Aquatic Habitat Indicators and Their Application to Water Quality Objectives within the Clean Water Act

Appendix D: Annotated Bibliography

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Abstract

This bibliography identifies 334 literature citations that are related to salmonid habitat. References have been categorized by subject group to include: bank stability; channel morphology; classification and stratification; depth; dissolved oxygen; large woody debris, riparian, and cover; management; monitoring and data analysis; pools; reference conditions, standards, and recommendations; restoration; species assemblages; specie preferences; substrate size and fine sediment; temperature; and velocity and flow. Many of the references provide an abstract of the article.

Note:

The annotated bibliography is an appendix to the report: "Application of Aquatic Habitat Indicators to Water Quality Objectives within the Clean Water Act" published by the Environmental Protection Agency (EPA). The objective of this project was to evaluate the potential for inclusion of aquatic habitat indicators into water quality programs as one component of a developing an EPA strategy to address declining salmonid populations in the Pacific Northwest. Habitat indicators, like water quality criteria and biological indicators, can be used to evaluate the protection of beneficial uses which are the cornerstone of water quality standards. Aquatic habitat indicators (variously referred to as habitat variables, parameters, metrics, etc.) are commonly used to evaluate biotic integrity and fish production capability.

KEYWORD LISTING

1. Aadland L.P. 1993. Stream habitat types: Their fish assemblages and relationship to flow. North American Journal of Fisheries Management. 13(4):790-806

   To simplify selection of target species for instream flow studies, 114 fish species-life stage combinations in six Minnesota streams were assigned membership in six habitat-preference guilds based on the habitat type supporting their highest densities. Shallow pools (<60 cm deep and velocities <30 cm/s) were preferred by most of the young-of-the-year fishes. Slow riffles (<60 cm deep and velocities 30-59 cm/s) were preferred by stonerollers *Campostoma spp.*; spawning sand shiners *Notropis stramineus*: adult river shiners *N. blennius*; juvenile, spawning and age-O suckers (*Moxstoma spp*., northern hog sucker *Hypentelium nigricans*, and white sucker *Catostomus commersoni)*; and most age-O darters (*Etheostoma flabellare, E. nigrum, E. caeruleum*, and *Percina phoxocephala*). Fast riffles (<60 cm deep and velocities 60 cm/s) were preferred by adult longnose dace *Rhinichthys cataractae* and most adult and spawning darters (*Percina spp.* and *Etheostoma spp*.). Raceways (60-149 cm deep and velocities 30 cm/s) were preferred by several adult catostomids. Medium pools (60-149 cm deep and velocities < 30 cm/s) and deep pools (150 cm deep) were preferred by adult channel catfish *Ictalurus punctatus* and most of the centrarchids. Shallow pool habitat was most abundant during low flows and was reduced during high flows. Medium and deep pool habitat area changed relatively little with changes in flow, whereas slow riffle, fast riffle, and raceway habitat became scarce or absent during low flows. Exclusive use of pool-oriented game fish as target species in instream flow studies may result in recommendations that do not protect species occupying flow-sensitive riffles. To preserve fish community diversity and integrity, instream flow assessments should include target species that occupy flow-sensitive habitat types.

2. Adams S.M. 1990. Status and use of biological indicators for evaluating the effects of stress on fish. p 1-8, *in* S.M. Adams, ed. Biological indicators of stress in fish. American Fisheries Society Symposium #8. Bethesda, MD.

   Laboratory bioassays of acute and chronic toxicity and measurement of a single stress response lack ecological realism. Environmental stressors are more complex than the acute stressors applied in most laboratory stress studies and extrapolation of these results can lead to incorrect evaluations of chronic stress effects on fish. Approaches are needed that: (1) permit the detection of stress-related variables that part biologically and ecologically relevant and (2) maximize predictive capabilities.

3. Alatalo R.V. 1981. Problems in the measurement of evenness in ecology. Oikos. 37:199-204

   Evenness is considered as the measure of equality of abundance in a community. By comparing artificial abundance distributions the Hill's ratio was found to be the most easily interpreted evenness measure, when assessing niche or habitat overlap by the components of diversity. It is emphasized that there is no single way to measure evenness, and because of the looseness of the concept we have to be cautious in its application.

4. Alderice D.F., R.A. Bams, and F.P.J. Velsen. 1977. Factors affecting deposition, development, and survival of salmonid eggs and alevins: bibliography, 1965-1975. Canada Fisheries and Marine Service, Technical Report #743, Ottawa, ON, Canada

   Bibliography is a result of an effort to organize a significant part of the available literature regarding physical, chemical and biological factors that influence egg deposition and development and survival of eggs and alevins of Pacific salmon.

5. Alexander G.R. and E.A. Hansen. 1983. Effects of sand bedload sediment on a brook trout population. Michigan Department of Natural Resources, Fisheries Division, Fisheries Research Report 1906Ann Arbor, MI

   An experimental introduction of sand sediment in Hunt Creek to increase the bedload 4 to 5 fold resulted in a significant reduction of trout and trout habitat. The trout population declined to less than half its normal abundance. The growth rate of individual trout was not affected. Population adjustment to the poorer habitat was via a decrease in the trout survival rates, particularly from the egg to fry and/or the fry to fall fingerling stage of the life cycle. Habitat for trout and trout food organisms became much poorer judged upon their drastic population reductions. Stream morphometry changed considerably with the channel widening and shallowing. Further, sand deposition aggregated the streambed and eliminated most pools. The channel became a continuous run, rather than a series of pools and riffles. Water velocities increased as did summer water temperatures. Relatively small bedload sediment concentrations of 80 to 100 ppm have a profound effect on trout and trout habitat.

6. Allen M.A. 1986. Population dynamics of juvenile steelhead trout in relation to density and habitat characteristics. Humboldt State University, Master's Thesis, Aracata, CA

   A significant ($P < 0.01$) inverse relationship was found between fry density and stream width, instream cover and water velocity. Stepwise regression models predicted 57% to 78% of the observed variation in fish populations. Fry that hatched and emerged from a gravel environment exhibited significantly ($P < 0.001$) higher survival after one year of stream residence than did fry reared in a non-gravel environment. No difference in growth was observed between gravel and non-gravel reared fry.

7. Anderson J.W., R.L. Beschta, P.L. Boehne, D. Bryson, R. Gill, B.A. McIntosh, M.D. Purser, J.J. Rhodes, J.W. Sedell, and J. Zakel. 1992. Upper Grande Ronde River anadromous fish habitat protection, restoration and monitoring plan. U. S. Forest Service, Wallowa-Whitman National Forest, Baker, OR

   The UGRRP set quantitative habitat standards as performance standards. The following were set as quantitative habitat standards in the UGRRP: fines in salmon spawning habitat, temperature, LWD frequency, pool volume and depth, and width-to-depth ratio.

8. Andrus C.W., B.A. Long, and H.A. Froehlich. 1988. Woody debris and its contribution to pool formation in a coastal stream 50 years after logging. Canadian Journal of Fisheries and Aquatic Sciences. 45:2080-6

   Large quantities of woody debris persisted 50 year after logging and fire in stream channels of a small coastal Oregon watershed. Debris from the current stand represented only 14% of total debris volume and 8% of debris volume responsible for creating pools. The greatest number of pools were located in downstream sections of the watershed where gradient was reduced, discharge was increased, and streambed material was finer. Seventy percent of pools with a volume greater than 1.0 m^3 were associated with woody debris in the channel. Composition of the current riparian forest varied with topography. Alder stands dominated moist terrace sites adjacent to channels, whereas slopes contained a mixture of alder and conifer. Study results indicate that riparian trees must be left to grow longer than 50 year to ensure that an adequate, long-term supply of woody debris is available to stream channels. Debris from previous stands plays a crucial role in the interim and should not be removed from stream channels.

9. Angermeier P.L. and I.J. Schlosser. 1995. Conserving aquatic biodiversity: Beyond species population. p 402-14, *in* J.L. Nielsen, eds. Evolution and the aquatic ecosystem: defining unique units in population conservation. American Fisheries Society Symposium. Bethesda, MD.

   Although biodiversity encompasses diversity at many organizational levels, the vast majority of conservation efforts has been directed at particular species and populations. This approach has not been effective at protecting aquatic populations or biodiversity in general. Biological conservation can be more effective by making policy more preventive and by broadening its focus to include large scale biotic elements and key ecological and evolutionary processes. Species-specific approaches should be complemented by efforts to protect distinctive assemblages which provide the ecological and evolutionary context for populations. Aquatic assemblages vary considerably with respect to composition and organization, but no widely accepted framework reflects that diversity. Before policy to protect assemblages can be established, biologists must develop a framework for taking stock of assemblage diversity. Such a framework would enable managers to collect data on distribution, status and trends and to build compelling cases for conservation. We develop a general taxonomy of aquatic assemblages after reviewing current approaches to ecological classification. The framework consists of 4 major hierarchical levels: geographic regions, regional landscapes, primary communities and secondary communities. At each level, assemblage are distinguished directly on the basis of biotic factors and indirectly on the basis of physical factors. The resulting classification is based on the best available knowledge, but it can be adapted in incorporate new information. We envision that the framework can be used by state or provincial resource managers to develop detailed classifications of aquatic assemblages, which should help conservation biologists to articulate the efforts in areas where biodiversity loss is not already served. However, comprehensive conservation strategies should focus on protecting ecological integrity rather than on accurately monitoring biodiversity loss.

10. Armantrout N.B. 1998. Aquatic Habitat Inventory Terminology, Glossary. American Fisheries Society

The terminology and methods used for aquatic habitat inventories vary among organizations, agencies and disciplines. The aim of this glossary is to standardize definitions of terms that are applicable to aquatic systems. Relevant terms from the disciplines of meteorology, hydrology, hydraulics and geomorphology are also included and, where there are differences in meaning between biological and physical science definitions, both definitions are provided for clarification.

11. Aumen N.G., C.P. Hawkins, and S.V. Gregory. 1990. Influence of woody debris on nutrient retention in catastrophically disturbed streams. Hydrobiologia. 190:183-92

To access prevailing stream canopy conditions on representative streams in the northern Rocky Mountains and the Great Basin of the western USA, we measured several riparian habitat components, including canopy density, light intensity, unobstructed sun arc, and average potential daily thermal input in grazed and ungrazed portions of each stream. We also determined to what extent, if any, these habitat components were correlated with salmonid biomass and whether either they or salmonid biomass differed significantly between geographic regions or between grazed or rested pastures. Unobstructed sum arc was significantly and positively correlated with thermal input ($P>0.01$) and it was their best overall predictor of salmonid biomass per unit volume ($r^2 =.058$). Thermal input was a better predictor of salmonid biomass per unit volume in the Great Basin ($r^2 =0.92$)than in the Rocky Mountains ($r^2 = 0.50$) where thermal regime may exert more influence on fish populations. Mean estimates of fish biomass per unit volume differed significantly ($P < 0.05$) between the Great Basin (55.9 g/m^3) and Rocky Mountains (13.1 g/m^3) study areas and were better related to stream canopy attributes than biomass estimates based on stream surface area: in the Great Basin study areas, the 2 types of biomass were only weakly correlated with each other. In the Rocky Mountains, ungrazed sites generally had more canopy cover than grazed sites. In the Great Basin study areas, however, differences in canopy were unimportant and were probably related to local management practices in several cases.

12. Austen D.J., P.B. Bayley, and B.W. Menzel. 1994. Importance of the guild concept to fisheries research and management. Fisheries. 19(6):12-20

The concept of the guild has appealed to fisheries researchers and managers for simplifying analysis and assisting in the prediction of community change. Guilds have been developed based on reproduction, feeding, habitat use, and morphology. In most published accounts, guilds were used to describe a community change in response to some environmental perturbation (e.g., stream habitat modification or siltation). Members of a guild are often expected to react similarly to environmental change. However, little evidence exists to support the extrapolation of population changes in one guild member to that of other members of the same guild. It may be more reasonable to assume that the combined abundance of all species in a guild can more accurately reflect changes in their primary resource or a limiting factor. Thus, we suggest that guilds reflect the characteristics of a super-species-a unit that responds to environmental change in a more predictable manner than individual species. We recommend that guilds be developed based on critical environmental variables that are most influential in determining community composition. Also, the use of guild definitions needs to be evaluated with long-term data sets to ascertain their true ability to describe community dynamics.

13. Austen D.J., D.L. Scarnecchia, and E.P. Bergersen. 1994. Usefulness of structural and condition indices in management of high-mountain stream salmonid populations. North American

Journal of Fisheries Management. 14(4):681-91

We assessed the utility of relative weight (Wr), young-to-adult ratio (YAR), and a stock density index (SDI) calculated in a manner similar to the proportional stock density index as management tools for populations of brook trout *Salvelinus fontinalis* in six high-elevation streams. On each stream, estimates were made for production, biomass, production:biomass ratio, and brook trout density, as well as 14 environmental variables. The SDI varied substantially among streams and was significantly related to mean depth and conductivity, but not to any other environmental variables or to any of the population parameters. Values of Wr varied substantially over the growing season and were inversely related to mean depth for fish 100-150 mm and more than 150 mm total length, and directly (but marginally) related to production:biomass ratio for medium (>150-mm) and large (>200-mm) fish. Estimates of YAR were related only to the production:biomass ratio. Structural indices, in general, were correlated with no habitat characteristics except mean depth. There was sufficient seasonal variation in the indices to recommend that researchers restrict comparisons between streams to samples collected within as short a period as possible, preferably 2 months or less.

14. Bain M.B., J.T. Finn, and H.E. Booke. 1985. Quantifying stream substrate for habitat analysis studies. North American Journal of Fisheries Management. 5:499-506

Quantifying the substrate surface of stream habitats is a necessary component of many stream habitat analysis and inventory procedures. Evaluating the effects of stream flow fluctuations on fish habitat has lead to problems developed in the measurement and analysis of the substrate. The substrate measurement approach used in our previous research involved visually assessing the percentage composition of the stream substrate by category at a position of interest. A stream substrate composed of more than one type of substrate was represented by an average of the percent composition of the stream substrate by category at a position of interest. The problems associated with this approach are: (1) inability to represent substrate composed of nonadjacent categories such as boulders and sand; (2) categorical nature of data that is inconsistent with associated habitat variables (depth and velocity) measured on a continuous scale; and (3) uncertainty regarding distributional properties of averages of percentages. A new technique was developed, two substrate parameters, coarseness and heterogeneity, circumvent problems associated with the percentage composition method.

15. Bain M.B., T.C. Hughes, and K.K. Arend. 1999. Trends in methods for assessing freshwater habitats. Fisheries. 24(4):16-21

Habitat assessment is an important form of management for species conservation, mitigation planning, environmental regulation and impact assessment. As part of an American Fisheries Society and U. S. Fish and Wildlife Service project, we surveyed state, provincial, federal and private organizations to obtain documentation about methods being used to assess aquatic habitats in the inland waters of North America. We then used this information to characterize attributes of established methods. We found that most methods target habitats associated with flowing waters, but a significant number of methods deal exclusively with lakes and reservoirs. The survey showed that the dominant purpose for having an established methods was to standardize measurements and data collection techniques. Methods for stream habitats include a wide array of measurements emphasizing channel structure, water movement, substrate, cover and riparian zones. The lentic habitat methods emphasized the littoral zone, shallow-water physical structure and riparian areas. Data analyses were primarily numerical summaries and calculations of descriptive statistics usually presented using databases. Assessment methods focused on aquatic environmental quality more so than fishery resource evaluations - although methods associated with fishery investigations remain prominent. The overall characteristics of currently used methods suggest that many or most agencies are actively advancing their practices, and rapid change can be expected in most methods.

16. Baldridge J.E. and D. Amos. 1982. A technique for determining fish habitat suitability criteria: A comparison between habitat utilization and availability. p 251-8, *in* N.B. Armantrout, ed. Acquisition and Utilization of Aquatic Habitat Information. American Fisheries Society. Bethesda, MD.

We developed habitat suitability criteria from field data by comparing frequency analyses of utilized and available habitat. Using hydraulic simulation models and point measurement of depth, velocity and substrate at active pink salmon redds, we determined the degree of utilization and availability of one habitat attribute -- flow depth. Habitat suitability functions which account for habitat availability can be markedly different from those developed only from utilized habitat.

17. Baltz D.M., B. VonDracek, L.R. Brown, and P.B. Moyle. 1991. Seasonal changes in microhabitat selection by rainbow trout in a small stream. Transactions of the American Fisheries Society. 120:166-71

Shifts in microhabitat selection by rainbow trout *Oncorhynchus mykiss* were related to seasonal and ontogenetic factors in a small stream characterized by short riffles, small pools, and boulder substrate. Resource availability did not differ significantly between summer and November sampling dates for most variables related to water velocity, substrate, and cover, although depths were greater and temperatures were significantly lower in November. Ontogenetic shifts were found for total depth, focal elevation, mean water column velocity, focal velocity, surface velocity, and substrate, but not for relative depth or temperature. When microhabitat selection was adjusted for fish size, selection was significantly different between seasons, most notably for velocity. Ontogenetic shifts in microhabitat use by young-of-year rainbow trout were interrupted by cooling winter temperatures. These changes resulted in substantially different microhabitat requirements for all rainbow trout size-classes in different seasons.

18. Bauer S.B. and T.A. Burton. 1993. Monitoring protocols to evaluate water quality effects of grazing management on Western rangeland streams. Environmental Protection Agency, Region 10, EPA 910/R-93-017, Seattle, WA

No author abstract provided.

19. Bayley P.B. 1995. Understanding large river-floodplain ecosystems. BioScience. 45:153-8

No author abstract provided.

20. Beauchamp D.A., M.F. Shepard, and G.B. Pauley. 1983. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)--chinook salmon. U.S. Fish and Wildlife Services. FWS/OBS-82/11.6. Washington, DC

Species profile and environmental requirements for chinook salmon were derived from existing literature. The following habitat requirements at each life stage of the species are listed: temperature, substrate, water depth, DO, water velocity, and turbidity.

21. Beecher H.A., J.P. Carleton, and T.H. Johnson. 1995. Utility of depth and velocity preferences for predicting steelhead parr distribution at different flows. Transactions of the American Fisheries Society. 124(6):935-8

We tested an assumption of the instream flow incremental methodology that depth and velocity preferences are independent of streamflows. We had previously developed depth and velocity preferences (P[d] and P[v]) for juvenile (parr) steelhead *Oncorhynchus mykiss* at 0.86 m^3/s in Morse Creek, Washington, and found parr distributed in microhabitats with higher combined depth-velocity preference (P[dv] = P[d] X P[v]) at a similar flow (0.69 m^3/s). In the present study, we evaluated the relationship between fish distribution and combined depth-velocity preference using an independent data set from a higher flow (2.41 m^3/s) in the adjacent stream segment. Most steelhead parr were distributed in microhabitats with high P[dv}, consistent with distribution at 0.69 m^3/s and significantly different than expected if fish distribution were independent of habitat preference (chi-square, $P < 0.02$). These results suggest that depth and velocity preferences are independent of flow.

22. Beechie T.J., E. Beamer, and L. Wasserman. 1994. Estimating coho salmon rearing habitat and smolt production losses in a large river basin, and implications for habitat restoration.

North American Journal of Fisheries Management. 14(4):797-811

To develop a habitat restoration strategy for the 8,270-km^2 Skagit River basin, we estimated changes in smolt production of coho salmon *Oncorhynchus kisutch* since European settlement began in the basin, based on changes in summer and winter rearing habitat areas. We assessed changes in coho salmon smolt production by habitat type and by cause of habitat alteration. We estimated that the coho salmon smolt production capacity of summer habitats in the Skagit River basin has been reduced from 1.28 million smolts to 0.98 million smolts (-24%) and that the production capacity of winter habitats has been reduced from 1.77 million to 1.17 million smolts (-34%). The largest proportion of summer non-mainstem habitat losses has occurred in side-channel sloughs (41%), followed by losses in small tributaries (31%) and distributary sloughs (29%). The largest loss of winter habitats has occurred in side-channel sloughs (52%), followed by losses in distributary sloughs (37%) and small tributaries (11%). By type of impact, hydromodification (diking, ditching, dredging) associated with agricultural and urban lands accounts for 73% of summer habitat losses and 91% of winter habitat losses. Blocking culverts on small tributaries account for 13% of the decrease in summer habitat and 6% of the decrease in winter habitat. Forestry activities account for 9% of summer habitat losses and 3% of winter habitat losses. Limitations of the analysis and implications for developing a habitat restoration strategy are discussed.

23. Beland K.F., R.M. Jordan, and A.L. Meister. 1982. Water depth and velocity preferences of spawning Atlantic salmon in Maine rivers. North American Journal of Fisheries Management. 2:11-3

Water velocity and depth preference of spawning Atlantic salmon in four rivers in Maine were measured during October in 1975-1977. Female Atlantic salmon constructed redds in water with a mean depth of 38 ± 0.8 cm. Mean water velocity measured 12 cm above the substrate was 53 ± 1.3 cm/sec. Management implications of water depth and velocity requirements of spawning salmonids are discussed.

24. Bell M.C. 1973. Fisheries handbook of engineering requirements and biological criteria. Useful factors in life history of most common species. U. S. Army Corps of Engineers, Office of the Chief of Engineers, Fish Passage Development and Evaluation Program, DACE57-68-C-0086, Portland, OR

No abstract provided.

25. Benke A.C., R.K. Henry, D.M. Gilepsie, and R.J. Hunter. 1985. Importance of snag habitat for animals production in southeastern streams. Fisheries. 10(5):8-13

A study was performed to assess the relative importance of the snag habitat as a site of invertebrate production in comparison to benthic habitats. Invertebrate diversity, biomass, and production were considerably higher on snag surfaces than in either sandy or muddy benthic substrates. Although snags represented a relatively small habitat surface, snags supported 60% of total invertebrate biomass and 16% of the production for a stretch of river. Four of the major fish species obtained at least 60% of their prey biomass from snags. Management practices involving wood removal from rivers could be devastating to the invertebrate community and consequently to the several fish species that depend on them. The return of woody material to previously snagged streams may help restore their natural levels of animal productivity.

26. Berggren T.J. and M.J. Filardo. 1993. Analysis of variables influencing the migration of juvenile salmonids in the Columbia River basin. North American Journal of Fisheries Management. 13:48-63

The amount of time that it takes juvenile salmon and steelhead to migrate at different flows through index reaches in the Snake and Columbia rivers was analyzed with bivariate and multiple-regression models. Travel time was found to be inversely related to average river flows. Average river flow made the largest contribution to explaining variation in smolt travel time.

27. Berman C.H. and T.P. Quinn. 1991. Behavioral thermoregulation and homing by spring chinook salmon, *Oncorhynchus tshawytscha*, in the Yakima River. Journal of Fish Biology. 39:301-12

Temperature sensitive radio transmitters were employed to study the patterns of behavioral thermoregulation, habitat preference and movement of 19 adult spring chinook salmon in the Yakima River. During the 4 months prior to spawning, fish maintained an average internal temperature 2.5 C below ambient river temperature. This represented a 12 to 20% decrease in basal metabolic demand or a saving of 17.3 - 29.9 cal. Fish were most commonly associated with islands, pools, and rock outcroppings along stream banks. Homing behavior appeared to be modified to optimize temperature regimes and energy conservation. As the time of spawning approached, fish left thermal refuges and migrated to spawning grounds upstream and downstream of refuge areas. Although spring chinook salmon residing within cool-water refuges may be capable of mitigating sub-lethal temperature effects, cool-water areas need to be abundant and available to the fish. The availability of suitable thermal refuges and appropriate holding habitat within mainstem rivers may affect long-term population survival.

28. Beschta R.L. 1997. Restoration of riparian and aquatic systems for improved aquatic habitats in the upper Columbia River basin. *in* D.P. Strouder, P.A. Bisson, and R.J. Naiman, eds. Pacific Salmon and Their Ecosystems. Chapman and Hall. New York, NY.

Linkages among soils, channel morphology, riparian hydrology, and stream side vegetation can be used, from an ecological perspective, to illustrate why instream structural manipulations to improve fish habitat may often be inappropriate. While the focus has been on the addition of structural elements, improving riparian and aquatic function is a more important requirement for restoring degraded habitats. Aquatic habitat restoration should be based upon an understanding of natural disturbance regimes, multiple roles of streamside vegetation, land-use history, and reference sites.

29. Beschta R.L., R.E. Bilby, and G.W. Brown. 1987. Stream temperature and aquatic habitat: Fisheries and forestry interactions. p 191-232, *in* E.O. Salo and T.W. Cundy, eds. Streamside management: Forestry and fishery interactions. University of Washington, Institute of Forest Resources, Contribution 57. Seattle, WA.

The temperature of water entering a forest stream system typically resembles that of the watershed's subsoil environment. As this water continues to flow down the stream system, seasonal and diurnal water temperature are strongly influenced by solar radiation. Pronounced differences in stream temperature patterns are evident for stream draining watersheds through the Pacific Northwest. Seasonal and diurnal patterns of stream temperature influence a wide range of responsed by instream biota. Furthermore, logging activities can initiate pronounced temperature changes by the removal of forest vegetation along channels. Buffer strips of forest vegetation are an effective means of minimizing stream temperature impacts associated with logging. Although direct mortality of fish is probably not a major concern through the Pacific Northwest when stream temperatures are altered by management activities, temperature changes can influence rates of egg development, rearing success , species competition and other factors.

30. Beschta R.L. and W.S. Platts. 1986. Morphology features of small streams: significance and function. Water Resource Bulletin. 22(3):369-79

Throughout the United States, land managers are becoming increasingly aware of the importance of small streams for a wide range of resource benefits. Where channel morphology is modified or structural features are added, stream dynamics and energy dissipation need to be considered. Unit stream power, defined here as the time-rate loss of potential energy per unit mass of water, can be reduced by adding stream obstruction, increasing channel sinuosity, or increasing flow resistance with large roughness elements such as woody root systems, logs, boulders, or bedrock. Notable morphological features of small streams are pools, riffles, bed material and channel banks. Pools, which vary in size, shape an causative factors, are important rearing habitat for fish. Riffles represent storage locations for bed material and are generally utilized for spawning. The particles sizes and distributions of bed material including channel characteristics, bedload transport, food supplies for fish, spawning conditions, cover and rearing habitat. Riparian vegetation helps stabilize channel banks and contributes in various way to fish productivity. Understanding each stream feature individually and in relation to all others is essential for proper stream management. Although engineered structures for modifying habitat may alter stream characteristics, channel morphology must ultimately be matched to the hydraulic, geologic, and vegetative constraints of a particular location.

31. Bilby R.E. 1981. Role of organic debris dams in regulating the export of dissolved and particulate matter from a forested watershed. Ecology. 23:185-9

An organic debris dam is an accumulation of organic matter in a stream which obstructs water flow. Debris dams trap sediments in the pool formed upstream from them and the dam structure itself collects particulate organic matter. An experimental approach was used in which all organic debris dams were removed from a section of second order stream, just above a gauging weir. Following dam removal, export of dissolved matter increased slightly due to an increase in the concentration of dissolved organic carbon in the stream water during periods of high discharge. Fine particulate matter export increased dramatically at high discharges following dam removal. Coarse particulate matter export also was greatly increased.

32. Bilby R.E. and J.W. Ward. 1989. Changes in characteristics and function of woody debris with increasing size of streams in Western Washington. Transactions of the American Fisheries Society. 118:368-78

In second- to fifth-order streams that drain old-growth timber in western Washington, characteristics and function of woody debris changed in relation to stream size. Average diameter, length, and volume of pieces of wood increased as stream size increased, whereas the frequency of occurrence of woody debris decreased. In streams with channel widths less than 7 m, 40% of the pieces of debris were oriented perpendicularly to the axis of flow; in streams with channel widths over 7 m, more than 40% of the pieces were oriented downstream. The types of pools most commonly associated with pieces of wood changed from plunge pools in small streams (42%) to debris scour pools in larger systems (62%). Pool area was correlated with the volume of the piece of wood forming the pool in streams of all sizes. However, this relationship was most evident in larger channels. Nearly 40% of the pieces of wood in channels less than 7 m wide were associated with sediment accumulations. Less than 30% of the pieces retained sediment in channels from 7 to 10 m wide, and less than 20% retained sediment in channels greater than 10 m wide. Surface area of sediment accumulations and the volume of the piece of wood forming the accumulation were related in all streams, but the relationship was clearest in the larger channels. Accumulations of particulate organic matter associated with woody debris were more frequent in small streams but were larger in large streams. No relationship was observed between the volume of fine particulate organic matter accumulated by a piece of wood and the piece of wood's volume.

33. Bilby R.E. and J.W. Ward. 1991. Characteristics and function of large woody debris in streams draining old growth, clear-cut, and second-growth forests in southwestern Washington. Canadian Journal of Fisheries and Aquatic Science. 48:2499-508

Amount of large woody debris (LWD) surveyed in 70 stream reaches flowing through old-growth, clear-cut, and second-growth forests decreased with increasing stream size for all stand types but was greatest at old-growth sites. Average piece volume was larger at old-growth sites than at other stand types in streams > 10 m wide, but no differences were seen in smaller streams. Scour pools accounted for 90% of the wood-associated pools at second-growth and clear-cut sites but only 50% at old-growth sites, which contained more pools than other stand types, particularly for larger streams. Pool size was similar for all stand types in smaller streams, but averaged 10 m^2 in streams > 10 m wide at old-growth sites and 4 m^2 for other stand types. Pool size was similar for all stand types in smaller streams. Sediment and fine organic matter retained by woody debris decreased with increasing stream size for all stand types, but old-growth sites contained greater amounts of both materials than other stand types. The frequency of pool formation, the type of pool formed, and sediment accumulation were influenced by the amount of fine debris associated with LWD. Changes in LWD amount, characteristics, and function occurred very rapidly following removal of streamside vegetation.

34. Bisson P.A., Reeves G. H., Bilby R. E., and Naiman R. J. 1997. Watershed management and Pacific salmon: Desired future conditions. D.P. Strouder, P.A. Bisson, and R.J. Naiman,

eds. Pacific Salmon and Their Ecosystem. Chapman and Hall. New York, NY.

Objectives for managing habitat should be focused on maintaining the full range of aquatic and riparian conditions generated by natural disturbance events at landscape scales large enough to encompass the freshwater life cycles of salmon and other species. The natural disturbance regime is the engine that drives habitat formation for salmon. A key goal is to allow unhindered interaction between aquatic and terrestrial ecosystems. To ensure ecological links will not be disrupted; riparian zones of adequate width must be maintained, and anthropogenic disturbances must be minimized.

35. Bisson P.A. 1988. Importance of identification of limiting factors in an evaluation program. *in* . Proceedings, fish habitat enhancement and evaluation workshop. Bonneville Power Administration. Portland, OR.

Increased production of salmonid fishes is the desired goal of many western stream enhancement project. Where the species of interest is anadromous, greater smolt yield from a watershed is usually considered the ultimate measure of success of habitat restoration. Habitat enhancement projects are often not followed by critical evaluations of their effectiveness in achieving desired goals. As a result, we have relatively little knowledge of the benefits derived from widespread habitat management programs. In order to engage in cost-effective habitat management it is necessary to accurately recognize the key factors limiting the production of seaward migrants. Where such factors are not successfully identified, enhancement projects strongly risk failure. There are a number of potential barriers to identifying important limiting factors: (a) excessive reliance on professional judgement in the absence of site-specific data, (b) attempting to extrapolate findings from limited reach surveys to entire drainages, (c) oversimplification of complex ecological conditions, (d) focusing exclusively on one importance of critical factors that are not directly linked to the condition of the stream's physical habitat. There is no *a priori* reason to believe that the same limiting factors apply equally over a broad geographical area. Therefore, recognition of key constraints on smolt yield will require detailed and accurate information from the area of concern, knowledge of the life history patterns of the species of interest, an appreciation of the complexity of the stream ecosystems and a perspective that is basin oriented. Such information will not be easily obtained. Short-cut approaches to evaluating habitat enhancement should be applied with caution and with an understanding of their assumptions and limitations.

36. Bisson P.A. 1995. Ecosystem and habitat conservation: More than just a problem geography. p 329-33, *in* J.L. Nielsen, ed. Evolution and the aquatic ecosystem: defining unique units in population conservation. American Fisheries Society, Symposium #17. Bethesda, MD.

In practice, the protection of endangered species and the ecosystems upon which they depend has been based on identifying remaining patches of ecologically intact habitat and preventing these areas from being adversely altered by human activity, although some human use typically is allowed.

37. Bisson P.A. 1998. Using standards to predict aquatic habitat conditions in dynamic environments: A need for new approaches. U. S. Forest Service, Pacific Northwest Research Station, Portland, OR

In recent years both biologists and physical scientists have emphasized the dynamic nature of forested landscaped in which watershed undergo cyclic changes mediated by natural disturbance events that occur erratically. Habitat conditions in streams change, suddenly or gradually, according to these disturbance processes and it is upon this template of natural disturbances that anthropogenci changes are superimposed.

38. Bisson P.A., R.E. Bilby, M.D. Bryant, C.A. Dollof, G.B. Grette, R.A. House, M.L. Murphy, K.V. Koski, and J.R. Sedell. 1987. Large woody debris in forested stream in the Pacific Northwest: past, present, and future. p 143-90, *in* E.O. Salo and T.W. Cundy, eds. Streamside Management: Forestry and Fishery Interactions. University of Washington, Institute of Forest Resources, Contribution #57. Seattle, WA.

This paper reviews the form, function and management of woody debris in streams and reaches three major conclusions: (1) large woody debris enhances the quality of fish habitat in all sizes of stream. (2) Removal of most trees in the riparian zone during logging, combined with thorough stream cleaning and short-rotation timber harvest, has altered the sources, delivery mechanisms and redistribution of debris in drainage systems, leading to changes in fish population abundance and species composition. (3) There is an urgent need for controlled field experiments and long-term studies that focus on the protection of existing large woody debris in stream channels and the recruitment of new debris from the surrounding forest.

39. Bisson P.A., J.L. Nielson, R.A. Palmason, and L.E. Gore. 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low stream flow. p 62-73, *in* N.B. Armantrout, ed. Acquisition and utilization of aquatic habitat information. American Fisheries Society. Bethesda, MD.

Fish habitat in small streams is classified into a number of types occurring to location within the channel, pattern of water flow, and nature of flow controlling structures. Riffles are divided into three habitat types: low gradient riffles, rapids, and cascades. Pools are divided into six types: secondary channel pools, backwater pools, trench pools, plunge pools, lateral scour pools and dammed pools. Glides, the last habitat type, are intermediate in many characteristics between riffles and pools. Habitat utilization by salmonids was studied during summer low streamflow conditions in four western Washington streams. Most age 0+ coho salmon reared in pools, particularly backwaters, and preferred cover provided by root wads. A few large coho occupied riffles and sought the cover of overhanging terrestrial vegetation and undercut banks. Age 0+ steelhead trout selected riffles with large wood debris: while age 1+ steelhead preferred plunge, trench and lateral scour pools with wood debris and undercut banks. The largest individuals of both steelhead age classes were found in swiftly flowing riffle habitats. Age 0+ cutthroat trout preferred low gradient riffles but switched to glides and plunge pools when steelhead and coho were present, thus suggesting that they had been competitively displaced from a preferred habitat. Age 1+ and 2+ cutthroat preferred backwater pools when coho were absent but avoided them when coho were present. Cutthroat of all age classes generally favored cover provided by wood debris in both pool and riffle habitats.

40. Bisson P.A., K. Sullivan, and J.L. Nielsen. 1988. Channel hydraulics, habitat use, and body form of juvenile coho salmon, steelhead, and cutthroat trout in streams. Transactions of the American Fisheries Society. 117(3):262-73

Habitat use by juvenile coho salmon *Oncorhynchus kisutch*, steelhead *Salmo gairdneri*, and the coastal subspecies of cutthroat trout *Salmo clarki clarki* in small streams in western Washington was influenced by the hydraulic characteristics of different types of channel units. Coho salmon preferred pools with average velocities less than 20 cm/s; very few fish were found in riffles with high current velocities. Steelhead occurred in riffles and also utilized deep pools with relatively high velocities along the center of the channel. Cutthroat trout were intermediate between coho salmon and steelhead in their use of swiftly flowing habitats. Variation in body shape and fin size among the three species generally fit the predicted morphologies that would be favored in different locations within the channel. Coho salmon possessed a deep, laterally compressed body with large median and paired fins. These features are believed to facilitate rapid turns and quick but transient burst swimming. Steelhead possessed a more cylindrical body shape with short median fins and relatively large paired fins, attributes that appear well adapted to holding a position in swift water. The cutthroat trout's lack of morphological adaptation to either fast or slow water may help to explain why this species is dominated by coho salmon and steelhead in areas of sympatry.

41. Bjornn T.C., J.P. Hunt, K.R. Tolotti, P.J. Keniry, and R.R. Ringe. 1993. Migration of adult chinook salmon and steelhead past dams through reservoirs in the lower Snake River and into tributaries - 1992. University of Idaho, Idaho Cooperative Fish and Wildlife Research Unit, Moscow, ID

A study of upstream migration of adult spring and summer chinook salmon and steelhead past the four lower Snake River dams, through the reservoirs, and into the tributaries of the Snake River drainage was initiated in 1991 and continued in 1992 and 1993. The objectives were to evaluate the effect of spill, powerhouse operation and flows on the rates of passage of the fish at the dams, migration through the reservoirs, the fish-way entrances used, fallback at the dams and movements into the tributaries upstream from the reservoirs.

42. Bjornn T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. p 83-138, *in* W.R. Meehan, eds. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication #19. Bethesda, MD.

    The major life stages of most salmonid species are associated with different uses of fluvial systems: migration of maturing fish from the ocean, lakes, or rivers to natal streams; spawning by adults; incubation of embryos; rearing of juveniles; and downstream migration juveniles to large-river, lacustrine, or oceanic rearing areas. Ranges of temperature, water velocities, water depths, cover, and substrates preferred by salmon, trout, and char are identified and listed specific to life stage and fluvial system location.

43. Booth G.D. n/a. Interpreting Statistical Tests.

    No author abstract provided.

44. Boussu M.F. 1954. Relationship between trout populations and cover on a small stream. Journal of Wildlife Management. 18:229-39

    14 sections were studied to look at the relationship of eastern brook trout, rainbow trout and brown trout in Trout Creek, Montana. The sections were selected on the basis of presence or absence of cover features such as over-hanging brush and under-cut banks.

45. Bovee K.D. 1982. Guide to stream habitat analysis using the instream flow incremental methodology. U. S. Fish and Wildlife Service, FWS/OBS-82/26Fort Collins, CO

    No abstract provided.

46. Bowlby J.N. and J.C. Roff. 1986. Trout biomass and habitat relationships in southern Ontario streams. Transactions of the American Fisheries Society. 115:503-14

    We examined relationships between the biomass of trout (species of Salvelinus and Salmo) and physical and biological habitat variables in streams to identify habitat factors that might limit trout biomass. Thirty sites were chosen to span a wide array of habitat types. At each site we measured a large number of habitat variables representing instream cover, substrate, stream morphology and velocity, stream temperature and food availability. Two habitat quality index models developed by Binns and Eiserman for Wyoming streams accounted for only 6.7 and 9.2% of the variation in trout biomass at Ontario stream sites. Different factors must limit trout biomass in Wyoming streams than in Ontario streams. Regression and discriminate function analyses indicated that trout biomass in southern Ontario is correlated with microcommunity biomass (measured as ATP of the suspended solids, and representing bacteria, fungi, and algae), percent pool area, mean maximum summer temperature, biomass of small benthic invertebrates, presence of piscivorous fish, and a variable representing pools and overhead cover. Microcommunity biomass was the most important habitat variable in these analyses and it was significantly correlated with basin yield. We hypothesize that microcommunity biomass is a surrogate measure of localized groundwater inflow, which, in turn, has a beneficial effect on the microhabitat of trout eggs and underyearlings.

47. Boyd M. and D. Sturdevant. 1998. Scientific Basis for Oregon's Stream Temperature Standard: Common Questions and Straight Answers. Oregon Department of Environmental Quality, Salem, OR

    No author abstract provided.

48. Bozek M.A. and F.J. Rahel. 1991. Assessing habitat requirements of young Colorado river cutthroat trout by use of macrohabitat and microhabitat analyses. Transactions of the American Fisheries Society. 120(5):571-81

We used both microhabitat and macrohabitat analyses to better assess habitat requirements of young Colorado River cutthroat trout *Oncorhynchus clarki pleuriticus*. Microhabitat analyses revealed that among the range of stream types, young cutthroat trout consistently preferred slow water (<0.06 m/s) and depths over 3 cm. Suitable habitat of this type was provided by different types of pool habitat within the geomorphically diverse study streams. Macrohabitat analysis indicated that the density of young cutthroat trout was positively correlated with the abundance of spawning gravel and negatively correlated with stream depth (adjusted $R^2 = 0.67$). This relationship helped explain the absence of young cutthroat trout from some stream reaches that had suitable microhabitat but that often lacked suitable spawning habitat. The two types of habitat analysis provided complementary information concerning the habitat requirements of young Colorado River cutthroat trout in the study streams.

49. Brannon E.L. and E.O. Salo. 1982. Proceedings on the salmon and trout migratory behavioral symposium. University of Washington, School of Fisheries, Seattle, WA

Proceedings of the first international symposium on salmon and trout migratory behavior.

50. Bray D.I. 1982. Flow resistance in gravel bed rivers. Gravel bed rivers. John Wiley and Sons. New York, NY.

No abstract provided.

51. Brusven M.A., W.R. Meehan, and J.F. Ward. 1986. Summer use of simulated undercut banks by juvenile chinook salmon in an artificial Idaho channel. North American Journal of Fisheries Management. 6:32-7

The effects of introducing simulated undercut stream banks on the distribution of juvenile chinook salmon were studied in a naturally vegetated, flow regulated channel. In all tests mean fish weight was greater in covered than in open sections. Preference for the covered versus uncovered experimental sections was highly significant during July and August tests. The results suggest that undercut banks are an important summer habitat component for juvenile chinook salmon. In addition to overhead cover, other variables such as water depth, velocity, substrate, and water volume are influential variables in the distribution of juvenile salmonids. It is a probable that synergistic relationships exist among these parameters.

52. Bryant M.D. 1983. The role and management of woody debris in west coast salmonid nursery streams. North American Journal of Fisheries Management. 3:322-30

Debris removal is a frequently used management technique for small streams in logged watersheds, but many stream-cleaning techniques overlook important habitat requirements of juvenile salmonids. A review of several studies shows the importance of woody debris as salmonid habitat. The role of organic debris in small stream systems is discussed and a set of criteria for debris removal is proposed.

53. Bryant M.D., P.E. Porter, and S.J. Paustian. 1991. Evaluation of a stream channel-type system for Southeast Alaska. U. S. Forest Service, PNW-GTR-267, Portland, OR

9 channel types within a hierarchical channel type classification system were surveyed to determine relations between salmonid densities and species distribution and channel type. 2 other habitat classification systems and the amount of large woody debris also were compared to species distribution and salmonid densities and to stream channel types. Although trends appeared in salmonid densities and channel types, populations estimates were too variable to show a relation between density and channel types. Depth velocity criteria that separated habitat into shallow-slow, deep-slow, shallow-fast and deep-fast were poorly related to fish populations and channel types. Within the Bisson classification system, coho salmon parr were positively correlated to off-channel habitat types. Large wood was more abundant in depositional channel types and coho salmon densities were positively related to debris accumulations of 10 or more pieces and to rootwads. Although salmonid densities were not statistically related to channel types within the

CTCS, the system seems to be a useful tool to classify stream habitat and to identify its use by salmonids.

54. Bugert R.M. 1985. Microhabitat selection of juvenile salmonids in response to stream cover alteration and predation. University of Idaho, MS Thesis, Moscow, ID

I conducted experiments in southeast Alaska streams and in artificial stream channels with three objectives: to evaluate the role of riparian and instream cover on juvenile coho salmon and steelhead trout habitat needs; to test the hypothesis that the mutual presence of coho salmon and steelhead in a stream affects the habitat selection of each other, and test the hypothesis that riparian and instream cover reduce predation upon juvenile coho salmon and steelhead trout.

55. Bugert R.M., T.C. Bjornn, and W.R. Meehan. 1991. Summer habitat use by young salmonids and their responses to cover and predators in a small southeast Alaska stream. Transactions of the American Fisheries Society. 120(4):474-85

We observed young coho salmon *Oncorhynchus kisutch,* steelhead *O. mykiss*, and Dolly Varden *Salvelinus malma* in a second-order stream on Prince of Wales Island, Alaska, to assess differences between species in habitat use and response to cover and predators. Habitat use by subyearlings of the three species differed primarily in depth of water and position in the water column. Coho salmon selected the relatively deep areas of the small stream; steelhead were more evenly spread across the bottom, regardless of depth; and Dolly Varden were close to the bottom in water less than 20 cm deep. All three species selected lower positions in the water column in pools without cover than in pools with riparian or instream cover. We detected no shift in habitat use in response to fish predators.

56. Burns D.C. 1991. Cumulative effects of small modifications to habitat. Fisheries. 16(1):12-7

Accumulation of localized or small impacts results in regional and global changes in fisheries. Cumulative effects of small habitat modifications cannot be simply written into a linear equation, due to mathematical limitations.. Even without the application of quantitative techniques, certain conclusions can be drawn. All individual effects to fish habitat result in cumulative effects to global fisheries. It is unclear whether improvement efforts to some fish habitats result in cumulative increases in production or whether they mitigate other habitat alterations.

57. Burton T.A. 1997. Effects of basin-scale timber harvest on water yield and peak streamflow. Journal of the American Water Resources Association.

Streamflow changes resulting from clearcut harvest of lodgepole pine *(Pinus contorta)* on a 2145 hectare drainage basin (Utah, USA) are evaluated by the paired watershed technique. Thirty years of continuous daily streamflow records were used in the analysis, including 10 pre-harvest and 20 post-harvest years of data. Regression analysis was used to estimate the effects of timber harvest on annual water yield and annual peak discharge. Removal of 14 million board feet of lodgepole pine *(Pinus contorta)* from about 526 hectares (25 % of the basin) produced an average of 14.7 cm additional water yield per year (an increase of 52%) and an increase in mean annual daily maximum discharge of 1.6 m3 s-1 (an increase of 66%). Increases occurred primarily during the period of May through August with little or no change in wintertime streamflows. Results suggest that clearcutting conifers in relatively large watersheds (> 2000 ha) may produce significant increases in water yield and flooding. Implications of altered streamflow regimes are important for assessing the future ecological integrity of stream ecosystems subject to large-scale timber harvest and other disturbances that remove a substantial proportion of the forest cover.

58. Burton T.A., W. Clark, G.W. Harvey, and T.R. Mater. 1992. Development of sediment criteria for the protection and propagation of salmonid fishes. Journal of the Idaho Academy of Science. 28(1):14

No author abstract provided.

59. Bustard D.R. and D.W. Narver. 1975. Preferences of juvenile coho salmon (*Oncorhynchus*

kisutch) and cutthroat trout (*Salmo clarki*) relative to simulated alteration of winter habitat. Journal of the Fisheries Research Board of Canada. 32(5):681-7

Winter habitat preferences of juvenile coho salmon *(Oncorhynchus kisutch)* and cutthroat trout *(Salmo clarki)* were tested by simulating conditions before and after stream disturbance such as might result from logging: (1) sidepools with or without an overhanging bank and roots and (2) sidepools with clean or silted rubble substrate. Both coho and cutthroat demonstrated a strong preference for sidepools offering overhanging bank cover as opposed to those without bank cover. Similarly they preferred sidepools with clean rubble substrate as opposed to silted rubble. In both the bank and rubble tests, when given the option of either remaining in the sidepools or of moving into the stream, a greater percentage of the total number of coho and cutthroat originally in the sidepools remained in the pools with cover as opposed to those without cover. Coho utilized bank cover more readily than rubble cover whereas cutthroat used both bank and rubble cover.

60. Cada G.F., M.D. Deacon, S.V. Mitz, and M.S. Bevelhimer. 1994. Review of information pertaining to the effect of water velocity on the survival of juvenile salmon and steelhead in the Columbia River basin. Oak Ridge National Laboratory, Oak Ridge, TN

This report was prepared to address the need for a critical review of information pertaining to relationships between flow and smolt survival.

61. Cairns J., P.V. McCormick, and B.R. Niederlehner. 1993. Proposed framework for developing indicators of ecosystem health. Hydrobiologia. 263:1-44

Considerations involved in developing a suite of indicators to monitor regional environmental health, similar in conception to management use of 'leading economic indicators' are described.

62. Callicott J.B. 1995. Conservation ethics at the crossroads. p 3-7, *in* J.L. Nielsen, ed. Evolution and the aquatic ecosystem: defining unique units in population conservation. American Fisheries Society Symposium. Bethesda, MD.

For most to the 20th century no consensus on conservation values existed, but in North America 2 simple conflicting philosophies of conservation, the wise use of natural resources and wilderness preservation prevailed. The former philosophy dominated state and federal conservation agencies. Hence fisheries were managed for maximum production of sport and meat. The latter philosophy dominated private conservation organizations. But because native fishes were out of sight, they were mostly out of preservationists minds an rarely benefited from protectionist efforts. Today both philosophies of conservation are obsolete. They seem to be giving way to a new conservation cleavage reflecting a long standing chasm in ecology between a focus on species populations and communities, on the one hand, an a focus on ecosystems on the other. From the former point of view, preserving species or aggregately preserving biodiversity is the overriding goal of conservation ethics. From the latter point of view, preserving ecosystem functions, now called ecosystem health, is the overriding goal. Fortunately these recent conceptions of conservation ethics are not as mutually exclusive as were resource management versus wilderness preservation. Preserving biodiversity, however is a more stringent conservation norm, because ecosystem health may not necessarily be compromised if a rare subspecies is replaced by a more commonplace cousin or even if a species proper is replaced by another that fills the same niche. Both of these recent conservation ethics, but especially biodiversity preservation, have been complicated by the current emphasis on dynamism in ecology. Biodiversity preservation has thus become the preservation of evolutionarily significant units; meanwhile proponents of ecosystem health struggle to define the health of ecosystem in circumstances of constant perturbation and shifting patch mosaics.

63. Carlson J.Y., C.W. Andrus, and H.A. Froehlich. 1990. Woody debris, channel features, and macroinvertebrates of streams with logged and undisturbed riparian timber in northeastern Oregon, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences. 47(6):1103-11

Macroinvertebrate communities and several aspects of fish habitat were examined for 16 northeastern Oregon stream segments, 11 with undisturbed riparian forests and five where 26-54% of the riparian forest had been harvested 6 to 17 year previously. Amounts of woody debris in streams and pools formed by the debris were similar between undisturbed and logged sites. Pool volume was inversely related to stream gradient and directly related to the amount of woody debris in the stream. Stream surface substrate composition was not significantly different between streams in logged and undisturbed areas. Macroinvertebrate density was 20 to 113 percent greater at the logged sites and diversity was similar at logged and undisturbed sites. Macroinvertebrates were most abundant at lower elevation streams and at streams that were shaded less by the surrounding vegetation. Timber harvesting activities do not appear to have damaged aquatic insect habitat and pool abundance was not altered, suggesting the habitat's carrying capacity for fish was not affected.

64. Chapman D.W. 1988. Critical review of variables used to define effects of fines in redds of large salmonids. Transactions of the American Fisheries Society. 117(1):1-21

Laboratory studies have failed to duplicate the structure and composition of egg pockets in redds of large salmonids, and thus have not accurately modeled survival of embryos and alevins in natural egg pockets. Field studies of natural redds have related survival to conditions in the redds or surrounding areas but not demonstrably in egg pockets. These data probably do not accurately reflect conditions faced by embryos or emerging alevins. The few data on egg pocket characteristics indicate that geometric mean particle diameter, fredle index, and permeability are higher in gravel surrounding the embryos than elsewhere. Survival to alevin emergence usually regresses positively on each of these factors separately and on dissolved oxygen in intragravel water. Survival to emergence usually related negatively to percentages of small fines. Quantitative predictors depend upon careful definition of egg pocket structure through field surveying of egg pocket centrum locations and on intensive study of pocket conditions. Laboratory duplication of egg pocket structure and physical variables will permit more accurate modeling of effects of fines on survival to emergence. Redd capping in natural redds can provide estimates of survival to emergence, which one may relate to average egg pocket conditions outside of the egg pocket to the environment within it and to survival-to-emergence.

65. Chapman D.W. and K.P. McLeod. 1987. Development of criteria for fine sediment in the Northern Rockies ecoregion. Environmental Protection Agency, EPA 910/9-87-162, Washington, DC

This document lists threshold levels of minimum dissolve oxygen and percent fines. These measures of streambed character offer indices of habitat quality that can be quantified by; percentages of fines, geometric mean particle size, fredle index, and permeability. Substrate scoring to describe habitat suitability for aquatic insects and fish correlate reasonably well with geometric mean particle size.

66. Chevalier B., C. Carson, and W.J. Miller. 1984. Report of engineering and biological literature pertaining to the aquatic environment: with special emphasis on dissolved oxygen and sediment effects on salmonid habitat. Colorado State University, ARS Project 5602-20813-008A, Fort Collins, CO

This report is the first of a two part study of the aquatic environment intended to develop a model of dissolved oxygen transport in the substrate. An accurate model is a necessary step in the assessment of impacts from such upstream sources as agricultural runoff. the model will be applicable to several problem areas, including the Tucannon River in the Columbia River basin.

67. Clarke S.E. and S.A. Bryce. 1997. Hierarchical subdivisions of the Columbia Plateau and Blue Mountains ecoregions, Oregon and Washington. U. S. Forest Service, PNW-GTR-395, Portland, OR

This document present 2 spatial scales of a hierarchical, ecoregional framework and provides a connection to both larger and smaller scale ecological classification The 2 spatial scales are subregions and landscape-level ecoregions by the Environmental Protection Agency because the resolution of national-scale ecoregions provided insufficient detail to meet the needs of state agencies for establishing biocriteria, reference sites, and attainability goals for water quality regulation. For this project, 2 ecoregions - the Columbia Plateau and the Blue Mountains were subdivided into more detailed level IV ecoregions. Similarly, the finer scale landscape-level ecoregions were developed to address local land management issues. The landscape-level ecoregions for northeast Oregon and Southeast Washington were created specifically to address the issue of anadromous fish habitat. Their delineation, however, employed landscape information similar to that used in other levels of the ecoregion hierarchy, thereby indicating the potential for general application of these regions to both terrestrial and aquatic research questions. The study area for the landscape-level ecoregions was defined by contiguous watershed within the ecoregions of the Columbia Plateau and Blue Mountains to merge the ecoregional information with units corresponding to fish distribution.

68. Clausen J.C. and J. Spooner. 1993. Paired watershed study design. North Carolina State University, Biological and Agricultural Engineering Department, Raleigh, NC

No author abstract provided.

69. Connor W.P., D. Burge, D. Steele, C. Eaton, and R. Bowen. Rearing and emigration of naturally produced Snake River fall chinook salmon juveniles. p 41-73, *in* Rondorf D.W. and Tifan K.F., eds. Identification of the Spawning, Rearing and Migratory Requirements of Fall Chinook Salmon in the Columbia River basin . Bonneville Power Administration, DOE/BP-21708-3. Portland, OR.

The objects of the 1993 study were to describe the early life history and emigration timing of naturally produced fall chinook salmon from the Snake and Clearwater rivers and to estimate the influence of water flow, water temperature and juvenile fall chinook salmon size on emigration rate.

70. Conquest L.L. and S.C. Ralph. 1998. Statistical design and analysis considerations for monitoring and assessment. p 455-75, *in* R.J. Naiman and R.E. Bilby, eds. River Ecology and Management: Lessons from the Pacific Coastal Ecoregion. Springer - Verlag. New York, NY.

Monitoring is often required as a condition to permit a wide range of land-use activities, or to document the response of a resource to those activities. Increasing attention is being paid to the design and execution of intensive field monitoring in a forested landscape, due to natural spatial and temporal heterogeneity in landscape responses. Monitoring programs need to be well designed in order to (1) assess reliably the status of the resource of concern and (2) be of value in guiding future management decisions associated with formulating effective public policy. The objectives of this paper are to outline key issues associated with monitoring.

71. Conquest L.L., S.C. Ralph, and R.J. Naiman. 1993. Implementation of large-scale stream monitoring efforts: sampling design and data analysis issues. p 69-90, *in* S.L. Loeb and A. Spacie, eds. Biological monitoring of aquatic systems. Lewis Press. Boca Raton, FL.

No author abstract provided.

72. Copp G.H. 1989. Habitat diversity and fish reproductive function of floodplain ecosystems. Environmental Biology of Fishes. 26:1-27

Fish reproduction in floodplain ecosystems, based on relative abundance and total biomass of 0+ juveniles, was studied using the synchronic approach to typological analysis in conjunction with Point Abundance Sampling by modified electrofishing. In 3 different flood plains of the Upper Rhone River, 1015 point samples yielding 4573 juveniles (0+) from 21 species were collected from 48 ecosystems of various geomorphological origins. The results demonstrated the lotic-to-lentic succession of floodplain ecosystems to be a series of non-sequential reproductive zones, with spawning conditions being reflected by the specific composition and guild structure of the YOY fish assemblages. The habitat diversity and the fish reproductive potential of floodplain ecosystems are strongly influenced by geomorpholgical origin and by past and present hydrological conditions. The YOY assemblages of autogenically driven ecosystems (usually of anastomose or meander origin) tend to differ both in composition and in quantity from those found in allogenically driven ecosystems (generally of braided origin). Ecosystems of intermediate character, and fish reproduction thereof, occur as the result of either ecosystem rejuvenation or senescence: authogenically driven ecosystems by allogenic mechanisms or allogenically driven ecosystems by anthropic and/or autogenic mechanism, respectively. Because of co-occurrence of ecosystems at similar and at different successional status, the flood plain as an entity is seen as "stable" with respect to fish reproduction.

73. Cordova J.J. 1995. Streamside forest, channel constraint, large woody debris characteristics, and pool morphology in low order streams, Blue Mountains, Oregon. Oregon State University, MS Thesis , Corvallis, OR

The identification of the natural variability of LWD characteristics and function among each level of channel constraint defines the need to compare streams of like geomorphic character. In order to successfully manage or restore degraded stream ecosystems, the stream must be viewed in a watershed context to accommodate natural variability between streams and stream reaches.

74. Curet T.S. 1993. Habitat use, food habits, and the influence of predation on subyearling chinook salmon in Lower Granite and Little Goose Reservoirs, Washington. University of Idaho, MS Thesis, Moscow, ID

The results of my research indicate Lower Granite and Little Goose reservoirs provide suitable rearing habitats for subyearling chinook salmon. The quantity of food ingested is limited either due to food limitations, competitive interactions or the influence of other biotic and abiotic factors. Temperatures appear to control both duration of shoreline residence and the duration of open water rearing for subyearling chinook salmon. Smallmouth bass and northern squawfish are both predators of subyearling chinook salmon with smallmouth bass being the most serious predator, particularly along the shoreline of Lower Granite Reservoir. These predators may consume up to 6% of the wild subyearling fall chinook salmon population as they rear and migrate through Lower Granite Reservoir.

75. Dambacher J.M. and K.K. Jones. 1994. Stream habitat of juvenile bull trout populations in Oregon and benchmarks for habitat quality. W.C. Mackay, M.K. Brewin, and M. Monita, eds. Proceedings, Friends of the Bull Trout Conference. Trout Unlimited, Bull Trout Task Force. Calgary, AB, Canada.

Fish population and habitat surveys of Oregon streams containing bull trout were conducted by the Aquatic Inventories Project, Oregon Department of Fish and Wildlife from 1990 to 1994. This paper examined the association of juvenile (<170 mm fork length) bull trout populations with other fish species, and with habitat characteristics at the watershed, reach and habitat unit level of organization. Juvenile bull trout were most commonly found with rainbow trout, but were frequently found alone or with sculpin, non-native brook trout, or cutthroat trout. Populations of juvenile bull trout were in watersheds that averaged 30 km^2 in size and on average ranged from 1,460 m to 2,320 m elevation. Populations were found nearly equally among hillslope constrained, terrace constrained and unconstrained channel types. Stream channels had average gradients of 5.0% slope, wetted widths of 2.9 m and were dominated by riffle and rapid habitat. Stream reached supporting juvenile bull trout populations were compared, by multivariate analysis, to reaches without bull trout using 31 habitat variables. Seven habitat variables were significant ($P<0.0001$) descriptors of the presence of juvenile bull trout: high levels of shade, undercut banks, large woody debris volume, large woody debris pieces and gravel in riffles and low levels of fine sediment in riffles and bank erosion. These variables describe important components of juvenile rearing habitat and collectively characterize stream reaches with juvenile bull trout as having healthy riparian zones and relatively undisturbed stream channels. Habitat quality benchmarks were developed based upon habitat supporting extant juvenile bull trout populations in Oregon. Suggestions for their application are discussed.

76. Davis W. 1995. Biological assessment and criteria: building on the past. W.S. Savis and T.P. Simon, eds. Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers. London, England.

Four tools have been developed in the past decade that provides the means to transform biological assemblage data into numeric criteria and standards: (1) a functional definition of biological integrity to serve as an understandable water resource goal; (2) minimizing the problems with interpreting the natural geographic and temporal variability of data by aggregating within regions of ecological similarity; (3) using multiple reference sites within ecological or faunal regions to obtain assemblage attributes or metrics to produce a single numeric measure of biological integrity. Progress on defining "biological integrity" has evolved with experience in applications of the Clean Water Act. Currently, the term biological integrity has been used synonymously with attaining the beneficial use for aquatic life protection.

77. DeGraaf D.A. and L.H. Bain. 1986. Habitat use by and preferences of juvenile Atlantic salmon in two Newfoundland rivers. Transactions of the American Fisheries Society. 115(5):671-81

We examined habitat use by juvenile Atlantic salmon *Salmo salar* in two Newfoundland rivers; one with riffle habitat, the most typical rearing habitat for this species, the other with extensive areas of deeper slow-flowing water and rooted macrophytes. We derived habitat-use curves for both habitat types from field data, then measured habitat availability to calculate habitat preference in each area. Both habitat use and habitat preference varied between young of the year and older juveniles (parr). There was little difference between habitat used by young of the year in the two rivers; however, parr habitat use differed significantly for some of the variables between sites. Water velocity at the fish's snout was the principal variable that defined habitat use. Substrate was unimportant in the riffle habitat but it had influence on habitat use in the slow-water environment. Water depth was unimportant within the range of depths examined during the present study. The use and preference curves for each variable were influenced by other habitat components, especially in the slow-water habitat. The differences noted between habitat preference measured in the two habitat types suggest that either the method used to compute preference is flawed or the other (unmeasured) factors are influencing habitat use. With our present understanding of the habitat requirements of juvenile Atlantic salmon, locally derived habitat-use information is recommended for habitat modeling.

78. Dollof C.A. Relationships of wood debris to juvenile salmonid production and microhabitat selection in small southeast Alaska streams. Montana State University, Ph. D. Dissertation, Bozeman, MT

Many small streams in Southeast Alaska contain both wood debris deposited by natural causes and/or logging and population of juvenile salmonids. Resource managers have assumed that large amounts of wood debris were detrimental to fish populations and have recommended debris removal. This study was initiated to describe the effects of wood debris and debris removal on populations of juvenile coho salmon and dolly varden in 4 tributary streams of Staney Creek, Prince of Wales Island, Alaska during the summers of 1979-1981. Three streams were located in clearcuts and had debris removed from selected subsections by manual labor. A fourth stream was located in a uncut forest stand and provided information on fish populations under natural conditions. Population densities and production of both species were typically higher in subsections having debris accumulations intact. Production during the June-September period for age 0+ and age 1+ coho combined ranged from 0.464-2.496 g/square meter. Dolly varden production ranged from 0.106-2.496 g/square meter. For coho debris provided visual isolation, permitting large numbers of fish to live together without excessive territorial interactions. Greater dolly varden numbers were related in increased cover provided by debris. There was little apparent competition between the species. An examination of microhabitat preference showed that each of 2 coho and 3 dolly varden age classes was found in distinct areas. Coho occupied midwater positions that they defended from other fish. Dolly varden were found on the stream bottom in dense cover. Analysis of stomach contents showed that coho selected most dietary items from the drift whereas dolly varden primarily exploited benthic prey. Discriminate analysis showed that depth of focal point, depth of water, distance to nearest fish and distance to nearest cover were the most important variables accounting for separation of the five species-age class groups. Discriminate analysis using species as groups and incorporating the proportion of diet from terrestrial sources as an independent variable revealed that dietary differences also contributed to group separation. Stream cleaning in streams similar to those studied will likely be detrimental to anadromous juvenile fish populations.

79. Dollof C.A. 1987. Seasonal population characteristics and habitat use by juvenile coho salmon in

a small southeast Alaska stream. Transactions of the American Fisheries Society. 116(6):829-38

The density, growth, production, and movements of juvenile coho salmon *Oncorhynchus kisutch* from a wild population were evaluated after the fish were transplanted into five types of habitat (clear-cut, forest, meadow, slough tributary, forest tributary) in a small southeastern Alaska stream. Instantaneous growth ranged from 0.0066 in the clear-cut habitat to 0.0055 in the slough tributary. Daily increase in fork length was about 0.10 mm/d system-wide. Annual production of coho salmon in each habitat type was: meadow, 3.32 g/m^2; slough tributary, 2.47 g/m^2; clear-cut, 1.75 g/m^2; forest, 1.59 g/m^2; and forest tributary, 1.34 g/m^2. During all sampling periods, most fish were recaptured at the site where they were released; those fish that moved neither selected nor avoided specific habitat types. These findings suggest that all habitats should be managed to meet both the summer and winter needs of juvenile coho salmon because most fish do not move among habitats after the initial population adjustment in the spring. The ability of a stream to produce fish depends not only on the amount and accessibility of habitat, but also on the distribution of habitat types.

80. Don Chapman Consultants. 1989. Summer and Winter Ecology of Juvenile Chinook Salmon and Steelhead Trout in the Wenatchee River, Washington. Don Chapman Consultants for Chelan County Public Works Utility District, Boise, ID

Describes the seasonal and diel habitat selected by chinook salmon and steelhead and assessed the degree of spatial interaction between the 2 species. Also describes the abundance, habitat use and overlap of juvenile steelhead of different sizes an stocked hatchery rainbow trout to catchable size.

81. Donald D. and D.J. Alger. 1993. Geographic distribution, species displacement, and niche overlap for lake trout and bull trout in mountain lakes. Canadian Journal of Zoology. 71(2):238-47

Indigenous lacustrine populations of bull trout and lake trout are spatially separated within the southern part of the zone of distributional overlap. In this area, lake trout occurred primarily in mountain lakes, while bull trout were found primarily in low-elevation lakes. The hypothesis was tested that lake trout displace bull trout from lakes before determining the outcome of introductions of lake trout into two lakes that support indigenous bull trout. The bull trout populations were decimated there, thus, lake trout can displace bull trout and may prevent bull trout from being established at certain low-elevation lakes. Niche overlap and the potential for competition between the two char species were substantial. In lakes with trophic structure ranging from simple to complex, bull trout and lake trout fed on similar foods and had similar ecological growth rates.

82. Dose J.J. and B.B. Roper. 1994. Long-term changes in low-flow channel widths within the South Umpqua Watershed, Oregon. Water Resources Bulletin. 30:993-1000

Recent stream survey data (1989-1993) from 31 stream segments of 21 streams within the upper South Umpqua Watershed, Oregon were compared to 1937 stream survey data collected from these same stream segments. There was significant differences in stream width since 1937. The observed change in stream width is related to timber harvest, road density, and the amount of large organic debris remaining within the active stream channel. These findings suggest that timber harvest and road construction may have resulted in changes in channel characteristics. These channel changes may also be a factor in the observed decline of three of the four populations of anadromous salmonids within the basin.

83. Dunne T. and L.B. Leopold. 1978. Water in Environmental Planning. W. H. Freeman and Co., San Francisco, CA

No author abstract provided.

84. Duodorf P. and C.E. Warren. 1965. Environmental requirements of fishes and wildlife: dissolved oxygen requirements of fishes. Oregon State University, Agriculture Experiment Station,

Special Report 141, Corvallis, OR

No author abstract provided.

85. Ebersole J.L. 1994. Stream habitat classification and restoration in the Blue Mountains of northeast Oregon. Oregon State University, MS Thesis, Corvallis, OR

No abstract provided.

86. Elmore W. and R.L. Beschta. 1987. Riparian areas: perceptions in management. Rangelands. 9(6):260-5

No abstract provided.

87. Environmental Protection Agency. 1991. Evaluation of the ecoregion concept. Report of the Ecoregions Subcommittee of the Ecological Processes and Effects Committee. Environmental Protection Agency, EPA-SAB-EPEC-91-003, Washington, DC

This report presents the conclusions and recommendations of EPA's Science Advisory Board on the Ecoregion Concept and results of its application for water quality management by three states. The Ecoregion concept is a method of dividing large geographic areas in regions or subunits in which the variability of selected ecological and physical characteristics is less than that of the entire area. The Ecoregion Concept is being used by states for water quality management. The principal concerns of the subcommittee are that limited guidance and documentation is available to users for defining and locating the boundaries and establishing adequate reference sites and that informal methods are used to subdivide areas. Recommendations are to conduct a pilot project to compare effectiveness of Ecoregions with other regionalization techniques, and develop a user guidance with case studies to assist future applications.

88. Environmental Protection Agency. 1997. Monitoring guidance for determining the effectiveness of nonpoint source controls. Environmental Protection Agency, EPA 841-B-96-004, Washington, DC

A nonpoint source monitoring and evaluation guide written for use by both those who monitor and those who evaluate and fund monitoring proposals. This guidance addresses the design of water quality monitoring programs to assess both impacts from nonpoint source pollution and the effectiveness of control practices and management measures. This guidance presents the theory and information needed to design monitoring programs tailored to particular situations.

89. Everest F.H., R.L. Beschta, and J.S. Scrivener. 1987. Fine sediment and salmonid production: a paradox. p 98-142, *in* E.O. Salo and T.W. Cundy, eds. Streamside management: Forestry and fishery interactions. University of Washington Institute of Forest Resources, Contribution #57. Seattle, WA.

The term sediment as commonly used by fishery biologist, means fine sediment and excludes up to 90% of sedimentary material in streams. In mountainous terrain, hillslope erosion provided periodic inputs of sediment into stream systems, often during periods of high flow when two major sediment transport mechanisms are active: 1) suspended sediment transport and 2) bedload transport. Suspended sediment consists primarily of silt and clay-size particles that may be rapidly transported downstream and locally deposited on floodplains and overbank storage locations or that may infiltrate into gravel interstices of the bed.

90. Everest F.H. and D.W. Chapman. 1972. Habitat selection and spatial interaction by juvenile chinook salmon and steelhead trout in two Idaho streams. Journal of the Fisheries Research Board of Canada. 29(1):91-100

During summer sympatric steelhead trout and summer chinook salmon segregated in Crooked Fork and Johnson creeks. In short-term allopatry, each species occupied the same types of habitat as in sympatry. Most age 0 steelhead lived over rubble substrate in water velocities and depths of less than 0.15 m/sec and 0.15 m, respectively; most age 0 chinook lived over silt substrate in water velocities of less than 0.15 m/sec and depths of 0.15-0.3 m; most age I steelhead resided over large rubble substrate in water velocities of 0.15-0.3 m/sec (near bottom) and 0.75-0.9 m/sec (near surface), and in depths of 0.6-0.75 m. As fish of each species became larger they moved into faster, deeper water. Juvenile chinook and steelhead of the same size used the same physical space. But steelhead spawn in spring and chinook spawn in early fall, and disparate times of spawning create discrete intra- and inter-specific size groups of pre-smolts. The size differences minimize potential for social interaction, both intra- and inter-specific.

91. Everett R.A. and G.M. Ruiz. 1993. Coarse woody debris as a refuge from predation in aquatic communities: an experimental test. Oecologia. 93(4):475-86

This study demonstrates experimentally that coarse woody debris can provide refuge from predation in aquatic habitats. In this study, we (1) measured the abundance of CWD, (2) examined the utilization of CWD by mobile epibenthic fish and crustaceans, and (3) tested experimentally the value of CWD as a refuge from predation. CWD was the dominant above bottom physical structure in shallow water, ranging in size from small branches to fallen trees. In response to experimental addition of CWD, densities of common epibenthic species increased significantly compared to control sites without CWD. Access to CWD increased survivorship of grass shrimp in laboratory and field experiments. These experimental results (1) support the hypotheses, commonly proposed but untested for freshwater habitats, that CWD can provide a refuge from predation for epibenthic fish and invertebrates and (2) extend the recognized functional importance of CWD in freshwater to estuarine and marine communities. We hypothesize that CWD is an especially important refuge habitat in the many estuarine and freshwater systems for which alternative physical structure are absent or in low abundance.

92. Fausch K.D. 1993. Experimental analysis of microhabitat selection by juvenile steelhead (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch*) in a British Columbia stream. Canadian Journal of Fisheries and Aquatic Sciences. 50(6):1198-207

Replicate experiments were conducted in the Salmon River, British Columbia, during early summer 1990 to test the relative importance of velocity refuge, visual isolation, and overhead cover to microhabitat selection by steelhead *(Oncorhynchus mykiss)* parr and age-0 coho salmon *(O. kisutch)*. Four types of artificial Plexiglas structures, the first three of identical construction, had different portions painted to provide increasing habitat complexity: velocity refuge alone, velocity refuge with visual isolation, all three features combined, and overhead cover alone. Steelhead parr selected structures with overhead cover alone or all three features significantly more often than those without overhead cover. Steelhead also selected structures adjacent to the swiftest velocities available and closest to other natural overhead cover, which accounted for most differences in use of the same structure in different locations. In contrast, few age-0 coho salmon used any structures. Those that did selected the three types of structures with velocity refuge about equally, but significantly more often than those with overhead cover alone, regardless of their location. Field experiments such as this hold promise for elucidating mechanisms of habitat selection by stream salmonids.

93. Fausch K.D. and T.G. Northcote. 1992. Large woody debris and salmonid habitat in a small coastal British Columbia stream. Canadian Journal of Fisheries and Aquatic Sciences. 49(4):682-93

Sections of a small coastal British Columbia stream that had previously been cleaned of large woody debris (LWD) were compared with sections where most debris was left and with others where debris had been relatively undisturbed for at least 40 yr. Three sections where debris had been removed had simple habitat that was less sinuous, wider, and shallower and had less pool volume and overhead cover than four sections with more complex habitat where debris was retained. Habitat in four relatively undisturbed sections was generally similar to complex sections. Most pools in all sections were scour or plunge pools formed by LWD or large roots oriented perpendicular to the flow or angled downstream. Standing crop (kilograms per hectare) and individual weights of age 1+ and older coho salmon *(Oncorhynchus kisutch)* and cutthroat trout *(O. clarki)* were significantly greater ($P < 0.02$) in complex than in simple sections. Biomass of age 1+

and older salmonids was closely related to section pool volume ($r^2 = 0.92$, $P = 0.0006$). Projections based on this model and average habitat conditions suggest that during 1990 a total of 8.0 kg of salmonid biomass, 5 times the current standing crop, was forgone in the 332-m simple reach due to the prior debris removal.

94. Fausch K.D. and M.K. Young. 1995. Evolutionary significant units and movement of resident stream fishes: A cautionary tale. p 360-70, *in* J.L. Nielson, ed. Evolution and the aquatic ecosystem: defining unique units in population conservation. American Fisheries Society, Symposium #17. Bethesda, MD.

Many taxa of resident stream fishes are reported to be relatively sedentary throughout their lives. Such discrete populations would make identification and management of evolutionarily significant units straightforward. However in contrast to this prevailing restricted movement paradigm, recent evidence indicated that even resident salmonids, such as interior stocks of cutthroat trout living in headwater streams, move often, sometimes over relatively long distances. Resident stream fishes likely move in response to various ecological constraints or because the habitat they occupy becomes suboptimal or unsuitable. This emerging paradigm shift has important implication for defining and managing ESUs of resident stream fishes. For example, timing of sampling may affect which of several different populations mobile individuals are chosen to represent. Isolating small populations of native fishes above barriers to prevent invasion by exotic species may trade this risks for other environmental, demographic or genetic risks caused by eliminating dispersals. Moreover isolating small populations fragments via natural or anthropogenic disturbances or management actions, may create artificial ESUs. Biologist must understand not only the genetics and taxonomy, but also the spatial and temporal dynamics of component populations of species if they are to accurately identify and wisely manage ESU's.

95. Fisher W.L. and C.S. Toepfer. 1998. Recent trends in Geographic Information Systems education and fisheries applications at U. S. universities. Fisheries. 23(5):10-3

Geographic information systems (GIS) technology is rapidly becoming a management and research tool for fisheries professionals. We surveyed fisheries programs at 42 U.S. universities about their training in GIS and uses of GIS in fisheries research; twenty-four universities responded. Our survey revealed that fisheries students who use GIS take introductory and advanced GIS courses offered in earth science departments at their universities and/or seminars on applications of GIS in natural resources offered in their departments. A solid core of GIS courses is available at U.S. universities for fisheries students interested in developing this expertise. On average, twenty-one percent to forty percent of fisheries faculty and students indicated they occasionally used GIS in their research. The most common fisheries-related uses of GIS were mapping and modeling fish distributions and aquatic habitats, and evaluating the effects of watershed land use on fish populations, communities, and habitats. In addition to traditional descriptive applications of GIS for mapping fish distributions and aquatic habitats for research and management purposes, we see the potential for prescriptive fisheries applications in areas such as modeling and forecasting changes in aquatic habitats, estimating fish population abundances in unsampled areas, developing fisheries sampling designs, and integrating human population trends with biological and aquatic habitat trends.

96. Flathead Basin Forest Practices Water Quality and Fisheries Cooperative Program. 1991. Summary of recommendations, Final report. p 153-62, *in* Flathead Basin Commission. Kalispell, MT.

No author abstract provided.

97. Fredrikson R.L. 1977. Comparative chemical water quality-Natural and disturbed streams following logging and slash burning. p 125, *in* Oregon State University. Forest Land Uses and Stream Environment. Oregon State University. Corvallis, OR.

The loss of nutrients from an old-growth Douglas fir forest was measured in the streams of experimental watersheds. Following timber harvest and slash burning, loss of nutrients cations increased 1.6 to 3.0 times the loss from the undisturbed watershed. A surge of nutrients that followed broadcast burning contained concentrations of ammonia and manganese that exceeded

Federal water quality standards for a period of 12 days. Annual nitrogen loss following burning averaged 4.6 pounds per acre; 53% of this was organic nitrogen contained in sediment. Inorganic nitrogen, dissolved in the stream, made up the remaining part. Annual loss of nitrogen from the undisturbed forest was very small - .16 pound per acre.

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

Classification of streams and stream habitats is useful for research involving establishment of monitoring stations, determination of local impacts of land-use practices, generalization from site-specific data and assessment of basin-wide, cumulative impacts of human activities on streams and their biota. This article presents a framework for a hierarchical classification systems, entailing an organized view of spatial and temporal variation among land within stream systems. Stream habitat systems, defined and classified on several spatio-temporal scales are associated with watershed geomorphic features and events. Variables selected for classification define relative long-term capacities of systems, not simply short-term states. Streams and their watershed environments are classified within the context of a regional biogeoclimatic landscape classification. The framework is a perspective that should allow more systematic interpretation and description of watershed-stream relationships.

99. Frissell C.A. and L.P. Queen. 1997. Variability of stream habitat response to landscape change: Indicators of cross-scale linkages. University of Montana, Missoula, MT

The goal of this study is to develop indicators of landscape condition and change that reflect aquatic habitat integrity in streams of importance to fish and other freshwater biota. Loss of habitat integrity as a consequence of land use has been implicated as a major cause of decline in anadromous and interior fishes and other aquatic biota in the western USA. We hypothesize that stream response to landscape change is chaotic, but predictable at regional and decadal scales as a result of 2 interacting mechanisms: 1) catchment-scale forcing that operates discontinuously through hydrologic and geomorphic processes over time frames of decades (e.g. large floods, sediment pulses), mediated by catchment-scale patterns of vegetation and erosion: 2) local, near-channel resistance mechanisms, including vegetative succession, recruitment of large woody debris and local sediment storage, that develop over time frames of years to centuries and are directly altered by local disturbance. Variability in stream habitat across a region develops as a consequence of divergence in resistance factors, but the state of a particular stream depends on the stochastic occurrence forcing events that drive much of the response. Thus, for streams, landscape indicators must be robust to changes in habitat variation over space and time, rather than simply predicting mean response states. We focus our study on alluvial streams in forested, montane catchments, which are sensitive to changes in both catchment forcing and local resistance from natural and human disturbances. Fish habitat values are typically greatest in these stream types. We predict that within a give ecoregion, landscape disturbance will increase variability in catchment forcing mechanisms and also usually reduce local resistance. This will tend to homogenize physical habitat within streams, but increase differences among streams. We will test the hypothesis that stream habitat in undisturbed catchments is more heterogeneous within streams but more homogeneous among streams, whereas disturbed catchments have higher homogeneity within streams and more heterogeneity among streams. Secondly, we will use the data and results from this test to develop appropriate indicators of landscape condition and change that can successfully predict patterns of variation in stream habitat over decadal time spans. Thirdly, we will test the robustness, sensitivity and efficiency of various field indicators of stream habitat condition. Because ecoregional differences in climate and geomorphology may impose inherent constraints on forcing mechanisms and local resistance factors, we will conduct equivalent studies in two different ecoregions. Using air photos chronosequences and stream gauging records, we will develop a detailed characterization of landscape change at approximately 4 decadal increments. We will also conduct detailed field surveys of habitat in 1-2 km long segments of alluvial streams of the 36 catchments. Catchments will be selected to include the following categories: unburned and unlogged; logging the past 40 y but unburned; unlogged but burned by wildfire during the past 40 y. The design will allow us to test whether different effects on local resistance cause streams to respond differently to logging that to natural wildfire. In addition to typical a priori statistical tests at multiple scales, multiple regression analysis and watershed pairing will be used to test relationships across landscape treatments, with landscape and habitat variation aggregated a range of spatial scales. This research will have specific value for landscape assessment and conservation management in the study regions, and will establish an explicit, variance-based and scale-explicitly conceptual framework, analytic protocol and tested methods that should be readily adaptable for use in other regions.

100. Gibson G.J. and J.C. Mason. 1988. Mechanisms regulating species composition, population structure, and production of stream salmonids; a review. Polskie Archiwum Hydrobiologii. 35:469-95

Streams supporting salmonids are characterized by riffles and pools, with the success of a species depending on the availability of suitable habitat for the ecological needs of the different life stages of the species. Juveniles of one species may be primarily riffle dwellers, which may be anadromous, such as the Atlantic salmon and a second species may primarily occupy the slower water and pools, such as brown trout or American brook trout. Social behavior is affected by a number of factors, including water velocity, availability of food and temperature, so that levels of aggression can change, affecting production.

101. Gibson R.J. 1978. Behavior of juvenile Atlantic salmon (*Salmo salar*) and brook trout with regard to temperature and to water velocity. Transactions of the American Fisheries Society. 107:703-12

Atlantic salmon parr and brook trout were observed in stream tanks at the Matamek Research Station, Quebec. In the autumn, at 10^c Atlantic salmon parr began sheltering in rubble, and at 9^c the majority had disappeared into hiding. Brook trout also had this tendency to hide at cold temperatures, but not as strongly as the salmon. In slow water flows (<5 cm/s), Atlantic salmon parr tended to hide in the rubble substrate at any temperature, and aggression decreased. In both slow and faster water velocities during summer and autumn the commonest agonistic act by Atlantic salmon parr was 'charge and chase. Brook trout in July showed 'nip' as the commonest agonistic act, but in September and October 'approach' and 'charge and chase' were more common, possibly due to aggression associated with spawning. Shade was attractive to both species in shallow water, but given the choice of a shallow (30 cm) tank with a shade cover, and a deeper (50 cm) tank with no shade, the majority of brook trout and Atlantic salmon selected the deeper tank. In one experiment in a shallow-water tank, turbulent water surface was more attractive to Atlantic salmon parr than shade.

102. Giger R.D. 1973. Streamflow requirements of salmonids. Oregon Wildlife Commission, AFS-62-1, Portland, OR

This report attempts to summarize present understanding of the streamflow requirements of juvenile salmonid fishes, and to relate current methodologies used for recommending minimum summer stream flows for fish to those requirements. The objective of the review is to stimulate thought about ecological concepts important to the development of methods for determining minimum flows, rather than to recommend particular techniques.

103. Gilbert R.O. 1987. Statistical methods for environmental pollution monitoring. Van Nostrand Reinhold, New York, NY

No abstract provided.

104. Gorman O.T. and J.W. Karr. 1978. Habitat structure and stream fish communities. Ecology. 59:507-15

Stream habitat complexity is correlated with fish species diversity in selected Indiana and Panama streams. Habitat diversity was measured along 3 dimensions judged important to a wide range of fish groups and applicable to many stream conditions: stream depth, bottom type, and current. Increasing community and habitat diversity followed stream-order gradients. Natural streams supported fish communities of high species diversity which were seasonally more stable than the lower-diversity communities of modified streams. After disturbances such as channelization, seasonal peaks in species diversity attain levels typical of undisturbed streams. Because seasonal changes in stream quality are high, the stability of the fish community is lower in modified than in natural streams. The general correlation between habitat characteristics and presence and absence of fish species suggests that most fishes of small streams are habitat specialists.

105. Gowan C., M.K. Young, K.D. Fausch, and S.C. Riley. 1994. Restricted movement in resident stream salmonids: A paradigm lost? Canadian Journal of Fisheries and Aquatic Sciences. 51(11):2626-37

Gerking (1959. Biol. Rev. 34: 221-242) proposed a theory about the restricted movement of stream fishes that may be considered a paradigm in salmonid biology. The restricted movement paradigm (our term) hold that resident stream salmonids are sedentary. Numerous studies have supported the restricted movement paradigm, but nearly all have relied on the recapture of marked fish from the same areas in which they were released, an approach we believe is biased against detecting movement. We found substantial movement of trout in streams in Colorado and Wyoming using two-way weirs and radio telemetry. A review of the research on Lawrence Creek, Wisconsin, also showed that movement was important in the response of the trout population to habitat enhancement. Movement of resident stream fish has profound implications for research (e.g., measuring production and habitat models) and management (e.g., habitat enhancement, special regulations, and stocking hatchery fish). Methods capable of detecting fish movement could be incorporated into many studies to assess its importance in systems of interest. New theories and experiments are needed to understand the mechanisms that cause stream salmonids to move.

106. Grabow G.L., J. Spooner, L.A. Lombardo, and D.E. Line. 1999. Detecting water quality changes before and after BMP implementation: use of SAS for statistical analysis . NWQEP Notes. (93):1-11

No author abstract provided.

107. Graham P.J., B.B. Shepard, and J.J. Fraley. 1981. Use of stream habitat classifications to identify bull trout spawning areas in streams. p 186-90, *in* N.B. Armantrout, ed. Acquisition and utilization of aquatic habitat information. American Fisheries Society. Bethesda, MD.

A basin wide inventory of bull trout spawning areas and habitat parameters was compiled in tributaries of the North and Middle forks of the Flathead River during 1979, 1980, and 1981. Stream order, channel gradient and two channel substrate variables were found to be significantly ($P<0.05$) correlated to bull trout redd frequencies. The combination of stream order and D-90 was the best variable combination. Variables ranked in order of their discriminating ability were stream order, D-90, channel gradient, overhanging bank cover and percent of the substrate in gravel and cobble combined. Two discriminating functions correctly classified 58 percent of the stream reaches into: 1) no-redd; 2) low redd frequency and 3) high redd frequency categories based solely on measurements of habitat parameters. Other factors affecting spawning distributions were side channel development and the influence of ground water. Land managers can use bull trout spawning habitat data to effectively induced cumulative impacts on fisheries in long term planning.

108. Grant G.E., F.J. Swanson, and S.V. Gregory. 1994. Valley floor morphology of mountain streams: controls on salmon habitat quality and channel disturbance processes. Geological Society of America. Abstracts With Programs 26. A-439

No abstract provided.

109. Grant G.E., F.J. Swanson, and M.G. Wolman. 1990. Pattern and origin of stepped-bed morphology in high-gradient streams, Western Cascades, Oregon. Geological Society of American Bulletin. 102:340-52

A general hierarchical framework for viewing stepped-bed morphology in high gradient channels is presented. We emphasize channel units-bed features that are one or more channel widths in length - as a particularly important scale of variation. Field studies in two streams in the Cascade Range in Oregon indicated that pool, riffle, rapid, cascade, and step channel units had distinct bed slope ranges, with average slopes of 0.005, 0.011, 0.029, 0.055, and 0.173, respectively. Steeper units (rapids and cascades) are composed of step-pool sequences created by particles representing the 90th or larger percentile size fraction of bed material. Step spacing is inversely proportional to bed slope. Hydraulic reconstruction indicates that channel units form during high-magnitude, low-frequency events with recurrence intervals of about 50 yr. Comparison of channel-unit morphology to high-gradient flume experiments with heterogenous bedload mixtures indicated that unit morphogenesis is linked to factors that cause congestion of large particles during bedload transport events; these include local constrictions in channel width, immobile bed material, and abrupt fluctuations in velocity due to hydraulic jumps that promote deposition.

110. Greenland D. 1998. Variability and stability of climatic/oceanic regimes in the Pacific Northwest. G.R. McMurray and R.J. Bailey, eds. Change in Pacific Northwest coastal ecosystems. NOAA, Coastal Ocean Program, Decision Analysis Series #11. Silver Spring, MD.

No abstract provided.

111. Gregory K.J., A.M. Gurnell, C.T. Hill, and S. Tooth. 1994. Stability of the pool-riffle sequence in changing river channels. Regulated Rivers: Research and Management. 9:35-43

The pool-riffle sequence as an important feature of river channels was described by Leopold et.al. (1964) to occur with a spacing of five to seven times the channel width. Subsequent work has generally confirmed this spacing, although more closely spaced pools and riffles are quoted for some channels in woodland basins and for some channelized streams. Although few detailed empirical studies have been made of adjustments of the pool-riffle spacing, a detailed survey of a 6 km channel reach containing over 300 riffles in the New Forest, southern England indicated that despite the influence of woody debris and channelization, the inter-riffle distance generally falls within the range of five to seven channel widths. As substantial adjustments in channel dimensions have been widely observed downstream of channelization scheme, land-use changes and dams and reservoirs, the associated adjustments in pool-riffle spacing should be a consideration in channel management and an ingredient of design for channel restoration.

112. Gregory S.V. and P.A. Bisson. 1997. Degradation and loss of anadromous salmonid habitat in the Pacific Northwest. D.P. Strouder, P.A. Bisson, and R.J. Naiman, eds. Pacific Salmon and Their Ecosystems. Chapman and Hall. New York, NY.

The goal of restoration is to reestablish an ecosystem's ability to maintain its function without continued intervention and does not mandate returning to some arbitrary prior state. The most critical question related to aquatic habitat restoration include the following: the degree to which the habitat can be repaired or restored, priorities for locations where restoration efforts will be beneficial, and ecologically sound approaches for habitat restoration. The major agent of aquatic ecosystem restoration in the Pacific Northwest is periodic flooding, and the challenge for human efforts is to supplement natural processes of restoration. This article contains a table that lists various types of habitat modifications and estimated time scale for recovery.

113. Grette G.B. 1985. Role of large organic debris in juvenile salmonid rearing habitat in small streams. University of Washington, MS Thesis, Seattle, WA

No abstract provided.

114. Griffith J.S. 1972. Comparative behavior and habitat utilization of brook trout (*Salvelinus fontinalis*) and cutthroat trout (*Salmo clarki*) in small streams in northern Idaho. Journal of the Fisheries Research Board of Canada. 29(3):265-73

Individual brook *(Salvelinus fontinalis)* and cutthroat *(Salmo clarki)* trout communicated with similar behavioral signals, both in laboratory stream-channels and in northern Idaho streams. Underyearling brook trout were less active socially than equal-sized cutthroat trout in laboratory observations. In study streams, brook trout maintained a 20-mm size advantage over cutthroat of the same age-groups throughout their lives, as they emerged from the gravel before cutthroat. Because of this size advantage, underyearling brook trout of sizes found in study streams in September consistently dominated in experiments the underyearling cutthroat with which they normally lived. But in study streams underyearlings of the two species utilized different microhabitats, particularly with resect to water depth, and so minimized chances for interactions. Yearling and older brook trout initiated 40% fewer aggressive encounters under laboratory conditions than did equal-sized cutthroat trout, and did not displace the cutthroat. In study streams with sympatric populations, cutthroat trout of these age-groups occupied territories with focal points of higher water velocities (averaging 10.2-10.3 cm/sec) than those occupied by brook trout (averaging 7.6-9.6 cm/sec). Considerable interspecific overlap in other habitat characteristics occurred for trout of age-groups I and II. The oldest members of the two species segregated more distinctly, as the brook trout lived closer to overhead cover.

115. Groot C. and L. Margolis. 1991. Pacific salmon life histories. University of British Columbia Press, Vancouver, BC, Canada

Provides detailed life descriptions of the different life phases through which each of the 7 species passes.

116. Grossman G.D. 1995. Observations on habitat structure, population regulation, and habitat use with respect to evolutionarily significant units: A landscape perspective for lotic systems. p 381-91, *in* J.L. Nielson, ed. Evolution and the aquatic ecosystem: defining unique units in population conservation. American Fisheries Society, Symposium #17. Bethesda, MD.

We attempt to synthesize a variety of developments in the fields of landscape and population ecology and apply these ideas to the physical and biological characteristics of lotic systems. First, most attempts to manage evolutionarily significant units are based on the notion that the physical characteristics of lotic habitat are stable. Yet, data from 3 permanent 100-m reaches in the Coweeta drainage of North Carolina indicated that these reaches possessed substantial variability with respect to both substratum composition and flow rates. In addition substratum data demonstrated that these reaches were patchy environments and that a landscape based approach might facilitate the management of species in this system. 2nd a simple landscape driven difference equation model of population dynamics based on biological characteristics common to many fishes indicated that the critical habitat for population maintenance may not always be the area in which the species is most abundant. Finally 2 test for habitat selection by stream fishes indicate that more biologically realistic models and a model that included explicity tests for the mechanism of selection itself may greatly increase our ability to identify and manage habitats that are crucial for survival of ESU's.

117. Grossman G.D., J.F. Dowd, and M. Crawford. 1990. Assemblage stability in stream fishes: a review. Environmental Management. 14(5):661-71

We quantified the stability of nine stream fish assemblages by calculating coefficients of variation of population size for assemblage members. Coefficients of variation were high and averaged over 96%; indicating that most assemblages were quite variable. The high variability exhibited by many stream fish assemblages suggests that it may be difficult to detect the effects of anthropogenic disturbances using population data alone. Consequently, we urge managers to exercise caution in the evaluation of the effects of these disturbances. We suggest that CVs are a better estimator of population/assemblage stability, than either Kendall's W or the standard deviation of the logarithms of numerical censuses.

118. Guenther P.M. and W.A. Hubert. 1993. Method for determining minimum pool requirements to maintain and enhance salmonid fisheries in small Wyoming reservoirs. Environmental Management. 17:645-53

Methods for determination of minimum pool levels in reservoirs that consider sport fishery values are being sought by managers. We developed a technique for assessing the effects of incremental changes in minimum pool levels on potential salmonid abundance in small (<100 surface hectares at full pool) reservoirs in Wyoming managed for irrigation and municipal water supplies. The method has two components. One component is used to determine the minimum pool level needed to eliminate the risk of overwinter loss of salmonids in reservoirs as a function of water depth and total dissolved solids concentration of the reservoir water. Application of the method is demonstrated for two reservoirs in Wyoming.

119. Hankin D.G. and G.H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Canadian Journal of Fisheries and Aquatic Sciences. 45:1746-59

We present sampling designs for estimating total areas of habitat types and total fish numbers in small streams. Designs are applied independently within strata constructed on the basis of habitat unit type and stream reach. Visual methods for estimating habitat areas and fish numbers are used to increase sample sizes and thereby reduce errors of estimation. Visual estimates of area are made for all habitat units and visual estimates of fish numbers are made for systematic samples of units within given habitat types. Use of systematic sampling circumvents the requirement for a preexisting map of habitat unit locations and simplifies selection of units. We adjust for possible proportional bias of visual estimation methods by calibrating visual estimates against more accurate estimates made in subsamples of those units for which visual estimate are made. In a test application of these sampling designs, correlations between visual estimates and more accurate estimates were generally high, r> 0.90. Calculated 95% confidence bounds on errors of estimation were 13 and 16% for total areas of pools and riffles, respectively and were 17 and 22% for total numbers of 1+ steelhead trout and juvenile coho salmon, respectively. Our methods appear to offer a cost-effective alternative to more traditional methods for estimating fish abundance in small streams. In addition, visual estimation surveys can produce detailed maps of the areas and locations of all stream habitat units.

120. Hanson D.L. 1977. Habitat selection and spatial interaction in allopatric and sympatric populations of cutthroat and steelhead trout. University of Idaho, Ph.D dissertation, Moscow, ID

We designed studies to assess and compare the distribution and density of allopatric populations of juvenile cutthroat and steelhead in large and small streams of central Idaho in relation to habitat parameters. We compared habitat parameters for individual fish at specific locations and in a more broad manner for large groups of fish. We observed behavior in relation to habitat in artificial stream channels. Juvenile cutthroat and steelhead utilized deeper water of faster velocities in areas of large substrate as they increased in size. Facing velocity explained 70 to 75% of the variability between increasing fish length and the seven physical variables tested for both species in stepwise regressions.

121. Harmon M.E., J.F. Franklin, F.J. Swanson, P. Sollins, S.V. Gregory, J.D. Lattin, N.H. Anderson, S.P. Cline, N.G. Aumen, J.R. Sedell and others. 1986. Ecology of coarse woody debris in temperate ecosystems. Advances in Ecological Research. 15:133-302

Coarse woody debris is an important component of temperature stream and forest ecosystems. We have reviewed the rates at which CWD is added and removed from ecosystems, the biomass found in streams and forests and many functions that CWD serves.

122. Harrelson C.C., C.L. Rawlins, and J.P. Potyondy. 1994. Stream channel reference sites: an illustrated guide to field technique. U. S. Forest Service, GTR-RM-245, Fort Collins, CO

No author abstract provided.

123. Harvey A.M. 1975. Some aspects of the relations between channel characteristics and riffle spacing in meandering streams. American Journal of Science. 275:470-8

Previous literature on the relationships of meaner wavelength and riffle spacing to channel and discharge characteristics presents two divergent views. On the one hand riffle spacing is seen primarily as a function of stream width rather than discharge, and on the other hand as a function of relatively frequent discharges rather than either rarer discharges or channel width. This paper examines these relationships on three small streams in southern England and demonstrates that both previous results are to some extent true and not mutually incompatible. However, the closest correlation results from the relationships between riffle spacing and the widths associated with relatively frequent discharges, rather than either the discharges themselves to the bankfull width of the channels.

124. Harvey G.W. 1991. Criteria addressing sedimentation of cobble, boulder and pool habitats of cold water biota. Idaho Department of Environmental Quality, Boise, ID

The purpose of this document is to foster technical review of 2 draft sediment criteria. The document and those cited by the text are designed to provide a technical rationale for the criteria and foster suggestion designed to improve the draft criteria.

125. Hausle D.A. and D.W. Coble. 1976. Influence of sand in redds on survival and emergence of brook trout (*Salvelinus fontinalis*). Transactions of the American Fisheries Society. 105(1):57-63

Report results of laboratory experiment where brook trout alevins were buried in spawning gravel mixtures with sand content varying from zero to 25% by weight. In addition, natural trout redds in a Wisconsin stream were excavated and the live eggs and fry were counted and related to sand content. In artificially constructed redds, dramatic decreases in egg survival were attributed to sand contents of between 10 and 20% by weight.

126. Havis R.N., C.V. Alonso, J.G. King, and R.F. Thurow. 1993. Mathematical model of salmonid spawning habitat. Water Resources Bulletin. 29(3):435-44

A simulation model was developed as a management tool to evaluate the relative impacts of stream sediment load and water temperature on salmonid egg survival. The model is useful for estimating acceptable sediment loads to spawning habitat that may result from upland development, such as logging and agriculture. These models drive the redd model which simulates sediment intrusion and dissolved oxygen concentration in the redd environment. The SSAM model predictions of dissolved oxygen and water temperature compared favorably with field data from artificial redds containing hatchery chinook salmon eggs.

127. Hawkins C.P., J.L. Kershner, P.A. Bisson, M.D. Bryant, L.M. Decker, S.V. Gregory, D.A. McCullough, C.K. Overton, G.H. Reeves, R.J. Steedman and others. 1993. Hierarchical approach to classifying stream habitat features. Fisheries. 18(6):3-12

We propose a hierarchical system of classifying stream habitats based on three increasingly fine descriptions of the morphological and hydraulic properties of channel geomorphic units. We define channel geomorphic units as areas of relatively homogeneous depth and flow that are bounded by sharp gradients in both depth and flow. Differences among these units provide a natural basis for habitat classification that is independent of spatial scale. At the most general level of resolution, we divide channel units into fast- and slow-water categories that approximately correspond to the commonly used terms "riffle" and "pool. "Within the fast-water category, we identify two subcategories of habitats, those that are highly turbulent (falls, cascades, chutes, rapids and riffles) and those with low turbulence (sheets and runs). Slow-water habitats include pools formed by channel scour (eddy pools, trench pools, mid-channel pools, convergence pools, lateral scour pools and plunge pools) and those formed behind dams. Dammed pools include those obstructed by debris dams, beaver dams, landslides and abandoned channels. We consider back-waters as a type of dammed pool. Fishes and other stream organisms distinguish among these habitats at one or more levels of hierarchy. Habitats defined in this way represent an important habitat template on which patterns of biological diversity and production form. We believe that a hierarchical system of classification will facilitate understanding of biotic-habitat relationships in streams and lead to more effective methods of evaluating the effects of environmental change on stream ecosystems. Refining the criteria by which habitats are distinguished, quantifying how different species use different habitats, and integrating the ways biota respond to habitat variation should facilitate the emergence of a theory of stream habitat organization.

128. Hawkins C.P., M.L. Murphy, N.H. Anderson, and M.A. Wilzbach. 1983. Density of fish and salamanders in relation to riparian canopy and physical habitat in streams of the northwestern United States. Canadian Journal of Fisheries and Aquatic Sciences. 40:1173-85

Relationships between density of fish and salamanders, riparian canopy, and physical habitat were investigated by studying 10 pairs of streams. Among vertebrate taxa, salmonids and sculpins were more abundant in streams without riparian shading than in shaded streams. Abundance of salamanders was not affected by canopy type. Densities of both salamanders and sculpins were correlated with substrate composition, whereas salmonid abundance was not or only weakly so. Salamanders were found only at high-gradient sites with finer-sized sediments. An interaction was observed between the influence of canopy and that of physical setting on density of both invertebrate prey and total vertebrates. Among shaded sites, densities decreased as percent fine sediment increased, but a similar relationship did not exist among open sites. Removal of the riparian vegetation surrounding a stream may therefore mask detrimental effects of fine sediment. These data provide one reason why it has been difficult in the past to generalize about the effects of fine sediment on stream biota.

129. Hayslip G.A. 1993. Region 10 In-stream biological monitoring handbook. For wadable streams in the Pacific Northwest. Environmental Protection Agency, EPA 910/9-92-013, Seattle, WA

The handbook provides a reference for those interested in conducting biological assessments of wadable streams in EPA Region 10. The document describes the minimum level of data that needs to be collected, as well as methods for additional levels of intensity, for each category (macroinvertebrates, fish, water column and physical habitat). The handbook is an attempt to provide a consistent minimal set of methods to facilitate information exchange and interpretation.

130. Hearn W.E. and B.E. Kynard. 1986. Habitat utilization and behavioral interaction of juvenile Atlantic salmon (*Salmo salar*) and rainbow trout (*S. gairdneri*) in tributaries of the White River of Vermont. Canadian Journal of Fisheries and Aquatic Sciences. 43(10):1988-98

Competition for space between stocked juvenile Atlantic salmon, *Salmo salar,* and wild juvenile rainbow trout, *S. gairdneri,* was examined in stream channel experiments, a field experiment, and in field habitat surveys. In stream channels providing riffle and pool habitats, species differed in their distribution both as underyearlings (0+) and as yearlings (1+). Yearling salmon occurred more often in stream channel riffles during trials with 1+ rainbow trout than during trials testing only salmon; trout distributions in the channels were unaffected by salmon. In a field experiment conducted to determine if the stocking of 0+ Atlantic salmon causes the displacement of resident 0+ rainbow trout, salmon fry were stocked at a density of 85 per 100 m^2. Emigration from the stocked zone and an unstocked control zone were then monitored daily with four weirs. The 0+ salmon had no apparent effect on the rate of movement of resident rainbow trout fry. During summer and fall field surveys, 0+ salmon occupied deeper and swifter water than 0+ rainbow trout; as yearlings these species occupied similar habitats. In late fall, segregation by habitat occurred: Atlantic salmon were primarily in riffles; rainbow trout were primarily in pools. We found no evidence of competition between cohorts of underyearlings; however, the niche shift by 1+ salmon in the stream channels suggested that, at times, juveniles of these species will compete for space.

131. Heede B.H. 1986. Response of a stream in disequilibrium to timber harvest. Environmental Management. 15:251-5

Timber was harvested on South Fork of Thomas Creek, White Mountains of Arizona, USA for the first time in 1978-1979. This caused significant increases in annual flow volumes and annual instantaneous peak flows. North Fork remained untouched, but both streams were in disequilbrium before harvest period, North Fork also experienced some flow increases, but the difference was not significant. Flow increases caused increased erosion in disequilibrium channels. While in South Fork channel cross sections enlarged by 10% since preharvest time, those in North Fork enlarged by only 2.5%. The number of knickpoints tripled in South Fork, which was about double that in North Fork. Knickpoint development resulted in destruction of the natural control structures (log steps and transverse gravel bars) in South Fork (47%), while in North Fork they increased by 23%. Knickpoints are scarps on the channel bed that have the appearance of gully headcuts. The tripling of the number of knickpoints signifies that adjustment processes of the bed profile are intensified drastically in South Fork. Yet, volumes of erosion are relatively small, as will be sediment volumes leaving the watershed at a given time, because of the stepwise sediment transport occurring in this ephemeral stream.

132. Heggenes J., T.G. Northcote, and A. Peter. 1991. Seasonal habitat selection and preferences by cutthroat trout (*Oncorhynchus clarki*) in a small, coastal stream. Canadian Journal of Fisheries and Aquatic Sciences. 48(8):1364-70

Habitat selection by cutthroat trout *(Oncorhynchus clarki)* larger than 9 cm total length was monitored during winter and summer. The trout had strong preferences for depths >25 cm and areas where instream and overhead cover exceeded 40% of the local surface area. The fish selected a variety of substrate sizes. Stream areas with mean water velocities <20 cm/s were preferred. Compared with previous studies, the trout used low-velocity areas more, and we suggest that this is due to less competitive interaction from other young salmonids. The trout used the larger pools (>20 m^2) considerably less during winter than during summer. Otherwise, little seasonal variation in habitat use was found. A composite measure of water depth and cover appeared to be the most important of the measured environmental factors influencing habitat selection in the stream. The larger trout which were presumably dominant, occupied the deepest pool areas. The trout selected spatial habitats in proportions significantly different from the available habitat, demonstrating strong habitat preferences. It is concluded that observations of habitat occupancy without considering habitat availability may give biased results.

133. Heifetz J.M., M.L. Murphy, and K.V. Koski. 1986. Effects of logging on winter habitat of juvenile salmonids in Alaska streams. North American Journal of Fisheries Management. 6:52-8

To identify preferred winter habitats, streams were classified into discrete habitat types and compared the density of salmonids within these habitat types with average density of the entire reach. Most salmonids occupied deep pools with cover. Riffles, glides, and pools without cover were not used.

134. Helsel D.R. and R.M. Hirsch. 1995. Statistical methods in water resources. Elsevier, Studies in Environmental Science #49, New York, NY

No author abstract provided.

135. Hicks B.J. 1990. Influence of geology and timber harvest on channel geomorphology and salmonid populations in Oregon Coast Range streams. Oregon State University, PhD. Dissertation, Corvallis, OR

No abstract provided.

136. Hicks B.J., J.D. Hall, P.A. Bisson, and J.R. Sedell. 1991. Response of salmonid populations to habitat changes caused by timber harvest. p 493-518, *in* W.R. Meehan, ed. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication #19. Bethesda, MD.

The effects of logging on salmonids and their freshwater habitats are considered in several ways. First, the effects of logging and other aspects of forest management on isolated parts of salmonid life cycles are described. Patterns of regional variation in the response to fish populations are discussed, and management practices are evaluated.

137. Hill M.T., W.S. Platts, and R.L. Beschta. 1991. Ecological and geomorphological concepts for instream and out of channel flow requirements. Rivers. 2(3)

Healthy fish populations are dependent on streamflow regimes that protect the ecological integrity of their habitat. Fish habitats are the consequence of linkage among the stream, floodplain, riparian and upland zones, and watershed geography. Fluvial-geomorphic processes form and control fish habitat. Because of this, multiple in-channel and out-of-channel flows are needed to maintain these processes. We present a conceptual methodology for measuring four types of streamflow regimes: instream flows, channel maintenance flows, riparian maintenance flows, and valley maintenance flows. The combination of these four streamflow types is designed to protect fish and their habitat. Using a case study of the Salmon River near Whitebird, Idaho, we demonstrate how the methodology could be used to develop a multiple flow recommendation.

138. Hillman T.W., D.W. Chapman, and J.S. Griffith. 1989. Seasonal habitat use and behavioral interaction of juvenile chinook salmon and steelhead. I: Daytime habitat selection. II: Nighttime habitat selection. p 42-108, *in* Don Chapman Consultants, ed. Summer and winter ecology of juvenile chinook salmon and steelhead trout in the Wenatchee River, Washington. Don Chapman Consultants for Chelan County Public Works Utility District. Boise, ID.

During summer and winter, chinook salmon and steelhead trout tended to use different nighttime habitat. Both species moved downstream and inshore in summer and fall at dusk and rested all night in shallow, quiet water. Chinook salmon occupied deeper water than did age-0 steelhead. At dawn, chinook salmon tended to move downstream and steelhead upstream. Intraspecific aggression occurred just before dark in salmon, but not steelhead. The 2 species did not interact. In May and early June, during high flow, stream zones with suitable night habitat were scarce, and only a small part of clustering salmon rested on the streambed, with the majority remaining higher in the water column. From later-June through autumn, night habitat was abundant and all salmon and steelhead rested on the streambed. Most young chinook salmon resided on sand and bedrock in water depths of 30- 91 cm; most age-0 steelhead lay on sand and boulder substrates in water depths of 18-60 cm. As fish of each species grew, they moved into deeper water. With declining steam temperature, both species selected deeper water and larger substrates. Through-out winter, chinook salmon stationed on sand and boulders in water depths of 70 to 146 cm; steelhead used sand and boulders in water depths of 50 to 130 cm. No inter- or intraspecific aggression was observed in the colder months.

139. Hilton S. and T.E. Lisle. 1993. Measuring the fraction of pool volume filled with fine sediment. U. S. Forest Service, PSW-RN-414, Berkeley, CA

The fraction of the pool volume filled with fine sediment can be a useful index of the sediment supply and substrate habitat of gravel-bed channels. In can be used to evaluate and monitor channel condition and to detect and evaluate and monitor channel condition and to detect and evaluate sediment sources. This fraction is the ratio of fine-sediment volume to pool water volume plus fine-sediment volume. These volumes are computed for the residual portion of the pool that lies below the elevation of the downstream riffle crest. Fine sediment thickness is measured by driving a graduated metal probe into a fine grained deposit until the underlying coarser substrate is felt. Water depth and fine sediment thickness are measured across transects, and volumes are computed by summing products of cross sectional areas and distances between transects. Replicate measurements of V* were made in 20 pools and the variability of V*w, the weighted mean value of V* for a reach, was analyzed in 12 reaches. The largest source of variability in V* was the measurement of fine sediment volume. Topographic irregularities in pools and on riffle crests and effects of variation in discharge on measurement of riffle crest elevation also affected V*. 10 to 20 pools are needed to estimate V*w in a reach, depending on acceptable error and variability between pools.

140. Hiram W.L., K. Currens, D. Bottom, S.E. Clarke, J.M. Dambacher, C.A. Frissell, P. Harris, R.M. Hughes, D.A. McCullough, A. McGie and others. 1995. Safe Havens: Refuges and evolutionarily significant units. p 371-80, *in* J.L. Nielson, ed. Evolution and the aquatic ecosystem: defining unique units in population conservation. American Fisheries Society, Symposium #17. Bethesda, MD.

Use of genetic refuge as a recolonization source to aid the recovery of evolutionarily significant units is an appealing concept. However, matching refuges with ESUs may prove problematical. Searching for aquatic diversity areas to protect Oregons' native fishes, we found that the best remaining habitats and populations are predominately at high elevations. Relatively few populations inhabit refuge quality habitats and these may be at the extremes of species ranges. The ramification is this: are any of these marginal populations ESUs? Landscapes are so fragmented that what appears to be a metapopulation actually may comprise fragments of a core and satellite pattern. In the metapopulation model, each of the populations carries equal evolutionary weight; in that core and satellite model, the core is more evolutionarily important than satellite populations. Mistaking one model for the other will affect the designation of an ESU and strategies for designing a reserve system. We suggest 2 alternative approaches to estimation of evolutionarily significance that may be helpful in minimizing these mistakes: employ phylogenetic systematics to develop phylogenies of populations or search for congruent patterns between biogeography and phylogeny among members to the fish assemblage.

141. Hubert W.A. 1997. Conceptual basis of habitat analysis: inventory, assessment and monitoring philosophies. American Fisheries Society, Annual Meeting. American Fisheries Society. Monterey, CA.

No abstract provided.

142. Hughes R.M. 1995. Defining acceptable biological status by comparing with reference condition. p 125-51, *in* W.S. Davis and T.P. Simon, Eds. Biological assessment and criteria: Tools for water resource planning and decision making. Lewis Publishers. London, England.

Benchmarks are needed for comparison to altered waterbodies and to identify what are acceptable and unacceptable deviations from these benchmarks. The approach for defining reference condition with the greatest potential for success combines regional reference sites and historical data, interpreted through use of linear models and expert judgement. Reference condition can estimated by plotting ecosystem variables against disturbance values. Such models become increasingly useful and accurate as the database size and complexity increases.

143. Hughes R.M., S.A. Heiskary, W.J. Mathews, and C.O. Yoder. 1994. Use of ecoregions in biological monitoring. p 125-51, *in* S.L. Loeb and A. Spacie, eds. Biological monitoring of aquatic systems. CRC Press. Boca Raton, FL.

The purpose of this paper is to (1) compare fish faunal regions and ecoregions, (2) summarize the experiences of 2 states that use ecoregions as management units and (3) discuss concerns about the use of ecoregions.

144. Hughes R.M., D.P. Larsen, and J.M. Omernik. 1986. Regional reference sites: a method for assessing stream potentials. Environmental Management. 10:629-35
No abstract provided.

145. Hughes R.M., E. Rexstad, and C.E. Bond. 1987. Relationship of aquatic ecoregions, river basins, and physiographic provinces to the icthygeographic regions of Oregon. Copeia. 1987(2):423-32

Records from 9100 collections of fishes from 1300 Oregon localities were subjected to cluster and detrended correspondence analyses to examine regional patterns in fish faunas. The results were compared to maps of aquatic ecoregions, river basins and physiographic provinces. There was considerable agreement between the results of the multivariate analyses and the aquatic ecoregions and river basins. This agreement supports the use of aquatic ecoregions to help explain ichthygeographic regions.

146. Hughes R.M., T.R. Whittier, C.M. Rohm, and D.P. Larsen. 1990. Regional framework for establishing recovery criteria. Environmental Management. 14(5):673-83

Effective assessments of aquatic ecosystem recovery required ecologically sound endpoints against which progress can be measured. Site-by-site assessments of end points and potential recovery trajectories are impractical for water resource agencies. Because of the natural variation among ecosystems, applying a single set of criteria nation-wide is not appropriate either. This article demonstrates the use of a regional framework for stratifying natural variation and for determining realistic biological criteria. A map of ecoregions, drawn from landscape characteristics, formed the framework for 3 statewide case studies and 3 separate studies at the river basin scale. Statewide studies of Arkansas, Ohio and Oregon, USA, streams demonstrated patterns in fish assemblages corresponding to ecoregions. The river basin study in Oregon revealed a distinct change at the ecoregion boundary, those in Ohio and Montana demonstrated the value of regional reference sites for assessing recovery. Ecoregions can be used to facilitate the application of ecological theory and to set recovery criteria for various regions of states or of the country. Such a framework provides an important alternative between site-specific and national approaches for assessing recovery rates and conditions.

147. Huntington C.W. 1995. Fish habitat and salmonid abundance within managed and unroaded landscapes on the Clearwater National Forest, Idaho. Clearwater BioStudies, Inc. No. 43-0E00-4-9106,

Fish habitat data collected from the Clearwater National Forest, which include: channel type, large woody debris abundance, percent pool habitat, and quality of streambank stability. Salmonids were present in both managed and unroaded landscapes. Rainbow steelhead were common in all type channels. Juvenile chinook were found only in unroaded C and B channel types. Bull trout were more abundant in unroaded areas, but age 0 bull trout were observed only at a few stations near key spawning areas within a single managed watershed.

148. Huntington C.W., W. Nehlsen, and J. Bowers. 1995. Survey of healthy native stocks of anadromous salmonids in the Pacific Northwest and California. Fisheries. 21(3):6-14

This report summarized a survey of healthy native stocks of anadromous salmonids in the Pacific Northwest and California. We used a questionnaire approach combined with spatial analysis to describe the status and distribution of stocks considered to be in relatively good condition. These stocks now constitute a small fraction of the region's historic anadromous salmonid resource but are critical to maintaining current resource productivity. Several agencies have developed, or are in the process of developing, computerized databases that will help organize predominantly quantitative date on native stocks of anadromous salmonids. Our survey supplements those efforts by summarizing some of the knowledge of biologists familiar with the stocks and my making status assessments that at times go beyond conservative analyses of quantitative data. The survey identified 99 healthy native wild stocks of salmon and steelhead that biologists consider to be at least one-third as abundant as would be expected without human impacts, including 20 considered at least two-thirds as abundant. More than three-quarters of these stocks are fall chinook, chum salmon or winter steelhead in Puget Sound or coastal watersheds of Oregon or Washington. Fewer healthy populations remain of summer steelhead and coho, pink and sockeye salmon and spring or summer chinook. We suggest that healthy stocks provide unique opportunities for conservation and research that are at least as important to the future of the regions' anadromous salmonids as those associated with at-risk stocks.

149. Jakober M.J. 1995. Influence of stream size and morphology on the seasonal distribution and habitat use of resident bull trout and westslope cutthroat trout in Montana. Montana State University, MS Thesis, Bozeman, MT

Information has been collected on movement patterns, habitat utilization, and microhabitat characteristics exhibited by resident bull trout and westslope cutthroat trout in Daily Creek and Meadow Creek, both upper tributaries in the Bitterroot River watershed in Western Montana. The objectives were; (1) compare and contrast the autumn and winter microhabitat characteristics preferred by resident bull trout and westslope cutthroat trout in a large, boulder-controlled (LBC) stream and a small, woody debris-controlled (SWD) stream; (2) determine the spawning movements, habitats, and locations of selected resident bull trout in a LBC and a SWC stream; and (3) determine differences in winter habitat use between resident bull trout and westslope cutthroat trout in a LBC and SWC stream.

150. Jensen M.E., C.H. McNicoll, and M. Prather. 1991. Application of ecological classification to environmental effects analysis. Journal of Environmental Quality. 20:24-30

The Northern Region of the USDA-FS has developed an efficient and consistent method for assessing environmental effects of management practices on the soil and vegetation resources it administrates. Ecological classification and analysis constitute the basis of this method. Because many of the management activities in the region alter the present vegetation of a site an understanding of plant succession relationships is critical to proper effects analysis. The ecological approach to effects analysis presented in this paper has proven effective in the Northern Region and is applicable to other wild land areas.

151. Johnson P.A. and T.M. Heil. 1996. Uncertainty in estimating bankfull conditions. Water

Resources Bulletin. 32(6):1283-91

Bankfull depth and discharge are basic input parameters to stream platform, stream restoration and highway crossing designs, as well as to the development of hydraulic geometry relationships and the classification of streams. Unfortunately, there are a wide variety of definitions for bankfull that provide a range of values, and the actual selection of bankfull is subjective. In this paper, the relative uncertainty in determining the bankfull depth and discharge is quantified, first by examining the variability in the estimates of bankfull and second by using fuzzy numbers to describe bankfull depth. Fuzzy numbers are used to incorporate uncertainty due to vagueness in the definition of bankfull and subjectivity in the selection of bankfull. Examples are provided that demonstrate the use of a fuzzy bankfull depth in sediment transport and in stream classification. Using fuzzy numbers to describe bankfull depth rather than a deterministic value allows the engineer to base designs and decisions on a range of possible values and associated degrees of belief that the bankfull depths take on each value in the range.

152. Karr J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries. 6(6):21-7

Man's activities have had profound, and usually negative, influences on freshwater fishes from the smallest streams to the largest rivers. Some negative effects are due to contaminants, while others are associated with changes in watershed hydrology, habitat modifications, and alteration of energy sources upon which the aquatic biota depends. Regrettably, past efforts to evaluate effects of man's activities on fishes have attempted to use water quality as a surrogate for more comprehensive biotic assessment. A more refined biotic assessment program is required for effective protection of freshwater fish resources. An assessment system proposed here uses a series of fish community attributes related to species composition and ecological structure to evaluate the quality of an aquatic biota. In preliminary trials this system accurately reflected the status of fish communities and the environment supporting them.

153. Karr J.R. 1989. Biological integrity: A long-neglected aspect of water resource management. Ecological Applications. 1:66-84

Water of sufficient quality and quantity is critical to all life. Increasing human population and growth of technology require human society to devote more and more attention to protection of adequate supplies of water. Although perception of biological degradation stimulated current state and federal legislations on the quality of water resources, that biological focus was lost in the search for easily measured physical and chemical surrogates. The "fishable and swimable" goal of the Water Pollution Control Act of 1972 and its charge to "restore and maintain" biotic integrity illustrate that law's biological underpinning. Further, the need for operational definitions of terms like "biological integrity?" and "unreasonable degradation" and for ecologically sound tools to measure divergence from societal goals have increased interest in biological monitoring. Assessment of water resource quality by sampling biological communities in the field is a promising approach that requires expanded use of ecological expertise. One such approach, the IBI provides a broadly based, multiparameter tool for the assessment of BI in running water. IBI based on fish community attributes has now been applied widely in North America. The success of IBI has stimulated the development of similar approaches using other aquatic taxa. Expanded use of ecological expertise in ambient biological monitoring is essential to the protection of water resources. Ecologists have the expertise to contribute significantly to those programs.

154. Karr J.R. 1995. Protecting aquatic ecosystems: clean water is not enough. W.S. Davis and T.P. Simon, eds. Biological assessment and criteria: tools for water resource planning and decision making. Lewis Publishers. London, England.

The degraded state of American rivers reflects the failure of agencies to adopt the conceptual framework necessary to identify the problem and failure of resource policy to focus on the correct problem. Altering the situation requires an approach that replaces conventional assessments with an understanding of rivers as integrated chemical, physical, and biological systems.

155. Kauffman J.B., R.L. Beschta, N. Otting, and D. Lytjen. 1997. Ecological perspective of riparian and stream restoration in the western United States. Fisheries. 22(5)

Ecological restoration is the reestablishment of processes, functions, and related biological, chemical, and physical linkages between the aquatic and associated riparian ecosystems; it is the repairing of damage caused by human activities. The first and most critical step in ecological restoration is passive restoration, the cessation of those anthropogenic activities that are causing degradation or preventing recovery. Given the capacity of riparian ecosystems to naturally recover, often this is all that is needed to achieve successful restoration. Prior to implementation of active restoration approaches (e.g. instream structures, channel and streambank reconfiguration, and planting programs), a period of time sufficient for natural recovery is recommended. Unfortunately, structural additions and active manipulations are frequently undertaken without halting degrading land use activities or allowing sufficient time for natural recovery to occur. These scenarios represent a misinterpretation of ecosystem needs, can exacerbate the degree of degradation, and can cause further difficulties in restoration. Restoration should be undertaken at the watershed or landscape scale. Riparian and stream ecosystems have largely been degraded by ecosystem-wide, off-channel activities and, therefore, cannot be restored by focusing solely on manipulations within the channel.

156. Kaufmann P.R., P. Levine, E.G. Robison, C. Seeliger, and D. Peck. 1998. Quantifying physical habitat in wadeable streams. Environmental Protection Agency (DRAFT) , Corvallis, OR

No author abstract provided.

157. Keller E.A. 1978. Pools, riffles and channelization. Environmental Geology. 2:119-27

Analysis of variance for pool-to-pool spacing data suggest that there are no significant difference with respect to channel width between those that form in natural streams and those in streams affected by a variety of human uses. Short of channelization, which changes the channel width, pools and riffles, within limits, are not particularly sensitive to environmental stress.

158. Keller E.A. and A. MacDonald. 1995. River channel change: the role of large woody debris. p 217-35, *in* G. Gurnell and G. Potts, eds. Changing River Channels. John Wiley and Sons. New York, NY.

No abstract provided.

159. Keller E.A. and A.N. Melhourn. 1978. Rhythmic spacing and origin of pools and riffles. Geologic Society of American Bulletin. 89:723-30

Quantitative analysis of the spacing of pools in bedrock and alluvial stream channels in California, Indiana, Virginia and North Carolina suggest that the tendency for streams to meander in the vertical dimension, as in the horizontal plane, is a fundamental characteristic of many streams that is independent of material type. Simple linear-regression and correlation models reveal that approximately 70% of the variability of the spacing of pools can be explained by the variabilty of channel width. Analysis of the spacing of 251 pools in 11 streams, utilizing the Kolmogorov-Smirnow goodness of fit test and one-way analysis of variance suggests that the hypothesis that the data from bedrock and alluvial channels are from the same population cannot be rejected at the 0.05 level of significance. Morphologic maps and field observations of stream channels incised in sandstone, limestone, metavolcanic rock and syenite suggest that although these streams have much in common with alluvial stream channels, there exist considerable differences in certain aspects of channel morphology. This results because bedrock control of morphology locally may be more significant that the effects of general processes that tend to produce rhythmic channel forms such as pools and riffles. However, local controls tend to mask rather than destroy the effects of more general processes that produce the third dimension of meandering streams.

160. Keller E.A. and F.J. Swanson. 1979. Effects of large organic material on channel form and fluvial processes. Earth Surface Processes. 4:361-80

Stream channel development in forested areas is profoundly influenced by large organic debris in the channels. Organic debris may greatly affect channel form and process by: increasing or decreasing stability of stream banks; influencing development of mid channel bars and short braided reaches; and facilitating, with other favorable circumstances, development of meaner cutoffs. The effect of live or dead trees anchored by rootwads into the stream bank may not only greatly retard bank erosion but also influence channel width and the development of small scour holes along the channel beneath tree roots. Once trees have fall in the stream, their influence on the channel form and process may be quite different than when they were defending the banks, and depending on the size of the debris, size of the stream, and other factors, their effects range from insignificant to very important.

161. Kelly J.R. and M.A. Harwell. 1990. Indicators of ecosystem recovery. Environmental Management. 14(5):527-45

Assessment of ecological changes relative to disturbance, either natural or human induces, confronts a fundamental problem. Ecosystems are complex, variable and diverse in nature; consequently, the need for simplification to essential features that would characterize ecosystems adequately is generally acknowledged. Yet there is no firm prescription for what to measure in order to describe the response and recovery of ecosystems to stress. Initial focus is provided by identifying relevant ecological endpoints, i.e., ecological changes of particular relevance to humans. Furthermore, we suggest generic purposes and criteria to be considered in making choices of ecological indicators that relate to those endpoints. Suites of indicators, with variety of purposes, are required to assess response and recovery of most ecosystems and most stresses. We suggest that measures of certain ecosystem processes may provide special insight on the early stages of recovery; the use of functional indicators as complimentary to other biotic indicators is high lighted in an extended example for lotic ecosystems.

162. Kershner J.L. 1990. Fish habitat relationships: foundation for fish habitat management in the Forest Service. Fisheries. 15(3):2

In 1981, a national steering committee was established to develop a program to provide systematic methods for evaluating fish and wildlife habitats and applying that information in land management planning and project decisions that affect fish and wildlife habitat. A goal identified for the Forest Service Fish Habitat Relationships Program was to integrate fish habitat inventory and evaluation into project and national forest level interdisciplinary planning and management. Three key areas have been identified. They are: (1) development of sound technology as the foundation for the program; (2) transfer of technology to field biologists in a manner they can apply on the ground; and (3) identification of research needs to further our understanding of aquatic ecosystems.

163. Kershner J.L. 1997. Monitoring and adaptive management. p 116-31, *in* J.E. Williams, C.A. Wood, and M.P. Dombeck, eds. Watershed Restoration: Principals and Practices. American Fisheries Society. Bethesda, MD.

No author abstract provided.

164. Key L.O., R. Garland, and E.E. Kerfoot. 1995. Nearshore habitat use by subyearling chinook salmon in the Columbia and Snake Rivers. p 74-107, *in* D.W. Rondorf and K.F. Tifan, eds. Identification of the spawning, rearing, and migratory requirements of fall chinook salmon in the Columbia river basin. Bonneville Power Administration, DOE/BP-21708-3. Portland, OR.

This 1993 study is the continuation of the habitat study initiated in 1992 to identify and describe the characteristics of rearing habitat used by naturally produced subyearling chinook salmon in riverine reaches and in main-stem reservoirs.

165. Kondolf G.M. 1993. Lag in stream channel adjustment to livestock enclosure, White Mountains, California. Restoration Ecology. 2:226-30

Livestock have been excluded from riparian zones along many streams in western North America in an effort to restore aquatic and riparian habitat degraded by livestock grazing. Within these exclosures channel adjustment to elimination of grazing pressure may lag behind plant recovery because of the time required to deposit sediment along the vegetated banks of the stream channel. Moreover, unless grazing is eliminated from the watershed, the channel within the exclosure must still accommodate increased runoff and sediment loads from upstream. This hydrologic regime may prevent a return to pre-disturbance channel morphology. Cross sections of the North Fork Cottonwood Creek in the White Mountains of California showed no significant difference in channel width within and downstream of a 24-year-old exclosure, despite a lush growth of stream bank vegetation that gives the impression of a narrower channel within the exclosure.

166. Konkel G.W. and J.D. McIntyre. 1987. Trends in spawning populations of Pacific anadromous salmonids. U. S. Fish and Wildlife Service, Technical Report #9, Washington, DC

No abstract provided.

167. Kozel S.J. and W.A. Hubert. 1989. Factors influencing the abundance of brook trout in forested mountain streams. Journal of Freshwater Ecology. 5(1):113-22

Physical and biological factors that appear to influence standing stocks (kg/ha) of brook trout were identified in the Medicine Bow National Forest, Wyoming, for 32 forested reaches of mountain streams in drainages unaltered by human activity. Brook trout abundance declined as stream size increased. This decline appeared to be related to at least 2 factors; decline in habitat quality with increasing stream size and interaction with brown trout at lower elevations. The greatest variation in brook trout abundance was accounted for by drainage basin area and elevation of the stream reach.

168. Kozel S.J., W.A. Hubert, and M.G. Persons. 1989. Habitat features and trout abundance relative to gradient in some Wyoming streams. Northwest Science. 63:175-82

Channel gradient has been shown to have a negative relation to trout standing stocks indication that separation of stream channels into gradient classes may provide a better understanding of the relationships between habitat and trout abundance. Our major objective was to determine if there are significant differences in habitat features and standing stocks of trout >100 mm between 2 classes of channel gradient, low and moderate. We also determined statistical relations between habitat features and trout standing stocks in each class of channel for unaltered streams on the Medicine Bow National Forest, Wyoming. Low gradient reaches were found to have deeper nearshore water depths, more undercut banks and more trench pools than moderate gradient reaches, while moderate gradient reaches had more cobble substrate, dammed pools formed by woody debris and plunge pools. The mean standing stock was 267 kg/ha in low-gradient reaches and 102 kg/ha in moderate gradient reaches. Habitat features correlated with trout standing stocks differed between the 2 gradient classes. Our results demonstrated that the separation of stream segments into reaches of similar gradient are important in identifying features of trout habitat that are otherwise obscured by variation over a wider gradient range.

169. Lanka R.P., W.A. Hubert, and T.A. Wesche. 1987. Relations of geomorphology to stream habitat and trout standing stock in small Rocky Mountain streams. Transactions of the American Fisheries Society. 116(1):21-8

Evidence that drainage basin morphology and trout standing stock are related through a functional link between geomorphic features and stream habitat quality is presented. Numerous significant univariate correlations were found between geomorphic variables, stream habitat variables, and trout standing stock in both high-elevation forest and low-elevation rangeland streams. Canonical correlations between geomorphic variables and stream habitat variables provided insight into the form of the functional link. Multiple-regression equations predicting trout standing stock were dominated by geomorphic variables. When geomorphic variables alone were incorporated into regression models they predicted trout standing stock as accurately as did stream habitat variables.

170. Lawson P.W. 1993. Cycles in ocean productivity, trends in habitat quality, and the restoration of salmon runs in Oregon. Fisheries. 18:6-10

Oregon's coastal natural coho salmon populations have drawn political attention because abundances are at critically low levels. One of the underlying problems is a long-term trend in habitat degradation. In addition, decadal-scale cycles in ocean survival of coho salmon may lead to cycles in abundance that are independent of freshwater habitat trends. When population abundance varies widely over time, a rise in abundance following the initiation of recovery measures can be taken as an indication of success even when the increase in numbers was independent of the actions taken. Support for recovery efforts must be sustained through the cycle of higher abundance. The true measure of success for such projects is the continued survival of the population through subsequent episodes of low abundance.

171. Lee D.C. and B.E. Rieman. 1996. Federal land management, freshwater habitat, and anadromous fishes in the Interior Columbia River Basin. U. S. Forest Service, Intermountain Research Station, Boise, ID

No abstract provided.

172. Leonard P.M. and D.J. Orth. 1988. Use of habitat guilds of fishes to determine instream flow requirements. North American Journal of Fisheries Management. 8(4):399-409

We grouped eight warmwater fishes, each represented by one to four life stages, into habitat-use guilds (i.e., groups of species) to select target species for instream flow studies. Cluster analysis of depth, velocity, substrate, and cover use identified four primary habitat-use guilds, which were distinguished largely on the basis of water velocity. Habitat-suitability criteria were developed for each species and life stage combination, and these criteria were used in physical habitat simulations to determine relations between weighted usable area (WUA) and discharge for three streams in the upper James River basin, Virginia. Weighted usable areas for species within each habitat-use guild generally exhibited similar responses to discharge except those for some stream-margin inhabitants and for strongly cover-oriented species. Four types of habitat-discharge relations, which were consistent among streams, were identified. Curves of WUA versus discharge for habitat generalists and some specialists indicated relatively stable WUA over a wide range of flows. Target species and life stages should be selected from appropriate habitat-use guilds to ensure that flow recommendations represent the best compromise between the needs of fast-water and slack-water inhabitants.

173. Lewis S.L. 1969. Physical factors influencing fish populations in pools of a trout stream. Transactions of the American Fisheries Society. 98:14-9

The relationship between fish populations and physical parameters of pools was studied in Little Prickly Pear Creek, Montana, during the summers of 1965 and 1966. The pools were mapped and their fish populations sampled. Surface area, volume, depth, current velocity and cover accounted for 70 to 77% of the variation in numbers of trout over 6.9 inches total length. Most of the variation was the result of differences in current velocity and cover. Cover was the most important factor for brown trout and current velocity for rainbow trout. The density of all trout per unit area of pool surface and cover increased significantly as current velocity became greater. Deep-slow pools with extensive cover had the most stable trout populations with brown trout showing greater stability than rainbow trout. The importance of cover to trout is discussed in terms of security and photonegative response and current velocity in terms of space-food relationships.

174. Li H.W., C.B. Shreck, C.E. Bond, and E. Rexstad. 1987. Factors influencing changes in fish assemblages of the Pacific Northwest streams. p 193-202, *in* W.J. Mathews and D.C. Heins, eds. Community and evolutionary ecology of North American stream fishes. University of Oklahoma Press. Norman, OK.

Dams have acted as physical zoogeographic barriers and may have increased the importance of fish diseases both as a barrier and as mechanisms structuring fish assemblages. The impoundments favor the establishment of exotic, temperate species from the Midwest. Forestry, grazing, and bank stabilization practices have changed the morphology of watersheds and diminished the role of large woody debris and riparian vegetation, which are important regulators of physical change and stream metabolism. Harvesting of salmonids has led to a significant reduction of nutrient input to nutrient poor streams complexes. Stock depletion has given rise to hatcheries that now produce fish that are different genetically from the ancestral populations.

175. Lichatowich J.A. 1989. Habitat alteration and changes in abundance of coho (*Oncoryncus*

kisutch) and chinook salmon (*O. tshawytscha)* in Oregon's coastal streams. p 92-9, *in* C.D. Levings, L.B. Boltby, and M.A. Anderson, eds. Proceedings of the National workshop of effects of habitat alteration on salmonid stocks. Canadian Special Publication in Fisheries and Aquatic Sciences. Ottawa, ON, Canada.

No abstract provided.

176. Lider E. 1985. Fisheries habitat and fish abundance in the North Fork of the Coeur d'Alene River. U. S. Forest Service, Coeur d'Alene National Forest, Fernan District, Coeur d'Alene, ID

No abstract provided.

177. Lienkaemper G.W. and F.J. Swanson. 1987. Dynamics of large woody debris in streams in old-growth Douglas fir forests. Canadian Journal of Forest Research. 17:150-6

Transfer of large woody debris from old growth Douglas-fir forests into five first-to fifth-order stream reaches has ranged from 2.0 to 8.8 Mg-ha^{-1}-year^{-1} in 7- to 9- year study periods. Amounts of large debris in these streams range from 230 to 750 Mg-ha^{-1}, with generally lower values in larger channels. The addition of woody debris is widely scattered in time and space and comes mainly from single trees rooted away from the streambank. We infer that wind is a major agent for entry of wood into these streams. Downstream movement of debris is strongly related to length of individual pieces; most pieces that moved were shorter than bankfull width.

178. Liknes G.A. and P.J. Graham. 1988. Westslope cutthroat trout in Montana: life history, status, and management. p 53-60, *in* American Fisheries Society. Bethesda, MD.

No abstract provided.

179. Lisle T.E. 1986. Effects of woody debris on anadromous salmonid habitat, Prince of Wales Island, southeast Alaska. North American Journal of Fisheries Management. 6(4):538-50

The effects of woody debris on anadromous salmonid habitat in eight streams on Prince of Wales Island, southeast Alaska, were investigated by comparing low-gradient (1-9%) first- or second-order streams flowing through either spruce-hemlock forests or 6-10 year-old clear-cuts, and by observing changes after debris was selectively removed from clear-cut reaches. Woody debris decreased the rate of shallowing as discharge decreased, thus helping to preserve living space for fish during critical low-flow periods. Debris dams were more frequent in clear-cut streams (14.9/100 m), which contained more debris, than in forested streams (4.2/100 m). As a result, total residual pool length (length when pools are filled with water but there is no flow) and length of channel with residual depth greater than 14 cm--the depth range occupied by 84% of coho salmon (Oncorhynchus kisutch)--were greater in clear-cut streams than in forested streams. Greater volumes of woody debris in clear-cut streams produced greater storage of fine sediment (<4-mm diameter) unless the stream gradient was sufficiently high to flush sediment from storage. One-half of the debris dams broke up or were newly formed over a 3-year period, which suggests that they usually released sediment and woody debris before the pools they formed were filled with sediment. Woody debris removal decreased debris-covered area, debris dam frequency, and hydraulic friction in some cases but, in others, these variables were unaffected or recovered within 2 years after erosion and adjustment of the streambed. No consistent differences in pool dimensions were found between treated and untreated clear-cut reaches. Comparisons of habitat in forested and clear-cut streams suggested that removing debris from clear-cut streams reduced salmonid carrying capacity. Retention and natural reformation of debris dams in cleared reaches prevented the expected deterioration of habitat. However, the removal and destabilization of existing woody debris may cause depletion of debris before riparian trees can regrow and furnish new material to the clear-cut streams.

180. Lisle T.E. 1987. Channel morphology and sediment transport in steepland streams. p 287-96, *in* R.L. Beschta, ed. Erosion and Sedimentation in the Pacific Rim. University of Oregon, IAHS Publication No. 165. Corvallis, OR.

New understanding of how steepland channels are formed is being pursued over a large range of scales from entrainment of bed particles to the transfer of stored sediment down channel systems. Low submergence of bed particles during transport and wide heterogeneity in particle sizes strongly affect bedload transport. At the scale of a reach, scour-lobes are becoming widely recognized as common constructional units governing behavior of braided, meandering and pool-riffle channels. Channel morphology and sediment transport can be radically altered by infrequent debris flows and torrents, however, which provide a common linkage between mass movement on hillslopes and sediment transport in channels. Because of the impracticality of monitoring the downstream progress of sediment routing is best approached by mathematical models that incorporate the age and volume of sediment in storage reservoirs.

181. Lisle T.E. and S. Hilton. 1991. Fine sediment in pools: an index of how sediment is affecting a stream channel. U. S. Forest Service, Pacific Southwest Region, Berkeley, CA

No author abstract provided.

182. Lister D.B. and H.S. Genoe. 1970. Stream habitat utilization by cohabiting underyearlings of chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon in the Big Qualicum River, British Columbia. Journal of the Fisheries Research Board of Canada. 27(7):1215-24

Habitat distributions of chinook and coho salmon underyearlings in the Big Qualicum River, Vancouver Island, BC., under controlled flow conditions indicated that at similar sizes their habitat requirements during the first 3 months of stream life were similar. Just after emergence, fry of both species occupied marginal areas in association with bank cover. With increased size, the young fish moved into habitat of progressively higher velocity. However, differences between the species in time of emergence and size evidently resulted in a high degree of spatial segregation. Chinook fry emerged about a month earlier than coho, were larger upon emergence, and grew at a faster rate. Apparently, because of their larger size at a given time, chinook preferred higher velocity locations than coho.

183. Loeb S.L. and A. Spacie. 1964. Biological monitoring of aquatic systems. Lewis Publishers, Boca Raton, FL

No author abstract provided.

184. Lorenze J.M. and J.H. Eiler. 1989. Spawning habitat and redd characteristics of sockeye salmon in the Glacial Taku River, British Columbia and Alaska. Transactions of the American Fisheries Society. 118(5):495-502

Spawning habitats of sockeye salmon in the Taku River and its tributaries in British Columbia and Alaska were studied to determine habitat use and redd characteristics in a glacial river system. We used radiotelemetry to track adult sockeye salmon to 26 spawning reaches and 63 spawning sites were sampled for habitat characteristics. Over 40% of the sockeye salmon in the sampling area had a freshwater age of zero, and most of these spawned in main channels or off-channel areas. The availability of upwelling groundwater influenced habitat use in the main stem of the river; upwelling groundwater was detected in nearly 60% of the sites sampled in main stem areas. Spawning sites with upwelling groundwater had lower water velocities and more variable substrate compositions that sites without upwelling groundwater. Redds had 2 to 4 times more fine sediment than previously reported. The probability of use was greatest when substrate had less than 15% fine sediment, water velocity was between 10 and 15 cm/s, and intragravel temperature was between 4.5 and 6.0° C.

185. MacDonald L.H. 1994. Developing a monitoring project. Journal of Soil and Water Conservation. 221-7

No author abstract provided.

186. MacDonald L.H., A. Smart, and R.C. Wissimar. 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska. Environmental

Protection Agency, EPA/901/9-91-001, Seattle, WA

The publication provides guidance for designing water quality monitoring projects and selecting monitoring parameters. Although the focus is on forest management and streams in the Pacific Northwest and Alaska, a broader perspective is taken and much of the information is more widely applicable. Part I reviews the regulatory mechanisms for nonpoint source pollution and defines seven types of monitoring. A step-by-step process for developing monitoring projects is presented. Because monitoring is a sample procedure, study design and statistical analysis are explicitly addressed. Part II is a technical review of the parameters, and these are grouped into seven categories: physical and chemical constituents, flow, sediment, channel characteristics, riparian, and aquatic organisms.

187. Magilligan F.J. and P.F. McDowell. 1997. Stream channel adjustments following elimination of cattle grazing. Journal of the American Water Resources Association. 33(4):867-78

Cattle grazing practices in the western United States have contributed to widespread riparian degradation resulting in unstable channel morphologies and the loss of fish habitat. Because of prolonged disturbance, numerous riparian areas on both public and private lands have been fenced to exclude cattle in order to promote vegetation establishment and riparian improvement. We selected four gravel-bedded, steep alluvial streams in eastern Oregon with cattle exclosures greater than 14 years old for an analysis of geomorphic adjustments following the removal of cattle grazing. We compare channels inside exclosures and in adjacent grazed reaches to identify the salient stream channel properties that respond to the removal of riparian stresses and to document the magnitude of these changes. Results indicate that significant changes occur, with reductions in bankfull dimensions and increases in pool area being the most common and identifiable changes. At all four sites, bankfull widths are narrower by 10 to 20 percent, and the percentage of channel area occupied by pools is higher in the exclosure by 8 to 15 percent. The increase in pool area is primarily offset by a reduction in the percent glide area. Not all of the channel properties demonstrate adjustment, indicating that perhaps 14 years is an insufficient duration for these variables to adjust.

188. Maret T.R., C.T. Robinson, and G.W. Minshall. 1997. Fish assemblages and environmental correlates in least-disturbed streams of the Upper Snake River Basin. Transactions of the American Fisheries Society. 126:200-16

Fish assemblages and environmental variables were evaluated from 37 least-disturbed 1st through 6th order stream and springs. Major environmental factors determining species distributions in the basin were stream gradient, watershed size, conductivity, and percentage of the watershed covered by forest. Fish assemblages differed between lowland streams (below 1,600 meters in elevation) and upland streams and in relation to large waterfalls. Springs also exhibited different habitat conditions and fish assemblages than streams. The data suggest that the evolutionary consequences of geographic features and fish species introductions transcend the importance of ecoregion boundaries on fish distributions in the upper Snake River basin.

189. Marston R.A. 1982. Geomorphic significance of log steps in forest streams. Annals, of the Association of American Geog. 72(1):99-108

No abstract provided.

190. Martin D.J. and M.E. Robinson. 1998. Effectiveness of riparian buffer zones for protection of salmonid habitat in Alaska coastal streams. Martin Environmental for Sealaska Corp. and Alaska Forest Association, Seattle, WA

For this study, low elevation aerial photographs were used to delineate potential LWD sources and these data were used to determine the effects of buffer zones on the short and long term supply of LWD. We used annual channel survey data from a 4-year period to monitor changes in LWD recruitment and to examine the interaction between LWD, channel morphology and fish habitat.

191. Matthews K.R., N.H. Berg, D.L. Azuma, and T.R. Lambert. 1994. Cool water formation and trout

habitat use in a deep pool in the Sierra Nevada, California. Transactions of the American Fisheries Society. 123(4):549-64

We documented temperature stratification in a deep bedrock pool in the North Fork of the American River, described the diel movement of rainbow trout *Oncorhynchus mykiss* and brown trout *Salmo trutta*, and determined whether these trout used cooler portions of the pool. From July 30 to October 10, 1992, the main study pool and an adjacent pool were stratified (temperature differences between surface and bottom were as great as 4.5°C) on all but two days. Six rainbow and one brown trout equipped with temperature-sensitive radio transmitters used water with temperatures ranging from 12 to 19.3°C. During the late afternoon, when the widest range of water temperature was available, trout were found in temperatures up to 19.3°C even though cooler (14.5°C) water was available. Radio tracking indicated that fish were significantly more active and had significantly larger home ranges at night; fish were least active during the day. Because we found no evidence of subsurface seepage into the pool and water flowing into the pool was warmer than the pool's maximum temperature, we concluded that the geometry and depth of deep pools may moderate elevated summer water temperatures that can stress trout populations.

192. Maxwell J.R., C.J. Edwards, M.E. Jensen, S.J. Paustian, H. Parrott, and D.M. Hill. 1995. Hierarchical framework of aquatic ecological units in North America (Neartic Zone). U. S. Forest Service, NC-GTR-176, St. Paul, MN

Proposes a framework for classifying and mapping aquatic systems at various scales using ecologically significant physical and biological criteria. Classification and mapping concepts follow tenets of hierarchical theory, pattern recognition and driving variables. Criteria are provided for the hierarchical classification and mapping of aquatic ecological units or riverine, lacustrine and ground water systems within their geoclimatic and watershed settings. Some hydrogeomorphic criteria for classifying wetland are also proposed.

193. McCullough D.A. 1988. Systems classification of watersheds and streams. Columbia River Inter-Tribal Fish Commission, Portland, OR

Adequate management and scientific investigation of ecosystems depends on classification of landscape systems based on all significant bio-physical and associated cultural properties. The present classification is a hierarchical systems design that can be modeled in terms of a natural system interacting with its level-specific environment. A watershed system in this context is embedded in a landscape environment organized into, for example, zonal and regional systems. A system at any level is classified by its capacity and the capacity of its environment, capacity defining temporally the scope of possible systems performances relative to the components, substrate, climate, biota, culture and water.

194. McCullough D.A. 1999. Monitoring of streambank stability and streamside vegetation in a livestock exclosure on the Warm Springs River, Oregon: comparison of ground based surveys with aerial photographic analysis. Columbia River Intertribal Fish Commission, Portland, OR

The objective of this monitoring project was to determine the baseline condition for a 960 m long stream reach and its associated streamside zone, which terminates at the confluence with the Deschutes River. This stream reach had been damaged heavily in the February 1996 flood and had also received many years of overuse by livestock grazing. The monitoring project was conducted in July 1997 just after installation of riparian exclosure fencing. Future resurvey of the study area will allow determination of progress made in ecological recovery.

195. McGreer D.J. 1995. National forest riparian and aquatic habitat management strategy (Fish 2000). p 32, *in* . An alternative for the protection and restoration of anadromous fish habitat in eastern Oregon and Washington. Northwest Forest Resource Council. Lewiston, ID.

No author abstract provided.

196. McIntosh B.A., D.M. Price, C.E. Torgersen, and H.W. Li. 1995. Distribution, habitat utilization, movement patterns, and the use of thermal refugia by spring chinook in the Grande Ronde, Imnaha, and John Day Basins. Bonneville Power Administration, Project #88-108 (draft), Portland, OR

The purpose of this study is to assess the quality of summer holding habitat for adult spring chinook salmon in eastern Oregon. Our primary objective is to examine the influence of stream temperature and other physical factors on habitat use by adult spring chinook salmon. Stream temperatures in eastern Oregon streams often rise to or exceed the upper incipient lethal temperature for spring chinook salmon during the diel cycle. These temperature patterns have been observed in each of our 3 field seasons.

197. McIntosh B.A., J.R. Sedell, R.F. Thurow, S.E. Clarke, and G.L. Chandler. 1995. Historical changes in pool habitat in the Columbia River Basin. Report to the Eastside Ecosystem Management Project, Walla Walla, WA

Knowledge of how stream habitats change over time in natural and human influenced ecosystems at large, regional scales is currently limited. A historical stream survey was compared to current surveys to assess changes in pool habitats in the Columbia River Basin.

198. McIntyre J.D. and B.E. Rieman. 1995. Westslope cutthroat trout . p 1-15, *in* M.K. Young, ed. Conservation Assessment for Inland Cutthroat Trout. U. S. Forest Service, RM-GTR-256. Fort Collins, CO.

No abstract provided.

199. McMahon T.E. and G.F. Hartman. 1989. Influence of cover complexity and current velocity on winter habitat use by juvenile coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences. 46:1551-7

Winter habitat use by juvenile coho salmon varied with cover type and flow level in outdoor stream channels. Cover utilization and the number of fish remaining in stream channels increased significantly as cover complexity increased. Most fish emigrated during a simulated freshet unless the most complex cover (low velocity, shade, and wood debris combined) was available. At both high and low flows, emigration occurred primarily during the rapid decline in light levels at twilight. Most coho formed aggregations beneath cover, exhibiting feeding and aggression at temperatures as low as 2.5 C. We conclude that (1) social interactions, in concert with habitat features, influence the abundance of coho salmon within specific stream habitats in winter, and (2) structural complexity of woody debris is an important consideration for management practices designed to protect or enhance winter habitat for this species.

200. Meador M.R., C.R. Hupp, T.F. Cuffney, and Gurtz M.E. 1993. Methods for characterizing stream habitat as part of the national water quality assessment program. U. S. Geological Survey, Open File report #93-408, Raleigh, NC

The goal of the stream habitat characterization is to relate to other physical, chemical, and biological factor to describe water quality conditions. A modification of Frissel et. al. (1986) hierarchical classification is used to evaluate habitat - basin, stream segment, stream reach, and micro-habitat. Basin denotes the area drained by all surface waters located upstream of a selected site. Stream segment is defined as that part of the stream bounded by tributary junctions or discontinuities, such as major waterfalls, landform features, significant changes in gradient, or point-source discharges. A stream reach is the least clearly defined in the spatial hierarchy. The stream reach is selected on the basis of observed sequence of geomorphic unit, stream type (channel form and process), channel dimensions, velocity, substrate embeddedness, canopy angle, aspect, habitat features (woody debris, boulders, macrophytes, etc.), bank geometry, and bank stability features.

201. Meehan W.R. 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society, Bethesda, MD

No author abstract provided.

202. Meehan W.R., M.A. Brusven, and J.F. Ward. 1987. Effects of artificial shading on distribution and abundance of juvenile chinook salmon (*Oncoryncus tshawytscha*). Great Basin Naturalist. 47:22-31

The influence of artificial shade on the distribution and abundance of juvenile chinook salmon was studied in a side channel of the South Fork Salmon River, Idaho. Fish biomass and abundance were greater in shaded than in unshaded areas when compared to both cumulative incident light reaching the study sections during the 72-hour test runs and instantaneous incident light conditions at the end of the 72-hour test runs. Because conditions may be atypical at the time of instantaneous light measurement, we prefer cumulative incident light for relating light and shade conditions to daytime distribution (abundance and biomass) of juvenile chinook salmon.

203. Minshall G.W., J.T. Brock, and J.D. Varley. 1989. Wildfire and Yellowstone's stream ecosystems. BioScience. 39:707-15

No abstract provided.

204. Montgomery D.R. 1995. Input- and output- oriented approaches to implementing ecosystem management. Environmental Management. 19(2):183-8

Input and output oriented approaches to landscape management have distinct roles for resource protection, environmental restoration and sustainable land management. Implementing recent proposals for ecosystem management in the western United States involves a synthesis of input and output management. Input management focuses on tailoring land use to the landscape, whereas output management employs assessments of resource condition to trigger modified management activity once resources are degraded to specified threshold conditions. Current approaches to landscape scale management, however, tend to rely primarily on output oriented strategies that are most effective for monitoring environmental conditions. Current uses of input management focus on environmental impact assessments, which generally are site or project specific analyses. The complexity and dynamic nature of ecosystems and the range of scales over which ecological processes operate, imply that development and incorporation of input oriented approaches into landscape scale management is necessary to implement ecosystem management as a strategy for sustainable land use.

205. Montgomery D.R. and J.M. Buffington. 1993. Channel classification, prediction of channel response, and assessment of channel condition. Washington State Timber/Fish/Wildlife agreement, Olympia, WA

A process based landscape and channel classification system is proposed as a framework for assessing watershed response to natural and anthropogenic environmental change.

206. Montgomery D.R. and J.M. Buffington. 1997. Channel reach morphology in mountain drainage basins. GSA Bulletin. 109(5):596-611

A classification of channel reach morphology in mountain drainage basins synthesizes stream morphologies into 7 distinct reach types: colluvial, bedrock and five alluvial channel types (cascade, step pool. plane bed, pool riffle and dune ripple). Coupling reach level channel processes with the spatial arrangements of reach morphologies, their links to hill slope processes and external forcing by confinement, riparian vegetation and woody debris defines a process based framework within which to assess channel condition and response potential in mountain drainage basins. Field investigations demonstrate characteristic slope, grain size, shear stress and roughness ranges for different reach types, observations consistent with our hypothesis that alluvial channel morphologies reflect specific roughness configurations adjusted to the relative magnitudes of sediment supply and transport capacity. Steep alluvial channels (cascade and step pool) have high ratios of transport capacity to sediment supply and are resilient to changes in discharge and sediment supply, whereas low-gradient alluvial channels (pool riffle and dune ripple) have lower transport capacity to supply ratios and thus exhibit significant and prolonged response to changes in sediment supply and discharge. General differences in the ratio of transport capacity to supply between channel types allow aggregation of reaches into source, transport and response segments, the spatial distribution of which provides a watershed level conceptual model linking reach morphology and channel processes. These 2 scales of channel network classification define a framework within which to investigate spatial and temporal patterns of channel response in mountain drainage basins.

207. Montgomery D.R., J.M. Buffington, and R.D. Smith. 1995. Pool spacing in forest channels. Water Resources Research. 31:1097-105

Field surveys of stream channels in forested mountain drainage basins in southeast Alaska and Washington reveal that pool spacing depends on large woody debris (LWD) loading and channel type, slope, and width. Mean pool spacing in pool-riffle, plane-bed, and forced pool-riffle channels systematically decreases from greater than 13 channel widths per pool to less than 1 channel width with increasing LWD loading, whereas pool spacing in generally steeper, step pool channels is independent of LWD loading. Although plane-bed and pool-riffle channels occur at similar low LWD loading, they exhibit typical pool spacing of greater than 9 to 2-4 channel widths, respectively. Forced pool-riffle channels have high LWD loading, typical pool spacing of <2 channel widths, and slopes that overlap the ranges of free-formed pool-riffle and plane-bed channel types. While a forced pool-riffle morphology may mask either of these low-LWD-loading morphologies, channel slope provides an indicator of probable morphologic response to wood loss in forced pool-riffle reaches. At all study sites, less than 40% of the LWD pieces force the formation of a pool. We also find that channel width strongly influences pool spacing in forest streams with similar debris loading and that reaches flowing through previously clear-cut forests have lower LWD loading and hence fewer pools than reaches in pristine forests.

208. Moore K.M.S. and S.V. Gregory. 1988. Summer habitat utilization and ecology of cutthroat trout fry (*Salmo clarki*) in Cascade Mountain streams. Canadian Journal of Fisheries and Aquatic Sciences. 45:1921-30

Emergent cutthroat trout fry were observed in the margins, backwaters and side channels, collectively called lateral habitats, of 2 study streams with different riparian vegetation. Most fry remained in these lateral habitats until the end of their first summer. The abundance of cutthroat fry was proportional to the area of lateral habitat in each of the study streams. Average size and growth rate of fry were related to the effect of site elevation on stream temperature and the influence of riparian vegetation on the availability of invertebrate food. Lateral habitats are characterized by slow, shallow water, abundant detritus and benthic invertebrates assemblages of high density. Stream margins and backwaters provided gradients of depth and velocity, cover and access to food that are appropriate to the habitat requirements of fry. Because fry populations are closely related to the abundance and quality of lateral habitats in small streams, these habitats should be included in the assessment of habitat requirements of cutthroat trout.

209. Moore K.M.S. and S.V. Gregory. 1989. Geomorphic and riparian influences on the distribution and abundance of salmonids in a cascade mountain stream. U. S. Forest Service, PSW-GTR-110. Berkeley, CA.

Abundance of resident cutthroat and rainbow trout was generally 1.5 to 3.5 times greater in unconstrained reaches than in constrained reaches of Lookout Creek, a fourth-order tributary to the McKenzie River, Oregon. The presence of adult rainbow trout depressed juvenile abundance in pools with little habitat complexity but had no effect in pools with more heterogeneous structure. The greater abundance of trout in unconstrained reaches was related to habitat structure, the influence of the riparian canopy on stream productivity and the effect of channel morphology on stream hydraulics. Valley floor landforms are major determinants to channel complexity and habitat structure, providing a hierarchical geomorphic contest for interpreting riparian influences on patterns of abundance and distribution of salmonids within a basin.

210. Moore K.M., K.K. Jones, and J.M. Dambacher. 1993. Methods for stream habitat surveys: version 3.1. Oregon Fish and Wildlife, Portland, OR

No abstract provided.

211. Moyle P.B. and D.M. Baltz. 1985. Microhabitat use by an assemblage of California stream fishes: developing criteria for instream flow determinations. Transactions of the American Fisheries Society. 114:695-704

Microhabitat requirements were determined for eight species of native California stream fishes: rainbow trout *Salmo gairdneri*; Sacramento sucker *Catostomus occidentalis*; Sacramento squawfish *Ptychocheilus grandis*; hardhead *Mylopharodon conocephalus*; California roach *Hesperoleucus symmetricus*; speckled dace *Rhinichthys osculus*; tule perch *Hysterocarpus traski*; and riffle sculpin *Cottus gulosus*. Two or three size classes were evaluated for each species. Each species had a preferred microhabitat (defined on the basis of depth, velocity, substrate), as did each size class within each species, but there was much similarity in microhabitat use within and among species. The amount of microhabitat available to each species differed in three stream reaches in which availability was quantified, but the differences were not enough to explain the differences in composition of the fish assemblage found at each site. This study indicates that recommendations for instream flows should be based on microhabitat use data collected on site together with habitat availability data. Even on-site data should be used cautiously because intraspecific interactions and changes in a stream's physical characteristics, especially in its temperature regime, may cause unexpected shifts in microhabitat use.

212. Mullan J.W., K. Williams, and G. Rhodus. 1992. Production and habitat of salmonids in mid-Columbia River tributary streams. U. S. Fish and Wildlife Service, Monograph #1, Wenatchee, WA

No author abstract provided.

213. Mundy P.R., T.W.H. Backman, and J.M. Berkson. 1995. Selection of conservation units for Pacific Salmon: Lessons from the Columbia River. p 28-38, *in* J.L. Nielson, ed. Evolution and the aquatic ecosystem: defining unique units in population conservation. American Fisheries Society Symposium. Bethesda, MD.

We present a working concept of a conservation unit for pacific salmon that we believe to be biologically effective, legally defensible and consistent with a composite tribal and biological perspective on resource management. The 2 principal elements of the conservation unit definition are achieving viability for all life history types and maintaining sufficient geographic distribution. Conservation unit definition requires the ability to identify the biological species, its life history types and the nature of the life history types dependence on other components of the ecosystem. Identifying sufficient geographic range compels identification of the collections of habitats occupied by the life history types. Defining geographic sufficiency also requires determining the likelihood of persistence of a collection of salmon populations. We compare our working definition with the current salmon conservation unit, the evolutionarily significant unit and find the ESU does not include the standards needed to enable recovery of damaged salmon populations. We explore the application of the current ESU to recovery of both spring chinook salmon and sockeye salmon and we suggest that the geographic range of the present ESU for both species is inadequate to effect recovery under the U. S. Endangered Species Act. In the legal context, the ESU is not materially different from its predecessor, the distinct populations segment. Finally we apply our conservation unit definition to identify four groups of salmon some of which are not presently protected, that should qualify as species for listing under the ESA.

214. Murphy M.L. 1995. Forestry impacts on freshwater habitat of anadromous salmonids in the Pacific Northwest and Alaska and requirements for protection and restoration. National Marine Fisheries Service, Washington, DC

This synthesis presents a scientific overview of the major forest management issues involved in the recovery of anadromous salmonids by timber harvest in the Pacific Northwest. It presents habitat requirements at each life stage as they pertain to the effects of logging. Numerical standards for temperature, velocity, DO, and turbidity; and qualitative standards for LWD and cover are discussed for each life stage.

215. Murphy M.L., C.P. Hawkins, and N.H. Anderson. 1981. Effects of canopy modification and accumulated sediment on stream communities. Transactions of the American Fisheries Society. 110:469-78

Small streams differing in sediment composition were compared in logged and forested reaches to determine effects of accumulated fine sediment on stream communities under different trophic conditions. Three stages of forest community succession were studied in the Cascade Mountains: recently clear-cut areas without forest canopy (5-10 years after logging); second-growth forest with deciduous canopy (30-40 years after logging); and old-growth coniferous forest (>450 years old). One stream with mostly coarse sediment (56-76% cobble) and one with more fine sediment (5-14% sand and 23-53% gravel) were contrasted for each successional stage. In general, streams traversing open clear-cuts had greater rates of microbial respiration, and greater densities or biomasses of aufwuchs, benthos, drift, salamanders, and trout than did the shaded, forested sites regardless of sediment composition. We conclude that for these small Cascade Range streams, changes in trophic status and increased primary productivity resulting from shade removal may mask or override effects of sedimentation.

216. Murphy M.L., J.M. Heifetz, J.F. Thedinga, S.W. Johnson, and K.V. Koski. 1989. Habitat utilization by juvenile Pacific salmon (*Oncorhynchus*) in the glacial Taku River, southeast Alaska. Canadian Journal of Fisheries and Aquatic Sciences. 46(10):1677-85

Habitat utilization was determined in summer 1986 by sampling 54 sites of nine habitat types: main channels, backwaters, braids, channel edges, and sloughs in the river; and beaver ponds, terrace tributaries, tributary mouths, and upland sloughs on the valley floor. Physical characteristics were measured at all sites, and all habitats except main channels (current too swift for rearing salmon) were seined to determine fish density. Sockeye (Oncorhynchus nerka) averaged 23 fish/100 m^2, nearly twice the density of coho (O. kisutch) and four times that of chinook (O. tshawytscha), 14 and 6 fish/100 m^2, respectively. Sockeye were age 0, 27-84 mm fork length (FL), and most abundant in upland sloughs, beaver ponds, and tributary mouths. Coho were ages 0 and 1, 33-132 mm FL, and most abundant in beaver ponds and upland sloughs. Chinook were age 0, 40-93 mm FL, and more abundant than the other species in habitats with faster currents (1-20 cm/s), particularly channel edges. Each species was absent from about one-quarter of the seining sites of each habitat type. Thus, the lower Taku River provides important summer habitat for juvenile salmon, but many suitable areas were unoccupied, possibly because of their distance from spawning areas and poor access for colonizing fish.

217. Myers T.J. and S. Swanson. 1996. Long-term aquatic habitat restoration: Mahogony Creek, Nevada, as a case study. Water Resources Bulletin. 32(5):241-52

We compared the recovery from abusive grazing of aquatic habitat due to different range management on two geomorphologically similar rangeland streams in northwest Nevada. Managers excluded livestock from the Mahogony Creek watershed from 1976 to 1990 while allowing rotation of rest grazing on its tributary Summer Camp Creek. Namk stability improved through the study period on both streams, but periodic grazing and flooding decreased stability more on Summer Camp Creek than flooding alone on Mahogony Creek. Pool quantity and quality decreased due to removal of coarse woody debris and sediment deposition during a drought. Fine stream bottom sediments decreased five years after the removal of livestock, but sedimentation increased during low flows. Tree cover increased 35 percent at both streams. Thus, recovery of stability in this stream type. Management activities such as coarse woody debris removal limited pool recovery.

218. Naiman R.J., D.G. Lonzarich, T.J. Beechie, and S.C. Ralph. 1992. General principles of classification and the assessment of conservation potential in rivers. p 93-123, *in* J.P. Boon, P. Calow, and G.E. Petts, eds. River Conservation and Management. John Wiley and Sons. New York, NY.

Classification of fluvial systems remains in a formative stage because running water have become recognized only recently as ecological systems in their own right, because of the dynamic changes that occur over broad spatial and temporal scales and because classification systems only reflect the current state of knowledge on river function. Most attention remains focused on conceptual and regional approaches to stream classification rather than on general approaches applicable across contrasting ecoregions.

219. National Marine Fisheries Service. 1996. Making endangered species act determinations of effect for individual or grouped actions at the watershed scale. National Marine Fisheries Environmental and Technical Division

These guidelines list ranges of habitat numerics for the purpose of standardizing determinations of effect for ESA consultations, focusing on anadromous fish. The following applicable indicators are listed: temperature, sediment, substrate, LWD, pool frequency, width/depth, connectivity, and riparian reserves.

220. National Marine Fisheries Service. 1998. Essential Fish Habitat Update [Web Page]. Accessed 1998.

No author abstract provided.

221. Nehlsen W., J.E. Williams, and J.A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries. 16(2):4-21

214 native, naturally-spawning Pacific salmon (Oncorhynchus spp.) and steelhead (anadromous O. mykiss) stocks from the 4 states in the US that appear to be facing a high or moderate risk of extinction are identified. Of these, 1 is threatened, 101 are at a high risk of extinction, 58 are at moderate risk, and 54 are of special concern. About half of the stocks have a high probability of introgression with hatchery stocks. ³ The American Fisheries Society herein provides a list of depleted Pacific salmon, steelhead, and sea-run cutthroat stocks from California, Oregon, Idaho, and Washington, to accompany the list of rare inland fishes reported by Williams et al. (1989). The list includes 214 native naturally-spawning stocks: 101 at high risk of extinction, 58 at moderate risk of extinction, 54 of special concern, and one classified as threatened under the Endangered Species Act of 1973 and as endangered by the state of California. The decline in native salmon, steelhead, and sea-run cutthroat populations has resulted from habitat loss and damage, and inadequate passage and flows caused by hydropower, agriculture, logging, and other developments; overfishing, primarily of weaker stocks in mixed-stock fisheries; and negative interactions with other fishes, including nonnative hatchery salmon and steelhead. A new paradigm that advances habitat restoration and ecosystem function rather than hatchery production is needed for many of these stocks to survive and prosper into the next century.; and negative interactions with other fishes, including nonnative hatchery salmon and steelhead. While some attempts at remedying these threats have been made, they have not been enough to prevent the broad decline of stocks along the West Coast. A new paradigm that advances habitat restoration and ecosystem function rather than hatchery production is needed for many of these stocks to survive and prosper into the next century.

222. Nelson R.L., W.S. Platts, D.P. Larsen, and S.E. Jensen. 1992. Trout distribution and habitat in relation to geology and geomorphology in the North Fork Humboldt River drainage, northeastern Nevada. Transactions of the American Fisheries Society. 121(4):405-26

We studied the existing distribution of native Lahontan cutthroat trout *Oncorhynchus clarki hensahwi* and exotic brook trout *Salvelinus fontinalis* with respect to geologic and geomorphic land-classes in the upper North Fork Humboldt River drainage, Nevada. We evaluated habitat conditions in study sites to determine which measured components of habitat structure provided the best discriminators among study stream reaches in the different land-classes and among trout-supporting and unpopulated study reaches. At a finer level of resolution, we used the habitat attributes with the most discriminatory power to plot the distributions of study areas by land-class and by presence or absence of trout along coordinate axes reflecting environmental gradients defined by these attributes. Elevation, substrate embeddedness, and streamflow were the variables with the most discriminatory power among land-classes defined by parent geologic material (geologic district), but gravel abundance in the substrate was more useful than streamflow in further discriminating among land-classes at the lower-level classification defined by geomorphic character (landtype association). Plots of study areas along environmental gradients defined by these variables visibly separated study areas by land-class. Trout distributions at specific sites were clearly related to geologic district and, to a lesser extent, to landtype association. Trout were almost exclusively restricted to sites in the sedimentary mountains defining the western boundary of the drainage, and occurred elsewhere only in study areas that were upstream from the fine-textured valley floor. Of the variables measured, embeddedness appeared to be the most likely cause of the segregation of trout by geologic district. Although unmeasured variables (e.g., temperature, winter conditions, and turbidity) cannot be eliminated as potential limiting factors, peripheral evidence suggests that they alone probably are not determinants of trout distribution in the region. Trout were common in the sedimentary geologic district, but did not occur in all study sites. Important discriminating attributes in this region were stream width, abundance of large substrate (rubble and boulder), and streamflow trout were principally associated with sites characterized by wider, well-watered stream reaches containing high percentages of large stream-bottom particles. Study sites meeting these criteria were concentrated in high mountain areas influenced by Pleistocene glaciation, but were also present in the fluvial canyons. All sites containing brook trout were in drainages that had been glaciated. These sites would normally be considered "better" trout habitat; native cutthroat trout occupied the more degraded sites.

223. Newcombe C.P. 1994. Suspended sediment in aquatic ecosystems: ill effects as a function of concentration and duration of exposure. British Columbia Ministry of Environment, Lands, and Parks, Victoria, BC, Canada

No abstract provided.

224. Newcombe C.P. and J.O. Jensen. 1996. Channel suspended sediment and fisheries: A synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management. 16:693-727

Our meta-analysis of 80 published and adequately documented reports of fish responses to suspended sediment in streams and estuaries has yielded six empirical equations that relate biological response to duration of exposure and suspended sediment concentration. These equations answer an important need in fisheries management; quantifying the response of fishes to suspended sediment pollution of streams and estuaries has been difficult historically, and the lack of a reliable metric has hindered assessment for risk and impact for fishes subjected to excess sedimentation. The six equations address various taxonomic groups of lotic, lentic, and estuarine fishes, life stages of species within those groups, and particle sizes of suspended sediments. The study also provided best available estimates of the onset of sublethal and lethal effects, and it supported the hypothesis that susceptible individuals are affected by sediment doses (concentration x exposure duration) lower than those at which population responses can be detected. Some species and life stages show "ultrasensitivity" to suspended sediment. When tested against data not included in the analysis, the equations were robust. They demonstrate that meta-analysis can be an important tool in habitat impact assessment.

225. Newcombe C.P. and D.D. MacDonald. 1991. Effects of suspended sediments on aquatic ecosystems. North American Journal of Fisheries Management. 11:72-82

Resource managers need to predict effects of pollution episodes on aquatic biota and suspended sediment is an important variable in considerations of freshwater quality. Despite considerable research, there is little agreement on environmental effects of suspended sediment as a function of concentration and duration of exposure. More than 70 papers on the effects of inorganic suspended sediments on freshwater and marine fish and other organisms were reviewed to compile a database on such effects. Regression analysis indicates that concentration alone is a relatively poor indicator of suspended sediment effects ($r^2 = 0.14$, NS). The product of sediment concentration (mg/L) and duration of exposure (h) is a better indicator of effects ($r^2 = 0.64$, $P < 0.01$). An index of pollution intensity (stress index) is calculated by taking the natural logarithm of the product of concentration and duration. The stress index provides a convenient tool for predicting effects for a pollution episode of known intensity. Aquatic biota respond to both the concentration of suspended sediments and duration of exposure, much as they do for other environmental contaminants. Researchers should, therefore, not only report concentration of suspended sediment but also duration of exposure of aquatic biota to suspended sediments.

226. Nickelson T.E., J.D. Rodgers, S.L. Johnson, and M.F. Solazzi. 1992. Seasonal changes in habitat

use by juvenile coho salmon (*Oncorhynchus kisutch*) in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences. 49(4):783-9

Habitat use by juvenile coho salmon *(Oncorhynchus kisutch)* during spring, summer, and winter was examined in Oregon coastal streams. Coho salmon fry were most abundant in backwater pools during spring. During summer, juvenile coho salmon were more abundant in pools of all types than they were in glides or riffles. During winter, juvenile coho salmon were most abundant in alcoves and beaver ponds. Because of the apparent strong preference for alcove and beaver pond habitat during winter and the rarity of that habitat in coastal streams, we concluded that if spawning escapement is adequate, the production of wild coho salmon smolts in most coho salmon spawning streams on the Oregon Coast is probably limited by the availability of adequate winter habitat.

227. Nielsen J., T.E. Lisle, and V.L. Ozaki. 1994. Thermally stratified pools and their use by steelhead in Northern California streams. Transactions of the American Fisheries Society. 123:613-26

Thermal stratification occurred in pools of 3 rivers in northern California when inflow of cold water was sufficiently great or currents were sufficiently weak to prevent thorough mixing of water of contrasting temperatures. Surface water temperatures in such pools were commonly 3-9^{o}C higher than those at the bottom. Cold water entered pools from tributaries, intergravel flow through river bars and streamside subsurface sources. In Redwook and Rancheria creeks, cold water was protected where gravel bars encroached into pools that were scoured along bedrock banks, creating isolated backwaters. 65% percent of the juvenile steelhead found in the Rancheria Creek study reaches moved into adjacent stratified pools during periods of high ambient stream temperature. Fish showed a decline in forage behavior and increased agonistic activity just before movement into stratified pools on the Middle Fork Eel River throughout summer when midday ambient stream temperature ranged from 26 to 29^{o}C and coldwater pockets averaged 3.5^{o}C cooler. Thermally stratified pools provided refuge habitat for significant numbers of young-of-the-year, yearling and adult steelhead in marginal river habitats where stream temperatures reached upper incipient lethal levels.

228. Nielson J.L. 1995. Evolution and the aquatic ecosystem: defining unique units in population conservation. American Fisheries Society, Symposium #17, Bethesda, MD

It presents the findings and opinions of many important scientists and administrators on the value and feasibility of defining unique units of aquatic populations for the purpose of conservation.

229. Olsen D.S., A.C. Whitaker, and D.F. Potts. 1997. Assessing stream channel stability thresholds using flow competence estimates at bankfull stage. Journal of American Water Resources Association. 33(6):1197-207

Stream channel stability is affected by peak flows rather than average annual water yield. Timber harvesting and other land management activities that contribute to soil compaction, vegetation removal or increased drainage density can increase peak discharges and decrease the recurrence interval of bankfull discharges. Increased peak discharges can cause more frequent movement of large streambed materials, leading to more rapid stream channel change or instability. This study proposes a relationship between increased discharge and channel stability and presents a methodology that can be used to evaluate stream channel stability thresholds on a stream reach basis. Detailed surveys of the channel cross section, water surface slope, streambed particle size distribution and field identification of bankfull stage are used to estimate existing bankfull flow conditions. These site specific stream channel characteristics are used in bed load movement formulae to predict critical flow conditions for entrainment of coarse bed material. The relative bed stability index, defines as a ratio of critical flow condition to the existing condition at bankfull discharge can predict whether increased peak discharges will exceed stream channel thresholds.

230. Omernik J.M. 1995. Ecoregions: A spatial framework for environmental management. W.S. Davis and T.P. Simon, eds. Biological assessment and criteria: Tools for water resource planning and decision making. Lewis Publishers. London, England.

Ecoregions comprise regions of relative homogeneity with respect to ecological systems involving interrelationships among organisms and their environment. The continuous United States was classified into 76 ecoregions by EPA in 1987. Since then efforts have been underway to refine ecoregions and delineate subregions for the purpose of environmental management including development of biocriteria. Reference sites have been based on the pragmatic approach of least-disturbed conditions. The watershed approach to environmental management should be implemented within a natural ecoregional framework that assumes patterns in the combination of geographical characteristics (e.g. soils, geology, physiology, vegetation, and land use) associated with regional differences in ecosystems. The ecoregional framework provides a logical approach for defining reference condition as the basis for program implementation at the watershed scale.

231. Omernik J.M. and R.G. Bailey. 1997. Distinguishing between watersheds and ecoregions. Journal of the American Water Resources Association. 33(5):935-49

In an effort to adopt more holistic ecosystem approaches to resource assessment and management, many state and federal agencies have begun using watershed or ecoregion frameworks. Although few would question the need to make this move from dealing with problems and issues on a case by case or point-type basis to broader regional contexts, misunderstanding of each of the frameworks has resulted in inconsistency in their use and ultimate effectiveness. The focus of this paper is on the clarification of both frameworks. We stress that the issue is not whether to use watersheds (or basins of hydrologic units) or ecoregions for needs such as developing ecosystem management and non point source pollution strategies or structuring water quality regulatory programs, but how to correctly use the frameworks together. Definitions, uses and misuses of each of the frameworks are discussed as well as ways watershed and ecoregions can be and have been used together effectively to meet resource management needs.

232. Omernik J.M. and G.E. Griffith. 1991. Ecological regions versus hydrologic units: frameworks for managing water quality. Journal of Soil and Water Conservation. 46(5):334-40

Water quality assessments need a regional framework that will help to achieve the following: compare regional land and water patterns, establish reasonable chemical and biological standards, predict the effects of management practices and controls, locate monitoring and special study sites, and extrapolate site-specific information to larger areas.

233. Oregon Department of Environmental Quality. 1996. Fact sheets and DEQ's response to public comments on the 1994/1996 listing of water quality limited streams. Oregon Department of Environmental Quality, Portland, OR

No abstract provided.

234. Orsborn J.O. 1990. Quantitative modeling of the relationships among basin, channel and habitat characteristics for classification and impact assessment, with appendices. Washington Department of Natural Resources, TFW Publication #9, Olympia, WA

No abstract provided.

235. Orth D.J. 1987. Ecological considerations in the development and application of in-stream flow habitat models. Regulated Rivers: Research and Management. 1(1):171-81

No abstract provided.

236. Overton C.K., S.P. Wollrab, B.C. Roberts, and M.A. Radko. 1997. R1/R4 (Northern/Intermountain Regions) Fish and fish habitat standard inventory procedures handbook. U. S. Forest Service, GTR-INT-346, Ogden, UT

No author abstract provided.

237. Ozaki V.L. 1987. Geomorphic and hydrologic conditions for cold pool formation on Redwood Creek, California. p 415-6, *in* R.L. Beschta, ed. Erosion and Sedimentation in the Pacific Rim. University of Oregon, IAHS Publication No. 165. Corvallis, OR.

No abstract provided.

238. Parsley M.J. and L.G. Beckman. 1993. White Sturgeon spawning and rearing habitat use in the lower Columbia River. North American Journal of Fisheries Management. 14(4):812-27

Estimates of spawning habitat for white sturgeons in the tailraces of the four dams on the lower Columbia River were analyzed to identify areas with suitable water depths, water velocities, and substrates. The relations between discharge and spawning habitat show that the operation of hydropower system can have large effects on the spawning habitat of white sturgeon. Hydropower production has reduced spring and summer discharges and construction of the dams inundated several rapids and falls that probably provided spawning habitat. Increasing the discharge by restoring a more natural hydrograph during the white sturgeon spawning period would improve the reproductive success of the impoundment populations.

239. Paustian S.J., K. Anderson, D. Blanchet, and et.al. 1992. Channel type user's guide for Tongass National Forest, Southeast Alaska. U. S. Forest Service, Alaska Region,

No author abstract provided.

240. Pearsons T.D., H.W. Li, and G.A. Lamberti. 1992. Influence of habitat complexity on resistance to flooding and resilience of stream fish assemblages. Transactions of the American Fisheries Society. 121:427-36

The structure of fish assemblages in five reaches of a high desert stream in north-central Oregon was determined by snorkeling before and after a summer flash flood and two spring floods. Stream reaches varied in habitat complexity as measured by hydraulic retention. Following the floods, hydraulically complex stream reaches lost proportionately fewer fish, had generally higher fish diversities, and had higher fish assemblage similarity than hydraulically simple stream reaches. Higher fish diversities in complex reaches after floods support predictions of the intermediate-disturbance hypothesis and suggest that fish assemblage resistance may be related to overall habitat complexity in these small streams.

241. Peterson J.T. and S.P. Wollrab. 1999. Analysis of potential stream fish and fish habitat monitoring procedures for the Inland Northwest. U. S. Forest Service, Rocky Mountain Research Station, Boise, ID

No author abstract provided.

242. Peterson N.P., A. Hendry, and T.P. Quinn. 1992. Assessment of cumulative effects on salmonid habitat: Some suggested parameters and target conditions. University of Washington, Timber Fish and Wildlife, TFW-F3-92-001, Seattle, WA

Target conditions based on conditions indicative of the streams of unmanaged forests are presented. The following in-channel target conditions have been established: LWD frequency, percent pool area, and substrate composition. It is noted that a stream classification system, based on such variables as gradient, stream size, and bank material, must be developed.

243. Phillips R.W. 1970. Effects of sediment on the gravel environment and fish production. Oregon State University. Forest land uses and stream environment. Oregon State University. Corvallis, OR.

Research in the field is summarized. Sediment influences fish in several ways. In suspension, 1) it blocks the transmission of light, reducing algae production and 2) it damages the gill membranes, causing death where concentrations are high and exposure is prolonged. When sediment settles on the gravel beds, it is harmful in the following ways: 1) it fills the interstices reducing interchange between surface waters and waters within the gravel bed. This reduces the supply of dissolved oxygen to the egg, and interferes with the removal of metabolites (carbon dioxide and ammonia). 2). Sediment also forms a barrier to fry emergence by blocking the route of egress. 3) Low dissolved oxygen and the physical barrier effect of sediment appear to be additive in reducing survival. 4) Survival after fry emergence is impaired because of a loss of escape cover and a reduction of aquatic organisms that are food for fish. Examples are cited showing that pink and chum salmon survival is inversely related to the amount of sediment in gravel beds.

244. Plafkin J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers. Environmental Protection Agency, EPA/444/4-89-001, Washington, DC

No abstract provided.

245. Platts W.S. 1974. Geomorphic and aquatic conditions influencing salmonids and stream classification- with application to ecosystem classification. U. S. Forest Service, Surface Environment and Mining Project Report, Billings, MT

Investigations were conducted from July 1970 through September 1972 of : the physical structure of aquatic environments in granitic, mountainous lands in Idaho; the relationship between physical stream structure and fish populations; the influence of geomorphic process of aquatic ecosystems; the relation of order within landforms in relation to uniformity in aquatic environments and the potential for classifying aquatic environments from land classification systems.

246. Platts W.S. 1991. Livestock grazing. p 389-423, *in* W.R. Meehan, ed. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society. Bethesda, MD.

No author abstract provided.

247. Platts W.S., C. Armour, D.G. Booth and others. 1987. Methods for evaluating riparian habitats with applications to management. U. S. Forest Service, INT-GTR-221, Ogden, UT

No author abstract provided.

248. Platts W.S., R.J. Torquemada, M.L. McHenry, and C.K. Graham. 1989. Changes in salmon spawning and rearing habitat from increased delivery of fine sediment to the South Fork Salmon River, Idaho. Transactions of the American Fisheries Society. 118(3):274-83

Levels of surface and subsurface fine sediment (<4.75 mm in diameter) were measured annually from 1965 to 1985 in spawning and rearing areas for chinook salmon *Oncorhynchus tshawytscha* and steelhead *O. mykiss* (formerly *Salmo gairdneri*) in the South Fork Salmon River, Idaho. Between 1950 and 1965, logging and road construction, in combination with large storm events of 1964 and 1965, resulted in the delivery of increased amounts of fine sediments to the South Fork Salmon River. Surface and subsurface fine sediment levels peaked at 46% of the surface area in 1966 and 48% of the volume in 1969, respectively. A logging moratorium initiated in 1965, coupled with natural recovery and watershed rehabilitation, led to significant decreases in the amounts of fine sediments delivered to and stored in the South Fork Salmon River; this reduction led to a limited resumption of logging operations within the watershed in 1978. By 1985, surface and subsurface sediment levels in chinook salmon spawning areas averaged 19.7% of the surface area and 25.4% of the volume, respectively. However, additional recovery to pre-logging fine sediment levels is probably contingent on both further watershed recovery and the occurrence of flood flows capable of transporting material downstream. An equilibrium between incoming sediment from the watershed and outgoing sediment from the river appears to have been reached under flow regimes that have occurred since 1975.

249. Poff N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Pertegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. Natural flow regime: paradigm for river conservation and restoration.

BioScience. 47(11):769-82

No abstract provided.

250. Poff N.L. and J.V. Ward. 1990. Physical habitat template of lotic ecosystems: recovery in the context of historical pattern of spatial heterogeneity. Environmental Management. 14:629-45

Spatial and temporal environmental heterogeneity in lotic ecosystems can be quantitatively described and identified with characteristic levels of ecological organization. The long-term pattern of physiochemical variability in conjunction with the complexity and stability of the substratum establishes a physical habitat template that theoretically influences which combinations of behavioral, physiological and life history characteristics constitute appropriate "ecological strategies" for persistence in the habitat. The combination of strategies employed with constrain ecological response to and recovery from disturbance. Physical habitat templates and associated ecological attributes differ geographically because of biogeoclimatic processes that constrain lotic habitat structure and stability and that influence physiochemical variability and disturbance patterns (frequency, magnitude and predictability). Theoretical considerations and empirical studies suggest that recovery from natural and anthropogenic disturbance also will vary among lotic systems, depending on historical temporal variability regime, degree of habitat heterogeneity and spatial scale of the perturbation. Characterization of physical habitat templates and associated ecological dynamics along gradients of natural disturbance would provide a geographic framework for predicting recovery from anthropogenic disturbance for individual streams. Description of lotic environmental templates at the appropriate spatial and temporal scale is therefore desirable to test theoretical expectations of biotic recovery rate from disturbance and to guide selection of appropriate reference study sites for monitoring impacts of anthropogenic disturbance. Historical streamflow data, coupled with stream-specific thermal and substratum - geomorphologic characteristics are suggested as minimum elements needed to characterize physical templates of lotic systems.

251. Poole G.C., C.A. Frissell, and S.C. Ralph. 1997. In-stream habitat unit classification: inadequacies for monitoring and some consequences for management. Journal of American Water Resources Association. 33(4):879-96

Habitat unit classification can be a useful descriptive tool in hierarchical stream classification. However, a critical evaluation reveals that it is applied inappropriately when used to quantify aquatic habitat or channel morphology in an attempt to monitor the response of individual streams to human activities. They should not use habitat unit classification as a means of quantifying and monitoring aquatic habitat and channel morphology. Monitoring must instead focus on direct, repeatable, cost-efficient, and quantitative measures of selected physical, chemical, and biological components and processes spanning several scales of resolution.

252. Pratt K.L. 1984. Habitat use and species interactions of juvenile cutthroat trout (*Salmo clarki lewisi*) and bull trout (*Salvelinus confluentus*) in the upper Flathead River basin. University of Idaho, MS Thesis, Moscow, ID

Habitat use of juvenile westslope cutthroat and bull trout in the upper Flathead basin was evaluated by 2 methodologies. Mapping and density estimation techniques were used to examine juvenile trout use of pool and run-riffle areas within a stream. Specific locations or focal points selected by individual fish were also described.

253. Rahel F.J. and W.A. Hubert. 1991. Fish assemblages and habitat gradients in a rocky mountain-great plains stream: biotic zonation and additive patterns of community change. Transactions of the American Fisheries Society. 120:319-32

We examined the importance of zonation and species additions in explaining longitudinal changes in the fish assemblage of a Rocky Mountain stream that descends onto the Great Plains of Wyoming. Community changes along an elevational gradient from 2,234 to 1,230 m above mean sea level reflected a combination of zonation and downstream addition of species. Zonation was evident on a broad spatial scale as a result of stream temperatures. A coldwater trout (Salmonidae) assemblage dominated headwater reaches but was replaced by a warmwater minnow-sucker (Cyprinidae-Catostomidae) assemblage below 2,000 m. Within the warmwater zone, fish community change was due mainly to the addition of new species downstream. Headwater sites were dominated by members of the insectivore feeding guild, and other trophic guilds were added downstream. The major gradient of habitat change downstream consisted of a decrease in pool habitat and increases in stream width, depth, current velocity, turbidity, and proportion of the channel consisting of run habitat. Minor gradients of habitat change involved streambank condition and substrate particle size. Contrary to streams in forested regions, habitat diversity did not increase downstream, suggesting that increased living space and moderate environmental conditions contributed to the downstream increase in species richness. Local habitat modification due to cattle grazing or alterations in streamflow caused minor changes in fish assemblages but did not disrupt the dominant longitudinal patterns. Broad-scale zonation based on temperature regime and additive patterns within zones should typify other streams originating in montane regions.

254. Raleigh R.F., T. Hickman, R.C. Solomon, and P.C. Nelson. 1984. Habitat suitability information: rainbow trout. U.S. Fish and Wildlife Services FWS/OBS-82/10.60, Washington, DC

The life history of rainbow trout and the habitat parameters required at each life stage have been derived through habitat suitability index curves. Cover, pool -to- riffle ratio, velocity, DO, pH, and temperature requirements are quantified by life stage.

255. Raleigh R.F., W.J. Miller, and P.C. Nelson. 1986. Habitat suitability index models and instream suitability curves: chinook salmon. U.S. Fish and Wildlife Services, Biological Report 82(10.122), Washington, DC

The Habitat Suitability Index models presented in this publication aid in identifying habitat variables required by chinook salmon. Requirements listed include: fluvial type, substrate, fines, canopy cover, velocity, DO, temperature, and pH. These parameters are further quantified by life stage.

256. Ralph S.C., T. Cardoso, G.C. Poole, L.C. Conquest, and R.J. Naiman. 1992. Status and trends of instream habitat in forested lands of Washington. Timber Fish and Wildlife Ambient Monitoring Project - 1989-1991, Biennial Progress Report. University of Washington, Center for Streamside Studies Report to the Washington Department of Natural Resources. Olympia, WA.

No abstract provided.

257. Ralph S.C., G.C. Poole, L.L. Conquest, and R.J. Naiman. 1994. Stream channel morphology and woody debris in logged and unlogged basins of western Washington. Canadian Journal of Fisheries and Aquatic Sciences. 51(1):37-51

Channel morphology and habitat characteristics of stream segments draining unharvested old-growth forests were compared with those from streams within intensively and moderately logged basins. Sites covered a broad geographic range in western Washington State and were stratified by basin area and channel gradient. Although the number of pieces of large woody debris (LWD) within stream channels was unaffected by timber harvest, there was a clear reduction in LWD size in harvested basins. Timber harvest also resulted in a shift in location of LWD towards the channel margins, outside the low-flow wetted width of the channel. Intensive harvest simplified channel habitat by increasing riffle area and reducing pool area and depth, although the commonly used index of pool-to-riffle ratio appears inadequate to document these changes. Given the natural variation from stream to stream, we conclude that simple counts of instream LWD and channel units (habitat types) are not useful as management objectives. Instead, these attributes should be used collectively as indicators of the complexity and stability of in-stream habitat with respect to the specific channel and valley geomorphology.

258. Rankin E.T. 1995. Habitat indices in water resource quality assessments. W.S. Davis and T.P. Simon, eds. Biological assessment and criteria: tools for water resource planning and

decision making. Lewis Publishers. London, England.

Habitat, both instream and riparian, can be the factor most limiting aquatic community potential in streams and rivers. However, water chemistry is often the only one of five major factors (flow regime, chemical variables, biotic factors, energy source, and habitat structure) that are regularly assessed to determine aquatic life use attainment for the Clean Water Act. Most of the habitat indices efforts have been directed towards game/sport fish management rather than towards broader efforts of protecting biointegrity or biodiversity. Ecoregions provide an organizational framework for habitat features since habitat varies by geomorphologic and natural factors used to delineate ecoregions. Common components of habitat quality indices are substrate type and quality, instream physical structure/cover, channel structure/stability/modifications, riparian width/quality, bank erosion, flow/stream gradient, and riffle/run/pool/glide characteristics. Incorporating habitat assessment and biosurveys into Ohio's water quality program has led to substantial improvement in water quality related to improved wastewater treatment, however, the surveys have documented continued decline in habitat.

259. Reeves G.H., L.E. Benda, K.M. Burnett, P.A. Bisson, and J.R. Sedell. 1995. Disturbance-based ecosystem approach to maintaining and restoring freshwater habitats of evolutionarily significant units of anadromous salmonids in the Pacific Northwest. p 334-49, *in* J.L. Nielson, ed. Evolution and the aquatic ecosystem: defining unique units in population conservation. American Fisheries Society Symposium. Bethesda, MD.

To preserve and recover evolutionarily significant units (ESU's) of anadromous salmonids *Oncorhynchus spp*. in the Pacific Northwest, long-term and short-term ecological processes that create and maintain freshwater habitats must be restore and protected. Aquatic ecosystems throughout the region are dynamic in space and times, and lack of consideration of their dynamic aspects has limited the effectiveness of habitat restoration program. Riverine-riparian ecosystems used by anadromous salmonids were naturally subjected to periodic catastrophic disturbances, after which they moved through a series of recovery states over periods of decades to centuries. Consequently the landscape was a mosaic of varying habitat conditions, some that were suitable for anadromous salmonids and some that were not. Life history adaptations of salmon, such as straying of adults, movement of juveniles and high fecundity rates, allowed populations of anadromous salmonid to persist in this dynamic environment. Perspectives gained from natural cycles of disturbance and recovery of the aquatic environment must be incorporated into recovery plans for freshwater habitats. In general, we do not advocate returning to the natural disturbance regime, which may include large-scale catastrophic processes such as stand replacing wildfires. This may be an impossibility given patterns of human development in the region. We believe that it is more prudent to modify human imposed disturbance regimes to create and maintain the necessary range of habitat conditions in space (10^3 km) and time (10^1 - 10^2 years) within and among watershed across the distributional range of an ESU. An additional component of any recovery plan, which is imperative in the short-term, is the establishment of watershed reserves that contain the best existing habitats and include the most ecologically intact watersheds.

260. Reeves G.H., F.H. Everest, and T.E. Nickelson. 1989. Identification of physical habitats limiting the production of coho salmon in western Oregon and Washington. U. S. Forest Service, PNW-GTR-245, Portland, OR

Fishery managers are currently spending millions of dollars per year on habitat enhancement for anadromous salmonids but often do not have the tools needed to ensure success. An analysis of factors limiting production of salmonids in streams must be completed before any habitat-enhancement program is begun. This paper outlines the first formal procedure for identifying physical habitats limiting production of coho salmon.

261. Reeves G.H. and J.R. Sedell. 1992. Ecosystem approach to the conservation and management of freshwater habitat for anadromous salmonids in the Pacific Northwest. Proceedings of the North American Wildlife and Natural Resources Conference. 57:408-15

No abstract provided.

262. Regier H.A. and J.D. Meisner. 1990. Anticipated effects of climate change on freshwater fishes and their habitat. Fisheries. 15(6):10-5

We sketch an iterative assessment process for the effects of climate change on freshwater fisheries that uses water temperature, water quantity, and water quality variables to link the atmosphere to fishery resources. Iterative interaction among atmospheric, ecological, and fisheries scientists clarifies the information needs of each discipline and progressively improves the assessments of effects. The process incorporates information at different scales, i.e., organism/laboratory, species/habitat, and population/ecosystem. We illustrate the operation of the iterative assessment process with recent work done on the water temperature linkage, and sketch some linkages through water quantity and water quality variables. A Wild Salmonid Watch (WSW) could provide a framework for monitoring climate change and its effects on salmonid stocks on a hemispheric scale. We discuss the initial steps required to mobilize a WSW for climate change and its role as climate change develops in the decades ahead.

263. Reice S.R., R.C. Wissmar, and R.J. Naiman. 1990. Disturbance regimes, resilience, and recovery of animal communities and habitats in lotic ecosystems. Environmental Management. 14(5):647-59

Disturbance regime is a critical organizing feature of stream communities and ecosystems. The position of a given reach in the river basin and the sediment type within that reach are 2 key determinants of the frequency and intensity of flow-induced disturbances. We distinguish between predictable and unpredictable events and suggest that predictable discharge events are not disturbances. We relate the dynamics of recovery from disturbance to disturbance regime. The most frequently and predictably disturbed sites can be expected to demonstrate the highest resilience. Spatial scale is an important dimension of community structure, dynamics and recovery from disturbance. We compare the effects on small patches to the effects of large reaches at the river basin level. At small scales, sediment movements and scour are major factors affecting the distribution or populations of aquatic insects or algae. At larger scales, we must deal with channel formation, bank erosion and interactions with the riparian zone that will affect all taxa and processes. Our understanding of stream ecosystem recovery rests on our grasp of the historical, spatial and temporal background of contemporary disturbance events.

264. Reid L.M. and M. Furniss. 1998. On the use of regional channel-based indicators for monitoring. U. S. Forest Service,

State of the art approaches to ecosystem management recognize that different impact mechanisms produce different impacts in different watersheds, so the approaches are designed to provide different management prescriptions in different areas. Despite this level of understanding, there remains a widespread desire to identify an suite of indicators of lotic ecosystem health that are applicable regionally or nationally, and geomorphological attributes of channel form and character have frequently been selected to fill the need. Such attributes, however, often do not satisfy the minimum requirements for a useful environmental indicator. Channel form usually responds slowly to changes in driving variables, the nature of the response differs greatly over small distances, a change in channel form cannot be readily interpreted to infer cause, and trends in channel condition are not necessarily associated with trends in lotic ecosystem condition. In some areas, maintenance of desired ecosystems requires that a range of channel conditions both good and bad be present at any time to ensure that phenotypic and genotypic variability are preserved, that cycles of change which preclude future prime habitats are unbroken and that indirect habitat dependencies are adequately sustained. In such cases, if a monitoring program revealed uniformly good conditions, severe ecological disruption could follow. Geomorphological channel characteristics may well be the most useful and tactable indicators for applications, but which characteristics are relevant and interpretable can be determined only on a case by case basis.

265. Reiser D.W. and J.B. Bradley. 1992. Fine sediment intrusion and salmonid habitat. p 257-64, *in* S.S.Y. Wang, ed. Advances in Hydro-Science and Engineering. Washington, DC.

Overview paper summarizing effects of fine sediment intrusion on salmonid egg survival and indices used to evaluate potential effect. In discussing techniques for monitoring fine sediment deposition, they point out that biological studies (redd counts, outmigration, invertebrates) will provide results too late for initiating preventive action. However, physical measurements of sedimentation in streams will be hampered by the same problem, eg., by the time a problem is detected, sediment has already entered the stream.

266. Reiser D.W. and R.G. White. 1988. Effects of two sediment-size classes on steelhead trout and chinook salmon egg incubation and juvenile quality. North American Journal of Fisheries Management. 8:432-7

We compared, in the laboratory, egg survival, and alevin and fry size of steelhead *Oncorhyncus mykiss* (formerly *Salmo gairdneri*) and chinook salmon *O. tshawytscha* after incubations in 16 mixtures of two distinct size-classes of sediment. Fine sediments were less than 0.84 mm in diameter, and coarse sediments were 0.84-4.6 mm in diameter. We incubated recently fertilized and eyed steelhead eggs and chinook salmon eggs in Whitlock-Vibert boxes placed in controlled-flow channels. Egg survival in both sediment types was inversely related to the percentage of sediments within the incubation gravel; the poorest survival occurred in fine sediments. Percentage egg survival was positively related to intragravel water velocities, which ranged from 36 to 1.550 cm/h. No definitive relationship was found between sediment size and concentration, and alevin and fry quality. Overall, our results indicated that different sizes and mixtures of sediment can affect egg survival differently. The results confirmed that it is the smaller sediments (<0.84 mm) that are the most detrimental to incubating eggs.

267. Reiser J.R. and T.C. Bjornn. 1979. Habitat requirements of anadromous salmonids. U. S. Forest Service, PNW-GTR-96, Portland, OR

No abstract provided.

268. Richards K.S. 1976. Channel width and the riffle-pool sequence. Geologic Society of America Bulletin. 87:883-90

Investigations of channel geometry in a headwater stream in Cornwall, England, reveal that systematic variations of channel width occur in conjunction with the oscillations of bed topography in the riffle-pool sequence. The channel tends to be about 15 percent wider in the riffle section, where central bars of coarse bed material divert the flow against the banks. This is reflected in the occurrence of distinct downstream trends of width as a function of bankfull discharge in riffle and pool sections. There is some evidence that the widest channel occurs just downstream from the summit of the riffle, which indicates that the width oscillation lags behind the profile oscillation, presumably because it is related to flow characteristics induced by bed topography.

269. Rieman B.E. and J.D. McIntyre. 1993. Demographic and habitat requirements of bull trout. U. S. Forest Service, INT-GTR-302, Ogden, UT

Considers the implications of habitat disturbance and land use management. There is a substantial amount of literature with examples of habitat disruption and its effects on salmonid fishes.

270. Rieman B.E. and J.D. McIntyre. 1995. Occurrence of bull trout in naturally fragmented habitat patches of varied size. Transactions of the American Fisheries Society. 124(3):285-96

Biologists have focused on defining and protecting critical stream channel characteristics, but there is little information regarding the scale or spatial geometry of habitat that may be necessary for the species long-term persistence. The influence of habitat patch size on the occurrence of bull trout was investigated by determining the presence or absence of fish in naturally fragmented watersheds of the Boise River basin in Idaho. Our results support the hypothesis that area of available habitat influences the distribution of disjunct populations of bull trout. An area effect is consistent with the predictions of island biogeography and metapopulation theory, and our work suggests that larger-scale spatial processes may be important to the persistence of species like bull trout.

271. Robison E.G. and R.L. Beschta. 1990. Coarse woody debris and channel morphology interactions for undisturbed streams in southeast Alaska, U.S.A. Earth Surface

Processes and Landforms. 15:149-56

Coarse woody debris and channel morphology were evaluated for five low gradient streams that ranged from first to fourth order. Debris volumes were directly related to variations in bankfull width. Woody debris was associated with 65 to 75 percent of all pools and the relative proportion of types varied with stream size. High variability in channel depths and widths was common. The result provide benchmark values of woody debris loadings and channel morphology for undisturbed coastal Alaskan stream systems.

272. Roderick E. and R. Milner. 1991. Management recommendations for Washington's priority habitats and species. Washington Department of Wildlife, Olympia, WA

No abstract provided.

273. Rondorf D.W. and K.F. Tiffan. 1994. Identification of the Spawning, Rearing, and Migratory Requirements of Fall Chinook Salmon in the Columbia River Basin. Bonneville Power Administration, DOE/BP-21708-3, Portland, OR

Spawning habitat availability was assessed by applying hydraulic and habitat models to known fall chinook salmon spawning sites. Using a total effective area model, suitable spawning habitat was that which successfully met slope, depth, velocity, substrate and scour criteria.

274. Roper B.B. and D.L. Scarnecchia. 1995. Observer variability in classifying habitat types in stream surveys. North American Journal of Fisheries Management. 15(1):49-53

We report on the ability of trained observers to independently classify habitat units within stream reaches into primary (pools, riffles, and glides) and secondary (types of pools and types of riffles) habitat types. Differences among observers in classifying habitat types increased with the number of habitat types and decreased with level of observer training. Observer variability also seemed to be affected by reach-specific physical attributes, such as gradient and the amount of wood in the stream channel. Attempts to classify stream habitats will be more consistent and useful if observers receive sufficient uniform training and are required to distinguish between fewer habitat types.

275. Rosgen D.L. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Spings, CO

It is critical that prescribed fisheries habitat improvement guidelines such as: desired width/depth; riffle/pool and step/pool sequence; and debris spacing be established as functions of slope and stream width. These morphological variables are mathematically described and integrated with the inherent capabilities and system response characteristics by specific morphological stream types.

276. Rosgen D.L., H.L. Silvey, and J.P. Potyondy. 1986. Use of channel maintenance flow concepts in the Forest Service. Hydrological Science and Technology. 2(1):19-26

A channel maintenance flow procedure developed by the USDA Forest Service is described. Channel maintenance flows consist of a specified range and duration of flows designed to provide for the self maintenance of stream channels. If such flows are not available, stream channels will in the long term accumulate sediment, accelerate bank erosion, and increase the potential for vegetation encroachment and other processes which reduce their capacity to pass flood flows. Increased streambank erosion, increased lateral extension, encroachment of floodplains, and increased risk of flood damage potentially result due to channel adjustment from flow reduction. Channel maintenance flows are developed for projects on National Forest lands where diminished natural stream flows are proposed.

277. Ruggles C.P. 1966. Depth and velocity as a factor in stream rearing and production of juvenile coho salmon. Canadian Fish Culturist. 38:37-53

Coho salmon smolt production was measured in four artificial stream channels. Two years data are presented on the effect of depth and velocity on fish food production, smolt production and fish behavior. A known number of wild coho fry were introduced to each channel and allowed to take up residence in the channel on a volitional basis. The amount of downstream migration was influenced by the availability of low velocity water. Over twice as many fry remained in a pool-like environment as in a riffle-like condition; an intermediate number remained when the depth-velocity situation was somewhere between pool-riffle. Whereas fish preferred the pool-like environment, fish food production was much higher in the riffle-like environment. The most coho smolt production occurred in a channel composed of one-half riffle and one-half pool. Differences in behavior were noted between coho fry which had migrated upstream of their place of emergence and fry which had moved downstream from their place of emergence.

278. Ryan S.E. and G.E. Grant. 1991. Downstream effects of timber harvesting on channel morphology in Elk River basin, Oregon. Journal of Environmental Quality. 20:60-72

Downstream effects, a type of cumulative watershed effect, were identified using changes in the width and distribution of open riparian canopies measured from aerial photography taken between 1956 and 1979 in Elk River basin, southwest Oregon. Open canopies appear on aerial photographs of densely forested basins as unvegetated areas bordering stream channels. Opening occurs when large disturbances, such as landslides, debris flows, large floods, and excessive sedimentation, disrupt the vegetation in the riparian corridor. Downstream changes in channel morphology, inferred by the changing pattern of open reaches were linked to upslope forestry activities; a causal link was assumed where; (1) open reaches extended continuously downstream from clearcuts and roads or (2) the timing and pattern of opening downstream varied in direct relation to the intensity of upslope forestry activities. Open riparian canopies were observed in first- through fifth-order channels, though only 11% of open reaches in low-order channels were spatially connected to reaches in higher order. Limited downstream change in riparian canopies associated with upslope forestry activity during the study period, which included a 100-yr storm, was attributed to three physical factors: (1) lack of debris flows in most parts of the basin; (2) channels constrained by competent hillslope limiting the potential for opening, and (3) low harvest levels over much of the basin at the time of the 100-yr storm.

279. Saffel P.D. and D.L. Scarnecchia. 1995. Habitat use of juvenile bull trout in belt-series geology watershed of northern Idaho. Northwest Science. 69(4):304-16

Bull trout, a native char of the Pacific Northwest, has declined in abundance and distribution in recent years. Little is known about the habitat use by salmonids in streams with substrate characterized by Belt-Series geology. Such information could be used by managers to evaluate potential effects of land use practices on the species, or to enhance or protect existing habitat. A total of 28 pools, 60 riffles and 46 runs we sampled in 14 reaches of 4 streams to determine habitat use of age 0 and age $\geq$1 juvenile bull trout in 3 habitat types and in channel margins and main channels. Age 0 bull trout used habitat types in equal proportion to availability, whereas age $\geq$1 juvenile bull trout selected pools and avoided riffles. Lateral position within the stream channel differed with age class: 88% of the age 0 fish were in the channel margins, whereas 91% of the age $\geq$ 1 fish were in the main channel. In addition to the habitat use study, 18 reaches in 6 streams were studied to determine habitat characteristics that influence abundance and distribution of juvenile bull trout. Reaches with high densities of bull trout had maximum summer temperatures. Density of juveniles in reaches increased with the number of pocket pools/100m. The combination of number of pocket pools and maximum summer temperature explained nearly 2/3rds. of the variation in density of juvenile bull trout.

280. Schuster E.G. and H.R. Zurring. 1986. Quantifying the unquantifiable. Journal of Forestry. 25-30

No author abstract provided.

281. Seaber P.R., F.P. Kapinos, and G.L. Knapp. 1987. Hydrologic unit maps. U. S. Geological Survey, Open File Report #84-708, Corvallis, OR

A set of maps depicting approved boundaries of and numerical codes for river-basin units of the U. S. has been developed by the USGS. These state hydrologic unit maps are 4-color maps that present information on drainage, culture, hydrography, and hydrologic boundaries and codes.

282. Sedell J.R., P.A. Bisson, and J.A. June. 1980. Ecology and habitat requirements of fish

populations in South Fork Hoh River, Olympic National Park. p 47-63, *in* . Proceedings, 2nd conference on scientific research in national parks. National Park Service, NPS/ST-80/02/7. Washington, DC.

No abstract provided.

283. Sedell J.R., P.A. Bisson, F.J. Swanson, and S.V. Gregory. 1988. What we know about large trees that fall into stream and rivers. U. S. Forest Service, PNW-GTR-229, Portland, OR

The most productive habitats for salmonid fish are small streams associated with mature and old-growth coniferous forests where large organic debris and fallen trees greatly influence the physical and biological characteristics of such streams.

284. Sedell J.R., G.H. Reeves, F.R. Hauer, and J.A. Stanford. 1990. Role of refugia in recovery from disturbance: modern fragmented and disconnected river systems. Environmental Management. 14:711-24

Habitats or environmental factors that convey spatial and temporal resistance and or resilience to biotic communities that have been impacted by biophysical disturbances may be called refugia. Most refugia in rivers are characterized by extensive coupling of the main channel with adjacent streamside forest, floodplain features, and ground water. These habitats operate at different spatial scales, from localized particles, to channel units such as pools and riffles, to reaches and longer sections and at the basin level. A spatial hierarchy of different physical components of a drainage network is proposed to provide a context for different refugia. Examples of refugia operating at different spatial scales, such as pools, large woody debris, floodplains, below dams and catchment basins are discussed. We hope that the geomorphic context proposed for examining refugia habitats will assist in the conservation of pristine areas and attributes of river systems and also allow a better understanding of rehabilitation needs in rivers that have been extensively altered.

285. Sedell J.R., F.J. Swanson, and S.V. Gregory. 1984. Evaluating fish response to woody debris. p 222-45, *in* T.J. Hassler, ed. Proceedings: Pacific Northwest Stream Habitat Management Workshop. Humboldt State University. Arcata, CA.

Fish respond favorably to debris in streams. Pristine streams contain vast amounts of large wood in their channels and along their edges. For decades the principal tool for fish habitat management has been debris jam removal. We examine the evidence for evaluation the role coarse woody debris plays in the geomorphology of streams, specifically: longitudinal profiles, channel patterns and position, channel geometry, sediment and organic matter storage and channel dynamics. From this debris: blockage to migration, water quality and summer and winter rearing habitat. The issue of current management practices for providing wood inputs to stream is discussed in terms of the question how much wood is enough.

286. Sedell R.J., G.H. Reeves, and P.A. Bisson. 1997. Habitat policy for salmon in the Pacific Northwest. D.P. Strouder, P.A. Bisson, and R.J. Naiman, eds. Pacific Salmon and Their Ecosystems. Chapman and Hall. New York, NY.

While federal forest lands are expected to anchor the recovery of some salmon stocks in the future, the location of these lands regionally and within river basins prevents then from serving as refugia for many salmon stocks that inhabit coastal lowlands containing urban, agricultural, and nonfederal forests. Comprehensive, region-wide improvement in aquatic ecosystems can only occur when habitat policy decisions are shared among affected natural resource users and when watershed-scale strategies are implemented that identify and protect remaining nodes of productive habitat and seek to restore riparian corridors and greenway systems, which reduce habitat fragmentation, are implemented.

287. Sheppard J.D. and J.H. Johnson. 1985. Probability-of-use for depth, velocity, and substrate by subyearling coho salmon and steelhead in Lake Ontario tributary streams. North American Journal of Fisheries Management. 5:277-82

Probability of use information for depth, velocity, and substrate by subyearling coho salmon and steelhead in three New York tributaries of Lake Ontario was obtained during June and October in 1980. In June, coho salmon occurred predominantly in areas with mean velocities of 3.0 - 0.70 ft/second and at depths of 2.00 - 2.40 ft, whereas steelhead occupied habitats with mean velocities of 0.40 - 0.80 ft/second and depths of 0.30 - 0.50 ft. In October, subyearling coho salmon were found in areas with mean velocities of 0.00 - 0.30 ft/second and at depths of 1.50 - 2.80 ft while steelhead occurred at depths of 0.60 1.20 ft where mean velocities 0.10 - 0.80 ft/second. Subyearling coho salmon occurred over gravel-cobble substrates during both seasons, whereas steelhead where found in areas with substrate material of larger sizes in the autumn. Observed seasonal differences in the habitat and flow preferences of both species were completely masked when the data were pooled to yield a single estimate for depth and mean velocity. Variations in the probability of use for these habitat parameters may be related to seasonal differences in fish size and the physical characteristics of the streams.

288. Shirvell C.S. 1990. Role of instream root wads as juvenile coho salmon and steelhead trout cover habitat under varying streamflows. Canadian Journal of Fisheries and Aquatic Sciences. 47:852-61

Coho salmon fry and steelhead parr occupied previously infrequently used mid-channel areas of Kloiya Creek, British Columbia, Canada, once artificial rootwads were placed there. 99% of all coho salmon fry and 83% of steelhead parr occupied positions downstream of natural or artificial rootwads during artificially created drought, normal and flood streamflows. Fish associated with rootwads regardless of distance from shore, but steelhead parr increased their use of artificial and natural rootwads where light remained low during droughts. Young fish apparently selected areas having slower water 80% of the time because they provided shelter from adverse current, and areas having reduced light intensities 20% of the time because they provided protection from predators. Juvenile coho salmon and steelhead in Kloiya Creek selected locations with slower water velocities and reduced light intensities irrespective of the physical structure that caused them.

289. Siedelman D.L. and P.D. Kissner. Importance of large organic debris for rearing chinook salmon habitat. p 26-30, *in* W.R. Heard. Report of the 1987 Alaska chinook salmon workshop. National Marine Fisheries Service. Auke Bay, AK.

No abstract provided.

290. Silver S.J., C.E. Warren, and P. Duodorf. 1963. Dissolved oxygen requirements of developing steelhead trout and chinook salmon embryos at different water velocities. Transactions of the American Fisheries Society. 92(4):327-43

Embryos of steelhead trout, *Salmo gairdneri gairdneri Richardson*, and chinook salmon, *Oncorhynchus tshawtscha (Walbaum)*, were reared from fertilization of the eggs to hatching at different constant oxygen concentrations and water velocities. For this purpose, an apparatus was developed that makes it possible to control oxygen concentration independently of water velocity, which was maintained at levels ranging from 6 to 1,350 centimeters per hour. Measurements of the embryos and hatched fry indicate that water velocities must be high enough not only to transport enough oxygen to the redd for supplying the total requirement of all embryos, but also to deliver sufficient oxygen to the surface of the chorion enveloping the individual embryo. Steelhead embryos held at 9.5°c and chinook salmon embryos held at 11° c all died at an oxygen concentration of 1.6 mg/l. Survival of large percentages of embryos reared at concentration as low as 2.5 mg/1 was apparently made possible by reduction of respiration rates and consequent reduction of growth and development rates. Sac fry from embryos reared at low and intermediate oxygen concentrations were smaller and weaker than sac fry from embryos reared at high concentrations. Although weak sac fry may survive under laboratory conditions, they cannot be expected to do so in nature. The size of steelhead trout and chinook salmon fry at hatching probably was dependent on water velocity even at velocities as high as 740 and 1,350 cm/hr, respectively, and on oxygen concentration even at concentrations near saturation levels. Mean size differences among embryos reared under different conditions at the higher velocity and oxygen-concentration levels were not great, particularly in the case of the steelhead trout.

291. Smith A.K. 1973. Development and application of spawning velocity and depth criteria for Oregon

salmonids. Transactions of the American Fisheries Society. 102:809-16

Water velocity and depth criteria were developed to formulate recommended stream flows for spawning of Oregon salmonids. Criteria have additional application in the design of artificial spawning channels. About 1,170 redd measurements of 10 species and races were made during a 10-year-period. Mean redd velocities ranged between 0.11 and 0.73 m/sec and depths between 0.22 and 0.43 m for all species. A velocity range and minimum depths were found for each species which included 80% of the measurements with 95% confidence.

292. Southerland M.T. and J.B. Stribling. 1995. Status of biological criteria development and implementation. p 81-96, *in* W.S. Davis and T.P. Simon, eds. Biological assessment and criteria: tools for water resource planning and decision making. Lewis Publishers. Boca Raton, FL.

No abstract provided.

293. Southwood T.R.E. 1977. Habitat, the template for ecological strategies? Journal of Animal Ecology. 46:337-65

It has been presented that the definition of habitats, or rather lack of it, is the one chief blind spot in Zoology. That although patterns may underlie, there is no single pattern. The multitude of ecological strategies that are observed in nature arise from the evolutionary trade-offs of cost versus benefit in the process of adaptation to habitats. Natural habitats have at least eight quantitative characters and these must be assessed against the organisms own dimensions in space and time. It is suggested that these characters be condensed into two axes: durational stability, which assesses spatial heterogeneity against time, and resource level and constancy, which expresses the temporal heterogeneity of the same space.

294. Spence B.C., G.A. Lomnicky, R.M. Hughes, and R. Novitzki. 1996. Ecosystem approach to salmonid conservation. Part II: Planning elements and monitoring strategies. Management Technology, TR-501-96-6057

Published data on habitat attributes in unmanaged systems may provide coarse level metrics for assessing whether a stream segment may be degraded. Published data has been reviewed and conceptual and numeric recommendations have been made on the following habitat attributes: channel type, large woody debris, pool frequency and quality, bank stability, substrate composition, and riparian buffers.

295. Spooner J., R.P. Maas, S.A. Dressing, M.D. Smolen, and F.J. Humenik. 1985. Appropriate designs for documenting water quality improvements for agricultural NPS control programs. p 30-4, *in* Environmental Protection Agency. Perspective on nonpoint source pollution. Environmental Protection Agency, EPA 44/5-85-001. Washington, DC.

Appropriate experimental designs are a function of the question to be answered. In the case of agricultural NPS control programs, the question is usually How does BMP implementation affect the magnitude of pollutant concentrations or loads? This paper discusses the assumptions, analysis techniques, and advantages and disadvantages of three basic experimental designs that can be used in practical terms. Monitoring above and below an implementation site is generally more useful for documenting the severity of an NPS than for documenting BMP effectiveness. Time trend designs may be helpful, however, water quality trends at a result of complex interactions between land treatment, hydrology and meteorological factors. Accounting for these variables will therefore greatly increase the probability of documenting water quality improvements from BMP implementation because of the ability to control for meteorologic and hydrologic variability.

296. Stoltenberg C.H. 1977. Resolving forest use conflicts. p 3, *in* Oregon State University. Forest Land Uses and Stream Environment. Oregon State University. Corvallis, OR.

With rapidly growing demands for every forest use and benefit, and a shrinking resource base, use conflicts must be resolved by harmonizing uses rather than separating them. Folklore on irreconcilable conflicts must be replaced by research-based facts on impacts and trade-offs. Resolving use conflicts so that net benefits are maximized will require greater attention to the quantification of all benefits, to alternative methods of achieving these benefits and to estimating more specifically, precisely and reliably the effects of resource practices on net benefits. Improved understanding of benefits, methods and impacts is needed by all who influence resource decisions if we are to even approach the goal of net-benefit maximization.

297. Sullivan K. 1986. Hydraulics and fish habitat in relation to channel morphology. John Hopkins University, PhD. Dissertation, Baltimore, MD

The purpose of this study was to determine the hydraulic organization of morphologically complex channels in headwaters streams and to determine the extent to which that organization affects the distribution of fish. Hydraulic characteristics were measured in third and fourth order gravel bedded streams in western Washington over the range of annual flow conditions from summer low flow to bankfull stormflow.

298. Swales S., R.B. Lauzier, and C.D. Levings. 1986. Winter habitat preferences of juvenile salmonids in two interior rivers in British Columbia. Canadian Journal of Zoology. 64:1506-14

The winter distribution and abundance of juvenile salmonids was investigated in various main channel and off-channel habitats in the Coldwater and Nicola rivers in the southern interior region of British Columbia. Catches were generally low in all main channel habitats, with coho salmon and steelhead trout being most abundance and chinook salmon and dolly varden char being present in smaller numbers. Coho salmon and steelhead trout catches were generally highest in pools with abundant instream and riparian cover. Steelhead trout was the main species in riprap bank protected areas, although catches were generally low. Highest overall catches were recorded in side channels and off-channel ponds, where water temperatures were usually several degrees higher than in the main river. Coho salmon was the main species in the 2 Coldwater off-channel ponds with overwintering populations of approximately 400 and 100 in 1- and 0.1 ha ponds, respectively: overwinter survival of coho salmon in the ponds was estimated to be 87 and 54 respectively. High densities of coho salmon were also recovered in side channels on the Nicola River, together with smaller numbers of chinook salmon and steelhead trout. Growth in ponds and side channels appeared to be faster than in main channel habitats. We conclude that juvenile salmonids in the rivers investigated showed considerable habitat segregation during the winter. As in coastal rivers, juvenile coho salmon made extensive use of off-channel ponds, while rainbow trout and chinook salmon were generally most abundance in riprap and deep pools containing log debris, respectively.

299. Swanson F.J. 1978. Physical consequences of large organic debris in Pacific Northwest streams. U. S. Forest Service, PNW-GTR-69, Portland, OR

Large organic debris in streams controls the distribution of aquatic habitats, the routing of sediment through stream systems, and the stability of streambed and banks. Management activities directly alter debris loading by addition or removal of material and indirectly by increasing the probability of debris torrents and removing standing streamside trees. We propose that by this combination of factors the character of small and intermediate-sized streams in steep forested terrain of the Pacific Northwest is being substantially altered by forest practices.

300. Swanson F.J., L.E. Benda, S.H. Duncan, G.E. Grant, W.F. Megahan, L.M. Reid, and R.R. Ziemer. 1987. Mass failure and other processes of sediment production in Pacific Northwest forest landscapes. p 9-38, *in* E.O. Salo and T.W. Cundy, eds. Streamside Management: forestry and fishery interactions. University of Washington. Seattle, WA.

Accelerated sediment production by mass failures and other erosion processes is an important link between management of forest resources and fish resources. Dominant processes and the rates of sediment production vary greatly through the Pacific Northwest in response to geologic and climatic factors. The complex sediment routing systems characteristic of the area involve numerous processes that move soil down hillslopes and sediment through channels. Sediment routing models and sediment budgets offer conceptual and quantitative descriptions of movement and storage of soil and sediment in drainage basins. Temporal and spatial patterns of sediment production and routing through basins have many direct and indirect effects on fish.

301. Swanson F.J., M.D. Bryant, G.W. Lienkaemper, and J.R. Sedell. 1984. Organic debris in small streams, Price of Wales Island, Southeast Alaska. U. S. Forest Service, PNW-GTR-166, Portland, OR

Quantities of coarse and fine organic debris in streams flowing through areas clearcut before 1975 are 3 and 6 times greater than quantities in streams sampled in old-growth stands in Tongass National Forest, central Prince of Wales Island, southeast Alaska. The concentration of debris in streams of clearcut Sitka-spruce-western-hemlock forests in southeast Alaska, however, is about half that in streams of clearcut Douglas-fir-western-hemlock forests in western Oregon. Management guidelines for maintaining natural debris conditions include minimizing the addition of fresh material to a channel during management activities, leaving natural accumulations of debris, and managing streamside areas for production of a continuous, long-term supply of large debris for channels. Considerations in planning stream cleanup include the length of time the debris has resided in the channel and the stability of debris, which is a function of its size, orientation and degree of burial and decay.

302. Swanston D.N. 1977. Principal mass movement processes influenced by logging, road building, and fire. p 29, *in* Oregon State University. Forest Land Uses and Stream Environment. Oregon State University. Corvallis, OR.

Dominant natural soil mass movement processes active on watershed of the western United States include 1) debris avalanches, debris flows and debris torrents; 2) slumps and earth flows; 3) deep-seated soil creep and 4) dry creep and sliding. A dominant characteristics of each is steep slope occurrence, frequently in excess of the angle of stability of the soil. All but dry creep and sliding occur under high soil moisture conditions an usually develop or are accelerated during periods of abnormally high rainfall. Further, all are encouraged or accelerated by destruction of natural mechanical support on the slopes. Logging, road building and fire play an important part in initiation and acceleration of these soil mass movement. Road building stands out at the present time as the most damaging activity, with soil failures resulting largely from slope loading, back-slope cutting and inadequate slope drainage. Logging and fire affect stability primarily through destruction of natural mechanical support for the soils, removal of surface cover and obstruction of main drainage channels by debris.

303. Symons P.E.K. and M. Heland. 1978. Stream habitats and behavioral interactions of underyearling and yearling Atlantic salmon (*Salmo salar*). Journal of the Fisheries Research Board of Canada. 35(2):175-83

From an examination of over 20 yr of data from the Northwest Miramichi River and some additional data from small tributaries to the Nashwaak River, highest densities of 100 underyearling and 80 yearling or older Atlantic salmon *(Salmo salar)* per 100 m^2 were found at sites where water velocities averaged 50-65 cm/s. At sites with lower or higher water velocities maximum observed densities decreased. Experiments in laboratory streams demonstrated that underyearling Atlantic salmon < 7 cm (total length) occurred in shallow (10-15 cm) pebbly (1.6-6.4 cm diam) riffles of natural streams by choice. As they grew they began to prefer deeper (> 30 cm) riffles with boulders (> 25.6 cm diam). Yearlings > 10 cm reduced the numbers of underyearlings < 6 cm in these deeper habitats by chasing them, and occasionally by catching and eating them. Social interactions, such as displays used in territorial defense, did not occur between yearlings and underyearlings until the latter exceeded 6.5 cm, the size at which they began to move to deeper riffles. Planting densities for hatchery-reared salmon recommended in the literature were refined, taking the space and habitat requirements of different-sized juvenile salmon into account.

304. Taylor C.A., M.L. Warren, J.F. Fitzpatrick, H.H. Hobbs, R.F. Jezerinac, W.L. Pflieger, and H.W. Robison. 1996. Conservation status of crayfishes of the United States and Canada. Fisheries. 21(4):25-38

This review by the American Fisheries Society Endangered Species Committee contains a list of all crayfishes (Astacidae and Cambaridae) in the USA and Canada, including their state and provincial distributions, and the conservation status of all taxa. The list contains 338 native crayfishes, of which 2 (<1%) of taxa are listed as endangered and possibly extinct, 65 (19.2%) as endangered; 45 (13.3%) as threatened, 50 (14.8%) as of special concern, and 176 (52.0%) as showing a stable population. it is suggested that a limited natural range is the primary factor responsible for those species that are at risk; other threats include habitat alteration and the introduction of non-indigenous crayfishes. It is concluded that almost 50% of crayfishes in the USA and Canada should be recognized as needing conservation. ³ The American Fisheries Society (AFS) Endangered Species Committee herein provides a list of all crayfishes (families Astacidae and Cambaridae) in the United States and Canada that includes state and provincial distributions; a comprehensive review of the conservation status of all taxa; and references on biology, conservation, and distribution of crayfishes. The list contains 338 native crayfishes, of which 2 (<1%) taxa are listed as endangered, possibly extinct; 65 (19.2%) as endangered; 45 (13.3%) as threatened; 50 (14.8%) as special concern; and 176 (52.0%) as currently stable. Limited natural range is implicated as the primary factor responsible for the noted imperilment of crayfishes; other threats include habitat alteration and the instruction of nonindegenous crayfishes. Using the best available information, we estimate that almost 50% of crayfishes in United States and Canada are in need of conservation recognition. We hope that this report spurs increased research efforts from aquatic biologists and proactive actions by resource personnel, citizens, and lawmakers.

305. The Independent Scientific Group. 1996. Return to the river: Restoration of salmonid fishes in the Columbia River ecosystem. Northwest Power Planning Council,

This document analyses existing data and measures currently in the Council's Fish and Wildlife program, and draw conclusions based on that analysis. Habitat standards are conceptually discussed and temperature thresholds are numerically expressed. Consequently, it is noted that the most promising way to help salmon populations rebuild is to reduce or remove conditions that limit the restoration of high quality salmon habitat at each of their life history stages.

306. Thurow R.F. and J. King. 1991. Effects of fine sediment on fish population. U. S. Forest Service, Intermountain Research Station, Boise, ID

To describe conditions in natural redds of steelhead trout, we evaluated the particle size distributed of egg pockets, redd pits and tailspills, artificially constructed redds, and undisturbed substrate outside redds. Egg pockets were located in upper strata, below the substrate surface. Egg pockets contained fewer fines than other sites, except in artificial redds. As substrate depth increased, percent fines among sites was reduced. We observed no change in percent fines sampled from May to July, except in cleaned intrusion sites where free interstitial areas rapidly accumulated sediments. Dissolved oxygen levels declined in redds during incubation. Limitations of the data are discussed.

307. Tinkler K.J. 1970. Pools, riffles, and meanders. Geological Society of America Bulletin. 81:547-52
The conventional view of pools and riffles in straight channels being identified with bends and inflections in meander trains in challenged; the alternative identification, pools and riffles inflections and bends is argued. Difficulties inherent in the conventional view are outlined and it is shown that the alternative is consistent with Bagnold's idea of "breakaways" when the radius of curvature is in the region of 2-3. The conflict could be resolved by experimental observation.

308. Triska F.J. 1984. Role of wood debris in modifying channel geomorphology and riparian areas of a large lowland river under pristine conditions: a historical case study. Internationale Vereinigung Fur Theoretische Und Angewandte Limnologie Verhandlungen. 22:1876-92

Effectiveness of wood as habitat depends on the size and number of logs, the state of log decay and physical orientation of logs in the channel. Wood debris is occasionally a major pool of organic carbon and a factor in overall geomorphology of rivers in many sections of the United States. This report concerns the role of wood debris in modifying channel morphology and riparian habitats of the Red River in Louisiana, before, during, and after removal in 1873 of a complex series of debris jams initiated by clumping massive numbers of logs during floods.

309. U. S. Fish and Wildlife Service. 1998. Framework to assist in making endangered species act

determination of effect for individual or grouped actions at the bull trout subpopulation watershed scale - DRAFT. U. S. Fish and Wildlife Service

No author abstract provided.

310. U. S. Forest Service and Bureau of Land Management. 1995. Decision Notice/Decision Record. Finding of no significant impact environmental assessment, for the interim strategies for managing anadromous fish-producing watersheds in eastern Oregon and Washington, Idaho, and portions of California. U. S. Forest Service and the Bureau of Land Management,

PACFISH was developed as an interim strategy designed to halt the degradation and begin restoration of anadromous fish habitat until comprehensive studies for long-term management strategies are completed. This document has set quantitative interim objectives for the following habitat attributes: pool frequency, temperature, LWD, bank stability, bank angle, and width-to-depth.

311. U. S. Forest Service and Bureau of Land Management. 1997. Interior Columbia Basin ecosystem management project, Upper Columbia River Basin Environmental Impact Statement. U. S. Forest Service and the Bureau of Land Management,

The ICRBEIS was designed to refine PACFISH concepts, improve interim strategies, and provide for species viability on an ecosystem basis, rather than a species-by-species approach. Riparian Management Objectives have been quantitatively identified and are subject to scientific review of the EIS.

312. U. S. Forest Service, National Marine Fisheries Service, Bureau of Land Management, U. S. Fish and Wildlife Service, National Park Service, and Environmental Protection Agency. 1993. Forest ecosystem management: an ecological, economic, and social assessment. U. S. Forest Service, Pacific Northwest Region, Portland, OR

Initial dimensions of riparian reserves have been established, that are subject to revision through results of a watershed analysis. No quantitative standards are set for aquatic habitat and such approaches are argued against. It is suggested that quantitative targets be set at the watershed scale.

313. Utter F.M., D.W. Chapman, and A.R. Marshall. 1995. Genetic population structure and history of chinook salmon of the upper Columbia River. p 149-65, *in* J.L. Nielson, ed. Evolution and the aquatic ecosystem: defining unique units in population conservation. American Fisheries Society Symposium. Bethesda, MD.

Chinook salmon *Oncorhynchus tshawytscha* that return to the upper Columbia River (upstream from the confluence of the Yakima River) are considered from the perspectives of allelic variation at 32 polymorphic loci, historical activities within this region, and ancestral affinities to downstream populations. Collections of summer-fall-run fish are distinguished from spring-run fish by an eightfold greater genetic distance between groups than exists within either group. Each group was related to but remained distinct from adjacent downstream groups within different major ancestral units, previously identified throughout the Columbia River. Summer-fall-run fish are most closely related to fall-run fish of the mid-Columbia and Snake rivers, and spring-run fish to the spring-summer-run fish of the Snake River. In both groups, the present geographic distributions and genetic population structures within the upper Columbia River reflect translocations, confinements, and cultural activities between 1939 and 1943 under the Grand Coulee Fish Maintenance Project, and subsequent introductions and fish culture. The considerable genetic homogeneity within the summer-fall-run group appears to have been maintained through past and present interbreedings and strayings over a single continuous run. Some degree of genetic distinction persists between cultured and wild spring-run fish; the cultured fish are genetically indistinguishable from their ancestral source of the downstream Carson Hatchery, derived during the 1950s from fish returning to the upper Columbia and Snake rivers. The entire summer-fall-run group and the wild component of the spring-run group qualify for consideration as different variation within these groups focus on measures that restrict excessive gene flow and permit maintenance and development of local adaptations.

314. Vannote R.L., G.W. Minshall, and K.W. Cummins. 1980. River continuum concept. Canadian Journal of Fisheries and Aquatic Sciences. 40:452-61

From headwaters to mouth, the physical variables within a river system present a continuous gradient of physical conditions. This gradient should elicit a series of responses within the consistent populations resulting in a continuum of biotic adjustments and consistent patterns of loading, transport, utilization and storage of organic matter along the length of a river. Based on the energy equilibrium theory of fluvial geomorphologists, we hypothesize that the structural and functional characteristics of stream communities are adapted to conform to the most probable position or mean state of the physical systems. We reason that producer and consumer communities characteristics of a given river reach become established in harmony with the dynamic physical conditions of the channel. In natural stream systems, biological communities can be characterized as forming a temporal continuum of synchronized species replacements. This continuous replacement functions to distribute the utilization of energy inputs over time. Thus, the biological system moves towards a balance between a tendency for efficient use of energy inputs through resource partitioning and an opposite tendency for a uniform rate of energy processing through the year. We theorize that biological communities developed in natural streams assumed processing strategies involving minimum energy loss. Downstream communities are fashioned to capitalize on upstream processing inefficiencies. Both the upstream inefficiency and the downstream adjustments seem predictable. We propose that this river continuum concept provides a framework for intergrating predictable and observable biological features of lotic systems. Implications of the concept in the areas of structure, function, and stability of riverine ecosystems are discussed.

315. Vigers G.A. 1984. [Review of] Research on fish and wildlife habitat. Canadian Journal of Fisheries and Aquatic Sciences. 41(2):392

Review of book by William T. Mason, Jr. No abstract available.

316. Vogel D.A. 1982. Preferred spawning velocities, depths, and substrates for fall chinook salmon in Battle Creek, California. U. S. Fish and Wildlife Service, Red Bluff, CA

No abstract provided.

317. Waples R.S. 1995. Evolutionarily significant units and the conservation of biological diversity under the Endangered Species Act. p 8-27, *in* J.L. Nielson, ed. Evolution and the aquatic ecosystem: defining unique units in population conservation. American Fisheries Society, Symposium #17. Bethesda, MD.

The U.S. Endangered Species Act (ESA) considers "distinct" populations of vertebrates to be "species" (and hence eligible for legal protection) but does not explain how distinctness should be evaluated. A review of the legislative and legal history of the ESA indicates that in implementing the ESA with respect to vertebrate populations, the Fish and Wildlife Service and the National Marine Fisheries Service (NMFS) should strive to conserve genetic diversity scientifically but sparingly. Based on these precepts, NMFS developed a species policy to guide ESA listing determinations for Pacific salmon *Oncorhynchus spp*. According to the policy, a population (or group of populations) will be considered distinct if it represents an evolutionarily significant unit (ESU) of the biological species. The unifying theme of the NMFS species policy is the desire to identify and conserve important genetic resources in nature, thus allowing the dynamic process of evolution to continue largely unaffected by human factors. A review of case histories in which the NMFS policy has been applied shows that it is flexible enough to provide guidance on many difficult issues for Pacific salmon, such as anadromy versus nonanadromy, variation in life history patterns, and the role of hatchery fish in regards to the ESA. Collectively, these case studies also provide insight into approaches for dealing with scientific uncertainty. Some criticisms of the ESU concept (e.g., that it is too subjective and relies too much-or not enough-on genetics) are discussed, as is its applicability to biological conservation outside the ESA.

318. Weaver T.M. and J.J. Fraley. 1991. Fisheries habitat and fish populations. Flathead Basin forest practices. Flathead Basin Commission Water Quality and Fisheries Cooperative Program, Kalispell, MT

No abstract provided.

319. Weins J.A. 1981. Scale problems in avian censusing. Studies in Avian Biology. 6:513-21

No abstract provided.

320. Werner E.E., D.J. Hall, D.R. Laughlin, D.J. Wagner, L.A. Wilsmann, and F.C. Funk. 1977. Habitat partitioning in a freshwater fish community. Journal of the Fisheries Research Board of Canada. 34(3):360-70

The patterns of habitat utilization in the littoral zone fish community of two small southern Michigan lakes were examined. Abundance and habitat use of the fish were quantified by underwater transect censuses. The sunfishes *(Centrarchidae)* dominated the communities numerically and by weight, with two species, the bluegill *(Lepomis macrochirus)* and largemouth bass *(Micropterus salmoides)* accounting for 85% of the community biomass. Spatial (habitat) segregation of species was evident along gradients of depth (distance from shore), vertical height in the water column, and vegetational structure. Several species showed intraspecific differences in the spatial distribution of size-classes. Comparative analyses of habitat use in the two lakes suggest that small size-classes are confined by predation to areas of dense cover and that within these areas competition determines space utilization by different species. The patterns of habitat use are discussed in relation to the food habits and morphology of species in this community. Only one clear case of segregation of two species by food size occurs (bass and bluegill); most other species segregate predominantly by habitat. The rarer centrarchids show strong niche complementarily with the codominant bass and bluegill.

321. Wesche T.A., C.M. Goertler, and C.B. Frye. 1987. Contribution of riparian vegetation to trout cover in small streams.

Cover is an important trout habitat component resulting from the geomorphologic characteristics of a stream channel, the stream-bank interface with the riparian community, and the stream flow. By means of regression analysis, this study quantitatively describes the relative importance of three cover parameters (overhead bank cover, rubble-boulder-aquatic vegetation areas, and deepwater areas) and two cover models as indicators of trout standing stock in eight small streams in southeast Wyoming. Results indicated that overhead bank cover, provided primarily by riparian vegetation is the cover parameter that explains the greatest amount of variation in trout population size.

322. Whittier T.R., R.M. Hughes, and D.P. Larsen. 1988. Correspondence between ecoregions and spatial patterns in stream ecosystems in Oregon. Canadian Journal of Fisheries and Aquatic Sciences. 45:1264-78

Multivariate analyses of biotic assemblages and physicochemical measures, species richness, diversity and composition were used to evaluate the robustness of Omernik's ecoregion classification for small streams in the 8 ecoregions of Oregon. Clearest differences were between the montane and nonmontane regions. For the 3 nonmontane regions, ordinations of fishes, macroinvertebrates, water quality and physical habitat measures show the clearest differences, with the Willamette Valley ecoregion being consistently most unlike all the other regions. Differences between the Columbia Basin and High Desert regions were cleared for water quality and physical habitat measures and fish assemblages. Differences among the montane regions were subtle. Of these regions the East Cascade Slopes showed the greatest variability, as shown by the ranges of ordination scores for fishes, water quality and physical habitat. Regional patterns in periphyton assemblages were markedly different from the patterns in the other groups of variables. Ecoregions can be used as a broad scale geographic framework for classifying streams. This framework provides managers of lotic resources a useful alternative to river basins.

323. Williams J.E., J.E. Johnson, D.A. Hendrickson, S. Contreras-Balderas, J.D. Williams, J. Navarro-Menoza, D.E. McAllister, and J.E. Deacon. 1993. Fishes of North America: endangered, threatened or of special concern. Fisheries. 18(9):6-22

The American Fisheries Society herein provides an update of their now decade-old list of rare North American fishes. The 1989 list add 139 new taxa to the list developed by Deacon et al. (1979) of 251 fishes and removes 26 for a total of 364 fishes in Canada, United States and Mexico that warrant protection because of the rarity. The 26 taxa removed from the 1979 list include 16 removed because of successful recovery efforts. In addition, 49 fishes have changed in status but remain on the list: 7 have improved in status, 24 have declined, and 18 have been reclassified because new information revealed that they were either more common or rarer than was earlier believed and therefore, were incorrectly classified in 1979. Comparison of the 1979 and 1989 lists indicated that recovery efforts have been locally effective for some species , but are clearly lagging behind deterioration of the overall fish fauna. The health of aquatic habitats in North America continues to decay. A major commitment to conservation of entire ecosystems, rather than the inconsistent recovery efforts for individual species, is needed to reverse this trend.

324. Wilzback M.A. 1989. How tight is the linkage between trees and trout. U. S. Forest Service, GTR-PSW-110. Portland, OR.

This paper explores the tightness of the linkage between stream dwelling salmonids and riparian vegetation. Comparison of original distributions of salmonid species with that of vegetation types shows that distribution within a given salmonid species is not limited to a specific vegetation type and that different salmonid species co-occur within a given vegetation type. Examination of reported differences in trout production among streams appear to be related to differences in riparian setting only indirectly an insofar as these reflect differences in prey availability and to a lesser extent, differences in habitat features. Variability in trout production estimates are minimized when comparisons are species-specific and normalized for temperature difference among streams. Within a riparian vegetation type, the relationship between trout production and successional age of the streamside vegetation is often inverse.

325. Wissmar R.C., J.E. Smith, B.A. McIntosh, W.L. Hiram, G.H. Reeves, and J.R. Sedell. 1994. Ecological health of river basins in forested regions of eastern Washington and Oregon. U. S. Forest Service, PNW-GTR-326, Portland, OR

A retrospective examination of the history of the cumulative influences of past land and water uses on the ecological health of select river basins in forest regions of western Washington and Oregon indicates the loss of fish and riparian habitat diversity and quality since the 19th century. A physiographic framework of the eastern Washington and Oregon in terms of spatial and temporal geologic, climatic and hydrologic conditions provides a regional perspective for reviewing influences of human patterns of settlement, resource development and management on the river basins. The study focuses on impacts of timber harvest, fire management, livestock grazing, mining and irrigation management practices on stream and riparian ecosystems. Extensive reviews of ecosystems damage and fish losses caused by hydroelectric and large irrigation projects, highway and railroad construction and other factors are beyond the scope of this analysis by are summarized. Case histories of the chronology of natural resource uses and health of select river basins, the Okanogan, Methow and Little Naches River basins and the Grande Ronde and John Day river basins show that during European settlement period livestock grazing, mining and irrigation developments were the major land and water uses impacting streams and riparian ecosystems. After the 1940's, timber harvest, road construction and irrigation were the major management impacts. The examination of past environmental management approaches for assessing stream, riparian and watershed conditions in forest regions shows numerous advantages and shortcomings. The select management approaches include: instream flow incremental methodology for the evaluation of the effect of water diversion on stream flows and salmonid habitats the equivalent clear-cut methods for assessing the hydrologic effects of logging; a watershed cumulative effects model for evaluating the effects of logging and roads on soil loss; and procedures for addressing soil compaction problems. The study concludes by providing recommendations for ecosystems management with emphasis on monitoring and restoration activities.

326. Wohl E.E., K.R. Vincent, and D.J. Merrits. 1993. Pool and riffle characteristics in relation to channel gradient. Geomorphology. 6:99-110

The depths of pools relative to the depths of runs and riffles were correlated with reach-scale channel gradient along three rivers in coastal northern California. The sample included 122 pools formed in channels with gradients from 0.172 to 0.002. Relative pool depth on these rivers, and relative distance between pools, increase as channel gradient decreases. Mean pool:riffle depth is 2.8:1 at the highest channel gradient, and 6.2:1 at the lowest gradient, while mean pool:riffle length is 1:0.8 at high channel gradient, as a result of the flow's ability to erode its channel boundaries. Channel reaches with high gradients are characterized by resistant channel boundaries, coarse material, and relatively low discharge and total stream power. Channel reaches with low gradients have less resistance channel boundaries, finer grained bed material, and higher values of discharge and total stream power. These changes in channel and flow characteristics with decreasing gradient result in flows in high-gradient reaches expending a greater proportion of their energy in overcoming boundary and internal resistance, with less energy available for channel-bed scour and the formation of pools in their relatively resistant channels. In contrast, flows in low-gradient reaches may more effectively scour the channel bed, creating deeper pools because the channel boundaries are less resistant, and the proportion of flow energy available for sediment entrainment and transport should be greater.

327. Wolman M.G. 1954. Method of sampling coarse river-bed material. Transactions of American Geophysical Union. 35(6):951-6

This determination of the size of material on the bed of a stream is based upon an analysis of the relative area covered by particles of given sizes. The method is applicable to those rivers which flow or coarse material and may be waded during periods of low water. Sampling consists of measuring the intermediate axis of 100 pebbles picked from the bed of the channel on the basis of a grid system. From this sample a frequency of the area sampling procedure over bulk sampling are (1) that it is applicable to very coarse materials and (2) that it provides a more representative sample of an entire reach of a stream.

328. Wolman M.G. and J.P. Miller. 1960. Magnitude and frequency of forces in geomorphic processes. Journal of Geology. 68(1):54-74

The relative importance in geomorphic processes of extreme or catastrophic events and more frequent events of smaller magnitude can be measured in terms of (1) the relative amounts of work done on the landscape and (2) in terms of the formation of specific features of the landscape.

329. Woodsmith R.D., M.D. Bryant, T. Geier, and R. Medel. Draft. Development of effectiveness monitoring protocols for aquatic habitat conditions on the Tongas National Forest: A TLMP information need. U. S. Forest Service, Ketchikan Ranger District, Ketchikan, AK

Apply state of the art methods of assessing the physical and biological condition of stream channels to develop, test and refine protocols for effectiveness monitoring of aquatic habitat in southeast Alaska.

330. Woodsmith R.D. and J.M. Buffington. 1996. Multivariate geomorphic analysis of forest streams: Implications for assessment of land use impacts on channel condition. Earth Surfaces Processes and Landforms. 21:377-93

Multivariate statistical analyses of geomorphic variables from 23 forest stream reaches in southeast Alaska result in successful discrimination between pristine streams and those disturbed by land management, specifically timber harvesting and associated road building. Results of discriminant function analysis indicate that a 3-variable model discriminates 10 disturbed from 13 undisturbed reaches with 90% and 92% correct classification respectively. These variables are the total number of pools per reach, the ratio of mean residual pool depth to mean bankfull shear stress. The last variable can be dropped without a decrease in rate of correct classification; however, the resulting 2-variable model may be less robust. Analysis of the distribution of channel units, including pool types, can also be used to discriminate disturbed from undisturbed reaches and is particularly useful for assessment of aquatic habitat condition. However, channel unit classification and inventory can be subject to considerable error and observer bias. Abundance of pool-related large woody debris is highly correlated with pool frequency and is an important factor determining channel morphology. Results of this study yield a much needed, objective, geomorphic discrimination of pristine and disturbed channel conditions, providing a reference standard for channel assessment and restoration efforts.

331. Yoder C.O. 1995. Policy issues and management applications of biological criteria. W.S. Davis and T.P. Simon, Biological assessment and criteria: Tools for water resource planning and decision making. Lewis Publishers. London, England.

Regulatory agencies have traditionally used nonbiological measures such as chemical/physical water quality to assess attainment of the goal of the Clean Water Act to restore and maintain biological integrity. Difficulty with this approach have led to development and application of biological criteria. The author identifies ten technical concerns (which may equally apply to habitat criteria) raised with biocriteria and discusses potential resolution. These concerns include cost of biosurveys, questionable scientific basis, conclusions from bioassessments are inconsistent with other measures, ability to detect cause-and-effect relationships, lack of predictive ability, and concerns from the regulated community regarding more stringent permit limits. Aquatic resources in the United States continue to decline and the reliance on technology-based solutions is insufficient. Biocriteria and bioassessments are critical tools required to assure that water quality is restored and maintained.

332. Young M.K. 1995. Conservation assessment for inland cutthroat trout. U. S. Forest Service, RM-GTR-256, Fort Collins, CO

This document focuses on the state of the science for 5 sub-species of cutthroat trout found largely on public lands in the Rocky Mountains and Intermountain West. These subspecies are restricted to a fragment of their former range and primarily occupy small, high-elevation streams. Little is know about the 3 rarest subspecies and the data on the more abundant subspecies were obtained from relatively few areas. The historic diversity of life history strategies has been reduced. All subspecies have suffered from introductions of nonnative fishes, habitat degradation and fragmentation, and overfishing. Current management often centers on restrictive angling regulations, barricading streams to prevent invasion by nonnative fishes and reintroductions into streams with existing barriers.

333. Yount J.D. and G.J. Niemi. 1990. Recovery of lotic communities and ecosystems from disturbance-a narrative review of case studies. Environmental Management. 14(5):547-69

We present a narrative account of case studies of the recovery of flowing water systems from disturbance, focusing on the investigators' conclusions about recovery time and the factors contributing to recovery. We restrict our attention to case studies in which the recovery of some biological property of the systems has been examined, excluding those that deal only with physical or chemical properties. Although natural processes and rates of recovery are emphasized, studies of reclamation or restoration of damaged ecosystems are included where they contribute to an understanding of recovery processes.

334. 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(2):81-93

Fish assemblages integrate physical and chemical habitat conditions and are used to evaluate the condition of water resources in the Pacific Northwest. To facilitate such evaluations, we classifies each of the 132 freshwater fish species known to occur in the Pacific Northwest (Idaho, Oregon, Washington) by its origin, overall pollution tolerances, adult habitat, adult feeding and water temperature preference. Recommendations from regional fishery experts, published literature and the aggregate experience of the authors were used to classify species. The attribute classification of fish species promotes use of fish assemblages to evaluate water resource conditions regionally and fosters greater acceptance of biological measures of water resource quality.