The Case for Salmon Conservation at the Watershed Scale in Southeast Alaska: An annotated bibliography

Trout Unlimited Alaska

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The numerous and diverse watersheds of southeast Alaska, in contrast to those elsewhere in the Pacific Northwest, support abundant and sustainable runs of five species of Pacific salmon (Baker et al. 1996; Halupka et al. 2000; Lohr and Bryant 1999). This can be attributed to the large number of intact watersheds and relatively low intensity of human impacts in many watersheds throughout the region (Bryant and Everest 1998). Wide distribution of watersheds with habitats that are formed and maintained by natural processes and conservative harvest practices are essential for sustainable salmon stocks (Baker et al. 1996; Meacham and Clark 1994; Schindler et al. 2008). The biological and physical processes that support these stocks are reasonably well documented in many cases throughout the Pacific Northwest and Alaska.

The purpose of this bibliography is to compile this information into a single, searchable source. The scope of the bibliography includes relevant studies, primarily from peer-reviewed literature, throughout the Pacific Northwest, including British Columbia, Washington, Oregon, and Idaho that would support the case for protecting whole watersheds as an integral tool in salmon conservation. Studies from other geographic locations are included if they are relevant at the watershed scale. The objective of the bibliography is to assemble a set of published studies that describe the structure and function of watersheds that are important to spawning and rearing habitats

of salmon in southeast Alaska. These include the five Pacific salmon; Chinook (*Oncorhynchus tshawytscha*), coho (*O. kitsutch*), sockeye (*O. nerka*), chum (*O. keta*), and pink salmon (*O. gorbuscha*); and steelhead (*O. mykiss*). These species also share habitats with cutthroat trout (*O. clarkii*) and Dolly Varden (*Salvelinus malma*). Citations include those that describe and discuss watershed structure and function as well as specific studies of various parts of the watershed, such as headwaters, tributaries, and main stream. The studies include those that typically describe the relationships between habitats and salmon populations and connectivity of elements within the watershed.

The bibliography consists of the complete citation listed by author and date, the publication, volume and pages, a set of keywords, and an abstract or brief summary of the article. Citations listed by author and date are organized into groups by keywords that describe their location within the watershed beginning at the watershed scale. The groups include studies that focus on the watershed scale, main stream, tributaries, headwaters, and estuaries. A group of studies that discuss effects or potential effects of climate change on salmon and their habitat is also included. Many studies may cover multiple parts of the watershed and the groups will include duplicate entries. The complete citation with the abstract and keywords is listed once alphabetically by author.

All of the listed citations are available in a searchable database using Endnote. The Endnote database can be searched using a robust combination of keywords, author, date, and by words or phrases found in the title or abstract. All citations in the database can be edited to include additional keywords or additional information in the abstract or summary. It can be updated to include addition references as they are found or become available.

Bibliography List

Watershed Scale

(Abrahams 1984; Amoros and Bornette 2002; Baron et al. 2002; Beamish et al. 1997; Benda et al. 2004; Benda et al. 1992; Bilby and Mollot 2008; Bilby and Ward 1989; Bilby and Ward 1991; Bisson et al. 2009; Bryant 1983; Bryant 1984a; Bryant and Everest 1998; Bryant et al. 1999; Bryant and Woodsmith 2009; Burnett et al. 2007; Clark et al. 2006; Cummins 1974; Davies and Walker 1986; Dunning et al. 1992; Ebersole et al. 2006; Feller and Kimmins 1984; Frissell et al. 1986; Good et al. 2008; Gowan et al. 1994; Greene et al. 2005; Gregory et al. 1991; Groot and Margolis 1991; Halupka et al. 2000; Halupka et al. 2003; Hartman et al. 1996; Hilborn et al. 2003; Hill et al. 2010; Hocking and Reimchen 2009; Hood 2007; Imhof et al. 1996; Johnson and Naiman 1987; Johnston and Naiman 1990; Jones 2010; Junk et al. 1989; Leisca and Allendorf 1995; Lohr and Bryant 1999; Lotspeich 1980; Meacham and Clark 1994; Meehan 1991; Milner and Bailey 1989; Minshall et al. 1985; Montgomery 1999; Montgomery et al. 1995a; Montgomery et al. 1995b; Montgomery et al. 2003; Moore et al. 1991; Muhar and Jungwirth 1998; Naiman et al. 2000; Naiman et al. 1997; Naiman et al. 1988a; Newbold et al. 1981; Nickelson and Lawson 1998; Northcote and Hartman 2004; Northcote and Healey 2007; Paustian 1992; Pess et al. 2002; Poff et al. 1997; Pringle 2001; Robison and Beschta 1990; Rot et al. 2000; Sedell and Froggatt 1984; Sharma and Hilborn 2001; Sheer and Steele 2006; Stanford et al. 1988; Stanford and Ward 1993; Statzner and Higler 1985; Steel et al. 2008; Swanston 1969; Tiegs et al. 2008; Vannote et al. 1980; Waples et al. 2009; Ward and Stanford 1983; Wissmar et al. 2010; Wright and Li 2002)

Main Stream

(Andrus et al. 1988; Beechie et al. 1994; Beechie and Sibley 1997; Benda et al. 1992; Bilby and Ward 1989; Bilby and Ward 1991; Bonneau and Scarnecchia 1998; Bramblett et al. 2002; Bryant 1980; Bryant 1984a; Bryant and Woodsmith 2009; Campbell et al. 2011; Carlson et al. 1990; Cederholm and Reid 1987; Coates et al. 1985; Collins et al. 2002; Colyer et al. 2005; Connor et al. 2003; Crone and Bond 1976; Dunham et al. 2002; Fausch 1993; Hartman and Scrivener 1990; Hauer et al. 1999; Hayes et al. 2008; Hilderbrand and Kershner 2000; Holtby et al. 1989; Holtby and Scrivener 1989; Johnson et al. 2005; Kahler et al. 2001; Kiffney et al. 2009; Lawson et al. 2004; Martin and Benda 2001; McHenry et al. 1998; McMahon and Blair Holtby 1992; Moir and Pasternack 2008; Murphy et al. 1989; Nass et al. 1996; Reeves et al. 2003; Reeves et al. 1993; Schmetterling 2001; Shirvell 1990; Tripp and Poulin 1986; Triska 1984; Tschaplinski and Hartman 1983)

Tributaries

(Allan et al. 2003; Anderson and Lehmkuhl 1968; Andrus et al. 1988; Beechie and Sibley 1997; Benda et al. 2004; Benda et al. 1992; Bilby and Ward 1989; Bilby and Ward 1991; Bjornn et al. 1991; Bramblett et al. 2002; Bryant 1984a; Bryant et al. 1998; Bugert et al. 1991; Bustard and Narver 1975; Carlson et al. 1990; Dolloff 1987; Dolloff and Reeves 1990; Duncan and Brusven 1985; Fausch and Northcote 1992; Feller and Kimmins 1984; Harvey 1998; Harvey et al. 1999; Heggenes et al. 1991a; Heggenes et al. 1991b; Heggenes et al. 1991c; Heifetz et al. 1986; Hetrick et al. 1998a; Hetrick et al. 1998b; Hogan and Church 1989; Johnson et al. 2005; Kahler et al. 2001; Keith et al. 1998; Lisle 1986;

Murphy et al. 1986; Murphy et al. 1989; Nass et al. 1996; Newbold et al. 1981; Nickelson et al. 1992; Rice et al. 2008; Rosenfeld et al. 2000; Rosenfeld and Boss 2001; Rosenfeld and Huato 2003; Solazzi et al. 2000; Stednick 2008; Swain and Holtby 1989; Swales et al. 1988; Thedinga et al. 1989; Tripp and Poulin 1986; Triska et al. 1989; Wissmar et al. 1997)

Off Channel

(Allred 1980; Beedle 1991; Bryant 1984b; Burchsted et al. 2010; Collen and Gibson 2001; Gard 1961; Johnson and Naiman 1987; Johnston and Naiman 1990; Leidbold-brunner 1992; Miller and Sadro 2003; Morley et al. 2005; Murphy et al. 1989; Naiman et al. 1988b; Nickelson et al. 1992; Peterson 1982a; Peterson 1982b; Rosenfeld et al. 2008; Swales et al. 1986; Swales and Levings 1989; Wigington et al. 2006)

Climate Change

(Beacham and Murray 1990; Beamish et al. 1997; Beamish et al. 1999; Berggren and Filardo 1993; Bryant 2009; Carpenter et al. 1992; Connor et al. 2003; Decamps 1993; Eaton and Adams 1995; Eaton and Scheller 1996; Finney et al. 2000; Hilborn et al. 2003; Lawson et al. 2004; Mantua 2009 ; McFarlane et al. 2000; Mote et al. 2003; Schindler et al. 2008; Shirvell 1994; Taylor 2008; Williams et al. 2009)

Literature Summaries

Abrahams, A. D. 1984. Channel networks: a geomorphological perspective. Water Resources Research 20(2):161-168.

'KEY WORDS'
Watershed Scale
Channel morhology
Geomorpholgy
'ABSTRACT'

The study of channel networks has been dominated since 1966 by the random model. However, recent work has shown (1) that although the topological properties of small networks conform to the random model more closely than those of large ones, even small networks exhibit systematic deviations from topological randomness and (2) that the topological and length properties of channel networks are controlled to a large degree by the spatial requirements of subbasins and the need for these subbasins to fit together in space, by the size, sinuosity, and migration rate of valley bends, and by the length and steepness of valley sides. The factors that control the density properties of channel networks vary with the scale of the investigation and the geomorphic processes governing channel initiation. Although progress has been made toward a satisfactory stream junction angle model, further work is needed. The evolution of channel networks has been investigated by a variety of methods, including the development of conceptual and simulation models, the monitoring of small-scale badland and experimental drainage basins, and the substitution of space for time. The morphology of most channel networks is largely inherited from the past or strongly influenced by inherited forms. Inasmuch as there is no way of ever knowing the origin or complex history of such networks, the use of stochastic models in their study seems unavoidable.

Allan, J. D., M. S. Wipfli, J. P. Caouette, A. Prussian, and J. Rodgers. 2003. Influence of sreamside vegetation on inputs of terrestrial invertebrates to salmonid food webs. Canadian Journal of Fisheries and Aquatic Sciences 60:309-320.

'KEY WORDS'
Tributaries
Southeast Alaska
Coho salmon
Feeding ecology
Riparian vegetation
'ABSTRACT'

Salmonid food webs receive important energy subsidies via terrestrial in-fall, downstream transport, and spawning migrations. We examined the contribution of terrestrially derived invertebrates (TI) to juvenile coho (Oncorhynchus kisutch) in streams of southeastern Alaska by diet analysis and sampling of TI inputs in 12 streams of contrasting riparian vegetation. Juvenile coho ingested 12.1 mg·fish−1 of invertebrate mass averaged across all sites; no significant differences associated with location (plant or forest type) were detected, possibly because prey are well mixed by wind and water dispersal. Terrestrial and aquatic prey composed approximately equal fractions of prey ingested. Surface inputs were estimated at ~80 mg·m−2·day−1, primarily TI. Direct sampling of invertebrates from the stems of six plant species demonstrated differences in invertebrate taxa occupying different plant species and much lower TI biomass per stem for conifers compared with overstory and understory deciduous plants. Traps placed under red alder (Alnus rubra) and conifer (mix of western hemlock (Tsuga heterophylla) and Sitka spruce (Picea sitchensis)) canopies consistently

captured higher biomass of TI under the former. Management of riparian vegetation is likely to influence the food supply of juvenile coho and the productivity of stream food webs.

Allred, M. 1980. A re-emphasis on the value of the beaver in natural resource conservation. Journal of the Idaho Academy of Science 16(1):3-10.
'KEY WORDS'
Off Channel
Beaver
Conservation
'ABSTRACT'
Beaver ponds provide a range of habitats for fish,wildlife, & vegetation succession.

Amoros, C., and G. Bornette. 2002. Connectivity and biocomplexity in waterbodies of riverine floodplains. Freshwater Biology 47:761-776.
'KEY WORDS'
Watershed scale
Theory
floods
biodiversity
river dynamics
succession
'ABSTRACT'
In river corridors, water plays a key role in connecting various landscape patches. This `hydrological connectivity' operates on the four dimensions of fluvial hydrosystems: longitudinal, lateral, vertical, and temporal. The present review focuses on: (1) lateral connectivity that links the main course of a river with floodplain waterbodies; and (2) vertical connectivity, the exchanges between the surface and groundwater via infiltration into the alluvial aquifer and exfiltration of phreatic water from the hillslope aquifer.The biocomplexity of fluvial hydrosystems results from interactions between processes operating at various spatial and temporal scales. Differences in the nature and intensity of hydrological connectivity contribute to the spatial heterogeneity of riverine floodplains, which results in high alpha, beta and gamma diversity. Differences in connectivity also provide complementary habitats that are required for the parts of life cycles and life-cycles of some species. Hydrological connectivity also produces antagonistic effects, even within the same waterbody. Two temporal scales are distinguished in connectivity dynamics. River level fluctuations within years lead to a pulsing connectivity that drives the functioning of floodplain ecosystems, namely the exchange of organic matter and inorganic nutrients and the shift between production and transport phases. On the scale of decades to centuries, the interactions between various processes increase the biocomplexity of floodplains; for example, river dynamics, which create highly connected waterbodies, compensate for succession that tends towards disconnection. Alternatively, river-bed incision leads to the reduction of fluvial dynamics and to the disconnection of waterbodies, although river incision may increase vertical connectivity where waterbodies are supplied by the hillslope aquifer.

Anderson, N. H., and D. M. Lehmkuhl. 1968. Catastrophic drift of insects in a woodland stream. Ecology 49(2):198-206.
'KEY WORDS'
Tributaries
Headwater streams
Oregon
Aquatic insects
Drift
'ABSTRACT'
The effect of early fall rains on the downstream drift or displacement of insects was studied for two seasons by collecting the entire streamflow at one point through a drift net. Drift rate

increased within 24 hr after the start of each rainy period, with the increase approximately proportional to the increase in stream flow. Freshets due to less than 1 in. (2.5 cm) of rain caused a fourfold increase in numbers and fivefold to eightfold increase in biomass. Major components of the drift were Ephemeroptera, Plecoptera, Diptera and terrestrial insects. Plecoptera and Ephemeroptera retained the day—night periodicity of behavioral drift during freshets, but drift of Chironomidae (Diptera) was attributed to catastrophic and constant drift. Mean weight per individual of several taxa was greater at night than day, in freshet than nonfreshet periods, and in drift compared with benthos samples. Though catastrophic drift due to fall freshets displaced large numbers of individuals, the standing crop of the benthos increased during the fall because of hatching. The drift may be beneficial in dispersing aggregations of young larvae. Removal of allochthonous food by increased water flow could be more detrimental to benthos populations than the direct mortality caused by catastrophic drift.

Andrus, C. W., B. A. Long, and H. A. Froehlich. 1988. Woody debris and its contribution to pool formation in a coastal stream 50 years after logging. Canadian Journal of Fisheries and Aquatic Sciences 45:2080--2086.

'KEY WORDS'
Tributaries
Main Stream
Oregon
Large wood
Stream habitat
Effects of logging
Stream succession
'ABSTRACT'

Large quantities of woody debris persisted 50 yr after logging and fire in stream channels of a small coastal Oregon watershed. Debris from the current stand represented only 14% of total debris volume and 8% of debris volume responsible for creating pools. The greatest number of pools were located in downstream sections of the watershed where gradient was reduced, discharge was increased, and streambed material was finer. Seventy percent of pools with a volume greater than 1.0 m3 were associated with woody debris in the channel. Composition of the current riparian forest varied with topography. Alder stands dominated moist terrace sites adjacent to channels, whereas slopes contained a mixture of alder and conifer. Study results indicate that riparian trees must be left to grow longer than 50 yr to ensure that an adequate, long-term supply of woody debris is available to stream channels. Debris from previous stands plays a crucial role in the interim and should not be removed from stream channels.

Baker, T. T., and coauthors. 1996. Status of Pacific salmon and steelhead escapements in Southeast Alaska. Fisheries 21(10):6-18.

'KEY WORDS'
Anadromous salmonids
steelhead
Escapement
Stock status
'ABSTRACT'

We evaluated the status of Pacific salmon and steelhead (*Oncorhynchus mykiss*) in southeastern Alaska. Of 9,296 spawning aggregates identified in this region, some data were available for 4,009 (43%), and 928 (10%) had sufficient information to analyze for escapement trend. Of those analyzed, 333 (36%) were increasing, 556 (60%) were stable, 37 (4%) were declining, and 2 (< 1%) showed precipitous declines. We evaluated risk of extinction of spawning aggregates using criteria similar to surveys outside Alaska. We rated 918 (99%) at no or low risk, 8 (≈ 1%) at moderate risk, and 2 (< 1%) at high risk. No spawning aggregates were identified as extinct based on our evaluation of escapement data dating back to 1960. Prior to

1960, two spawning aggregates, one sockeye salmon (*0. nerka*) and one chum salmon (*0. keta*), were identified as extinct based on responses to a postal questionnaire. The Alaska Department of Fish and Game grouped spawning aggregates into management units for each species. Management units vary in number and size for each species. Of 141 management units defined, 129 (92%) had enough information to evaluate; all had stable or increasing escapement trends. However, escapement data for this study had limitations for two reasons. First, monitoring spawning aggregates for escapement in all spawning locations in southeastern Alaska is impractical; interpretations are based instead on estimates of key indicator streams (usually commercially important runs) in the region. Second, most escapement estimates are based on aerial surveys rather than more accurate methods such as weirs or sonar estimates. Our results, based on the limited data, indicated that Pacific salmon in the region were generally in good health at two levels of salmon population structure: spawning aggregates and management units. The small amount of escapement data for steelhead precludes a generalization about their status and overall health.

Baron, J. S., and coauthors. 2002. Meeting ecological and societal needs for freshwater. Ecological Applications 12(5):1247-1260.

'KEY WORDS'
Watershed scale
Ecological integrity
Ecosystem protection
Ecosystem services
Freshwater ecosystems
Restoration, rivers
Waterflow
Water management policy
'ABSTRACT'

Human society has used freshwater from rivers, lakes, groundwater, and wetlands for many different urban, agricultural, and industrial activities, but in doing so has overlooked its value in supporting ecosystems. Freshwater is vital to human life and societal well-being, and thus its utilization for consumption, irrigation, and transport has long taken precedence over other commodities and services provided by freshwater ecosystems. However, there is growing recognition that functionally intact and biologically complex aquatic ecosystems provide many economically valuable services and long-term benefits to society. The short-term benefits include ecosystem goods and services, such as food supply, flood control, purification of human and industrial wastes, and habitat for plant and animal life—and these are costly, if not impossible, to replace. Long-term benefits include the sustained provision of those goods and services, as well as the adaptive capacity of aquatic ecosystems to respond to future environmental alterations, such as climate change. Thus, maintenance of the processes and properties that support freshwater ecosystem integrity should be included in debates over sustainable water resource allocation.

The purpose of this report is to explain how the integrity of freshwater ecosystems depends upon adequate quantity, quality, timing, and temporal variability of water flow. Defining these requirements in a comprehensive but general manner provides a better foundation for their inclusion in current and future debates about allocation of water resources. In this way the needs of freshwater ecosystems can be legitimately recognized and addressed. We also recommend ways in which freshwater ecosystems can be protected, maintained, and restored.

Freshwater ecosystem structure and function are tightly linked to the watershed or catchment of which they are a part. Because riverine networks, lakes, wetlands, and their connecting groundwaters, are literally the "sinks" into which landscapes drain, they are greatly influenced by terrestrial processes, including many human uses or modifications of land and water. Freshwater ecosystems, whether lakes, wetlands, or rivers, have specific requirements in terms of quantity, quality, and seasonality of their water supplies. Sustainability normally requires these systems to fluctuate within a natural range of

variation. Flow regime, sediment and organic matter inputs, thermal and light characteristics, chemical and nutrient characteristics, and biotic assemblages are fundamental defining attributes of freshwater ecosystems. These attributes impart relatively unique characteristics of productivity and biodiversity to each ecosystem. The natural range of variation in each of these attributes is critical to maintaining the integrity and dynamic potential of aquatic ecosystems; therefore, management should allow for dynamic change. Piecemeal approaches cannot solve the problems confronting freshwater ecosystems.

Scientific definitions of the requirements to protect and maintain aquatic ecosystems are necessary but insufficient for establishing the appropriate distribution between societal and ecosystem water needs. For scientific knowledge to be implemented science must be connected to a political agenda for sustainable development. We offer these recommendations as a beginning to redress how water is viewed and managed in the United States: (1) Frame national and regional water management policies to explicitly incorporate freshwater ecosystem needs, particularly those related to naturally variable flow regimes and to the linking of water quality with water quantity; (2) Define water resources to include watersheds, so that freshwaters are viewed within a landscape, or systems context; (3) Increase communication and education across disciplines, especially among engineers, hydrologists, economists, and ecologists to facilitate an integrated view of freshwater resources; (4) Increase restoration efforts, using well-grounded ecological principles as guidelines; (5) Maintain and protect the remaining freshwater ecosystems that have high integrity; and (6) Recognize the dependence of human society on naturally functioning ecosystems.

Beacham, T. D., and C. B. Murray. 1990. Temperature, egg size, and development of embryos and alevins of five species of Pacific salmon: a compararive analysis. Transactions of the American Fisheries Society 119:927-945.

'KEY WORDS'
Climate change
Temperture effects
Salmon
Climate change
Embryo development
'ABSTRACT'

We examined rate of development to alevin hatching and fry emergence, embryo and alevin survival, and alevin and fry size for five Pacific salmon species. There was little difference among values for hatching and emergence time predicted by a modified thermal sums model, power law model (log-inverse Belehrádek), or quadratic model. Coho salmon Oncorhynchus kisutch had the fastest rates of development to hatching and emergence of the five species investigated; rankings for the other species depended upon temperature range. Coho salmon embryos had the highest survival rates at low incubation (1.5°C) temperatures. Embryos of pink salmon O. gorbuscha had the lowest survival at temperatures less than 4°C. For all five species, incubation temperature was the more important factor in determining alevin length, and egg size was the more important factor in determining alevin weight. Egg weight was a major determinant of fry weight at emergence. Rates of development to hatching and emergence, and alevin and fry size, differed by species in response to changes in temperature, Coho salmon alevins and fry were proportionately larger at 4°C than at 8°C or 12°C, but alevins and fry of pink salmon and chum salmon O. keta were largest at 8°C. Variation in development characters of Pacific salmon reflected adaptations to each species' life history pattern.

Beamish, R. J., C. M. Neville, and A. J. Cass. 1997. Production of Fraser River sockeye salmon (Oncorhynchus nerka) in relation to decadal-scale changes in the climate and the ocean. Canadian Journal of Fisheries and Aquatic Sciences 54:543-554.

'KEY WORDS'

Climate change
Watershed scale
Decadal climate shift
Marine survival
Sockeye salmon
'ABSTRACT'
The abundance of Fraser River sockeye salmon (Oncorhynchus nerka) stocks was low in the 1960s, increased to high levels in the 1980s, and possibly entered a period of low abundance in recent years. The abundance changes of the combined stocks can be separated into productivity regimes that correspond to changes in climate trends. The most distinct change occurred when there was a major change in the climate over the Pacific Ocean in the winter of 1976-1977. The existence of natural shifts in abundance trends means that the high returns that occur during periods of high productivity would not be expected to occur during the low-productivity periods. The response of Fraser River sockeye to climate changes may be a specific example of a more general response by a number of species of fishes in the Pacific and perhaps in other oceans. Because the shift from one regime to the other occurred quickly in the 1970s, future shifts could also occur quickly. It is necessary to detect natural shifts in productivity when attempting to manage fishing impacts to ensure that economic expectations are sound and that overfishing does not occur.

Beamish, R. J., and coauthors. 1999. The regime concept and natural trends in the production of Pacific salmon. Canadian Journal of Fisheries and Aquatic Sciences 56:516-526.
'KEY WORDS'
Climate change
Temperature regimes
Production
'ABSTRACT'
Large fluctuations in the trends of Pacific salmon production in this century have been linked to trends in climate in the Pacific that are in turn associated with climate trends throughout the Northern Hemisphere. The close correspondence in the persistence of climate trends and the synchrony of the changes is evidence that a common eventmay cause the regime shifts. The trends or regimes can be characterized by stable means in physical data series or multiyear periods of linked recruitment patterns in fish populations. The regime concept is important in fisheries management because the natural shifts in abundance may be large and sudden, requiring that these natural impacts be distinguished from fishing effects. An equally important consideration is that biological and physical mechanisms may change when regimes shift, resulting in conditions that may not be characterized in the earlier part of the data series. Fluctuations in Pacific salmon abundance in this century were synchronous with large fluctuations in Japanese sardine abundance, which can be traced back to the early 1600's. The synchrony in the fluctuations suggests that Pacific salmon abundance may have fluctuated for centuries in response to trends in climate. The concept of regimes and regime shifts stresses the need to improve our understanding of the mechanisms that regulate the dynamics of fish and their ecosystems

Beechie, T., E. Beamer, and L. Wasserman. 1994. Estimating coho salmon rearing habitat and smolt production losses in a large river basin, and implications for habitat restoration. North American Journal of Fisheries management 14:797-811.
'KEY WORDS'
Main Stream
Restoration
Coho salmon
Large rivers
'ABSTRACT'
To develop a habitat restoration strategy for the 8,270-km2 Skagit River basin, we estimated changes in smolt production of coho salmon Oncorhynchus kisutch since European settlement began

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

Beechie, T. J., and T. H. Sibley. 1997. Relationships between channel characteristics, woody debris, and fish habitat in Northwestern Washington streams. Transactions of the American Fisheries Society 126:217-229.

'KEY WORDS'
Tributaries
Main stream
Washington
Forest management
Large woody debris
Salmon habitat
Channel morphology
'ABSTRACT'

Relationships between large woody debris (LWD) and pool area or pool spacing varied with channel slope and channel width for streams in second-growth forests in northwest Washington. Pool spacing (expressed as the number of channel widths between pools) decreased as number of woody debris increased in both moderate-slope (0.02 < slope < 0.05) and low-slope (0.001 < slope ≤ 0.02) channels, but the relationship was stronger in moderate-slope channels. Percent pool was also more strongly correlated with woody debris volume in moderate-slope channels than in low-slope channels. Multiple-regression analyses showed that pool spacing and percent pool were correlated with an interaction term between LWD abundance and channel slope, suggesting that the influence of LWD on pool formation changes with channel slope. Analysis of pool-forming mechanisms indicated that low-slope channels are less sensitive to LWD abundance because pools are formed by mechanisms other than LWD when LWD abundance is low. Size of LWD that formed pools increased with increasing channel width, but was not related to channel slope. Percent gravel (proportion of the bed in patches of gravel 16–64 mm in diameter) was best explained by channel slope and channel width, and there was no significant relationship between woody debris and percent gravel. A regression between median particle size of sediment on the stream bed and basal shear stress showed that the relationships among percent gravel, channel width, and channel slope are adequately explained by the channel's capacity to transport particles of various sizes.

Beedle, D. L. 1991. Physical dimensions and hydrological effects of beaver ponds on Kuiu Island in southeast Alaska. MS Thesis. Oregon State University.

'KEY WORDS'
Off Channel
Southeast Alaska
Beaver ponds
Hydrology
Stream morphology

'ABSTRACT'
Describes characteristics of beaver dams and their reponse to season flows.

Benda, L., K. Andras, D. Miller, and P. Bigelow. 2004. Confluence effects in rivers: Interactions of basin scale, network geometry, and disturbance regimes. Water Resources Research 40:1-15.
'KEY WORDS'
Watershed scale
River ecology
Landscape ecology
Tributaries
Channel morphology
Disturbance
'ABSTRACT'
We reviewed 14 studies documenting the effects of tributaries on river morphology at 167 confluences along 730 km of river spanning seven orders of magnitude in drainage area in western United States and Canada. In both humid and semiarid environments the probability of observing significant confluence-related changes in channel and valley morphology due to tributary influxes of sediment (e.g., changes in gradient, particle size, and terraces, etc.) increased with the size of the tributary relative to the main stem. Effects of confluences on river morphology are conditioned by basin shape and channel network patterns, and they include the nonlinear separation of geomorphically significant confluences in river networks. Other modifying factors include local network geometry and drainage density. Confluence-related landforms (i.e., fans, bars, terraces, etc.) are predicted to be dominated by older features in headwaters and younger features downstream, a pattern driven by the frequency and magnitude of floods and punctuated sediment supply that scale with watershed size.

Benda, L., T. J. Beechie, A. Johnson, and R. C. Wissmar. 1992. The geomorphic structure of salmonid habitats in a recently deglaciated river basin, Washington state. Canadian Journal of Fisheries and Aquatic Sciences 49(6):1246-1256.
'KEY WORDS'
Watershed scale
Main Stream
Tributaries
Washington
Salmon habitat
Geomorphology
Landslides
Headwater streams
'ABSTRACT'
Morphology and distribution of salmonid habitats were related to the geomorphology of a river basin at three spatial scales including reach (102–103 m2), subbasin (2–26 km2), and the watershed (240 km2). Stream reaches on a young fluvial terrace (1700 yr old) adjacent to the main river contain the most extensive areas of rearing and spawning habitats. In tributary subbasins, the area of spawning habitat varies according to discharge rates and channel gradients. The most extensive salmonid habitats are located along wide glacial deposits in geologically unconstrained areas of the main valley floor. During the early Holocene (~10 000 – 12 000 years before present (B.P.)), the recently deglaciated watershed of the South Fork Stillaguamish River was extremely erosive and vegetated by alpine forest. Fish habitats then were less suitable for salmonid rearing and spawning. A much lower erosion rate after 8000 yr B.P., and the advent of old growth conifer forests after 6000 yr B.P., indicates that stream habitats attained their present-day morphology between 8000 and 6000 yr ago. Although habitats increased in quality with increasing watershed stability and evolution of forests, they decreased in quantity after 7000 yr B.P as landforms changed because of continuous river incision into glacial deposits.

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

'KEY WORDS'
Climate change
Anadromous migrations
Flow measurement
Modelling
Smolts
Regression analysis
Migration
Oncorhynchus tshawytscha
Oncorhynchus mykiss
Usa, columbia r.
Usa, columbia r. Basin

'ABSTRACT'

The amount of time that it takes juvenile chinook salmon Oncorhynchus tshawytscha and steelhead O. mykiss to migrate (travel time) at different river flows through index reaches in the Snake and Columbia rivers was analyzed with bivariate- and multiple-regression models. Smolt travel time estimates for yearling chinook salmon and steelhead in the Snake River, steelhead in the middle Columbia River, and subyearling chinook salmon in the lower Columbia River were inversely related to average river flows. In the multiple-regression analyses, additional predictor variables that were related either to flow or to smoltification were used. These predictor variables were calculated over the same time period as the travel time estimates. Flow-related variables were referenced at a key hydroelectric site within each index reach, and included average river flow, minimum river flow, and absolute change in river flow. The smoltification-related variables provided indirect indices of smoltification. They included water temperature, date of entry into an index reach, chinook salmon race, and travel time prior to entry into an index reach. The final models included those predictor variables explaining significant variation in smolt travel time. The variables in the final multiple-regression models explained 74% and 39% of the variation in the travel time for yearling chinook salmon within the Snake and middle Columbia river index reaches, respectively; 90% and 62% for steelhead within the Snake and middle Columbia reaches; and 65% for subyearling chinook salmon in the lower Columbia reach. Average river flow made the largest contribution to explaining variation in smolt travel time in the majority of the multiple-regression models. Additional variation in smolt travel time could be explained by including other flow- and smoltification-related variables in the models.

Bilby, R. E., and L. A. Mollot. 2008. Effect of changing land use patterns on the distribution of coho salmon (Oncorhynchus kisutch) in the Puget Sound region. Canadian Journal of Fisheries and Aquatic Sciences 65:2138-2148.

'KEY WORDS'
Watershed scale
Pacific Northwest
Puget Sound
Salmon
Land use

'ABSTRACT'

Population increase in the Pacific Northwest of North America over the last century has led to the removal of forests for various purposes. Evidence of salmon response to these alterations in land use is rare owing to a scarcity of fish population data and a high degree of interannual variation in abundance. We examined the relationship between the spatial distribution of spawning coho salmon (Oncorhynchus kisutch) and changes in land use from 1984 through 2001 at 84 sites in four rivers draining into northern Puget Sound. Changes in land use over this period were determined from LandSat imagery, county zoning designations, and aerial

photographs. Substantial reduction in forest cover occurred in many of the index watersheds during this time. The proportion of salmon using sites subjected to increased urban land use over the study period declined about 75%. Increases were observed at forested sites and those with increased rural residential use. Maintaining salmon populations in rapidly developing areas may require the identification and protection of sites that support large salmon populations and steering development to areas supporting few fish.

Bilby, R. E., and J. W. Ward. 1989. Changes in characteristics and function of woody debris with increasing size of streams in western Washington. Transactions of the American Fisheries Society 118:368-378.

'KEY WORDS'
Main stream
Tributaries
Watershed scale
Washington
Large wood
Channel morpholgy
'ABSTRACT'

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

Bilby, R. E., and J. W. Ward. 1991. Characteristics and function of large woody debris in streams draining old-growth, clear-cut, and second-growth forests in southwestern Washington. Canadian Journal of Fisheries and Aquatic Sciences 48:2499-2508.

'KEY WORDS'
Watershed scale
Tributaries
Main Stream
Effects of logging
Woody debris
Washington
'ABSTRACT'

Amount of large woody debris (LWD) surveyed in 70 stream reaches flowing through old-growth, clear-cut, and second-growth forests decreased with increasing stream size for all stand types but was greatest at old-growth sites. Average piece volume was larger at old-growth sites than at other stand types in streams >10 m wide, but no differences were seen in smaller streams. Scour pools accounted for 90% of the wood-associated pools at second-growth and clear-cut sites but only 50% at old-growth sites, which contained more pools than other stand types, particularly for larger streams. Pool size was similar for all stand types in smaller streams,

but averaged 10 m2 in streams >10 m wide at old-growth sites and 4 m2 for other stand types. Pool size was similar for all stand types in smaller streams. Sediment and fine organic matter retained by woody debris decreased with increasing stream size for ail stand types, but old-growth sites contained greater amounts of both materials than other stand types. The frequency of pool formation, the type of pool formed, and sediment accumulation were influenced by the amount of fine debris associated with LWD. Changes in LWD amount, characteristics, and function occurred very rapidly following removal of streamside vegetation.

Bisson, P. A., J. B. Dunham, and G. H. Reeves. 2009. Freshwater Ecosystems and Resilience of Pacific Salmon: Habitat Management Based on Natural Variability. Ecology and Society 14(1):np.

'KEY WORDS'
Watershed Scale
Oregon
restoration
salmon
'ABSTRACT'

In spite of numerous habitat restoration programs in fresh waters with an aggregate annual funding of millions of dollars, many populations of Pacific salmon remain significantly imperiled. Habitat restoration strategies that address limited environmental attributes and partial salmon life-history requirements or approaches that attempt to force aquatic habitat to conform to idealized but ecologically unsustainable conditions may partly explain this lack of response. Natural watershed processes generate highly variable environmental conditions and population responses, i.e., multiple life histories, that are often not considered in restoration. Examples from several locations underscore the importance of natural variability to the resilience of Pacific salmon. The implication is that habitat restoration efforts will be more likely to foster salmon resilience if they consider processes that generate and maintain natural variability in fresh water. We identify three specific criteria for management based on natural variability: the capacity of aquatic habitat to recover from disturbance, a range of habitats distributed across stream networks through time sufficient to fulfill the requirements of diverse salmon life histories, and ecological connectivity. In light of these considerations, we discuss current threats to habitat resilience and describe how regulatory and restoration approaches can be modified to better incorporate natural variability.

Bjornn, T. C., S. C. Kirking, and W. R. Meehan. 1991. Relation of cover alterations to the summer standing crop of young salmonids in small Southeast Alaska Streams. Transactions of the American Fisheries Society 120:562-570.

'KEY WORDS'
Tributaries
Southeast Alaska
Coho Salmon
Steelhead
'ABSTRACT'

Summer abundance of young coho salmon Oncorhynchus kisutch, steelhead O. mykiss, and Dolly Varden Salvelinus malma was assessed in small streams on Prince of Wales Island, Alaska, in an attempt to measure the response of these fish to various types of cover alterations. The standing crop of subyearlings decreased during summer, but none of the decrease could be attributed to the changes in cover we made. Subyearling coho salmon (about 75% of the fish present) did not respond either to the removal of natural riparian vegetation or to the addition of simulated riparian canopy, large boulders, woody debris, or simulated undercut banks. Localized movements within the streams were sufficient to provide relatively rapid recolonization of the experimental habitat units. The forms of cover we evaluated were relatively unimportant in regulating abundance of young coho salmon in small streams.

Bonneau, J., and D. Scarnecchia. 1998. Seasonal and diel changes in habitat use by juvenile bull trout (Salvelinus confluentus) and cutthroat trout (Oncorhynchus clarki) in a mountain stream. Canadian Journal of Zoology 76:783-790.

'KEY WORDS'
Main stream
Idaho
Bull Trout
Cutthroat trout
Habitat selection
Movement
Water depth
Ecological distribution
Environmental factors
Stream flow
Substrate preferences
Diurnal variation
Salvelinus confluentus
Oncorhynchus clarki

'ABSTRACT'

Habitat use by juvenile bull trout (Salvelinus confluentus) and cutthroat trout (Oncorhynchus clarki) in Trestle Creek, Idaho, changed seasonally and dielly. Both cutthroat and bull trout selected pools over riffles in both summer and winter. Both species used a wide range of depths at night but were absent from shallow water (<15 cm) during the day in summer and winter. During summer, juveniles of both species occupied areas of lower velocity water at night than during the day. Both species also occupied lower velocity water during winter days than summer days. During winter days, juvenile bull trout were located below or directly on cobble substrate, whereas cutthroat trout often formed aggregations suspended in the water column of large pools. Both species were more closely associated with cover during the day, and made the greatest use of cover during winter days. Land management activities resulting in decreased pool habitat, instream cover, and stream-bed stability may be especially detrimental to bull trout and cutthroat trout in winter.

Bramblett, R. G., M. D. Bryant, B. E. Wright, and R. G. White. 2002. Seasonal use of small tributary and main-stem habitats by juvenile steelhead, coho salmon, and Dolly Varden in a Southeastern Alaska drainage basin. Transactions of the American Fisheries Society 131:498-506.

'KEY WORDS'
Tributaries
Main Stream
Movement
Steelhead
Coho salmon
Dolly Varden
Southeast Alaska

'ABSTRACT'

The movement of juvenile salmonids between small tributaries and main-stem habitats in southeast Alaska watersheds is poorly understood. We observed movements of steelhead Oncorhynchus mykiss, coho salmon O. kisutch, and Dolly Varden Salvelinus malma between main-stem and tributary habitats at weirs located on tributaries in the Staney Creek watershed in southeast Alaska. We used seasonal relative abundance (catch per unit effort) in eight main-stem reaches and eight tributaries to corroborate observed movement in the two streams with weirs. We observed juvenile steelhead and coho salmon moving through the weirs into tributaries during the fall as flows increased and temperatures decreased. The relative abundance of steelhead was greater in main-stem sites than in tributaries during the summer, whereas during spring and fall relative abundance in the tributaries was similar to that in the main stem. Juvenile coho salmon were abundant in tributaries during all seasons. The relative

abundance of Dolly Varden was greater in the tributaries than in the main-stem during all seasons. These results underscore the significance of links between main-stem habitats and small tributaries for production of juvenile salmonids.

Bryant, M. D. 1980. Evolution of large, organic debris after timber harvest: Maybeso Creek, 1949 to 1978. U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, General Technical Report PNW-101, Portland, OR.

'KEY WORDS'
Main Stream
Southeast Alaska
Large wood
'ABSTRACT'

Hand drawn scale maps of Maybeso Creek were used to describe the dynamics of large wood shortly before, during and after logging in Maybeso Creek from 1952 to 1960. Large accumulations were present during logging, declined in the few years after logging but many large accumulations remained.

Bryant, M. D. 1983. The role and management of woody debris in west coast salmonid nursery streams. North American Journal of Fisheries Management 3:322-330.

'KEY WORDS'
Watershed scale
southeast Alaska
large wood
'ABSTRACT'

Debris removal is a frequently used management technique for small streams in logged watersheds, but many stream-cleaning techniques overlook important habitat requirements of juvenile salmonids. Reviews of some past management practices show little systematic evaluation or monitoring of physical or biological effects. A review of several studies (most of them not associated with debris removal) shows the importance of woody debris as salmonid habitat. The role of organic debris in small stream systems is discussed and a set of criteria for debris removal is proposed.

Bryant, M. D. 1984a. Distribution of salmonids in the Trap Bay Basin, Tenakee Inlet. Pages 17-31 *in* W. R. Meehan, T. R. Merrell, and T. A. Hanley, editors. Fish and Wildlife Relationships in Old-Growth Forests: Proceedings of a symposium. American Institute of Fishery Research Biologists, Juneau, AK.

'KEY WORDS'
Watershed scale
Main Stream
Tributaries
Southeast Alaska
Coho Salmon
Dolly Varden
Cuthroat trout
'ABSTRACT'

Describes distribution of anadromous salmonids in the Trap Bay watershed. Coho salmon were found throughout the watershed. Density declined as gradient increased. Dolly Varden and cutthrout trout were common in the headwaters and tributaries.

Bryant, M. D. 1984b. The role of beaver ponds as coho salmon habitat in southeast Alaska streams. Pages 183-192 *in* J. M. Walton, and D. B. Houston, editors. Proceedings of the Olympic Wild Fish Conference, Port Angles, WA.

'KEY WORDS'
Off channel Habitat
Southeast Alaska

Beaver ponds
'ABSTRACT'
Beaver ponds are distributed througout southeast Alaska. Previously dams were thought to be barriers to juvenile coho salmon. Results from this study demonstrate that beaver ponds are widely used by coho salmon in southeast Alaska.

Bryant, M. D. 2009. Global climate change and potential effects on salmonids in freshwater ecosystems of southeast Alaska. Climatic Change 95:169-193.
'KEY WORDS'
Climate change
Southeast Alaska
Beaver ponds
Stream habitat
Life history
Salmonids
'ABSTRACT'
General circulation models predict increases in air temperatures from 1°C to 5°C as atmospheric CO2 continues to rise during the next 100 years. Thermal regimes in freshwater ecosystems will change as air temperatures increase regionally. As air temperatures increase, the distribution and intensity of precipitation will change which will in turn alter freshwater hydrology. Low elevation floodplains and wetlands will flood as continental ice sheets melt, increasing sea-levels. Although anadromous salmonids exist over a wide range of climatic conditions along the Pacific coast, individual stocks have adapted life history strategies—time of emergence, run timing, and residence time in freshwater—that are often unique to regions and watersheds. The response of anadromous salmonids will differ among species depending on their life cycle in freshwater. For pink and chum salmon that migrate to the ocean shortly after they emerge from the gravel, higher temperatures during spawning and incubation may result in earlier entry into the ocean when food resources are low. Shifts in thermal regimes in lakes will change trophic conditions that will affect juvenile sockeye salmon growth and survival. Decreased summer stream flows and higher water temperatures will affect growth and survival of juvenile coho salmon. Rising sea-levels will inundate low elevation spawning areas for pink salmon and floodplain rearing habitats for juvenile coho salmon. Rapid changes in climatic conditions may not extirpate anadromous salmonids in the region, but they will impose greater stress on many stocks that are adapted to present climatic conditions. Survival of sustainable populations will depend on the existing genetic diversity within and among stocks, conservative harvest management, and habitat conservation.

Bryant, M. D., and F. H. Everest. 1998. Management and condition of watersheds in southeast Alaska: The persistence of anadromous salmonids. Northwest Science 72:249-267.
'KEY WORDS'
Watershed Scale
Southeast Alaska
Effects of logging
Forest management
Riparian management
'ABSTRACT'
In contrast to most of North America and Europe, numerous intact or highly disturbed watersheds are present throughout southeast Alaska. These watersheds support abundant and diverse populations of anadromous salmonids. While the watersheds throughout the northern hemisphere have been exposed to human disturbance from millennia to centuries, significant human disturbance to the watersheds of southeast Alaska did not begin until the 1950's with the start of industrial logging. Although management of watersheds has evolved to reduce risks to aquatic habitat, the most intensive logging occurred during the first 20 years of timber harvest when few restraints were placed on timber harvest in watersheds. As a result,

a legacy of streams with deteriorating habitat remains. While few salmon stocks in southeast Alaska appear to be in decline, escapement records on specific watersheds, particularly those most severely affected by management are non-existent or qualitative. The present status of salmon stocks may be attributed to abundant intact watersheds, high marine survival, and escapement levels that fully seed most watersheds. The numerous intact watersheds throughout southeast Alaska are a critical factor in maintaining sustainable salmon stocks in southeast Alaska

Bryant, M. D., B. J. Frenette, and S. J. McCurdy. 1999. Colonization of a watershed by anadromous salmonids following the installation of a fish ladder in Margaret Creek, southeast Alaska. North American Journal of Fisheries Management 19:1129-1136.

'KEY WORDS'
Watershed scale
Southeast Alaska
Coho salmon
Migration
'ABSTRACT'

We evaluated the colonization of a watershed blocked by a 7-m falls following the installation of an Alaska steeppass fish ladder to provide access for anadromous salmonids. Coho salmon Oncorhynchus kisutch, pink salmon O. gorbuscha, and chum salmon O. keta were present below the falls. Fry of sockeye salmon O. nerka were stocked into Margaret Lake once in 1988 and annually from 1990 through 1994. Pink salmon were the most numerous species to colonize habitat above the falls. Coho salmon moved up the ladder during all years. However, progeny from 25,000 coho salmon presmolts that were stocked in 1991 were the greatest proportion of the returns in 1992, 1995, and 1996. During the study, only 1,595 sockeye salmon returned from more than 1.4 million that were stocked. The rapidity of colonization by naturally occurring anadromous salmonids, including cutthroat trout O. clarki, Dolly Varden Salvelinus malma, and steelhead O. mykiss, underscores a life history strategy of exploiting newly accessible habitat as it becomes available. Although anadromous salmonids successfully colonized the watershed, effects of interbreeding among stocked and natural runs of coho salmon may not be observed for several generations.

Bryant, M. D., D. N. Swanston, R. C. Wissmar, and B. E. Wright. 1998. Coho salmon populations in the karst landscape of north Prince of Wales Island, southeast Alaska. Transactions of the American Fisheries Society 127:425-433.

'KEY WORDS'
Tributaries
Karst
Southeast Alaska
Coho Salmon
'ABSTRACT'

Karst topography is a unique and distinct landscape and its geology may have important implications for salmon productivity in streams. The relationship between salmonid communities and water chemistry and the influence of habitat was examined in a set of streams on north Prince of Wales Island, southeast Alaska. Streams in karst landscapes showed higher alkalinities (1,500–2,300 μeq/L) than streams not influenced by karst landscapes (750–770 μeq/L). A significant, positive relationship was observed between alkalinity and density of coho salmon parr Oncorhynchus kitsutch. Backwater pools supported higher densities of coho salmon than did other habitat units. Both coho salmon fry and parr tended to be larger in most karst-influenced streams than in nonkarst streams. Although past timber harvest practices in the riparian areas of several of the streams appeared to influence stream habitat and water temperature, streams flowing through karst landscapes had a distinct water chemistry. Furthermore, these streams appeared to support more fish than nonkarst streams.

Bryant, M. D., and R. D. Woodsmith. 2009. The Response of salmon populations to geomorphic measurements at three scales. North American Journal of Fisheries Management 29(3):549-559.

'KEY WORDS'
Watershed scale
Main stream
Southeast Alaska
Habitat
Coho salmon
Cutthroat trout

'ABSTRACT'

Protocols to assess stream channel response to disturbances often focus on physical aspects of the stream at the reach scale without measurements of fish populations. In this study, estimates of juvenile salmon abundance in 511 habitat units within 25 reaches of 12 streams were made over 4 years and juxtaposed with measurements of physical habitat at the habitat unit, reach, and watershed scales. Fish ranged in size from about 50 to 160 mm fork length. The amount of variation among densities differed by species and geographic scale. For most species, the habitat unit scale accounted for the most variation. Relationships between salmon density and measurements at the habitat unit scale varied. At the reach scale, we observed a negative relationship between abundance of coho salmon Oncorhynchus kisutch parr and number of pools. A positive relationship appeared between coho salmon parr and large wood. At the watershed scale, a positive relationship was observed between coho salmon parr and valley morphology. Valley morphology also entered the model for cutthroat trout O. clarkii. Differences in salmonid densities observed between northern and southern watersheds were attributed to differences in landforms, geology, and soils among islands in southeast Alaska. Simple habitat measures, such as pool counts, were not good predictors of fish abundance. However, geomorphic measures from multiple scales that are accompanied by estimates of fish abundance can provide managers with an integrated picture of watershed productivity and a better means to evaluate features that influence productivity.

Bugert, R. M., T. C. Bjornn, and W. R. Meehan. 1991. Summer habitat use by young salmonids and their responses to cover and predators in a small Southeast Alaska stream. Transactions of the American Fisheries Society 120:474-485.

'KEY WORDS'
Tributaries
Southeast Alaska
Coho Salmon
Dolly Varden
Steelhead
Habitat use

'ABSTRACT'

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

Burchsted, D., M. Daniels, R. Thorson, and J. Vokoun. 2010. The River Discontinuum: Applying Beaver Modifications to Baseline Conditions for Restoration of Forested Headwaters. BioScience 60(11):908-922.

'KEY WORDS'

Off channel
Beaver
Fluvial geomorphology
Hierarchical patch dynamics
Sream ecology
Rriver continuum concept
River restoration
'ABSTRACT'
Billions of dollars are being spent in the United States to restore rivers to a desired, yet often unknown, reference condition. In lieu of a known reference, practitioners typically assume the paradigm of a connected watercourse. Geological and ecological processes, however, create patchy and discontinuous fluvial systems. One of these processes, dam building by North American beavers (Castor canadensis), generated discontinuities throughout precolonial river systems of northern North America. Under modern conditions, beaver dams create dynamic sequences of ponds and wet meadows among free-flowing segments. One beaver impoundment alone can exceed 1000 meters along the river, flood the valley laterally, and fundamentally alter biogeochemical cycles and ecological structures. In this article, we use hierarchical patch dynamics to investigate beaver-mediated discontinuity across spatial and temporal scales. We then use this conceptual model to generate testable hypotheses addressing channel geomorphology, natural flow regime, water quality, and biota, given the importance of these factors in river restoration.

Burnett, K. M., and coauthors. 2007. Distribution of salmon-habitat potential relative to landscape characteristics and implications for conservation. Ecological Applications 17:66-80.
'KEY WORDS'
Watershed scale
Oregon
Coho salmon
Landscape models
Habitat
salmon
'ABSTRACT'
The geographic distribution of stream reaches with potential to support high-quality habitat for salmonids has bearing on the actual status of habitats and populations over broad spatial extents. As part of the Coastal Landscape Analysis and Modeling Study (CLAMS), we examined how salmon-habitat potential was distributed relative to current and future (+100 years) landscape characteristics in the Coastal Province of Oregon, USA. The intrinsic potential to provide high-quality rearing habitat was modeled for juvenile coho salmon (Oncorhynchus kisutch) and juvenile steelhead (O. mykiss) based on stream flow, valley constraint, and stream gradient. Land ownership, use, and cover were summarized for 100-m analysis buffers on either side of stream reaches with high intrinsic potential and in the overall area encompassing the buffers. Past management seems to have concentrated nonindustrial private ownership, agriculture, and developed uses adjacent to reaches with high intrinsic potential for coho salmon. Thus, of the area in coho salmon buffers, 45% is either non-forested or recently logged, but only 10% is in larger-diameter forests. For the area in steelhead buffers, 21% is either non-forested or recently logged while 20% is in larger-diameter forests. Older forests are most extensive on federal lands but are rare on private lands, highlighting the critical role for public lands in near-term salmon conservation. Agriculture and development are projected to remain focused near high-intrinsic-potential reaches for coho salmon, increasing the importance of effectively addressing nonpoint source pollution from these uses. Percentages of larger-diameter forests are expected to increase throughout the province, but the increase will be only half as much in coho salmon buffers as in steelhead buffers. Most of the increase is projected for public lands, where policies emphasize biodiversity protection. Results suggest that widespread recovery of coho salmon is unlikely unless habitat can be improved in high-intrinsic-potential reaches on private

lands. Knowing where high-intrinsic-potential stream reaches occur relative to landscape characteristics can help in evaluating the current and future condition of freshwater habitat, explaining differences between species in population status and risk, and assessing the need for and feasibility of restoration.

Bustard, D. R., and D. W. Narver. 1975. Aspects of the winter ecology of juvenile coho salmon (Oncorhynchus kisutch) and steelhead trout (Salmo gairdneri). Journal of the Fisheries Research Board of Canada 32(5):667-680.

'KEY WORDS'
Tributaries
British Columbia
Winter habitat
Coho Salmon
'ABSTRACT'

The major physical characteristics of overwintering areas for juvenile coho salmon (oncorhynchus kisutch) and steelhead trout (salmo gairdneri) were described for a small, unlogged stream. Mean depths of water, maximum water velocities, water temperatures, winter cover selection, feeding and hiding behavior, tributary movements and environmental change effects were discussed for the coho salmon and steelhead trout.

Campbell, E. Y., and coauthors. 2011. Timber harvest intensifies spawning-salmon disturbance of macroinvertebrates in southeastern Alaskan streams. Journal of the North American Benthological Society 30(1):49-59.

'KEY WORDS'
Main Stream
Southeast Alaska
Effects of logging
Oncorhynchus spp
Benthic invertebrates
Ecosystem engineering
Bioturbation
Watershed management
'ABSTRACT'

We addressed how timber harvest can interact with salmon (Oncorhynchus spp.) spawning activities to influence benthic macroinvertebrate communities in streams on Prince of Wales Island, Alaska. We predicted that spawning salmon would cause greater disturbance to macroinvertebrates in streams in watersheds with high than with low timber-harvest intensity because finer sediments that accumulate in streams after timber harvesting would be readily dislodged by spawning salmon and lower volumes of large wood in the streams would decrease availability of macroinvertebrate refugia from salmon activity. We used a modified Hess sampler to collect benthic macroinvertebrates from 6 riffles in each of 7 streams before and during the annual salmon run. Diptera biomass was lower and Plecoptera biomass was higher during the salmon run than before it. During the run, insect biomass, scraper biomass, and Ephemeroptera biomass were higher in streams with low than with high timber-harvest intensity, possibly because the finer sediments in the high timber-harvest intensity streams were more readily dislodged by salmon. Macroinvertebrate community structure (density and biomass) differed between before and during the run. Epeorus longimanus, Baetis, Seratella tibialis, Suwallia, Chironomidae, and Simuliidae were significant indicators of before-salmon benthic communities, whereas Sweltsa and Zapada cinctipes typified during-salmon communities. Some taxa probably are more tolerant of salmon disturbance than others, and their life histories might be adapted to the autumn salmon run. Overall, our results indicate that strong interactive effects can occur between anthropogenic activities and natural disturbance and that timber-harvest activity can intensify the effects of spawning-salmon disturbance on macroinvertebrates.

Carlson, J. Y., C. W. Andrus, and H. A. Froehlich. 1990. Woody debris, channel features, and macroinvertebrates of streams with logged and undisturbed riparian timber in Northeastern Oregon, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences 47:1103-1111.

'KEY WORDS'
Tributaries
Main stream
Effects of logging
Invertebrates
Oregon
Riparian habitat
Woody debris
'ABSTRACT'

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

Carpenter, S. R., S. G. Fisher, N. B. Grimm, and J. F. Kitchell. 1992. Global change and freshwater ecosysytems. Annual Review of Ecology and Systematics 23:119-139.

'KEY WORDS'
Climate change
Aquatic ecosystems
Lakes
Streams
Wetlands
'ABSTRACT'

Reviews potential effects of climate change on lake and stream ecosystems. Considers effects on distribution and interactions of species. Consequences depend on spacial and temporal scales. Some generalizations are that precipitation and evapotranspiration will increase, precipitation and runoff are non-linear, some regions will become wetter, other drier. Increasing temperature regimes will place additional pressure on cold water species.

Cederholm, C. J., and L. M. Reid. 1987. Impact of Forest Management on coho salmon (*Oncorhynchus kitsutch*) popualtions of the Clearwater River, Washington: Project Summary. Pages 373-397 *in* E. O. Salo, and T. W. Cundy, editors. Streamside Management: Forestry and Fishery Interactions, Seattle, WA.

'KEY WORDS'
Main Stream
Washington
Landslides
Forest Mangement
Effects of logging
'ABSTRACT'

Reviews major effects of logging in the clearwater drainage. Landslides and roads increase sediment inputs.

Clark, J. H., A. McGregor, R. D. Mecum, P. Krasnowski, and A. M. Carrol. 2006. The commercial fishery in Alaska. Alaska Fishery Research Journal 12(1):1-146.

'KEY WORDS'
Watershed Scale
Fishery management
Econonic value
salmon harvest
History
'ABSTRACT'

Alaska's commercial fsalmon fisheries harvested and average of 172 million salmon annually since 1990 with a range of 123-221 million fish. In 1950's annual harvest was 41 million fish. Policies and harvest regulation were insituted to rebuild the run over the ensuing years to it's present sustainable levels. Primary causes for depressed stocks was over-fishing.

Coates, R., L. Collins, J. Florsheim, and D. Kaufman. 1985. Channel change, sediment transport, and fish habitat in a coastal stream: effects of an extreme event. Environmental Management 9(1):35-48.

'KEY WORDS'
Main stream
California
Channel change
Sediment transport
Fish habitat
Floods
'ABSTRACT'

A study on sediment transport and channel change was conducted on Zayante Creek and the lower San Lorenzo River in Santa Cruz County, California. A rainstorm with a recurrence interval locally in excess of 150 years occurred during the study year, 1982 WY. Stream surveys indicated that significant aggradation occurred during and after the peak flood. Upper study reaches were substantially recovered after high flows of early April, but the lower study reaches still had significant filling of pools and burial of riffles by sand. Increases in width-depth ratio were minor and localized in upper reaches, but were significant in lower reaches. Large inputs of sand, primarily from landsliding, altered the sediment transport regime. A higher proportion of the bedload is now transported by lower flows than before the January event. Roads and sand quarries contributed significantly to sediment input to the stream. A proposed dam may alter the sediment transport regime of Zayante Creek. Mitigating the effects of this dam on downstream fish habitat may require occasional bankfull discharges.

Collen, P., and R. J. Gibson. 2001. The general ecology of beavers (Castor spp.) as related to their influence on stream ecosystems and riparian habitats, and subsequent effects on fish-- a review. Reviews in Fish Biology 10:439-461.

'KEY WORDS'
Off channel
North America
Beaver
Beaver ponds
Stream habitat
Life history
Salmonids
'ABSTRACT'

The Eurasian and North American beavers are similar in their ecological requirements, and require water deep enough to cover the entrance to their lodge or burrow. A food cache is often built next to the lodge or burrow, exceptin some southern areas. On small streams (upto fourth order) dams are frequently built tocreate an impoundment, generally on low gradient streams, although at high populationdensities dams may be built on steeper gradientstreams.

On large rivers or in lakes, simply alodge with its food cache may be built. The beaver is a keystone riparian species in thatthe landscape can be considerably altered byits activities and a new ecosystem created. The stream above a dam changes from lotic tolentic conditions. There are hydrological,temperature and chemical changes, depending ontypes of dams and locations. Although theinvertebrates may be fewer per unit area, totalnumber of organisms increases, and diversityincreases as the pond ages. In cool, smallorder streams, the impoundments provide betterhabitat for large trout, possibly creatingangling opportunities. However, at sites wherewater temperatures rise above their optimum preferenda, salmonids may be replaced by other species, such as cyprinids, catostomids,percids or centrarchids. As the habitat isaltered, interactions amongst co-habiting species may change. For example, brown troutor brook trout (charr) may become dominant overAtlantic salmon. In warm water streams theremay be a shift from faster water dwellers topond dwellers. Larger bodied fish, such ascentrarchids and esocids may displace smallerbodied fish such as cyprinids, providing betterangling. Refugia from high or low water flows,low oxygen or high temperatures, may beprovided in adverse conditions in winter orsummer. However, in some cases dams areobstructions to upstream migration, andsediment may be deposited in former spawningareas. The practicality and benefits ofintroducing or restoring beaver populationswill vary according to location, and should beconsidered in conjunction with a managementplan to control their densities.

Collins, B. D., D. R. Montgomery, and A. D. Haas. 2002. Historical changes in the distribution and functions of large wood in Puget Sound lowland rivers. Canadian Journal of Fisheries and Aquatic Sciences 59:66-76.

'KEY WORDS'
Main stream
Washington
Large wood
Stream morphology
Historical
Habitat
'ABSTRACT'

We examined changes in wood abundance and functions in Puget Lowland rivers from the last ~150 years of land use by comparing field data from an 11-km-long protected reach of the Nisqually River with field data from the Snohomish and Stillaguamish rivers and with archival data from several Puget Lowland rivers. Current wood abundance is one to two orders of magnitude less than before European settlement in the Snohomish and Stillaguamish basins. Most importantly, wood jams are now rare because of a lack of very large wood that can function as key pieces and low rates of wood recruitment. These changes in wood abundance and size appear to have fundamentally changed the morphology, dynamics, and habitat abundance and characteristics of lowland rivers across scales from channel unit to valley bottom. Based on our field studies, rivers had substantially more and deeper pools historically. Archival data and field studies indicate that wood jams were integral to creating and maintaining a dynamic, anastomosing river pattern with numerous floodplain channels and abundant edge habitat and routed floodwaters and sediment onto floodplains. Establishing the condition of the riverine landscape before European settlement sets a reference against which to evaluate contemporary conditions and develop restoration objectives.

Colyer, W. T., J. L. Kershner, and R. H. Hilderbrand. 2005. Movements of fluvial bonneville cutthroat trout in the Thomas Fork of the Bear River, Idaho. North American Journal of Fisheries Management 25:954-963.

'KEY WORDS'
Main stream
Cutthroat trout
Idaho

Wyoming
Movement
Radio tracking
'ABSTRACT'
The majority of interior subspecies of cutthroat trout Oncorhynchus clarkii have been extirpated from large rivers by anthropogenic activities that have fragmented habitats and introduced nonnative competitors. Selective pressures against migratory behaviors and main-stem river occupation, coupled with conservation strategies that isolate genetically pure populations above barriers, have restricted gene flow and prevented expression of the fluvial life history in many populations. Existing knowledge about the movements and home range requirements of fluvial cutthroat trout is, therefore, limited. Our objectives in this study were to (1) determine the extent of seasonal home ranges and mobility of Bonneville cutthroat trout O. c. utah (BCT) in the Thomas Fork and main-stem Bear River and (2) evaluate the role of a water diversion structure functioning as a seasonal migration barrier to fish movement. We implanted 55 BCT in the Thomas Fork of the Bear River, Idaho, with radio transmitters and located them bimonthly in 1999–2000 and weekly in 2000–2001. We found fish to be more mobile than previously reported. Individuals above the diversion barrier occupied substantially larger home ranges than those below the barrier (analysis of variance: P = 0.0003; median = 2,225 m above barrier; median = 500 m below barrier) throughout our study, and they moved more frequently (mean, 0.89 movements/contact; range, 0.57–1.00) from October 2000 through March 2001 than fish below the barrier (mean, 0.45 movements/contact; range, 0.00–1.00). During the spring of both years, we located radio-tagged fish in both upstream and neighboring tributaries as far as 86 km away from our study site. Our results document the existence of a fluvial component of BCT in the Bear River and its tributaries and suggest that successful efforts at conservation of these fish must focus on main-stem habitats and the maintenance of seasonal migration corridors.

Connor, W. P., H. L. Burge, J. R. Yearsley, and T. C. Bjornn. 2003. Influence of Flow and Temperature on Survival of Wild Subyearling Fall Chinook Salmon in the Snake River. North American Journal of Fisheries Management 23(2):362-375.
'KEY WORDS'
Main Stream
Climate change
Idaho
Chinook
Fishery management
Smolts
Dams
Water temperature
Tagging
Temperature effects
Hydroelectric power plants
'ABSTRACT'
Summer flow augmentation to increase the survival of wild subyearling fall chinook salmon Oncorhynchus tshawytscha is implemented annually to mitigate for the development of the hydropower system in the Snake River basin, but the efficacy of this practice has been disputed. We studied some of the factors affecting survival of wild subyearling fall chinook salmon from capture, tagging, and release in the free-flowing Snake River to the tailrace of the first dam encountered by smolts en route to the sea. We then assessed the effects of summer flow augmentation on survival to the tailrace of this dam. We tagged and released 5,030 wild juvenile fall chinook salmon in the free-flowing Snake River from 1998 to 2000. We separated these tagged fish into four sequential within-year release groups termed cohorts (N = 12). Survival probability estimates (mean +/- SE) to the tailrace of the dam for the 12 cohorts when summer flow augmentation was implemented ranged from 36% +/- 4% to 88% +/- 5%. We fit an ordinary least-squares multiple regression model from indices of flow and

temperature that explained 92% (N = 12; P < 0.0001) of the observed variability in cohort survival. Survival generally increased with increasing flow and decreased with increasing temperature. We used the regression model to predict cohort survival for flow and temperature conditions observed when summer flow augmentation was implemented and for approximated flow and temperature conditions had the summer flow augmentation not been implemented. Survival of all cohorts was predicted to be higher when flow was augmented than when flow was not augmented because summer flow augmentation increased the flow levels and decreased the temperatures fish were exposed to as they moved seaward. We conclude that summer flow augmentation increases the survival of young fall chinook salmon.

Crone, R. A., and C. E. Bond. 1976. Life history of coho salmon (*Oncorhynchus kisutch*), in Sashin Creek, southeastern Alaska. Fishery Bulletin 74(4):897-923.
'KEY WORDS'
Main Stream
Southeast Alaska
Coho salmon
Life history
'ABSTRACT'
Extensive review of life history of coho salmon in Sashin Creek from 1963-1968. Reports age composition and fecundity of returning adults, escapement numbers, and mean redd life. Reports age composition of smolt, 37% 1-y 59% 2-yr , 4% 3-yr. Average fork length 83 mm, 105, and 104 respectively.

Cummins, K. W. 1974. Structure and function of stream ecosystems. BioScience 24(11):631.
'KEY WORDS'
Watershed scale
Aquatic insects
Ecology
Foraging strategies
Functional groups
Invertebrates
'ABSTRACT'
General functional, interrelated components have been defined and initially dimensioned for representative stream ecosystems. Additional or alternative functional criteria are sought to replace classical taxonomic units. Attention is now focused on the efficient conversion of organic matter to CO2 and the maintenance of a minor role for in-stream plant growth.

Davies, B. R., and K. F. Walker. 1986. The ecology of river systems, volume 60. DR W. Junk, Dordrecht.
'KEY WORDS'
Watershed scale
Mian Stream
Large rivers
fish
invertebrate
'ABSTRACT'
Reviews chemical, physical, and biological aspects of large river systems in Africa, North America, Asia, & Europe, includes McKenzie River system. Papeers include dscriptions of fish and invertebrate populations with an emphasis on rivers as eclogicla units.

Decamps, H. 1993. River margins and environmental change. Ecological Applications 3(3):441-445.
'KEY WORDS'
Riparian vegetation
Ecosystem mangement
Climate change

'ABSTRACT'

The paper discusses how variability of river margins interacts with riparian function at the landscape level, in order to develop inferences about the future of this interaction with respect to potential effects of a global climatic change. A riparian approach to the ecology of river landscapes should be useful in that it offers an opportunity to improve our understanding and management of the effects of environmental change at the ecosystem level.

Dolloff, C. A. 1987. Seasonal population characteristics and habitat use by juvenile coho salmon in a small southeast Alaska stream. Transactions of the American Fisheries Society 116(6):829-838.

'KEY WORDS'

Tributaries
Southeast Alaska
Coho Salmon
Effects of logging
Habitat use

'ABSTRACT'

The density, growth, production, and movements of juvenile coho salmon Oncorhynchus kisutch from a wild population were evaluated after the fish were transplanted into five types of habitat (clear-cut, forest, meadow, slough tributary, forest tributary) in a small southeastern Alaska stream. Instantaneous growth ranged from 0.0066 in the clear-cut habitat to 0.0055 in the slough tributary. Daily increase in fork length was about 0.10 mm/d system-wide. Annual production of coho salmon in each habitat type was: meadow, 3.32 g/m2; slough tributary, 2.47 g/m2; clear-cut, 1.75 g/m2; forest, 1.59 g/m2; and forest tributary, 1.34 g/m2. During all sampling periods, most fish were recaptured at the site where they were released; those fish that moved neither selected nor avoided specific habitat types. These findings suggest that all habitats should be managed to meet both the summer and winter needs of juvenile coho salmon because most fish do not move among habitats after the initial population adjustment in the spring. The ability of a stream to produce fish depends not only on the amount and accessibility of habitat, but also on the distribution of habitat types.

Dolloff, C. A., and G. H. Reeves. 1990. Microhabitat partitioning among stream-dwelling juvenile coho salmon,(*Oncorhynchus kisutch*), and Dolly Varden,(*Salvelinus malma*). Canadian Journal of Fisheries and Aquatic Sciences 47(12):2297-2306.

'KEY WORDS'

Tributaries
Southeast Alaska
Large wood
Coho salmon
Dolly Varden

'ABSTRACT'

Microhabitat use and partitioning among age 0+ and 1+ coho salmon, Oncorhynchus kisutch, and age 0+, 1+ and 2+ Dolly Varden, Salvelinus malma, was studied in small (<2 m wide), natural streams on Prince of Wales Island, Alaska, and in laboratory stream channels. Coho salmon occupied midwater positions that they defended from other fish. Dolly Varden were more closely associated with the stream bottom and were seldom territorial. For each species, the depth of water, depth of focal point, and distance to nearest fish increased with fish size, whereas the distance to nearest cover decreased as fish size increased. Most fish selected focal point velocities between 0.0–9.0 cm·s−1.Woody debris was the most frequently used cover type and most fish occurred over gravel substrates ranging from 2–100 mm particle diameter. Habitat use by each species in the laboratory was similar to the pattern observed in the field. Each species occupied similar habitats both when alone and when the other species was present. Although habitat use by juveniles of coho salmon and Dolly Varden overlapped among several key parameters, each species primarily exploited resources not readily available to or selected by the other in the natural streams we studied.

Duncan, W. F. A., and M. A. Brusven. 1985. Energy dynamics of three low-order southeast Alaska streams; Allochthonous Processes. Journal of Freshwater Ecology 3(2):233-248.

'KEY WORDS'
Tributaries
Southeast Alaska
Allochthonous debris
Organic debris
Riparian vegetation
Woody debris
'ABSTRACT'

Physical and biotic processes of three low-order southeast Alaska streams located on Prince of Wales Island were studied. These streams drained an undisturbed watershed representing a coniferous climax forest, a recently logged watershed with little riparian regeneration, and a logged watershed with heavy riparian growth. Community respiration and production were measured in closed, recirculating 12-L Plexiglas metabolism chambers using the dissolved oxygen method. Gross production among the streams varied from 0.1-2.7 g O sub(2)/m super(2)/d; respiration varied from 0.1-1.0 g O sub(2)/m super(2)/d. Highest rates of production and respiration occurred in the recently logged stream; lowest rates were measured in the mature, climax forest stream. Seasonal differences in production and respiration were apparently influenced by logging.

Dunning, J. B., B. J. Danielson, and H. R. Pulliam. 1992. Ecological processes that affect populations in complex landscapes. Oikos 65(1):169-175.

'KEY WORDS'
Watershed scale
Ecological theory
Landscape ecology
Population dynamics
'ABSTRACT'

We describe a general framework for understanding the ecological processes that operate at landscape scales. The composition of habitat types in a landscape and the physiognomic or spatial arrangement of those habitats are the two essential features that are required to describe any landscape. As such, these two features affect four basic ecological processes that can influence population dynamics or community structure. The first two of these processes, landscape complementation and landscape supplementation, occur when individuals move between patches in the landscape to make use of non-substitutable and substitutable resources, respectively. The third process, source-sink dynamics, describes the consequences of having different individuals in the same population occupy habitat patches of different qualities. The fourth process, the neighborhood effect, describes how landscape effects can be amplified when the critical resources are in the landscape immediately surrounding a given patch. Definition of these landscape features and general processes will allow a better synthesis of how landscape variation affects populations and communities.

Eaton, D. W., and F. J. Adams. 1995. The effects of global warming on the distribution of steelhead trout populations on the Alaska Peninsula, Alaska. King Salmon Fishery Resource Office, U.S. Fish and Wildlife Service, King Salmon, Alaska.

'KEY WORDS'
Steelhaed ttrout
Climate change
Temperature
Alaska
'ABSTRACT'

Eaton, J. G., and R. M. Scheller. 1996. Effects of climate warming in fish thermal habitat in streams of the United States. Limnology and Ocenaography 41(4):1109-1115.

'KEY WORDS'
Climate change
Thermal tolerance
General circulation model
Fish habitat
'ABSTRACT'

The effects of climate warming on the thermal habitat of 57 species of fish of the U.S. were estimated using results for a doubling of atmospheric carbon dioxide that were predicted by the Canadian Climate Center general circulation model. Baseline water temperature conditions were calculated from data collected at 1,700 U.S. Geological Surveys stream monitoring stations across the U.S. Water temperatures after predicted climate change were obtained by multiplying air temperature changes by 0.9, a factor based on several field studies, and adding them to baseline water temperatures at stations in corresponding grid cells. Results indicated that habitat for cold and cool water fish would be reduced by ~ 50%, and that this effect would be distributed throughout the existing range of these species. Habitat losses were greater among species with smaller initial distributions and in geographic regions with the greatest warming (e.g. the central Midwest). Results for warm water fish habitat were less certain because of the poor state of knowledge regarding their high and low temperature tolerance; however, the habitat of many species of this thermal guild likely will also be substantially reduced by climate warming, whereas the habitat of other species will be increased.

Ebersole, J. L., and coauthors. 2006. Juvenile coho salmon growth and survival across stream network seasonal habitats. Transactions of the American Fisheries Society 135:1681-1697.

'KEY WORDS'
Watershed scale
Oregon
Columbia River
Willamette River
Movement
'ABSTRACT'

Understanding watershed-scale variation in juvenile salmonid survival and growth can provide insights into factors influencing demographics and can help target restoration and mitigation efforts for imperiled fish populations. We assessed growth, movement, and apparent overwinter survival of individually tagged juvenile coho salmon Oncorhynchus kisutch in a coastal Oregon watershed from June 2002 to June 2003 and related growth and survival parameters to stream characteristics. Fall body size of juvenile coho salmon was a good predictor of smolt size and survival, but smolt size was also influenced by overwintering location. This was due to strong spatial patterns in winter growth rates associated with residency and movement into a small intermittent tributary. Though nearly dry in midsummer, this stream supported high densities of spawning coho salmon in the fall, and juveniles rearing there exhibited relatively high growth rates and emigrated as larger smolts. Improved winter growth and survival of juvenile coho salmon utilizing tributary habitats underscore the importance of maintaining connectivity between seasonal habitats and providing a diversity of sheltering and foraging opportunities, particularly where main-stem habitats have been simplified by human land uses.

Fausch, K. D. 1993. Experimental analysis of microhabitat selection by juvenile steelhead (Oncorhynchus mykiss) and coho salmon (O. kisutch) in a British Columbia stream. Canadian Journal of Fisheries and Aquatic Sciences 50:1198-1207.

'KEY WORDS'
Main Stream
British Columbia

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

Fausch, K. D., and T. G. Northcote. 1992. Large woody debris and salmonid habitat in a small coastal. Canadian Journal of Fisheries and Aquatic Sciences 49:682-693.
'KEY WORDS'
Tributaries
British Columbia
Woody debris
Pools
Coho salmon
Cutthroat trout
'ABSTRACT'
Sections of a small coastal British Columbia stream that had previously been cleaned of large woody debris (LWD) were compared with sections where most debris was left and with others where debris had been relatively undisturbed for at least 40 yr. Three sections where debris had been removed had simple habitat that was less sinuous, wider, and shallower and had less pool volume and overhead cover than four sections with more complex habitat where debris was retained. Habitat in four relatively undisturbed sections was generally similar to complex sections. Most pools in all sections were scour or plunge pools formed by LWD or large roots oriented perpendicular to the flow or angled downstream. Standing crop (kolograms per hectare) and individual weights of age 1 + and older coho salmon (Oncorhynchus kisutch) and cutthroat trout (O. clarki) were significantly greater ($P < 0.02$) in complex than in simple sections. Biomass of age 1 + and older salmonids was closely related to section pool volume ($r2 = 0.92$, $P = 0.0006$). Projections based on this model and average habitat conditions suggest that during 1990 a total of 8.0 kg of salmonid biomass, 5 times the current standing crop, was forgone in the 332-m simple reach due to prior debris removal.

Feller, M. C., and J. P. Kimmins. 1984. Effects of clearcutting and slash burning on streamwater chemistry and watershed nutrient budgets in southwestern British Columbia. Water Resources Research 20(1):29-40.
'KEY WORDS'
Tributaries
Watershed Scale
British Columbia
Chemistry-stream
Effects of logging
Nutrient budget

Slash burning
Stream management
Watershed study
'ABSTRACT'
Two small forested watersheds near Haney in southwestern British Columbia were partially clearcut, and the slash on one of them was subsequently burned. Streamwater chemistry was monitored in these treated watersheds and an undisturbed control watershed for 2 years prior to treatment and up to 9 years after treatment. The chemical parameters that were studied responded differently to the treatments, but there was a general pattern of increased concentrations and fluxes in Streamwater for the first 2–3 years following treatment followed by a decline to, and sometimes below, pretreatment values. The most pronounced increases were observed for K and NO3. It was not possible to determine the exact causes of these changes in concentrations and fluxes, due to the great variability in the ecosystems present. This variability precluded determination of statistically significant changes in annual terrestrial nutrient fluxes and pools. Stream nutrient exports usually were <10 kg/ha/yr for each of N, P, K, and Mg, <20 kg/ha/yr for Na and Cl, and <30 kg/ha/yr for Ca. These values were considerably less than nutrient exports in harvested logs and in losses to the atmosphere during the slashburn. Clearcutting and burning caused greater nutrient losses than Clearcutting alone, particularly in the case of N, where the Clearcutting and Clearcutting and burning treatments resulted in total losses of 245 kg/ha and 1293 kg/ha, respectively, for the first two years after treatment.

Finney, B. P., I. Gregory-Eaves, J. Sweetman, M. S. V. Douglas, and J. P. Smol. 2000. Impacts of Climatic Change and Fishing on Pacific Salmon Abundance Over the Past 300 Years. Science 290(5492):795-799.
'KEY WORDS'
Climate change
Alaska
Sockeye salmon
'ABSTRACT'
The effects of climate variability on Pacific salmon abundance are uncertain because historical records are short and are complicated by commercial harvesting and habitat alteration. We use lake sediment records of δ15N and biological indicators to reconstruct sockeye salmon abundance in the Bristol Bay and Kodiak Island regions of Alaska over the past 300 years. Marked shifts in populations occurred over decades during this period, and some pronounced changes appear to be related to climatic change. Variations in salmon returns due to climate or harvesting can have strong impacts on sockeye nursery lake productivity in systems where adult salmon carcasses are important nutrient sources.

Frissell, C. A., W. J. Liss, C. E. Warren, and M. D. Hurley. 1986. A Hierarchical Framework for Stream Habitat Classification: Viewing Streams in a Watershed Context. Environmental Management 10(2):199-214.
'KEY WORDS'
Watershed scale
Habitat classification
Stream habitat
Variation-spacial
Variation-temporal
'ABSTRACT'
Classification of streams and stream habitats is useful for research involving establishment of monitoring stations, determination of local impacts of land-use practices, generalization from site-specific data, and assessment of basin-wide, cumulative impacts of human activities on streams and their biota. This article presents a frame-work for a hierarchical classification system, entailing an organized view of spatial and temporal variation among and within stream systems. Stream habitat systems, defined and classified on several spatiotemporal

scales, are associated with watershed geomorphic features and events. Variables selected for classification define relative long-term capacities of systems, not simply short-term states. Streams and their watershed environments are classified within the context of a regional biogeoclimatic landscape classification. The framework is a perspective that should allow more systematic interpretation and description of watershed-stream relationships.

Gard, R. 1961. Effects of beaver on trout in Sagehen Creek California. Journal of Wildlife Management 25:221-242.
'KEY WORDS'
Off channel
Beaver
Habitat use
Invertebrates
Spawning
Trout
'ABSTRACT'
Beaver ponds are productive habitats for trout

Good, T. P., J. Davies, B. J. Burke, and M. H. Ruckelshaus. 2008. Timber harvest transforms ecological roles of salmon in southeast alaska rain forest streams. Ecological Applications 18(1):246-257.
'KEY WORDS'
Watershed scale
Pacific Northwest
Puget Sound
Catastrophic loss
Chinook salmon
Evolutionarily significant unit (ESU)
Onchorhynchus tshawytscha
Population viability
Risk analysis
'ABSTRACT'
Catastrophic die-offs can have important consequences for vertebrate population growth and biodiversity, but catastrophic risks are not commonly incorporated into endangered-species recovery planning. Natural (e.g., landslides, floods) and anthropogenic (e.g., toxic leaks and spills) catastrophes pose a challenge for evolutionarily significant units (ESUs) of Pacific salmon listed under the Endangered Species Act and teetering at precariously low population levels. To spread risks among Puget Sound chinook salmon populations, recovery strategies for ESU-wide viability recommend at least two viable populations of historical life-history types in each of five geographic regions. We explored the likelihood of Puget Sound chinook salmon ESU persistence by examining spatial patterns of catastrophic risk and testing ESU viability recommendations for 22 populations of the threatened Puget Sound chinook salmon ESU. We combined geospatial information about catastrophic risks and chinook salmon distribution in Puget Sound watersheds to categorize relative catastrophic risks for each population. We then analyzed similarities in risk scores among regions and compared risk distributions among strategies: (1) population groups selected using the ESU viability recommendations of having populations spread out geographically and including historical life-history diversity, and (2) population groups selected at random. Risks from individual catastrophes varied among populations, but overall risk from catastrophes was similar within geographic regions. Recovery strategies that called for two viable populations in each of five geographic regions had lower risk than random strategies; strategies that included life-history diversity had even lower risks. Geographically distributed populations have varying catastrophic-risks profiles, thus identifying and reinforcing the spatial and life-history diversity critical for populations to respond to environmental change or needed to rescue

severely depleted or extirpated populations. Recovery planning can promote viability of Pacific salmon ESUs across the landscape by incorporating catastrophic risk assessments.

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.

'KEY WORDS'
Watershed scale
Movement
Trout
North America
'ABSTRACT'

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

Greene, C. M., D. W. Jensen, G. R. Pess, E. A. Steel, and E. Beamer. 2005. Effects of Environmental Conditions during Stream, Estuary, and Ocean Residency on Chinook Salmon Return Rates in the Skagit River, Washington. Transactions of the American Fisheries Society 134(6):1562-1581.

'KEY WORDS'
Watershed scale
Estuarine
Washington
Chinnook salmon
Models
'ABSTRACT'

We predicted 22 years of return rates for wild Chinook salmon Oncorhynchus tshawytscha as a function of environmental conditions experienced during residency in freshwater, tidal delta, bay, and ocean habitats as well as as an indicator of density dependence (based on egg production) across life stages. The best predictors of return rate included the magnitude of floods experienced during incubation, a principal components factor describing environmental conditions during bay residency, a similar factor describing conditions experienced during the third ocean year, and an estimate of egg production. Our models explained up to 90% of the variation in return rate and had a very high forecasting precision, yet environmental conditions experienced during ocean residency explained only 5% of the variation. Our results suggest that returns of wild Chinook salmon can be predicted with high precision by incorporating habitat residency and that freshwater and nearshore environmental conditions strongly influence the survival of Skagit River Chinook salmon.

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An ecosystem perspective of riparian zones. BioScience 41(8):540-551.

'KEY WORDS'
Watershed scale

Ecology
Stream ecology
'ABSTRACT'
A conceptual model of riparian zones integrates the physical processes that shape the landscapes, the succession of terrestrial plant communities on the geomorphic surfaces, the formation of habitat, and the production of nutritional resources for aquatic ecosystems. This ecosystem perspective of riparian zones emphasizes lotic ecosystems and the geomorphic organization of fluvial landforms. The linear nature of lotic ecosystems enhances the importance of riparian zones in landscape ecology. River valleys connect montane headwaters with lowland terrains, providing avenues for the transfer of water, nutrients, sediment, particulate organic matter, and organisms. Frequent disturbance events in riparian zones create complex mosaics of landforms and associated biological communities that often are more heterogeneous and diverse than those associated with upslope landscapes. Flooding is frequent, often annual or even more frequent, and a single flood may modify hundreds of square kilometers of river valley. Interactions between terrestrial and aquatic ecosystems include modification of microclimate, alteration of nutrient inputs from hillslopes, contribution of organic matter to streams and floodplains, and retention of inputs. It is concluded that an ecosystem perspective of riparian zones provides a rigorous ecological basis for identifying riparian zone management objectives, evaluating current land-use practices, and developing future resource alternatives.

Groot, C., and L. Margolis, editors. 1991. Pacifc Salmon Life Histories. UBC Press, Vancouver, BC.
'KEY WORDS'
Watershed scale
Life history
Pacific salmon
coho
sockeye
pink
chum
chinook
'ABSTRACT'
Provides separate life history for the five species of Pacific salmon by separate authors

Halupka, K. C., M. D. Bryant, M. F. Willson, and F. H. Everest. 2000. Biological characteristics and population status of anadromous salmon in southeast Alaska. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. General Technical Report GTR-PNW-468, Portland, OR.
'KEY WORDS'
Watershed scale
Southeast Alaska
Assessments
Population biology
Salmonid biology
Stock dynamics
'ABSTRACT'
Reviews various life history and morphometric feature to identify unique characteristics of salmon in southeast Alaska. Provides a review of a range of life history features of stock, including run size and timing. Identifies some stocks with unique feeatures and run timing.

Halupka, K. C., M. F. Willson, M. D. Bryant, F. H. Everest, and A. J. Gharret. 2003. Conservation of population diversity of Pacific Salmon in southeast Alaska. North American Journal of Fisheries Management 23:1057-1086.
'KEY WORDS'
Watershed scale

Southeast Alaska
Conservation biology
Anadromous salmonids
Population diversity
'ABSTRACT'
We analyzed intraspecific variation in selected biological characteristics of five species of Pacific salmon Oncorhynchus spp. in southeast Alaska and adjacent areas of Canada with a particular interest in describing the variation among populations and suggesting conservation priorities to preserve existing variation. We identified traits that showed high levels of among-population variation, evaluated the interspecific consistency of variation patterns, and noted the relationship of these traits to potential adaptive variation. In addition, we graphically identified populations with distinctive phenotypic and demographic characteristics as outliers from the distribution of mean values of traits taken from populations throughout the region. We also reviewed allozyme surveys to identify populations that differed in terms of the geographic clustering patterns of allele frequencies. Approximately 9,000 salmon populations occur in the study area, and sufficient data were available from 2,062 (23%) of them to analyze at least one characteristic. We identified 47 populations represented by adequate data sets that have distinctive characteristics. An additional 35 populations, represented by limited samples or unusual nominal traits, may be regionally distinctive. Of the 47 adequately sampled, distinctive populations, 22 met our criteria for conservation consideration: (1) high potential for adaptive variation (including distinctive run timing), (2) a distinctive trait combined with high spawner abundance or allozyme frequencies that diverge from geographic clustering patterns, and (3) more than one distinctive characteristic or freshwater habitat shared with other distinctive populations. Freshwater habitats for 6 of those 22 populations are located in watersheds that do not have restrictive land use designations and warrant the highest conservation priority.

Hartman, G. F., and J. C. Scrivener. 1990. Impacts of forestry practices on a coastal stream ecosystem, Carnation Creek, British Columbia. Canadian Bulletin Fisheries and Aquatic Sciences 223.
'KEY WORDS'
Main Stream
British Columbia
Carnation Creek
Habitat
Effects of logging
Forest management
Stream ecology
'ABSTRACT'
Results from the first 17 yr of a multi-disciplinary study about the effects of logging activities on a small stream ecosystem in the coastal rainforest of British Columbia have been reviewed. The main hydrological, fluvial-geomorphological, thermal, and production relationships are integrated in four schematic illustrations. The study has revealed that each activity conducted within an overall forest management plan may affect the physical components of an ecosystem differently.

Hartman, G. F., J. C. Scrivener, and M. J. Miles. 1996. Impacts of logging in Carnation Creek, a high-energy coastal stream in British Columbia, and their implications for restoring fish habitat. Canadian Journal of Fisheries and Aquatic Sciences 53(Suppl. 1):237-251.
'KEY WORDS'
Watershed scale
Main channel
British Columbia
Salmon habitat
Carnation Creek
Movement

Sediment
Effects of logging
Habitat restoration
'ABSTRACT'
Review of studies and result on the Carnation Creek watershed and effects of logging. Reviews effects on sediment., temperature, and habitat. Speceis include chum, coho, steelhead, and trout. Applies result to problems of restroration.Describes logging effects over > 20 year period that include reduced rearing and spawning habitat as a result of landslids, bank erosion, and loss of large wood. Presents a case for habitat improvement projects that include the life history of all species in the system and processes that maintain production and those that limit production.

Harvey, B. C. 1998. Influence of large woody debris on retention, immigration, and growth of coastal cutthroat trout (Oncorhynchus clarki clarki) in stream pools. Canadian Journal of Fisheries and Aquatic Sciences 55:1902-1908.
'KEY WORDS'
Tributaries
Headwater streams
California
Cutthroat trout
Large wood
Pools
'ABSTRACT'
Over 4 months and about 1 year, coastal cutthroat trout (Oncorhynchus clarki clarki) age-1 in Little Jones Creek, California, remained at similar rates in pools with and without large woody debris. This result was based on attempts in July and November 1995 to collect and tag all fish in 22 pools and three collections of fish from the same pools in November 1995, May 1996, and August 1996. Retention of fish appeared to be greater in pools with large woody debris in May 1996. The presence of large woody debris in pools did not influence immigration or growth of cutthroat trout. However, both immigration and growth increased downstream over the 3850-m study reach. Low retention and substantial immigration of cutthroat trout into experimental pools indicate that movement is important in the dynamics of this population. First- and second-order channels appear to be important sources of fish for the third-order study reach, while the study reach may export significant numbers of fish to downstream reaches accessible to anadromous fish.

Harvey, B. C., R. J. Nakamoto, and J. L. White. 1999. Influence of large woody debris and a bankfull flood on movement of adult resident coastal cutthroat trout (Oncorhynchus clarki) during fall and winter. Canadian Journal of Fisheries and Aquatic Sciences 56(1):2161-2166.
'KEY WORDS'
Tributaries
Cutthroat trout
California
Large wood
Pools
Habitat
Movement
Radio telemetry
'ABSTRACT'
To improve understanding of the significance of large woody debris to stream fishes, we examined the influence of woody debris on fall and winter movement by adult coastal cutthroa*t trout (Oncorhynch*us clarki) using radiotelemetry. Fish captured in stream pools containing large woody debris moved less than fish captured in pools lacking large woody debris or other cover. Fish from pools lacking cover commonly moved to habitats with large boulders or brush, particularly during the day. Movements by fish over 1-day periods were strongly

influenced by large woody debris or other elements providing cover. Fish initially found in habitats lacking large woody debris, large boulders, or brush cover moved the most extensively, while fish initially found in pools with large woody debris moved the least. Fish did not move extensively in response to a bankfull flood, although some moved to habitat downstream of large woody debris in tributaries or secondary channels. Habitat downstream of woody debris in the main channel was not used during the flood, apparently because of extreme turbulence. Overall, these observations provide additional evidence for the value of habitat complexity to some stream fishes and support previous observations of minimal effects of flooding on adult fish.

Hauer, F., G. Poole, J. Gangemi, and C. Baxter. 1999. Large woody debris in bull trout (Salvelinus confluentus) spawning streams of logged and wilderness watersheds in northwest Montana. Canadian Journal of Fisheries and Aquatic Sciences 56:915-924.

'KEY WORDS'
Main Stream
Montana
Large Wood
Habitat
Debris flow
Spawning
Forest mamagement
Transport processes
Salvelinus confluentus
bull trout
'ABSTRACT'

Large woody debris (LWD) was measured in 20 known bull trout (Salvelinus confluentus) spawning stream reaches from logged and wilderness watersheds in northwestern Montana. Mean bankfill width of stream reaches was 14.1 m ranging from 3.9 to 36.7 m. Streams were large enough to move LWD and form aggregates. The characteristics were determined of individual pieces of LWD that were interactive with the stream channel. Large, short pieces of LWD attached to the stream bank were the most likely to be positioned perpendicular to stream flow, while large, long pieces either tended to be parallel to the flow or, when attached, were most apt to extend across the channel. Observations indicated that the majority of pools were formed as scour pools by either very large LWD pieces that were perpendicular to the stream or multipiece LWD aggregates. Among reaches in wilderness watersheds, ratios of large to small LWD, attached to unattached LWD, and with and without rootwads were relatively consistent. Among reaches with logging in the watershed, these ratios varied substantially. Results suggest that logging can alter the balance of delivery, storage, and transport of LWD in northern Rocky Mountain streams, and therefore, the likely substantive change in stream habitats.

Hayes, S. A., and coauthors. 2008. Steelhead Growth in a Small Central California Watershed: Upstream and Estuarine Rearing Patterns. Transactions of the American Fisheries Society 137(1):114-128.

'KEY WORDS'
Esturaries
Main Stream
California
Steelhead
Growth
'ABSTRACT'

We monitored growth and life history pathways of juvenile steelhead Oncorhynchus mykiss and compared growth rates between the upper watershed and estuary in Scott Creek, a typical California coastal stream. Growth in the upper watershed was approximately linear from May to December for age-0 fish. For passive integrated transponder (PIT) tagged, age-1+ fish,

growth transitioned to a cyclic pattern, peaking at 0.2% per day during February–April, when maximum flows and temperatures of 7–12°C occurred. Growth of PIT-tagged fish then slowed during August–September (0.01% per day), when temperatures were 14–18°C and flows were low. During each spring, smolts (mean fork length [FL] ± SE = 98.0 ± 1.2 mm) and fry migrated to the estuary; some fish remained there during summer–fall as low flows and waves resulted in seasonal sandbar formation, which created a warm lagoon and restricted access to the ocean. Growth in the estuary–lagoon was much higher (0.2–0.8% per day at 15–24°C). Our data suggest the existence of three juvenile life history pathways: upper-watershed rearing, estuary–lagoon rearing, and combined upper-watershed and estuary–lagoon rearing. We present a model based upon the above data that reports size at age for each juvenile life history type. The majority of fish reaching typical steelhead ocean entry sizes (150–250 mm FL; age 0.8–3.0) were estuary–lagoon reared, which indicates a disproportionate contribution of this habitat type to survival of Scott Creek steelhead. In contrast, steelhead from higher latitudes rear in tributaries during summer, taking several years to attain ocean entry size.

Heggenes, J., T. G. Northcote, and A. Peter. 1991a. Seasonal habitat selection and preferences by cutthroat trout ({IOncorhynchus clarki}) in a small, coastal stream. Canadian Journal of Fisheries and Aquatic Sciences 48:1364-1370.

'KEY WORDS'
Tributaries
British Columbia
Cutthroat trout
Water velocity
Habitat use
'ABSTRACT'

Habitat selection by cutthroat trout (Oncorhynchus clarki) larger than 9 cm total length was monitored during winter and summer. The trout had strong preferences for depths >25 cm and areas where instream and overhead cover exceeded 40% of the local surface area. The fish selected a variety of substrate sizes. Stream areas with mean water velocities <20 cm/s were preferred. Compared with previous studies, the trout used low-velocity areas more, and we suggest that this is due to less competitive interaction from other young salmonids. The trout used the larger pools (>20 m2) considerably less during winter than during summer. Otherwise, little seasonal variation in habitat use was found. A composite measure of water depth and cover appeared to be the most important of the measured environmental factors influencing habitat selection in the stream. The larger trout, which were presumably dominant, occupied the deepest pool areas. The trout selected spatial habitats in proportions significantly different from the available habitat, demonstrating strong habitat preferences. It is concluded that observations of habitat occupancy without considering habitat availability may give biased results.

Heggenes, J., T. G. Northcote, and A. Peter. 1991b. Seasonal habitat selection and preferences by cutthroat trout (Oncorhynchus clarki) in a small, coastal stream. Canadian Journal of Fisheries and Aquatic Sciences 48:1364-1370.

'KEY WORDS'
Tributaries
British Columbia
Cutthroat trout
Habitat selection
'ABSTRACT'

Habitat selection by cutthroat trout (Oncorhynchus clarki) larger than 9 cm total length was monitored during winter and summer. The trout had strong preferences for depths >25 cm and areas where instream and overhead cover exceeded 40% of the local surface area. The fish selected a variety of substrate sizes. Stream areas with mean water velocities <20 cm/s were preferred. Compared with previous studies, the trout used low-velocity areas more, and we suggest that this is due to less competitive interaction from other young salmonids. The

trout used the larger pools (>20 m2) considerably less during winter than during summer. Otherwise, little seasonal variation in habitat use was found. A composite measure of water depth and cover appeared to be the most important of the measured environmental factors influencing habitat selection in the stream. The larger trout, which were presumably dominant, occupied the deepest pool areas. The trout selected spatial habitats in proportions significantly different from the available habitat, demonstrating strong habitat preferences. It is concluded that observations of habitat occupancy without considering habitat availability may give biased results.

Heggenes, J., T. G. Northcote, and A. Peter. 1991c. Spatial stability of cutthroat trout (*Oncorhynchus clarki*) in a small, coastal stream. Canadian Journal of Fisheries and Aquatic Sciences 48:757-762.

'KEY WORDS'
Tributaries
British Columbia
Cutthroat trout
Movement
Pools

'ABSTRACT'

Spatial stability and local movement of a cutthroat trout (Oncorhynchus clarki) population were studied from winter to late summer in a small, coastal stream. The majority of the population was static and resided within a home range < 22 m2, while a small fraction of the fish apparently was more mobile. Local movement was very restricted; 32.4% of the individually marked cutthroat were recaptured within 1 m of their original capture and marking site, and 48% remained within 3 m of that site. Only 17.9% of the fish moved more than 50 m. This behaviour was stable during winter, spring, and summer and may be of adaptive significance. Fish occupying pool areas moved considerably less than fish occupying shallow habitats, indicating that pool dwellers were dominant fish.

Heifetz, J., M. L. Murphy, and K. V. Koski. 1986. Effects of logging on winter habitat of juvenile salmonids in Alaskan streams. North American Journal of Fisheries Management 6:52-58.

'KEY WORDS'
Tributaries
Southeast Alaska
Coho salmon
Effects of logging
Overwinter survival

'ABSTRACT'

Effects of logging on preferred winter habitats of juvenile salmonids in southeastern Alaskan streams were assessed by comparing the area of preferred winter habitat in 54 reaches of 18 streams. Three types of streams were sampled at each of six locations: a stream in a mature, undisturbed forest; a stream in a clear-cut area but logged on at least one bank; and a stream in a clear-cut area with strips of forest (buffer strips) along the stream bank. To identify preferred winter habitats, we classified stream areas in 12 of 18 streams into discrete habitat types and compared the density of salmonids within these habitat types with average density of the entire reach. Most wintering coho salmon (Oncorhynchus kisutch), Dolly Varden (Salvelinus malma), and steelhead (Salmo gairdneri) occupied deep pools with cover (i.e., upturned tree roots, accumulations of logs, and cobble substrate). Riffles, glides, and pools without cover were not used. Seventy-three percent of all pools were formed by large organic debris. Reaches in clear-cut areas without buffer strips had significantly less area of pool habitat than old-growth reaches. Buffer strips protected winter habitat of juvenile salmonids by maintaining pool area and cover within pools. In some cases, blowdown from buffer strips added large organic debris to the stream and increased the cover within pools.

Hetrick, N. J., M. A. Brusven, T. C. Bjornn, R. M. Keith, and W. R. Meehan. 1998a. Effects of canopy removal on invertebrates and diet of juvenile coho salmon in a small stream in southeast Alaska. Transactions of the American Fisheries Society 127:876-888.

'KEY WORDS'
Tributaries
Southeast Alaska
Coho salmon
Invertebrates

'ABSTRACT'

We assessed changes in availability and consumption of invertebrates by juvenile coho salmon Oncorhynchus kisutch in a small stream in southeast Alaska where patches of dense second-growth riparian vegetation bordering the stream had been removed. Benthic invertebrate populations were assessed during summer 1988 and 1989 with a Hess sampler. Aerial invertebrates were sampled during summer 1989 with wire-mesh sticky traps hung just above the water surface and with floating clear-plastic pan traps. Invertebrate drift was assessed during summer 1989 with nets placed at the downstream end of closed- and open-canopy stream sections. Diets of age-0 and age-1 coho salmon were sampled by flushing stomach contents of fish collected from closed- and open-canopy stream sections. Abundance and biomass of benthic invertebrates were larger in open- than in closed-canopy stream sections and were primarily dipterans, ephemeropterans, and plecopterans. More insects were caught on sticky traps in open than in closed sections on two of four dates sampled, and composition of the catch was primarily dipterans (74% in both closed- and open-canopy sections). Catch rates of invertebrates in the pan traps were significantly higher in closed than in open sections on 12 July and were greater in open than in closed sections on 11 August. No significant canopy effect was detected with regard to dry weight of insects captured in pan traps. Composition of the pan-trap catches was primarily dipterans in both closed and open sections (65% and 72%). Abundance of invertebrates in the drift was significantly higher in closed sections than in open sections on two of four dates sampled; dry weight of invertebrate drift did not differ significantly between canopy types. Dry weight of stomach contents of age-0 and age-1 coho salmon was greater for fish sampled in closed- than open-canopy sections on one of four dates sampled; no significant canopy effect was detected for the other three dates sampled. Aerial insects were more abundant in drift and in diets of age-0 and age-1 coho salmon in closed- than in open-canopy sections. Diet of age-0 coho salmon in both closed and open sections and diet of age-1 fish in closed sections overlapped significantly with composition of the drift. Diet of age-1 coho salmon in open sections, however, did not overlap significantly with drift, an indication of selectivity in feeding behavior. Based on higher abundance of aerial invertebrates above the water surface and increased standing crop of benthic invertebrates that we observed in open- versus closed-canopy sections of Eleven Creek, it appears that canopy removal has the potential to increase the carrying capacity of juvenile coho salmon in streams where populations are food limited.

Hetrick, N. J., M. A. Brusven, W. R. Meehan, and T. C. Bjornn. 1998b. Changes in solar input,water temperture, periphyton accumulation, and allochthonous input and storage after canopy removal along two small salmon streams in southeast Alaska. Transactions of the American Fisheries Society 127:859-875.

'KEY WORDS'
Tributaries
Southeast Alaska
Coho Salmon
Effects of logging

'ABSTRACT'

Changes in solar radiation, water temperature, periphyton accumulation, and allochthonous inputs and storage were measured after we removed patches of deciduous, second-growth riparian vegetation bordering two small streams in southeast Alaska that produce coho salmon Oncorhynchus kisutch. Solar radiation and leaf litter input were measured at the water

surface at random locations dispersed through six alternating closed- and open-canopy stream sections. Water temperature, periphyton, and stored organic samples were collected near the downstream end of each section. Solar radiation intensity was measured with digital daylight integrators and pyronometers, periphyton biomass and chlorophyll a were measured on red clay tile substrates, allochthonous input was measured with leaf litter baskets, and benthic organic matter was measured with a Hess sampler. Average intensity of solar radiation that reached the water surface of open-canopy sections was significantly higher than in closed-canopy sections of two streams measured during daylight hours in summer 1988 and of one stream measured day and night in summer 1989. Average daily water temperature was similar in the two canopy types in summer 1988, but was higher in open- than in closed-canopy sections in 1989. Accumulation of periphyton biomass was significantly higher in open- than in closed-canopy sections of the two streams studied in the summer of 1988 and of the one stream sampled in 1989. Accrual of periphyton biomass on tiles placed in the stream for 30-d colonization periods during the summer months of 1989 was also significantly higher in the open than closed sections. Accumulation of chlorophyll a was significantly higher in the open- than in closed-canopy sections of the two streams in 1988 but did not differ significantly between canopy types in 1989. Thirty-day accrual of chlorophyll a was greater in open- than in closed-canopy sections of the one stream studied in 1989. Allochthonous input to the streams decreased after canopy removal, but the amount of organic material stored in the substrate did not differ significantly between open- and closed-canopy sections. Weather was predominantly overcast and rainy in summer 1988 and mostly sunny with infrequent rain in 1989. We speculate that advective heat transfer and high stream discharge from frequent rains moderated the effect of canopy removal and increased solar radiation on water temperatures in open-canopy stream sections in 1988. In 1989, solar radiation was a significant factor in regulating water temperature, especially when streamflows were low. Using a model, we predicted that water temperatures would change little in a 160-m open-canopy reach of Eleven Creek during any weather condition when flows were high. With low flows, however, stream temperatures in open sections of Eleven Creek were predicted to exceed the optimum for growth of juvenile coho salmon in about 20 m during clear sunny weather and in about 50 m when cloudy and overcast.

Hilborn, R., T. P. Quinn, D. E. Schindler, and D. E. Rogers. 2003. Biocomplexity and fisheries sustainability. Proceedings of the National Academy of Sciences of the United States of America 100(11):6564-6568.

'KEY WORDS'
Watershed Scale
Biological diversity
Climate change
'ABSTRACT'

A classic example of a sustainable fishery is that targeting sockeye salmon in Bristol Bay, Alaska, where record catches have occurred during the last 20 years. The is an amalgamation of several hundred discrete spawning populations. Structured within lake systems, individual populations display diverse life history characteristics and local adaptations to the variation in spawning and rearing habitats. This biocomplexity has enabled the aggregate of populations to sustain its productivity despite major changes in climatic conditions affecting the freshwater and marine environments during the last century. Different geographic and life history components that were minor producers during one climatic regime have dominated during others, emphasizing that the biocomplexity of fish stocks is critical for maintaining their resilience to environmental change.

Hilderbrand, R. H., and J. L. Kershner. 2000. Movement patterns of stream-resident cuthroat trout in Beaver Creek, Idaho-Utah. Transactions of the American Fisheries Society 129:1160-1170.

'KEY WORDS'
Main Stream
Idaho

Utah
Movement
'ABSTRACT'
We used mark–recapture, radiotelemetry, and two-way traps to determine daily, seasonal, and annual movements of cutthroat trout Oncorhynchus clarki in Beaver Creek, Idaho–Utah. We recaptured 26 of 167 (16%) passive integrated transponder (PIT)-tagged cutthroat trout; 16 of the fish were recaptured less than 300 m from the point of capture 1 year earlier, whereas 10 fish were recaptured a median of 1,407 m (range 331–3,292 m) from their captured point of the previous year. Radio-tagged individuals moved less frequently and shorter distances (median = 0 m) during autumn and winter, more frequently and farther during spring in association with spawning (median = 576 m), and variably and sporadically during summer (median = 55 m). We found substantial local movements during a diel period that would not have been found using a once weekly observation period. Frequency of cutthroat trout movement through two-way traps was greatest in July and early August and had stopped almost entirely by early September. Movement timing and frequency were similar between the traps and the radio-tagged fish. Our results demonstrate the mobility potential of cutthroat trout and the importance of selecting appropriate spatial and temporal scales of observation when studying their ecology.

Hill, A. C., T. S. Bansak, B. K. Ellis, and J. A. Stanford. 2010. Merits and Limits of Ecosystem Protection for Conserving Wild Salmon in a Northern Coastal British Columbia River. Pages np *in* Ecology and Society.
'KEY WORDS'
Watershed scale
Pacific Northwest
Conservation
Ecology
Resilience
Fisheries
Resource management
Salmon
Habitats
'ABSTRACT'
Loss and degradation of freshwater habitat reduces the ability of wild salmon populations to endure other anthropogenic stressors such as climate change, harvest, and interactions with artificially propagated fishes. Preservation of pristine salmon rivers has thus been advocated as a cost-effective way of sustaining wild Pacific salmon populations. We examine the value of freshwater habitat protection in conserving salmon and fostering resilience in the Kitlope watershed in northern coastal British Columbiaâ€"a large (3186 km2) and undeveloped temperate rainforest ecosystem with legislated protected status. In comparison with other pristine Pacific Rim salmon rivers we studied, the Kitlope is characterized by abundant and complex habitats for salmon that should contribute to high resilience. However, biological productivity in this system is constrained by naturally cold, light limited, ultra-oligotrophic growing conditions; and the mean (Â± SD) density of river-rearing salmonids is currently low (0.32 Â± 0.27 fish per square meter; n = 36) compared to our other four study rivers (grand mean = 2.55 Â± 2.98 fish per square meter; n = 224). Existing data and traditional ecological knowledge suggest that current returns of adult salmon to the Kitlope, particularly sockeye, are declining or depressed relative to historic levels. This poor stock statusâ€"presumably owing to unfavorable conditions in the marine environment and ongoing harvest in coastal mixed-stock fisheriesâ€"reduces the salmon-mediated transfer of marine-derived nutrients and energy to the systemâ€™s nutrient-poor aquatic and terrestrial food webs. In fact, Kitlope Lake sediments and riparian tree leaves had marine nitrogen signatures (Î´15N) among the lowest recorded in a salmon ecosystem. The protection of the Kitlope watershed is undoubtedly a conservation success story. However, 'salmon strongholds' of pristine watersheds may not adequately sustain salmon populations and foster social and ecological

resilience without more holistic and risk-averse management that accounts for uncertainty and interactions between ecosystem fertility, harvest, climate dynamics, and food web dynamics in the marine and freshwater environments encompassed by the life cycle of the fish.

Hocking, M. D., and T. E. Reimchen. 2009. Salmon species, density and watershed size predict magnitude of marine enrichment in riparian food webs. Oikos 118(9):1307-1318.

'KEY WORDS'
Watershed scale
British Columbia
Nutrients
Marine derived nutrients
'ABSTRACT'

Resource subsidies across habitat boundaries can structure recipient communities and food webs. In the northern Pacific region, bears Ursus spp. foraging on anadromous salmon Oncorhynchus spp. provide a key link between marine and terrestrial ecosystems, with salmon density, fish size and watershed size as potential predictors of the magnitude of marine subsidy to terrestrial habitats. We use nitrogen and carbon stable isotopes to provide an assessment of the patterns of marine-enrichment in riparian plants (11 species, 4 guilds) and litter invertebrates (4 guilds) sampled from 27 watersheds in coastal British Columbia, Canada. Watersheds occurred in three geographical regions (Vancouver Island, mainland midcoast and Haida Gwaii) and varied in size, and in biomass (kg m−1 of spawning length) and species of salmon (chum O. keta, pink O. gorbuscha and coho O. kisutch). δ15N values in all plant species and invertebrate guilds were positively predicted by total salmon biomass (kg m−1) and negatively predicted by watershed size. We observed replicated parallel slopes among plant species and invertebrate guilds across the gradient in salmon biomass, with differences in means hypothesized to be due to plant fractionation and animal trophic position. As such, we derived a watershed δ15N-index averaged across guilds, and using an information theoretic approach we find that the biomass of chum salmon is a much stronger predictor of the δ15N-index than either pink or coho salmon, or the sum biomass of all species. The top linear model contained chum biomass and watershed size. Chum salmon biomass independently predicted δ15N-index variation in all three regions of British Columbia. Chum salmon are larger than pink or coho and provide an energetic reward for bears that facilitates carcass transfer, tissue selective foraging, and nutrient distribution by insect scavengers. Analyses of biodiversity and habitat data across many watersheds moves towards a long-term goal in fisheries ecology to better integrate ecosystem values in salmon conservation.

Hogan, D. L., and M. Church. 1989. Hydraulic Geometry in Small, Coastal Streams: Progress Toward Quantification of Salmonid Habitat. Canadian Journal of Fisheries and Aquatic Sciences 46:844-852.

'KEY WORDS'
Tributaries
British Columbia
Stream morphology
Salmon habitat
'ABSTRACT'

It is difficult to quantify in-stream physical attributes of salmonid habitats, yet quantification is necessary if conditions are to be compared within or between streams over time or space. This paper presents an objective method based on hydraulic geometry to quantify hydraulic characteristics of fish habitat. Two small streams in coastal British Columbia provide examples. Morphological mapping and streamflow measurements were used to generate the bivariate distributions of mean depth and mean velocity at cross sections within the study reaches at various discharges. The distributions are used to generate measures of potentially useable area within the streams. Survey criteria and numerical adjustments are presented to improve comparability between channels. The streams respond similarly to a change in

discharge. The main hydraulic difference is a decrease in area useful to coho salmon (Oncorhynchus kisutch) for rearing at higher discharges in Bonanza Creek (logged) compared with Hangover Creek (unlogged). The example indicates that quantitative comparisons can be made, at comparable flows, between reaches and between streams, or over time.

Holtby, L. B., T. E. McMahon, and J. C. Scrivener. 1989. Stream temperatures and inter-annual variability in the emigration timing of coho salmon (Oncorhynchus kisutch) smolts and fry and chum salmon(O. keta) fry from Carnation Creek, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 46:1396-1405.

'KEY WORDS'
Main Stream
British Columbia
Carnation Creek
Temperature
Emigration
Coho salmon
Chum salmon
'ABSTRACT'

Variability in average stream temperatures between peak spawning and fry emergence accounted for 82 and 77% of the variance in the median emigration date of fry of chum (Oncorhynchus keta) and coho salmon (O. kisutch) respectively over a 9 to 10-yr period. The modeled relationships were indistinguishable from laboratory models that predicted time to maximum alevin wet weight. Variability in stream temperatures during the spring accounted for 60% of the variability in the median date of coho smolt emigration. As stream temperatures increased, the predicted thermal summations required for emigration were nearly constant for coho salmon fry, increased moderately for chum salmon fry and increased strongly for coho salmon smolts The duration of the emigration period also differed between the groups: 50% of the chum salmon fry emigrated over a 1-wk period compared with a 2- to 3-wk period for coho salmon fry and smolts. We speculate that the emigration timing —temperature relationships and timing of adult spawning represent adaptations for synchronizing emigration with "windows of opportunity" in the ocean or stream. The windows are of different widths and levels of predictability for coho and chum salmon fry and coho salmon smolts.

Holtby, L. B., and J. C. Scrivener. 1989. Observed and simulated effects of climatic variability, clear-cut logging and fishing on the numbers of chum salmon (Oncorhynchus keta) and coho salmon (O. kisutch) returning to Carnation Creek, British Columbia. Pages 62-81. *in* C. D. Levings, L. B. Holtby, and M. A. Henderson, editors. Proceedings of the National Workdhop on effects of habitat alteration on salmon stocks. Canadian Special Publication of Fisheries and Aquatic Sciences 105.

'KEY WORDS'
Main Stream
British Columbia
Effects of Logging
Salmonid habitat
Temperature models
'ABSTRACT'

The population dynamics of coho and chum salmon have been studied at Carnation Creek since 1970 as part of a multi-disciplinary study of the effects of logging on a small salmon stream in a coastal rainforest. The authors have developed models that predict the numbers of chum and coho salmon from correlative relationships between survival and growth at various life stages and (1) climatic, hydrologic and physical variables, (2) indices of those features of the stream habitat that were affected by logging and, (3) exploitation rates in the fishery. The authors suggest that overall variability in the salmon abundance will tend to increase in the wake of land-use activities, particularly when accompanied by high levels of exploitation and adverse environmental conditions.

Hood, W. 2007. Landscape allometry and prediction in estuarine ecology: Linking landform scaling to ecological patterns and processes. Estuaries and Coasts 30(5):895-900.

'KEY WORDS'
Watershed scale
Esturaries
Land forms
landscape
'ABSTRACT'

Spatial variation in landforms and associated physical processes can often be described by allometric scaling relationships, similar to those describing organismal allometry. Because plant and animal distribution, abundance, and behavior are generally affected, if not sometimes controlled, by the physical environment, landform scaling likely causes parallel scaling of ecological patterns and process across the landscape, i.e., landscape allometry. Organismal allometry has a long history, well-established tradition, and well-developed body of theory. Landscape allometry is a newly emerging conceptual framework that offers explanation for ecological patterns and utility for practical issues such as allowing landscape-scale replication of experimental and control treatments, providing landscape-scale predictions of ecological pattern and process, providing design guidelines for landscape management, and providing diagnostic methods for assessing historical anthropogenic effects to landscapes. Organismal and landscape allometry could be used in complementary fashion, and perhaps ultimately integrated, to form a useful theoretical framework for ecology.

Imhof, J. G., J. Fitzgibbon, and W. K. Annable. 1996. A hierarchical evaluation system for characterizing watershed ecosystems for fish habitat. Canadian Journal of Fisheries and Aquatic Sciences 53(Suppl. 1):312-326.

'KEY WORDS'
Watershed scale
Habitat
Classifciation
Watershed management
'ABSTRACT'

Presents a hierarachical classification based on scale habitat unit to landscape.Evaluatesion of watershed system to determine relationships between processes such as watershed geometry and physical features and there use by fish. Employs a framework that encompasses three hierarchies, watershed, reach, and site to model and analyze processes that affect life histories of fish.

Johnson, C. A., and R. J. Naiman. 1987. Boundary dynamics at the aquatic-terrestrial interface: The influence of beaver and geomorphology. Landscape Ecology 1:47-57.

'KEY WORDS'
Off channel
Watershed scale
Beaver
Geomorphology
Landscape ecology
Riparian habitat
Trophic ecology
'ABSTRACT'

Beaver (Castor canadensis) impoundments are used to illustrate the effect of large animals on the boundary dynamics of lsquopatch bodiesrsquo, volumetric landscape units which have surficial boundaries with upper and lower strata, and lateral boundaries with adjacent patches within the same stratum. Patch bodies created by beaver impoundments include the beaver pond, the aerobic soil beneath the pond, and the underlying anaerobic soil. Beaver herbivory in the riparian zone creates an additional patch body concentric to the pond.

Beaver and water are the primary biotic and abiotic vectors mediating fluxes across lateral patch body boundaries; vegetation and microbes are the primary biotic vectors mediating fluxes across surficial patch body boundaries. Basin geomorphology affects the permeability of pond boundaries (i.e., their ability to transmit, energy and materials) by affecting the kinetic energy of water, the surface-to-volume ratio of the impoundment, and the movement of beaver between the pond and the riparian foraging zone. We suggest that: (1) permeability of lateral boundaries to abiotic vectors is a function of kinetic energy; (2) within-patch retention of particulate matter transferred by abiotic vectors across lateral boundaries is maximized by a decrease in kinetic energy; (3) lateral patch boundaries between safe refuge and a resource used by an animal vector are most permeable when they are narrow; and (4) total amount of energy and materials transferred across surficial boundaries is maximized by increasing surface area.

Johnson, S. L., J. D. Rodgers, M. F. Solazzi, and T. E. Nickelson. 2005. Effects of an increase in large wood on abundance and survival of juvenile salmonids (Oncorhynchus spp.) in an Oregon coastal stream Canadian Journal of Fisheries and Aquatic Sciences 62:412–424 'KEY WORDS'
Tributaries
Main Stream
Oregon
Large wood
Population size
Steelhead
Coho
'ABSTRACT'
We examined the effect of an increase in large wood on the summer population size, smolt abundance, and freshwater survival of steelhead (Oncorhynchus mykiss), coastal cutthroat trout (Oncorhynchus clarki clarki), and coho salmon (Oncorhynchus kisutch). We examined these parameters for five brood years prior to the addition of wood and five brood years after in Tenmile Creek, a direct ocean tributary on the Oregon coast. Over the same time frame, a nearby reference stream, Cummins Creek, was also sampled for the same parameters. The input of large wood into Tenmile Creek resulted from a planned habitat restoration project in 1996 and an unplanned addition of wood from a winter storm the same year. Steelhead smolt abundance, steelhead freshwater survival, and coho salmon freshwater survival increased in Tenmile Creek after the input of large wood. Steelhead age-0+ summer populations and steelhead smolt populations increased in the reference stream, although steelhead freshwater survival did not. Coho salmon populations remained nchanged in the reference stream. Our results illustrate the potential shortcomings of the before-aftercontrol-impact study design under field conditions and the potential for is interpreting results had we employed amore modest sampling plan.

Johnston, C. A., and R. J. Naiman. 1990. Aquatic patch creation in relation to beaver population trends. Ecology 71:1617-1621.
'KEY WORDS'
Off channel
Watershed scale
Minnesota
Beaver
Disturbance
Landscape ecology
'ABSTRACT'
The creation of aquatic patches by beaver (Castor canadensis) in the boreal forest of northern Minnesota, USA, was studied to determine how the population dynamics of a disturbance—causing animal are linked to rates of patch formation and growth over a period of population expansion and stabilization. Using six series of aerial photographs taken between 1940 and 1986, we determined the size and growth rates of individual patches, and the numbers, area,

density, and establishment rate of the patch population. The rate of patch formation was much higher during the first two decades of colonization than during the subsequent two decades. The average area of all ponds sites, which included both filled and drained ponds, remained at °ha throughout the time period, but the average area of new ponds decreased significantly over time. Ponds established by 1961 constituted 75% of the total number and 90% of the total pond—site area as of 1986. When pond sites of similar age but different pond cohort (i.e, decade of establishment) were compared, the average area per pond site was always significantly larger for the earlier cohort. Although the rate of pond creation paralleled the increase in number of beaver colonies between 1961 and 1986, the rate of new pond creation prior to 1961 greatly exceeded the increase in number of beaver colonies. We conclude that the rate of patch formation after the first two decades of beaver colonization was constrained by geomorphology, which limited the availability of sites at which a beaver dam could impound a large area of water.

Jones, N. E. 2010. Incorporating lakes within the river discontinuum: longitudinal changes in ecological characteristics in streamlake networks. Canadian Journal of Fisheries and Aquatic Sciences 67:1350-1362.

'KEY WORDS'
Watershed scale
Lakes
Aquatic networks
Landscape ecology
'ABSTRACT'

Lakes and rivers are intimately connected in an alternating series of lentic and lotic reaches in many regions. The study of lakes and their outlets in hierarchical and branching river networks has not gained the attention of stream ecologists, and little effort has been focused on synthesizing the ecology of lake-stream interactions within a drainage network. Rapid and predictable changes in the ecological characteristics of streams occur at the interface with lakes. The influence that a lake might have on a stream is dependent on its position within the stream, stream type and size, lake size and shape, and the inlet and outlet positions. Little is known about the influences of multiple lakes within stream-lake networks and how these influences are determined by network shape and pattern. Fruitful collaborations and novel insights will come from the combined efforts of limnologists, stream ecologists, and landscape ecologists. Geographic information systems and network analyses will play an important role in summarizing aquatic landscape characteristics and creating a predictive science of aquatic networks. Lakes need to be more explicitly incorporated into ecological concepts in stream ecology, and reciprocally, streams need to be incorporated into ecological concepts involving lakes for the successful management and conservation of our aquatic resources

Junk, W. G., P. B. Bayley, and R. E. Sparks. 1989. The flood pulse concept in river-flooding systems. Pages 110-127 *in* D. P. Dodge, editor Proceedings of the International Large River Symposium. Canadian Special Publications in Fisheries and AquaticSciences.

'KEY WORDS'
Watershed scale
Floodplain
Floods
Stream ecology
'ABSTRACT'

Time and duration of floods are an important effect on river and flood plain productivity. Low order stream pylses tend to be brief and unpredictable, but may be important to transport of nutrients and organisn across the flood plain. A predictble, long duration pulse allows organism to adapt and use the flood pulse for activities such as feeding and reproduction.

Kahler, T. H., P. Roni, and T. P. Quinn. 2001. Summer movement and growth of juvenile anadromous salmonids in small western Washington streams. Canadian Journal of Fisheries and Aquatic Sciences 58:1947-1956.

'KEY WORDS'
Main Stream
Tributaries
Washington
Movement
Juvenile salmonids
Coho salmon
Cutthroat trout
Steelhead
'ABSTRACT'

Movements of juvenile coho salmon (*Oncorhynchus kisutch*), cutthroat trout (*Oncorhynchus clarki clarki*), and steelhead trout (*Oncorhynchus mykiss*) were studied by observations and recapture of marked individuals in three western Washington streams to test the hypotheses that few fish would move, downstream movement would predominate, movers would be initially smaller and grow slower after movement than residents, and habitat quality would influence movement. Contrary to predictions, from 28 to 60% of marked fish moved at least one habitat unit, and immigration of unmarked fish also indicated considerable movement. Upstream movement predominated but the stream with the step-pool/cascade channel type had fewer upstream movers and greater distances moved downstream. Coho movers were not smaller than nonmovers, as predicted based on assumptions that movement results from competitive exclusion. Habitat units that coho left were smaller and shallower but lower in density than units where coho remained. Thus, movement is a common phenomenon rather than an aberration, and may reflect habitat choice rather than territorial eviction. Moreover, movers grew faster than nonmovers, so the "mobile fraction" of the population was not composed of competitively inferior fish but rather individuals that thrived. The phenomenon of small-scale habitat- and growth-related movements should be considered when planning and interpreting studies of juvenile salmonid ecology in streams.

Keith, R. M., T. C. Bjornn, W. R. Meehan, N. J. Hetrick, and M. A. Brusven. 1998. Response of juvenile salmonids to riparian and instream cover modifcations in small streams flowing through second-growth forests of southeast Alaska. Transactions of the American Fisheries Society 127:889-907.

'KEY WORDS'
Tributaries
Southeast Alaska
Coho Salmon
Dolly Varden
Riparian Habitat
'ABSTRACT'

We manipulated the canopy of second-growth red alder Alnus rubra and instream cover to assess the effects on abundance of juvenile salmonids in small streams of Prince of Wales Island, southeast Alaska, in 1988 and 1989. Sections of red alder canopy were removed to compare responses of salmonids to open- and closed-canopy sections. At the start of the study, all potential instream cover was removed from the study pools. Alder brush bundles were then placed in half the pools to test the response of juvenile salmonids to the addition of instream cover. Abundance of age-0 coho salmon Oncorhynchus kisutch decreased in both open- and closed-canopy sections during both summers, but abundance decreased at a higher rate in closed-canopy sections. More age-0 Dolly Varden Salvelinus malma were found in open-canopy sections than in closed-canopy during both summers. Numbers of age-1 and older coho salmon and Dolly Varden were relatively constant during both summers, and there was no significant difference in abundance detected between open- and closed-canopy sections. Abundance of age-0 coho salmon decreased in pools with and without additional instream

cover during both summers. Abundance of age-1 and older coho salmon and age-0 Dolly Varden did not differ significantly in pools with or without added cover during either summer. Abundance of age-1 and older Dolly Varden was higher in pools with added instream cover than in pools without cover during both summers. Age-0 coho salmon decreased in abundance throughout the summer in both years. Emigration was measured in 1989 and accounted for most of the decrease in abundance. Age-0 coho salmon emigrants were significantly smaller than age-0 coho salmon that remained in the stream.

Kiffney, P. M., and coauthors. 2009. Changes in fish communities following recolonization of the Cedar River, WA, USA by Pacific salmon after 103 years of local extirpation. River Research and Applications 25(4):438-452.

'KEY WORDS'
Main Stream
Washington
Barriers
Habitat fragmentation
Migration corridors
Salmon
'ABSTRACT'

Migration barriers are a major reason for species loss and population decline of freshwater organisms. Significant efforts have been made to remove or provide passage around these barriers; however, our understanding of the ecological effects of these efforts is minimal. Installation of a fish passage facility at the Landsburg Dam, WA, USA provided migratory fish access to habitat from which they had been excluded for over 100 years. Relying on voluntary recruitment, we examined the effectiveness of this facility in restoring coho (Oncorhynchus kisutch) salmon populations above the diversion, and whether reintroduction of native anadromous species affected the distribution and abundance of resident trout (O. mykiss and O. clarki). Before the ladder, late summer total salmonid (trout only) density increased with distance from the dam. This pattern was reversed after the ladder was opened, as total salmonid density (salmon + trout) approximately doubled in the three reaches closest to the dam. These changes were primarily due to the addition of coho, but small trout density also increased in lower reaches and decreased in upper reaches. A nearby source population, dispersal by adults and juveniles, low density of resident trout and high quality habitat above the barrier likely promoted rapid colonization of targeted species. Our results suggest that barrier removal creates an opportunity for migratory species to re-establish populations leading to range expansion and potentially to increased population size.

Lawson, P. W., E. A. Logerwell, N. J. Mantua, R. C. Francis, and V. N. Agostini. 2004. Environmental factors influencing freshwater survival and smolt production in Pacific Northwest coho salmon (Oncorhynchus kisutch). Canadian Journal of Fisheries and Aquatic Sciences 61:360-373.

'KEY WORDS'
Main Stream
Washington
Coho salmon
Production
Survival
Climate change
Stream flow
Temperature
'ABSTRACT'

Climate variability is well known to affect the marine survival of coho salmon (Oncorhynchus kisutch) in Oregon and Washington. Marine factors have been used to explain up to 83% of the variability in Oregon coastal natural coho salmon recruitment, yet about half the variability in coho salmon recruitment comes from the freshwater life phase of the life cycle. This seeming

paradox could be resolved if freshwater variability were linked to climate and climate factors influencing marine survival were correlated with those affecting freshwater survival. Effects of climate on broad-scale fluctuations in freshwater survival or production are not well known. We examined the influence of seasonal stream flows and air temperature on freshwater survival and production of two stock units: Oregon coastal natural coho salmon and Queets River coho salmon from the Washington Coast. Annual air temperatures and second winter flows correlated strongly with smolt production from both stock units. Additional correlates for the Oregon Coast stocks were the date of first fall freshets and flow during smolt outmigration. Air temperature is correlated with sea surface temperature and timing of the spring transition so that good freshwater conditions are typically associated with good marine conditions.

Leidbold-brunner. 1992. Beaver dam location and effects on the distribution and abundance of coho salmon fry in an Oregon stream. Northwest Science 66:218-223.

'KEY WORDS'
Off channel
Oregon
Coho Salmon
'ABSTRACT'

Beaver (Castor canadensis) dams and coho salmon (Oncorhynchus kisutch) fry were examined for their relationships in two coastal Oregon streams in 1987. Our initial spring survey of 19 km of stream found only one dam still complete after winter. By autumn, the number of dams had increased to 1.1 and 1.2 per km on the two streams. Beaver dams increased summer pool habitat 7 to 14% over unmodified conditions. Although density of coho (per m super(2) and m super(3)) was similar among pool types, beaver ponds were larger and contained more coho fry than non-beaver pools; thus, beaver increased rearing habitat for coho during the late summer low flow. Beaver represent a low-cost tool deserving more consideration for stream rehabilitation projects.

Leisca, P., and F. W. Allendorf. 1995. When are peripheral populations valuable for conservation. Conservation Biology 9(4):753-760.

'KEY WORDS'
Watershed scale
Conservation
Genetic diversity
Natural selection
Population biology
'ABSTRACT'

A great deal of effort is spent protecting geographically peripheral populations of widespread species. We consider under what conditions it is appropriate to expend resources to protect these populations. The conservation value of peripheral populations depends upon their genetic divergence from other conspecific populations. Peripheral populations are expected to diverge from central populations as a result of the interwoven effects of isolation, genetic drift, and natural selection. Available empirical evidence suggests that peripheral populations are often genetically and morphologically divergent from central populations. The long-term conservation of species is likely to depend upon the protection of genetically distinct populations. In addition, peripheral populations are potentially important sites of future speciation events. Under some circumstances, conservation of peripheral populations may be beneficial to the protection of the evolutionary process and the environmental systems that are likely to generate future evolutionary diversity.

Lisle, T. E. 1986. Effects of woody debris on anadromous salmonid habitat, Prince of Wales Island, Southeast Alaska. North American Journal of Fisheries Management 6:538-550.

'KEY WORDS'
Tributaries

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

Lohr, S. C., and M. D. Bryant. 1999. Biological Characteristics and Population status of steelhead (Oncorhyncus mykiss) in southeast Alaska. General Technical Report PNW-GTR-407. U.S.D.A. Forest Service, Pacific Northwest Research Station, Portland, OR.
'KEY WORDS'
Watershed scale
Southeast Alaska
Anadromous salmonids
Life history
Steelhead trout
Stock dynamics
'ABSTRACT'
Reveiws life history and population characteristics of steelhead to identify unique or endangered stocks. Provides run timing and escapement where known.

Lotspeich, F. B. 1980. Watersheds as the basic ecosystem: this conceptual framework provides a basis for a natural classification system. Journal of the American Water Resources Association 16(4):581-586.
'KEY WORDS'
Watershed Scale
Climate
'ABSTRACT'
A scheme is outlined to classify watersheds as ecosystems, based on their natural attributes. Two physical factors of the environment, climate and geology, are selected as state factors. Climate is the master factor that supplies energy and water to all ecosystems; geologic structure supplies the materal from which the forces of climate carve landforms to establish

ecosystems. At the next lower level, soil and vegetation interact in a succession of transactions to produce a mosaic of tesseras within each watershed. It is these interacting tesseras that moderate climate and store energy within the ecosystem that influences the embedded stream. At the bottom of the scale is the stream with its passive role and inability to interact with the higher factors of the ecosystem. Thus, we have a controlling force consisting of two elements (climate and geology), a reacting force (soil and vegetation) that responds by circular conditioning to controlling forces, and at the lowest level, the stream which responds to all factors of the living system within its watershed.

Mantua, N. J. 2009 Patterns of change in climate and Pacific salmon production. American Fisheries Society Symposium 70.

'KEY WORDS'
Climate change
Pacific salmon
Pacific Decadal Ossillation
'ABSTRACT'

For much of the 20th century a clear north-south inverse production pattern for Pacific salmon had a time dynamic that closely followed that of the Pacific Decadal Oscillation (PDO), which is the dominant pattern of North Pacific sea surface temperature variability. Total Alaska salmon production was high during warm regimes of the PDO, and total Alaska salmon production was relatively low during cool regimes of the PDO. Leading hypotheses for the link between climate and Pacific salmon production have focused on changes in early ocean survival for juvenile salmon, but it is clear that climate also affects freshwater life stages and influences productivity. Over broad spatial scales, the PDO-related patterns in climate and Pacific salmon production were less prominent in the period 1990-2004 than in earlier decades of the 20th century, yet the regional associations between salmon production and temperatures were generally the same: warm periods coincided with high salmon production in Alaska, and cool periods off the west coast of the continental U.S. and British Columbia coincided with high salmon production in those regions. A case study of Norton Sound pink salmon provides one regional perspective on the links between changes in climate and salmon production. In the period 1962-1995, anomalously warm winter and spring climate in western Alaska and warm spring/summer temperatures in the eastern Bering Sea generally coincided with high pink salmon production. However, especially warm conditions for freshwater and early marine life stages for Norton Sound pink salmon coincided with both high and low levels of recruits per spawner for brood years 1996-2003, a period that experienced large inter-annual variations in Bering Sea, North Pacific, and tropical Pacific Ocean conditions.

Martin, D. J., and L. E. Benda. 2001. Patterns of instream wood recruitment and transport at the watershed scale. Transactions of the American Fisheries Society 130:940-958.

'KEY WORDS'
Main Stream
Southeast Alaska
Large woody debris
Channel morphology
'ABSTRACT'

A wood budget was constructed for the Game Creek basin (132 km2) in southeast Alaska to identify spatial and temporal controls on the abundance and distribution of large woody debris (LWD). Field measurements of wood storage, size, and age were used to estimate volumetric rates of LWD recruitment and transport. Mortality recruitment did not follow a spatial pattern and ranged from 0.1 to 8.1 m3·km−1·year−1 (recruitment corresponded to forest mortality rates of 0.1–2.6% per year). Wood recruitment by bank erosion increased with increasing drainage area and ranged from 1 m3·km−1·year−1 at the smallest drainage areas to about 16 m3·km−1·year−1 at 60 km2. Bank erosion recruitment exceeded the maximum mortality recruitment at a drainage area of approximately 20 km2 (about 10-m-wide channel). Recruitment from land-sliding was only locally significant. The contribution of

fluvial transport (flux) to total LWD storage increased with drainage area to an asymptotic maximum of 50% at about 50 km2 (about 20-m-wide channel). Mean predicted transport distances for mobile LWD over the lifetime of individual pieces ranged from about 200 m in small, jam-rich streams to about 2,500 m in larger channels with fewer jams. Fluvial transport of LWD increased interjam spacing and jam size and decreased jam age with increasing distance downstream. Constructing LWD budgets at the watershed scale has numerous geomorphic and ecological implications, including identifying spatial controls on the abundance and diversity of aquatic habitats. In addition, information on LWD budgets may be useful for determining how and where to protect LWD sources to streams.

McFarlane, G. A., J. R. King, and R. J. Beamish. 2000. Have there been recent changes in climate? Ask the fish. Progress In Oceanography 47(2-4):147-169.

'KEY WORDS'
Climate change
Climate models
Decadal climate shift
'ABSTRACT'

It is generally accepted that a climate shift occurred about 1977 that affected the dynamics of North Pacific marine ecosystems. Agreement on the possibility of further climate shifts in 1989 and the late 1990s is yet to be achieved. However, there have been changes in the dynamics of key commercial fishes that indicate changes in their environment occurred in the early 1990s, and possibly around 1998. One method of measuring climate change is to observe the dynamics of species that could be affected. Several studies have described decadal-scale changes in North Pacific climate-ocean conditions. Generally, these studies focus on a single index. Using principal components analysis, we use a composite index based on three aspects of climate ocean conditions: the Aleutian Low Pressure Index, the Pacific Atmospheric Circulation Index and the Pacific Interdecadal Oscillation Index. We link this composite index (Atmospheric Forcing Index) to decadal-scale changes in British Columbia salmon and other fish populations. Around 1989 there was a change from intense Aleutian Lows (above average south-westerly and westerly circulation patterns and warming of coastal sea surface temperatures) to average Aleutian Lows (less frequent south-westerly and westerly circulation and slightly cooler coastal sea surface temperatures in winter). These climate-ocean changes were associated with changes in the abundance and ocean survival of salmon (Oncorhynchus spp.), distribution and spawning behaviour of hake (Merluccius productus) and sardines (Sardinops sagax) and in recruitment patterns of several groundfish species.

McHenry, M. L., E. Shott, R. H. Conrad, and G. B. Glenn B. Grette. 1998. Changes in the quantity and characteristics of large woody debris in streams of the Olympic Peninsula, Washington, U.S.A. (1982.1993). Canadian Journal of Fisheries and Aquatic Sciences 55:1395-1407.

'KEY WORDS'
Main stream
Washington
Large wood
Stream habitat
'ABSTRACT'

We assessed the changes in large woody debris (LWD) abundance and composition at 28 sites in 27 low-gradient Olympic Peninsula streams between 1982 and 1993. The average number of pieces of debris was virtually identical (P = 0.98) in both years (50.7 versus 50.6). However, we found a significant (P< 0.01) reduction in the total volume of LWD material in the stream sites surveyed (51.7 m3×100 m 1 in 1982 to 38.2 m3×100 m 1 in 1993). While the mean volume of second-growth derived LWD increased from 3.6 to 10.9 m3×100 m 1 (P < 0.01), the increase was insufficient to offset the loss of old-growth derived LWD. The mean volume of old-growth derived LWD for all sites decreased from 48.1 to 27.4 m3×100 m 1 between sample years (P < 0.01). The mean diameter of second-growth derived LWD was significantly larger in 1993 than in 1982, although still smaller than old-growth derived pieces. We

measured a significant increase in the percentage of LWD pieces rated as highly decayed from 1982 to 1993. The results indicate that the loss of old-growth derived LWD following the removal of old-growth riparian forests is initially very rapid, followed by a slower rate of depletion associated with watershed destabilization. Inputs of LWD from second-growth riparian forests up to 73 years old were characterized by small diameter, high mobility, and high decay rates.

McMahon, T. E., and L. B. Blair Holtby. 1992. Behaviour, Habitat Use, and Movements of Coho Salmon (Oncorhynchus kisutch) smolts during Seaward Migration. Canadian Journal of Fisheries and Aquatic Sciences 49:1478-1 485.
'KEY WORDS'
Main Stream
Esturaries
British Columbia
Movement
Large wood
'ABSTRACT'
Coho salmon (Oweorhynchus kisutch) smolts formed aggregations in pools with large woody debris during their migration downstream and into the Carnation Creek estuary, British Columbia. Smolts utilized the estuary throughout the smolt run, with periods of high outmigration coinciding with spring tides which brought warmer, more saline water into the estuary. Smolt abundance in the stream and estuary was positively related to debris volume, and 82% of the 1260 srnolts observed during underwater counts occurred within 1 m of debris. Debris volume and srnolt density were significantly lower in clearcut than in buffered stream sections. Our observations support the need to retain and manage large woody debris for smolt habitat in streams and estuaries.

Meacham, C. P., and J. H. Clark. 1994. Pacific Salmon Management--The view from Alaska. Alaska Fishery Bulletin 1:76-80.
'KEY WORDS'
Watershed Scale
Southeast Alaska
Catch
salmon harvest
sustainability
'ABSTRACT'
Presents case for ADF&G management policies and rebuilding and ustaining salmon stocks

Meehan, W. R. 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society, Bethesda.
'KEY WORDS'
Watershed Scale
Ecosystem management
Forest management
Habitat management
Salmonid habitat
'ABSTRACT'
A compendeum of papers on land management and salmon throughout the Pacific Northwest, including Alaska and Idaho.

Miller, B. A., and S. Sadro. 2003. Residence Time and Seasonal Movements of Juvenile Coho Salmon in the Ecotone and Lower Estuary of Winchester Creek, South Slough, Oregon. Transactions of the American Fisheries Society 132(3):546-559.
'KEY WORDS'
Estuaries

Off channel
Oregon
Coho salmon
movement
'ABSTRACT'
The juvenile life history of coho salmon Oncorhynchus kisutch in the stream–estuary ecotone of Winchester Creek, South Slough, Oregon, was investigated in 1999–2001. Seines and a rotary screw trap were used to capture fish for dye-marking, and residence time within the ecotone was determined for recaptured marked fish. In the lower estuary, ultrasonic transmitters were used to document residence time and patterns of movement for smolts migrating to the ocean. Nearly half of each brood year moved to the estuary as subyearlings. A portion of age-0 juveniles that moved downstream during spring lived in the ecotone through summer for up to 8 months, then most moved back upstream to overwinter. Fish that moved to the ecotone during fall and winter had mean minimum residence times of 48 d in 1999 and 64 d in 2000. Some of the fish that moved to the ecotone during fall and winter moved into an off-channel beaver pond and resided there for a mean of 49 d. Spring age-1 smolts had a mean minimum residence time in the ecotone of 18 d for both years and used recently restored salt marshes and other off-channel habitats. Smolts implanted with ultrasonic transmitters lived in the lower estuary for an average of 5.8 d, during which their direction of movement corresponded to the direction of tidal flow.

Milner, A. M., and R. G. Bailey. 1989. Salmonid colonization of new streams in Glacier Bay National Park, Alaska. Aquaculture Research 20:179-192.
'KEY WORDS'
Watershed Scale
Southeast Alaska
Coho salmon
Dolly varden
Glacial rivers
Riparian vegetation
Sockeye salmon
Species diversity
Woody debris
'ABSTRACT'
Following the rapid recession of a neoglacial ice sheet within the last 250 years, colonization of recently deglaciated streams by salmonid fishes was investigated in Glacier Bay National Park, south-eastern Alaska. The primary factors governing the establishment, species diversity composition and abundance of salmonids in Glacier Bay streams were water temperature, sediment loading and stream discharge. No salmonids were found in the turbid meltwater streams emerging from retreating ice. Coho, Oncorhynchus kisutch (Walbaum), and sockeye, Oncorhynchus nerka (Walbaum). salmon and Dolly Vardcn, Salvelinus malma (Walbaum), charr were the first salmonids to colonize the youngest clearwater stream. Juvenile Dolly Varden were more abundant than juvenile coho salmon in the most recently formed clearwater stream because of the characteristic absence of pool habital. Densities of juvenile coho salmon were six times greater in a stream with a series of lakes compared with a stream of similar age without lakes. Future advancement of salmonid stocks will probably depend upon the rate and extent of the development of riparian vegetation and inputs of large woody debris from the developing forest to provide further instream cover, habitat variation and channel stabilization.

Minshall, G. W., and coauthors. 1985. Developments in stream ecosystem theory. Canadian Journal of Fisheries and Aquatic Sciences 42:1045-1055.
'KEY WORDS'
Watershed scale
Watershed theory

Aquatic Ecology
'ABSTRACT'
Four significant areas of thought, (1) the holistic approach, (2) the linkage between streams and their terrestrial setting, (3) material cycling in open systems, and (4) biotic interactions and integration of community ecology principles, have provided a basis for the further development of stream ecosystem theory. The River Continuum Concept (RCC) represents a synthesis of these ideas. Suggestions are made for clarifying, expanding, and refining the RCC to encompass broader spatial and temporal scales. Factors important in this regard include climate and geology, tributaries, location-specific lithology and geomorphology, and long-term changes imposed by man. It appears that most riverine ecosystems can be accommodated within this expanded conceptual framework and that the RCC continues to represent a useful paradigm for understanding and comparing the ecology of streams and rivers.

Moir, H. J., and G. B. Pasternack. 2008. Relationships between mesoscale morphological units, stream hydraulics and Chinook salmon (Oncorhynchus tshawytscha) spawning habitat on the Lower Yuba River, California. Geomorphology 100(3-4):527-548.
'KEY WORDS'
Main Stream
Chinook salmon
California
Spawning
Morphological units
Hydraulics
Two-dimensional modeling
Fluvial geomorphology
'ABSTRACT'
An expert-based approach was used to identify 10 morphological unit types within a reach of the gravel bed, regulated Yuba River, California, that is heavily utilized by spawning Chinook salmon (Oncorhynchus tshawytscha). Analysis of these units was carried out using two-dimensional hydrodynamic modeling, field-based geomorphic assessment, and detailed spawning surveying. Differently classified morphological units tended to exhibit discrete hydraulic signatures. In most cases, the Froude number adequately differentiated morphological units, but joint depth-velocity distributions proved the most effective hydraulic classification approach. Spawning activity was statistically differentiated at the mesoscale of the morphological unit. Salmon preferred lateral bar, riffle, and riffle entrance units. These units had moderately high velocity (unit median > 0.45 m s- 1) and low depth (unit median < 0.6 m), but each exhibited a unique joint depth-velocity distribution. A large proportion of redds (79%) were associated with conditions of convective flow acceleration at riffle and riffle entrance locations. In addition to reflecting microhabitat requirements of fish, it was proposed that the hydraulic segregation of preferred from avoided or tolerated morphological units was linked to the mutual association of specific hydraulic conditions with suitable caliber sediment that promotes the provision and maintenance of spawning habitat.

Montgomery, D. 1999. Process domains and the River Continuum. Journal of the American Water Resources Association 35:397-410.
'KEY WORDS'
watershed scale
Topography
Geology
Geomorphology
Catchment Areas
Stream classification
TectonicsWater resources
Watersheds

Mountain streams
'ABSTRACT'
The concept of process domains is proposed as an alternative to the River Continuum Concept for the influence of geomorphic processes on aquatic ecosystems. Broadly defined, the Process Domain Concept is a multi-scale hypothesis that spatial variability in geomorphic processes governs temporal patterns of disturbances that influence ecosystem structure and dynamics. At a coarse scale, regional climate, geology, vegetation, and topography control the suite of geomorphic processes that are distributed over a landscape. Within the broad context so defined, stream channel classification can guide identification of functionally similar portions of a channel network, but the response of otherwise similar reaches can depend upon their geologic and geomorphic context. Within geomorphic province defined by differences in topography, climate history, and tectonic setting, areas with generally similar geology and topography define lithotopo units, which are useful for stratifying different suites of dominant geomorphic processes. Process domains are spatially identifiable areas characterized by distinct suites of geomorphic processes, and the Process Domain Concept implies that channel networks can be divided into discrete regions in which community structure and dynamics respond to distinctly different disturbance regimes. The concepts of process domains and lithotopo units provide both a framework for the application of patch dynamics concepts to complex landscapes and context for addressing the effects of watershed processes on the ecology of mountain drainage basins.

Montgomery, D., G. Grant, and K. Sullivan. 1995a. Watershed analysis as a framework for implementing ecosystem management. Water Resources Bulletin 31:369-386.
'KEY WORDS'
Ecosystem management
Watershed Scale
Environmental protection
Land management
Planning
Watershed management
'ABSTRACT'
Implementing ecosystem approaches to land use decision making and land management requires new methods for linking science and planning. Greater integration is crucial because under ecosystem management sustainable levels of resource use are determined by coupling management objectives to landscape capabilities and capacities. Recent proposals for implementing ecosystem management employ analyses organized at a hierarchy of scales for analysis and planning. Within this hierarchy, watershed analysis provides a framework for delineating the spatial distribution and linkages between physical processes and biological communities in and appropriate physical context: the watershed. Several such methods are currently in use in the western United States, and although there is no universal procedure for either implementing watershed analysis or linking the results to planning, there are a number of essential elements. A series of questions on landscape-level ecological processes, history, condition, and response potential guide watershed analysis. Individual analysis modules are structured around answering these questions through a spatially-distributed, process-based approach. The planning framework linked to watershed analysis uses this information to either manage environmental impacts or to identify desired conditions and develop land management prescriptions to achieve these conditions. Watershed analysis offers a number of distinct advantages over contemporary environmental analyses for designing land management scenarios compatible with balancing environmental and economic objectives.

Montgomery, D. R., J. M. Buffington, R. D. Smith, K. M. Schmidt, and G. Pess. 1995b. Pool spacing in forest channels. Water Resources Research 31:1097-1105.
'KEY WORDS'
Watershed scale

Southeast Alaska
Geomorphology
Large wood
Stream habitat
Woody debris
'ABSTRACT'

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

Montgomery , D. R., T. M. Massong , and S. C. S. Hawley 2003. Influence of debris flows and log jams on the location of pools and alluvial channel reaches, Oregon Coast Range. GSA Bulletin (Geological Society of America) 115:78-88.
'KEY WORDS'
Watershed scale
Oregon
Alluvial channels
Debris flows
Log jams
Oregon coast range
Pools
'ABSTRACT'

We investigated the influence of debris-flow deposits and log jams on the location of pools and alluvial channel reaches in three Oregon Coast Range watersheds. Our surveys reveal differences in the type and location of log jams and the associated influences on pool formation and the extent of alluvial channel beds between channels flowing through old-growth and industrial forests. In channels we surveyed, debris-flow deposits formed 3% of log jams in reaches flowing through old-growth forest and 12% and 25%, respectively, in the two industrial forest channels. Pools formed by the direct effects of debris flows accounted for 4%-7% of all pools in reaches surveyed in both old-growth and industrial forest channels. Logs and log jams accounted for about half of the pools formed in old-growth reaches, but just 12%-13% of pools in reaches flowing through industrial forest. The distribution of bedrock and alluvial reaches was influenced by drainage area, channel-reach slope, sediment trapping by log jams, and boulders deposited by debris flows. Although debris-flow deposits can locally create or influence aquatic habitat, our field observations suggest general contrasts between old-growth and industrial forest in both log jam locations and the relative importance of debris-flow processes in the formation of pools and alluvial reaches.

Moore, J. N., S. N. Luoma, and D. Peters. 1991. Downstream effects of mine effluent on an intermontaine Riparian system. Canadian Journal of Fisheries and Aquatic Sciences 48:222-232.
'KEY WORDS'

Watershed scale
Minning effects
Contamination
Metals
'ABSTRACT'
Metal concentrations were determined in benthic biota, fish livers, water, and fine-grained sediment through 215 km of an intermontane river system (Blackfoot River, Montana, USA) affected by headwater inputs of acid-mine effluent. Solute and particulate contaminants decreased rapidly downstream from headwater sources, but some extended through an extensive marsh system. Particulate contaminants penetrated through the marsh system, effectively resulting in food web contamination downstream of the marshes. Metals differed in their bioavailability within and below the marsh system. Cadmium was most consistently accumulated in the food web, and the general order of downstream mobilization of bioavailable metals appears to be Cd, Zn > Cu > As, Ni. Depauperate benthic communities and reduced fish populations occurred coincident with the sediment contamination.

Morley, S. A., P. S. Garcia, T. R. Bennett, and P. Roni. 2005. Juvenile salmonid(Oncorhynchus spp.) use of constructed and natural side channels in Pacific Northwest rivers. Canadian Journal of Fisheries and Aquatic Sciences 62:2811-2821.
'KEY WORDS'
Off channel
Coho salmon
Pacific Northwest
Sloughs
Enhancement
Artificial channels
'ABSTRACT'
Off-channel habitats, critical components in the life histories of Pacific salmonids (Oncorhynchus spp.), have become increasingly rare in human-modified floodplains. The construction of groundwater-fed side channels is one approach that has been used in the Pacific Northwest to recreate off-channel habitats. We evaluated the effectiveness of this technique by comparing 11 constructed side channels with paired reference sites (naturally occurring channels fed by mixed groundwater and surface water) in western Washington. While total salmonid densities were not significantly different between channel types, coho salmon (Oncorhynchus kisutch) densities were higher in constructed channels and trout densities were higher in reference channels during the winter. Constructed channels were deeper than reference channels and warmer in the winter and cooler in the summer but had lower physical habitat diversity, wood density, and canopy coverage. We did not detect significant differences in water chemistry or invertebrate parameters between channel types. Summer coho density was inversely correlated with minimum daily temperature and with total nitrogen and total phosphorous concentrations. Relative to other stream habitats, both constructed and reference channels supported high densities of juvenile coho salmon during the summer and winter.

Mote, P. W., and coauthors. 2003. Preparing for Climatic Change: The Water, Salmon, and Forests of the Pacific Northwest. Climatic Change 61(1):45-88.
'KEY WORDS'
Climate change
climate models
Snowpack
Pacific Decadel Oscillation
PDO
Management
'ABSTRACT'

The impacts of year-to-year and decade-to-decade climatic variations on some of the Pacific Northwest's key natural resources can be quantified to estimate sensitivity to regional climatic changes expected as part of anthropogenic global climatic change. Warmer, drier years, often associated with El Niño events and/or the warm phase of the Pacific Decadal Oscillation, tend to be associated with below-average snowpack, streamflow, and flood risk, below-average salmon survival, below-average forest growth, and above-average risk of forest fire. During the 20th century, the region experienced a warming of 0.8 °C. Using output from eight climate models, we project a further warming of 0.5–2.5 °C (central estimate 1.5 °C) by the 2020s, 1.5–3.2°C (2.3 °C) by the 2040s, and an increase in precipitation except in summer. The foremost impact of a warming climate will be the reduction of regional snowpack, which presently supplies water for ecosystems and human uses during the dry summers. Our understanding of past climate also illustrates the responses of human management systems to climatic stresses, and suggests that a warming of the rate projected would pose significant challenges to the management of natural resources. Resource managers and planners currently have few plans for adapting to or mitigating the ecological and economic effects of climatic change.

Muhar, S., and M. Jungwirth. 1998. Habitat integrity of running waters — assessment criteria and their biological relevance. Hydrobiologia 386(1):195-202.

'KEY WORDS'
Watershed scale
Habitat assessment
Ecological integrity
Habitat integrity
Habitat quality
'ABSTRACT'

Based upon well-known relations between abiotic and biotic components of river systems, habitat assessment can serve as an indirect procedure to evaluate the ecological integrity by demonstrating the degree of man-induced alterations of the physical environment. Detailed habitat analysis has been an integral part of aut- or synecological investigations in aquatic environments. In many countries, however, the assessment of the physical environment on a larger spatial scale has become a regular part of watershed management programmes. A primary methodological aspect of large-scale habitat assessment is the selection and definition of evaluation criteria specifically designed to identify key functions and processes of intact river systems. Therefore, special emphasis has to be given to integrative parameters, that reflect the spatial and temporal dynamics of running waters as well as the interactions between rivers and their wetlands. Four groups of evaluation criteria are discussed within the framework of their relevance for aquatic biocoenoses and their validity to identify severe human impacts on running water ecosystems: (1) discharge regime; (2) morphological character; (3) lateral connectivity and (4) longitudinal corridor.

Murphy, M., J. Heifetz, S. Johnson, K. Koski, and J. Thedinga. 1986. Effects of clear-cut logging with and without buffer strips on juvenile salmonids in Alaskan streams. Canadian Journal of Fisheries and Aquatic Sciences 43:1521-1533.

'KEY WORDS'
Tributaries
Southeast Alaska
Effects of logging
Coho salmon
Karst
Habitat
'ABSTRACT'

To assess short-term effects of logging on juvenile Oncorhynchus kisutch, Salvelinus malma, Salmo gairdneri , and Salmo clarki in southeastern Alaska, the authors compared fish density and habitat in summer and winter in 18 streams in old-growth forest and in clearcuts with and

without buffer strips. Buffered reaches did not consistently differ from old-growth reaches; clear-cut reaches had more periphyton, lower channel stability, and less canopy, pool volume, large woody debris, and undercut banks than old-growth reaches. In summer, if areas had underlying limestone, clear-cut reaches and buffered reaches with open canopy had more periphyton, benthos, and coho salmon fry (age 0) than old-growth reaches. In winter, abundance of parr (age > 0) depended on amount of debris. If debris was left in clear-cut reaches, or added in buffered reaches, coho salmon parr were abundant (10-22/100 m super(2)). If debris had been removed from clear-cut reaches, parr were scarce

Murphy, M. L., J. Heifetz, J. F. Thedinga, S. W. Johnson, and K. V. Koski. 1989. Habitat utilization by juvenile Pacific salmon (Oncorhynchus) in the glacial Taku River, southeast Alaska. Canadian Journal of Fisheries and Aquatic Sciences 46:1677-1685.

'KEY WORDS'
Main Stream
Tributaries
Off channel
Southeast Alaska
Beaver ponds
Chinook
Coho salmon
Sockeye salmon
Taku river
'ABSTRACT'

Habitat utilization by juvenile Pacific salmon (Oncorhynchus) was determined in summer 1986 by sampling 54 sites of nine habitat types: main channels, backwaters, braids, channel edges, and sloughs in the river; and beaver ponds, terrace tributaries, tributary mouths, and upland sloughs on the valley floor. Physical characteristics were measured at all sites, and all habitats except main channels (current too swift for rearing salmon) were seined to determine fish density. Each species of Oncorhynchus was absent from about one-quarter of the seining sites of each habitat type. The lower Taku River provides important summer habitat for juvenile salmon, but many suitable areas were unoccupied possibly because of their distance from spawning areas and poor access for colonizing fish.

Naiman, R. J., R. E. Bilby, and P. A. Bisson. 2000. Riparian Ecology and Management in the Pacific Coastal Rain Forest. BioScience 50(11):996-1011.

'KEY WORDS'
watershed scale
Riparian habitat
Pacific northwest
'ABSTRACT'

Summarize the recent advances of the last decade on the ecology Pacific coastal rainforests and application to management of streams anad watrersheds

Naiman, R. J., P. A. Bisson, R. C. Lee, and M. C. Turner. 1997. Approaches to Management at the Watershed Scale K. Kohn, and J. F. Franklin, editors. Creating a forestry for the 21st century: The science of ecosystem management. Island Press, Washington,DC.

'KEY WORDS'
Watershed scale
Management
'ABSTRACT'

Integrates several diverse issues that affect management decisions, social needs, management policies, and natural sciences. Lists four watershed scale issues affecting management, variability in time and space, invasive species, connectivity, and human influence.

Naiman, R. J., H. DeCamps, J. Pastor, and C. A. Johnston. 1988a. The potential importance of boundaries to fluvial ecosystems. Journal of the North American Benthological Society 7(4):289-396.

'KEY WORDS'
Watershed Scale
Ecotone
Riparian forests
Riparian habitat
Rivers
Stream ecology
'ABSTRACT'

Boundaries separating adjacent resource patches are dynamic components of the aquatic landscape. This article addresses some fundamental questions about boundary structure and function in lotic ecosystems. We give examples of longitudinal and lateral boundaries associated with stream systems, demonstrate the application of chaos theory to understanding the inherent variability of boundary properties, and compare characteristics of boundaries in an arctic-tropical transect. We conclude that studies of resource patches, their boundaries, and the nature of exchange with adjacent patches will improve our perspective of drainage basin dynamics over a range of temporal and spatial scales.

Naiman, R. J., C. A. Johnston, and J. C. Kelley. 1988b. Alteration of North American streams by beaver. BioScience 38:753-762.

'KEY WORDS'
Off channel
Beaver Ponds
Alaska
North America
'ABSTRACT'

The objectives of this article are to briefly summarize the history of beaver in North America, then describe some of the ecosystem-level responses of streams to beaver-induced alterations and, finally, to describe beaver-induced changes in the landscape that take place over broad spatial and temporal scales. This research has been conducted in Quebec, Minnesota, Montana, and Alaska, and it should be representative of northern regions.

Nass, B., K. English, and H. Frith. 1996. Assessment of summer rearing habitat and juvenile coho abundance in the Kwinageese River, B.C., 1992. Canadian Manuscript Report of Fisheries and Aquatic Sciences, Department of Fisheries and Oceans, 2375, Prince Rupert, BC Canada.

'KEY WORDS'
Main Stream
British Columbia
Limiting factors
Rearing
Ponds
Pools
Tributaries
Coho Salmon
Oncorhynchus kisutch
'ABSTRACT'

Habitat use by juvenile coho salmon (Oncorhynchus kisutch) was examined in the Kwinageese River, British Columbia, as part of the 1992-1993 Nisga'a Interim Measures Program (IMP). Foot and snorkel surveys were carried out during Aug and Sep to quantify wetted area and juvenile coho abundance by habitat and cover type. To determine if coho production was limited by available habitats, comparisons of observed total coho abundance and densities (by habitat type) were made with those presented in the literature. Linear densities of coho fry were the highest in small tributaries and pools with cover, followed by runs with cover. Runs and riffles with no cover had the lowest densities. Densities between habitats with cover

and habitats without cover were significantly different in some comparisons. Side channels accounted for the greatest total linear habitat and the highest total abundance of juvenile coho. Pools contributed only 11.7% to total linear habitat but accounted for 16.5% of total abundance. Total estimated coho fry abundance was only 27% of the potential abundance estimated using a coho production model. Comparison of maximum density and biomass estimates for 29 B.C. streams revealed that the Kwinageese maximum for age 2 coho maximum was substantially higher than the maximum for all other streams surveyed. The average value for the 5 sites surveyed on the Kwinangeese River was only 20% of these maximum levels. Factors such as escapement or winter rearing habitat are more likely to be limiting coho production in the Kwinageese River than summer rearing habitat.

Newbold, J. D., J. W. Elwood, R. V. O'Neill, and W. Van Winkle. 1981. Measuring nutrient spiraling in streams. Canadian Journal of Fisheries and Aquatic Sciences 38:860-863.

'KEY WORDS'
Tributaries
Watershed scale
Nutrient cycling
Phosphorus
Nutrient spiralling
Stream ecology
'ABSTRACT'

Nutrient cycling in streams involves some downstream transport before the cycle is completed. Thus, the path traveled by a nutrient atom in passing through the cycle can be visualized as a spiral. As an index of the spiralling process, we introduce spiralling length, defined as the average distance associated with one complete cycle of a nutrient atom. This index provides a measure of the utilization of nutrients relative to the available supply from upstream. Using 32P as a tracer, we estimated a spiralling length of 193 m for phosphorus in a small woodland stream.

Nickelson, T., and P. Lawson. 1998. Population viability of coho salmon, Oncorhynchus kisutch, in Oregon coastal basins: application of a habitat-based life cycle model. Canadian Journal of Fisheries and Aquatic Sciences 55:2383-2392.

'KEY WORDS'
Watershed scale
Oregon
Coho salmon
Habitat
Model
'ABSTRACT'

To assess extinction risk for Oregon coastal coho salmon, Oncorhynchus kisutch, we developed a life cycle model based on habitat quality of individual stream reaches estimated from survey data. Reach-specific smolt output was a function of spawner abundance, demographic stochasticity, genetic effects, and density- and habitat-driven survival rates. After natural mortality and ocean harvest, spawners returned to their natal reaches. Populations in reaches with poor habitat became extinct during periods of low marine survival. With favorable marine survival, high productivity reaches served as sources for recolonization of lower quality reaches through straying of spawners. Consequently, both population size and distribution expanded and contracted through time. Within a reach, populations lost resilience at low numbers when demographic risk factors became more important than density-dependent compensation. Population viability was modeled for three coastal basins having good, moderate, and poor habitat. With constant habitat conditions, extinction risk in 99 years was negligible in basins with good and moderate habitat and 5-10% in the basin with poor habitat. Reductions in habitat quality up to 60% in 99 years resulted in reduced coho salmon populations in all basins and significantly increased extinction risk in the basin with poor habitat.

Nickelson, T. E., J. D. Rodgers, S. L. Johnson, and M. F. Solazzi. 1992. Seasonal changes in habitat use by juvenile coho salmon (*Oncorhynchus kisutch*) in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences 49:783-789.

'KEY WORDS'
Main channel
Tributaries
Off channel
Seasonal use
Coho salmon
Oregon
Beaver pond
'ABSTRACT'

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

Northcote, T. G., and G. F. Hartman. 2004. Fishes and Forestry: Worldwide watershed interaction. Blackwell Publishing Company, Oxford, UK.

'KEY WORDS'
Watershed scale
Effects of logging
Forest conservation
Watershed management
Riparian management
Rivers
Lakes
'ABSTRACT'

The books presents a series of papers as chapters that cover worldwide issues on logging, fores practices and interaction with fish. Topics include forest ecology stream ecology, estuarine ecology as it relates to fish and the forest. Aspects of fish biology and life history, migration, reproduction, and feeding that are related to forest practices are also covered in separate papers. A review of various forest harvest activities are discussed. Effects of forest practices on rivers and stream, lakes, and estuarine systems are presented. Papers on fish-forestry interactions from a range of major geographic areas from North America, South American, Europe, and Asia are included in several chapters.

Northcote, T. G., and M. C. Healey. 2007. Fundamental Aspects of Estuarine Ecology Relevant to Fish-Forestry Interactions. Blackwell Science Ltd.

'KEY WORDS'
Estuaries
fish-forestry interactions
physical and chemical characteristics
biological characteristics
'ABSTRACT'

Summary 10.1002/9780470995242.ch5.abs This chapter contains sections titled: * Introduction * Physical and chemical characteristics * Biological characteristics * Concluding remarks

Paustian, S. J. 1992. A channel type users guide for the Tongass National Forest, southeast Alaska. The heirarchial system is based on stream channel gradient, incision, size, and other geomorphic

features within stream reaches. . Technical Paper 26. U.S.D.A. Forest Service, Region 10 (Alaska Region), Juneau, AK.

'KEY WORDS'
Watershed Scale
Stream classification
Watershed management
Habitat management
'ABSTRACT'
Presents a process driven stream classification system used throughout southeast Alaska.

Pess, G. R., and coauthors. 2002. Landscape characteristics, land use, and coho salmon (*Oncorhynchus kisutch*) abundance, Snohomish River, Wash., U.S. A. Canadian Journal of Fisheries and Aquatic Sciences 59:613-623.

'KEY WORDS'
Watershed scale
Land management
Coho salmon
Stream gradient
Habitat
Habitat models
Geology
Urbanization
Forest management
Agricultural effects
'ABSTRACT'
We used temporally consistent patterns in the spatial distribution of returning adult coho salmon (Oncorhynchus kisutch) to explore relationships between salmon abundance, landscape characteristics, and land use patterns in the Snohomish River watershed, Wash. The proportion of total adult coho salmon abundance supported by a specific stream reach was consistent among years, even though interannual adult coho salmon abundance varied substantially. Wetland occurrence, local geology, stream gradient, and land use were significantly correlated with adult coho salmon abundance. Median adult coho salmon densities in forest-dominated areas were 1.5–3.5 times the densities in rural, urban, and agricultural areas. Relationships between these habitat characteristics and adult coho salmon abundance were consistent over time. Spatially explicit statistical models that included these habitat variables explained almost half of the variation in the annual distribution of adult coho salmon. Our analysis indicates that such models can be used to identify and prioritize freshwater areas for protection and restoration.

Peterson, N. P. 1982a. Immigration of juvenile coho salmon (Oncorhynchus kisutch) into riverine ponds. Canadian Journal of Fisheries and Aquatic Sciences 39:1308-1310.

'KEY WORDS'
Off channel
Coho Salmon
Oregon
Migration
Ponds
Winter habitat
'ABSTRACT'
Riverine ponds on the Olympic Peninsula provide important winter refuge for juvenile coho salmon (Oncorhynchus kisutch). A total of 9530 juvenile coho migrated into two riverine ponds of the Clearwater River in 1977, principally during fall freshets. Extensive movement by marked fish (as much as 32.6 km downstream) before entering the ponds suggests that a system-wide approach to habitat management is important in maintaining freshwater production potential of large river systems.

Peterson, N. P. 1982b. Population characteristics of juvenile coho salmon (*Oncorhynchus kisutch*) overwintering in riverine ponds. Canadian Journal of Fisheries and Aquatic Sciences 39:1303-1307.

'KEY WORDS'
Off channel
Oregon
Coho salmon
Ponds
Overwinter survival
'ABSTRACT'

Survival and growth from immigration to smolt outmigration differed substantially between pond populations of juvenile coho salmon (Oncorhynchus kisutch). In Pond 1 (the deeper, less-productive pond) overall survival was 78% but average fish weight increased only 49%, whereas in Pond 2 (the shallow, more-productive pond) survival was only 28% but average fish weight increased 94%. Diet of resident coho in the early spring was characterized by chironomid larvae and newly emerged adults in Ponds 1 and 2, respectively. Manipulation of pond morphometry may have potential for enhancing coho stocks.

Poff, N. L., and coauthors. 1997. The Natural Flow Regime. BioScience 47(11):769-784.

'KEY WORDS'
Watershed Scale
River ecology
Floods
Hydrology
Discharge
Biodiversity
'ABSTRACT'

Present a case for preserving natural flow regimes in conservation.

Pringle, C. M. 2001. Hydrologic connectivity and the management of biological reserves: a global perspective. Ecological Applications 11(4):981-998.

'KEY WORDS'
Watershed scale
biological reserves
connectivity
'ABSTRACT'

Increasingly, biological reserves throughout the world are threatened by cumulative alterations in hydrologic connectivity within the greater landscape. Hydrologic connectivity is used here in an ecological sense to refer to water-mediated transfer of matter, energy, and/or organisms within or between elements of the hydrologic cycle. Obvious human influences that alter this property include dams, associated flow regulation, groundwater extraction, and water diversion, all of which can result in a cascade of events in both aquatic and terrestrial ecosystems. Even disturbances well outside the boundaries of reserves can have profound effects on the biological integrity of these "protected" areas. Factors such as nutrient and toxic pollution and the spread of nonnative species are perpetuated by hydrologic connectivity, and their effects can be exacerbated by changes in this property. Hydrological alterations are now affecting reserves through increasingly broad feedback loops, ranging from overdrawn aquifers to atmospheric deposition and global climate change. Such alterations are often beyond the direct control of managers because they lie outside reserve boundaries, and data on hydrologic connection between reserves and surrounding landscapes are scant. The subject of water has also been typically excluded from the literature pertaining to both theoretical and practical aspects of reserve size, isolation, and design. This results, in part, from early management strategies developed when the landscape matrix outside of reserves

was not excessively fragmented, and when awareness of hydrologic connectivity was in its infancy.

The location of a given reserve within a watershed, relative to regional aquifers and wind and precipitation patterns, can play a key role in its response to human disturbance transmitted through the hydrologic cycle. To illustrate this point, I discuss reserves of varying sizes from diverse regions throughout the world. Reserves located in middle and lower watersheds often suffer direct hydrologic alterations that cause severe habitat modification and exacerbate the effects of pollution. In contrast, reserves in upper watersheds may have intact physical habitat and contain important source populations of some native biota, yet hydrologic disturbances in lower watersheds may cause extirpation of migratory species, cascading trophic effects, and genetic isolation. Worldwide, <7% of land area is either strictly or partially protected, and many reserves are in danger of becoming population "sinks" for wildlife if we do not develop a more predictive understanding of how they are affected by hydrologic alterations that originate outside of their boundaries.

Reeves, G. H., K. M. Burnett, and E. V. McGarry. 2003. Sources of large wood in the main stem of a fourth-order watershed in coastal Oregon. Canadian Journal of Forest Research 33:1363-1370.

'KEY WORDS'
Main Stream
Oregon
Large wood
Landslides
Debris flows
Salmon habitat
'ABSTRACT'

We compared the contribution of large wood from different sources and wood distributions among channel zones of influence in a relatively pristine fourth- order watershed in the central Coast Range of Oregon. Wood in the main stem of Cummins Creek was identified as coming from either (i) streamside sources immediately adjacent to the channel or (ii) upslope sources delivered by landslides or debris flows more than 90 m from the channel. About 65% of the number of pieces and 46% of the estimated volume of wood were from upslope sources. Streamside sources contributed about 35% of the number of pieces and 54% of the estimated volume of wood. The estimated mean volume of upslope- derived pieces was about one-third that of streamside-derived pieces. Upslope- derived pieces were located primarily in the middle stream reaches and in the zones of influence that had the most contact with the low-flow channel. Streamside-derived pieces were more evenly distributed among the examined reaches and were predominately in the influence zones that had the least contact with the low-flow channel. Our findings suggest that previous studies that examined only streamside sources of wood have limited applications when designing and evaluating riparian management approaches in landslide-prone areas. The failure to recognize the potential sources of wood from upslope areas is a possible reason for the decline of large wood in streams in the Pacific Northwest.

Reeves, G. H., F. H. Everest, and J. R. Sedell. 1993. Diversity of juvenile anadromous salmonid communities in basins in coastal Oregon, U.S.A. with different levels of timber harvest activity. Transactions of the American Fisheries Society 122(3):309-317.

'KEY WORDS'
Main Stream
Oregon
Juvenile salmonids
Effects of logging
'ABSTRACT'

We examined the relationships of timber harvest, stream habitat complexity, and diversity of juvenile anadromous salmonid assemblages in 14 small- to intermediate-sized basins in coastal Oregon between 1985 and 1989. Diversity (the inverse of a species dominance index) of assemblages in streams in basins with low harvest levels (≤25% of the basin area harvested) was greater than in streams in basins with high harvest levels (>25% of the basin area harvested) (P = 0.02). Assemblages in basins with high levels of harvest were more dominated by a single species than were assemblages in basins with low harvest, Percent of basin harvested was more strongly associated with assemblage diversity (P = 0.07) than were basin area (P = 0.90) or gradient (P = 0.22) when the influence of the other two factors was controlled. Habitat features were compared between three pairs of streams. Streams in basins with low timber harvest had more complex habitat, as manifested by more large pieces of wood per 100 m (P < 0.01). We conclude that a community and basin-level perspective is necessary to fully assess the effects of timber harvest and other human activities on stream fish.

Rice, S. P., P. R. Kiffney, C. Greene, and G. R. Pess. 2008. The Ecological Importance of Tributaries and Confluences. John Wiley & Sons, Ltd.
'KEY WORDS'
Tributaries
Pacific Northwest
Confluences
River ecology
Spawning patterns
Beaver pond utrient levels enhancement
'ABSTRACT'
This chapter contains sections titled: * Introduction * Tributaries, confluences and river ecology * Tributaries, ecosystem functions and river management * Constraints on understanding and progress * A case study * Conclusion * Acknowledgments * References

Robison, E. G., and R. L. Beschta. 1990. Characteristics of coarse woody debris for several coastal streams of southeast Alaska, USA. Canadian Journal of Fisheries and Aquatic Sciences 47:1684-1693.
'KEY WORDS'
Watershed scale
Southeast Alaska
Woody debris
'ABSTRACT'
Coarse woody debris (> 0.2 m in diameter and 1.5 m long) was measured along five undisturbed low-gradient stream reaches; volume, decay class, and horizontal orientation in relation to channel flow of first-, second-, third-, and fourth-order coastal streams were determined. Debris was also classified into four influence zones based on stream hydraulics and fish habitat. Average debris length, diameter, and volume per piece increased with stream size. Eighty percent of debris volume of the first-order and the smaller second-order streams was suspended above or lying outside the bankfull channel, while less than 40% was similarly positioned in the fourth-order stream. Approximately one-third of all debris was oriented perpendicular to stream flow, regardless of stream size. First-, second-, and third-order streams had a higher proportion of recent debris in the channel than the fourth-order stream (19 vs. 8%), most new debris being attributable to a major 1984 windstorm. Tree blowdown had a major influence on debris distribution along the smaller stream reaches. Debris jams and accumulations in the largest stream were formed from floated debris. These characterizations are useful for evaluating the distribution and amount of woody debris associated with land-management activities.

Rosenfeld, J., M. Porter, and E. Parkinson. 2000. Habitat factors affecting the abundance and distribution of juvenile cutthroat trout (Oncorhynchus clarki) and coho salmon (Oncorhynchus kisutch). Canadian Journal of Fisheries and Aquatic Sciences 57:766-774.

'KEY WORDS'
Tributaries
British Columbia
Habitat
Pools
Abundance
Cutthroat trout
Oncorhynchus clarki
Coho salmon
'ABSTRACT'

The distribution, abundance, and habitat associations of juvenile anadromous coastal cutthroat trout (Oncorhynchus clarki) and coho salmon (Oncorhynchus kisutch) were evaluated using survey data from 119 sites in coastal British Columbia. Both cutthroat and coho occurred at their highest densities in very small streams (<5 m channel width), and bankfull channel width was the single best predictor of cutthroat presence (p = 0.0001) and density (R super(2) = 0.55). Within a channel, densities of coho and larger (yearling and older) cutthroat parr were highest in pools, while densities of young-of-the-year cutthroat were significantly lower in pools and highest in shallower habitats. Abundance of larger cutthroat parr and pool habitat were positively correlated with large woody debris (LWD) within a subset of intermediate-gradient gravel-cobble streams, where pools appear to be limiting to larger cutthroat parr abundance. More than 50% of pools were formed by scour associated with LWD in streams ranging from 1.2 to 11 m channel width, and pools formed by LWD scour were on average 10% deeper than pools formed by other mechanisms. Disproportionate use of small streams by cutthroat indicates that protection of small stream habitat is important for long-term conservation of sea-run populations.

Rosenfeld, J. S., and S. Boss. 2001. Fitness consequences of habitat use for juvenile cutthroat trout: energetic costs and benefits in pools and riffles. Canadian Journal of Fisheries and Aquatic Sciences 58:585-593.

'KEY WORDS'
Tributaries
British Columbia
Cutthroat trout
Bioenergetics
Habitat use
growth
'ABSTRACT'

To assess freshwater habitat requirements of juvenile anadromous cutthroat trout, Oncorhynchus clarki, we measured habitat preference and growth rates of young-of-the-year (YOY) and 1- to 2-year-old fish confined to either pools or riffles in Husdon Creek, British Columbia, during 1999. YOY preferred pools to riffles in habitat-preference experiments, despite normally occurring at lower densities in pools. YOY grew in both pools and riffles when experimentally confined to either habitat, but growth rates were higher in pools. Larger juvenile cutthroat trout, on average, grew in pools, but consistently lost weight in riffles, indicating that pools are a habitat preference for YOY but a requirement for larger fish. A bioenergetic cost–benefit analysis (based on swimming costs and energy intake from invertebrate drift) indicates that energetics alone are sufficient to account for avoidance of riffles by larger cutthroat trout, without having to invoke greater predation risk in shallow habitats. Energetics modeling demonstrates that the smaller size and energetic needs of YOY allow exploitation of habitats (e.g., pocket pools in riffles) that are unavailable to larger fish.

Rosenfeld, J. S., and L. Huato. 2003. Relationship between large woody debris characteristics and pool formation in small coastal British Columbia streams. North American Journal of Fisheries Management 23:928-938.

'KEY WORDS'

Tributaries
British Columbia
Large wood
Stream ecology
Pools
Salmonid habitat

'ABSTRACT'

The characteristics and function of large woody debris (LWD) were measured in 41 small (1.2–11.2-m bank-full channel width), fish-bearing streams in coastal British Columbia to determine how total LWD abundance and the features of individual LWD pieces (diameter, length, orientation, and presence of a rootwad) influenced the effectiveness of pool formation. Pool spacing (the number of channel widths between channel-spanning pools) was a decreasing power function of total LWD abundance, but the relationship was relatively weak. Stratification of sites by channel gradient improved the model fit, steeper streams (≥2% gradient) having a significantly lower pool spacing than lower-gradient streams (<2%). The proportion of LWD that formed pools increased from 6% for pieces with a diameter of 15–30 cm to 43% for pieces with a diameter of more than 60 cm. Large woody debris more than 60 cm in diameter formed a higher proportion of pools across all channel widths. A simple, size-structured model of LWD abundance in small streams suggests that loss of LWD larger than 60 cm in diameter will greatly decrease pool frequency across all channel widths but have the greatest impact on large streams. Models that estimate pool frequency based on total LWD abundance irrespective of size distribution may underestimate the impact of riparian management that reduces the number of larger-diameter trees recruiting to the stream channel.

Rosenfeld, J. S., E. Raeburn, P. C. Carrier, and R. Johnson. 2008. Effects of Side Channel Structure on Productivity of Floodplain Habitats for Juvenile Coho Salmon. North American Journal of Fisheries Management 28(4):1108-1119.

'KEY WORDS'

Off channel
Artificial channels
Coho salmon

'ABSTRACT'

Numerous artificial side channels have been constructed in British Columbia and the Pacific Northwest to compensate for habitat loss from floodplain development. We reviewed data from published studies on natural and restored side channel habitats to determine how design features influence productive capacity for juvenile coho salmon Oncorhynchus kisutch. Average density and biomass of coho salmon parr were significantly higher in stream-type side channels (3.4 parr/m2 and 8.01 g/m2, respectively) than in pond-type side channels (0.8 parr/m2 and 2.37 g/m2). Although total parr biomass was three times higher in stream-type side channels, average parr weight was 47% lower, suggesting greater density-dependent limitation of growth from higher recruitment of juveniles to stream-type habitats. Parr abundance declined from late summer to early spring in both side channel types but appeared to decrease more quickly in stream-type side channels, suggesting greater self-thinning in stream-type habitat from mortality or immigration to slower pond or main-stem habitat as fish sought lower velocities for overwintering. Fish density in a single off-channel complex that contained both stream and pond habitats (fish were able to move between habitats) was also higher in stream habitats, although fish were significantly larger in pond habitats than in stream habitats. Parr density in stream-type side channels was constant with increasing channel size, whereas density in pond-type side channels was a decreasing function of side channel area. Smolt production data were more limited and variable, and production was not

significantly different between stream- and pond-type side channels. Smolt density (smolts produced/m2 of channel habitat) was also a decreasing function of total side channel area, indicating that the optimal side channel habitat size (or pond size within a side channel complex) was below 5,000–10,000 m2. Side channels that incorporate a diversity of flowing- and standing-water areas are most likely to provide the variety of habitats (i.e., spawning, summer rearing, and overwintering) required by salmonids to complete their life cycle.

Rot, B. W., R. J. Naiman, and R. E. Bilby. 2000. Stream channel configuration, landform, and riparian forest structure in the Cascade Mountains, Washington. Canadian Journal of Fisheries and Aquatic Sciences 57:699-707.

'KEY WORDS'
Watershed scale
Large wood
Stream ecology
Channel morphology
'ABSTRACT'

The hierarchical relationship of five key elements, valley constraint, riparian landform, riparian plant community, channel type, and channel configuration, are described for 21 sites in mature to old-growth riparian forests of the western Cascades Mountains, Washington, U.S.A. Channel type (bedrock, plane-bed, and forced pool-riffle) was closely related to channel configuration (especially large woody debris (LWD) volume, density, and LWD-formed pools) at the smallest spatial scale and valley constraint at the largest. Valley constraint significantly influenced off-channel habitat (r2 = 0.71) and LWD volume within forced pool-riffle channels (r2 = 0.58). Riparian plant community composition was differentiated by four landform classes: three alluvial landforms based on height above the channel and one based on hillslope. Just above the active channel, floodplain landforms contained more deciduous stems than conifer and greater conifer basal area than deciduous. Conifers dominated other landforms. The diameter of in-channel LWD increased with the age of the riparian forest (r2 = 0.34). In old-growth forests, LWD diameter was equivalent to or greater than the average riparian tree diameter for all sites. In younger forests, the mixed relationship between LWD and riparian tree diameter may reflect a combination of LWD input from the previous old-growth stand and LWD input from the existing stand.

Schindler, D. E., and coauthors. 2008. Climate Change, Ecosystem Impacts, and Management for Pacific Salmon. Fisheries 33(10):502-506.

'KEY WORDS'
Climate change
Management
'ABSTRACT'

As climate change intensifies, there is increasing interest in developing models that reduce uncertainties in projections of global climate and refine these projections to finer spatial scales. Forecasts of climate impacts on ecosystems are far more challenging and their uncertainties even larger because of a limited understanding of physical controls on biological systems. Management and conservation plans that explicitly account for changing climate are rare and even those generally rely on retrospective analyses rather than future scenarios of climatic conditions and associated responses of specific ecosystems. Using past biophysical relationships as a guide to predicting the impacts of future climate change assumes that the observed relationships will remain constant. However, this assumption involves a long chain of uncertainty about future greenhouse gas emissions, climate sensitivity to changes in greenhouse gases, and the ecological consequences of climate change. These uncertainties in forecasting biological responses to changing climate highlight the need for resource management and conservation policies that are robust to unknowns and responsive to change. We suggest how policy might develop despite substantial uncertainties about the future state of salmon ecosystems.

Schmetterling, D. A. 2001. Seasonal Movements of Fluvial Westslope Cutthroat Trout in the Blackfoot River Drainage, Montana. North American Journal of Fisheries Management 21(3):507-520.

'KEY WORDS'
Main stream
Montana
Cuthroat trout
Movement
Radio telemetry

'ABSTRACT'

I studied the seasonal movements and habitat use of fluvial westslope cutthroat trout Oncorhynchus clarki lewisi from 1997 to 1999 in the Blackfoot River drainage in western Montana to help guide restoration efforts and lead to a better understanding of this subspecies. Of 22 radio-tagged fish, 16 migrated during the spawning period (mean length, 371 mm). Ten of the 22 fish were tracked over a 2-year period, and 2 of these fish migrated in both 1997 and 1998. Migrations to tributaries occurred during the rising limb of the hydrograph in both years and lasted for an average of 10 d (range, 1–14 d) in 1998. Migratory fish moved both upriver and downriver to reach spawning tributaries during both years. In 1998 the mean distance traveled to access tributaries was 31 km (range, 3–72 km). Fish staged at the mouths of tributaries for up to 14 d before entering near the peak in the hydrograph. They remained in tributaries for an average of 27 d (range, 4–63 d), the duration varying with size of tributary and flow year. Once in tributaries, fish generally remained within a 200-m reach, but frequently moved within the area. In four tributaries to the Blackfoot River, actively spawning fish were observed in May 1998 as flows subsided after the peak discharge. Neither of the two repeat migrants spawned within 3 km of their previous year's spawning location, though both spawned in the same tributaries. After leaving tributaries, fish moved both up- and downriver to overwintering areas and did not move more than 100 m thereafter. Fish did not exhibit fidelity to their prespawning main-stem locations. At least six fish died after spawning (38%). Westslope cutthroat trout movements, prespawning and postspawning, exhibited a plasticity not previously reported in Montana and demonstrate the large spatial extent to which fluvial westslope cutthroat trout utilize aquatic resources. To enable continued improvement of the westslope cutthroat trout population in the Blackfoot River drainage, I recommend riparian timber management that continues long-term input of large woody debris to tributaries, continued closure of the Blackfoot River watershed to angling harvest, and the use of culvert designs that will pass spawning fish under most flow conditions.

Sedell, J. R., and J. L. Froggatt. 1984. Importance of streamside forests to large river: The isolation of the Willamette River, Oregon, U.S.A., from its floodplain by snagging and streamside forest removal. Verhandlungendern Internationalen Vereinigung Limnologie 22(1828-1834).

'KEY WORDS'
Watershed Scale
Debris removal
Riparian habitat
River continuum
Woody debris

'ABSTRACT'

Historical perspective of the develpment of riparian habitat following debris removal from snagging etc following European settlement

Sharma, R., and R. Hilborn. 2001. Empirical relationships between watershed characteristics and coho salmon (Oncorhynchus kisutch) smolt abundance in 14 western Washington streams. Canadian Journal of Fisheries and Aquatic Sciences 58:1453-1463.

'KEY WORDS'
Watershed Scale
Washington
Coho Salmon

Large wood
Pools
Population number
Smolts
Escapement
'ABSTRACT'
Data were assembled on coho salmon (Oncorhynchus kisutch) from 14 streams in western Washington, including annual smolt counts and annual escapement, either as absolute counts or as an index. Data was also compiled on large woody debris, road densities in the watersheds, gradient of the streams, valley slope adjacent to the stream, drainage area in the watershed, and pool, pond, and lake areas. The relationships between habitat variables and two measures of coho production, the maximum production of smolts in the stream (capacity) and the maximum smolts/spawner (productivity) were explored. Using the 11 streams with pool and pond counts, it was found that pool and pond densities served as good predictors of smolts density (r super(2) = 0.85 for pools and 0.68 for ponds, independently). Pools produced 0.39 smolts times m super(-2) and ponds produced 0.07 smolts times m super(-2) in the multiple regression fit, accounting for 92% of the residual error. It was also found that lower valley slopes, lower road densities, and lower stream gradients were correlated with higher smolt density.

Sheer, M. B., and E. A. Steele. 2006. Lost watersheds: Barriers, aquatic habitat connectivity, and salmon persistence in the Willamette and lower Columbia Basins. Transactions of the American Fisheries Society 135:1654-1669.
'KEY WORDS'
Watershed scale
Oregon
Columbia River
Connectivity
Migration
Barriers
'ABSTRACT'
Large portions of watersheds and streams are lost to anadromous fishes because of anthropogenic barriers to migration. The loss of these streams and rivers has shifted the distribution of accessible habitat, often reducing the diversity of accessible habitat and the quantity of high-quality habitat. We combined existing inventories of barriers to adult fish passage in the Willamette and Lower Columbia River basins and identified 1,491 anthropogenic barriers to fish passage blocking 14,931 km of streams. We quantified and compared the stream quality, land cover, and physical characteristics of lost versus currently accessible habitat by watershed, assessed the effect of barriers on the variability of accessible habitats, and investigated potential impacts of habitat reduction on endangered or threatened salmonid populations. The majority of the study watersheds have lost more than 40% of total fish stream habitat. Overall, 40% of the streams with spawning gradients suitable for steelhead (anadromous rainbow trout Oncorhynchus mykiss), 60% of streams with riparian habitat in good condition, and 30% of streams draining watersheds with all coniferous land cover are no longer accessible to anadromous fish. Across watersheds, hydrologic and topographic watershed characteristics were correlated with barrier location, barrier density, and the impacts of barriers on habitat. Population-based abundance scores for spring Chinook salmon O. tshawytscha were strongly correlated with the magnitude of habitat lost and the number of lowland fish passage barriers. The characteristics of barrier and habitat distribution presented in this paper indicate that barrier removal projects and mitigation for instream barriers should consider both the magnitude and quality of the lost habitat.

Shirvell, C. S. 1990. Role of instream rootwads as juvenile coho salmon (Oncorhynchus kisutch) and steelhead trout (O. mykiss) cover habitat under varying streamflows. Canadian Journal of Fisheries and Aquatic Sciences 47:852-860.

'KEY WORDS'
Main Stream
British Columbia
Coho salmon
Steelhead
Rootwads
'ABSTRACT'
Coho salmon fry (Oncorhynchus kisutch) and steelhead parr (O. mykiss) occupied previously infrequently-used mid-channel areas of Kloiya Creek, British Columbia, Canada, once artificial rootwads were placed there. Ninetynine percent of all coho salmon fry and 83% of steelhead parr occupied positions downstream of natural or artificial rootwads during artificially created drought, normal, and flood streamflows. Fish associated with rootwads regardless of distance from shore, but steelhead parr preferred rootwads away from shore while coho salmon fry preferred rootwads next to shore. Coho salmon fry increased their use of natural rootwads where currents were slow during floods, while steelhead parr increased their use of artificial and natural rootwads where light remained low during droughts. Young fish apparently selected areas having slower water 80% of the time because they provided shelter from adverse current, and areas having reduced light intensities 20% of the time because they provided protection from predators, juvenile coho salmon and steelhead in Kloiya Creek selected locations with slower water velocities and reduced light intensities irrespective of the physical structure that caused them.

Shirvell, C. S. 1994. Effect of changes in streamflow on microhabitat use and movements of sympatric juvenile coho salmon (Oncorhynchus kisutch) and chinook salmon (O. tshawytscha) in a natural stream. Canadian Journal of Fisheries and Aquatic Sciences 51:1644-1652.
'KEY WORDS'
Climate change
Steamflow
Stream habitat
Behavior
Salmonids
Coho salmon
Chinook salmon
'ABSTRACT'
The microhabitats at positions selected by juvenile coho (Oncorhynchus kisutch) and chinook salmon (O. tshawytscha) following a change in streamflow differed from microhabitats occupied at normal streamflows. At drought streamflow (37% mean seasonal streamflow (MSF)), juvenile coho salmon selected slower, darker, and higher sites above the streambed ($P < 0.05$) than sites selected at normal (75% MSF) or flood (159% MSF) flows. Juvenile chinook salmon microhabitat use changed similarly with changes in streamflow, but the differences were not significant. Up to one fifth of the fish chose positions with faster water velocities than those available either 30 cm above or 30 cm lateral to them. These fish chose positions inconsistent with the hypothesis of optimal position selection based on maximizing net energy gain. On average, fish moved 6.8 m following a change in streamflow. Juvenile coho salmon generally moved upstream in response to decreasing streamflows and downstream in response to increasing streamflows. Juvenile chinook salmon tended to move offshore and downstream in response to all streamflow changes. These results show that juvenile coho and chinook salmon will move to find suitable microhabitat following a change in streamflow and that the microhabitats are not the same at all streamflows.

Solazzi, M. F., T. Nickelson, S. Johnson, and J. Rodgers. 2000. Effects of increasing winter rearing habitat on abundance of salmonids in two coastal Oregon streams. Canadian Journal of Fisheries and Aquatic Sciences 57:906-914.
'KEY WORDS'
Tributaries

Oregon
Abundance
Habitat improvement (physical)
Overwinter habitat
Steelhead
Oncorhynchus mykiss
Coho salmon
Oncorhynchus kisutch
Cutthroat trout
Oncorhynchus clarki
'ABSTRACT'
A BACI (before-after-control-impact) experimental design was used to examine the effects of increasing winter habitat on the abundance of downstream migrant salmonids. Two reference streams and two treatment streams were selected in the Alsea and Nestucca basins of Oregon. Population parameters for juvenile coho salmon (Oncorhynchus kisutch), age-0 trout (Oncorhynchus spp.), steelhead (Oncorhynchus mykiss), and coastal cutthroat trout (Oncorhynchus clarki) were estimated each year for 8 years in each stream. Stream habitat was modified to increase the quality and quantity of winter habitat during the summers of 1990 (Nestucca Basin) and1991 (Alsea Basin). Complex habitat was constructed by adding large woody debris to newly created alcoves and dammed pools. Numbers of coho salmon summer juveniles and smolts increased in the treatment streams relative to the control streams during the posttreatment period. Overwinter survival of juvenile coho salmon also increased significantly in both treatment streams posttreatment. Summer trout populations in the treatment streams did not change, but downstream migrant numbers the following spring did increase. These increases suggest that winter habitat was limiting abundance of all three species.

Stanford, J. A., R. F. Hauer, and J. V. Ward. 1988. Serial discontinuity in a large river system. Verhandlungendern Internationalen Vereinigung Limnologie 23:1114-1118.
'KEY WORDS'
Watershed scale
Stream Ecology
'ABSTRACT'
The paper reviews the River Continuum Concept and suggests modifications on the basis of dams in the watershed. They discuss the ability of dam to retain sediment and organic matter which will alter downstream tranport and processing of organic matter.

Stanford, J. A., and J. V. Ward. 1993. An Ecosystem Perspective of Alluvial Rivers: Connectivity and the Hyporheic Corridor Journal of the North American Benthological Society 12:48-60.
'KEY WORDS'
Watershed scale
hyporheic zone
connectivity
'ABSTRACT'
Floodplains of large alluvial rivers are often expansive and characterized by high volume hyporheic flow through lattice-like substrata, probably formed by glacial outwash or lateral migration of the river channel over long time periods. River water downwells into the floodplain at the upstream end; and, depending on bedrock geomorphology and other factors, groundwater from the unconfined aquifer upwells directly into the channel or into floodplain springbrooks at rates determined by head pressure of the water mass moving through the floodplain hydrologic system. These large scale (km³) hyporheic zones contain speciose food webs, including specialized insects with hypogean and epigean life history stages (amphibionts) and obligate groundwater species (stygobionts). Biogeochemical processes in the hyporheic zone may naturally load groundwaters with bioavailable solutes that appear to exert proximal controls on production and biodiversity of surface benthos and riparian

vegetation. The effect is especially evident in floodplain springbrooks. Dynamic convergence of aquifer-riverine components adds physical heterogeneity and functional complexity to floodplain landscapes. Because reaches of aggraded alluvium and attendant ecotonal processes occur serially, like beads on a string, along the river continuum, we propose the concept of a hyporheic corridor in alluvial rivers. We expect predictable zonation of groundwater communities and other aquifer-riverine convergence properties within the corridor from headwaters to river mouth. The landscape-level significance and connectivity of processes along the hyporheic corridor must be better understood if river ecosystems, especially those involving large floodplain components, are to be protected and/or rehabilitated.

Statzner, B., and B. Higler. 1985. Questions and comments on the river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 42:1038-1044.

'KEY WORDS'
Watershed scale
River continum concpet
Aquatic ecology
'ABSTRACT'

The River Continuum Concept (RCC) is a generalized conceptual framework for characterization of pristine running water ecosystems. Of the numerous tenets of the concept we particularly reevaluated the following: biological analogues of energy equilibrium and entropy in the physical system; maximization of energy consumption through continuous species replacement over a year; absence of succession in stream ecosystems, which can thus be viewed in a time-independent fashion; and maximization of biotic diversity in midreaches of streams as a result of the occurrence of highest environmental variability there together with spatial abundance shifts of insects, molluscs, and crustaceans. When emphasis is placed on rapid changes in the downstream hydraulics dependent on discharge and slope (both of which are expressed by stream order in the RCC and are key factors of the concept) and on results from tropical studies, some of these tenets are partly refuted or need extension. Some of them are in conflict with the current state of knowledge in other domains of stream ecology or are at least open to various interpretations. Therefore, we advocate modifications of the theoretical background of the RCC.

Stednick, J. D. 2008. Long-term Streamflow Changes Following Timber Harvesting. Pages 139-155 *in* Hydrological and Biological Responses to Forest Practices, volume 199. Springer New York.

'KEY WORDS'
Tributaries
Effects of logging
Hydological regime
Riparian management
'ABSTRACT'

Studies under virtually every environmental condition indicate that vegetation removal results in increased annual water yield (Rothacher 1970; Harr 1976, 1979, 1983; Bosch and Hewlett 1982; Stednick 1996). However, treatment responses are variable.

Steel, E. A., and coauthors. 2008. A Spatially Explicit Decision Support System for Watershed-Scale Management of Salmon. Ecology and Society 13(2):np.

'KEY WORDS'
Watershed scale
Oregon
Salmon
Watershed management
'ABSTRACT'

Effective management for wide-ranging species must be conducted over vast spatial extents, such as whole watersheds and regions. Managers and decision makers must often consider results of

multiple quantitative and qualitative models in developing these large-scale multispecies management strategies. We present a scenario-based decision support system to evaluate watershed-scale management plans for multiple species of Pacific salmon in the Lewis River watershed in southwestern Washington, USA. We identified six aquatic restoration management strategies either described in the literature or in common use for watershed recovery planning. For each of the six strategies, actions were identified and their effect on the landscape was estimated. In this way, we created six potential future landscapes, each estimating how the watershed might look under one of the management strategies. We controlled for cost across the six modeled strategies by creating simple economic estimates of the cost of each restoration or protection action and fixing the total allowable cost under each strategy. We then applied a suite of evaluation models to estimate watershed function and habitat condition and to predict biological response to those habitat conditions. The concurrent use of many types of models and our spatially explicit approach enables analysis of the trade-offs among various types of habitat improvements and also among improvements in different areas within the watershed. We report predictions of the quantity, quality, and distribution of aquatic habitat as well as predictions for multiple species of species-specific habitat capacity and survival rates that might result from each of the six management strategies. We use our results to develop four on-the-ground watershed management strategies given alternative social constraints and manager profiles. Our approach provides technical guidance in the study watershed by predicting future impacts of potential strategies, guidance on strategy selection in other watersheds where such detailed analyses have not been completed, and a framework for organizing information and modeled predictions to best manage wide-ranging species.

Swain, D., and B. Holtby. 1989. Differences in morphology and behavior between juvenile coho salmon (*Oncorhynchus kisutch*) rearing in a lake and in its tributary stream. Canadian Journal of Fisheries and Aquatic Sciences 46:1406-1414.

'KEY WORDS'
Tributaries
British Columbia
Coho salmon
Lakes
Stream
Competition
'ABSTRACT'

Juvenile coho salmon (Oncorhynchus kisutch) rear both in Mesachie Lake, B.C., and in its inlet stream. The duration and frequency of aggressive behavior were greater among stream-rearing than lake-rearing juveniles in mirror image stimulation and stream tank tests of agonistic behavior. Lateral displays made up a higher proportion of total behavior among the stream-rearing fish compared with the lake-rearing fish. Lake-type fish had more posteriorly placed pectoral fins, shallower bodies and smaller, less brightly colored dorsal and anal fins than did stream-type fish, even after 2 mo of laboratory rearing in a common environment. Diminished aggression, a shift in aggressive behavior away from lateral displays, a more streamlined shape, and reduced coloration, all appear to be adaptations to a schooling lifestyle in the open waters of the lake.

Swales, S., F. Caron, J. R. Irvine, and C. D. Levings. 1988. Overwintering habitats of coho salmon (Oncorhynchus kisutch) and other juvenile salmonids in the Keogh River system, British Columbia. Canadian Journal of Zoology 66:254=261.

'KEY WORDS'
Tributaries
British Columbia
Overwinter habitat
Coho salmon
'ABSTRACT'

Catches of overwintering juvenile coho salmon (Oncorhynchus kisutch) in the Keogh River system, Vancouver Island, were higher in two small (8 and 25 ha), shallow (mean depth 2 - 3 m) lakes and their outlet and inlet streams than in the main river, where steelhead trout (Salmo gairdneri) were predominant. Dolly Varden char (Salvelinus mulmu), cutthroat trout (Salmo clarki), and threespine stickleback (Gasterosteus aculeatus) were also present in the lakes. The distribution of coho salmon in the lakes was restricted largely to areas close to the bank, with few fish being captured in offshore areas or in mid-water. Aapparent differences in the abundance of coho salmon between the two lakes may have been related to differences in fish community composition, with sticklebacks being particularly numerous in Misty Lake, where catches of coho salmon were lower than in Long Lake. The population density and biomass of coho salmon overwintering in Long Lake were estimated to be 176 fishlha and 1.14 kg ha-', respectively. The mean length of coho salmon in the lakes was greater than that of coho salmon in the tributary streams and main river, and the mean length of the salmon in the lakes generally increased with distance away from shore.

Swales, S., R. B. Lauzier, and C. D. Levings. 1986. Winter habitat preferences of juvenile salmonids in two interior rivers in British Columbia. Canadian Journal of Zoology 64:1506-1514.

'KEY WORDS'
Off Channel
Main channel
British columbia
Coho salmon
Off-channel habitat
Salmonid ecology
Salmonid habitat
Steelhead trout
Winter habitat

'ABSTRACT'

The winter distribution and abundance of juvenile salmonids was investigated in various main channel and off-channel habitats in the Coldwater and Nicola rivers in the southern interior of British Columbia. Catches were generally low in all main channel habitats, with coho salmon (Oncorhynchus kisutch) and steelhead trout (Salmo gairdneri) being most abundant and chinook salmon and Dolly Varden char being present in smaller numbers. Coho salmon and steelhead trout catches were generally highest in pools with abundant instream and riparian cover. Steelhead trout was the main species in riprap bank protected areas, although catches were generally low. Highest overall catches were recorded in side channels and off-channel ponds, where water temperatures were usually several degrees higher than in the main river. The authors conclude that juvenile salmonids in the rivers investigated showed considerable habitat segregation during the winter. As in coastal rivers, juvenile coho salmon made extensive use of off-channel ponds, while rainbow trout and chinook salmon were generally most abundant in riprap and deep pools containing log debris, respectively.

Swales, S., and C. D. Levings. 1989. Role of off-channel ponds in the life cycle of coho salmon (Oncorhynchus kisutch) and other juvenile salmonids in the Coldwater River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 46:232-242.

'KEY WORDS'
Off channel
British Columbia
Coho Salmon
Steelhead

'ABSTRACT'

Off-channel ponds in the upper reaches of the Coldwater River, British Columbia, were major rearing areas for juvenile coho salmon (Oncorhynchus kisutch). Chinook salmon (Oncorhynchus tshawytscha), steelhead trout (Salmo gairdneri), and Dolly Varden char (Salvelinus malma) were generally scarce in the ponds, although they were numerous in the main river. Coho

salmon were predominant at "natural" river sites while steelhead trout was the main species at sites with "rip-rap" bank stabilization. Catches of juvenile coho were much lower in the main river than in the ponds where they were the main species, and were more variable in the river. Population density and biomass estimates of juvenile coho in the ponds ranged from 0.100 fish·m−2 and 1.00 g·m−2 to 1.00 fish·m−2 and 5.15 g·m−2, compared with density estimates of 0.08–0.23 fish·m−2 in the river. The coho population in the ponds consisted of 0+ and 1+ age-groups in similar proportions, while in the main river the 0+ age-group was much more abundant. The growth rate of coho in the ponds was faster than in the main river, with pond fish reaching mean lengths of 62–79 mm at the end of the first growing season, compared with 53 mm in the main river. Smolt outmigration from the main study pond occurred in late spring with peak outmigration in May and June coinciding with peak river discharge and increasing water temperatures in the main river and pond.

Swanston, D. N. 1969. Mass Wasting in coastal Alaska. Institute of Northern Forestry, Pacific Northwest Forest and Range Experiment Station, Portland, OR.

'KEY WORDS'
Watershed scale
Southeast Alaska
Effects of logging
Erosion control
Landslides
Sediment
Water quality
'ABSTRACT'
Present various aspects of landslides in southeast Alaska. Idendifies landslide prone landscapes.

Taylor, S. G. 2008. Climate warming causes phenological shift in Pink Salmon, Oncorhynchus gorbuscha, behavior at Auke Creek, Alaska. Global Change Biology 14(2):229-235.

'KEY WORDS'
Climate change
Southeast Alaska
Migration timing
Oncorhynchus gorbuscha
Pink salmon
Water temperature
'ABSTRACT'
Abstract Thirty-four years (1972–2005) of water temperature data and extensive biological observations at Auke Creek, Alaska indicate a general warming trend that affected the native pink salmon (Oncorhynchus gorbuscha) population. Serial environmental records at nearby Auke Bay, Alaska over 46 years show trends of increasing air and sea surface temperatures. Trends of increased total precipitation and earlier date of ice out on nearby Auke Lake also occurred, but not at significant rates. Average water temperatures during the incubation of pink salmon in Auke Creek increased at a rate of 0.03 °C yr−1 over the 34-year period. For the 1972–2005 broods, midpoints of fry migrations from Auke Creek ranged between April 2 and May 7, and there was a trend of earlier migration of pink salmon fry at a rate of −0.5 days yr−1. The migration timing of adult salmon into Auke Creek also showed a trend toward earlier timing. The earlier adult migration combined with warmer incubation temperatures are related to earlier migration of pink salmon fry. If the observed warming trend continues, Auke Creek may become unsuitable habitat for pink salmon. Given the trend for salmon fry to migrate earlier, a larger portion of the population may become mismatched with optimum environmental conditions during their early marine life history. If salmon adults continue to migrate into the creek earlier when water temperatures are commonly high, it will result in increased prespawning mortality.

Thedinga, J. F., M. L. Murphy, J. Heifetz, K. V. Koski, and S. W. Johnson. 1989. Effects of Logging on Size and Age Composition of Juvenile Coho Salmon (*Oncorhynchyus kisutch*) and Density of Presmolts in Southeast Alaska Streams. Canadian Journal of Fisheries and Aquatic Sciences 46:1383--1391.

'KEY WORDS'
Tributaries
Southeast Alaska
Effects of Logging
Coho salmon
'ABSTRACT'

Short-term effects of logging on age composition and size of juvenile coho salmon (Oncorhynchus kisutch) were studied in 18 streams in Southeast Alaska in 1982 and 1983; studies were in old-growth and clear-cut reaches with or without buffer strips. The number of fry (age 0) in summer and winter was proportionately higher in buffered and clear-cut reaches than in old-growth reaches, and all treatments averaged a 20% decrease in fry from summer to winter. Fry length and condition factor were greater for buffered and clear-cut reaches than for old-growth reaches, whereas parr (age 1 and older) size did not differ among treatments. Fry and parr were larger in the southern than in the northern regions and their length and weight were directly related to periphyton biomass and benthos density.

Tiegs, S. D., and coauthors. 2008. Timber Harvest Transforms Ecological Roles Of Salmon In Southeast Alaska Rain Forest Streams
Ecological Applications 18(1):4-11.

'KEY WORDS'
Watershed scale
Southeast Alaska
salmon
Nutrients,
Stream ecosystem
Tongass National Forest
'ABSTRACT'

Although species commonly modify habitats and thereby influence ecosystem structure and function, the factors governing the ecological importance of these modifications are not well understood. Pacific salmon have repeatedly been shown to positively influence the abundance of benthic biota by annually transferring large quantities of nutrients from marine systems to the nutrient-poor freshwaters in which they spawn. Conversely, other studies have demonstrated that salmon can negatively influence the abundance of freshwater biota, an effect attributed to bioturbation during upstream migration and nest construction. The factors determining which of these contrasting ecological effects predominates are unknown, including how human activities, such as land use, influence ecological responses to salmon. We sampled a key basal food resource, sediment biofilm, in seven southeast Alaskan streams impacted to varying degrees by timber harvest. Biofilm abundance (measured as chlorophyll a and ash-free dry mass) was positively related to timber-harvest intensity prior to salmon arrival. However, during the salmon run, an inverse relationship emerged of more abundant biofilm in less-harvested watersheds. Among-stream variability in biofilm response to salmon was largely explained by sediment particle size, which was larger in less-harvested watersheds. Collectively, these results suggest that, by altering stream sediment size, timber harvest transformed the dominant effect of salmon from nutrient enrichment to physical disturbance, thus modifying nutrient linkages between marine and freshwater ecosystems.

Tripp, D. B., and V. A. Poulin. 1986. The effects of logging and mass wasting on salmonid spawning habitat in streams on the Queeen Charlotte Islands. Research Branch, Ministry of Forests and Lands, Victoria, Briitish Columbia.

'KEY WORDS'
Main Stream

Tributaries
British Columbia
Effects of logging
Landslides
Salmonid habitat
Spawning habitat
'ABSTRACT'
Describes the efects of landslides on fish habitat in streams including increased sedimentation, washout of LWD, and erosion of streambanks.

Triska, F. 1984. Role of Wood Debris in Modifying Channel Geomorphology and Riparian Areas of a Large Lowland River under Pristine Conditions: A Historical Case Study. Verhandlung Internationale Vereinigung Limnologie 22(3):1876-1892.
'KEY WORDS'
Main Stream
Channel morphology
Geomorphology
Riparian areas
History
Debris
Red River
large Wood
Alluvial deposits
Debris dams
Floods
Snags
'ABSTRACT'
Historical records were reviewed to estimate the impact of wood debris on a 400-500 km reach of the Red River, Louisiana. In the primal condition the banks consisted of unstable alluvial deposits easily eroded during floods. Sediment and riparian trees from eroded banks formed organic debris dams which blocked the channel and promoted channel aggradation. Over a period > 375 years wood debris dams formed in series. The longest instantaneous length of impacted channel was 225 km. The average rate of channel blockage was 1.3 to 1.6 km/year between 1793-1876. Maximum debris accumulation recorded in a single flood was 8.1 km. Exposed wood covered 80-120 km of channel. Debris dams remained in place 80-150 years. Wood debris impacted adjacent riparian areas by flooding forests and forming a series of large lakes. Under natural conditions lakes could become nearly permanent features of the riparian landscape if tributary channels filled with alluvium and organic debris. After removal of organic debris the most recently formed lakes drained over a period of approximately 30 years. Flow reversal in tributaries resulted in channel enlargement and diversion of one half to three quarters of the river 's discharge adjacent to riparian lowlands. Wood debris reduced the river 's width from about 185 m to approximately 40 m, and aggraded the river bed a maximum of 7 m. Tributary channels were dammed or filled with organic debris, and the river was permanently opened to navigation in 1873. Restoration of full channel flow exposed previously buried logs and eroded forested banks. By 1904, seventy years of debris dams and snag removal, levee projects, dredging and cutting bankside trees resulted in a cleared, wide, meandering channel, which might today be mistaken as typical of a pristine lowland river.

Triska, F. J., V. C. Kennedy, R. J. Avanzino, G. W. Zellweger, and K. E. Bencala. 1989. Retention and Transport of Nutrients in a Third-Order Stream in Northwestern California: Hyporheic Processes Ecology 70:1993-1905.
'KEY WORDS'
Tributaries
California
Nutrients

Hyporhreic zone
Nutrient cycles
'ABSTRACT'

Chloride and nitrate were coinjected into the surface waters of a third-order stream for 20 d to examine solute retention, and the fate of nitrate during subsurface transport. A series of wells (shallow pits) 0.5-10 m from the adjacent channel were sampled to estimate the lateral interflow of water. Two subsurface return flows beneath the wetted channel were also examined. The conservative tracer (chloride) was hydrologically transported to all wells. Stream water was >88% of flow in wells <4 m from the wetted channel. The lowest percentage of stream water was 47% at a well 10 m perpendicular to the stream. Retention of solutes was greater in the hyporheic zone than in the channel under summer low-flow conditions. Nominal travel time (the interval required for chloride concentration to reach 50% of the plateau concentration) was variable by well location, indicating different flow paths and presumably permeability differences in subsurface gravels. Nominal travel time was M 24 h for wells <5 m from the wetted channel. Coinjected nitrate was not conservative. Two wells were significantly (P < .05) higher in nitrate-N than would be predicted from chloride, while four were significantly lower. Wells 2.0-4.0 m from the wetted channel tended to have higher nitrate concentration than predicted, whereas nitrate sink locations tended to have transport distances >4.3 m. The capacity of the hyporheic zone for transient solute storage and as potential biological habitat varies with channel morphology, bed roughness, and permeability. A conceptual model that considers the groundwater-stream water interface as the fluvial boundary is proposed. Emerging paradigms of the riverine network should consider the hyporheic zone and associated nutrient cycling as an integral component of fluvial structure and function.

Tschaplinski, P. J., and G. F. Hartman. 1983. Winter distribution of juvenile coho salmon (Onchorhynchus kisutch) before and after logging in Carnation Creek, British Columbia, and some implications for overwinter survival. Canadian Journal of Fisheries and Aquatic Sciences 40:452-461.

'KEY WORDS'
Main Stream
British Columbia
Carnation creek
Coho salmon
Effects of logging
Winter habitat
'ABSTRACT'

Numbers of juvenile coho salmon (Oncorhynchus kisutch) in streams are reduced substantially in winter compared to those that occur in summer. Most of this reduction occurs early in autumn with the onset of the first seasonal freshets. Stream sections containing adequate winter habitat in the form of deep pools, log jams, and undercut banks with tree roots and debris lost fewer fish during freshets and maintained higher numbers of coho in winter than sections without these habitat characteristics. These features provide shelter and reduce stream velocities. Microhabitats occupied by coho juveniles in winter after logging were unchanged from those described before logging — all microhabitats were characterized by low water velocities (≤ 0.3 m/s). Up to 48% of the coho population inhabiting stream sections with adequate shelter remained there by midwinter (Jan. 3). This percentage was typical of stream sections where at least some trees remained after logging. Streamside trees stabilized the banks and prevented their collapse. In contrast, two of three study sections that had been clear-cut logged had unstable banks which collapsed during winter freshets. Almost no coho remained in these sections in winter. Many coho emigrate from the main stream to seek the shelter of low-velocity tributaries and valley sloughs concurrent with the decline of coho populations in Carnation Creek during autumn and early winter. This seasonal shift in distribution reverses in the spring when large numbers of coho reenter the main stream. Fish overwintering in these sites have a high apparent survival rate. Before logging a 4-yr mean of

169 ± 44 coho entered one tributary (a slough called 750-m site) in autumn. Of these numbers entering, 72.2% came out in spring. During and after logging, an annual mean of 288 coho entered the same site. The apparent survival rate during and after logging was 67.4%, essentially unchanged from the prelogging value. Logging has neither reduced the numbers of coho juveniles that enter such sites in autumn to overwinter, nor reduced the numbers leaving these sites to reenter Carnation Creek in spring.

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.

'KEY WORDS'
Watershed Scale
River continuum
Stream ecosystems
Ecosystem structure
Ecosystem stability
Community succession
Stream geomorphology
'ABSTRACT'

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

Waples, R. S., T. Beechie, and G. R. Pess. 2009. Evolutionary History, Habitat Disturbance Regimes, and Anthropogenic Changes: What Do These Mean for Resilience of Pacific Salmon Populations?

'KEY WORDS'
Watershed scale
Estuaries
Pacific Northwest
North America
Water Resources
'ABSTRACT'

Because resilience of a biological system is a product of its evolutionary history, the historical template that describes the relationships between species and their dynamic habitats is an important point of reference. Habitats used by Pacific salmon have been quite variable throughout their evolutionary history, and these habitats can be characterized by four key attributes of disturbance regimes: frequency, magnitude, duration, and predictability. Over the past two centuries, major anthropogenic changes to salmon ecosystems have dramatically

altered disturbance regimes that the species experience. To the extent that these disturbance regimes assume characteristics outside the range of the historical template, resilience of salmon populations might be compromised. We discuss anthropogenic changes that are particularly likely to compromise resilience of Pacific salmon and management actions that could help bring the current patterns of disturbance regimes more in line with the historical template.

Ward, J. V., and J. A. Stanford. 1983. The serial discontinuity concept of lotic ecosystems. Pages 29-42 *in* T. D. Fontaine, and S. M. Bartell, editors. Dynamics of Lotic Ecosystems. Ann Arbor Scientific Publishers, Ann Arbor, MI.

'KEY WORDS'
Watershed scale
Ecological theory
Ecology
Rivers
Serial dicontinuity
Streams
'ABSTRACT'
The papee expands on river continuum paradigm with the role of dams on flow and connectivity of stream systems. They suggest that dams alter the function of river systems.

Wigington, P. J., and coauthors. 2006. Coho salmon dependence on intermittent streams. Frontiers in Ecology and the Environment 4(10):513-518.

'KEY WORDS'
Headwater streams
Off channel
Oregon
Coho salmon
Movement
'ABSTRACT'
In February 2006, the US Supreme Court heard cases that may affect whether intermittent streams are jurisdictional waters under the Clean Water Act. In June 2006, however, the cases were remanded to the circuit court, leaving the status of intermittent streams uncertain once again. The presence of commercial species, such as coho salmon (Oncorhynchus kisutch), can be an important consideration when determining jurisdiction. These salmon spawn in the upper portions of Oregon coastal stream networks, where intermittent streams are common. In our study of a coastal Oregon watershed, we found that intermittent streams were an important source of coho salmon smolts. Residual pools in intermittent streams provided a means by which juvenile coho could survive during dry periods; smolts that overwintered in intermittent streams were larger than those from perennial streams. Movement of juvenile coho into intermittent tributaries from the mainstem was another way in which the fish exploited the habitat and illustrates the importance of maintaining accessibility for entire stream networks. Loss of intermittent stream habitat would have a negative effect on coho salmon populations in coastal drainages, including downstream navigable waters

Williams, J. E., A. L. Haak, H. M. Neville, and W. T. Colyer. 2009. Potential Consequences of Climate Change to Persistence of Cutthroat Trout Populations. North American Journal of Fisheries Management 29(3):533-548.

'KEY WORDS'
Climate change
cutthroat trout
Pacific Norhtwest
'ABSTRACT'
Warmer water, changes in stream flow, and the increasing frequency and intensity of other disturbances are among the factors associated with climate change that are likely to impact

native trout populations in the western USA. We examined how three of these factors—increased summer temperatures, uncharacteristic winter flooding, and increased wildfires—are likely to affect broad-scale population persistence among three subspecies of cutthroat trout Oncorhynchus clarkii. Our results suggest that as much as 73% of the habitat currently occupied by Bonneville cutthroat trout O. c. utah, 65% of that occupied by westslope cutthroat trout O. c. lewisi, and 29% of that occupied by Colorado River cutthroat trout O. c. pleuriticus will be at high risk from one or more of the these three factors. Within the next 50 years, wildfire, floods, and other disturbances may have a greater impact on population persistence than increasing water temperature alone. Our results also suggest that the risk will vary substantially within subspecies. For each subspecies, our analyses identified large portions of their ranges where all populations either currently fail to meet basic persistence criteria, are at high risk from climate change, or both, indicating a high likelihood of losing the genetic and life history diversity in those areas. Stress from climate change is likely to compound existing problems associated with habitat degradation and introgression from introduced salmonids. Recognition of the increased risk from climate change may warrant altering the management paradigm of isolation and require increased control efforts for invasive nonnative species. Regardless of the management avenue chosen, more populations are likely to become isolated and vulnerable in the near future. Our results argue for immediate restoration actions within certain subbasins to increase the resistance and resilience of at-risk populations and habitats to additional disturbances caused by rapid climate change.

Wissmar, R. C., D. N. Swanston, M. D. Bryant, and K. McGee. 1997. Factors influencing stream chemistry in catchments on Prince of Wales Island, Alaska. Freshwater Biology 38:301-314.

'KEY WORDS'
Tributaries
Southeast Alaska
Geochemistry
Karst

'ABSTRACT'

Factors influencing the water chemistry of streams were evaluated for remote catchments on Prince of Wales Island, Alaska, a high-latitude geologically diverse landscape. We evaluated the hypothesis that weathering rates of dominant geological formations of catchments would be the major factor influencing the water chemistry of streams. Catchments were compared by synoptic sampling of stream and cave waters, mapping to define the distribution of geological formations, and laboratory studies of rock weathering. Carbonation was identified as the major mechanism influencing the weathering of rocks. High Pco2 levels of cave and upwelling waters in streams suggested CO2, supplied by soil respiratory processes, was the major factor controlling the concentration of dissolved CO2, carbonic acid dissociation, and H+ replacement of cations on rock surfaces. Additional evidence of carbonation included the relationship between HCO31– and Ca2+ + Mg2+ (r2 = 0.95) for low- and high-alkalinity waters. The relationship suggested that the high-alkalinity waters were associated with the weathering of calcareous rocks. Waters with high alkalinities (> 1254 μeq l–1), pH (> 7.0), Ca : Mg ratios (> 6.0.) and saturation values for Ca2+ (SIc = –0.59–0.06) indicated that karst (limestone) formations with calcite minerals were the major sources of calcium (> 1266 μeq l–1). Waters with the lowest alkalinity, pH, HCO31– and cation concentrations were associated with granodiorite (igneous) rocks. Laboratory studies substantiated these findings, with weathering being highest when waters contacted Heceta and Bay of Pillars limestone formations and lowest with igneous rocks. Weathering of rocks, and possibly soils, appeared to be facilitated by surface and subsurface movements of CO2 and water through fractured karst formations, and water availability in rain-dominated forests. The proximity of the sea and sulphur in marine aerosols and rainfall, and sulphate reacting with water, may also supply hydrogen ions to weathering reactions. This study provides a basis for developing a better understanding of the influences of surface–subsurface geological and hydrological factors, and climatic conditions, on stream chemistry and biota in high-latitude ecosystems.

Wissmar, R. C., R. K. Timm, and M. D. Bryant. 2010. Radar-derived digital elevation models and field-surveyed variable to predict distribution of juvenile coho salmon and Dolly Varden in remote streams of Alaska. Transactions of the American Fisheries Society 139:288-302.

'KEY WORDS'
Watershed scale
Southeast Alaska
Landscape models
Coho salmon
Distribution
Remote sensing
Digital elevation models

'ABSTRACT'

We used field-surveyed and digital elevation model (DEM) parameters to predict density distributions of juvenile coho salmon Oncorhynchus kisutch and Dolly Varden Salvelinus malma in remote streams on Prince of Wales Island, southeast Alaska, and to identify influences of associated reach-level habitat characteristics. Fish densities were highest in two reach types (low-gradient floodplain reaches and moderately contained reaches) characterized by numerous pool habitats, low pool spacing distances, and abundant large woody debris. Regression analyses indicated that channel gradients measured during field surveys (M-gradients) accounted for significant amounts of the variance in coho salmon and Dolly Varden juvenile densities. The DEMs derived from a 2000 space-shuttle radar mapping mission were used to estimate channel gradients (DEM-gradients) and gradient zones: (0–3, >3–6, >6–15, and >15%) in stream networks. A high correlation between DEM-gradients and M-gradients (r = 0.92), along with the regressions of M-gradient and fish density, provided a template for comparing DEM-gradient and M-gradient predictions of fish densities within gradient zones of the watersheds. Juvenile coho salmon and Dolly Varden densities (number/100 m2) predicted from the DEM-gradients and M-gradients were consistent for a majority of the gradient zones. Our results and expanded analyses should facilitate development of paradigms for assessing fish distributions in remote landscapes.

Wright, K. K., and J. L. Li. 2002. From continua to patches: examining stream community structure over large environmental gradients. Canadian Journal of Fisheries and Aquatic Sciences 59:1404-1417.

'KEY WORDS'
Watershed scale
Oregon
Community structure
Landscape ecology
Stream ecology
Stream habitat
Distribution
Fish
Invertebrates
Algae
Primary production

'ABSTRACT'

We present an approach that integrates a conceptual framework with multivariate ordination techniques and traditional parametric analyses to examine biotic and abiotic gradients in stream ecosystems. Ordinations were used to examine multivariate patterns along an environmental gradient, with individual variables used to interpret those patterns across spatial scales. The conceptual framework provides a consistent context to compare community distributions and consequently allows for hypothesis testing using ordinations. To illustrate the approach, we examined the physical template, fish and benthic macroinvertebrate communities, and algal biomass and production along a 1st- through 5th-order stream gradient in eastern Oregon. We hypothesized that longitudinal distributions of

physical habitat characteristics, fishes, macroinvertebrates, and periphyton would reflect highly variable, discontinuous gradients. Multivariate patterns were determined by rotating nonparametric ordinations to a common set of variables and comparing them to conceptual models of (i) an ideal continuum, (ii) a random distribution, and (iii) discrete patches. Physical habitat and fishes reflected strong longitudinal gradients, macroinvertebrates were the most patchy, and algal biomass and production were highly variable. Distributions of individual variables from site and stream-order perspectives revealed how different factors, potentially influencing stream communities, may be continuous or patchy depending on spatial scale.