Trout Unlimited's
North American Salmonid Policy:
Science-Based Guidance
for 21st Century Coldwater Conservation

Approved 2 August 1997,
Amended 22 August 1998,
by Trout Unlimited's National Resource Conservation Board

This document may be cited:
Trout Unlimited 1997. Trout Unlimited's North America Salmonid Policy: science-based guidance for 21st century coldwater conservation. Trout Unlimited, Arlington, VA 22209 (USA). 47 pp.

Acknowledgments

Trout Unlimited gratefully acknowledges the following fisheries and aquatic scientists for providing peer review for this document: Dr. Paul L. Angermeier (Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute & State University, Blacksburg, Virginia); Dr. Gordon H. Reeves (Pacific Northwest Research Station, US Forest Service, Corvallis, Oregon); Dr. Robert C. Behnke (Department of Fishery and Wildlife Biology, Colorado State University, Ft. Collins, Colorado); Dr. Kurt D. Fausch (Department of Fishery and Wildlife Biology, Colorado State University, Ft. Collins, Colorado); Dr. Chris A. Frissell (Flathead Biological Station, Poulson, Montana); Dr. Charles C. Krueger (Department of Natural Resources, Cornell University, Ithaca, New York); Dr. Peter B. Moyle (Department of Wildlife, Fish, and Conservation Biology, University of California, Davis, California); Dr. Thomas Quinn (School of Fisheries, University of Washington, Seattle, Washington). The principal author of this document, N. LeRoy Poff, Ph.D. also gratefully acknowledges the support of Trout Unlimited's Coldwater Conservation Fund, particularly CCF members George Wiegers and Peter Storer, and the Curtis and Edith Munson Foundation for their financial support of his work.

Table of Contents

I. Scope and Purpose -- Science and Policy

The mission of Trout Unlimited (TU) is to conserve, protect, and restore North America’s coldwater fisheries and their watersheds. The long-term goal implicit in this mission statement is achieving *self-sustainability* of salmonid populations and species (as opposed to simple short-term enhancements of abundance).   To achieve this goal, Trout Unlimited recognizes that the best available scientific information must be incorporated into advocacy policies that guide local or national activity. Doing so ensures that actions have the highest probability of long-term success; it also enhances TU’s recognized role as a leader in the arena of aquatic conservation. New information in the areas of salmonid ecology, genetics, and conservation, combined with the growing threats to many native salmonid species and populations, have created new priorities for conservation. This policy specifies TU’s advocacy positions for salmonid resource issues by incorporating currently available scientific understanding of the complex suite of processes that regulate the abundance, distribution, and diversity of salmonid populations, subspecies, and species. The policy expands on previous TU policy on salmonid resources (Trout Unlimited 1990), and it integrates existing TU positions on activities on federal lands such as grazing, mining, and forestry (Trout Unlimited 1994).

TU recognizes that any policy based on the best available scientific knowledge will contain some uncertainty. Imperfect knowledge is no excuse for inaction; indeed, it points to the need for adaptive management and for conservative action that does not preclude future options (including reversing previous actions) when more information becomes available. In the face of uncertainty and where the risk to the resource is deemed high, Trout Unlimited will use the best science to act aggressively to maximize protection of salmonid fishes, habitats, and ecosystems.

II. Background -- Principles and Assumptions

A. Biodiversity and Watershed Ecosystems

Science-based conservation in the 21st Century will increasingly be framed in terms of the ecosystem context in which native biodiversity (including salmonids) is sustained. Therefore, in order for TU’s conservation agenda to be scientifically credible and consistent, our focus on salmonids must not be so narrow as to exclude the broader ecosystem and its constituent species. Further, from the perspective of policy implementation, failure to recognize the importance of the ecological roles played by co-existing species and failure to appreciate the physical-chemical processes that support these species, over time, will result in activities that have only a low probability of success in achieving sustainability of salmonid populations. Trout Unlimited, therefore, recognizes natural biodiversity stewardship and ecosystem protection as essential components of our coldwater fisheries' mission (Trout Unlimited 1994). Indeed, salmonids often serve as “flagship” or “indicator” species in this broader framework, due to their sensitivity to environmental quality, position as top aquatic predators, and high visibility to the public. They can also serve as “umbrella” species, in that measures to protect salmonid habitat can benefit other species (fishes, invertebrates) if appropriately crafted and implemented. We must continue to recognize that salmonids are only one component of the ecosystem and that their persistence depends on the normal functioning of all ecosystem components (biological, chemical and physical).

Biodiversity in the broadest sense can be defined as the variety and variability among living organisms and the ecological complexes in which they occur at many biological levels ranging from genes to species to ecosystems (OTA 1987, Noss 1990). Ecosystems in which natural evolutionary and biogeographic processes and relationships are intact generally have high native biodiversity relative to the regional potential for that kind of ecosystem. The presence of native species is generally indicative of high ecological integrity (Angermeier and Karr 1994). Thus, coldwater ecosystems that have naturally low fish species diversity (compared to warmwater ecosystems) can still have high ecological integrity if native species assemblages remain intact.

The diversity in life forms and landscape elements we observe today represents the product of dynamic evolutionary and geomorphic processes that have played out over tens of thousands to millions of years. These processes (including extinction of diversity components) typically occur very slowly, as in the formation of new species or uplifting of new mountains, and they are generally not directly observable. Human beings, however, are dramatically accelerating the normal extinction rates of native biodiversity on a global scale (Wilson 1988). Such human-accelerated extinctions represent permanent losses of our biological, cultural, and socioeconomic heritage. From a scientific perspective, the loss of biodiversity is of grave concern for several reasons: a major share of existing species and ecological processes are needed to support the Earth's life support system; many species and processes are needed to support the valued components of natural ecosystems (e.g., salmonid populations); and the largely unpredictable consequences of species extinctions and changes in ecological processes argue for conserving species (and ecosystems) and ecological processes (Wilson 1988). Therefore, the science-based conservationist's mandate must be to protect the components of this biodiversity and the natural processes that generate it.

The ecosystems in which salmonids have evolved, and which continue to support them, must be understood and incorporated into the conservation and restoration agenda (Power et al.1997). Aquatic ecosystems are strongly constrained by processes occurring at the watershed or catchment (basin) scale (kinds and distribution of habitat types, water chemistry, type of food resources, etc.); therefore, the watershed is the basic landscape unit in which management of salmonids and other aquatic species should be operationally undertaken (Naiman 1992, Doppelt et al. 1993, Lichatowich et al. 1995, Maxwell et al. 1995, Naiman et al. 1995). The watershed size appropriate for conserving or managing salmonids will depend on the size, mobility, and life history needs of the population(s) of interest. Resident populations may be manageable within the confines of relatively small watersheds, whereas migratory populations can require conservation action aimed across very large watersheds under more complex governmental control. Anadromous species also occupy marine environments where humans have little or no control, but where conditions strongly influence population success for both Pacific salmonids (Pearcy 1992) and Atlantic salmon (Friedland et al. 1993). Although institutional and governmental authority over salmonid populations may vary geographically and with watershed size, Trout Unlimited will look to whoever has authority for science-based, well-considered action.

Intact watershed ecosystems provide numerous “free” services to human societies, including flood storage in wetlands, clean drinking water, bird and wildlife habitat, etc. (Postel and Carpenter 1997). Indeed, sustainable populations of salmonids can be included in the list of services provided by coldwater ecosystems. Healthy salmonid populations often indicate healthy coldwater ecosystems, defined, for example, as those having high native fish and invertebrate diversity relative to the regional potential. New scientific evidence indicates that the ability of ecosystems to provide sustained services to humans can be enhanced by high native diversity (Tilman 1997). This suggests the possibility that healthy salmonid populations may themselves be indicators of a coldwater ecosystem’s ability to provide “free” services over the long term.

> *Fundamental Principle #1.* Human stewardship of all life forms, habitat types, and ecosystem processes is essential for the self-sustainability of coldwater fisheries.

> *Fundamental Principle #2.* The watershed is the basic landscape unit in which management of salmonids and other aquatic species should be undertaken.

B. Connections -- Salmonids and Watershed Ecology

Fishes of the family Salmonidae include salmon, trout, chars, whitefishes, and graylings. These are freshwater and anadromous species that range widely and are dominant components of the coldwater fauna in the northern temperate zone and montane regions of North America. Salmonids require cold, clean water with high levels of dissolved oxygen for survival and growth, and clean, stable, and permeable gravel substrate for spawning and egg incubation (Stolz and Schnell 1991). The presence of salmonids in thermally suitable waters is generally indicative of high water quality.

Salmonid diversity can be practically defined at four levels: species, subspecies, assemblages of species or subspecies, and populations or stocks within species or subspecies. Among North American trout and salmon, 17 species are recognized as native (Table 1), although numerous subspecies have been identified (Behnke 1992), many of which are federally-listed as threatened or endangered. Assemblages of species or subspecies are distinct combinations of species or subspecies that occur locally. Within species or subspecies, stocks typically differ genetically and are "locally-adapted" to prevailing environmental regimes. The concept of stock diversity is of recognized and documented importance for several salmonid species. For example, in the Pacific Northwest, hundreds of stocks have been recognized for anadromous species on the basis of their isolation and subtle, yet significant, differences in patterns of life history adaptation to local conditions (e.g., timing of spawning, out-migration, etc.). Of these, several hundred stocks are considered at risk of extinction (Nehlsen et al. 1991, Allendorf et al. 1997). Similarly, stocks have been identified for Atlantic salmon (Saunders 1981) and for non-anadromous species, such as lake trout (Brown et al. 1981, Krueger and Ihssen 1995) and brook trout (Perkins and Krueger 1993).

Successful salmonid conservation and restoration requires an understanding of some basic principles of aquatic ecosystem structure and function. In stream and river ecosystems, there are three fundamental spatial "dimensions." The first is the *longitudinal* (upstream-downstream) connection that defines the largely one-way, downhill flow of water, sediments, and nutrients (Vannote et al. 1980). The second is the *lateral* connection between the stream channel and the floodplain and riparian zone, which provide nutrients, organic matter (including woody debris) and sediments to the channel (Gregory et al. 1991). The third is the *vertical* connection between the streambed and the hyporheic zone (deeper, saturated sediments), which represents a very important location for energy processing and storage of nutrients and water (Stanford and Ward 1988). These three spatial dimensions are connected and integrated over *time*, the fourth dimension of the stream ecosystem (Ward 1989). These four dimensions are naturally

Table 1. Native and Introduced North American Trout and Salmon in the Subfamily Salmoninae (from Robins et al. 1991)

Genus and Species Name	Common Name
Oncorhynchus aguabonita	golden trout
Oncorhynchus apache	Apache trout
Oncorhynchus chrysogaster	Mexican golden trout
Oncorhynchus clarki	cutthroat trout
Oncorhynchus gilae	Gila trout
Oncorhynchus gorbuscha	pink salmon
Oncorhynchus keta	chum salmon
Oncorhynchus kisutch	coho salmon
Oncorhynchus mykiss	rainbow trout
Oncorhynchus nerka	sockeye salmon
Oncorhynchus tshawytscha	chinook salmon
Salmo salar	Atlantic salmon
Salmo trutta[*]	brown trout
Salvelinus alpinus	arctic char
Salvelinus confluentus	bull trout
Salvelinus fontinalis	brook trout
Salvelinus malma	dolly varden
Salvelinus namaycush	lake trout

[*] Introduced from Europe

expressed in the watershed context (Townsend 1996a). Salmonids clearly depend on all four dimensions: longitudinal for dispersal and migrations, lateral for backwater habitat and provision of woody debris, vertical for spawning and egg incubation, and temporal for seasonal connectivity of habitat elements that allow for completion of the life cycle.

Many coldwater ecosystems in North America are also characterized by natural lakes connected by streams or rivers. These lake-river ecosystems have been created by natural geomorphic and tectonic processes in montane and glaciated regions of North America and by the activities of beavers. Lakes temporarily store water, sediment and nutrients moving downstream and constitute unique environments that support many forms of aquatic life not present in downstream streams and rivers. The nutrients and organisms exported from lake outlets provide important food resources for downstream systems. Many salmonid species depend on lakes for spawning, rearing, growing, and/or overwintering.

The strength of the longitudinal-lateral-vertical linkages over time in a watershed ecosystem varies naturally within and among watersheds, depending on factors such as stream size, climate, geologic setting, topographic setting, terrestrial vegetation, and the occurrence of lakes. These environmental controls vary greatly across the landscape and thus influence the distribution and abundance of salmonids and other aquatic species. Human activities that disrupt the longitudinal-lateral-vertical linkages over time on a particular river will have profound effects on the aquatic ecosystem and, subsequently, on resident salmonid species or populations.

The environmental conditions under which North American salmonid species evolved have been dramatically altered by European settlement of the North American continent (Reeves et al. 1995, Ebersole et al. 1997, Gregory and Bisson 1997). These altered conditions pose significant challenges to successful conservation and management of self-sustaining salmonid populations, including wild populations of many species that have been transplanted beyond their original geographic ranges. For example, many native salmonid species now occupy only a small portion of their historical ranges, due to land use changes, polluted runoff, river impoundment, and introduction of dominant exotic species (Nehlsen et al. 1991, Behnke 1992, Frissell 1993). The isolation of local populations has prevented movement of individual fish among local populations (which comprise the natural meta-population), resulting in diminished population sizes, blocked pathways of recolonization, and reduced natural genetic exchange (Schlosser and Angermeier 1995). All of these factors contribute to a change in salmonid diversity and an increase in the extinction risk for many local populations of both inland (e.g., bull trout, Rieman and McIntyre 1995; cutthroat, Young 1995) and anadromous (Pacific salmon, Reeves et al. 1995) species.

> *Fundamental Principle #3.* Salmonid diversity can be defined at four levels: species, subspecies, assemblages of species or subspecies, and populations or stocks within species or subspecies.

> *Fundamental Principle #4.* Self- sustainability of salmonid populations and maintenance of natural salmonid diversity depend on connections among the fundamental spatial dimensions of watershed ecosystems – longitudinal (upstream and downstream), lateral, and vertical – that interact over time and that are frequently disrupted by human activities.

C. Legacies and Lag Times -- How Habitats and Populations Change

Watershed ecosystems are naturally variable in space and time, and the species that have evolved in these dynamic environments can persist even in the face of a wide range of natural disturbance. However, when environmental conditions change greatly relative to the historical range of environmental variation, the local population must either adjust to the new habitat conditions through short-term acclimation or long-term adaptation, or it will be eliminated. Such dramatic changes in environmental conditions (e.g., habitat modification and loss, elevated temperatures, exposure to novel chemical stressors, exotic species introductions, etc.) are contributing to species endangerment and extinction (Wilson 1988, Nehlsen et al. 1991, Frissell 1993, Flather et al. 1994, The Nature Conservancy 1996). Dramatic environmental changes can leave an imprint on habitat quality or quantity for decades to centuries. Many such *legacies* of habitat modification can be identified in the contemporary North American landscape: toxic chemicals spill into waterways below abandoned mines; high sediment loads characterize streams in forested watersheds that were clear-cut decades ago; dams at outlets of lakes block upstream access; reduced habitat complexity occurs in streams and rivers where log drives occurred in the last century or where rivers and streams were cleared of woody debris. If salmonid populations are able to respond to these dramatic environmental changes, the response often occurs with some *lag time*.

Despite high natural variability in numbers of salmonid populations, in most cases declines or persistent low natural productivity in salmonid populations are the result of human activity. For example, extinction of some stocks of anadromous salmonids are clearly related to large dams that block migratory pathways. The general decline of salmonids in the Columbia River over the last century is strongly associated with the legacy of inaccessible habitat imposed by numerous mainstem dams on the Columbia and Snake Rivers (NRC 1996, Williams 1996). Similarly, the absence of brook trout from many watersheds in the southern Appalachians can be attributed to excessive logging activities in the early 20th Century (Moore et al. 1983). Recognition of legacies and lag times points to the need to preserve the remaining high quality habitats (watersheds) that have been minimally perturbed by human activities, which may serve as core habitats or refuges in a highly modified landscape (Frissell and Bayles 1996, Reisenbichler 1996).

> *Fundamental Principle #5.* Human beings have dramatically accelerated the normal rates of extinction of salmonid biodiversity (species, subspecies, populations, and stocks) beyond background levels, in large part by altering the longitudinal-lateral-vertical linkages in watersheds.

> *Fundamental Principle #6.* Recognition of legacies and lag times requires that the last remaining high quality habitats be protected and actively managed to preserve their natural values as core or refuge habitats.

III. Policy Positions and Recommendations: Habitat, Hydro, Harvest, and Hatcheries

TU's North American Salmonid Policy provides general guidance for TU actions. The policy is based on fundamental scientific principles that are discussed above: the importance of biological diversity and ecosystem processes in a watershed context (Section II A), the connections between salmonids and watershed ecology (Section II B), and the changes in populations and habitats over time (Section II C). These general principles reflect the needs for salmonid survival and for population self-sustainability.

Conserving and maintaining healthy and fishable trout and salmon populations requires that at least three conditions be met. First, favorable environmental factors (physical, chemical, biological) are needed over a species' entire life cycle. Second, population size must be large enough to prevent natural or human-caused fluctuations in abundance from driving the local population extinct. Third, the adaptation of local salmonid populations to prevailing environmental conditions (and the capacity to further adapt to likely changes in local conditions) requires conservation of local genetic heritage.

For the purpose of promulgating a policy that is consistent with institutional history and that is technically sufficient, Trout Unlimited addresses these broad concerns by placing conservation and management of salmonid fisheries in the context of the "4 H's": habitat, hydro, harvest, and hatcheries (as described below).

A. Habitat

<u>General</u> <u>position</u>: *Promote land-use practices that maximize habitat quantity and quality, that optimize connectivity of habitats for salmonid populations at scales ranging from local sites to whole watersheds and that, to the extent possible, reflect historical conditions.*

Habitat is central to understanding the distribution, abundance, and sustainability of salmonid populations. Habitat is often considered to be the quantity and quality of the physical/chemical environment in which salmonids complete their life cycles. However, habitat is more than the static physical structure of the environment; the dynamic temporal variation (including natural disturbances) in structure is critically important, because that dynamism is part of the “template” to which salmonids and other species are adapted (Minshall 1988, Poff and Ward 1990, Reeves et al. 1995, Stanford et al. 1996). Recognizing the importance of habitat dynamics requires that habitat be considered at more than simply the local scale. For example, individual habitat structures (such as large woody debris) may not remain in one place for long periods due to variable flows. However, if the number (or frequency) of pieces of woody debris at the larger scale of a stream reach remains relatively unchanged over time, then a dynamic equilibrium exists between habitat availability and watershed hydrology. Indeed, the dynamic destruction and recreation of local habitat elements are central to maintaining high native biological diversity and ecosystem integrity (Poff et al. 1997).

In a life cycle context, the fundamental habitat elements include those required for spawning and egg incubation, for juvenile rearing, and for adult foraging and holding. For some species, migration to the ocean or to large lakes is also required. The habitat elements required by the various life stages are typically spatially discrete, but they must be *connected* through time to accommodate the necessary seasonal movements of salmonid life stages. Therefore, a watershed perspective is required to consider the habitat needs for self-sustaining salmonid populations. This is also true for non-anadromous, resident species, because individual fish may move widely to find new habitat or to gain access to suitable spawning grounds (Gowan et al. 1994, Fausch and Young 1995). For example, some salmonids require access to portions of upstream spawning habitat that may be seasonally intermittent (e.g., Humboldt cutthroat trout, Behnke 1992). The opportunity for trout and salmon to move throughout a watershed is important during periods of naturally stressful conditions or to recolonize habitats following catastrophic events (such as flooding or drought). During severe winter periods, salmonids may move into warmer winter refuges (e.g., lakes or beaver ponds; Chisholm et al. 1987). During periods of high water temperatures, salmonids will search out and find cool water refuges (Kaeding 1995). Thus, the occurrence of thermal refuges can be critical to salmonid survival and can limit salmonid distributions at both local and regional scales (Meisner 1990, Rieman and McIntyre 1995, Rahel et al. 1996).

Watershed processes strongly influence the quantity and quality of local stream and lake habitat. For example, the riparian zone along streams influences local water temperature conditions, provides large woody structure to the channel, and regulates the quality of the aquatic food base that supports salmonids (Gregory et al. 1991). Local additions of large woody debris, natural or otherwise, to the channel can increase stream-wide abundance of wide-ranging salmonids (Fausch et al. 1995, Gowan and Fausch 1996). However, the ability of such structures to provide this function may depend on watershed hydrology and geology, which regulate the stability and permanence of such structures. Accordingly, degraded local habitat may be only symptomatic of larger scale watershed processes that cause the degradation. Conservation or restoration actions that focus only on local conditions and fail to consider the watershed context have a low likelihood of persistent success (Frissell and Nawa 1992, Minns et al. 1996, Roper et al. 1997). Although local fish habitat projects are important components of an overall watershed conservation program, watershed restoration and management also require the expertise of hydrologists, geomorphologists, and others (Dombeck et al. 1997, Roper et al. 1997).

Habitat degradation--Because human activities often modify natural watershed processes (hydrologic, sediment, thermal, and nutrient regimes), they also frequently degrade salmonid habitat quantity, quality and connectivity over time. Some of the major human activities that modify watersheds and degrade habitat include:

- *Roads:* Poorly constructed roads can cause hillslope and bank failure that result in episodic inputs of sediments to streams (Jones and Grant 1996). The stream may not be able to move coarse sediment, and the bed may rise to the point that passage is prevented (Cacek 1989, Furniss et al. 1991). Frequently, excess fine sediments are deposited and they may smother salmonid eggs and many of the aquatic insects that provide the forage base (Waters 1995).

Additionally, improper placement of culverts can prevent the upstream or downstream movement of fish (Trout Unlimited 1994).

- *Forest harvest:* Overharvest of trees from a forested watershed has well known effects on watershed ecosystems. For example, infiltration rates into the soil are reduced and streams can become “flashier” (i.e., subject to wider variations in flow) and hence less buffered from climatic extremes (Wright et al. 1990). Also, flushing of nutrients through the soil alters chemistry of receiving waters (Likens et al. 1970). Because forest harvest characteristically requires road development for access, sediment delivery rates to streams and lakes can also increase (Beschta 1978, Furniss et al. 1991). Further, the delivery rate and availability of large woody debris may decline with harvest, and the thermal buffering of streamwater provided by riparian shading can be lost.

- *Grazing:* Grazing by livestock often severely degrades water quality and stream habitats for salmonids and other aquatic life. In general, the greater the intensity of grazing in a watershed, the more severe the impact on aquatic life. Grazing reduces stream habitat diversity by exacerbating bank instability and failure, by compacting the soil and increasing surface runoff, by increasing fine sediment delivery to the channel, by widening the channel, by lowering the groundwater table and by elevating water temperatures due to loss of shading (Armour et al. 1991, Platts 1991).

- *Mining:* Toxic leachates from mining operations (e.g., acid-mine drainage) severely degrade water quality and damage aquatic life, including salmonids. Toxic effects can be both lethal and sublethal or indirect. Continuous exposure to sublethal levels may produce such chronic effects as behavioral changes and reproductive failure (Chapman 1973). In addition, mining mineral particles from streambeds (e.g., gravel mining or placer gold mining) can cause severe degradation to instream and riparian habitats (Trout

Unlimited 1994). Further, activities associated with mine development (e.g., road construction) also cause sedimentation, elevated water temperatures and changes in hydrology.

- *Agriculture:* Poorly managed agricultural lands degrade salmonid habitat in many ways. For example, farming on floodplains reduces riparian buffer zones and contributes to elevated water temperatures, accelerated inputs of fine sediments and increased nutrient loading to streams, rivers, and lakes (Karr and Schlosser 1978, Lowrance et al. 1984). Indeed, siltation has been identified as the most important pollutant responsible for degrading more than a third of the stream and river miles assessed in the United States (US EPA 1994). Channelization or straightening of stream channels to promote drainage also simplifies and reduces in-channel habitat suitable for salmonids (Karr and Schlosser 1978). Polluted runoff, resulting from large-scale fertilizer and pesticide applications, severely reduces water quality by stimulating the growth of nuisance algae, especially where fueled by increased solar energy when riparian cover is removed. Additionally, irrigation diversions and groundwater pumping can reduce water table levels and thus deplete streamflows, causing deterioration of water quality and loss of salmonid habitat. Drainage of wetlands by tiling results in increased water temperature, lowered baseflows and increased flow variability.

- *Urbanization and suburbanization*: In watersheds with rapid commercial or residential development, increases in impervious surfaces (e.g., parking lots, rooftops) prevent infiltration into the soil, thereby increasing flood frequency and intensity (Beven 1986), increasing bank erosion and channel widening (Hammer 1972) and reducing baseflows during periods lacking precipitation (Harris and Rantz 1964, Beven 1986). Rapid runoff during summer storms and loss of groundwater recharge can greatly elevate water temperatures and reduce salmonid habitat quantity and quality. Further, application of pesticides and fertilizers and pollution from petroleum products are common impacts associated with urbanization and suburbanization.

Need for habitat assessment and monitoring--Human activities that degrade habitat occur at many scales, from the local, to entire watersheds (e.g., logging, road building), to multiple watersheds (e.g., acid precipitation), to regional/global (climate change, ocean productivity for anadromous salmon). Habitat maintenance and restoration require that all levels of human activity impinging on a local population or a species be taken into account, and, to the extent possible, integrated into a comprehensive plan for action.

Appropriate techniques should be used both to *assess* the extent of habitat degradation, so that restoration actions can be initiated, and to *monitor* habitat recovery, so that effectiveness of the restoration actions can be judged (Kondolf and Micheli 1995). Habitat assessment techniques may or may not be derived from biological criteria. Biologically based techniques are those that assess habitat in terms of the needs or tolerances of aquatic species. Examples include rapid bioassessment techniques for fish and invertebrates (Plafkin et al. 1989) and more detailed techniques for quantifying fish habitat (Platts et al. 1983). Non-biologically-based techniques that characterize physical channel features from a geomorphic point of view have also become available (Rosgen 1996) and can be useful when properly implemented.

In addition to assessment and monitoring purely physical habitat conditions, some assessment of biological or ecological restoration is needed. Trout Unlimited recognizes that multi-species indicators of habitat quality and biological conditions are generally superior to single-species' indicators because the former reflect the broader concept of ecological or ecosystem integrity (Karr 1991, Angermeier and Karr 1994). The most widely accepted of these multi-species assessment tools is the Index of Biotic Integrity (IBI), a composite of metrics on species richness and composition, local indicator species, proportion of exotic or tolerant species, and individual fish health (Karr 1981). Proper application of the IBI allows comparison of local biotic integrity to a regionally attainable standard. IBI’s have been developed both for fish (Fausch et al. 1984, Karr et al. 1986), and for macroinvertebrates (Plafkin et al. 1989**,** Kerans and Karr 1994, Fore et al. 1996), and they are widely used by regulatory agencies. Coldwater ecosystems naturally have relatively low native species diversity and low biological productivity; therefore, IBI's developed specifically for coldwaters need to be applied to these types of aquatic ecosystems (Lyons et al. 1996).

In any habitat restoration project, *monitoring* is critical to judging effectiveness or success. Coldwater ecosystems are dynamically variable systems (Poff and Ward 1990, Reeves et al. 1995), as are the species that reside in them, so caution is required when using "snapshots" of habitat condition to conclude restoration success. For example, observation of a high density of salmonid redds in a restored gravel bed may not result in increased numbers of juvenile and adult fish if the gravel is hydrologically unstable and prone to movement during annual high flows. Similarly, electroshocking high numbers of fish around a log-drop structure does not necessarily indicate that stream-wide salmonid production has increased (Minns et al. 1996). Monitoring programs should be designed to accommodate the lag time of physical and ecological recovery to a particular legacy of habitat alteration. Again, multiple sources of expertise should be marshaled to accomplish this (Dombeck et al. 1997, Roper et al. 1997).

Mitigation--Trout Unlimited opposes the use of mitigation to "replace" habitats and ecological functions that may be lost to proposed new human activities. However, in many circumstances, such activities are permitted by regulatory agencies, and mitigation may be required. In such situations, Trout Unlimited generally supports the guidelines set forth by the U.S. EPA and U.S. Army Corps of Engineers to demonstrate compliance with the Clean Water Act Section 404(b)(1) Guidelines (MOU 1990). This is a three-step process. First, the most environmentally damaging practicable alternatives should be *avoided*. Second, the impact of an unavoidable activity to the resource should be *minimized* to maintain ecological function. Third, appropriate *compensatory mitigation* should be favored for unavoidable adverse impacts. The goal of compensatory mitigation should be to restore the lost ecological function (e.g., salmonid habitat) using the following ranking of options: on-site (in situ) > off-site, same drainage > off-site, out-of-drainage. Restoration of ecological function can be problematic and, at the least, requires long-term monitoring and maintenance to judge success.

POLICY RECOMMENDATIONS

A. Work with governmental agencies (federal, state, county, town), stakeholder organizations (e.g., local watershed councils), and private landowners to conserve, protect, and restore stream and lake habitat in a watershed context.
B. Strongly support the protection and connectivity of habitats that are recognized as being of high quality for any or all salmonid life stages.
C. Pursue habitat improvement in the context of:
    1. providing habitat needs of each salmonid life cycle stage.
    2. integrating habitat elements into a watershed context (i.e., the availability of different habitat types should remain relatively constant over time, in dynamic balance with watershed-scale hydrology, sediment flux, and land-use).
    3. connecting habitats across the whole watershed to allow for a) completion of life cycle, b) restoration of natural meta-population structure, and/or c) isolation of native species from threatening, exotic species.
    4. supporting ecosystem components that enhance the quantity and quality of habitat (riparian, aquatic invertebrates, etc.)
    5. using locally native plant species in restoration efforts.
D. Oppose activities that degrade habitat quality or quantity in minimally perturbed “core habitats” or “key watersheds” that are capable of supporting self-sustaining salmonid populations and that can serve as recolonization sources for restored habitats elsewhere.
E. Oppose mitigation measures that do not avoid, minimize, or compensate for lost ecological functions associated with new human activities in watersheds. Advocate for the least damaging alternatives, i.e. those with the greatest likelihood of both short-term and long-term success in protecting or restoring natural habitat structure and function.

B. Hydro

General position: Support flow regimes that promote and sustain healthy salmonid populations and their ecosystems.

The quantity and timing of streamflow in a river is a critical regulator of habitat quantity and quality, as previously mentioned. For the purposes of this policy, Trout Unlimited uses the term “hydro” to refer to that set of issues related to modification of natural hydrological regimes (and associated water quality factors such as temperature or dissolved gases) that directly threaten the self-sustainability of salmonid populations. Human activities that affect flows include:

Dams--Diversions and impoundments of streams and rivers by dams have dramatically altered natural flows and connectivity of headwater streams for most rivers in the U.S. (Echeverria et al. 1989, Benke 1990, NRC 1992). Dams create significant disruptions in the three fundamental spatial dimensions of river ecosystems, and pose significant challenges to salmonids. By storing water, dams modify the natural (historical) patterns of streamflow by altering magnitude, timing, frequency, duration, and rate of change of flow events (Collier et al. 1996), depending on a particular dam’s operations. Alteration of these components of the natural flow regime has significant ecological consequences for both aquatic and riparian species and communities (Collier et al. 1996, Stanford et al. 1996, Poff et al. 1997). Dams also interrupt the natural downstream flow of sediment, capturing fine particles in the reservoir and subsequently causing downstream habitats to be eroded by the sediment-hungry water released by the dam. This coarsens the streambed and may make spawning more difficult and reduce insect production (Petts 1984). In situations where no high flows are released from dams, silt may accumulate in spawning gravel and reduce habitat quality and production of aquatic invertebrates (Sear 1995). Over time, the absence of overbank flows disconnects the main channel from the floodplain and results in riparian changes that influence habitat quality in the main channel (Ligon et al. 1995, Poff et al. 1997).

Dams block movements of fish, both upstream and downstream and have directly contributed to the loss of anadromous salmonid populations from formerly occupied headwater streams (Williams et al. 1996). For example, only 9.5% of the federally licensed hydroelectric dams in the U.S. have some form of fish passage (Francfort et al. 1994). Further, the effectiveness of fish passage facilities at these and other dams remains unclear and debatable (OTA 1995). For anadromous species, downstream movement of smolts (and adults of some species) is impeded by large dams that convert flowing rivers to reservoirs (Stanford et al. 1996), where elevated risk of mortality results from predation in reservoirs, entrainment in turbines at the dam, and spill over the dams (Williams et al. 1996). The effect of dams on the movement of non-anadromous salmonids is not clear, but the high mobility of many inland salmonids suggests that dams could contribute to fragmentation of resident populations (Gowan et al. 1994, Fausch and Young 1995).

Dams also create ecological problems downstream. For example, deep-release dams greatly alter thermal and nutrient regimes, thereby affecting numerous downstream ecosystem processes (Ward and Stanford 1979). Surface spill over high dams is often super-saturated with atmospheric nitrogen, which causes gas bubble disease (Ebel 1969), whereas water released from deep layers in thermally stratified reservoirs often contains little dissolved oxygen (Ward and Stanford 1979). Hydroelectric dams that operate on a demand/peaking mode create severe downstream ecological problems, not only for salmonid populations, but also for the aquatic ecosystem as a whole. The frequent and unnaturally rapid fluctuations of water level can strand and kill many aquatic insects and fish (Cushman 1985, Gore 1994), displace young fish (Harvey 1987), reduce the abundance of specialist riverine fish species (Kingsolving and Bain 1993), and alter the supporting invertebrate food base (Weisberg et al. 1990, Power et al. 1996, Wootton et al. 1996). Natural salmonid production in these severely disturbed systems is thus likely to be greatly reduced.

Water withdrawals--Among other major hydrological alterations that damage salmonids, irrigation diversions in arid and semi-arid lands leave less water in the channel for salmonids and reduce critical habitat during the summer irrigation season. Smolts may be entrained in irrigation flows and become stranded in agricultural fields. Unnaturally low winter flows may occur below dams maintained for summer irrigation or for municipal water supplies, and the loss of winter habitat can limit salmonid abundance (Cunjak 1996). Similarly, groundwater pumping for agricultural, municipal, or residential use can reduce water table levels and thus deplete streamflows, causing loss of riparian vegetation and elevation in water temperatures that degrade habitat.

Alteration of runoff or recharge areas--Loss of groundwater recharge areas due to urbanization, suburbanization, or certain agricultural practices can severely degrade salmonid habitat quantity and quality. In many streams, baseflow is maintained by groundwater, which can provide cool thermal refuges in summer months or warm (ice-free) refuges in winter months.

POLICY RECOMMENDATIONS

A. Oppose impoundment and dewatering of streams or rivers of importance to wild salmonids.
B. In regulated streams, support the creation of flow (and thermal) regimes that mimic natural, pre-modification, flow (and thermal) regimes, which are likely, in conjunction with other restoration activities, to restore ecosystem complexity and enhance natural salmonid production.
C. On streams and rivers of importance to wild salmonids, support the removal of dams from streams and rivers, unless such removal will damage the upstream ecosystem (e.g., by allowing upstream movement of harmful non-native species, including pathogens).
D. Actively oppose artificially large daily fluctuations in flow at hydroelectric dams that harm fish and their ecosystems. Advocate that hydroelectric dams be operated in true run-of-river mode, i.e., outflow from the dam equals inflow into the reservoir at all times.
E. Where recreation of a natural-like flow regime is not feasible, advocate that guaranteed minimum flows be implemented to protect fish and their habitats.

Ensure sufficient thermal regimes to maintain salmonid populations. Different minimum flows will generally be required at different times of the year in accordance with natural seasonal variation and the needs of salmonid life stages.

F. Advocate the installation, operation, and continuous monitoring of effective passage facilities that allow both upstream and downstream fish movement of native and wild salmonids and other native fishes at all relevant life stages, unless such removal will damage the upstream ecosystem (e.g., by allowing upstream movement of harmful non-native species, including pathogens).

G. Advocate the protection of groundwater recharge areas that maintain stream baseflow conditions and favorable water temperatures for salmonids and supporting aquatic life.

C. Harvest

General position: Support harvest that is consistent with the goal of maintaining stable, self-sustaining populations and support restricted harvest of wild populations through harvest methods and catch and release fisheries to restore depleted populations.

Trout Unlimited recognizes that recreational angling has aesthetic, cultural and economic value, and it can contribute directly to a socially responsible conservation ethic. TU also recognizes the federally granted treaty rights of Native American tribes that include legitimate cultural and economic needs. We recognize that our international treaty obligations, such as with Canada through the U.S./Canada Salmon Treaty, have great bearing on our ability to harvest salmonid fisheries across international boundaries, and thereby place on TU an international obligation to practice, and advocate for, sustainable harvest practices. We further recognize that recreational and commercial fisheries are privileges. The priority of fisheries management should go to the industry that generates the greatest economic impact. It should demonstrate the ability to selectively harvest hatchery stocks at a high level while minimizing mortality to wild salmonids and other species as by-catch. As a potential source of mortality for salmonids, however, all types of fishing must be conducted in a manner that is consistent with the goal of achieving and maintaining population self-sustainability. Three major harvest activities that impact salmonids are:

Over-fishing--Excessive harvest limits, both recreational and commercial, can damage the fishery by precluding population sustainability. Such excessive harvest may occur for either resident freshwater species or for anadromous species in either their marine or freshwater phases. Over-harvest, especially when combined with high natural mortalities associated with unfavorable ocean conditions and freshwater habitat degradation, can threaten the continued existence of anadromous salmon stocks (NRC 1996). Trout populations can benefit from catch and release regulations for recreational fisheries, even when bait is used (Carline et al. 1991).

Selective fishing--Some fishing practices strongly select against particular life histories of wild and native salmonid species. Loss of life history variation within populations can threaten the self-sustainability of natural productivity and adaptive capacity by restricting the age and size structure of these populations (Ricker 1981).

By-catch--The inadvertent taking of individuals from non-target populations in a mixed stock fishery can have severe consequences for the sustainability of the non-target population. Harvest methods that selectively minimize or eliminate by-catch are needed to protect wild trout and salmon from being depleted. For anadromous salmonids, over-harvesting of weak stocks in a mixed stock fishery that contains strong stocks can lead to population losses (NRC 1996). In the absence of selective harvest methods, a mixed-stock fishery cannot be managed for “maximum sustainable yield” without endangering the weak stock(s) (Larkin 1977). Similarly, inability to selectively harvest hatchery-produced fish that have been added to a mixed stock fishery can artificially increase pressure on wild stocks, resulting in population declines (NRC 1996).

Finally, TU recognizes that salmonids are part of intricate food webs, where they are predators, as well as prey for humans and other species, such as marine mammals. Increase in some west coast marine mammal populations have raised concerns about impacts of these mammals on declining Pacific salmonid stocks. Although predation by marine mammals is not a major factor in the current decline in salmon overall (NRC 1996), some human-induced modifications of salmonid habitats (such as locks and dams) may make salmonids much more vulnerable to mammal and fish (e.g., squawfish) predation.

POLICY RECOMMENDATIONS

A. Advocate sustainable harvest. Oppose harvest practices that are not conservative and that potentially endanger individual stocks or species by not accounting for natural fluctuations in population size over time (e.g., between years). Support restricted harvest to restore depleted populations.
B. Support harvest measures that reduce by-catch and that do not significantly deplete wild or native populations of concern. Advocate the mass marking of all hatchery salmonids as a priority action for the implementation of selective fisheries.
C. Advocate that the best scientific and statistical information be used to set harvest limits for local fisheries. Seek expertise from fishery biologists and biostatisticians in professional societies, government agencies, or academia to assess proposed or established harvest levels. Encourage fisheries management agencies to monitor the fishery to assess the effectiveness of the harvest management plan.
D. Promote harvest measures that maintain natural age-structure, size-structure, and genetic diversity of salmonid populations.

D. Hatcheries

<u>General</u> <u>position</u>: *Hatchery production and stocking are appropriate in the context of conserving and restoring native salmonid biodiversity and natural ecosystems, but use of hatcheries should not be substituted for proper management (based on the other 3 H's), which aims to restore self-sustaining wild and native salmonid populations. Where stocking is appropriately used, a rigorous program of biological risk management is required.*

Trout Unlimited applies the word “hatcheries” broadly to the artificial propagation (hatchery production) and associated human-aided dispersal (stocking) of fish. Hatchery practices have developed over the last 150 years or so (Bowen 1970), primarily to supplement natural reproduction and to increase the number of fish in the wild for recreational and commercial harvest. More recently, hatcheries have seen some use in the preservation of threatened and endangered salmonids. The widespread use of hatcheries and stocking continues to generate controversy, in part because the technical issues associated with artificial propagation are complex and the success of hatcheries to “mitigate” losses of natural population production is arguable. Trout Unlimited strives to briefly demonstrate here the proper role for, and the risks associated with, hatcheries.

Role of hatcheries in conservation and restoration--Healthy, pristine, or otherwise high quality aquatic systems should be managed to preserve their ecological and genetic integrity. Less healthy systems should be managed to rehabilitate or restore lost elements and function. In this latter case, hatcheries may sometimes be able to provide valuable services – when used in a temporary and scientifically monitored and constrained fashion and as part of a larger conservation strategy. For example, efforts to recover threatened or endangered native species may require use of artificial propagation and stocking as a stop-gap measure until a larger restoration program can be implemented. Hatcheries can also offer positive benefits in highly modified or disturbed ecosystems, such as urbanized watersheds or highly altered tailwaters below reservoirs that do not or cannot otherwise support the natural reproduction of wild salmonids.

Threats to Native and Wild Salmonids--Hatcheries and stocking are often used as “mitigation” to “restore” fisheries that are impaired by human activities that harm native fish populations (for example, dam-building, loss of habitat, introduction of exotic predators). Trout Unlimited recognizes that native fish populations can thrive only when the *causes* of population decline (e.g., poor habitat, inadequate hydrologic conditions, over-harvest) are solved rather than when the *symptoms* (not enough fish) are treated through stocking (Frissell and Nawa 1992, Meffe 1992, White 1992, Lichatowich et al.

1995, Stanford et al. 1996). For example, the intensive artificial propagation designed to mitigate extensive habitat loss in the Pacific Northwest due to river regulation over the last 100 years has not stemmed the decline in salmonid stocks (NRC 1996, Williams et al. 1996). The threats posed to native fishes by the continuing, improper use of hatcheries (stocking with non-native or inappropriate stocks or species, stocking in excess of local carrying capacities, etc.) are of paramount concern to Trout Unlimited, which recognizes the irreplaceable value of native biodiversity (at the stock, subspecies, species, and species assemblage levels).

TU recognizes three broad classes of problems and risks that are associated with hatchery production and stocking: disease, ecological, and genetic (Krueger and May 1991). *Diseases* such as whirling disease have been spread directly to wild salmonid populations from releases of infected hatchery fish (Nehring and Walker 1996, Vincent 1996). *Ecological interactions* between wild/native fish and introduced hatchery fish are also of concern. For example, releases of large numbers of hatchery fish into wild populations may result in increased predation on, or competition with, wild fish (Hilborn 1992, Fresh 1997), especially if the hatchery releases are of larger body size than wild fish. Mortality rates of wild fish may also indirectly rise due to increased harvest pressure associated with the supplemented fishery. The *loss of genetic heritage* (i.e., genetic composition, structure, function) in native stocks and populations due to hatchery production and stocking is of grave concern to TU. The genetic introgression and hybridization of pure stocks or species of salmonids resulting from artificial propagation are direct threats to native salmonid diversity. Interbreeding of native salmonids with non-locally-adapted, transferred hatchery fish generally results in reduced population production and diminished genetic resilience in the face of natural environmental variability; such genetic losses can be irreversible (Hindar et al. 1991, Waples 1991, Busack and Currens 1995, Reisenbichler 1997). “Thoughtless [genetic] introgression through human intervention” violates the principal goals of conservation biology and should be avoided (Ryman et al. 1995).

Threats to Aquatic Ecosystems--The introduction of exotic species, salmonids or not, can have tremendous negative consequences for native biodiversity (Moyle 1986, Fausch

1988, Krueger and May 1991, Minckley and Deacon 1991, OTA 1993, Moyle and Light 1996, The Nature Conservancy 1996, Townsend 1996b). The rapid decline in native freshwater biodiversity in the United States (Allan and Flecker 1993, The Nature Conservancy 1996, Richter et al. 1997) has contributed to the evolution of a conservation ethic that challenges the intentional spread of species beyond their natural or historical ranges. The concern of spreading non-natives certainly applies to native salmonids at risk from exotic species (including other salmonids). In far too many cases today, barriers are needed to protect isolated, small populations of native salmonids from encroachment by non-natives (Dudley and Embury 1995, Young 1995). This isolation, while preventing deleterious ecological interactions, has reduced the natural, low (and variable) rates of genetic exchange between populations, with uncertain consequences for long-term genetic maintenance (Mills and Allendorf 1996) and population persistence. This concern applies equally to non-salmonid species imperiled by the spread of hatchery-produced salmonids. Conflicts between non-native salmonids and native threatened or endangered non-salmonid species already occur (e.g., amphibians in California – Bradford 1989, Dudley and Embury 1995, Gill and Matthews 1998), and Trout Unlimited recognizes that harm can be caused to freshwater ecosystems by human-assisted range expansions of trout or salmon.

Trout Unlimited advocates that naturally fishless waters of natural diversity value not be stocked with non-native species at present or in the future. Further, where a body of scientific evidence shows that stocking in historically non-salmonid waters adversely affects native biodiversity (e.g., Bradford 1989, Dudley and Embury 1995, Gill and Matthews 1998), such stocking should cease. In all cases where stocking occurs, the burden of proof should lie with the state or federal agencies (or other proponents) to demonstrate that stocking does not cause ecological harm. Trout Unlimited does not necessarily advocate the removal of wild, non-native salmonid populations from ecosystems in which they are presently established. While this may be desirable in some situations (for example, to protect or restore native salmonids or endangered species), it may not be possible or ecologically practicable to effectively remove an established exotic except locally (Stanford et al. 1996, Townsend 1996b) and the risks posed to the entire aquatic ecosystem by aggressive intervention must be carefully evaluated. In all these situations, actions must be considered on a case-by-case basis.

Threats from aquaculture on public waters--The unmitigated effects of foodfish aquaculture, a special case of artificial propagation, conducted in public waters is also a growing concern in many parts of the country. The intensive culture of east coast Atlantic salmon in the northwestern oceanic waters of the United States and Canada typifies the growing commercial industry in foodfish production. A single net-cage, or net-pen, operation can potentially produce hundreds of thousands of market-sized fish. However, such intensive culture operations threaten native salmonids and their ecosystems through habitat alteration, pollution from concentrated metabolic waste, genetic modification, ecological interactions with escapees, and the introduction or spread of disease (Kohler 1992, Ellis 1996). These threats have already been realized in some countries where wild fisheries have collapsed due to over-harvest and habitat degradation. For example, in Norway, a net-cage aquaculture of Atlantic salmon has directly contributed to outbreaks of *Gyrodactylus* and *Furunculosis* in remaining wild populations due to escapement from the aquaculture industry (Hindar and Jonsson 1995, Ellis 1996).

At present there is no clear delineation of jurisdiction or uniform environmental oversight of aquaculture in North America. In the U.S., the Departments of Agriculture and Commerce, the Environmental Protection Agency, the Army Corps of Engineers, the individual states, and the various fishery management councils each claim some level of jurisdiction over the industry. Trout Unlimited will work with all these entities to minimize the disease, ecological, and genetic risks associated with this unregulated industry.

POLICY RECOMMENDATIONS

A. Support hatchery production and stocking of salmonids only as part of an integrated program that first seeks to correct problems with habitat, hydro, and harvest.

B. Adhere to scientifically-defensible conservation principles when using hatchery production and stocking. This includes use of locally-adapted fish for hatchery stock and application of rigorous monitoring and risk management techniques that fully account for the disease, ecological, and genetic risks associated with artificial propagation.

C. Oppose the stocking of fish known or suspected to be diseased.

D. Oppose stocking (or supplementation) in waters where healthy, self-sustaining salmonid populations or stocks exist.

E. Support activities that protect and/or restore native biodiversity. Such preservation measures should be carefully evaluated to minimize potential impacts on other species. Such actions include but are not limited to: (1) restoration of native salmonid stocks to their formerly occupied habitats, (2) the elimination of non-native stocking where it could adversely affect native salmonid populations (e.g., rainbow trout in cutthroat trout habitats, walleye in salmon migration routes), and (3) the prevention of native and wild salmonid stock introgression caused by mixing historically isolated populations of salmonids. In the limited case of endangered species preservation, it may be appropriate to support release of native salmonids outside of their historic range into historically non-salmonid waters that can serve as refugia for the species. In addition, oppose salmonid stocking in historically documented non-salmonid waters where scientific evaluation indicates that such stocking would be likely to adversely affect native biodiversity (e.g., stocking of O. mykiss in water historically devoid of salmonids but supporting California yellow-legged frogs in the Sierra Nevada).

F. Work with federal and state wildlife and resource management and protection agencies, local communities, local sport clubs and the legal system to enforce applicable laws and regulations that govern stocking practices.

G. Support stocking of unsustainable or non-self reproducing salmonids only where there is a low risk, based on an assessment, of ecological, environmental, or genetic harm to adjacent or resident native fish or other native species of concern.

H. Oppose the use of public resources to subsidize commercial aquaculture where the risks of escapement, disease transfer, or harmful nutrient/waste loading into recipient waters are excessive. Where aquaculture practices are in place, demand that strict monitoring plans be developed and implemented.

IV. Glossary

Adaptive management Use of planned experiments in a management context to guide future management action.

Anadromous Moving from the freshwater spawning areas to marine rearing areas, and back to freshwater for reproduction.

Artificial propagation Any assistance provided by man in the reproduction of salmonids. This includes, but is not limited to, spawning and rearing in hatcheries, stock transfers, creation of spawning habitat, egg bank programs, captive broodstock programs, and cryopreservation of gametes. (SOWSC 1994)

Biodiversity The variety and variability among living organisms and the ecological complexes in which they occur at many biological levels ranging from genes to species to ecosystems. (OTA 1987)

Carrying Capacity Maximum average number or biomass of organisms that can be sustained in a habitat over the long term. Usually refers to a particular species, but can be applied to more than one. (Meehan 1991)

Ecosystem A unit composed of interacting organisms considered together with their environment. (SOWSC 1994)

Floodplain Level lowland bordering a stream or river onto which the flow spreads at flood stage. (Meehan 1991)

Flow The quantity (volume) of water passing a fixed point per unit of time.

Flow Regime Patterns of flow volumes and variation over time space (including magnitude, frequency, duration, timing, and rate of change).

Habitat The quantity and quality of the physical/chemical environment in which salmonids complete their life cycles.

Indicator Species A species so highly adapted to a particular kind of environment that its presence is sufficient indication that specific conditions are met. (SOWSC 1994)

Lake A body of standing fresh water created by natural processes (compare to Reservoir).

Life History A succession of life stages that collectively exhibit unique demographic and ecological patterns. The life history of a specific salmon stock, for example, would be comprised of such particulars for that stock as length of residence in freshwater and marine habitats, timing of juvenile and adult migrations, distribution across and within watersheds, timing of spawning, age structure, and size. (SOWSC 1994)

Meta-population A population consisting of local populations that are linked by migrants, allowing for recolonization of unoccupied habitats after local extinction events. (SOWSC 1994)

Migratory An extended, directional movement that is an integral part of the life cycle, such as a spawning migration from the ocean or a lake up a river or the migration of juveniles downstream to the ocean or a lake. (Behnke 1992)

Native Salmonids Individuals of a species, subspecies, or stock of salmonid that are indigenous to a water body.

Population A collection of individual organisms of the same species that potentially interbreed and share a common gene pool. (SOWSC 1994)

Refuges or Refugia Locations and habitats that support populations of organisms that are limited to small fragments of their previous geographic range.

Rehabilitation The re-establishment of specific ecosystem components or processes to some degree of their previous state, but not with complete recovery of ecological function. (Gregory and Bisson 1997)

Restoration The re-establishment of the structure and ecological functions of specific components (e.g., habitat, population, species) in an entire ecosystem to a condition where the components and the ecosystem are self-maintaining, i.e., no longer requiring continued human intervention. (cf. Gregory and Bisson 1997)

Reservoir A body of standing fresh water created by human impoundment of a stream or river (compare to Lake).

Riparian Vegetation Vegetation growing on or near the banks of a stream or other body of water in soils that exhibit some wetness characteristics during some portion of the growing season. (Meehan 1991)

Salmonid Fish of the family Salmonidae, which comprises the salmon, trout, chars, whitefishes, and graylings.

Smolt Juvenile salmonid one or more years old that has undergone physiological changes to cope with a marine environment; the seaward migrant stage of an anadromous salmonid. (Meehan 1991)

Species A population or series of populations within which free gene flow occurs under natural conditions.

Stock The fish spawning in a particular lake or stream (or portion of it) at a particular season, which to a substantial degree do not interbreed with any group spawning in a different place, or in the same place at a different season. (Ricker 1972)

Subspecies A geographical race or group that differs morphologically from all other such groups of similar species.

Watershed (also basin, catchment, drainage area) The drainage basin contributing water, organic matter, dissolved nutrients, and sediments to a stream or lake. (SOWSC 1994)

Wild Salmonids Individuals of a species, subspecies, or stock that persist through natural reproduction. (Wild salmonids are not necessarily native species.)

V. Bibliography

Allan, J.D., and A.S. Flecker. 1993. Biodiversity conservation in running waters. BioScience 43:32-43.

Allendorf, F.W., D. Bayles, D.L. Bottom, K.P. Currens, C.A. Frissell, D. Hankin, J.A. Lichatowich, W. Nehlsen, P.C. Trotter, and T.H. Williams. 1997. Prioritizing Pacific salmon stocks for conservation. Conservation Biology 11:140-152.

Angermeier. P.A., and J.R., Karr. 1994. Biological integrity versus biological diversity as policy directives. BioScience 44:690-697.

Armour, C.L., D.A. Duff, and W. Elmore. 1991. The effects of livestock grazing on riparian and stream ecosystems. Fisheries 16(9):7-11.

Behnke, R.J. 1992. Native trout of western North America. American Fisheries Society Monograph 6. Bethesda, Maryland.

Benke, A.C. 1990. A perspective on America’s vanishing streams. Journal of the North American Benthological Society 9:77-88.

Beschta, R.L. 1978. Long-term patterns of sediment production following road construction and logging in the Oregon coast range. Water Resources Research 14:1011-1016.

Beven, K.J. 1986. Hillslope runoff processes and flood frequency characteristics. Pages187-202 in A.D. Abrahams, editor. Hillslope processes. Allen and Unwin, Boston, Massachusetts.

Bowen, J.T. 1970. A history of fish culture as related to development of fishery programs. Pages 71-93, in Benson, N. G. (ed.). A Century of Fisheries in North America. American Fisheries Society, Special Publication No. 7.

Bradford, D.F. 1989. Allotropic distribution of native frogs and introduced fishes in High Sierra Lakes of California: implication of the negative effect of fish introductions. Copeia 1989:775-778.

Brown, E.H., G.W. Eck, N.R. Foster, R.M. Horrall, and C.E. Coberly. 1981. Historical evidence for discrete stocks of lake trout (*Salvelinus namaycush*) in Lake Michigan. Canadian Journal of Fisheries and Aquatic Sciences 38:1747-1758.

Busack, C.A., and K.P. Currens. 1995. Genetic risks and hazards in hatchery operations: fundamental concepts and issues. American Fisheries Society Symposium 15:71-80.

Cacek, C.C. 1989. The relationship of mass wasting to timber harvest activities in the Lightning Creek basin, Idaho and Montana. Master's of Science Thesis. Eastern Washington State University, Cheney, Washington.

Carline, R.F., T. Beard, and B.A. Hollender. 1991. Response of wild brown trout to elimination of stocking and to no-harvest regulations. North American Journal of Fisheries Management 11:253-266.

Chapman, G. 1973. Effect of heavy metals on fish. Pages 141-162 in Heavy metals in the environment. Oregon State University, Water Resources Research Institute, Report SEMN-WR-D16.73, Corvallis, Oregon.

Chisholm, I.M., W.A. Hubert, and T.A. Wesche. 1987. Winter stream conditions and use of habitat by brook trout in high-elevation Wyoming streams. Transactions of the American Fisheries Society 116:176-184.

Collier, M., R.H. Webb, and J.C. Schmidt. 1996. Dams and rivers: primer on the downstream effects of dams. U.S. Geological Survey Circular 1126, Reston, Virginia.

Cunjak, R.A. 1996. Winter habitat of selected stream fishes and potential impacts from land-use activity. Canadian Journal of Fisheries and Aquatic Sciences 53 (Supplement 1): 267-282.

Cushman, R.M. 1985. Review of ecological effects of rapidly varying flows downstream from hydroelectric facilities. North American Journal of Fisheries Management 5:330-339.

Dombeck, M.P., J.E. Williams, and C.A. Wood. 1997. Watershed restoration: social and scientific challenges for fish biologists. Fisheries 22(5):26-27.

Doppelt, B., M. Scurlock, C. Frissell, and J. Karr. 1993. Entering the watershed: A new approach to save America's river ecosystems. Island Press, Washington, DC. P. 504.

Dudley, T. and M. Embury. 1995. Non-indigenous species in wilderness areas: The status and impacts of livestock and game species in designated wilderness in

California. Pacific Institute for Studies in Development, Environment, and Security. Oakland, California.

Ebel, W.J. 1969. Supersaturation of nitrogen in the Columbia River and its effects on salmon and steelhead trout. U.S. Fish & Wildlife Service Fisheries Bulletin 68:1-11.

Ebersole, J.L., W.J. Liss, and C.A. Frissell. 1997. Restoration of stream habitats in the Western United States: restoration as re-expression of habitat capacity. Environmental Management 21:1-14.

Echeverria, J.D., P. Barrow, and R. Roos-Collins. 1989. Rivers at Risk: The Concerned Citizen's Guide to Hydropower. Island Press, Washington, DC.

Ellis, D. W. 1996. Net Loss: the salmon netcage industry in British Columbia. Report to the David Suzuki Foundation, Vancouver, British Columbia.

Fausch, K.D. 1988. Tests of competition between native and introduced salmonids in streams: What have we learned? Canadian Journal of Fisheries and Aquatic Sciences 45:2238-2246.

Fausch, K.D., and M.K. Young. 1995. Evolutionary significant units and movement of resident stream fishes: A cautionary tale. American Fisheries Society Symposium 17:360-370.

Fausch, K.D., C. Gowan, A.D. Richmond, and S.C. Riley. 1995. Rôle de la dispersion dans la réponse des populations de truites aux habitata formés par les grands débrix lingeux dans les ruisseaux de montagne du Colorado. Bull. Fr. Pêche Piscic. 337/338/339:179-190.

Fausch, K.D., J.R. Karr, and P.R. Yant. 1984. Regional application of an index of biotic integrity based on stream fish communities. Transactions of the American Fisheries Society. 113:39-55.

Flather, C.H., L.A. Joyce, and C.A. Bloomgarden. 1994. Species endangerment patterns in the United States. U.S. Forest Service General Technical Report RM-241, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado.

Fore, L. S., J. R. Karr, and R. W. Wisseman. 1996. Assessing invertebrate responses to human activities: evaluating alternative approaches. Journal of the North American Benthological Society 15:212-231.

Francfort, J.E., G.F. Cada, D.D. Dauble, R.T. Hunt, D.W. Jones, B.N. Rinehart, G.L. Sommers, and R.J. Costello. 1994. Environmental mitigation at hydroelectric projects. Volume II. Benefits and costs of fish passage and protection. U.S. Department of Energy, Idaho National Engineering Laboratory, EG&G Idaho, Inc., Idaho Falls, Idaho.

Fresh, K.L. 1997. The role of competition and predation in the decline of Pacific salmon and steelhead. Pages 245-275 in D.J. Stouder, P.A. Bisson, and R.J. Naiman (editors). Pacific salmon & their ecosystems. Chapman & Hall, New York, New York.

Friedland, K.D., D.G. Reddin, and J.F. Kocik. 1993. Marine survival of North American and European Atlantic salmon: effects of growth and environment. ICES Journal of Marine Science 50:481-492.

Frissell, C.A. 1993. Topology of extinction and endangerment of native fishes in the Pacific Northwest and California (U.S.A.). Conservation Biology 7:342-354.

Frissell, C.A. 1997**.** Ecological principles. In J.E. Williams, C.A. Wood, and M.P. Dombeck (editors). Watershed restoration: principles and practices. American Fisheries Society, Bethesda, Maryland. In Press.

Frissell, C.A., and R.K. Nawa. 1992. Incidence and causes of physical failure of artificial fish habitat structures in streams of western Oregon and Washington. North American Journal of Fisheries Management 12:182-197.

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

Furniss, M.J., T.D. Roelofs, and C.S. Yee. 1991. Road construction and maintenance. Pages 297-323 in W.R. Meehan (editor). Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19, Bethesda, Maryland.

Gill C. and K. Matthews. 1998. Frogs or fish? Forestry Research West. August 1998 pp. 1-4. USDA Forest Service. Washington, DC.

Gore, J.A., 1994. Hydrologic change. Pages 33-54 in P. Calow and G.E. Petts (editors). The rivers handbook, vol. 2. Wiley & Sons, Chichester, United Kingdom.

Gowan, C., and K.D. Fausch. 1996. Long-term demographic responses of trout populations to habitat manipulation in six Colorado streams. Ecological Applications 6:931-946.

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 51:2626-2637.

Gregory, S.V., and P.A. Bisson. 1997. Degradation and loss of anadromous salmonid habitat in the Pacific Northwest. Pages 277- 314 in D.J. Stouder, P.A. Bisson, and R.J. Naiman (editors). Pacific salmon & their ecosystems. Chapman & Hall, New York, New York.

Gregory, S.V., F.J. Swanson, and W.A. McKee. 1991. An ecosystem perspective of riparian zones. BioScience 41:540-551.

Hammer, T.R. 1972. Stream channel enlargement due to urbanization. Water Resources Research 8:1530-1540.

Harris, E.E., and S.E. Rantz. 1964. Effect of urban growth on streamflow regime of Permanente Creek, Santa Clara County, CA. U.S. Geological Survey Professional Paper 485-E.

Harvey, B. C. 1987. Susceptibility of young-of-the-year fishes to downstream displacement by flooding. Transactions of the American Fisheries Society 116:851-855.

Hilborn, R. 1992. Hatcheries and the future of salmon in the Northwest. Fisheries 17:5-8.

Hindar, K. and B. Jonsson. 1995. Impacts of aquaculture and hatcheries on wild fish. Pages 70-87 in D.P. Philipp, J. M. Epifanio, J. E. Marsden, J.E. Claussen, and R.J. Wolotira, Jr. (editors). Proceedings of the World Fisheries Congress, vol. 3. Oxford Press International. New Delhi, India.

Hindar, K., N. Ryman and F. Utter. 1991. Genetic effects of cultured fish on natural fish populations. Canadian Journal of Fisheries and Aquatic Sciences 48:945-57.

Jones, J.A., and G.E. Grant. 1996. Peak flow responses to clear-cutting and roads in small and large basins, western Cascades, Oregon. Water Resources Research 32: 959-974.

Kaeding, L.R. 1995. Summer use of coolwater tributaries of a geothermally heated stream by rainbow and brown trout, *Oncorhynchus mykiss* and *Salmo trutta*. American Midland Naturalist. 135: 283-292.

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

Karr, J.R. 1991. Biological integrity: A long-neglected aspect of water resource management. Ecological Applications 1:66-84.

Karr, J.R., and I.J. Schlosser. 1978. Water resources and the land water interface. Science 201:229-234.

Karr, J. R., K. D. Fausch, P. L. Angermeier, P. R. Yant, and I. J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Illinois Natural History Survey Special Publication 5.

Kerans, B. L., and J. R. Karr. 1994. A benthic index of biotic integrity (B-IBI) for rivers of the Tennessee Valley. Ecological Applications 4:768-785.

Kingsolving, A. D., and M. B. Bain. 1993. Fish assemblage recovery along a riverine disturbance gradient. Ecological Applications 3:531-544.

Kohler, C. C. 1992. Environmental risk management of introduced aquatic organisms in aquaculture. ICES Marine Science Symposium 194:15-20.

Kondolf, G.M., and E.R. Micheli. 1995. Evaluating stream restoration projects. Environmental Management. 19:1-15.

Krueger, C.C., and P.E. Ihssen. 1995. Review of genetics of lake trout in the Great Lakes: history, molecular genetics, physiology, strain comparisons, and restoration management. Journal of Great Lakes Research (Suppl.) 21:348-363.

Krueger, C. C., and B. May. 1991. Ecological and genetic effects of salmonid introductions in North America. Canadian Journal of Fisheries and Aquatic Sciences. 48:66-77.

Larkin, P.A. 1977. An epitaph for the concept of maximum sustained yield. Transactions of the American Fisheries Society 106:1-11.

Lichatowich, J., L. Mobrand, L. Lestelle, and T. Vogel. 1995. An approach to the diagnosis and treatment of depleted Pacific salmon populations in Pacific Northwest watersheds. Fisheries 20(1):10-18.

Ligon, F.K., W.E. Dietrich, and W.J. Trush. 1995. Downstream ecological effects of dams, a geomorphic perspective. BioScience 45:183-192.

Likens, G.E., F.H. Bormann, N.M. Johnson, D.W. Fisher, and R.S. Pierce. 1970. Effects of forest cutting and herbicide treatment on nutrient budgets in the Hubbard Brook watershed-ecosystem. Ecological Monographs 40:23-47.

Lowrance, R., R. Todd, J. Fail, O. Hendrickson, R. Leonard, and L. Asmussen. 1984. Riparian forests as nutrient filters in agricultural watersheds. BioScience 34: 374-377.

Lyons, J., L. Wang, and T.D. Simonson. 1996. Development and validation of an index of biotic integrity for coldwater streams in Wisconsin. North American Journal of Fisheries Management 16:241-256.

Maxwell, J. R., C. J. Edwards, M. E. Jensen, S. J. Paustian, H. Parrott, and D. M. Hill. 1995. A hierarchical framework of aquatic ecological units in North America (Nearctic Zone). General Technical Report NC-GTR-176, US Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota.

Meehan, W.R. (editor). 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19, Bethesda, Maryland.

Meffe, G.K. 1992. Techno-arrogance and halfway technologies: Salmon hatcheries on the Pacific Coast of North America. Conservation Biology 6:350-354.

Meisner, J.D. 1990. Effect of climatic warming on the southern margins of the native range of brook trout, *Salvelinus fontinalis*. Canadian Journal of Fisheries and Aquatic Sciences. 47:1065-1070.

Memorandum of Understanding (MOU). 1990. Memorandum of agreement between the Environmental Protection Agency and the Department of the Army concerning the determination of mitigation under the Clean Water Act Section 404(b)(1) guidelines.

Mills, L.S., and F.W. Allendorf. 1996. The one-migrant-per-generation rule in conservation and management. Conservation Biology 10:1509-1518.

Minckley, W.L., and J.E. Deacon (editors). 1991. Battle against extinction: Native fish management in the American West. University of Arizona Press, Tucson, Arizona.

Minns, C.K., M.R.M. Kelso, and R.G. Randall. 1996. Detecting response of fish to habitat alterations in freshwater ecosystems. Canadian Journal of Fisheries and Aquatic Sciences 53 (Suppl. 1):403-414.

Minshall, G.W. 1988. Stream ecosystem theory: a global perspective. Journal of the North American Benthological Society 7:263-288.

Moore, S.E., B. Ridley, and G.L. Larson. 1983. Standing crops of brook trout concurrent with removal of rainbow trout from selected streams in Great Smoky Mountains National Park. North American Journal of Fisheries Management 3:72-80.

Moyle, P.B. 1986. Fish introductions into North America: patterns and ecological impact. Pages 27-43 in H.A. Mooney and J.A. Drake, editors. Ecology of biological invasions of North America and Hawaii. Springer-Verlag, New York, New York.

Moyle, P.B., and T. Light. 1996. Fish invasions in California: Do abiotic factors determine success? Ecology 77:1666-1669.

Naiman, R.J. (editor). 1992. Watershed management: balancing sustainability and environmental change. Springer-Verlag, New York, New York.

Naiman, R.J, J.J. Magnuson, D.M. McKnight, and J.A. Stanford. 1995. The freshwater imperative: a research agenda. Island Press, Washington, DC.

National Research Council (NRC) 1992. Restoration of Aquatic Systems: Science, Technology, and Public Policy. National Academy Press, Washington, DC. (USA)

National Research Council (NRC). 1996. Upstream: salmon and society in the Pacific Northwest. National Academy Press, Washington, DC.

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.

Nehring, R. B., and P. G. Walker. 1996. Whirling disease in the wild: the new reality in the intermountain West. Fisheries 21:28-30.

Noss, R.F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology 4:355-364.

Office of Technology Assessment (OTA). 1987. Technologies to maintain biological diversity. Congress of the United States, OTA-F-330. Washington, DC.

Office of Technology Assessment (OTA). 1995. Fish passage technologies: protection at hydropower facilities. Congress of the United States, OTA-ENG-641, Washington, DC.

Office of Technology Assessment (OTA). 1993. Harmful non-indigenous species in the United States. Congress of the United States, OTA-F-565, Washington, DC**.**

Pearcy, W.G. 1992. Ocean ecology of North Pacific salmonids. University of Washington Press, Washington Sea Grant Program, Seattle, Washington.

Perkins, D.L, and C.C. Krueger. 1993. Heritage brook trout in Northeastern USA: genetic variability within and among populations. Transactions of the American Fisheries Society 122:515-532.

Petts, G.E. 1984. Impounded rivers: perspectives for ecological management. John Wiley & Sons, New York, New York.

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: benthic macroinvertebrates and fish. U.S. Environmental Protection Agency EPA/444/4-89-011, Washington, DC.

Platts, W.S. 1991. Livestock grazing. Pages 389-424 in W.R. Meehan (editor). Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19.

Platts, W.S., W.F. Megahan, and G.W. Minshall. 1983. Methods for evaluating stream, riparian and biotic conditions. US Forest Service, General Technical Report INT-138. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Poff, N.L., and J.V. Ward. 1990. Physical habitat template of lotic ecosystems: recovery in the context of historical pattern of spatiotemporal heterogeneity. Environmental Management 14:629-645.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The natural flow regime: a paradigm for river conservation and restoration. BioScience (In Press).

Postel, S., and S. Carpenter. 1997. Freshwater ecosystem services. Pages 195-214 in G. Daily (ed.). Nature's services: societal dependence on natural ecosystems. Island Press, Washington, DC.

Power, M.E., W.E. Dietrich, and J.C. Finlay. 1996. Dams and downstream aquatic biodiversity: potential food web consequences and geomorphic change. Environmental Management 20:887-895.

Power, M.E., S.J. Kupferberg, G.W. Minshall, M.C. Molles, and M.S. Parker. 1997. Sustaining Western aquatic food webs. Pages 45-61 in Western Water Policy Review, Presidential Advisory Commission, Fifth Meeting - Aquatic Ecology Symposium, Arizona State Universtity.

Rahel, F.J., C.J. Keleher, and J.L. Anderson. 1996. Potential habitat loss and populations fragmentation for cold water fish in the North Platte drainage of the Rocky Mountains: response to climate warming. Limnology and Oceanography 41:1116-1123.

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

Reisenbichler, R.R. 1997. Genetic factors contributing to declines of anadromous salmonids in the Pacific Northwest. Pages 223-244 in D.J. Stouder, P.A. Bisson, and R.J. Naiman (editors). Pacific salmon & their ecosystems. Chapman & Hall, New York, New York.

Richter, B.D., D.P. Braun, M.A. Mendelson, and L.L. Master. 1997. Threats to imperiled freshwater fauna. Conservation Biology (In Press).

Ricker, W.E. 1972. Hereditary and environmental factors affecting certain salmonid populations. Pages 19-160 in R.C. Simon and P.A. Larkin, editors. The stock concept in Pacific salmon. University of British Columbia, Institute of Animal Resource Ecology, Vancouver, British Columbia.

Ricker, W.E. 1981. Changes in the average size and average age of Pacific salmonids. Canadian Journal of Fisheries and Aquatic Sciences 38:1636-1656.

Rieman, B.E., and J.D. McIntyre. 1995. Occurrence of bull trout in naturally fragmented habitat patches of various size. Transactions of the American Fisheries Society 124:285-296.

Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1991. Common and scientific names of fishes from the United States and Canada (5th ed.). American Fisheries Society Special Publication 20. Bethesda, Maryland.

Roper, B.B., J.J. Dose, and J.E. Williams. 1997. Stream restoration: is fisheries biology enough? Fisheries 22(5):6-11.

Rosgen, D.R. 1996. Applied river morphology. Wildland Hydrology, Pagosa Springs, Colorado.

Ryman, N., F. Utter, and K. Hindar. 1995. Introgression, supportive breeding, and genetic conservation. Pages 341-365 in J.D. Ballou, M. Gilpin, and T.J. Foose (editors). Population management for survival and recovery: analytical methods and strategies in small population conservation. Columbia Univ. Press, New York, New York.

Saunders, R.L. 1981. Atlantic salmon (*Salmo salar*) stocks and management implications in the Canadian Atlantic Provinces and New England, USA. Canadian Journal of Fisheries and Aquatic Sciences 38:1612-1625.

Save Our Wild Salmon Coalition (SOWSC). 1994**.** Wild salmon forever: a citizen’s strategy to restore Northwest salmon and watersheds.

Schlosser, I.J., and P.L. Angermeier. 1995. Spatial variation in demographic processes of lotic fishes: conceptual models, empirical evidence, and implications for conservation. American Fisheries Society Symposium 17:392-401.

Sear, D.A. 1995. Morphological and sedimentological changes in a gravel-bed river following 12 years of flow regulation for hydropower. Regulated Rivers: Research & Management 10:247-264.

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

Stanford, J.A., J.V. Ward, W.J. Liss, C.A. Frissell, R.N. Williams, J.A. Lichatowich, and C.C. Coutant. 1996. A general protocol for restoration of regulated rivers. Regulated Rivers: Research & Management 12:391-414.

Stolz, J., and J. Schnell (editors). 1991. Trout. Stackpole Books, Harrisburg, Pennsylvania.

The Nature Conservancy. 1996. Troubled waters: protecting our aquatic heritage. The Nature Conservancy, Arlington, Virginia.

Tilman, D. 1997. Biodiversity and ecosystem functioning. Pages 93-112 in G. Daily (ed.). Nature's services: societal dependence on natural ecosystems. Island Press, Washington, DC.

Townsend, C. R. 1996a. Concepts in river ecology: pattern and process in the catchment hierarchy. Archiv für Hydrobiologie Supplement 113 Large Rivers 10:3-21.

Townsend, C.R. 1996b. Invasion biology and ecological impacts of brown trout, *Salmo trutta*, in New Zealand. Biological Conservation 78:13-22.

Trout Unlimited. 1990. Trout Unlimited's salmonid resource policy. Arlington, Virginia.

Trout Unlimited. 1994. Conserving salmonid biodiversity on federal lands: Trout Unlimited's policy on mining, grazing, and timber harvest. Arlington, Virginia.

US EPA. 1994. National water quality inventory - 1992 report to Congress. Environmental Protection Agency, 841-R-94-001, Washington, DC.

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

Vincent, E. R. 1996. Whirling disease and wild trout: The Montana experience. Fisheries 21:32-33.

Waples, R.S. 1991. Genetic interactions between hatchery and wild salmonids: lessons from the Pacific Northwest. Canadian Journal of Fisheries and Aquatic Sciences 48:124-133.

Ward, J.V. 1989. The four-dimensional nature of lotic ecosystems. Journal of the North American Benthological Society 8:2-8.

Ward, J.V., and J.A. Stanford. 1979. The ecology of regulated streams. Plenum Press, New York, New York.

Waters, T.F. 1995. Sediment in streams: sources, biological effects, and control. American Fisheries Society, Bethesda, Maryland.

Weisberg, S.B., A.J. Janicki, J. Gerritsen, and H.T. Wilson. 1990. Enhancement of benthic macroinvertebrates by minimum flow from a hydroelectric dam. Regulated Rivers: Research & Management 5:265-277.

White, R.J. 1992. Why wild fish matter: balancing ecological and aquacultural fishery management. Trout. Autumn issue, pages 18-48.

Williams, R.N., L.D. Calvin, C.C. Coutant, M.W. Erho, Jr., J.A. Lichatowich, W.J. Liss, W.E. McConnaha, P.R. Mundy, J.A. Stanford, and R.R. Whitney. 1996. Return to the river: restoration of salmonid fishes in the Columbia River ecosystem. Independent Scientific Group report prepared for the Northwest Power Planning Council.

Wilson, E.O. (editor). 1988. Biodiversity. National Academy Press, Washington, DC.

Wootton, J.T., M.S. Parker, and M.E. Power. 1996. Effects of disturbance on river food webs. Science 273:1558-1561.

Wright, K.A., K.H. Sendek, R.M. Rice, and R.B. Thomas. 1990. Logging effects on streamflow: storm runoff at Caspar Creek in northwestern California. Water Resources Research 26:1657-1667.

Young, M.K. (technical editor). 1995. Conservation assessment for inland cutthroat trout. General Technical Report RM-256. Fort Collins, CO: US Forest Service, Rocky Mountain Forest and Range Experiment Station. page 61.