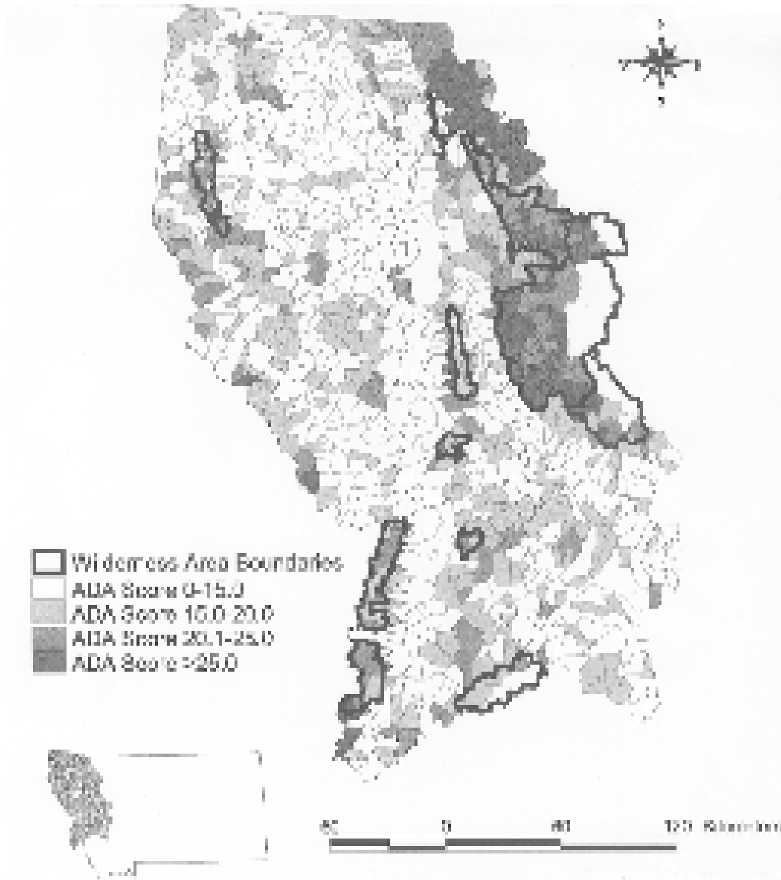

Figure 2—Aquatic Diversity Area (ADA) scores (from Frissell and others 1996) and wilderness areas in western Montana. Higher scores indicate high relative aquatic biointegrity for indices of road density, fish stocking history, native fish presence/absence, and sensitive and endangered species presence. Potential scores ranged from 0-40. Actual scores ranged from 1.46 to 31.13.

ecosystem decline (Bitterroot National Forest 1992; Frissell and others 1995; Roth and others 1996; Haskins and Mayhood 1997; Lee and others 1997; Rothrock and others 1998). Moreover, recent direction from the U.S. Fish and Wildlife Service (USFWS) has acknowledged the importance of road densities for bull trout (*Salvelinus confluentus*) conservation, recognizing an average road density of .45 mi/mi^2 in bull trout strongholds and the general exclusion of bull trout in watersheds with over 1.7 mi/mi^2 of roads (USDI Fish and Wildlife Service 1998). The USFWS concluded that bull trout "are exceptionally sensitive to the direct, indirect, and cumulative effects of roads" (USDI Fish and Wildlife Service 1998). Similarly, Quigley and Arbelbide (1997) recommended using "roads as a catch-all indicator of human disturbance."

To draw inferences about the role of Congressionally-designated wilderness from the results of this ADA study, we mapped seven wilderness complexes (Selway-Bitterroot, Welcome Creek, Anaconda-Pintler, Rattlesnake, Mission Mountains, Cabinet Mountains, Great Bear/Bob Marshall/Scapegoat) and recorded the number of subwatersheds which contained wilderness (>0%). We then evaluated the role of wilderness in two ways: 1) We used a chi-squared analysis to compare the ADA scores for wilderness-containing subwatersheds to the regional distribution of scores, and 2) we evaluated the ability of wilderness-containing subwatersheds to predict regions of high aquatic biointegrity.

Results and Discussion

High-scoring subwatersheds (>25.0 points) were located predominately within the Middle and South Forks of the Flathead River in westcentral Montana and on east-draining slopes of the Bitterroot Range in southwestern Montana. Mid-range scoring subwatersheds (15.1-20.0 and 20.1-25.0) were found in all major river basins. The largest concentrations of these scores were located in the western portion of the Lower Clark Fork Basin, the west half of the Upper Clark Fork Basin, and the Flint/Rock Creek Basin in southwestern Montana. Low-scoring subwatersheds (<15.0) were scattered throughout the region, with clusters in the eastern sections of the Bitterroot Basin; they comprised a majority of the Stillwater, Blackfoot, Main Flathead, and Fisher Basins. A map of ADA scores and wilderness area boundaries is presented in figure 2.

Wilderness-containing subwatersheds showed disproportionately more high ADA scores (>25.0 points) than subwatersheds with other uses (X^2=115.71; P<0.001). Over 65% of the high-scoring ADAs were found within wilderness subwatersheds. In several cases, clear patterns of high-scoring watersheds followed the boundaries of wilderness areas. However, the distribution of wilderness scores was not consistent: Of the 148 wilderness-containing subwatersheds, 43 (29%) scored within the highest category, 56 (38%) scored within the upper-mid range, 35 (24%) scored within the lower mid-range, and 14 subwatersheds (9%) scored within the lowest category for aquatic biointegrity. As a result, although wilderness is a major source of aquatic biointegrity in western Montana, the presence of wilderness within a subwatershed is not a deterministic predictor of integrity.

These findings highlight several important considerations for modern wilderness designation and management. First, we must recognize that the importance of wilderness in aquatic conservation is extraordinary. Other than wilderness-containing subwatersheds, only 24 subwatersheds scored within the highest category. Of these, 20 were located within Glacier National Park. As remarkable exceptions, the remaining high-scoring subwatersheds were located within the Lolo and Bitterroot National Forests (LNF and BNF): 1) the Great Burn area (LNF) 2) the Sheep Mountain/Stateline area (LNF), and 3) the Blue Joint area (BNF). Although the Great Burn area merited protection in the Lolo National Forest Land and Resource Management Plan, prolific and unregulated off-road vehicle use has threatened the integrity of this area. Important low-elevation areas within the Sheep Mountain/Stateline subwatersheds (LNF) also face development and resource extraction. Additionally, the Blue Joint area in the BNF area is jeopardized by the USDA Forest Service's failure to propose protection for more than high-elevation areas west of Razorback Ridge. To improve aquatic conservation in western Montana, we suggest that the low-elevation areas of the Blue Joint should be protected as well.

Although the boundaries of the contiguous Great Bear/Bob Marshall/Scapegoat complex were clearly discernible by high ADA scores in the South Fork of the Flathead River basin, smaller, more isolated wilderness areas contributed less to the regional distribution of high ADA scores, as illustrated by the Welcome Creek, Anaconda-Pintler, and Cabinet Mountains Wilderness Areas. With the exception of the adjacent Mission Mountains Tribal Wilderness, subwatersheds contained within the Mission Mountains Wilderness Area were found to provide the least benefits to regional aquatic biointegrity; all of these watersheds ranked in the lowest tiers. These marginal and low ADA scores are due to a number of factors, including the frequent encroachment of roads on wilderness area boundaries and the historical and current fish stocking in high-elevation lakes, as well as the absence of sufficient spawning, rearing and migration habitats for native fishes.

Conclusions

Conservation of aquatic species and ecosystems necessitates consideration of landscape-level processes and conditions. Due to the multi-faceted nature of aquatic ecosystems, multiple factors should be considered in any landscape analysis of aquatic biointegrity. Our application of results from a previous Aquatic Diversity Areas (ADA) study for western Montana indicates that 1) wilderness areas are important areas of aquatic biointegrity in western Montana, 2) the presence of wilderness does not guarantee aquatic biointegrity, and 3) given their importance and rarity, unprotected areas with relative aquatic biointegrity merit permanent protection for conservation of aquatic ecosystems. Ultimately, we believe that our society must decide either to systematically protect landscapes or face the continued deterioration of natural systems and additional listings under the Endangered Species Act.

Acknowledgments

We would like to thank Rick Landenburger, Jennifer O'Loughlin, and 2 anonymous reviewers for their thoughtful and instructive critiques of an earlier draft of this manuscript.

References

Allan, J. D. and A. S. Flecker. 1992. Biodiversity conservation in running waters. BioScience 43: 32-43.

Allan, J. D., Erickson, D.L., and J. Fay. 1997. The influence of catchment land use on stream integrity across multiple spatial scales. Freshwater Biology 37: 149-161.

Bitterroot National Forest. 1992. Validation of aquatic habitat quality and fish population to predict effects of activities. Pages 67-80. Forest Plan Monitoring and Evaluation Report. USDA Forest Service, Hamilton, Montana.

Davies, B. R. and K. F. Walker. 1986. The Ecology of River Systems. Dr. W. Junk Publishers, Dordrecht, Holland.

Doppelt, B., Scurlock, M., Frissell, C.A., and J. Karr. 1993. *Entering the Watershed: a New Approach to Save America's River Ecosystems*. Island Press, Washington, D.C.

Frissell, C. A., Liss, W. J., Warren, C. E., and M. D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. Environmental Management 10(2):199-214.

Frissell, C. A., Doskocil, J., Gangemi, J.T., and J.A. Stanford. 1995. Identifying priority areas for protection and restoration of aquatic biodiversity: a case study in the Swan River Basin, Montana, USA. Flathead Lake Biological Station, University of Montana. Polson, Montana.

Frissell, C. A., and D. Bayles. 1996. Ecosystem management and the conservation of aquatic biodiversity and ecological integrity. Water Resources Bulletin 32: 229-240.

Frissell, C. A., Gangemi, J.T., Poole, G.C., and S. Beckwit. 1996. Prioritization of Aquatic Diversity Areas for design of a conservation reserve network in western Montana. Flathead Lake Biological Station, University of Montana, Polson, Montana.

Harig, A. L. and M. B. Bain. 1998. Defining and restoring biological integrity in wilderness lakes. Ecological Applications 8: 71-87.

Haskins, W. and D. Mayhood. 1997. Stream crossing density as a predictor of watershed impacts. Seventeenth Annual ESRI User Conference. Paper 457.

Henjum, M. G., Karr, J.R., Bottom, D.L., Perry, D.A., Bednarz, J.C., Wright, S.G., Beckwit, S.A., and E. Beckwitt. 1994. Interim protection for late-successional forests east of the Cascade crest, Oregon and Washington. The Wildlife Society, Washington, D.C.

Hynes, H. B. N. 1970. *The Ecology of Running Waters*. University of Toronto Press, Toronto, Ontario.

Karr, J. R. 1981. Assessment of biotic integrity using fish communities. Fisheries (Bethesda) 6:21-27.

Karr, J. R. and D. R. Dudley. 1981. Ecological perspective on water quality goals. Environmental Management 11: 249-256.

Lee, D. C., Sedell, J.R., Rieman, B.E. and others. 1997. Broadscale Assessment of Aquatic Species and Habitats. In: *The Interior Columbia Basin Ecosystem Management Project: Scientific*

Assessment. T. M. Quigley and S. J. Arbelbide, eds.General Technical Report PNW-GTR-405. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon.

McCormick, F. 1999. Principals of Ecosystem Management and Sustainable Development. Pages 3-22 In: *Ecosystem Management for Sustainability*. J. D. Peine, ed. Lewis Publishers, Boca Raton, Florida.

Moyle, P. B. and J. P. Ellison. 1991. A conservation-oriented classification system for the inland waters of California. California Fish and Game 77:161-180.

Moyle, P. B. and G. M. Sato. 1991. On the Design of Preserves to Protect Native Fishes. Pages 155-169 In: *Battle Against Extinction: Native Fish Management in the American West*. W. L. Minkley and J. E. Deacon, eds. University of Arizona Press, Tucson, Arizona.

Moyle, P. B. and R. M. Yoshiyama. 1994. Protection of aquatic biodiversity in California: a five-tiered approach. Fisheries 19: 6-17.

Moyle, P. B. and P. J. Randall. 1998. Evaluating the biotic integrity of watersheds in the Sierra Nevada, California. Conservation Biology 12: 1318-1326.

Moyle, P. B. and M. P. Marchetti. 1999. Applications of Indices of Biotic Integrity to California Streams and Watersheds. Pages 367-380 In: *Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities*. T. P. Simon, ed. CRC Press, Boca Raton, Florida.

Nash, R. 1967. *Wilderness and the American Mind*. Yale University Press, New Haven.

Noss, R. 1999. A Citizen's Guide to Ecosystem Management. Biodiversity Legal Foundation, Boulder, Colorado.

Quigley, T. M. and S. J. Arbelbide. 1997. *An assessment of ecosystem components in the interior Columbia Basin and portions of the Klamath and Great Basins: Volume III*. Quigley, T. M. and S. J. Arbelbide, technical editors. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Reeves, G. H., Benda, L.E., Burnett, K.M., Bisson, P.A., and J.R. Sedell. 1995. A disturbance-based ecosystem approach to maintaining and restoring freshwater habitats of evolutionary significant units of anadromous salmonids in the Pacific Northwest. American Fisheries Society Symposium 17: 334-349.

Roth, N. E., Allan, J.D., and D.L. Erickson. 1996. Landscape influences on stream biotic integrity assessed at multiple spatial scales. Landscape Ecology 11: 141-156.

Rothrock, J. A., Barten, P.K., and G.L. Ingman. 1998. Land use and aquatic biointegrity in the Blackfoot River watershed, Montana. Journal of the American Water Resources Association 34: 565-581.

Rudzitis, G. and H. E. Johansen. 1991. How important is Wilderness? Results from a United States survey. Environmental Management 15: 227-233.

Salwasser, H. 1991. Roles for Land and Resource Managers in Conserving Biological Diversity. Pages 11-32 In: *Conservation of Biological Resources*. Decker and others, eds. Westview Press, Boulder, Colorado.

Salwasser, H. 1992. From new perspectives to ecosystem management: response to Frissell et al. and Lawrence and Murphy. Conservation Biology 6: 469-472.

Schlosser, I. J. 1991. Stream fish ecology: a landscape perspective. BioScience 41: 704-712.

Sedell, J. R., Reeves, G.H., Hauer, F.R., Stanford, J.A., and C.P. Hawkins. 1990. Role of refugia in recovery from disturbances: modern fragmented and disconnected river systems. Environmental Management 14: 711-724.

Slocombe, D. S. 1998. Defining goals and criteria for ecosystem-based management. Environmental Management 22: 483-493.

Sparks, R. E. 1995. Need for ecosystem management of large rivers and their floodplains. BioScience 45: 168-182.

USDA Forest Service. 1997. Water/Road Interaction Technology Series. San Dimas Technology and Development Program, San Dimas, California.

USDI Fish and Wildlife Service. 1998. Bull Trout Interim Conservation Guidance., Washington, D.C.

Stanford, J. A. and J. V. Ward. 1988. The hyporheic habitat of river systems. Nature 335: 64-66.

Vannote, R. L., Minshall, G.W., Cummins, K.W., Sedell, J.R., and C.E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37: 130-137.