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New Perspectives In Riparian Management: Why Might We Want To Consider Active Management For Certain Portions Of Riparian Habitat Conservation Areas?[1]

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[1] White papers are internal reports; they receive only limited review. The viewpoints expressed in this paper include input from Jonathan Day (Heppner Ranger District) and Lea Baxter (North Fork John Day Ranger District).

INTRODUCTION

This white paper provides thoughts and considerations relating to active management for certain portions of riparian habitat conservation areas (RHCAs). The intent of this document is not to promote any particular perspective, as in the 'right' interpretation of RHCA management, but to provide thoughts, concepts, and principles contributing to ongoing dialogue about active management of RHCAs.

Placing Riparian Areas In A Landscape Ecology Context

Riparian areas, and their associated RHCAs, do not exist in a vacuum. Before embarking on a discussion about possible active management scenarios for RHCAs, it might be helpful to place them in a landscape ecology context in order to better understand and appreciate their ecological function.

Ecologists refer to landscapes as large areas comprised of interconnected or repeated patterns of habitats or ecosystems (Forman 1997, Turner and Gardner 1991). The science of landscape ecology studies the biological functions and interactions of vegetation patterns across large areas, assuming that there are strong links between ecosystem pattern and ecological function and process. Landscape structure has a strong influence on the flow of energy, nutrients, water, and disturbances, as well as organisms and their genes (Diaz and Apostol 1992, Gustafson 1998).

A single drainage basin may be considered a landscape if it is large enough to contain a variety of repeating patterns, but often a landscape will include more than one watershed. To be considered a landscape, an area must contain a variety of components that interact over time and space to provide ecological functions and processes (Forman and Godron 1986, Turner 1998).

Some landscape ecologists use a simple, three-component model as a conceptual tool to classify a landscape's spatial elements. The most common element in a landscape is referred to as the matrix. The matrix in many landscapes of the Pacific Northwest would be a continuous forest cover of conifers. In grass-tree mosaic landscapes of the northern Blue Mountains, however, the matrix would consist of grassland dominated by bluebunch wheatgrass, Idaho fescue, and prairie junegrass.

An important quality of the matrix is that it is the most connected element in the landscape; there are no inherent barriers to movement from one portion of the matrix to another. Like the open space in a pinball machine, energy, animals, or objects can move freely within the matrix area. Because it tends to be the most uniform of the three landscape elements, the matrix exerts the greatest control over landscape function (Diaz and Apostol 1992, Eng 1998).

An area within the landscape that is distinct from the matrix and isolated from other similar areas is called a patch. Patches are the second element in a conceptual model of landscape structure. Discrete patches result from disturbance events and from variation in the physical (abiotic) environment. Like the pins in a pinball machine, patches lack the connectivity of the matrix. A patch may consist of a single opening in a forest, or it could be a remnant stand of mature forest in a landscape matrix dominated by young trees or agricultural development (Diaz and Apostol 1992, Eng 1998).

The third element in a conceptual model of landscape structure is the corridor. Corridors are linear features or strips that differ from their surroundings on both sides. Corridors in a forested landscape can provide important connections between patches or non-adjacent portions of the matrix. Natural features such as riparian habitats along streams or rivers often function as corridors, providing connectivity between upper elevations or mid-slopes and the valley bottoms (Harrison and Voller 1998).

As important as corridors are, however, much of the connectivity in mature and old forests is through the matrix (Voller and Harrison 1998). In many landscapes and for numerous organisms, the matrix will be as important as, or more important than, corridors for connectivity. Since landscape patterns differ significantly from one ecosystem type to another, the type and degree of connectivity that exists in the natural landscape should serve as the primary blueprint when managers develop plans to provide corridors in managed landscapes (Franklin 1993).

Most connectivity objectives should be met using a coarse-filter approach (Aplet and Keeton 1999). Semi-permanent corridors (e.g., those with a relatively fixed location through time) are simple and flexible management tools that, because of their carefully chosen locations, can be more biologically effective than shifting or transient corridors. Semi-permanent corridors are often implemented as buffers adjoining streams, rivers, or other biologically sensitive components of the landscape (Harrison and Voller 1998).

Buffers provide some flexibility in terms of their characteristics (width, tree density, etc.) but are often inflexible with respect to their geographical location. Corridors should be designed to maintain continuity through time; therefore, it is important to consider buffer longevity in light of both native disturbance processes (such as wildfire- and insect-caused tree mortality) and planned disturbances such as timber harvesting or road building. If shifting corridors are to be used, then it is important to ensure that replacement corridors have the necessary attributes before existing corridors are exposed to planned disturbances such as timber harvest (Harrison and Voller 1998).

Riparian areas represent a dynamic interface or ecotone between water- and land-based ecosystems, where components of both systems interact. Native disturbance events (e.g., flooding, erosion, and sedimentation) are regular and predictable phenomena in these areas, causing fluctuations in plant communities, and in fish and wildlife populations. Some wildlife species use riparian corridors as a way to migrate from one area to another, but others find their primary habitat in a riparian zone because its greater diversity of plant species provides a wide variety of habitat conditions and niches (Voller and Harrison 1998).

BASIC PREMISE

To be successful, active management of RHCAs should emulate one or more aspects of the natural disturbance regime.

The management strategy most likely to sustain high levels of ecosystem integrity and resilience is emulation of natural disturbance processes. A disturbance emulation strategy outlines objectives and practices resulting in the least possible difference between active management practices and natural disturbance. A fundamental principle of disturbance emulation is that silvicultural practices, including prescribed fire and other management activities, should mimic the natural disturbance regime – and not just the fire characteristics, but all aspects including consideration of wind and other processes.

While a safe presumption is that active management will never function as a perfect surrogate for disturbance, presumably because nature has tremendous inherent variability and no two successive disturbance events will ever be identical anyway, it is also true that silvicultural interventions can effectively mimic certain aspects of disturbance regimes. “The object of disturbance emulation is not to make a clearcut look like a fire, but rather to recognize and understand the differences between management and natural disturbance, and to use that knowledge to improve harvest methods so as to impair ecosystems and their processes as little as possible” (Thompson 2002).

Disturbance emulation is similar to the range of variation in one important respect – disturbance functioned within an envelope of variability that was characteristic to both the process and to site potential, but the effect of repeated events fluctuated between upper and lower limits of a range, corroborating that nature did not ‘manage’ with perfect replication from one event to another.

When land is managed to produce water, wood, and other commodities desired by human society, a basic premise is that the greater the similarity between the effects of management activities and the effects of native disturbance regimes, the higher the probability that inherent ecological processes will continue without significant impairment (Aplet and Keeton 1999; DeLong and Tanner 1996; Hunter 1990, 1996, 1999; Mitchell et al. 2002; Roberts and Gilliam 1995; Rowe 1992).

FUNDAMENTAL ASSUMPTION

If active management can mimic nature well enough to ensure its effects are within the range of variation for a process, then it is reasonable to assume that management is not causing impact beyond what would have been produced naturally.

“During the 1990s, a consensus emerged among ecologists that the most promising approach for conserving biological diversity and ecosystem function in managed forests was to emulate the disturbance processes that drive forest succession and dynamics in natural, unmanaged forests (Hunter 1993, Attiwill 1994, Christiansen et al. 1996, Bergeron and Harvey 1997, Kohm and Franklin 1997).

A fundamental assumption of the disturbance emulation strategy is that plants and animals of a forest are adapted to conditions created by natural disturbance, so they should cope most easily with the ecological changes caused by forest management if the pattern and structure created by these activities resemble those of natural disturbance (DeLong 2011). Legacies are very important – “the importance of biological legacies is one reason that we should be careful in accepting management treatments as analogs for natural disturbances” (White et al. 1999).

From Naiman and Décamps (1997): “Long-term sustainability is likely to occur when managed systems imitate natural ones. Improved land use practices within the catchment and the maintenance of riparian zones for interception of groundwater flows by vegetation in various stages of succession (which differ in absorption capacity) are key factors for the long-term vitality of buffer strips and streams. Other benefits obtained from creative management and restoration of riparian zones includes provision of diversified habitat for terrestrial and aquatic wildlife, corridors for plant and perhaps animal dispersion, and input of organic matter to streams.”

IMPORTANT QUESTIONS

Are disturbance regimes similar for upland environments and adjacent RHCAs and, if so, under which circumstances might this be true? For situations where the disturbance regime appears to be similar for these two environmental settings, how might this influence a disturbance emulation strategy?

“Riparian forests exist within a matrix of sideslope forests and the role riparian forests play in the propagation or suppression of fire disturbance on the landscape is poorly understood. Riparian areas with heavy fuel loading and fuel continuity may serve as conduits (disturbance corridors) for the rapid spread of fire (Agee 1993). Conversely, the more mesic riparian areas may serve as fire breaks in surface fires. The disturbance relationship between riparian and sideslope forests can be anticipated to change in different landforms and plant associations. We know there are many feedback loops between riparian and sideslope forest systems but we do not understand how closely the fire disturbance regimes of riparian and sideslope forests are intertwined” (Everett et al. 2003).

“Pre-settlement forest structure and composition along first and second order streams in the Mixed Conifer zone resembled upland forests in the region. Given the historic continuity of fire disturbance between riparian forests and the adjacent uplands (Everett et al. 2003, Olson and Agee 2005), it may be beneficial to permit partial harvest treatments and prescribed fire in some riparian areas to allow the restoration of desirable characteristics of the pre-settlement forest structure and composition. Treatments may include the creation of large canopy gaps, untreated 'islands', clumps, and irregularly spaced trees. Because most riparian forests have not burned for 70-100 years, many trees that would have been killed by low- or moderate-severity fires are now too large to be killed by low-severity prescribed fires" (Messier et al. 2012).

Everett et al. (2003) came to a similar conclusion when they noted "our historical cohort information indicates reduced fire effects since the early 1900s have altered the number and age structure of cohorts in both sideslope and riparian forests, making them more similar. Increased homogeneity (reduced patchiness) has negative attributes of increased continuity in fuels and insect hosts that create significant problems in the management of sustainable forests" (Everett et al. 2003, p. 45).

The observation that forest composition and structure along low-order streams may not vary much from adjacent upland conditions (Dwire and Kauffman 2003, Messier et al. 2012) has also been noted for the Blue Mountains. "Olson (2000) found fire occurrence in riparian zones to be only slightly less frequent than on adjacent uplands in similar forest types in the Blue Mountains in Oregon" (Wright and Agee 2004, p. 454). As Olson noted in her thesis: "Keeping fire out of the ecosystem will not only continue to alter the structure and vegetational composition of these riparian forests, but will also allow the buildup of fuels that could result in unprecedented fire intensities, and subsequently higher fire severities, than were present in the system historically. If the goal of forest management is to restore historical disturbance regimes to these forests, results from this study indicate riparian forests should be managed according to the historical fire regime of the forest type rather than distance from a stream" (Olson 2000, p. 78) (in this context, "distance from a stream" refers to a process of using designated buffer widths (in feet), varying by stream class, to establish riparian habitat conservation areas).

Results from the Everett et al. (2003) research "indicate the percentage of shared fire disturbance between the riparian forest and the sideslopes is, in part, the combined result of the riparian forest plant association group, the sideslope plant association groups, and the topography of the site" (Everett et al. 2003, p. 41). And, a study examining Sierra mixed-conifer riparian vegetation (Russell and McBride 2001) "showed that proximity to water exerted a greater influence on vegetation composition than did historical fire occurrence" (Kobziar and McBride 2006).

From Rieman et al. (2000): "Because of a common history of past management disturbances, the apparent need to restore forests by active management will often coincide both spatially and temporally with the need to restore more functional aquatic networks. By extension, opportunities to conserve functional and healthy forests may coincide with opportunities to conserve functional and healthy aquatic ecosystems as well."

Many of the stand reconstruction studies cited in this section reported historical regimes of frequent fire that do not seem to differ from adjacent upland areas (Everett et al. 2003, Olson 2000, Olson and Agee 2005, Van de Water and North 2010). Results from these studies, however, do suggest that perennial streams may have greater influence on understory vegetation, fuel moisture, and relative humidity than was observed for intermittent or ephemeral channels, and perennial streams may have noticeably lower fire frequency than adjacent upland areas.

Therefore, the perennial-stream riparian areas may have functioned as filters (but not necessarily barriers) for fire spread because fires tended to burn through these areas only when regional (broad-scale) conditions were most favorable for fire spread (e.g., during drought periods or significant wind events).

CASE STUDIES

Fire history information for the Blue Mountains of northeastern Oregon and southeastern Washington is derived primarily from academic work completed by graduate students at the University of Washington. These students worked under the leadership of Jim Agee, fire ecologist and professor in the College of Forest Resources. Several of these studies deal in one way or another with aquatic ecosystems.

Diana Olson's M.S. thesis specifically addressed fire in riparian zones, and her work is cited several times in this white paper (Olson 2000, Olson and Agee 2005). Although her findings and conclusions are directly applicable to the issues examined in this white paper, she did not map fire extents so it is not possible to overlay her study areas with stream classes and RHCAs.

Emily Heyerdahl's Ph.D. dissertation examined spatial and temporal variation in historical fire regimes, and how they were influenced by climate, for four large watersheds in the Blue Mountains (Heyerdahl 1997, Heyerdahl et al. 2001). Although her work did not specifically target riparian ecosystems, she mapped her reconstructed fire extents, and it is possible to overlay the fire areas with stream classes and their associated RHCAs (and this was done – see Powell 2009 for the results).

Kat Maruoka's M.S. thesis examined the fire history for 15 sites located on three national forests in the Blue Mountains (Maruoka 1994), with a primary emphasis on dryer forest types in the Douglas-fir and dry grand fir forest series. Her study design did not involve mapping fire extents, so it is not possible to overlay her fire areas with stream classes and RHCAs.

Nate Williamson's M.S. thesis compared levels of crown-fire hazard between adjacent riparian and upslope habitats in the Blue Mountains of northeast Oregon. This work has some direct applicability to the issues examined in this white paper, but due to constraints associated with the study design, it is not possible to compare his sample areas with stream classes and RHCAs.

Case Study 1: Historical Fires of the Tucannon River Watershed

A large subwatershed within the Tucannon River watershed was one of four areas included in Emily Heyerdahl's study of historical fire regimes for the Blue Mountains (Heyerdahl 1997, Heyerdahl and Agee 1996). [The other three areas included Imnaha Creek and the Baker City watershed on the Wallowa-Whitman NF, and Dugout Creek on the Malheur NF.] Forty individual fire years were interpreted for the Tucannon River watershed, with the first one occurring in 1583 and the last one in 1898 (table 1).

Emily Heyerdahl provided us with shapefiles of her mapped fire extents for the Tucannon River study area. The individual fire extents were then overlaid with a base map consisting of four biophysical environments: cold upland forest, dry upland forest, moist upland forest, and nonforest (nonforest is comprised of all shrubland and herbland potential vegetation groups or PVGs). The geographical extent of the base map is one large subwatershed (HUC 170601070601) within the Tucannon River watershed.

The base map also includes riparian habitat conservation areas (RHCAs) consisting of buffered areas along streams, and it also shows the streams themselves. Note that the size (buffer width) of RHCAs varies by stream class; although stream class differences are not depicted on the fire maps portrayed in Powell (2009), the acreage summaries in table 1 do distinguish between stream classes 1, 2, 3, and 4. Base map themes (PVGs, RHCAs, streams) were derived from the same data sources used to prepare the Tucannon River watershed analysis released in August 2002 (USDA Forest Service 2002).

Note that fire-history studies generally result in reconstructed fire shapes that are undoubtedly simpler in outline than the actual fire extent. Mapped fire extents depicted in Powell (2009) with regular geometric shapes (1583 and 1618, for example) are probably portrayed with a less complex boundary than what actually occurred. Even if the intricacies of fire shape cannot be depicted perfectly, including unburned inclusions (skips) within a larger perimeter, the spatial extent and location of a fire on the landscape should be relatively accurate from either the fire-scar or the stand-age fire-history reconstruction technique (Heyerdahl and Agee 1996, Heyerdahl 1997).

Results of an analysis examining spatial interactions between historical fire extents in the Tucannon River drainage and RHCAs are summarized in table 1. Table 1 shows that:

- For the Tucannon River study area, 39 of the 40 fire years affected the dry-forest biophysical environment (defined as the Dry Upland Forest PVG), with the smallest fire extent on dry-forest sites being 29 acres and the largest affecting 1,935 acres. Mean fire extent on the dry-forest portion of 39 fires in a headwaters subwatershed of the Tucannon River watershed was 531 acres. Of the mean fire extent for dry forests, about 34.9 acres (6.5%) occurred within RHCAs, with 93% of the RHCA acreage associated with stream classes 3 and 4.
- For the Tucannon River study area, 37 of the 40 fire years affected the moist-forest biophysical environment (defined as the Moist Upland Forest PVG), with the smallest fire extent on moist-forest sites being 29 acres and the largest affecting 3,129 acres. Mean fire extent on the moist-forest portion of 37 fires in a headwaters subwatershed of the Tucannon River watershed was 532 acres. Of the mean fire extent for moist forests, about 125.3 acres (23.5%) occurred within RHCAs, but unlike the dry-forest situation, only 47% of the moist-forest RHCA acreage was associated with stream classes 3 and 4.
- For the Tucannon River study area, 18 of the 40 fire years affected the nonforest biophysical environment (defined as shrubland or herbland PVGs intermingled with the forest study areas), with the smallest fire extent on nonforest sites being 20 acres and the largest 113 acres. Mean fire extent on the nonforest portion of 18 fires in a headwaters subwatershed of the Tucannon River watershed was 60.6 acres. Of the mean fire extent for nonforest environments, about 3.2 acres (5.3%) occurred within RHCAs, and all of the RHCA acreage was associated with stream class 4.

Table 1. Acreage summary by fire year, potential vegetation group (PVG), and RHCA by stream class.

FIRE YEAR	TOTAL FIRE ACRES	DRY UPLAND FOREST PVG					MOIST UPLAND FOREST PVG					NONFOREST AREAS				
		Total Acres	RHCA Acres By Stream Class 1	2	3	4	Total Acres	RHCA Acres By Stream Class 1	2	3	4	Total Acres	RHCA Acres By Stream Class 1	2	3	4
1583	900.9	423.9	1.5		15.4		477.0	63.2		54.6	0.1	0.0				
1618	954.4	561.5			3.0	7.5	348.6			20.6	9.3	44.4				3.2
1630	973.4	663.9	0.1		34.7		309.5	51.2		29.2		0.0				
1635	354.4	41.4				2.4	313.0			20.7	0.9	0.0				
1652	1939.6	1133.0	2.2		37.9	0.2	751.2	51.3		68.5	7.3	20.1				
1664	544.3	344.8	0.1		9.1		199.4	35.9		22.4		0.0				
1671	1930.4	1157.5			13.5	5.4	727.5	31.8		53.9	16.2	45.5				3.2
1685	397.8	40.8					357.0			21.7		0.0				
1695	1049.7	638.4	1.4		37.7		411.3	67.3		50.1		0.0				
1703	1185.2	431.4	2.5		1.9	25.6	711.6	62.8		30.6	21.6	42.2				3.2
1705	317.6	231.8			0.7		85.9			6.6		0.0				
1706	1205.7	792.0					339.1	24.6			0.9	44.2				
1712	707.5	119.0			3.9	4.0	588.5	52.1		35.8	17.6	0.0				
1734	375.8	165.1					210.7	18.8			0.9	0.0				
1743	1056.2	352.9	0.0		7.6	25.6	670.0	63.1		39.5	22.7	33.4				3.2
1748	515.0	215.3	0.0		4.8		299.7	45.8		8.4	0.9	0.0				
1751	74.9	29.2	2.1				45.7	7.7		7.8		0.0				
1754	248.9	70.1					123.8			8.7		55.0				
1756	250.2	221.8					0.0					0.0				
1759	3190.8	1523.7	7.8		53.5	25.6	1571.7	170.0		90.6	31.8	95.4				
1765	670.5	192.8	2.4				414.7	44.7			0.9	63.0				
1774	4158.3	1393.3	3.4		58.9	4.0	2731.5	261.0		247.0	30.0	33.5				
1776	295.5	135.6					159.9	15.1				0.0				
1779	823.0	179.6			4.1	4.2	643.5	54.5		32.7	19.4	0.0				
1791	424.9	187.1			2.7		237.8			27.3	6.2	0.0				
1799	173.5	163.3					0.0					0.0				
1816	1131.1	650.9	2.7				417.2	42.3			0.9	63.1				

FIRE YEAR	TOTAL FIRE ACRES	DRY UPLAND FOREST PVG					MOIST UPLAND FOREST PVG					NONFOREST AREAS				
		Total Acres	RHCA Acres By Stream Class				Total Acres	RHCA Acres By Stream Class				Total Acres	RHCA Acres By Stream Class			
			1	2	3	4		1	2	3	4		1	2	3	4
1828	2443.1	967.9	3.4		8.3	25.6	1349.7	105.4		50.1	40.0	112.6				3.2
1839	1816.9	1258.9	4.0			18.2	459.9	52.6			0.9	80.6				3.0
1841	296.4	0.0					253.9			5.1		42.4				
1855	2543.4	1107.8	3.6		6.4	25.6	1309.9	105.2		46.3	40.4	102.4				3.2
1863	268.6	239.3			25.2		29.3	3.0		6.8		0.0				
1865	857.0	573.0	1.5		35.3		284.0	41.8		22.7		0.0				
1869	1088.3	643.2	0.1				382.2	38.4			0.9	62.9				
1873	507.0	320.7	2.6		3.5	0.3	186.2	9.6	1.7	46.6	8.8	0.0				
1883	74.9	29.2	2.1				45.7	7.7		7.8		0.0				
1886	1867.9	1285.3	3.4			21.3	480.4	53.5			0.9	83.0				3.2
1888	5137.6	1935.1	1.8	0.4	74.2	4.0	3129.0	269.1	3.2	236.8	50.1	67.1				
1893	47.1	46.4					0.8					0.0				
1898	489.7	257.3	1.6		12.7		232.3	69.1		15.8		0.0				
Mean	1082.2	531.4	2.2	0.4	19.8	12.5	532.2	63.9	2.4	45.3	13.7	60.6				3.2
Total	43287.2	20724.0	50.5	0.4	454.8	199.5	21288.7	1918.3	4.8	1314.5	329.5	1090.7	0.0	0.0	0.0	25.5

Sources/Notes: This tabular summary and the maps were prepared by David C. Powell and Robin L. Harris, Umatilla National Forest. The location, shape, and size of historical fires portrayed on the accompanying maps are based on Heyerdahl and Agee (1996) and Heyerdahl (1997). The base map, which shows four categories of potential vegetation group (cold upland forest, moist upland forest, dry upland forest, nonforest), was initially prepared for the Tucannon River ecosystem analysis released in August 2002. The base map pertains to one subwatershed: HUC 170601070601. Potential vegetation groups (PVG) are described in Powell et al. (2007). Riparian habitat conservation areas (RHCA) were calculated by using standard buffer widths, in feet (which vary by stream class), along with the Umatilla National Forest GIS theme providing stream location and stream classification (by class). Note that "RHCA Acres By Stream Class" values are not mutually exclusive – the acres shown by stream class are included in the "Total Acres" column by PVG. Also note that for nine of the fire years (1652, 1706, 1756, 1799, 1828, 1839, 1855, 1886, and 1888), the category acreages ("Total Acres" for the dry PVG, moist PVG, and nonforest sections) will not add up to the total (TOTAL FIRE ACRES) because a small portion of the mapped fire extended beyond the watershed boundary.

RECENT RHCA TREATMENT PROPOSALS

Several recent planning efforts for broad-scale vegetation management projects (timber sales and associated management activities) include proposals for RHCA treatment. Here are the RHCA treatment proposals for four recent projects on the Umatilla National Forest:

1. **Kahler project, Heppner Ranger District:** "Approximately 800 acres of dry upland, high density forest stands are within intermittent stream riparian habitat conservation areas (class IV RHCAs) in proposed units and would be treated to maintain or restore riparian habitat and upland vegetation including improvement of channel function and floodplain connectivity using a variable width no-mechanical zone adjacent to the stream channels. The no-mechanical zone width would vary depending on topography, stream type and vegetation. Within selected areas of the no-mechanical zone, hand thinning of small diameter (≤7" dbh) trees may occur. Selected trees may be felled along streams and left in the channel to provide for down wood. Some skipped areas within units would be located adjacent to stream no-mechanical zones to create variability along the stream corridor" (from Kahler scoping letter).
2. **South George project, Pomeroy Ranger District:** "Approximately 25 acres are proposed for non-commercial mechanical thinning with an improvement cut silvicultural prescription. To reduce the chance of crown fire, thinning would be used to disrupt canopy continuity in dry forest RHCAs, and prescribed fire would be used to reduce existing and created ground fuel. Trees would be removed in the 4 to 18 inches DBH range. Yarding would be accomplished by utilizing full suspension methods. No trees would be skidded through RHCAs. Material would be decked, but not included in South George commercial timber sales" (from FEIS for South George Vegetation and Fuels Management Project, chapter 1, Purpose and Need).
3. **Tollgate project, Walla Walla Ranger District:** "Alternative B would treat Riparian Habitat Conservation Areas (RHCAs) that hold strategic importance within the analysis area. RHCAs located within units 19, 38, 66, and 75 would be affected by fuels reduction activities. A buffer with no fuels reduction activities will be retained 30-100 feet beyond each side of the stream channel (Table 1-3). These RHCAs would be treated with mechanical means such as timber harvest. Logging systems would be designed so that no harvest or skidding would cross active stream channels. Only RHCAs within the units identified above would receive treatment, all other RHCAs would receive the standard Pacfish buffers."
4. **Wilkins project, North Fork John Day Ranger District:** "Treatments in Riparian Habitat Conservation Areas (RHCAs): Under the commercial thinning (CT) with potential noncommercial thinning (NCT) treatment, units 3 and 27 have been proposed for commercial thinning in the RHCA. Trees up to 21 inches DBH would be commercially harvested within the outer 50 feet of the 100 foot buffer along the Class IV streams in these units. This commercial harvest in the outer 50 feet of the stream buffer proposes the use of mechanized equipment. Non-commercial thinning may take place within the inner 50 feet of the 100 foot stream buffer, but no mechanized equipment will be used within the inner 50 feet along the Class IV stream. No commercial or noncommercial thinning will take place in an RHCA in any other units designated for CT with NCT treatment" (wording for CT with NCT units). "Treatments

in Riparian Habitat Conservation Areas (RHCAs): RHCAs in all units designated NCT (mechanical) or NCT (hand only) are proposed for noncommercial thinning where a localized need to reduce fuels within the 100 foot Class IV stream buffer is identified. This thinning will be done by hand only, even if the unit is designated NCT (mechanical). Use of mechanized equipment within the 100 foot stream buffer is not proposed for any units designated NCT (mechanical) or NCT (hand only)" (wording for NCT-only units).

OPPORTUNITIES AND RECOMMENDATIONS

Dialogue about riparian thinning and other active management practices for RHCAs provides an excellent opportunity for interdisciplinary learning. And, I believe we will ultimately learn that dialogue is powerful; it can be used both to understand riparian ecosystems, and to influence their management. To effectively capitalize on learning opportunities, RHCA treatment planning and implementation should occur in an adaptive management framework (fig. 1).

When considering RHCA treatments for the first time, we should consider applying them on a small scale. We need to be aware of, and understand, the risks being taken, and recognize that mistakes are probably inevitable. Because each implementation is a new learning experience, we need to be creative and innovative to whatever extent the circumstances will allow, while remembering that we learn best from our mistakes. The bottom line is: start slowly with a forgiving project area or management context, so the lessons we learn come with minimal pain and are less likely to foreclose future options for further learning opportunities.

The following opportunities and recommendations are viewed as contributing to an interdisciplinary learning environment by fostering adaptive active management of RHCAs.

1. **Go slow at first** – *focus riparian thinning proposals on RHCAs associated with intermittent drainages (class IV) in the dry upland forest biophysical environment*. Credible scientific rationale suggests that RHCA treatments could also be considered for these moist forest environments: (1) the low fire-return-interval portion of the mixed-severity fire regime (fire regime IIIa), and (2) moist-forest plantations where RHCAs need to be restored because they received inappropriate silvicultural treatments during an earlier era (i.e., the RHCAs were clearcut along with the adjoining uplands). The ecological need for dry-forest RHCA treatments, however, is more pressing now than it is for moist-forest RHCAs.
2. **Recognize scientific realities** – *peer-reviewed science with high relevance for northeastern Oregon and southeastern Washington already exists for dry forest* (such as Everett et al. 2003, Heyerdahl 1996, Howell 2006, Olson 2000, and Williamson 1999). Although perfect scientific consensus will never exist for any subject, we have enough scientific clarity to move forward on dry-forest RHCA treatments, particularly if we do so in an adaptive management context (fig. 1).
3. **Acknowledge data realities** – *the need for dry-forest RHCA treatment is pressing, and treatments cannot wait for detailed, reach-specific inventory before proceeding*. In a perfect world, we would have access to high-quality information about the biotic and abiotic components for every RHCA on the Umatilla NF (regardless of whether they occur in dry, moist, or cold biophysical environments), but such is not the case. Even so, *we know enough about*

dry-forest RHCAs to proceed in a cautious manner and still meet our project planning time-lines, especially since RHCA data can be gathered as project planning progresses.

4. **Learn from previous experiences and events**. RHCAs in dry forest were affected by salvage harvest following the 1996 Wheeler Point Fire. What did we learn there? Dry-forest RHCAs have been affected by many wildfires across the Forest (including the 1996 Tower Fire; the 2005 School and Monument fires; and Sugarbowl, Bull Springs, and other small fires; fig. 2). Can lessons learned from wildfire (such as Howell 2006) be instructive when crafting a disturbance emulation strategy for RHCA management? For example, *how might RHCA treatment proposals be formulated to avoid the undesirable fire effects associated with certain fuel complexes, or to mimic some of the desirable fire ecology associated with properly functioning wildfire*?
5. **Consider riparian management in a forward-looking context**. We know climate change is already here, and its impact will become more pronounced over the next 30-50 years, including effects such as ramped-up fire occurrence (fig. 3). Since forest ecosystems respond relatively slowly to modification (especially when compared with short-rotation agricultural cropping such as dryland wheat production), *we must look forward by anticipating the ecosystem and climate conditions of 2050 when designing active management treatments for implementation in 2015*.
6. **Consider resiliency when planning for RHCA treatments**. The projected fire trends in figure 3 are alarming, particularly since temperature modeling predicts substantially more than 1° C (1.8° F) of future warming. As these climate change trends unfold, we will be well served if our contemporary treatments have been planned in a fire-safe context (but they really need to be climate-safe by considering climate change effects beyond just the wildfire information presented in fig. 3). How might we do this? One way is to use our knowledge of species-specific life-history traits to *create a future species composition best adapted to future climate and disturbance trends*. Table 2 provides life-history traits, by tree species, which are specifically directed toward climate change effects.
7. **Consider the ecological setting in which RHCAs occur**. RHCAs established for dry-forest, intermittent drainages seldom contain water-influenced vegetation. Even so, they are believed to represent a riparian-influence zone. But when placed on an ecological temperature-moisture gradient, dry-forest RHCAs for intermittent channels (class IV) have a stronger affinity with adjacent uplands (figs. 4-5) than with hydric sites adjoining perennial streams (class I RHCAs). This reality means that *well-designed RHCA treatments could incorporate many of the same concepts and principles used for dry-forest uplands* (such as Fulé et al. 2012), but with inclusion of additional mitigation measures to ensure that riparian management objectives are achieved. [Research suggests a correspondence between upland and riparian settings for some situations – Danehy and Kirpes (2000) found that within 10 m (about 33 feet) of the stream edge, relative humidity (RH) was similar to upland conditions, with little additional RH change beyond 10 m.]
8. **Acknowledge the fire dependence of dry-forest RHCAs**. While there is not as much science examining dry-forest riparian environments as there is for dry-forest uplands, we have locally relevant science specifically addressing riparian environments (Olson 2000 and Williamson

1999 are two primary sources for the Blue Mountains, and Everett et al. 2003 is an excellent secondary source from eastern Washington). These relevant sources suggest that *dry-forest riparian zones experienced similar amounts of stand-maintaining surface fire as adjacent dry-forest uplands*.

9. **Account for special vegetation types such as quaking aspen**. Aspen is often viewed as a riparian-obligate species, particularly for areas such as the Blue Mountains where aspen tends to occur along swales or in intermittent channels (but aspen is seldom found along large perennial streams, which typically support black cottonwood, willows, river birch, and thinleaf alder). Aspen is in very tough shape in the Blues (Swanson et al. 2010) – *if we hope to improve aspen's resilience and ensure its persistence, we need to be willing to treat dry-forest RHCAs containing aspen by removing competing conifers* (fig. 6).
10. **Use relevant science <u>and</u> local disturbance history when planning RHCA treatments**. Peer-reviewed, locally-relevant science (such as Everett et al. 2003, Heyerdahl 1996, Howell 2006, Olson 2000, and Williamson 1999) provides an indispensable and compelling context for dry-forest RHCA treatments, but science cannot tell the whole story. For example, when large ponderosa pines with basal fire scars are found within a dry-forest RHCA (fig. 7), we know that fire was an important process because basal fire scars ('catfaces') form in response to recurring fire. [Indicators like catfaces are important because they provide evidence about an area's disturbance regime, rather than reflecting the effects of a single disturbance event.] So, *local science should be used in combination with on-site indicators of disturbance history when preparing ecologically appropriate treatments* (fig. 7).
11. **Develop tools to help identify RHCAs during project layout**. If the Forest continues to cautiously move forward with dry-forest RHCA treatments, then layout personnel need additional resources to properly identify and delineate class IV RHCAs in the field. *Perhaps a field guide could be developed, and perhaps it could include photographs to illustrate common channel situations*? A guide will never substitute for on-site training provided by a hydrologist, and on-site training must occur for RHCA treatments to be successful, but a hydrologist cannot be present during the entire time a project is being laid out and prepared.
12. **Recognize that initial RHCA treatments may be similar to adjacent upland treatments**. We are just beginning to consider RHCA treatments for dry forests, so initial treatment proposals are not very sophisticated. This is appropriate because like any endeavor, *the natural evolution of RHCA treatments will be from simple to complex*. We must crawl before walking; current RHCA treatment proposals reflect the 'crawling' phase of this progression. After learning from our crawling experience, we will eventually reach the 'walking' phase, and RHCA treatments will then include enough sophistication to clearly distinguish them from upland treatments, although I suspect the differences may continue to be subtle for some dry-forest settings.
13. **Vegetation treatment options for RHCAs could be handled consistently.** A wide variety of activities are being used to actively modify vegetation conditions, ranging from prescribed fire to silvicultural treatments. Prescribed fire projects such as the Bear Creek burn (Walla Walla RD; fig. 8), for example, accomplished many interdisciplinary objectives across a rela-

tively broad spectrum of habitats, including RHCAs, so *wouldn't it be consistent to also consider modifying vegetation conditions in RHCAs by implementing silvicultural treatments*?

14. **Consider the influence of riparian vegetation on riparian food webs (fig. 9).** Riparian vegetation affects the characteristics and amount of autumn leaf-shed into lotic systems, which in turn affects the composition and abundance of invertebrates and other consumers of this material (Giller and Malmqvist 2008). Alder litter, for example, is broken down very quickly due to its high nitrogen content and relatively low levels of volatile compounds (phenols, tannins, etc.). When considering both litter quality and quantity, the following hierarchy is important:
    - High: alders;
    - Moderate: maple, willow, and cottonwood;
    - Low: oak, conifers.

    Implications: This hierarchy suggests that if a riparian reach has transitioned from a shrub-dominated plant community featuring Rocky Mountain maple, Bebb willow, black cottonwood, and perhaps a few thinleaf alders, as the historical condition, to a community dominated by conifers (Douglas-fir, grand fir, and perhaps a few Engelmann spruces) as the existing condition, then a dramatic change in the composition and abundance of lotic invertebrates, and the fish species relying on them as a food source, would be expected. Salmon ecologists have long known that the fresh-water food chain on which young salmon depend begins with the nitrogen-fixing capability of alders and their bacterial symbionts (Hocking and Reimchen 2002) (bacteria fix nitrogen in nodules located on the root system of these species). The nitrogen necessary for the salmon food chain gets into the streams through alder leaf and twig fall, and possibly through additions from groundwater and subsurface seepage (including from the hyporheic zone). Alders and similar species (birch, aspen, cottonwood, etc.) are early-successional (early-seral) and relatively short-lived species (table 2), so some level of stand-initiating disturbance at recurring intervals is necessary not only for alder and birch persistence, but also for the continuity and well-being of salmon.

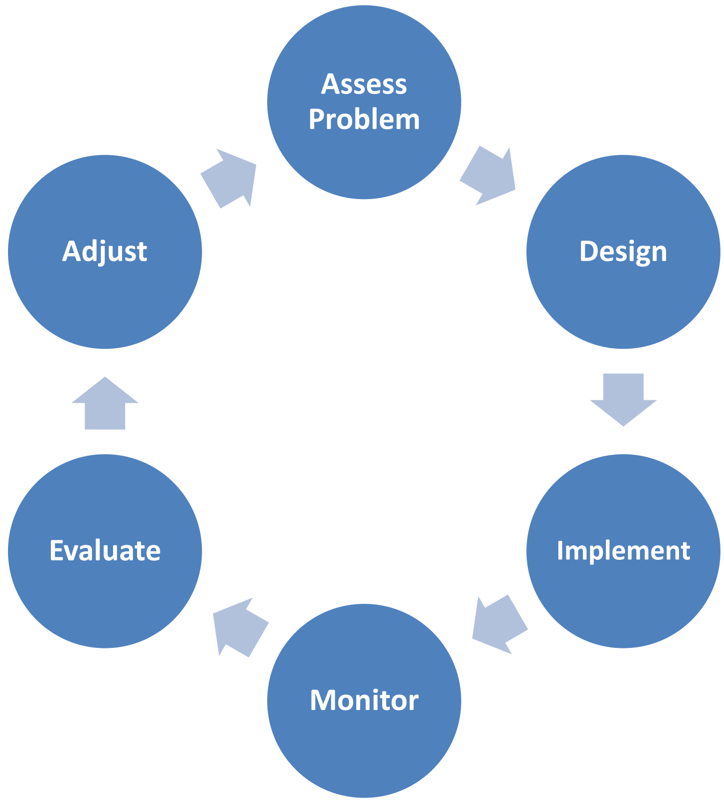

Figure 1 – Adaptive management cycle. Adaptive monitoring efforts must be capable of measuring (detecting) the outcomes of alternative management approaches; this is fundamental to any effective partnership between management and adaptive monitoring. Monitoring implies continuous assessment of one or more variables. It is a set of measures taken as a time series, thereby providing trend data through time. And in a management context, monitoring is "the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective" (Elzinga et al. 1998). Muddling through (Lindblom 1959) is sometimes adopted as a management strategy, but its lack of tactical clarity leaves a lot to be desired.

[My subjective opinion is that we really need to reduce our amount of muddling through by creatively deciding how to free up sufficient resources (money, manpower) to replace a muddling-through approach with explicit monitoring.]

The adaptive management cycle could be especially important for RHCA-management because this approach accounts for seemingly opposite judgments about an issue – stakeholders can support active and passive management (or no management) simultaneously because of their expectation that each of them would be applied in different and carefully selected areas, in which case both active and passive management could easily coexist somewhere on the same landscape (Olsen and Shindler 2010).

Figure 2 – Fire effects experienced in the Oriental Creek drainage of the North Fork John Day Ranger District as a result of the 1996 Tower Fire (photo acquired by Dave Powell, July 1998). The Tower fire contains at least three different fire regimes, and each regime features varying amounts (proportions) of fire severity.

Some proportion of high-severity fire effects, where much of the aboveground vegetation is top-killed, is an expected (characteristic) outcome for two of the fire regimes (e.g., fire regimes III, mixed-severity, and IV, replacement), including the large extent of mixed-severity fire regime found in the Cable Creek, Winom Creek, and Big Creek portions of the fire area.

But for the Texas Bar Creek and Oriental Creek portions of the Tower Fire, where the prevailing fire regime is a low-severity, high-frequency situation (e.g., fire regime I) and the biophysical environment features dry forests, we would not expect long, continuous, connected portions of the drainages and their associated RHCAs to experience stand-replacing fire effects.

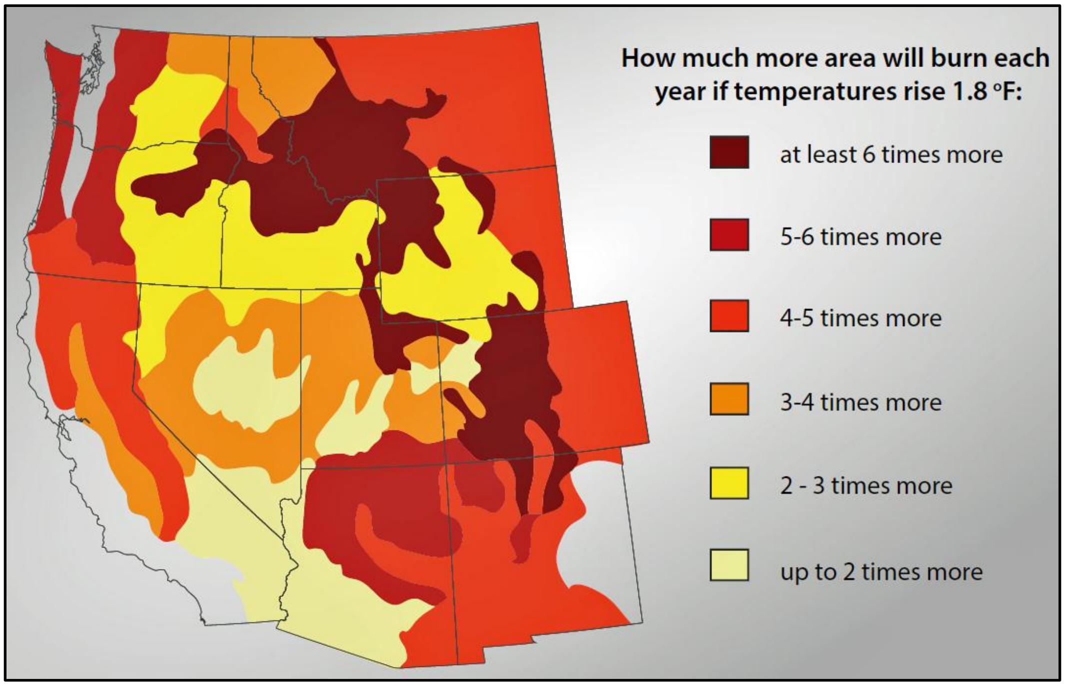

Figure 3 – Predicted increase in area burned by wildfire as associated with a mean annual temperature increase of 1 °C (1.8 °F), shown as the percentage change relative to the median annual area burned during 1950-2003 (source: Climate Central 2012). Results are aggregated to ecoprovinces (Bailey 1995) of the western U.S. Climate-fire models were derived from National Climatic Data Center climate division records and observed area burned data following methods described in Littell et al. (2009). The prediction shown here is similar to several reports from the National Research Council showing at least a quadrupling of area burned in the western U.S. with each 1 °C of temperature increase (figure adapted from figure 5.8 in National Research Council 2011).

This prediction is alarming because over the period from 1970-99 to 2070-99, an increase in average annual temperature of 3.3 to 9.7 °F is projected, depending largely on whether global emissions eventually decline (the B1 greenhouse gas emissions scenario) or continue to rise (the A1B and A2 emission scenarios), and the temperature increase is projected to be largest in summer.

"The divergence in fire and climate since the mid 1800s has created a fire deficit in the West that is jointly attributable to human activities and climate change, and unsustainable given the current trajectory of climate change. Current fire exclusion and suppression however, is taking place under conditions that are warmer and dryer than those that occurred during the MCA (Medieval Climate Anomaly) (ca. 950-1250), which calls into question their efficacy" (Marlon et al. 2012).

Note that summer precipitation is also projected to decrease by as much as 30% by the end of the century. [And the summer of 2012, when many areas went 90 days or more without any recorded precipitation, experienced just such a decrease. Climatologists have already coined a term for this long period under a high-pressure dome – global stilling.] Northwest summers have a Mediterranean summer-dry climate and are already dry, so a 30% reduction in summer precipitation represents a relatively small amount of the total annual precipitation, but unusually dry summers have noticeable consequences, including low streamflow west of the Cascades and greater extent of wildfires throughout the region (Littell et al. 2010).

Table 2: Life history traits for tree species of the Blue Mountains; traits were selected with relevance to climate-change adaptability.

	Pacific ponderosa pine (*Pinus ponderosa* var. *ponderosa*)	**Western larch (*Larix occidentalis*)**	**Rocky Mtn. lodgepole pine (*Pinus contorta* var. *latifolia*)**	**Quaking aspen (*Populus tremuloides*)**	**Black cottonwood (*Populus balsamifera* ssp. *trichocarpa*)**	**Thinleaf alder (*Alnus incana* ssp. *tenuifolia*)**	**Water birch (*Betula occidentalis*)**	**Western white pine (*Pinus monticola*)**	**Interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca*)**	**Engelmann spruce (*Picea engelmannii*)**	**Grand fir (*Abies grandis*)**	**Subalpine fir (*Abies lasiocarpa*)**
Tolerance to shading	L	L	L	L	L	M	M	M	M	H	H	H
Tolerance to full sunlight	H	H	H	H	H	H	M	H	M	L	L	L
Seral status	Early	Early	Early	Early	Early	Early	Mid	Mid	Mid	Late	Late	Late
Tolerance to frost	L	L	H	H	M	H	H	H	L	H	M	M
Tolerance to drought	H	M	M	L	L	L	L	M	M	L	M	L
Rooting habit (depth)	D	D	M	S	M	S	S	M	D	S	S	S
Average lifespan (years)	300	300	100	100[4]	100	50-75	50-75	400[1]	200	250	200	150
Fire resistance	H	H	L	L[2]	L[2]	L[2]	L[2]	M	M	L	L	L
Evolutionary mode	Inter	Inter	Spec	NR	NR	NR	NR	Gen	Spec	Inter	NR	NR
Regeneration on charred or ashy soil	IN	NE	NE	IN	IN	IN	IN	IN	IN	RE	IN	NR
Maximum seed dispersal distance (feet)	120	150	200	1600[3]	660[3]	NR	300[3]	400	330	120	200	100
Potential for regeneration in the open	H	H	H	H	H	H	M	H	H	M	L	L
Overall reproductive capacity	H	H	H	H	H	H	H	H	H	M	M	M

Sources/Notes: Ratings are derived from the Fire Effects Information System (USDA Forest Service 2013), the North America silvics manuals (Burns and Honkala 1990a, 1990b), autecological summaries such as Klinka et al. (2000) and Minore (1979), and a variety of other sources. Rating codes are: L, low; M, moderate; H, High; D, deep; S, shallow; IN, increased; NE, no effect; and RE, reduced. Average lifespan values are taken from Powell (2000) and a few other sources. Evolutionary mode refers to the amount of genetic differentiation; it is an indicator of how well a species could adapt to future climates (Gen is generalist; Inter is intermediate; Spec is specialist; NR is not rated; source is Rehfeldt 1994). Overall reproductive capacity considers minimum seed-bearing age, seed crop frequency and size, seed soundness, and related factors.

[1] This average lifespan value is based on historical western white pine populations unaffected by white pine blister rust, an introduced disease with negative influence on the longevity of western white pine and other five-needled pines.

[2] Fire resistance ratings reflect the ability of existing stems to survive exposure to fire. All of these species have relatively thin bark that does not insulate the stem's cambium layer from fire damage, so fire generally top-kills them. All have high reproductive capacity, however, because they have many adaptations assisting with their post-fire recovery (e.g., root-crown sprouting, root-system suckering, rooting capacity of leafy stems that excise from the stem (cotton-wood), etc.)

[3] These riparian trees have very small seeds, and some also have 'cotton' appendages on their seed to aid in long-distance dispersal. Due to their common proximity to perennial streams, water transport of their seeds (e.g., hydrochory) is also important. The combination of light seed weight and water dispersal often results in a small proportion of their seed being dispersed for several miles or more from the parent tree.

[4] A commonly cited average age for aspen ramets (stems produced from the underground root system called a genet) is 100 years, with a maximum lifespan of 200 years claimed (Burns and Honkala 1990b). However, the genet (root system) of aspen clones has been found to be thousands of years old, so the individual ramets of an aspen clone may be short-lived, but the genet (clone) may be thousands of years old and older than the oldest giant sequoia or Great Basin bris-tlecone pine (two conifers known for longevity exceeding a thousand or more years). This also means that a single root system may have produced 50 to 100 generations of aspen ramets (stems) during its lifespan, each of which persisted for a hundred years or more. Genetic testing, for example, indicates that an ancient clone has existed for thousands of years in the Morsay Creek drainage of the North Fork John Day Ranger District (Shirley and Erickson 2001)

Figure 4 – Class IV RHCA in a dry-forest biophysical environment of the Kahler planning area, Heppner Ranger District (photo provided by Jonathan Day). Note that the predominant species in this RHCA is ponderosa pine, a tree adapted to fire-dependent ecosystems evolving in response to recurring surface fire on a return interval of 5-20 years in the Blue Mountains. Also note the presence of a small patch of snowberry (probably common snowberry, *Symphoricarpos albus*) in the center of the photograph. Areas adjacent to the snowberry are dominated by herbaceous plants, probably rhizomatous graminoids such as pinegrass (*Calamagrostis rubescens*) and elk sedge (*Carex geyeri*). In this forest setting, the snowberry functions as an indicator of a slightly increased soil moisture regime when compared with the adjacent graminoid areas, but snowberry is not a riparian shrub (e.g., it is not considered to be a riparian-obligate plant species for forested environments). In other words, the vegetation on this site represents a soil moisture continuum, with graminoid-dominated areas located on sites with slightly less soil moisture, and common snowberry in areas with slightly elevated soil moisture.

[But this discussion is context-specific: for some nonforest environments such as the Zumwalt Prairie in far northeastern Oregon, common snowberry occurs with black hawthorn, mockorange, and other shrubs as riparian vegetation.]

This discussion illustrates the value of being able to interpret an area's existing vegetation composition when deciding if a riparian environment is present. A useful definition of a riparian zone or environment is provided by Naiman and Décamps (1997): "it is the portion of the stream channel occurring between the low and high water marks and adjacent terrestrial areas extending from the high water mark toward the uplands where vegetation may be influenced by elevated water tables or flooding." This definition demonstrates that hydrologic and geomorphic connections exist, at least intermittently, between a stream (channel) and its riparian area.

Figure 5 – Class IV RHCA in a dry-forest biophysical environment of the Kahler planning area, Heppner Ranger District (photo provided by Jonathan Day). The class IV drainage is the shallow swale located just to the right of the large ponderosa pine, and continuing toward the middle-ground portion of the photograph. Note how the channel becomes more pronounced in the middle-ground scene where it passes beneath the small downed log.

No obvious differences in vegetation composition between the channel vicinity and adjacent uplands are apparent in this photograph. The presence of ponderosa pine on this site suggests that at some point in the past, presumably before Euro-American influence resulted in widespread fire exclusion, conditions were acceptable for establishment, survival, and persistence of ponderosa pine – an early-seral species requiring mineral soil for seed germination, and open (unshaded) conditions for establishment and normal (unsuppressed) development (table 2 describes some of the regeneration-ecology traits allowing ponderosa pine to become established and persist on open sites, including site conditions providing mineral-soil or fire-influenced substrates).

Figure 6 – Large-diameter ponderosa pines occurring within a fenced aspen clone on the North Fork John Day Ranger District (photo provided by Dave Powell). This site does not appear to have hydrophytic plants or other vegetative indicators suggesting it would qualify as an RHCA. In some circumstances, however, the mere presence of aspen is enough to declare an area an RHCA (particularly when aspen is considered to be a riparian-obligate plant species like certain sedges or rushes). In other instances, aspen is associated with class IV RHCAs on dry-forest biophysical environments and, in many of these situations, the aspen is comingled with conifers casting shade and otherwise competing with aspen for site resources.

One common indicator of impaired clonal function is a single cohort of aspen stems (Swanson et al. 2010), generally in conjunction with a lack of regeneration in the form of root sprouts (aspen is a coppice species – it does not regenerate from basal-stem or root-collar sprouts like cottonwood and many other broadleaf trees – it regenerates from the root system by using suckers).

Removing the large ponderosa pines in this photograph could be problematic due to the Eastside Screens amendment to the Forest Plan, but an alternative would be to kill many of the pines in place (by girdling them, for example) and thereby nullify their influence as a suppressor. But consider the fence when evaluating a girdling operation because the fence may be compromised when girdled trees (snags) fall in 5-6 years.

Some folks disagree with removing old ponderosa pines to favor aspen regeneration and persistence, but consider that the aspen root system (genet) may be thousands of years old, whereas the pines may be only 200-300 years old. Genetic testing, for example, indicates that an ancient clone has existed for thousands of years in the Morsay Creek drainage (Shirley and Erickson 2001) (and see footnote 4 to table 2).

Figure 7 – Many ponderosa pine trees have basal scars ('catfaces') caused by recurrent surface fire, a pervasive disturbance process before wildfire exclusion began around 1900 (image acquired by Dave Powell on the North Fork John Day Ranger District in October 2009). Species like ponderosa pine achieve fire tolerance by developing thick bark to protect their cambium, and by self-pruning their lower crown to raise the crown height base above average flame height in the event of a fire. "Both of these characteristics are size dependent; thick bark is a relative characteristic with individuals of larger diameter having thicker bark, and crown height is dependent on the height of individuals" (Roberts and Betz 1999). When present in dry-forest RHCAs, catfaces and similar indicators (Gutsell and Johnson 1996) provide insights about disturbance history, and these clues are valuable when formulating ecologically relevant treatments.

Figure 8 – Distant view of a portion of the Bear Creek prescribed fire project area on the Walla Walla Ranger District (photo provided by Eric Pfeifer). This burn was completed in the 'grass-tree mosaic' ecosystem type of the northern Blue Mountains. Much of the tree portion of this ecosystem type occurs as timber stringers on moist aspects (north and east facing slopes), or on lower slope positions accumulating soil moisture as it moves downslope under gravity's influence.

By virtue of their lower slope position, some of the areas affected by this prescribed fire project occur within RHCAs, and some of them experienced high-severity fire effects when fire moved up-drainage during periods of active fire behavior. This fire was intensively monitored after project implementation, including the RHCA portions, where a specific objective was to limit mineral soil exposure to less than 20 percent of the project area (Pfeifer 2005).

[Note that sampling was stratified to distinguish between effects within and outside of RHCAs, and when project-wide totals were calculated, the monitoring results were weighted according to the RHCA proportion of the overall project area.]

Figure 9 – Riparian planting near Texas Bar Creek in the Tower wildfire area, North Fork John Day Ranger District. Riparian areas are known for their capability to recover following disturbance, but their resilience is not limitless, so planting and other post-disturbance activities are often completed to help boost the recovery processes. For the Texas Bar Creek portion of the Tower Fire (the fire occurred in 1996), the uplands were planted with a conventional mixture of trees involving 3-4 species for most sites, and the riparian areas were planted with a mix of thinleaf alder, water birch, red-osier dogwood, black hawthorn, black cottonwood, alderleaf buckthorn, and either coyote or dusky willow.

Many of the riparian species were established by using nursery-produced seedlings (either bare-root or containerized), whereas some of the black cottonwood and willow plantings were established by using rooted cuttings or freshly harvested whips – cottonwood tended to use autumn cuttings that were overwintered and then rooted during the following spring (i.e., cuttings collected in November 1997, overwintered as cuttings, rooted in the spring of 1998, matured through the summer and autumn of 1998, placed into winter dormancy or cold storage, and then out-planted in the spring of 1999 as containerized stock); willows tended to use whips (branch cuttings) harvested from local, adjacent sources and then out-planted immediately into suitable microsites within an identified stream reach.

The mixture of species used for riparian plantings varied by stream reach as based on each reach's specific characteristics (elevation, floodplain width and gradient, etc.). This reach-specific approach requires quite a bit of preparatory work to be successful.

Plastic mesh (Vexar©) tubing was installed around most of the seedlings to prevent or limit browsing damage from large, native ungulates (deer and elk primarily). Similar riparian planting occurred in portions of the Oriental Creek drainage in the Tower Fire (see fig. 2), and in the Alder Creek drainage of the Wheeler Point wildfire, another large fire that also occurred in late summer of 1996.

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The photographs and graphics used in this report were acquired or produced by David C. Powell unless noted otherwise in the figure caption.

APPENDIX 1: RIPARIAN MANAGEMENT REFERENCES

This appendix includes references dealing with riparian management. The Silviculture Library (managed using EndNote bibliographic software) was queried for all references where the word 'riparian' was associated with any of the keywords. This query returned more than 250 references. I reviewed the query list and pared it down to just the most relevant references (in my opinion); they are included in this appendix.

Since the context for this white paper is active vegetation management, only references pertaining to vegetation considerations, disturbance ecology, and biotic components of riparian ecosystems are included here. References about physical or hydrological processes are not included unless they address a vegetation management practice, activity, or treatment (e.g., fine sediment production in response to timber harvest or another treatment).

Some references have an 'Abstract,' which is provided exactly as it was phrased in the published work. Other references include a 'Summary,' which was prepared by the author of this white paper. Summaries are only provided for works without a published abstract.

Particularly relevant citations (from my perspective), primarily because of their geographical or topical context, are shown in red text. With some exceptions, references pertaining to the Blue Mountains, the Eastside (eastern Oregon and eastern Washington), or the intermountain West are included here. References dealing with western Oregon or western Washington (the Westside) are generally not included in this appendix due to significant climatic differences between the Eastside and the Westside (and climatic differences result in differing disturbance regimes, along with other processes or functions, between the two areas).

For journal papers, a digital object identifier (doi) is provided when one has been assigned; for books, an international standard book number (isbn) is provided.

Abernethy, B.; Rutherfurd, I.D. 2000. The effect of riparian tree roots on the mass-stability of riverbanks. Earth Surface Processes and Landforms. 25(9): 921-937. doi:10.1002/1096-9837(200008)25:9<921::AID-ESP93>3.0.CO;2-7

Abstract: Plants interact with and modify the processes of riverbank erosion by altering bank hydrology, flow hydraulics and bank geotechnical properties. The physically based slope stability model GWEDGEM was used to assess how changes in bank geotechnical properties due to the roots of native Australian riparian trees affected the stability of bank sections surveyed along the Latrobe River. Modeling bank stability against mass failure with and without the reinforcing effects of River Red Gum (*Eucalyptus camaldulensis*) or Swamp Paperbark (*Melaleuca ericifolia*) indicates that root reinforcement of the bank substrate provides high levels of bank protection. The model indicates that the addition of root reinforcement to an otherwise unstable bank section can raise the factor of safety (Fs) from Fs = 1.0 up to about Fs = 1.6. The addition of roots to riverbanks improves stability even under worst-case hydrological conditions and is apparent over a range of bank geometries, varying with tree position. Trees growing close to potential failure plane locations, either low on the bank or on the floodplain, realize the greatest bank reinforcement.

Alpert, P.; Kagan, J. 1998. The utility of plant community types: a practical review of riparian vegetation classification in the intermountain United States. Natural Areas Journal. 18(2): 124-137.

Abstract: We address three questions concerning the utility of classifying vegetation into plant community types: How are vegetation classifications used? How are vegetation classifications conducted? How should classifications be conducted so as to be most useful? We focus on riparian vegetation classifications, with particular emphasis on the intermountain United States, and add examples from other habitats. We conclude that community types are useful units of vegetation classification largely because they are few in number relative to species, are easy to detect relative to species or ecological functions, yet often are correlated with these and other biological and physical factors. In practice, vegetation classifications show an apparently inevitable trade-off between scope and rigor. Hierarchical classifications based on quantitative, directly measured characters seem to be the most adaptable to different uses.

Alstad, K.P.; Hart, S.C.; Horton, J.L.; Kolb, T.E. 2008. Application of tree-ring isotopic analyses to reconstruct historical water use of riparian trees. Ecological Applications. 18(2): 421-437. doi:10.1890/06-1969.1

Abstract: Historical patterns of water source use by trees inferred from long-term records of tree-ring stable isotopic content could assist in evaluating the impact of human alterations to natural stream flow regimes (e.g., water impoundments, stream flow diversions, and groundwater extraction). Our objective was to assess the utility of the hydrogen stable isotopic composition (δD) of tree rings as an index of historical water source use by riparian trees. We investigated the influence of site conditions that varied in climate and hydrology on the relationship between δD of Populus xylem water (δDxyl) and tree-ring cellulose (δDcell). δDxyl and δDcell were strongly correlated across sites ($r^2 = 0.89$). However, the slope of this relationship was less than 1, indicating that factors other than δDxyl influenced δDcell. Inverse modeling with an isotopic fractionation model for tree-ring cellulose suggested that the lack of one-to-one correspondence between δDxyl and δDcell was due to the influence of the hydrogen isotopic content of the atmospheric water vapor (δDatm). Empirically measured values of δDcell were typically within the seasonal range of δDcell predicted from the fractionation model. Sensitivity analyses showed that changes in δDxyl generally had a greater influence at high-elevation montane sites, whereas δDxyl and δDatm had about equal influence on δDcell at low-elevation desert sites. The intrasite relationship between δDcell and δDxyl among individual trees was poor, perhaps because of the within-site spatial variation in hydrologic conditions and associated tree physiological responses. Our study suggests that historical variation in δDcell of Populus provides information on historical variation in both time-integrated water source use and atmospheric conditions; and that the influence of atmospheric conditions is not consistent over sites with large differences in temperature and humidity. Reconstruction of xylem water sources of Populus in riparian ecosystems from δDcell will be more direct at higher elevation mountain sites than at low-elevation desert sites.

Arkle, R.S.; Pilliod, D.S. 2010. Prescribed fires as ecological surrogates for wildfires: a stream and riparian perspective. Forest Ecology and Management. 259(5): 893-903. doi:10.1016/j.foreco.2009.11.029

Abstract: Forest managers use prescribed fire to reduce wildfire risk and to provide resource benefits, yet little information is available on whether prescribed fires can function as ecological surrogates for wildfire in fire-prone landscapes. Information on impacts and benefits of this management tool on stream and riparian ecosystems is particularly lacking. We used a beyond-BACI (Before, After, Control, Impact) design to investigate the effects of a prescribed fire on a stream ecosystem and compared these findings to similar data collected after wildfire. For 3 years after prescribed fire treatment, we found no detectable changes in periphyton, macroinvertebrates, amphibians, fish, and riparian and stream habitats compared to data collected over the same time period in four unburned reference streams. Based on changes in fuels, plant and litter cover, and tree scorching, this prescribed fire was typical of those being implemented in ponderosa pine forests throughout the western U.S. However, we found that the extent and severity of riparian vegetation burned was substantially lower after prescribed fire compared to nearby wildfires. The early-season prescribed fire did not mimic the riparian or in-stream ecological effects observed following a nearby wildfire, even in catchments with burn extents similar to the prescribed fire. Little information exists on the effects of long-term fire exclusion from riparian forests, but a "prescribed fire regime" of repeatedly burning upland forests while excluding fire in adjacent riparian forests may eliminate an important natural disturbance from riparian and stream habitats.

Armour, C.L.; Duff, D.A.; Elmore, W. 1991. The effects of livestock grazing on riparian and stream ecosystems. Fisheries. 16(1): 7-11.

Summary: This is a draft position paper approved by the Executive Committee of the American Fisheries Society on 25 August 1990. AFS members were encouraged to comment on this draft. The American Fisheries Society advocates actions that will contribute to improved livestock management to improve and maintain habitat of streams on the public lands. Objectives for this advocacy include restoring damaged streams to a productive fisheries status and protecting undamaged streams to prevent them from being lost as fisheries. Specific, advocated actions include a total of 13 items.

Arnold, J.S.; Koro-Ljungberg, M.; Bartels, W.-L. 2012. Power and conflict in adaptive management: Analyzing the discourse of riparian management on public lands. Ecology and Society. 17(1): art19 (12 p). doi:10.5751/ES-04636-170119

Abstract: Adaptive collaborative management emphasizes stakeholder engagement as a crucial component of resilient social-ecological systems. Collaboration among diverse stakeholders is expected to enhance learning, build social legitimacy for decision making, and establish relationships that support learning and adaptation in the long term. However, simply bringing together diverse stakeholders does not guarantee productive engagement. Using critical discourse analysis, we examined how diverse stakeholders negotiated knowledge and power in a workshop designed to inform adaptive management of riparian livestock grazing on a National Forest in the southwestern USA. Publicly recognized as a successful component of a larger collaborative effort, we found that the workshop effectively brought together diverse participants, yet still restricted dialogue in important ways. Notably, workshop facilitators took on the additional roles of riparian experts and instructors. As they guided workshop participants toward a consensus view of riparian conditions and management recommendations, they used their status as riparian experts to emphasize commonalities with stakeholders supportive of riparian grazing and accentuate differences with stakeholders skeptical of riparian grazing, including some Forest Service staff with power to influence management decisions. Ultimately, the management plan published one year later did not fully adopt the consensus view from the workshop, but rather included and acknowledged a broader diversity of stakeholder perspectives. Our findings suggest that leaders and facilitators of adaptive collaborative management can more effectively manage for productive stakeholder engagement and, thus, social-ecological resilience if they are more tentative in their convictions, more critical of the role of expert knowledge, and more attentive to the knowledge, interests, and power of diverse stakeholders.

Auble, G.T.; Friedman, J.M.; Scott, M.L. 1994. Relating riparian vegetation to present and future streamflows. Ecological Applications. 4(3): 544-554. doi:10.2307/1941956

Abstract: The intense demand for river water in arid regions is resulting in widespread changes in riparian vegetation. We present a direct gradient method to predict the vegetation change resulting from a proposed upstream dam or diversion. Our method begins with the definition of vegetative cover types, based on a census of the existing vegetation in a set of 1 × 2 m plots. A hydraulic model determines the discharge necessary to inundate each plot. We use the hydrologic record, as defined by a flow duration curve, to determine the inundation duration for each plot. This allows us to position cover types along a gradient of inundation duration. A change in river management results in a new flow duration curve, which is used to redistribute the cover types among the plots. Changes in vegetation are expressed in terms of the area occupied by each cover type. We applied this approach to riparian vegetation of the Black Canyon of the Gunnison National Monument along the Gunnison River in Colorado. We used TWINSPAN to cluster plots according to species occurrence. This analysis defined three vegetative cover types that were distinct in terms of inundation duration. Quantitative changes in the extent of cover types were estimated for three hypothetical flow regimes: two diversion alternatives with different minimum flows and a moving average modification of historical flows. Our results suggest that (1) it is possible to cause substantial changes in riparian vegetation without changing mean annual flow, and (2) riparian vegetation is especially sensitive to changes in minimum and maximum flows. Principal advantages of this method are simplicity and reliance on relatively standard elements of plant community ecology and hydrologic engineering. Limitations include use of a single environmental gradient, restrictive assumptions about changes in channel geometry, representation of vegetation as quasi-equilibrium cover types, and the need for model validation.

Bahuguna, D.; Mitchell, S.J.; Miquelajauregui, Y. 2010. Windthrow and recruitment of large woody debris in riparian stands. Forest Ecology and Management. 259(10): 2048-2055. doi:10.1016/j.foreco.2010.02.015

Abstract: To document the impacts of windthrow in riparian leave strips and identify the components needed for small stream large woody debris (LWD) recruitment modeling, we monitored nine small streams at a temperate rainforest site in coastal British Columbia. This study was a component of a larger integrated study of forest management impacts on small streams. A series of small clearcuts were harvested in 1998 in a 70-year-old second growth stand that had regenerated naturally following logging and wildfire. Three cutblocks each were assigned to 10 m and 30 m buffer width treatments and three areas were assigned as unharvested controls. Seven years after the 1998 logging, all logs greater than 10 cm diameter that spanned at least part of stream channel width were measured. A total of 179 logs were recorded. Post-harvest windthrow was higher in the 10 m buffer treatment, while competition-related standing tree mortality was higher in the controls. The major windthrow events had occurred in the first and second years after logging of adjacent stands. There was no significant difference in the number of spanning and in-stream logs in the 10 m, 30 m buffer and control treatments. More than 90% of the LWD was in the 10-30 cm diameter classes. The majority of logs were oriented perpendicular to the stream channel. At the time of measurement, the majority of these trees were still suspended above the stream channel, indicating that the recruitment of logs into the stream channel is a long-term process. Time to recruitment into the channel is dependent on log and valley geometry, log size, species, and log condition prior to toppling. Log height above stream was negatively correlated with log decay class and valley width. Log length was negatively correlated with state of decay, and many windthrown logs were in an advanced state of decay before they entered the stream.

Banner, A.; MacKenzie, W. 1998. Riparian areas: providing landscape habitat diversity. Extension Note 17. Victoria, BC, Canada: British Columbia Ministry of Forests. 8 p.
Abstract: This extension note is the fifth in a series designed to raise awareness of landscape ecology concepts and to provide background for the ecologically based forest management approach recommended in the Biodiversity Guidebook. The focus here is on riparian areas. We first define and describe riparian areas. We then discuss several ecological principles underlying the common structural and functional characteristics of riparian areas and review their implications for biodiversity. We also briefly examine some of the functions of healthy riparian areas and cumulative harmful effects of poor management at the landscape level. We conclude by suggesting how these concepts can be applied in landscape-level planning for biodiversity.

Barrett, H.; Cagney, J.; Clark, R.; Fogg, J.; Gebhart, K.; Hansen, P.L.; Mitchell, B.; Prichard, D.; Tippy, D. 1995. Riparian area management: process for assessing proper functioning condition. Tech. Ref. 1737-9. Denver, CO: USDI Bureau of Land Management, Service Center. 51 p.
Abstract: This technical reference outlines the Bureau of Land Management process for assessing the functioning condition of riparian areas on public lands. Emphasis is placed on the interaction of vegetation, landform/soils, and hydrology in defining capability and potential of an area. The importance of using an interdisciplinary team is also stressed. The document describes four categories of functioning condition – proper functioning condition, functional-at risk, nonfunctional, and unknown, and discusses management strategies for each.

Bartels, D. 1996? Pataha Creek, its changing ways. In: Proceedings Watershed '96. Moving ahead together; 1996 June 8-12; Baltimore (MD): Environmental Protection Agency. 3 p.

Abstract: From a determination by the Northwest Power Planning Council in 1993, the Pataha Creek Watershed was included with the Tucannon and Asotin watersheds as model watersheds to develop a plan to restore habitat for the endangered Snake River salmon. A coordinated resource management system process had started. Two committees consisting of landowners and technical personnel were formed to begin the process of writing a watershed plan to restore fish habitat. The purpose of the technical committee is to provide expertise with the existing problems and their proposed solutions. The purpose of the landowner steering committee is to provide the local input regarding the feasibility and economical aspects of the solutions to the problems. The resulting watershed plan includes a compromised solution from the different groups that are involved in writing the watershed plan.

Beche, L.A.; Stephens, S.L.; Resh, V.H. 2005. Effects of prescribed fire on a Sierra Nevada (California, USA) stream and its riparian zone. Forest Ecology and Management. 218(1-3): 37-59. doi:10.1016/j.foreco.2005.06.010

Abstract: Concerns about the effects of fire on ecologically sensitive habitats have limited the use of prescribed fire in the management of forest riparian areas. Using a beyond-BACI (Before-After-Control-Impact) experimental design, we examined the effects of a 26-ha prescribed fire that burned upland and riparian areas of a first-order watershed, and compared this to five unburned sites examined from 1 to 7 years pre-fire and 1 year post-fire. We monitored pre- and post-fire riparian vegetation, large woody debris, sediment, water chemistry, periphyton, and benthic macroinvertebrates. The prescribed fire in the riparian zone was patchy in terms of intensity, consumption, and severity; it consumed 79% of the pre-fire fuel in the riparian zone, 34% of the total surface fuel, and 90% of the total ground fuel. The prescribed fire significantly reduced percent cover of surface vegetation and plant taxa richness in comparison to unburned sites but not plant diversity (Simpson's D). Community composition of understory riparian vegetation changed post-fire, most likely as a result of the reduction in taxa richness and cover. Riparian tree mortality (>11.5 cm DBH) was only 4.4% post-fire. Similarly, there was no post-fire change in large woody debris volume and recruitment, or fine sediment in pools (V*). Post-fire, there were increases in some water chemistry parameters (SO_4^-, total P, Ca^{2+}, and Mg^{2+}) and a decrease in periphyton biomass; however, these changes were short-term, and recovery occurred in <=1 year. Macroinvertebrate community composition but not density, richness, or diversity was affected 10-19 d post-fire; composition recovered within 1 year. The trends observed in this study examining multiple abiotic and biotic parameters suggest that this prescribed fire either had no or short-lasting (<=1 year) impacts on Dark Canyon Creek and its riparian zone. The limited observed impacts are at least partially a result of the small portion (<20%) of the watershed area burned, moderate topography, the low- to moderate-severity of the fire, and the relatively low precipitation (and thus, stream flow) that occurred post-fire.

Beckham, S.D. 1995a. Grande Ronde River, Oregon: river widths, vegetative environment, and conditions shaping its condition, Imbler vicinity to headwaters. Unpublished report submitted to Eastside Ecosystem Management Project in Walla Walla, Washington. Lake Oswego, OR: Stephen Dow Beckham. 85 p.

Summary: This report describes historical conditions associated with the Grande Ronde River in northeastern Oregon, ranging from the river's headwaters in the Blue Mountains to the vicinity of Imbler, Oregon. Although several historical sources were used during its compilation (diaries of fur trappers and overland travelers; newspaper accounts for the first decade of the 1900s; and cadastral survey notes), it is based primarily on an analysis of survey notes and maps prepared by the General Land Office during establishment of the public land survey (townships, ranges, sections) during the late 1800s (from 1863 to 1884). Since land surveyors were required to record the river's width and course whenever they crossed it while surveying exterior (township, range) or interior (section) lines, the GLO survey notes were used to examine the historical width of the river itself and its associated floodplain. Survey notes also provide early records of vegetative composition (species of trees and shrubs) found along the river's edge for the presettlement era.

Beckham, S.D. 1995b. Tucannon River, Washington: river widths, vegetative environment, and conditions shaping its condition, mouth to headwaters. Unpublished report submitted to Eastside Ecosystem Management Project in Walla Walla, Washington. Lake Oswego, OR: Stephen Dow Beckham. 63 p.

Summary: This report describes historical conditions associated with the Tucannon River watershed in southeastern Washington, ranging from the river's headwaters in the Blue Mountains to its confluence with the Snake River in southeastern Washington. Although several historical sources were used during its compilation (including diaries associated with early travels along the Nez Perce Trail from the mouth of the Clearwater River west to the Walla Walla River), it is based primarily on an analysis of survey notes and maps prepared by the General Land Office during establishment of the public land survey (townships, ranges, sections) during the late 1800s (from 1864 to 1912). Since land surveyors were required to record the river's width and course whenever they crossed it while surveying exterior (township, range) or interior (section) lines, the GLO survey notes were used to examine the historical width of the river itself and its associated floodplain. Survey notes also provide early records of vegetative composition (species of trees and shrubs) found along the river's edge for the presettlement era.

Beier, A.; Langheinrich, L. 1996? Building partnerships – a case study of the Umatilla River watershed. In: Proceedings Watershed '96. Moving ahead together; 1996 June 8-12; Baltimore (MD): Environmental Protection Agency. 6 p.

Abstract: Despite these environmental problems, there is a strong foundation of cooperation and partnership in the Umatilla River Watershed. In the late 1980s, with increasing conflicts between irrigation and fisheries needs, representatives of the Bureau of Reclamation, the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) and local irrigation districts came up with a proposal to restore the watershed's fisheries while protecting irrigation uses. The group solicited federal funds for the Lower Umatilla Basin project, a water transfer project. This project diverts water from the Columbia River, and stores it in an off-stream reservoir for summer release to meet irrigation needs. This water substitutes for Umatilla River water retained instream for fisheries. This effort, in conjunction with hatchery development projects co-sponsored by the Bonneville Power Administration, CTUIR, and the

Oregon Department of Fish and Wildlife (ODFW) has been a success. Salmon have returned to the Umatilla River for the first time in over seventy years.

Belsky, A.J.; Matzke, A.; Uselman, S. 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. Journal of Soil and Water Conservation. 54(1): 419-431.

Abstract: This paper summarizes the major effects of livestock grazing on stream and riparian ecosystems in the arid West. The study focused primarily on results from peer-reviewed experimental studies, and secondarily on comparative studies of grazed versus naturally or historically protected areas. Results were summarized in tabular form. Livestock grazing was found to negatively affect water quality and seasonal quantity, stream channel morphology, hydrology, riparian zone soils, instream and streambank vegetation, and aquatic and riparian wildlife. No positive environmental impacts were found. Livestock also were found to cause negative impacts at the landscape and regional levels. Although it is sometimes difficult to draw generalizations from the many studies, due in part to differences in methodology and environmental variability among study sites, most recent scientific studies document that livestock grazing continues to be detrimental to stream and riparian ecosystems in the West.

Benda, L.; Miller, D.; Bigelow, P.; Andras, K. 2003. Effects of post-wildfire erosion on channel environments, Boise River, Idaho. Forest Ecology and Management. 178(1-2): 105-119. doi:10.1016/S0378-1127(03)00056-2

Abstract: What is the geological or ecological context that earth scientists, biologists, and resource managers use to understand large-scale watershed disturbances, such as fires, mass wasting, and floods? We address this question using a field study of post-fire channel changes in the Boise River basin in central Idaho based on surveys of over 27 km of channels. Intense rill and gully erosion from the Rabbit Creek fire (1995) greatly increased sediment supply to numerous third- through sixth-order valley floors. We concentrated our field study where recently aggraded and enlarged alluvial fans impinged on channels in drainage areas of 100-350 km^2. Alluvial fans that had enlarged because of post-fire sedimentation triggered a number of morphological changes in channels and valley floors. Alluvial fans created nick points in receiving channels that caused an increase in channel gradient immediately downstream of fans and a decrease in channel gradients upstream of fans for distances up to 4 km. Wide floodplains, side channels, and the beginning of terrace construction were associated with increased sediment storage in proximity to aggraded fans. Fan-related changes in channel gradients also affected the spatial distribution of channel substrates. Studies across western North America indicate that periodic, large influxes of sediment to channels are a fundamental part of stream ecosystems. In addition, new perspectives in riverine ecology focus on the patchy distribution of aquatic habitats. Our study integrates those two perspectives by illustrating how fire-related sediment production coupled with irregularly spaced tributary junctions contributed to the formation of certain types of riverine habitats.

Bendix, J.; Cowell, C. 2010. Impacts of wildfire on the composition and structure of riparian forests in southern California. Ecosystems. 13(1): 99-107. doi:10.1007/s10021-009-9303-z

Abstract: In southern California, wildfire is a ubiquitous agent shaping plant communities. Although fire impacts have been widely studied in chaparral-covered uplands, few data are available regarding fire and riparian vegetation. This study provides an example of the impact of a severe fire on riparian habitat. Plant species found in southern California gallery forests are typically adapted to maintaining populations following flood disturbances; we seek to determine whether structural and compositional changes following fire here demonstrate a similar quasi-equilibrium response. We sampled 65 quadrats on 11 transects along two streams in the Los Padres National Forest to characterize tree species size-class distributions before and after the 2002 Wolf Fire. We tested whether species exhibited differential patterns of survivorship and regeneration following the fire, and also tested for spatial variability in mortality within the floodplain. *Alnus rhombifolia* dominated the pre-fire forest, but experienced severe mortality in the fire and showed very limited resprouting after 3 years. Other prominent taxa (*Populus*, *Salix*, *Quercus* spp.) also lost considerable standing basal area, but had substantially greater rates of resprouting, resulting in a dramatically altered post-fire vegetation composition and structure. Fire impacts did not vary with landform position, leading to a distinctive homogenizing disturbance that contrasts with the spatially zoned and relatively stabilizing compositional influence that flood events have in this same riparian setting.

Berg, D.R. 1995. Riparian silviculture system design and assessment in the Pacific Northwest Cascade Mountains, USA. Ecological Applications. 5(1): 87-96. doi:10.2307/1942054

Abstract: Active management of riparian zones can be economically as well as ecologically beneficial. Restoration of riparian forests is simulated with forest growth models. Logs were generated using the model to be of sufficient size to resist annual floods in salmon habitat streams on the west side of the Pacific Northwest Cascade Mountains. The economic feasibility is reported at real interest rates. Economic viability depends on the initial volume removed, costs of regeneration and monitoring, volume of thinnings, and interest rate. Harvest operations allow for the restoration of forest structure and composition that is beneficial for salmonid habitat in areas where the primary forest has been replaced with early seral hardwood species and fiercely competitive shrubs. This silvicultural system restores natural functions of riparian forests of watersheds in the Pacific Northwest.

Berg, N.; Carlson, A.; Azuma, D. 1998. Function and dynamics of woody debris in stream reaches in the central Sierra Nevada, California. Canadian Journal of Fisheries and Aquatic Sciences. 55(8): 1807-1820. doi:10.1139/f98-064

Abstract: In 1993, we located, measured, and tagged almost 1,700 woody debris pieces on six streams in California's central Sierra Nevada. The stability, geomorphic function, and use by fish for cover of each piece were recorded. In 1994 and 1995, piece movement was quantified and new debris pieces were measured. In the 60 study reaches, debris was not influential in shaping channel morphology and fish cover. Although woody debris was often associated with habitat units, few pieces deflected flow or contributed to the formation of pools or steps. Fish used deep water as cover more often than debris or any other cover type. Medium-sized debris was, however, used in a greater proportion than its availability to fish. Little sediment was stored by debris, and five large pieces stored 85% of the sediment volume measured. Debris frequency and volume did not differ significantly by channel type. After a low stream flow year (1993-1994), few pieces had moved and few new pieces were identified. After a high-flow season (1994-1995), 31% of the pieces had either moved or were not found and new pieces represented over 5% of the originally surveyed volume of wood.

Beschta, R.L.; Ripple, W.J. 2005. Rapid assessment of riparian cottonwood recruitment: Middle Fork John Day River, northeastern Oregon. Ecological Restoration. 23(3): 150-156. doi:10.3368/er.23.3.150

Abstract: We recently conducted a vegetation assessment along the Middle Fork of the John Day River in northeastern Oregon. Black cottonwoods (*Populus trichocarpa*) occur along this portion of the river and are also found in many riparian systems throughout the Pacific Northwest. Preliminary observations of streamside areas along the Middle Fork of the John Day River indicated that recruitment of cottonwood and willow (*Salix* spp.) may no longer be occurring in many areas. Because of cottonwood's overstory dominance in many riparian plant communities, its ease of visual identification relative to other riparian plants, and its overriding importance in the ecological functions of many riparian systems in the western United States, we selected it as the primary species for our study. The objectives of this research were twofold: 1) To develop a rapid visual assessment methodology for enumerating black cottonwood, by height class, along an extended reach of river; 2) To use the results of this methodology to evaluate the recruitment status of black cottonwood along this reach.

Bilby, R.E. 1984. Removal of woody debris may affect stream channel stability. Journal of Forestry. 82(10): 609-613.

Abstract: Several western states mandate the removal of logging debris from streams in order to prevent accumulations impassable to anadromous fish. Monitoring a small western Washington stream revealed large changes in channel structure during the first high flow after cleaning. Nearly 60 percent of the monitored pieces of debris moved during this storm, channel cross sections were substantially altered by movement of stored sediment, and the number, area, and volume of pools decreased. The degree of channel rearrangement was greater than in a comparable undisturbed stream. Subsequent storms caused much less debris movement and channel change than the first high flow, even though some of the later flows were of greater magnitude. An interim guide to stream cleaning is prescribed.

Bilby, R.E.; Heffner, J.T.; Fransen, B.R.; Ward, J.W.; Bisson, P.A. 1999. Effects of immersion in water on deterioration of wood from five species of trees used for habitat enhancement projects. North American Journal of Fisheries Management. 19(3): 687-695. doi:10.1577/1548-8675(1999)019<0687:EOIIWO>2.0.CO;2

Abstract: Logs of standard dimensions from five species of trees were submerged in a stream to evaluate changes in strength and decomposition over a period of 5 years. Changes in structural properties occurred only for wood near the outer surface of the logs. Nearly all bark was removed from the logs within 12 months. Diameter loss for the five species ranged from 10.6 mm (western hemlock *Tsuga heterophylla*) to 21.8 mm (bigleaf maple *Acer macrophyllum*) after 5 years. Decreases in the density of surface wood for the five species ranged from 23% (red alder *Alnus rubra*) to 31% (western hemlock). Modulus of rupture, modulus of elasticity, and wood density did not change for wood more than 12 mm from the log surface for any of the species. Bigleaf maple exhibited the highest resistance to rupture, and western redcedar *Thuja plicata* exhibited the lowest. Western redcedar was also the most easily flexed. Microbial activity on the surface of the logs was highest at the start of the experiment and decreased rapidly with time of immersion. The two hardwood species (bigleaf maple and red alder) generally had higher levels of microbial activity than the conifer species (Douglas fir *Pseudotsuga menzesii*, western hemlock, western redcedar) from 12 months through 60 months of immersion. Differences in the rate of decomposition between conifer and hardwood logs were much less than in terrestrial environments. Our results suggest that hardwood logs can be used in stream enhancement projects where the wood will be submerged.

Bisson, P.A.; Rieman, B.E.; Luce, C.; Hessburg, P.F.; Lee, D.C.; Kershner, J.L.; Reeves, G.H.; Gresswell, R.E. 2003. Fire and aquatic ecosystems of the western USA: current knowledge and key questions. Forest Ecology and Management. 178(1-2): 213-229. doi:10.1016/S0378-1127(03)00063-X

Abstract: Understanding of the effects of wildland fire and fire management on aquatic and riparian ecosystems is an evolving field, with many questions still to be resolved. Limitations of current knowledge, and the certainty that fire management will continue, underscore the need to summarize available information. Integrating fire and fuels management with aquatic ecosystem conservation begins with recognizing that terrestrial and aquatic ecosystems are linked and dynamic, and that fire can play a critical role in maintaining aquatic ecological diversity. To protect aquatic ecosystems we argue that it will be important to: (1) accommodate fire-related and other ecological processes that maintain aquatic habitats and biodiversity, and not simply control fires or fuels; (2) prioritize projects according to risks and opportunities for fire control and the protection of aquatic ecosystems; and (3) develop new consistency in the management and regulatory process. Ultimately, all natural resource management is uncertain; the role of science is to apply experimental design and hypothesis testing to management applications that affect fire and aquatic ecosystems. Policy-makers and the public will benefit from an expanded appreciation of fire ecology that enables them to implement watershed management projects as experiments with hypothesized outcomes, adequate controls, and replication.

Biswas, S.R.; Mallik, A.U. 2010. Disturbance effects on species diversity and functional diversity in riparian and upland plant communities. Ecology. 91(1): 28-35. doi:10.1890/08-0887.1

Abstract: Understanding disturbance effects on species diversity and functional diversity is fundamental to conservation planning but remains elusive. We quantified species richness, diversity, and evenness of riparian and upland plants along 24 small streams subjected to a range of anthropogenic disturbances in the boreal forest of northwestern Ontario, Canada. We included a total of 36 functional traits related to productivity, competitive ability, reproduction, disturbance tolerance, life history, and tolerance to habitat instability. Using nested ANOVA, we examined the response of diversity indices to disturbance and whether it followed the intermediate disturbance hypothesis (IDH) and varied with habitat stability. We found that, like species richness and diversity, functional richness and diversity reached

peaks at moderate disturbance intensity; functional diversity followed the predictions of the IDH. Second, disturbance-habitat-stability coupling has very little effect on overall species and functional diversity, but the effect on particular life forms and functions may be significant. Since species richness and diversity patterns are context and system dependent, our findings should be most applicable to similar temperate riparian systems.

Bragg, D.C. 2000. Simulating catastrophic and individualistic large woody debris recruitment for a small riparian system. Ecology. 81(5): 1383-1394. doi:10.1890/0012-9658(2000)081[1383:SCAILW]2.0.CO;2

Abstract: Surprisingly little research has been done to partition the contribution of catastrophic disturbance from that of small-scale individualistic mortality events on riparian large woody debris (LWD) recruitment. This study compared the impact of both processes on recruitment through simulation of several catastrophic disturbances (a spruce beetle outbreak, a moderately intense fire, and a clearcut) and undisturbed (individualistic mortality only) old growth for a small headwater stream in the Intermountain West of the United States. All scenarios progressed through a two-stage process, with the Forest Vegetation Simulator growth and yield model controlling forest dynamics and a postprocessor (CWD, version 1.2) predicting riparian LWD recruitment. Projections indicate that individualistic-only conditions delivered 2.5 m^3 LWD·100 m $reach^{-1}$·10-yr $cycle^{-1}$; while the spruce beetle-, fire-, and clearcut-affected stands averaged 2.9, 3.2, and 1.5 m^3 LWD·100 m $reach^{-1}$·$cycle^{-1}$, respectively. Stands impacted by natural catastrophic disturbance significantly ($P < 0.05$) increased cumulative (300 yr) LWD recruitment over the individualistic-only scenario, whereas clear-cutting significantly decreased total delivery. In-stream LWD loads, relatively stable in undisturbed riparian zones, fluctuated sharply under catastrophic disturbance. Peak channel loads associated with natural perturbation occurred ~30 yr after the event while debris volumes under clear-cutting immediately declined. The post-event recruitment and in-stream LWD stocks of all disturbance scenarios eventually fell below undisturbed conditions, requiring decades to recover historical volumes. Catastrophic disturbances induced such steep oscillations in riparian LWD load that the systems experiencing frequent large-scale perturbations never achieved a long-term steady state, as some have postulated. Because of the inflation in cumulative LWD delivery, it may prove advantageous to encourage (or imitate) some catastrophic disturbance in forests along streams noticeably depauperate of LWD.

Bragg, D.C.; Kershner, J.L.; Roberts, D.W. 2000. Modeling large woody debris recruitment for small streams of the central Rocky Mountains. Gen. Tech. Rep. RMRS-GTR-55. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 36 p. http://www.treesearch.fs.fed.us/pubs/29133

Abstract: As our understanding of the importance of large woody debris (LWD) evolves, planning for its production in riparian forest management is becoming more widely recognized. This report details the development of a model (CWD, version 1.4) that predicts LWD inputs, including descriptions of the field sampling used to parameterize parts of the model, the theoretical and practical underpinnings of the model's structure, and a case study of CWD's application to a stream in Wyoming's Bridger-Teton National Forest.

Bren, L.J. 1995. Aspects of the geometry of riparian buffer strips and its significance to forestry operations. Forest Ecology and Management. 75(1-3): 1-10. doi:10.1016/0378-1127(95)03553-M

Abstract: A stream buffer strip is an area within a defined distance from a stream in which land use activities are restricted for stream protection purposes. This study used a sophisticated Geographic Information System to examine the extent, distribution, and boundary properties of land defined by buffer strips of differing widths. The prototype catchment studied was the mountainous 65 km^2 Tarago River catchment in eastern Victoria. The West Tarago River is a fourth-order stream network. This was accurately delineated using the topographic map supplemented by high quality aerial color transparencies. This showed that the map had inadequate detail of smaller streams. The streams had a branching network with an overall fractal dimension (measure of complexity) of 1.75, although the fractal dimension of the individual stream reaches was only slightly greater than one. The area of land occupied by buffers increased substantially with increasing width of buffers, with 95% of the catchment occupied by buffers of 300 m width. As buffer width increased to 100 m, many areas became entrapped by buffers and hence became effectively inaccessible. Individual boundaries reached their greatest complexity at 10 m buffer width, but the buffer/non-buffer network achieved greatest complexity at 100 m buffer width. Small buffers had a very high perimeter/area ratio. As buffer width increased the perimeter/area ratio of non-buffer areas slowly increased, reflecting that non-buffer areas were becoming smaller and more fragmented.

Bridges, C.; Hagenbuck, W.; Krapf, R.; Leonard, S.; Prichard, D. 1994. Process for assessing proper functioning condition for lentic riparian-wetland areas. Tech. Ref. 1737-11. Denver, CO: USDI Bureau of Land Management, Service Center. 37 p.

Abstract: This technical reference outlines the Bureau of Land Management process for assessing the functioning condition of lentic riparian-wetland areas on public lands. Emphasis is placed on the interaction of vegetation, landform/soils, and hydrology in defining capability and potential of an area. The importance of using an interdisciplinary team is also stressed.

British Columbia Ministry of Forests. 1995. Riparian management area guidebook. Victoria, BC: Ministry of Forests, Public Affairs Branch. 68 p.

Abstract: This guidebook is provided to help managers, planners, and field staff comply with the Forest Practices Code of British Columbia Act and to set and achieve the management objectives for riparian management areas (RMA) specified in operational plans. It provides guidance on planning and conducting operations within the RMA and fisheries- and marine-sensitive zones. It should be used in conjunction with other guidebooks such as those developed for forest development plans, biodiversity, managing identified wildlife, and range use. Riparian areas occur next to the banks of streams, lakes, and wetlands and include both the area dominated by continuous high moisture content and the adjacent upland vegetation that exerts an influence on it. Riparian ecosystems contain many of the highest value non-timber resources in the natural forest. Streamside vegetation protects water quality and provides a "green zone" of vegetation that stabilizes streambanks, regulates stream tem-

peratures, and provides a continual source of woody debris to the stream channel. The majority of fish food organisms come from overhanging vegetation and bordering trees while leaves and twigs that fall into streams are the primary nutrient source that drives aquatic ecosystems. Riparian areas frequently contain the highest number of plant and animals species found in forests, and provide critical habitats, home ranges, and travel corridors for wildlife. Biologically diverse, these areas maintain ecological linkages throughout the forest landscape, connecting hillsides to streams and upper headwaters to lower valley bottoms. There are no other landscape features within the natural forest that provide the natural linkages of riparian areas.

Brookshire, J.; Kauffman, B.; Lytjen, D.; Otting, N. 2002. Cumulative effects of wild ungulate and livestock herbivory on riparian willows. Oecologia. 132(4): 559-566. doi:10.1007/s00442-002-1007-4

Abstract: We examined the effects of wild ungulates (deer and elk) and domestic sheep browsing on the growth, structure, and reproductive effort of two common willow species, *Salix boothii* and *S. geyeriana*, in a montane northeast Oregon riparian zone. With the use of exclosures, large herbivore effects on willows were studied in an area browsed by native mammals only and an adjacent area in which domestic sheep also lightly grazed during summer months. Growth variables were repeatedly measured on individual plants over a 5-year period to understand physiognomic and flowering responses of native willows to different levels of browsing pressure. At the beginning of the study, all willows were intensely browsed but were significantly taller in the area browsed only by native mammals than in the area also grazed by sheep (69 versus 51 cm, respectively). Willows inside exclosures responded with pronounced increases in height, crown area, and basal stem diameters while the stature of browsed plants outside exclosures stayed constant or declined. In the area browsed by both sheep and wild herbivores, the size of browsed plants remained at pretreatment levels (<60 cm in height) for the duration of the study. There was no significant difference in growth rates of enclosed willows, indicating that current herbivory was the primary cause of growth retardation in the study area. Foliar area was strongly correlated with basal stem numbers for enclosed plants but much less so for browsed plants. Willows inside exclosures had more than twice as much foliar area per stem. Stem diameters were a positive function of crown area: stem-number ratios, suggesting lower photosynthetic potential was correlated with diminished radial growth among browsed plants. No flowering was observed until 2 years after exclusion when plants inside all exclosures and browsed willows in the wild ungulate area responded with a large pulse in flowering. Browsed plants in the sheep + wild ungulate area did not flower. The number of catkins produced per plant was significantly associated with willow height and plants <70 cm in height did not flower, thus suggesting a size threshold for reproduction in these species. Our results suggest that even relatively light levels of domestic livestock grazing, when coupled with intense wild ungulate browsing, can strongly affect plant structure and limit reproduction of riparian willows.

Brown, J.; Bach, L.; Aldous, A.; Wyers, A.; DeGagné, J. 2011. Groundwater-dependent ecosystems in Oregon: an assessment of their distribution and associated threats. Frontiers in Ecology and the Environment. 9(2): 97-102. doi:10.1890/090108

Abstract: Effective protection and management of groundwater-dependent ecosystems (GDEs) are hindered by inadequate information on their locations and the condition of associated groundwater supplies. We addressed this knowledge gap by developing a methodology that uses existing datasets to locate GDEs (including groundwater-dependent springs, lakes, rivers, wetlands, and species) and assess threats to groundwater quantity and quality. Here we report on the application of this method across the US state of Oregon. Nearly 40% of watersheds in Oregon contain two or more types of GDEs – termed "GDE clusters" – indicating the widespread importance of groundwater to ecosystems. Documented problems may underestimate the threat to ecosystems from altered groundwater supply or quality. Although documented occurrences of water-table declines are limited, high densities of permitted wells (for irrigation or other commercial purposes) pose a threat to groundwater availability in 18% of GDE clusters. Furthermore, although only 5% of GDE clusters have known groundwater contamination, our assessment indicates that 30% of GDE clusters are threatened with groundwater contamination by nitrates, 30% by industrial chemicals, and 70% by pesticides. This initial assessment of GDEs and threats to their groundwater supply highlights the ecological importance of groundwater and the need to incorporate protection of GDEs in water management policy.

Bryce, S.A. 2006. Development of a bird integrity index: measuring avian response to disturbance in the Blue Mountains of Oregon, USA. Environmental Management. 38(3): 470-486. doi:10.1007/s00267-005-0152-z

Abstract: The Bird Integrity Index (BII) presented here uses bird assemblage information to assess human impacts to 28 stream reaches in the Blue Mountains of eastern Oregon. Eighty-one candidate metrics were extracted from bird survey data for testing. The metrics represented aspects of bird taxonomic richness, tolerance or intolerance to human disturbance, dietary preferences, foraging techniques, and nesting strategies that were expected to be positively or negatively affected by human activities in the region. To evaluate the responsiveness of each metric, it was plotted against an index of reach and watershed disturbance that included attributes of land use/land cover, road density, riparian cover, mining impacts, and percent area in clearcut and partial-cut logging. Nine of the 81 candidate bird metrics remained after eliminating unresponsive and highly correlated metrics. Individual metric scores ranged from 0 to 10, and BII scores varied between 0 and 100. BII scores varied from 78.6 for a minimally disturbed, reference stream reach to 30.4 for the most highly disturbed stream reach. The BII responded clearly to varying riparian conditions and to the cumulative effects of disturbances, such as logging, grazing, and mining, which are common in the mountains of eastern Oregon. This BII for eastern Oregon was compared to an earlier BII developed for the agricultural and urban disturbance regime of the Willamette Valley in western Oregon. The BII presented here was sensitive enough to distinguish differences in condition among stream riparian zones with disturbances that were not as obvious or irreversible as those in the agricultural/urban conditions of western Oregon.

Buckhouse, J.C.; Skovlin, J.M.; Knight, R.W. 1981. Streambank erosion and ungulate grazing relationships. Journal of Range Management. 34(4): 339-340.

Abstract: Streambank erosional patterns have been studied for 3 years (1 year of calibration and 2 years of active grazing treatment) on the Starkey Experimental Forest and Range in the Blue Mountains of northeastern Oregon. Livestock grazing use at the rate of 3.2 ha/AUM (8 acres/AUM) has not accelerated streambank degradation on Meadow Creek. Most erosion occurred during wintering periods and this erosion has been independent of grazing season treatments. It appears that high runoff and occasional ice flows are the most significant factors in bank cutting on this stream.

Burton, T.A. 2005. Fish and stream habitat risks from uncharacteristic wildfire: Observations from 17 years of fire-related disturbances on the Boise National Forest, Idaho. Forest Ecology and Management. 211(1-2): 140-149. doi:10.1016/j.foreco.2005.02.063

Abstract: Several large, uncharacteristic wildfires occurred on the Boise National Forest in Southwest Idaho, from 1986 to 2003. From 1987 to 1994, severe wildfires burned almost 50% of the ponderosa pine forest types (about 200,000 ha). The intensity of the fires varied across the landscape, with a mix of low to moderate severity, and lesser amounts of high burn severity. After the fires, localized debris flows favored smaller order streams in watersheds less than 4000 ha in size, where there had been mostly high severity burning. Locally, areas experiencing high heat and post-fire debris flows had reduced fish numbers and altered fish habitats. Uncharacteristic wildfires on the managed portions of the Boise National Forest appeared to have more pronounced, short-term effects on fish habitats as compared with characteristic wildfires in the Central Idaho Wilderness. Even in the most severely impacted streams, habitat conditions and trout populations improved dramatically within 5-10 years. Post-fire floods apparently rejuvenated stream habitats by exporting fine sediments and by importing large amounts of gravel, cobble, woody debris, and nutrients, resulting in higher fish productivities than before the fire. These observations suggest that important elements of biodiversity and fish productivity may be influenced, or even created by fire-related disturbances. In some cases, habitats that were completely devoid of salmonid fishes just after the debris floods, were later re-colonized with migrants returning from downstream or nearby tributary rearing habitats. Re-population was likely enhanced by higher fecundity, homing instinct, and greater mobility of the larger migratory fish. Ecosystem restoration activities that reduce both short- and long-term threats of uncharacteristic wildfire on imperiled fishes could be emphasized in areas where local populations may be weak and/or isolated, but potentially recoverable. But forest ecosystem restoration alone may not reduce risks to fish if existing habitat conditions and isolation are limiting the population.

Capon, S.J.; Chambers, L.E.; Mac Nally, R.; Naiman, R.J.; Davies, P.; Marshall, N.; Pittock, J.; Reid, M.; Capon, T.; Douglas, M.; Catford, J.; Baldwin, D.S.; Stewardson, M.; Roberts, J.; Parsons, M.; Williams, S.E. 2013. Riparian ecosystems in the 21st century: Hotspots for climate change adaptation? Ecosystems. 16(3): 359-381. doi:10.1007/s10021-013-9656-1

Abstract: Riparian ecosystems in the 21st century are likely to play a critical role in determining the vulnerability of natural and human systems to climate change, and in influencing the capacity of these systems to adapt. Some authors have suggested that riparian ecosys-

tems are particularly vulnerable to climate change impacts due to their high levels of exposure and sensitivity to climatic stimuli, and their history of degradation. Others have highlighted the probable resilience of riparian ecosystems to climate change as a result of their evolution under high levels of climatic and environmental variability. We synthesize current knowledge of the vulnerability of riparian ecosystems to climate change by assessing the potential exposure, sensitivity, and adaptive capacity of their key components and processes, as well as ecosystem functions, goods and services, to projected global climatic changes. We review key pathways for ecological and human adaptation for the maintenance, restoration and enhancement of riparian ecosystem functions, goods and services and present emerging principles for planned adaptation. Our synthesis suggests that, in the absence of adaptation, riparian ecosystems are likely to be highly vulnerable to climate change impacts. However, given the critical role of riparian ecosystem functions in landscapes, as well as the strong links between riparian ecosystems and human well-being, considerable means, motives and opportunities for strategically planned adaptation to climate change also exist. The need for planned adaptation of and for riparian ecosystems is likely to be strengthened as the importance of many riparian ecosystem functions, goods and services will grow under a changing climate. Consequently, riparian ecosystems are likely to become adaptation 'hotspots' as the century unfolds.

Carlson, J.Y.; Andrus, C.W.; Froehlich, H.A. 1990. Woody debris, channel features, and macroinvertebrates of streams with logged and undisturbed riparian timber in northeastern Oregon, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences. 47(6): 1103-1111. doi:10.1139/f90-127

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.

Carr, M. 2005. Earth…water…fire: the role and management of fire in aquatic ecosystems. Wildland Waters; Summer Issue (FS-828): 1-24.

Summary: For the past century or two, we have considered the sight of smoke and fire in our wildlands contrary to the health of forests and aquatic ecosystems. Although fire can be a real threat, for millennia, fire also has been a shaper and keeper of many natural communities whose origins, evolution, and survival may be closely linked to and even depend on the ecological force of fire. The presence of wildland fire across the country has changed dramatically in recent decades, as have the ecosystems in which fire occurs. Large fires in

the West and rising concerns about forest health have ignited efforts to recover ecosystem patterns and processes and to reduce the risk of "catastrophic" fires through active forest and fire management. At the same time, we have increased our attention to the conservation and restoration of the Nation's fish and aquatic species and their habitats – efforts whose goals may sometimes seem to conflict with forest restoration and fire management goals. Are fire and water as "contrary" and incompatible as the tarot of ancient elements suggests? Is fire always a threat to fish and other aquatic species, or can fire actually benefit aquatic communities? What kind of management is appropriate to address wildland fire, and when might the management of fuels and suppression of fire be worse for aquatic ecosystems than fire itself? Vigorous current debate over such questions reflects the complexity of fire and the systems affected by it. In this issue, we explore the role of fire in aquatic ecosystems, with an emphasis on forested watersheds in the Western United States. We look at the ecological influence and impacts of fire on water, watersheds, and aquatic species; examine some management challenges and the debates in which they are enmeshed; and sample research and policy needs for effectively addressing fire, forest, water, and fish-related issues in the future.

Case, R.L.; Kauffman, J.B. 1997. Wild ungulate influences on the recovery of willows, black cottonwood and thin-leaf alder following cessation of cattle grazing in northeastern Oregon. Northwest Science. 71(2): 115-126.

Abstract: Restoration of degraded riparian ecosystems is of great importance for the recovery of declining and endangered stocks of Columbia River salmonids as well as riparian-obligate wildlife species. Willows (*Salix* spp.), thin-leaf alder (*Alnus incana*), and black cottonwood (*Populus trichocarpa*) are important features of western riparian ecosystems having multiple functional roles that influence biological diversity, water quality/quantity, and aquatic/terrestrial food webs and habitats. Removal of domestic livestock and the construction of big game exclosures have been hypothesized to be effective restoration techniques for riparian ecosystem as well as for salmonid habitat recovery. Following more than a century of livestock grazing, cattle were removed from Meadow Creek in 1991 and the rates of riparian shrub recovery were measured for the two years following. Elk and deer-proof exclosures were constructed to quantify the browsing influences of native large ungulates. The initial mean height of 515 deciduous trees and shrubs (14 species) was 47 cm. After two years in the absence of livestock, significant increases in height, crown area, crown volume, stem diameter and biomass were measured both outside and inside of the exclosures. Mean crown volume of willows increased 550% inside of wild ungulate exclosures and 195% outside. Black cottonwood increased 773% inside and 808% outside, while thin-leaf alder increased 1046% inside and 198% outside. Initial shrub densities on gravel bars were low averaging 10.7 woody plants/100m^2. Shrub numbers significantly increased ≈ 50% (to 15.8 plants/100m^2 or one new shrub for every 9 meters of transect length) outside of elk and deer proof exclosures through both clonal and seedling establishment. At the beginning of the study (1991), catkin production on willows was low (i.e., only 10% produced catkins). Wild herbivores had a significant influence on the reproductive output of willows; in 1993 catkins were produced by 34% of the tagged willows within exclosures but only 2% outside

of exclosures. Wild herbivores were found to have significant influences on the rate of height growth of black cottonwood. For willows, wild herbivores had a significant influence on the rate of growth for the parameters of height, crown area, crown volume, and standing biomass. Nevertheless, due to the inherent resilience and adaptions to natural disturbance processes displayed by the riparian species, there was a rapid and positive response to cessation of those land use activities (i.e. cattle grazing) that caused habitat degradation and/or were preventing recovery.

Chen, X.; Wei, X.; Scherer, R. 2005. Influence of wildfire and harvest on biomass, carbon pool, and decomposition of large woody debris in forested streams of southern interior British Columbia. Forest Ecology and Management. 208(1-3): 101-114. doi:10.1016/j.foreco.2004.11.018

Abstract: Large woody debris (LWD) is an important component in the biogeochemistry cycle of carbon and nutrients in forested stream ecosystems. In-stream LWD volume, biomass and carbon pool were investigated in 19 forested streams in the south central interior of British Columbia. The stream channels were classified into four disturbance categories based upon condition of the adjacent riparian forest. The categories are: (1) riparian forest harvested approximately 10 years ago (HT10), (2) riparian forest harvested approximately 30 years ago (HT30), (3) riparian forest burned by a wildfire approximately 40 years ago (WF), and (4) undisturbed old-growth riparian forest (OF). Streams with riparian forests that were affected by wildfire or were recently harvested were observed to have significantly higher LWD volumes, biomass, and carbon pool as compared to streams flowing through old-growth riparian forests. LWD stocks averaged 376 m^3 ha^{-1} (volume), 112 Mg ha^{-1} (biomass), 52 Mg C ha^{-1} (carbon) in WF, 258 m^3 ha^{-1}, 78 Mg ha^{-1} and 36 Mg C ha^{-1} in HT10, 180 m^3 ha^{-1}, 52 Mg ha^{-1} and 23 Mg C ha^{-1} in HT30, and 114 m^3 ha^{-1}, 37 Mg ha^{-1} and 17 Mg C ha^{-1} in OF. Volume, biomass, and carbon stock were 2.3, 2.0, 2.1, and 1.3, 1.1, and 1.1 times higher in WF and HT10 than in OF, respectively, but LWD loading did not differ significantly between HT30 and OF. Major differences were also observed in the state of decay of LWD between the four disturbance categories based upon three decomposition classes. Our study supports the conclusion that harvesting creates a short-term increase in LWD stocks. However, harvesting may greatly reduce LWD loadings over the long-term due to relatively rapid decomposition of LWD due to increased rate of decay, transport, and reduced recruitment from the adjacent riparian forest. In the study streams, the wood density of LWD ranged from 0.273 to 0.427 g cm^{-3} depending upon the species and decomposition level. An average decay rate constant of 0.0095 $year^{-1}$ was calculated for the LWD based upon wood density. Based upon this decay rate, the time required to loss 50% (t0.5) and 95% (t0.95) of wood is 74 and 316 years, respectively.

Chen, X.; Wei, X.; Scherer, R.; Luider, C.; Darlington, W. 2006. A watershed scale assessment of in-stream large woody debris patterns in the southern interior of British Columbia. Forest Ecology and Management. 229(1-3): 50-62. doi:10.1016/j.foreco.2006.03.010

Abstract: In-stream large woody debris (LWD) is a structurally and functionally important component of forested stream ecosystems. To assess the role played by LWD in sustaining aquatic ecosystems at the watershed scale, the amount, distribution, dynamics and function

of LWD within channel networks have to be determined. We surveyed 35 sites in first- through fifth-order streams within forested watersheds in the southern interior of British Columbia, and the spatial variation and distribution of LWD characteristics (frequency, density, volume, biomass, orientation, submersion, and decay state) were quantified based on four stream size categories. We found that the average diameter, length, volume and biomass of individual LWD pieces increased as a function of increasing bank-full width. However, LWD density (piece per 100 m^2 of the stream area) decreased with an increase in bank-full width. LWD volume ranged from 0.78 to 1.58 $m^3/100\ m^2$ of stream area, with intermediate sized streams (sizes II and III) having the largest value and large sized streams (size IV) having the lowest values. Results showed that LWD biomass averaged 383 kg/100 m^2 (range 265-651 kg/100 m^2) in stream size I, increased to 491 kg/100 m^2 (range 81-1254 kg/100 m^2) in stream size II, and slightly decreased to 465 kg/100 m^2 (range 247-938 kg/100 m^2) in stream size III and further decreased to 250 kg/100 m^2 (range 88-533 kg/100 m^2) in stream size IV. The large majority of LWD pieces in the smallest sized streams was orientated perpendicular to streamflow and was located in spanning the channel. Conversely, most LWD pieces in intermediate sized streams were orientated parallel to the direction of flow and were situated below the bank-full height of the channel. With a difference in the orientation and position, LWD pieces within different sized streams are expected to have varying potentials to affect streamflow and channel habitats. These results highlight the need to recognize spatial variation of in-stream LWD loading and function through channel networks when maintaining suitable LWD pieces and making riparian management decisions at watershed scales.

Clemmer, P. 1994. The use of aerial photography to manage riparian-wetland areas. Tech. Ref. 1737-10. Denver, CO: USDI Bureau of Land Management, Service Center. 54 p.

Abstract: This technical reference provides basic information, concepts, and procedures associated with using aerial photography to establish baseline data for effective management of riparian-wetland areas. Suggestions for the use of various scales of photography, guidance for acquiring aerial photography, and general procedures for conducting a vegetation inventory are included.

Coles-Ritchie, M.C.; Henderson, R.C.; Archer, E.K.; Kennedy, C.; Kershner, J.L. 2004. Repeatability of riparian vegetation sampling methods: How useful are these techniques for broad-scale, long-term monitoring? Gen. Tech. Rep. RMRS-GTR-138. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 18 p.
http://www.treesearch.fs.fed.us/pubs/8386

Abstract: Tests were conducted to evaluate variability among observers for riparian vegetation data collection methods and data reduction techniques. The methods are used as part of a large-scale monitoring program designed to detect changes in riparian resource conditions on Federal lands. Methods were evaluated using agreement matrices, the Bray-Curtis dissimilarity metric, the coefficient of variation, the percentage of total variability attributed to observers, and estimates of the number of sites needed to detect change. Community type (CT) cover data differed substantially among the six to seven observers that sampled the same sites. The mean within-site similarity in the vegetation data ranged from 40 to 65 percent. Converting CT data to ratings (bank stability, successional, and wetlands ratings) resulted in better repeatability, with coefficients of variation ranging from 6 to 13 percent and a percentage of variability attributed to observers of 16 to 44 percent. Sample size estimates for the ratings generated from CT cover data ranged from 56 to 224 sites to detect a change of 10 percent between two populations. The woody species regeneration method was imprecise. The effective ground cover method was quite precise with a coefficient of variation of two, but had so little variability among sites that statistically significant change in this attribute would not be expected. In general, reducing the CTs to ratings increased precision because of the elimination of differences among observers that were not important from the perspective of the rating. Studies that seek to detect change at a single site would need to take into account the observer variability described here. Studies that seek to detect differences between populations of sites could detect relatively large changes with these methods and ratings. Small differences among populations would be difficult to detect with a high degree of confidence, unless hundreds of sites were sampled.

Committee on Riparian Zone Functioning and Strategies for Management. 2002. Riparian areas: Functions and strategies for management. Washington, DC: National Academies Press. 428 p. isbn:9780309082952

Summary: Lands next to water are fundamental to the livelihood of many species of plants and animals, including humans. Birds and other wildlife aggregate in riparian areas, often in great abundance. At the same time, society values riparian areas for production of food and fiber, access to transportation, opportunities for recreation, and natural scenic beauty. This report examines the structure and functioning of riparian areas, how they have been altered by human activity, their legal status, and their potential for management and restoration.

Cooper, D.J.; Merritt, D.M. 2012. Assessing the water needs of riparian and wetland vegetation in the western United States. Gen. Tech. Rep. RMRS-GTR-282. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 125 p.
http://www.treesearch.fs.fed.us/pubs/41207

Abstract: Wetlands and riparian areas are unique landscape elements that perform a disproportionate role in landscape functioning relative to their aerial extent on the landscape. The purpose of this guide is to provide a general foundation for the reader in several interrelated disciplines for the purpose of enabling him/her to characterize and quantify the water needs of riparian and wetland vegetation. Topics discussed are wetland and riparian classification, characteristics and ecology, surface and groundwater hydrology, plant physiology and population and community ecology, and techniques for linking attributes of vegetation to patterns of surface and groundwater and soil moisture.

Crowe, E.A.; Clausnitzer, R.R. 1997. Mid-montane wetland plant associations of the Malheur, Umatilla and Wallowa-Whitman National Forests. Tech. Pap. R6-NR-ECOL-TP-22-97. Baker City, OR: USDA Forest Service, Pacific Northwest Region, Wallowa-Whitman National Forest. 299 p. Crowe and Clausnitzer 1997

Abstract: This guide presents a classification of wetland plant associations, community types and communities (described below) occurring within the Malheur, Umatilla and Wallowa-Whitman National Forests. Included are plant associations occurring on fluvial surfaces in

valley bottoms that may not be classified as jurisdictional wetlands but that do function as "xeric" or "transitional" riparian areas (Kovalchik 1987). These fluvial surfaces are usually terraces or inactive floodplains. Jurisdictional wetlands must (under current regulations) have three components: wetland hydrology, hydric soils and hydrophytes. The Natural Resources Conservation Service has devised the list of soil types that qualify as hydric soils, the definitions of wetland hydrology are found wetland delineation manual (Federal Interagency Committee for Wetland Delineation 1989), and the USFWS has prepared the list of hydrophytes and their degree of wetland affinity.

Crowe, E.A.; Kovalchik, B.L.; Kerr, M. 2004. Riparian and wetland vegetation of central and eastern Oregon. Portland, OR: Oregon State University, Institute for Natural Resources, Oregon Natural Heritage Information Center. 473 p.
http://orbic.pdx.edu/documents/crowe2004.pdf

No abstract provided; Introduction from book: Aquatic, riparian and other wetland systems occupy a small portion of the landscape but provide a disproportionate amount of important habitat for unique plant species and terrestrial animals (Crowe and Clausnitzer 1997). Vegetative productivity is generally higher in riparian areas and other wetlands than in surrounding uplands, and the cooler, moister microclimate provides a contrasting habitat to that of drier uplands. Riparian areas also contribute to fish habitat and help to control floods through water storage and sediment trapping (Crawford 2001). Wetland, riparian and aquatic systems east of the Cascade Range are also of very high value for human uses including: recreation; water supplies for municipalities and irrigation districts; placer mining; crop production; livestock grazing; and transportation corridors. The structure and components of riparian areas influence the rate, amount, and timing of water, nutrients, organic debris, and inorganic materials that enter streams and rivers. The energy of floodwaters and their ultimate volume, timing and erosive power is influenced by the soils, vegetation and geomorphology of fluvial surfaces within valley bottoms. Decades of intensive use of riparian areas and other wetlands in central and eastern Oregon have caused substantial degradation of their ecological structure, composition and function. Rehabilitation, restoration and monitoring of wetland ecosystems are currently a high priority for many land management agencies and landowners. In order to improve conditions in these habitats, an understanding of wetland ecosystems is necessary. Classification of plant associations provides a means of stratifying these ecosystems into easily recognizable and repeatable units. Wetland plant associations integrate potential natural vegetation, soil characteristics, fluvial geomorphology, hydrology and climate. This classification provides a common framework for various disciplines to manage wetland ecosystems, including planning management activities and analyzing the effects of these activities.

Cummins, K.W. 1974. Structure and function of stream ecosystems. BioScience. 24(11): 631-641. doi:10.2307/1296676

No abstract provided; Conclusions section from the article: In summary, the basic features of stream ecosystem structure and function are now established and various functional ecological components and their interrelationships have been defined and initially dimensioned for some representative streams. The search continues for additional or alternative functional criteria to replace partially or totally the previous dependence on classical taxonomic units. Attention is now focused on two apparently generalizable conditions in nonperturbated running waters: The efficient conversion of organic matter, especially particulates, to CO_2 and the maintenance of a minor role played by in-stream plant growth. Clearly the time is at hand to infuse the "new stream ecology" into management strategies directed at our precious running waters.

Dahlström, N.; Jönsson, K.; Nilsson, C. 2005. Long-term dynamics of large woody debris in a managed boreal forest stream. Forest Ecology and Management. 210(1-3): 363-373. doi:10.1016/j.foreco.2005.02.022

Abstract: Little is known about how past forest management in Sweden influenced the quantity and quality of large woody debris (LWD) in streams. The present study provides information of the long-term dynamics of LWD in a reach of a boreal stream intersecting a managed forest. Dendrochronological methods were used to reconstruct mortality years of the pieces of LWD and the general history of fire and cuttings of the surrounding riparian forest. Today, spruce dominates among the living trees, whereas the LWD is dominated by birch in the forest and by pine in the stream. Fire frequency prior to active fire suppression was similar to values reported from boreal forests. Pine trees were more abundant in the riparian forest before selective logging operations and active fire suppression began in the 1800s. Many of the pieces of LWD found in the stream today died more than 200 years ago and derived from a cohort of pines that generated in the early 1600s. Pine LWD in stream channels is highly resistant to decomposition and can reside for more than 300 years. A substantial amount of the LWD found today in managed forest streams in boreal Sweden most likely derives from the time before extensive human influence and is likely to decrease further in the future. Management of riparian forests to ascertain future supply of long-lived LWD in streams should target to increase the proportion of pine trees.

Danehy, R.J.; Kirpes, B.J. 2000. Relative humidity gradients across riparian areas in eastern Oregon and Washington forests. Northwest Science. 74(3): 224-233.

Abstract: Riparian relative humidity gradients were examined at twelve sites east of the Cascade Mountains in Oregon and Washington in 1997. Relative humidity was monitored at increasing distances from stream edge to 30 m in the adjacent forested stands. Within 10 m of stream edge relative humidity was similar to upland conditions with little change beyond 10 m. In 9 of the 12 sites differences in mean minimum relative humidity were significant ($P < 0.05$) between 0 and 5 m. The length of time that relative humidity was less than 50% between 0 and 5 m was significant at 11 of the 12 sites. Diurnal fluctuations ranges of more than 75% RH with maximums close to 100% occurred at night at all sites. The diurnal pattern of temperature is the dominant process in air moisture regime in these eastside forests. The small daytime increases in relative humidity close to the stream, which can be maintained over short distances by steep local topography, are apparently due to evaporation from wetted stream width and transpiration from vegetation immediately adjacent to the stream.

Danehy, R.J.; Colson, C.G.; Parrett, K.B.; Duke, S.D. 2005. Patterns and sources of thermal heterogeneity in small mountain streams within a forested setting. Forest Ecology and Management. 208(1-3): 287-302. doi:10.1016/j.foreco.2004.12.006

Abstract: Spatial thermal patterns and the sources of those patterns were examined in four mountain streams in northeast Oregon and Idaho during hot summer days in 2001. Summer baseflow ranged from <0.007 to 0.22 m^3/s. Maximum and minimum temperatures increased in the downstream direction, with the diurnal range decreasing with increasing stream size. Each stream was thermally diverse spatially, diurnally, and seasonally, with unique landform and geologic influences on the daily temperature maxima. Insolation was the most important predictor for maximum temperature at each stream. Minimum daily temperatures were less variable than maxima and followed a seasonal and elevation gradient, with minimum air temperature a more important predictor than either the insolation from the previous day or channel features. Models for each stream using insolation and physical habitat characteristics explain 32 to 67% of maximum temperature and 17 to 51% of minimum temperature variability. Groundwater inputs moderated thermal conditions, particularly local maxima, but did not subsume the predominant temperature range controls of insolation and air temperature.

Darambazar, E. 2003. Factors influencing diet composition of beef cattle grazing mixed conifer mountain riparian areas. Master of Science thesis. Corvallis, OR: Oregon State University. 116 p.

Abstract: Two trials were conducted to evaluate changes in the quantity, quality, and moisture of available forage in the pasture, and shrub utilization by cattle during a 30-d late summer grazing period (Trial 1) and the effect of cow age (experience) on grazing distribution and diet composition (Trial 2) in mountain riparian areas. In the trial 1, a pasture (44.7 ha) in the Catherine Creek site at OSU's Hall Ranch in northeast of Oregon was grazed with 30 yearlings and 30 mature cow/calf pairs from early August to early September in 2001, and from late July to late August in 2002. Sampling dates were d 0, d 10, d 20, and d 30 of the grazing period. The forage availability before grazing was 1058 kg/ha and declined to 323 kg/ha at the end of the grazing period ($P < 0.10$). Grasses dominated the pasture, followed by forbs, grasslikes, and shrubs. Kentucky bluegrass was the most prevalent forage species followed by timothy, sedges, and common snowberry. The highest percent disappearances of forage species was (83.7-92.7%) observed with quackgrass, western fescue, California brome, redtop, and heartleaf arnica, though their initial contributions to the available forage were less than 5%. High levels of shrub utilization were observed from d 20 through the end of the grazing period (45% for willow and 59% for alder). Forbs and shrubs did not vary in moisture content between the 10 d intervals and across the years averaging 59% and 61%, respectively ($P > 0.10$). In contrast, the moisture content of grasses were over 50% at the beginning of the grazing period but declined dramatically to 34% from d 10 to d 20. Likewise, forbs and shrubs were higher $P < 0.05$) than grasses in CP (11, 14, and 6%, respectively) and IVDMD (58, 49, and 42% respectively). In summary, our results suggest that cattle grazing late summer riparian pastures will switch to intensive shrub utilization when grasses decline in quality and quantity, and forbs decline in quantity. In the trial 2, thirty first calf heifers, and thirty mature cows were randomly assigned to four pastures (15 head per pasture, average 21.5 ha) in the Milk Creek site of Hall Ranch from late July to early September of 2000 and 2001. Botanical composition of diets was determined by analyzing the feces

from 10 animals (5 per pasture) in each treatment during the fourth week of the trial using the microhistological procedure. Correction factors were calculated for the 22 major plant species. First calf heifers had higher portions of grasses (75% versus 71 %; P < 0.05), but lower portions of shrubs and trees (9% versus 13%; P < 0.10) as compared to mature cow diets, respectively. On an individual species basis, ponderosa pine consumption was a major contributor with mature cows consuming greater quantities (P < 0.1 0) than first calf heifers. In summary, mature cows seem to have selected diet less in the amount of grasses and more in the amount of shrubs and trees as compared to younger cows.

Davidson, A.S.; Knight, R.L. 2001. Avian nest success and community composition in a western riparian forest. Journal of Wildlife Management. 65(2): 334-344. doi:10.2307/3802913

Abstract: Riparian cottonwood (*Populus angustifolia*) forests provide avian habitats that are of high conservation value throughout western North America. We compared avian nest success, brood parasitism, species richness, and species abundance among 24 cottonwood forest patches representing a range of sizes and shapes. We randomly selected patches in 3 ranges of size, small (0.1-0.6 ha), medium (1.2-2.5 ha), and large (4.0-6.2 ha); and 2 ranges of shape, compact (1.00-1.83) and edgy (1.87-3.30). We measured patch shape using the Patton Diversity Index. We monitored 313 nests of 20 species over 2 years. Only American robin (*Turdus migratorius*) nests exhibited a negative relationship between distance from edge and probability of daily nest survival. We found no relationship between the probability of nest parasitism and patch size, patch shape, or nest distance from edge. Point counts revealed that both richness and abundance of forest-interior bird species increased with patch size. Forest-interior species abundance also increased with decreasing Patton Diversity Index. Our results suggest that patch edginess has a negative effect on the abundance of forest-interior birds. Although our results do not show that patch edginess has a negative effect on nest success, they emphasize the importance of species autecology in relation to the effects of edge on avian nesting success.

Dawson, T.E.; Ehleringer, J.R. 1991. Streamside trees that do not use stream water. Nature. 350(6316): 335-336. doi:10.1038/350335a0

Abstract: A long-standing axiom is that plant distribution is strongly influenced by soil moisture content. While it has been shown that plant taxa inhabiting streamside communities receive or use more water, it is assumed that this water is obtained from the stream adjacent to where they are found growing. Here we show, using hydrogen isotope ratio analyses at natural abundance levels, that mature streamside trees growing in or directly next to a perennial stream used little or none of the surface stream water. The deuterium to hydrogen content of both source and xylem waters indicated that mature trees were using waters from deeper strata. Although adult trees may have roots distributed continuously throughout a soil profile, it seemed that the most active sites of water absorption were limited to deeper soil layers. In contrast, small streamside individuals appeared to use stream water, whereas small non-streamside individuals used recent precipitation as their primary water source. Our analyses provide both a relatively non-destructive method for assessing water sources of plants and a means of assessing potential competitive interactions among co-

occurring taxa. In addition, the method may aid in resolving the role of water in determining plant distributions in areas characterized by sharp soil moisture gradients.

DeBano, L.F.; Schmidt, L.J. 1989. Improving southwestern riparian areas through watershed management. Gen. Tech. Rep. RM-182. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 33 p. http://www.treesearch.fs.fed.us/pubs/37647

Abstract: This paper reviews opportunities and watershed restoration techniques available for rehabilitating and enhancing riparian ecosystems in southwest environments. As such, it is intended to serve as a state-of-the-art report on riparian hydrology and improvement in both naturally occurring and man-made riparian areas throughout the Southwest.

Decocq, G. 2002. Patterns of plant species and community diversity at different organizational levels in a forested riparian landscape. Journal of Vegetation Science. 13(1): 91-106. doi:10.1658/1100-9233(2002)013[0091:POPSAC]2.0.CO;2

Abstract: Integrated synusial phytosociology combined with traditional measures of diversity is used to describe the structure of vascular vegetation diversity along the forested riparian landscape of the upper Oise valley (Belgium and France). The two dimensions (longitudinal and lateral) of the geomorphological complex are examined at four scales: synusia, phytocoenosis, tesela and catena. The results support the following hypotheses: (1) the environmental gradients observed, particularly the lateral ones, are very complex; (2) there is a clear lack of coupling between the tree, shrub and herb layers, which indicates a differential response to the underlying influence of environmental controls; (3) moderate flooding-induced disturbance enhances herb species richness; (4) stressful environments support a low plant species diversity but a high synusial richness; (5) natural factors (substrate, climate, disturbance) are more important at the synusia and phytocoenose scales, but (6) anthropogenic disturbances, mainly through forest and river management, are more important at the landscape level. By considering plant communities as structural-dynamic entities of ecosystems in a landscape context, integrated synusial phytosociology provides a basis for decomposing a complex system since the different hierarchical levels are both nested and thus strongly relational and process-based.

Dick, L.H., Jr. 1990. Water is a medicine: it can touch your heart. Oregon Humanities. Winter: 8-10.

Abstract: August 3, 1990. 9:00 A.M. A hot morning in the foothills of the Blue Mountains, Umatilla County, Oregon. Once in a while, a single-engine plane moans through the cloudless sky. The rabbits are still eating breakfast under the junipers next to the road. The cicadas have not begun to sing so it must be cooler than 80 degrees. Louie Dick, vice chairman of the Confederated Tribes of the Umatilla, drives up in a big blue van. As he comes up the walk, his hair shines. It hangs in two long braids down the front of his workshirt, which is tucked neatly into his Levis. Louie has agreed to tell me stories about water on this dry, bright morning. He starts with his memories of the forest-use planning sessions he attended when he was employed by the United States Forest Service.

Disalvo, A.C.; Hart, S.C. 2002. Climatic and stream-flow controls on tree growth in a western montane riparian forest. Environmental Management. 30(5): 678-691. doi:10.1007/s00267-002-2719-2
Abstract: Humans have severely impacted riparian ecosystems through water diversions, impoundments, and consumptive uses. Effective management of these important areas is becoming an increasingly high priority of land managers, particularly as municipal, industrial, and recreational demands for water increase. We examined radial tree growth of four riparian tree species (*Pinus jeffreyi, Populus trichocarpa, Betula occidentalis*, and *Pinus monophylla*) along Bishop Creek, California, and developed models relating basal area increment (BAI) and relative basal area increment (RBAI) to climatic and stream flow variables. Between years 1995-1999, univariate regression analysis with stream flow explained 29 to 61% of the variation in BAI and RBAI among all species except *P. trichocarpa*; growth by *P. trichocarpa* was not significantly related to stream flows over this period. Stepwise linear regression indicated that species responded differently to climatic variables, and models based on these variables explained between 33 to 86% of variation in BAI and RBAI during the decade of the 1990s. We examined branch growth of *P. trichocarpa* for sensitivity to differences in stream flow regimes and found that annual branch growth did not vary between a high- and low-flow site, but that annual branch growth was significantly higher in wet years with greater stream flows. Our results support the establishment of site-specific management goals by land managers that take into account all of the important tree species present in riparian ecosystems and their differential responses to altered hydrologic condition. Instream flow requirements for maintaining tree growth and vigor are only one of the species-specific responses that need to be evaluated, and these assessments should attempt to separate experimentally stream-flow (managed) controls from climatic (unmanaged) controls on growth.
Dwire, K.A.; Kauffman, J.B. 2003. Fire and riparian ecosystems in landscapes of the western USA. Forest Ecology and Management. 178(1-2): 61-74. doi:10.1016/S0378-1127(03)00053-7
Abstract: Despite the numerous values of riparian areas and the recognition of fire as a critical natural disturbance, few studies have investigated the behavior, properties, and influence of natural fire in riparian areas of the western USA. Riparian areas frequently differ from adjacent uplands in vegetative composition and structure, geomorphology, hydrology, microclimate, and fuel characteristics. These features may contribute to different fire environments, fire regimes, and fire properties (frequency, severity, behavior, and extent) in riparian areas relative to uplands. In certain forested riparian areas, fire frequency has generally been lower, and fire severity has been more moderate than in adjacent uplands, but in other areas, fires have appeared to burn riparian areas with comparable frequency. Impacts of land use and management may strongly influence fire properties and regimes in riparian areas. Fire suppression, livestock grazing, logging, damming and flow regulation, agricultural diversions, channel modifications, and introduction of invasive species have led to shifts in plant species composition, structure and distribution of fuel loads, and changes in microclimate and areal extent of riparian areas. Cumulative impacts of human alterations are likely

to exert the most pronounced influence on fire behavior during periods of drought and under conditions of extreme fire weather. Riparian plant species possess adaptations to fluvial disturbances that facilitate survival and reestablishment following fires, thus contributing to the rapid recovery of many streamside habitats. Given the critical resource values of riparian zones, additional data are needed to understand interactions between fire and riparian ecosystems, and how riparian zones affect spatial and temporal patterns of fires at the landscape scale. An improved understanding of fire ecology and effects in riparian areas is needed to prescribe ecologically sound rehabilitation projects following fire.

Elliot, W.J.; Miller, I.S.; Audin, L. 2010. Cumulative watershed effects of fuel management in the western United States. Gen. Tech. Rep. RMRS-GTR-231. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 299 p. http://www.treesearch.fs.fed.us/pubs/34301

Abstract: Fire suppression in the last century has resulted in forests with excessive amounts of biomass, leading to more severe wildfires, covering greater areas, requiring more resources for suppression and mitigation, and causing increased onsite and offsite damage to forests and watersheds. Forest managers are now attempting to reduce this accumulated biomass by thinning, prescribed fire, and other management activities. These activities will impact watershed health, particularly as larger areas are treated and treatment activities become more widespread in space and in time. Management needs, laws, social pressures, and legal findings have underscored a need to synthesize what we know about the cumulative watershed effects of fuel management activities. To meet this need, a workshop was held in Provo, Utah, on April, 2005, with 45 scientists and watershed managers from throughout the United States. At that meeting, it was decided that two syntheses on the cumulative watershed effects of fuel management would be developed, one for the eastern United States, and one for the western United States. For the western synthesis, 14 chapters were defined covering fire and forests, machinery, erosion processes, water yield and quality, soil and riparian impacts, aquatic and landscape effects, and predictive tools and procedures. We believe these chapters provide an overview of our current understanding of the cumulative watershed effects of fuel management in the western United States.

Elmore, W.; Beschta, R.L. 1987. Riparian areas: perceptions in management. Rangelands. 9(6): 260-265.

Abstract: The objectives of this paper are: 1) to promote awareness and discussion of riparian issues by and among livestock owners, land managers, environmentalists, biologists, and the general public; 2) to identify the characteristics and benefits of productive riparian systems; 3) to encourage managers of public and private lands to reconsider the effects of traditional grazing practices and of recent efforts to control channels structurally.

Everett, R.; Schellhaas, R.; Ohlson, P.; Spurbeck, D.; Keenum, D. 2003. Continuity in fire disturbance between riparian and adjacent sideslope Douglas-fir forests. Forest Ecology and Management. 175(1-3): 31-47. doi:10.1016/S0378-1127(02)00120-2

Abstract: Fire-scar and stand-cohort records were used to estimate the number and timing of fire disturbance events that impacted riparian and adjacent side-slope Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco) forests. Data were gathered from 49 stream segments on 24 separate streams on the east slope of the Washington Cascade Range. Upslope

forests had more “traceable” disturbance events than riparian forests in each of the valley types with a mean difference of 8-62%. Approximately 55-73% of the total traceable fire disturbance for a stream segment occurred on either side slope, and 24-27% in the riparian forest. Plant association groups in the riparian forest had 25-42% fewer fire disturbance events than the same plant association group upslope. Fewer traceable disturbance events in riparian forests may indicate a reduced disturbance frequency or a more severe disturbance regime or both. The two side-slopes on either side of the riparian forest shared the same fire event in 65 and 54% of the recorded fire events on east/west and north/south side-slopes, respectively. Riparian forests shared fire events with adjacent side-slope forests 58-79% among valley types, and 64-76% among aspects. Shared fire events indicate significant continuity in fire disturbance between riparian and adjacent side-slope forests. Fire disturbance regimes of side-slope and riparian forests are quantitatively different, but interconnected through shared fire disturbance events. Disturbance events play a role in maintaining ecosystem integrity and we suggest that disturbance may need to be planned for in administratively defined riparian buffer strips to protect long-term ecological integrity of riparian and adjacent upslope forests.

Fetherston, K.L.; Naiman, R.J.; Bilby, R.E. 1995. Large woody debris, physical process, and riparian forest development in montane river networks of the Pacific Northwest. Geomorphology. 13(1-4): 133-144. doi:10.1016/0169-555X(95)00033-2

Abstract: We present a conceptual biogeomorphic model of riparian forest development in montane river networks. The role of physical process in driving the structure, composition, and spatial distribution of riparian forests is examined. We classify the drainage network into disturbance process-based segments including: (1) debris-flow and avalanche channels, (2) fluvial and debris-flow channels, and (3) fluvial channels. Riparian forests are shown to be significant in the development of channel morphology through the stabilization of active floodplains and as sources of large woody debris (LWD). LWD is operationally defined as wood > 0.1 m diameter and > 1 m length. LWD plays a key role in the development of montane riparian forests. LWD deposited in the active channel and floodplain provides sites for vegetation colonization, forest island growth and coalescence, and forest floodplain development. Riparian forest patterns parallel the distribution of hill-slope and fluvial processes through the network. Riparian forest structure:, composition, and spatial distribution through the network are driven by the major disturbance processes including: (1) avalanches, (2) debris-flows, and (3) flooding. Riparian forest patterns also reflect the action of LWD in the organization and development of forested floodplains in gravel bedded montane river networks. The focus of our examples is montane river networks of the Pacific Northwest, USA.

Fisher, H.M.; Thomas, A.E. 1990. Riparian communities: An annotated bibliography of ecosystem and management topics with emphasis on the intermountain West. Tech. Bull. 90-7. Boise, ID: Bureau of Land Management, Idaho State Office. 76 p.

Summary (taken from Introduction of report): This technical bulletin updates and expands earlier bibliographies of riparian topics (Thomas and Wentzell, 1986; Clifton and Thomas, 1988). Sources of literature for this bibliography include published workshop and symposia proceedings (60 citations); reports issued by the U.S. Forest Service (29 citations), Fish and Wildlife Service (22 citations), Bureau of Land Management (14 citations), Soil Conservation Service (3 citations), Environmental Protection Agency (2 citations), and other Federal Government bodies (3 citations); reports issued by Institutes and Associations associated with seven western Universities (14 citations); reports published in scientific and technical journals (79 citations from 35 journals; a thesis; and several miscellaneous documents. Of 230 references, 187 were published since 1987.

Fleischner, T.L. 1994. Ecological costs of livestock grazing in western North America. Conservation Biology. 8(3): 629-644. doi:10.1046/j.1523-1739.1994.08030629.x

Abstract: Livestock grazing is the most widespread land management practice in western North America. Seventy percent of the western United States is grazed, including wilderness areas, wildlife refuges, national forests, and even some national parks. The ecological costs of this nearly ubiquitous form of land use can be dramatic. Examples of such costs include loss of biodiversity; lowering of population densities for a wide variety of taxa; disruption of ecosystem functions, including nutrient cycling and succession; change in community organization; and change in the physical characteristics of both terrestrial and aquatic habitats. Because livestock congregate in riparian ecosystems, which are among the biologically richest habitats in arid and semiarid regions, the ecological costs of grazing are magnified in these sites. Range science has traditionally been laden with economic assumptions favoring resource use. Conservation biologists are encouraged to contribute to the ongoing social and scientific dialogue on grazing issues.

Fletcher, R.J.J.; Hutto, R.L. 2008. Partitioning the multi-scale effects of human activity on the occurrence of riparian forest birds. Landscape Ecology. 23(6): 727-739. doi:10.1007/s10980-008-9233-8

Abstract: Conservationists, managers, and land planners are faced with the difficult task of balancing many issues regarding humans impacts on natural systems. Many of these potential impacts arise from local-scale and landscape-scale changes, but such changes often covary, which makes it difficult to isolate and compare independent effects arising from humans. We partition multi-scale impacts on riparian forest bird distribution in 105 patches along approximately 500 km of the Madison and Missouri Rivers, Montana, USA. To do so, we coupled environmental information from local (within-patch), patch, and landscape scales reflecting potential human impacts from grazing, invasive plant species, habitat loss and fragmentation, and human development with the distribution of 28 terrestrial breeding bird species in 2004 and 2005. Variation partitioning of the influence of different spatial scales suggested that local-scale vegetation gradients explained more unique variation in bird distribution than did information from patch and landscape scales. Partitioning potential human impacts revealed, however, that riparian habitat loss and fragmentation at the patch and landscape scales explained more unique variation than did local disturbances or landscape-scale development (i.e., building density in the surrounding landscape). When distribution was correlated with human disturbance, local-scale disturbance had more consistent impacts than other scales, with species showing consistent negative correlations with grazing but positive correlations with invasives. We conclude that while local vegetation

structure best explains bird distribution, managers concerned with ongoing human influences in this system need to focus more on mitigating the effects of large-scale disturbances than on more local land use issues.

Fonnesbeck, C.J. 2007. Spatial modeling of riparian state dynamics in eastern Oregon, USA by using discrete event simulation. Landscape and Urban Planning. 80(3): 268-277. doi:10.1016/j.landurbplan.2006.10.007

Abstract: In order to relate the effects of small- to mid-scale riparian state dynamics to land use management goals at a broader, watershed scale, I developed a general, simulation-based modeling framework for riparian landscape dynamics. Discrete event simulation (DES) was used to implement a set of models incorporating state dynamics for several potential morphological groups, along with a set of landscape events that interact with successional changes in stream vegetation and morphology. These models operate concurrently on a connected landscape, parameterized by extant spatial databases, and expert opinion. As a sample application, two landscape disturbance scenarios were simulated, representing contrasting forest management regimes for a subbasin in eastern Oregon, USA. This case study incorporates the individual dynamics of almost 8000 polygons and 10 types of events in a common framework. Both scenarios resulted in relatively homogeneous landscapes, with primarily mature multi-strata forest states under historical conditions, and a mix of mature forest and pioneer forb community under current conditions. These simulation results do not appear to accurately represent current or historical landscape conditions, likely because of insufficient information for adequately calibrating model parameters and their associated uncertainty. Still, this modeling approach provides an effective method for incorporating riparian landscape dynamics in forest landscape decision support systems.

Friedman, J.M.; Lee, V.J. 2002. Extreme floods, channel change, and riparian forests along ephemeral streams. Ecological Monographs. 72(3): 409-425. doi:10.1890/0012-9615(2002)072[0409:EFCCAR]2.0.CO;2

Abstract: The geomorphic effectiveness of extreme floods increases with aridity and decreasing watershed size. Therefore, in small dry watersheds extreme floods should control the age structure and spatial distribution of populations of disturbance-dependent riparian trees. We examined the influence of extreme floods on the bottomland morphology and forest of ephemeral streams in a semiarid region. Along six stream reaches on the Colorado Piedmont we examined channel changes by analyzing a rectified sequence of aerial photographs spanning 56 yr, and we investigated the spatial distribution of different-aged patches of forest by aging 189 randomly sampled cottonwood trees. Channel change in these ephemeral sand-bed streams is dominated by widening, which occurs over a span of hours during infrequent floods, and post-flood narrowing, which occurs over decades between floods. Narrowing is accelerated where reliable moisture increases the density and growth rate of vegetation on the former bed. Reproduction of cottonwood trees has occurred mostly in former channel bed during periods of channel narrowing beginning after floods in 1935 and 1965 and continuing for as long as two decades. Thus cottonwood establishment is related to low flows at the time scale of a year, but to high flows at the time scale of decades. At sites that have not experienced major floods in the last 80 yr, little channel change has occurred, cottonwood reproduction has been limited, tree density has declined, and succession to grassland is occurring. Because channel change and tree reproduction in this region are driven by infrequent local events, channel width and tree age distributions vary greatly over time and among sites. For the same reason, riparian forests along these ephemeral streams can be as wide as forests along perennial rivers with much higher mean discharge.

Furniss, M.J.; Staab, B.P.; Hazelhurst, S.; Clifton, C.F.; Roby, K.B.; Ilhadrt, B.L.; Larry, E.B.; Todd, A.H.; Reid, L.M.; Hines, S.J.; Bennett, K.A.; Luce, C.H.; Edwards, P.J. 2010. Water, climate change, and forests: watershed stewardship for a changing climate. Gen. Tech. Rep. PNW-GTR-812. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 75 p. http://www.treesearch.fs.fed.us/pubs/35295

Abstract: Water from forested watersheds provides irreplaceable habitat for aquatic and riparian species and supports our homes, farms, industries, and energy production. Secure, high-quality water from forests is fundamental to our prosperity and our stewardship responsibility. Yet population pressures, land uses, and rapid climate change combine to seriously threaten these waters and the resilience of watersheds in most places. Forest land managers are expected to anticipate and respond to these threats and steward forested watersheds to ensure the sustained protection and provision of water and the services it provides. Effective, constructive watershed stewardship requires that we think, collaborate, and act. We think to understand the values at risk and how watersheds can remain resilient, and we support our thinking with knowledge sharing and planning. We collaborate to develop common understandings and goals for watersheds and a robust, durable capacity for response that includes all stakeholders and is guided by science. We act to secure and steward resilient watersheds that will continue to provide crucial habitats and water supplies in the coming century by implementing practices that protect, maintain, and restore watershed processes and services.

Gage, E.; Cooper, D.J. 2013. Historical range of variation assessment for wetland and riparian ecosystems, U.S. Forest Service Rocky Mountain Region. Gen. Tech. Rep. RMRS-GTR-286WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 239 p. http://www.treesearch.fs.fed.us/pubs/43268

Abstract: This document provides an overview of historical range of variation concepts and explores their application to wetland and riparian ecosystems in the US Forest Service Rocky Mountain Region (Region 2), which includes National Forests and National Grasslands occurring in the states of Colorado, Wyoming, Nebraska, Kansas, and South Dakota. For each of five ecosystem types – riparian areas, fens, wet meadows, salt flats, and marshes – we review key structural and functional characteristics including geomorphic setting, principal ecological drivers, classification, and dominant vegetation. In addition, we discuss anthropogenic factors known to influence the abundance or condition of each main wetland type.

Gaither, R.E.; Buckhouse, J.C. 1983. Infiltration rates of various vegetative communities within the Blue Mountains of Oregon. Journal of Range Management. 36(1): 58-60.

Abstract: Mean infiltration rates differed among several natural vegetation communities with ponderosa pine (*Pinus ponderosa*) exhibiting the lowest mean infiltration rate of 6.0 cm/hr and larch (*Larix occidentalis*) demonstrating the highest at 8.8 cm/hr. A trend toward increasing infiitration rates corresponded to increasingly mesic sites. Alpine, Douglas fir (*Psuedotsuga menziesii*), mountain meadow, and larch types demonstrated the greatest vegetative cover, occupied the most mesic sites, and exhibited the highest infiltration rates. Infiltration differences within vegetative communities, based upon changes in condition and productivity were also noted. The forested sites were more dependent upon condition class than productivity class, with higher infiltration rates being exhibited on pole sites than on timbered sites, apparently in response to higher plant densities associated with the pole thickets. Nonforested sites were responsive to both productivity and condition class with higher infiltration rates being exhibited on these sites with the more productive or better condition classifications.

Gergel, S.; Stange, Y.; Coops, N.; Johansen, K.; Kirby, K. 2007. What is the value of a good map? An example using high spatial resolution imagery to aid riparian restoration. Ecosystems. 10(5): 688-702. doi:10.1007/s10021-007-9040-0

Abstract: Riparian areas contain structurally diverse habitats that are challenging to monitor routinely and accurately over broad areas. As the structural variability within riparian areas is often indiscernible using moderate-scale satellite imagery, new mapping techniques are needed. We used high spatial resolution satellite imagery from the QuickBird satellite to map harvested and intact forests in coastal British Columbia, Canada. We distinguished forest structural classes used in riparian restoration planning, each with different restoration costs. To assess the accuracy of high spatial resolution imagery relative to coarser imagery, we coarsened the pixel resolution of the image, repeated the classifications, and compared results. Accuracy assessments produced individual class accuracies ranging from 70 to 90% for most classes; whilst accuracies obtained using coarser scale imagery were lower. We also examined the implications of map error on riparian restoration budgets derived from our classified maps. To do so, we modified the confusion matrix to create a cost error matrix quantifying costs associated with misclassification. High spatial resolution satellite imagery can be useful for riparian mapping; however, errors in restoration budgets attributable to misclassification error can be significant, even when using highly accurate maps. As the spatial resolution of imagery increases, it will be used more routinely in ecosystem ecology. Thus, our ability to evaluate map accuracy in practical, meaningful ways must develop further. The cost error matrix is one method that can be adapted for conservation and planning decisions in many ecosystems.

Gillen, R.L.; Krueger, W.C.; Miller, R.F. 1985. Cattle use of riparian meadows in the Blue Mountains of northeastern Oregon. Journal of Range Management. 38(3): 205-209.

Abstract: The intensity and pattern of cattle use of small riparian meadows were studied by periodically sampling vegetative standing crop and by continuously monitoring meadows with time-lapse photography. The seasonal pattern of cattle occupation was influenced by the location where cattle entered a pasture but not by seasonal temperatures. Temperature and the temperature-humidity index did not differ between riparian and upland plant communities between 12 noon and 6 PM.

Giller, P.S.; Malmqvist, B. 2008. The biology of streams and rivers. Biology of habitats. Oxford, UK: Oxford University Press. 296 p. isbn:978-0-19-854977-2

Abstract: An easy-to-read, beautifully illustrated undergraduate-level introduction to fresh- and running-water biology. Each chapter includes practical information on simple studies and experiments for students to try. The text begins with the physical features that define running water (lotic) habitats then continues with organisms that inhabit these habitats, and concludes with a discussion of applied issues surrounding water use, including pollution, species diversity, and conservation. The authors outline the range of living organisms in lotic habitats, and the environmental adaptations they exhibit. They discuss population, community, and ecosystem patterns and processes, such as energy flow, nutrient cycling, migration, food webs, and community structure. Particular consideration is given to links between stream and river channels and their surrounding landscapes, to short-term and seasonal changes, and to historical and biogeographical factors. The text concludes with a section of additional practical field work activities and a list for further reading.

Green, D.M.; Kauffman, J.B. 1995. Succession and livestock grazing in a northeastern Oregon riparian ecosystem. Journal of Range Management. 48(4): 307-313.

Abstract: Comparisons of vegetation dynamics of riparian plant communities under livestock use and exclusions over a 10 year period were quantified in a Northeastern Oregon riparian zone. We measured species frequency, richness, diversity, evenness, and livestock utilization in 8 plant communities. Livestock grazed the study area from late August until mid-September at a rate of 1.3 to 1.8 ha/AUM. Utilization varied from > 70% in dry meadow to < 3% in cheatgrass dominated stands. Ungrazed dry and moist meadow communities had significantly lower ($P \leq 0.1$) species richness and diversity when compared to grazed counterparts. In the most heavily grazed communities, ruderal and competitive ruderal species were favored by grazing disturbance. In exclosures of the same communities, competitive or competitive stress tolerant species were favored. Both height and density of woody riparian species were significantly greater in ungrazed gravel bar communities. Our results indicate that influences of herbivory on species diversity and evenness varies from 1 community to another and basing management recommendation on 1 component ignores the inherent complexity of riparian ecosystems.

Gregory, S.V.; Swanson, F.J.; McKee, W.A.; Cummins, K.W. 1991. An ecosystem perspective of riparian zones. BioScience. 41(8): 540-551. doi:10.2307/1311607

Abstract: Riparian zones are the interfaces between terrestrial and aquatic ecosystems. As ecotones, they encompass sharp gradients of environmental factors, ecological processes, and plant communities. Riparian zones are not easily delineated but are comprised of mosaics of landforms, communities, and environments within the larger landscape. We propose a conceptual model of riparian zones that integrates the physical processes that shape valley floor landscapes, the succession of terrestrial plant communities on these geomorphic surfaces, the formation of habitat, and the production of nutritional resources for aquatic ecosystems.

Gresswell, R.E. 1999. Fire and aquatic ecosystems in forested biomes of North America. Transactions of the American Fisheries Society. 128(2): 193-221. doi:10.1577/1548-8659(1999)128<0193:FAAEIF>2.0.CO;2

Abstract: Synthesis of the literature suggests that physical, chemical, and biological elements of a watershed interact with long-term climate to influence fire regime, and that these factors, in concordance with the postfire vegetation mosaic, combine with local-scale weather to govern the trajectory and magnitude of change following a fire event. Perturbation associated with hydrological processes is probably the primary factor influencing postfire persistence of fishes, benthic macroinvertebrates, and diatoms in fluvial systems. It is apparent that salmonids have evolved strategies to survive perturbations occurring at the frequency of wildland fires (10^0-10^2 years), but local populations of a species may be more ephemeral. Habitat alteration probably has the greatest impact on individual organisms and local populations that are the least mobile, and reinvasion will be most rapid by aquatic organisms with high mobility. It is becoming increasingly apparent that during the past century fire suppression has altered fire regimes in some vegetation types, and consequently, the probability of large stand-replacing fires has increased in those areas. Current evidence suggests, however, that even in the case of extensive high-severity fires, local extirpation of fishes is patchy, and recolonization is rapid. Lasting detrimental effects on fish populations have been limited to areas where native populations have declined and become increasingly isolated because of anthropogenic activities. A strategy of protecting robust aquatic communities and restoring aquatic habitat structure and life history complexity in degraded areas may be the most effective means for insuring the persistence of native biota where the probability of large-scale fires has increased.

Hairston-Strang, A.B.; Adams, P.W. 2000. Riparian management area condition for timber harvests conducted before and after the 1994 Oregon water protection rules. Western Journal of Applied Forestry. 15(3): 147-153.

Abstract: The 1994 Oregon Water Protection Rules introduced new and expanded requirements for streamside timber harvesting. Postharvest conditions in Riparian Management Areas (RMAs) were evaluated on 21 harvests throughout Oregon in 1995 and compared to results of 22 harvests from a study completed in 1993. Average conifer retention in these RMAs increased from 35% in 1993 to 75% in 1995, a desirable change for long-term supplies of large woody debris for fish habitat. Differences in distance from stream to harvest edge and percent of exposed mineral soil in the RMAs were not significant. Sites visited in 1995 averaged significantly more snags in RMAs than sites from the 1993 study, although snag diameters tended to be smaller, and greater numbers could be related to pre-harvest snag densities on sites. Although the RMA shade data were limited in this study, the 1994 Rules apparently provide at least as much shade as under the previous rules on most sites.

Hall, F.C. 2005. Emigrant Creek cattle allotment: lessons from 30 years of photomonitoring. Gen. Tech. Rep. PNW-GTR-639. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 37 p. http://www.treesearch.fs.fed.us/pubs/9843

Abstract: Emigrant Creek cattle allotment is located 48 km northwest of Burns, Oregon. It was photo sampled at nine original sites, starting in 1975. Photos were taken three times per year: June 15 prior to cattle grazing, August 1 at pasture rotation, and October 1 at the end of grazing. An additional four photopoints were established following disturbance from flooding and beavers. Results reported here cover 30 years, 1975 to 2005. Cattle did not sig-

nificantly impact the riparian area. Beavers (*Castor canadensis*) arrived in 1984 and departed in 1994. They seriously reduced aboveground willow biomass by harvesting stems for food and dam construction. Dams raised the water table causing a dry meadow to become moist, and increased water in a wet meadow that inhibited willow growth. Beaver departure in 1994 left dams unmaintained. A 50-year flood event in February 1996 eroded dams and created a new channel. The water table was reduced below that of the 1984 levels, causing a dry meadow to revert to pre-1984 conditions and permitting willows to vigorously expand in a wet meadow. Dynamic riverine riparian environmental conditions seriously challenge the typical range management concepts of "condition and trend." There is no "climax good condition." Instead a "state-and-transition" concept seems a more apt range management concept to describe range conditions resulting from beaver dams and flooding over a 30-year period on Emigrant Creek cattle allotment.

Hall, F.C.; Bryant, L. 1995. Herbaceous stubble height as a warning of impending cattle grazing damage to riparian areas. Gen. Tech. Rep. PNW-GTR-362. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 10 p. http://www.treesearch.fs.fed.us/pubs/3062
Abstract: Prevention of damage to riparian areas from cattle grazing is essential for sound watershed management. Various stubble heights of the most palatable species are used to predict when unacceptable impacts – heavy use or trampling, or both – are about to occur. Managers can observe stubble height and usage and recommend moving the cattle if undesirable effects from continued livestock grazing are anticipated. Three guides for determining when to move cattle are presented: (1) stubble height approaches 3 inches; (2) stubble height changes from 3 inches to ¾ of an inch; and (3) the most palatable vegetation starts drying regardless of stubble height.

Halofsky, J.E.; Hibbs, D.E. 2008. Determinants of riparian fire severity in two Oregon fires, USA. Canadian Journal of Forest Research. 38(7): 1959-1973. doi:10.1139/X08-048
Abstract: We sought to understand how vegetation indicators and local topographic factors interact to influence riparian fire severity in two recent fires in Oregon, USA. A stratified random sampling design was used to select points in a range of fire severity classes, forest stand ages, and stream sizes in each fire. At each point, plots were sampled in riparian areas and adjacent uplands. Fire severity was assessed in each plot, and measurements were made of factors that have been found to influence riparian fire severity. Understory fire severity (percent exposed mineral soil and bole char height) was significantly lower in riparian areas compared with adjacent uplands in both fires, suggesting a decoupling in understory fire effects in riparian areas versus uplands. However, overstory fire severity (percent crown scorch and percent basal area mortality) was similar in riparian areas and adjacent uplands in both fires. Fire severity in riparian areas was most strongly associated with upland fire severity. In addition, vegetation indicators, particularly those describing riparian fine fuel component and species composition, were strong predictors of riparian fire severity. Consistency in factors controlling fire severity in the two fires suggests that controls on riparian fire severity may be similar in other regions.

Halofsky, J.E.; Hibbs, D.E. 2009. Controls on early post-fire woody plant colonization in riparian areas. Forest Ecology and Management. 258(7): 1350-1358. doi:10.1016/j.foreco.2009.06.038

Abstract: Fire in riparian areas has the potential to influence the functions riparian vegetation provides to streams and aquatic biota. However, there is little information on the effects of fire on riparian areas. The objectives of the present study were to: (i) determine how fire severity interacts with riparian topographic setting, micro-environmental conditions, and pre-fire community composition to control post-fire regeneration; (ii) determine how riparian regeneration patterns and controls change during early succession; and (iii) determine how critical riparian functions are influenced by and recover after fire. Study locations included the Biscuit Fire in southwestern Oregon and the B&B Complex Fire in the Cascade Mountain Range of west-central Oregon, USA. We measured post-fire woody species regeneration, and measured factors such as fire severity, pre-fire species composition, and stream size as potential factors associated with post-fire regeneration patterns. At a relatively coarse spatial scale, patterns in post-fire colonization were influenced by elevation. At finer spatial scales, both conifer- and hardwood-dominated riparian plant communities were self-replacing, suggesting that each community type tends to occur in specific ecological settings. Abundant post-fire regeneration in riparian areas and the self-replacement of hardwood- and conifer-dominated communities indicate high resilience of these disturbance-adapted plant communities.

Halofsky, J.E.; Hibbs, D.E. 2009. Relationships among indices of fire severity in riparian zones. International Journal of Wildland Fire. 18(5): 584-593. doi:10.1071/WF07050

Abstract: There is no standard quantitative measure of fire severity. Although different measures of fire severity are often assumed to be closely related, information on the relationships between these measures of fire severity is limited. Information on the relationship between various fire severity indices is particularly lacking for riparian zones, critical areas of the landscape for both habitat and water quality. The present study explores relationships among several ground-based and remotely sensed indices of fire severity in riparian areas of recent fires in Oregon, including ground-based indices of overstory fire severity (crown scorch and basal area mortality) and understory fire severity (height of bole char and exposed mineral soil). There were relatively strong associations between the two overstory indices of fire severity and also between the two understory indices of fire severity. However, there were weaker associations between understory and overstory fire severity indices, suggesting they are at least partially independent. Results also suggested weak associations between ground-based fire severity indices and remotely sensed fire severity assessments in riparian areas. Overall, we show there are limitations to the interpretation and use of these commonly used fire severity assessments in riparian areas.

Hancock, P.J.; Boulton, A.J.; Humphreys, W.F. 2005. Aquifers and hyporheic zones: towards an ecological understanding of groundwater. Hydrogeology Journal. 13(1): 98-111. doi:10.1007/s10040-004-0421-6

Abstract: Ecological constraints in subsurface environments relate directly to groundwater flow, hydraulic conductivity, interstitial biogeochemistry, pore size, and hydrological link-

ages to adjacent aquifers and surface ecosystems. Groundwater ecology has evolved from a science describing the unique subterranean biota to its current form emphasizing multidisciplinary studies that integrate hydrogeology and ecology. This multidisciplinary approach seeks to elucidate the function of groundwater ecosystems and their roles in maintaining subterranean and surface water quality. In aquifer-surface water ecotones, geochemical gradients and microbial biofilms mediate transformations of water chemistry. Subsurface fauna (stygofauna) graze biofilms, alter interstitial pore size through their movement, and physically transport material through the groundwater environment. Further, changes in their populations provide signals of declining water quality. Better integrating groundwater ecology, biogeochemistry, and hydrogeology will significantly advance our understanding of subterranean ecosystems, especially in terms of bioremediation of contaminated groundwaters, maintenance or improvement of surface water quality in groundwater-dependent ecosystems, and improved protection of groundwater habitats during the extraction of natural resources. Overall, this will lead to a better understanding of the implications of groundwater hydrology and aquifer geology to distributions of subsurface fauna and microbiota, ecological processes such as carbon cycling, and sustainable groundwater management.

Harner, M.J.; Stanford, J.A. 2003. Differences in cottonwood growth between a losing and a gaining reach of an alluvial floodplain. Ecology. 84(6): 1453-1458. doi:10.1890/0012-9658(2003)084[1453:DICGBA]2.0.CO;2

Abstract: Interstitial flow of river (hyporheic) water influences algal productivity, benthic assemblages, and locations of fish spawning. However, little is known of the effects of hyporheic flow on the growth of riparian vegetation. By increasing water availability and nutrient delivery, regional upwelling of hyporheic water may increase the growth of terrestrial vegetation. We tested and accepted the hypothesis that cottonwood trees (*Populus trichocarpa*) in a gaining reach of an alluvial floodplain grow faster than trees in a losing reach by comparing basal areas and ages on an expansive floodplain in western Montana (USA). Trees in the gaining reach had basal areas twice the size of the trees in the losing reach, after correcting for tree age. In addition, the carbon-to-nitrogen ratios in leaves were 16% lower in the gaining reach. Lower cottonwood stem densities, deeper layers of fine sediments, and a higher water table occurred in the gaining compared to the losing reach. Each of these variables was significantly correlated with tree growth and likely interacted to influence the productivity of cottonwoods. We concluded that hydration and fertilization of riparian trees likely is mediated by hyporheic flow.

Harrelson, C.C.; Rawlins, C.L.; Potyondy, J.P. 1994. Stream channel reference sites: an illustrated guide to field technique. Gen. Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61 p.

Abstract: This document is a guide to establishing permanent reference sites for gathering data about the physical characteristics of streams and rivers. The minimum procedure consists of the following: (1) select a site, (2) map the site and location, (3) measure the channel cross-section, (4) survey a longitudinal profile of the channel, (5) measure stream flow, (6) measure bed material, and (7) permanently file the information with the Vigil network. The document includes basic surveying techniques, provides guidelines for identifying bankfull indicators and measuring other important stream characteristics. The object is to establish the baseline of existing physical conditions for the stream channel. With this foundation, changes in the character of streams can be quantified for monitoring purposes or to support other management decisions.

Hartman, G.F.; Scrivener, J.C.; McMahon, T.E. 1987. Saying that logging is either "good" or "bad" for fish doesn't tell you how to manage the system. Forestry Chronicle. 63(3): 159-164. doi:10.5558/tfc63159-3

Abstract: A 16-year multi-disciplinary watershed study at Carnation Creek, British Columbia, revealed that different activities in a forest harvest program had different impacts on the physical and biological components of the system. Changes in stream temperature, as a result of logging and a climatic warming trend, and changes in the distribution and volume of woody debris in the channel caused complex sequence of processes to influence salmonid production in both a positive and negative manner. The influence depended on the type of physical change, the fish species and its life history stage, and on the elapsed time after the logging activity. Some direct implications of the research to the problems of managing in the face of complexity are discussed.

Heede, B.H. 1980. Stream dynamics: an overview for land managers. Gen. Tech. Rep. RM-72. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 26 p. http://www.treesearch.fs.fed.us/pubs/31935

Abstract: Concepts of stream dynamics are demonstrated through discussion of processes and process indicators; theory is included only where helpful to explain concepts. Present knowledge allows only qualitative prediction of stream behavior. However, such predictions show how management actions will affect the stream and its environment.

Hemstrom, M.A.; Smith, T.; Evans, D.; Clifton, C.; Crowe, E.; Aitken, M. 2002. Midscale analysis of streamside characteristics in the upper Grande Ronde subbasin, northeastern Oregon. Res. Note PNW-RN-534. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 16 p. http://www.treesearch.fs.fed.us/pubs/5058

Abstract: Riparian or streamside areas are the focus of considerable management and public interest in the interior Northwest. Unfortunately, the vegetation and geomorphic characteristics of streamside areas are difficult to assess across large landscapes because streamside areas are geographically small in much of the arid interior. However, managers and scientists need methods to assess streamside conditions across large landscapes for land management planning, watershed analysis, and landscape simulation modeling. We present proposed methods for characterizing streamside vegetation and topography by using geographic information systems, terrain models, and photo-interpreted vegetation maps. We propose application of resulting information for restoration planning and linkage to landscape wildlife and aquatic habitat models in the upper Grande Ronde subbasin of northeastern Oregon.

Henjum, M.G.; Karr, J.R.; L., B.D.; Perry, D.A.; Bednarz, J.C.; Wright, S.G.; Beckwitt, S.A.; Beckwitt, E. 1994. Interim protection for late-successional forests, fisheries, and watersheds; national forests east of the Cascade crest, Oregon, and Washington. Wildlife Society Tech. Review 94-2. Bethesda, MD: The Wildlife Society. 245 p.

Abstract: The forests east of the crest of the Cascade Range in Oregon and Washington States have undergone dramatic changes during the last 50 years. Legislated increases in timber harvests and an expanding network of roads have fragmented forests across the landscape. Other human activities, including grazing, fire control, and mining, have seriously degraded watersheds and riparian areas, and, among other things, led to disease and pest outbreaks. The result is declining habitat quality for a variety of biological resources and lengthening lists of endangered, threatened, and sensitive fish and wildlife species. Eastside forests comprise mostly pine, Douglas fir, and true fir; they grow on the relatively dry eastern slopes of the Cascades; in the cold, dry Okanogan Highlands near the Canadian border; and in the Blue Mountains rising from the deserts of eastern Oregon. Recently, much public attention has focused on the need to protect these resources. Unfortunately, no comprehensive review exists of the status of eastside forests or their associated resources; thus the federal government has yet to consider eastside forests in legislation or administrative proposals affecting Pacific Northwest forestlands. To begin to fill this void, a bipartisan group of seven members of the US House of Representatives approached several scientific societies to form the Eastside Forests Scientific Society Panel to "initiate a review and report on the Eastside Forests of Oregon and Washington."

Higgins, D.A.; Tiedemann, A.R.; Quigley, T.M.; Marx, D.B. 1989. Streamflow characteristics of small watersheds in the Blue Mountains of Oregon. Water Resources Bulletin. 25(6): 1131-1149. doi:10.1111/j.1752-1688.1989.tb01326.x

Abstract: Streamflow data for water years 1978-84 were evaluated to identify streamflow characteristics for 13 small watersheds (0.46-7.00 mi^2) in the Blue Mountains of eastern Oregon and to determine differences among grazing intensities and vegetation types. The ranges for mean annual water yields, peak flows, and 7-day low flows for the 13 watersheds were 5.5-28.1 inches, 2.0-34.7 cfsm, and 0.006-0.165 cfsm, respectively. Two classes of vegetation were evaluated: (1) western larch-Douglas-fir (nine watersheds) and (2) other (four watersheds representing fir-spruce, lodgepole pine, ponderosa pine, and mountain meadow). The means for annual peak flows and the slopes of the flow-duration curve were significantly different ($p=0.05$) for the two vegetation classes; differences in mean annual water yield were marginally significant ($0.05 < p < 0.10$). After they were adjusted for precipitation, the means for annual water yield, peak flows, and slopes of the flow-duration curve were significantly different for the two vegetation classes; differences in the means for annual 7-day low flows were marginally significant. The western larch-Douglas-fir group had somewhat lower water yields but, overall, tended to have more favorable streamflow characteristics including lower peak flows, higher low flows, and more evenly distributed flow regimes (flatter flow-duration curves) than the "other" class. Four levels of grazing intensity had no effect on streamflow characteristics.

Hitt, N.P. 2003. Immediate effects of wildfire on stream temperature. Journal of Freshwater Ecology. 18(1): 171-173. doi:10.1080/02705060.2003.9663964

Abstract: Wildfires have an important role in many freshwater ecosystems, yet the immediate effects of wildfire are poorly documented. Stream temperatures before, during, and after a recent high-severity wildfire are presented for Deadhorse Creek, Montana, USA. The recorded peak temperature (17.2°C) occurred while the forest was burning and exceeded concurrent water temperatures in an unburned control stream by 7.8°C. Following the wildfire, daily thermal maxima exceeded unburned stream conditions but burned and unburned daily minima corresponded closely. Recorded water temperatures did not exceed thermal limits for fishes or aquatic insects but may have contributed to the chemical toxicity of the stream.

Howell, P.J. 2006. Effects of wildfire and subsequent hydrologic events on fish distribution and abundance in tributaries of North Fork John Day River. North American Journal of Fisheries Management. 26(4): 983-994. doi:10.1577/M05-114.1

Abstract: Recent large wildfires in western states have fueled increasing concerns of resource managers and the public about the effects of fire, including risks to fish, particularly endangered species. However, there are few empirical studies on the response of fish to fire and none that include anadromous species. The Tower Fire was one of four large fires in the upper John Day River basin in Oregon in 1996. Much of the area burned at moderate to high severity, consistent with the pattern of increasing fire severity and size projected for the region. Intense spring storms in 1997 and 1998 triggered large floods, landslides, and debris torrents that affected streams within and downstream of the fire. We investigated the effects of the fire and ensuing floods on fish distribution and abundance in three streams immediately after the fire through 2003. Immediately after the fire, no fish were found in moderate- and high-intensity burn areas. Fish began to repopulate defaunated reaches the year after the fire, and within 4 years distribution of juvenile steelhead (anadromous rainbow trout *Oncorhynchus mykiss*) and resident rainbow trout was similar to that before the fire. Juvenile spring Chinook salmon *O. tshawytscha* also began to use lower reaches of one of the streams after the flood, which had eliminated a culvert near the mouth of the stream suspected to be a barrier. Densities in most burned reaches and in unburned reaches downstream of the fire have rebounded to levels similar to or greater than densities in reference streams outside of the fire. An isolated introduced population of brook trout *Salvelinus fontinalis* also recovered. Thus, despite the size and severity of the fire, postfire hydrologic events, and human-induced changes to watersheds, fish populations were highly resilient.

Hruby, T. 2009. Developing rapid methods for analyzing upland riparian functions and values. Environmental Management. 43(6): 1219-1243. doi:10.1007/s00267-009-9283-y

Abstract: Regulators protecting riparian areas need to understand the integrity, health, beneficial uses, functions, and values of this resource. Up to now most methods providing information about riparian areas are based on analyzing condition or integrity. These methods, however, provide little information about functions and values. Different methods are needed that specifically address this aspect of riparian areas. In addition to information on functions and values, regulators have very specific needs that include: an analysis at the site scale, low cost, usability, and inclusion of policy interpretations. To meet these needs a rapid method has been developed that uses a multi-criteria decision matrix to categorize riparian areas in Washington State, USA. Indicators are used to identify the potential of the site to provide a function, the potential of the landscape to support the function, and the value the function provides to society. To meet legal needs fixed boundaries for assessment units are

established based on geomorphology, the distance from "Ordinary High Water Mark" and different categories of land uses. Assessment units are first classified based on ecoregions, geomorphic characteristics, and land uses. This simplifies the data that need to be collected at a site, but it requires developing and calibrating a separate model for each "class." The approach to developing methods is adaptable to other locations as its basic structure is not dependent on local conditions.

Ice, G.C.; Skaugset, A.; Simmons, A. 2006. Estimating areas and timber values of riparian management on forest lands. Journal of the American Water Resources Association. 42(1): 115-124. doi:10.1111/j.1752-1688.2006.tb03827.x

Abstract: Buffers, filter strips, and other riparian protection zones are widely accepted practices used to minimize water quality impacts from forest management and other land use activities. Riparian management prescriptions are often developed with limited or inconsistent consideration of the impact they will have on land management opportunities or economics. A combination of factors influences the area and value of riparian management zones (RMZs). A simple tool can determine the percentage of a watershed in RMZs where they comprise only a small fraction of the watershed. For a more detailed analysis, the Oak Creek Watershed in Oregon served as an example of a geographic information system (GIS) assessment. The same watershed can have dramatically different areas and values of timber in RMZs depending on the resolution used to determine the stream network, different stream types (perennial fish-bearing, perennial non-fish bearing, and non-perennial; small, medium, and large), and different RMZ widths and management restrictions for each stream type. The areas of watershed put into riparian protection for two drainage densities and three RMZ prescriptions were determined. Finally, the volumes of merchantable timber in the RMZs and their subsequent values were determined.

Jackson, B.K.; Sullivan, S.M.P. 2009. Influence of wildfire severity on riparian plant community heterogeneity in an Idaho, USA wilderness. Forest Ecology and Management. 259(1): 24-32. doi:10.1016/j.foreco.2009.09.036

Abstract: Despite the increasing recognition of riparian zones as important ecotones that link terrestrial and aquatic ecosystems and of fire as a critical natural disturbance, much remains unknown regarding the influence of fire on stream-riparian ecosystems. To further this understanding, we evaluated the effects of mixed severity wildfire on riparian plant community structure and composition in headwater streams of the Big Creek Watershed of the Frank Church 'River of No Return' Wilderness of central Idaho. Five years after a large stand-replacing fire, we conducted riparian vegetation surveys at sixteen reaches across a range of burn types. Non-metric Multidimensional Scaling (NMS) and Multi-Response Permutation Procedure (MRPP) analyses showed an overall shift in community composition and structure between vegetation at unburned and severely burned reaches. Although total plant cover was significantly less at severely burned areas, recovery of the deciduous understory was apparent. Severely burned reaches were characterized by a marked increase in cheatgrass (*Bromus tectorum*). Reaches that were exposed to low-severity fire were indistinguishable from unburned reaches relative to vegetation community composition and

structure, pointing to a possible disturbance threshold that may need to be crossed in order to alter riparian plant communities.

Jackson, B.K.; Sullivan, S.M.P.; Malison, R.L. 2012. Wildfire severity mediates fluxes of plant material and terrestrial invertebrates to mountain streams. Forest Ecology and Management. 278: 27-34. doi:10.1016/j.foreco.2012.04.033

Abstract: Wildfire effects upon riparian plant community structure, composition, and distribution may strongly influence the dynamic relationships between riparian vegetation and stream ecosystems. However, few studies have examined the influence of fire on these processes. To that end, we compared the quantity and composition of allochthonous inputs of plant material and terrestrial invertebrates among stream tributaries characterized by various degrees of burn severity 5 years post-fire in the Frank Church Wilderness of central Idaho, USA. The magnitude of inputs of coniferous leaf litter to unburned stream reaches was five times that of inputs to severely burned reaches. Deciduous leaf litter inputs to unburned reaches were 1.5 times, and inputs of terrestrial invertebrates were twice, the magnitude of inputs to severely burned reaches. NMS ordination and MRPP analysis indicated that the taxonomic composition of terrestrial invertebrate inputs to unburned stream reaches was significantly different than the composition of invertebrate inputs to either high-severity or low-severity reaches ($A = 0.057$, $p = 0.040$). Unburned and low-severity stream reaches received greater inputs of large-bodied invertebrates belonging to the orders Hymenoptera, Lepidoptera, Orthoptera, and Diptera. Taken as a whole, our results indicate that fire can significantly alter terrestrial-aquatic connectivity via alterations in riparian-to-stream inputs of leaf material and arthropods. Given these findings, wildfire severity might be expected to be a critical factor in shaping stream-riparian food webs in fire-prone areas.

Johansen, K.; Coops, N.C.; Gergel, S.E.; Stange, Y. 2007. Application of high spatial resolution satellite imagery for riparian and forest ecosystem classification. Remote Sensing of Environment. 110(1): 29-44. doi:10.1016/j.rse.2007.02.014

Abstract: Terrestrial Ecosystem Mapping provides critical information to land and resource managers by incorporating information on climate, physiography, surficial material, soil, and vegetation structure. The main objective of this research was to determine the capacity of high spatial resolution satellite image data to discriminate vegetation structural stages in riparian and adjacent forested ecosystems as defined using the British Columbia Terrestrial Ecosystem Mapping (TEM) scheme. A high spatial resolution QuickBird image, captured in June 2005, and coincident field data covering the riparian area of Lost Shoe Creek and adjacent forests on Vancouver Island, British Columbia, was used in this analysis. Semi-variograms were calculated to assess the separability of vegetation structural stages and assess which spatial scales were most appropriate for calculation of grey-level co-occurrence texture measures to maximize structural class separation. The degree of spatial autocorrelation showed that most vegetation structural types in the TEM scheme could be differentiated and that window sizes of 3 × 3 pixels and 11 × 11 pixels were most appropriate for image texture calculations. Using these window sizes, the texture analysis showed that co-occurrence contrast, dissimilarity, and homogeneity texture measures, based on the bands

in the visible part of the spectrum, provided the most significant statistical differentiation between vegetation structural classes. Subsequently, an object-oriented classification algorithm was applied to spectral and textural transformations of the QuickBird image data to map the vegetation structural classes. Using both spectral and textural image bands yielded the highest classification accuracy (overall accuracy = 78.95%). The inclusion of image texture increased the classification accuracies of vegetation structure by 2-19%. The results show that information on vegetation structure can be mapped effectively from high spatial resolution satellite image data, providing an additional tool to ongoing aerial photograph interpretation.

Johnson, R.R.; Ziebell, C.D.; Patton, D.R.; Ffolliott, P.F.; Hamre, R.H. 1985. Riparian ecosystems and their management: reconciling conflicting uses; first North American riparian conference. Gen. Tech. Rep. RM-120. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 523 p. http://www.treesearch.fs.fed.us/pubs/41622

Abstract: These proceedings include 105 papers and 12 poster presentations. Primary topics include: physical characteristics, hydrology, and ecology of riparian ecosystems; riparian resources; recreation, agriculture, wildlife, livestock use, fisheries, and amphibians and reptiles; multiple-use planning and management; legal and institutional needs; and riparian ecosystems in dryland zones of the world. A model Riparian Habitat Protection Statute is appended.

Jones, T.A.; Daniels, L.D. 2008. Dynamics of large woody debris in small streams disturbed by the 2001 Dogrib fire in the Alberta foothills. Forest Ecology and Management. 256(10): 1751-1759. doi:10.1016/j.foreco.2008.02.048

Abstract: We investigated the temporal dynamics of large woody debris (LWD) in five headwater streams before and after the 2001 Dogrib fire in the foothills of Alberta. The density of LWD varied from 5 to 41 logs per 50 m of stream reach and accounted for 19.4 ± 5.1 m^3 ha^{-1} (mean ± standard error) of wood in the riparian zones and 114.1 ± 30.1 m^3 ha^{-1} of wood in the bank full margins of the stream channel. Individual logs averaged 18.9 ± 1.15 cm in diameter, 5.5 ± 0.7 m in length, and 0.2 ± 0.02 m^3 in volume. Logs became significantly shorter in decay classes II-IV. Bridges were longer than partial bridges, which were longer than loose and buried LWD. Individual log volume was greatest for bridges, but not significantly different among other position classes. Bridges and loose LWD contributed little to stream morphology and function; however, 55% of partial bridges and all buried logs contributed to sediment storage, channel armoring, or riffles and pools in the stream channel. Using dendroecological methods, we estimated the year of death of 108 of 115 spruce logs. LWD resulted from tree deaths that occurred between 1874 and 2001, so that time since death ranged from 5 to 132 years. Time since death increased from decay class II to III to IV and bridges were younger than LWD in all other position classes. Due to high rates of recruitment after fire, 16.5% LWD recruited between 2001 and 2006, most of which were bridges or partial bridges in decay class II. We anticipate a delay of 30-45 years before newly recruited logs contribute significantly to stream morphology and function. Depletion rates of LWD were exponential, such that 50% of LWD would be lost to decay, erosion or downstream transport within 30 years of tree death and < 12% of LWD would persist more than 100 years. Since recruitment of new LWD in post-fire lodgepole pine stands is delayed by ca. 40 years while trees establish and stands develop, we anticipate periods of ca. 70 years between stand-replacing fires and recruitment of new, functional LWD into stream channels. During this time, fire-killed snags are an important source of LWD to small streams. For headwater streams in environments susceptible to floods and erosion we recommend that buffer zones comprised of snags to be established after fires. The goal of these post-fire buffers is to ensure a supply of LWD into streams for years to decades after a stand-replacing fire.

Jones, K.; Slonecker, E.; Nash, M.; Neale, A.; Wade, T.; Hamann, S. 2010. Riparian habitat changes across the continental United States (1972-2003) and potential implications for sustaining ecosystem services. Landscape Ecology. 25(8): 1261-1275. doi:10.1007/s10980-010-9510-1

Abstract: Riparian ecosystems are important elements in landscapes that often provide a disproportionately wide range of ecosystem services and conservation benefits. Their protection and restoration have been one of the top environmental management priorities across the US over the last several years. Despite the level of concern, visibility and management effort, little is known about trends in riparian habitats. Moreover, little is known about whether or not cumulative efforts to restore and protect riparian zones and floodplains are affecting the rates of riparian habitat change nationwide. To address these issues, we analyzed riparian land cover change between the early 1970s and the late 1990s/early 2000s using existing spatial data on hydrography and land cover. This included an analysis of land cover changes within 180 m riparian buffer zones, and at catchment scales, for 42,363 catchments across 63 ecoregions of the continental US. The total amount of forest and natural land cover (forests, shrublands, wetlands) in riparian buffers declined by 0.7 and 0.9%, respectively across the entire study period. Gains in grassland/shrubland accounted for the 0.2% lower percentage of total natural land cover loss relative to forests. Conversely, urban and developed land cover (urban, agriculture, and mechanically disturbed lands) increased by more than 1.3% within riparian buffers across the entire study period. Despite these changes, we documented an opposite trend of increasing proportions of natural and forest land cover in riparian buffers versus the catchment scale. We surmise that this trend might reflect a combination of natural recovery and cumulative efforts to protect riparian ecosystems across the US. However, existing models limit our ability to assess the impacts of these changes on specific ecosystem services. We discuss the implications of changes observed in this study on the sustainability of ecosystem services. We also recommend opportunities for future riparian change assessments.

Kalischuk, A.R.; Rood, S.B.; Mahoney, J.M. 2001. Environmental influences on seedling growth of cottonwood species following a major flood. Forest Ecology and Management. 144(1-3): 75-89. doi:10.1016/S0378-1127(00)00359-5

Abstract: A major flood in June 1995 along most streams in southern Alberta (AB) and southeastern British Columbia (BC), Canada, permitted the comparison of natural seedling establishment of different cottonwood species across different environments. Nine study

sites were established along a 340-km corridor from BC, over the Rocky Mountain Continental Divide, and onto the foothills and then prairies of AB. Four native cottonwood species occurred from BC to AB: the black cottonwood, *Populus trichocarpa* Torr. and Gray, balsam poplar, *P. balsamifera* L., and narrow-leaf cottonwood, *P. angustifolia* James, of section Tacamahaca, and the prairie cottonwood, *Populus deltoides* Bartr. ex Marsh, of section Aigeiros. Cottonwood seedlings of the 1995 cohort were monitored from 1995 through 1998 in quadrats along riparian transects. The study confirmed that a major flood enabled extensive cottonwood recruitment along mountain, foothills, and prairie river reaches and revealed that both, environment and species influenced cottonwood seedling growth in situ. Across the sites, seedling heights varied ten-fold and were closely negatively correlated with site elevation (1995: n = 9, r^2 = 0.93; 1997: n = 4, r^2 = 0.92). The increased growth at lower elevations was probably associated with warmer temperatures and a longer growing season; seedling growth was positively correlated with the accumulation of growing degree days of nearby weather stations (1995: n = 6, r^2 = 0.88). Growth rate was also influenced by species as height varied up to three-fold across species at sites where species co-occurred. *P. deltoides* seedlings grew fastest followed by *P. trichocarpa*/*P. balsamifera* and intersectional hybrids and, finally, *P. angustifolia* and intrasectional hybrids. The superior seedling growth of *P. deltoides* is consistent with its life history and distribution. *P. deltoides* occurs along prairie river reaches with warmer and drier climates and higher-order streams with finer substrate textures; these physical conditions would favor seedling recruitment. The alternate environmental conditions of foothills and mountain regions probably encourage clonal (asexual) recruitment that may supplement seedling recruitment, particularly for the Tacamahaca species.

Karr, J.R.; Rhodes, J.J.; Minshall, G.W.; Hauer, F.R.; Beschta, R.L.; Frissell, C.A.; Perry, D.A. 2004. The effects of postfire salvage logging on aquatic ecosystems in the American west. BioScience. 54(11): 1029-1033. doi:10.1641/0006-3568(2004)054[1029:TEOPSL]2.0.CO;2

Abstract: Recent changes in the forest policies, regulations, and laws affecting public lands encourage postfire salvage logging, an activity that all too often delays or prevents recovery. In contrast, the 10 recommendations proposed here can improve the condition of watersheds and aquatic ecosystems.

Karrenberg, S.; Edwards, P.J.; Kollmann, J. 2002. The life history of Salicaceae living in the active zone of floodplains. Freshwater Biology. 47(4): 733-748. doi:10.1046/j.1365-2427.2002.00894.x

Abstract: 1. Exposed riverine sediments are difficult substrata for seedling establishment because of extremes in the microclimate, poor soil conditions and frequent habitat turnover. Various species of willows and poplars (Salicaceae) appear to be particularly successful in colonizing such sediments and are often dominant in floodplain habitats throughout the northern temperate zone. 2. In many Salicaceae regeneration seems to be adapted to regular disturbance by flooding. Efficient seed dispersal is achieved by the production of abundant seed in spring and early summer, which are dispersed by air and water. Seeds are short-lived and germinate immediately on moist surfaces. Seedling establishment is only possible if these surfaces stay moist and undisturbed for a sufficient period of time. 3. Larger plants of Salicaceae have exceptional mechanical properties, such as high bending stability, which enable them to withstand moderate floods. If uprooted, washed away or fragmented by more powerful floods these plants resprout vigorously. 4. While these life characteristics can be interpreted as adaptations to the floodplain environment, they may also cause a high genetic variability in populations of Salicaceae and predispose Salicaceae to hybridization. Thus, a feedback between adaptive life history characteristics and the evolutionary process is proposed.

Kauffman, J.B. 1988. The status of riparian habitats in Pacific Northwest forests. In: Raedeke, K.J., ed. Streamside management: riparian wildlife and forestry interactions. Contribution 59. Seattle, WA: University of Washington, Institute of Forest Resources: 45-55.

Abstract: Riparian ecosystems occupy a small percentage of the total area in forested regions of the Northwest. For example, in the Blue Mountains of eastern Oregon they occupy 1 to 2 percent of the land area. Even though they occupy small areas, they are the ecosystem most heavily utilized by a large number of wildlife species. Riparian zones are also disproportionately valued for other forest and range uses. They are among the most productive timber and forage-producing sites. People also utilize riparian zones heavily for recreational purposes. In this paper I will review the ecological components relevant to the conceptualization of an optimal status for riparian ecosystems. These include the concepts of diversity, succession, and juxtaposition of riparian communities. In addition, the causal factors affecting the current and future status of mountain riparian ecosystems are discussed.

Kauffman, J.B.; Krueger, W.C. 1984. Livestock impacts on riparian ecosystems and streamside management implications...a review. Journal of Range Management. 37(5): 430-438.

Abstract: Historically, riparian vegetation has been defined as vegetation rooted at the water's edge (Campbell and Franklin 1979). Quite often, however, the stream influences vegetation in many ways and well beyond the water line. In lotic systems, the stream is not only responsible for increased water availability, but also for the soil deposition, unique microclimate, increased productivity, and the many consequential, self-perpetuating biotic factors associated with riparian zones. These factors all contribute in the formation of a unique assemblage of plant communities quite distinct from upland communities surrounding the riparian zone. Therefore, along streambanks, other lotic systems, and even ephemeral drainages, riparian ecosystems could best be defined as those assemblages of plant, animal, and aquatic communities whose presence can be either directly or indirectly attributed to factors that are stream-induced or related (Kauffman 1982). Public grazing lands must be managed on a true multiple use basis that recognizes and evaluates the biological potential of each ecological zone in relation to the present and future needs of our society as a whole. Management strategies that recognize all resource values must be designed to maintain or restore the integrity of riparian communities.

Kauffman, J.B.; Krueger, W.C.; Vavra, M. 1983. Effects of late season cattle grazing on riparian plant communities. Journal of Range Management. 36(6): 685-691.

Abstract: Livestock impacts on riparian plant community composition, structure, and productivity were evaluated. After 3 years of comparison between fall grazed and exclosed (nongrazed) areas, 4 plant communities out of 10 sampled displayed some significant spe-

cies composition and productivity differences. Two meadow types and the Douglas hawthorn (*Crataegus douglasii*) community type had significant differences in standing phytomass. These also were utilized more heavily than any other communities sampled. Shrub use was generally light except on willow (*Salix* spp.)-dominated gravel bars. On gravel bars, succession appeared to be retarded by livestock grazing. Few differences were recorded in other plant communities sampled, particularly those communities with a forest canopy. [The study area is located on the Eastern Oregon Agriculture Research Center near the town of Union, Oregon, in the southwest foothills of the Wallowa Mountains.]

Kauffman, J.B.; Krueger, W.C.; Vavra, M. 1983. Impacts of cattle on streambanks in northeastern Oregon. Journal of Range Management. 36(6): 683-685.

Abstract: Impacts of a late season livestock grazing strategy on streambank erosion, morphology, and undercutting were studied for 2 years along Catherine Creek in northeastern Oregon. Streambank loss, disturbance, and undercutting were compared between grazing treatments, vegetation type, and stream-meander position. No significant differences were found among vegetation types or stream-meander location. Significantly greater streambank erosion and disturbance occurred in grazed areas than in exclosed areas during the 1978 and 1979 grazing periods. Over-winter erosion was not significantly different among treatments. However, erosion related to livestock grazing and trampling was enough to create significantly greater annual streambank losses when compared to ungrazed areas.

Kauffman, J.B.; Krueger, W.C.; Vavra, M. 1985. Ecology and plant communities of the riparian area associated with Catherine Creek in northeastern Oregon. Tech. Bull. 147. Corvallis, OR: Oregon State University, Agricultural Experiment Station. 35 p.

Abstract: A multitude of biotic and physical factors, many of them unique to riparian environments, interacted to form an extremely complex ecosystem along Catherine Creek in the Wallowa Mountains. A total of 258 stands of vegetation representing 60 communities was identified. At least 20 species of mammals and 81 species of birds utilize the area from May through October. The factors believed to be responsible for much of the diversity of riparian communities include soil characteristics, streamflow dynamics, climate, plant community interactions, animal effects, and man's effects. Analysis of the nine most common community types in the study area indicated their composition and structure were significantly affected by these factors.

Kauffman, J.B.; Beschta, R.L.; Otting, N.; Lytjen, D. 1997. An ecological perspective of riparian and stream restoration in the western United States. Fisheries. 22(5): 12-24. doi:10.1577/1548-8446(1997)022<0012:AEPORA>2.0.CO;2

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

Kauffman, J.B.; Thorpe, A.S.; Brookshire, E.N.J. 2004. Livestock exclusion and belowground ecosystem responses in riparian meadows of eastern Oregon. Ecological Applications. 14(6): 1671-1679. doi:10.1890/03-5083

Abstract: Ecological restoration of riparian zones that have been degraded by decades of overgrazing by livestock is of paramount importance for the improvement of water quality and fish and wildlife habitats in the western United States. An increasingly common approach to the restoration of habitats of endangered salmon in the Columbia Basin of the Pacific Northwest (USA) is to exclude livestock from streamside communities. Yet, few studies have examined how ending livestock grazing changes ecosystem properties and belowground processes in herbaceous-dominated riparian plant communities (meadows). Along the Middle Fork John Day River, Oregon, we compared ecosystem properties of dry (grass and forb-dominated) and wet (sedge-dominated) meadow communities at three sites that had been managed for sustainable livestock production with three sites where livestock had been excluded for 9-18 years as a means of riparian and stream restoration. Profound differences in the belowground properties of grazed and exclosed communities were measured. In dry meadows, total belowground biomass (TBGB consisting of roots and rhizomes) was 50% greater in exclosures (1105 and 1652 g/m^2 in the grazed and exclosed sites, respectively). In exclosed wet meadows, the TBGB was 62% greater than in the grazed sites (1761 and 2857 g/m^2, respectively). Soil bulk density was significantly lower, and soil pore space was higher in exclosed sites of both meadow types. The mean infiltration rate in exclosed dry meadows was 13-fold greater than in grazed dry meadows (142 vs. 11 cm/h), and in wet meadows the mean infiltration rate in exclosures was 233% greater than in grazed sites (24 vs. 80 cm/h). In exclosed wet meadows, the rate of net potential nitrification was 149-fold greater (0.747 vs. 0.005 µg NO_3-N·[g soil]$^{-1}$·d^{-1}), and the rate of net potential mineralization was 32-fold greater (0.886 vs. 0.027 µg N·[g soil]$^{-1}$·d^{-1}, respectively) when compared to grazed sites, though changes observed in dry meadows were not significant. Livestock removal was found to be an effective approach to ecological restoration, resulting in significant changes in soil, hydrological, and vegetation properties that, at landscape scales, would likely have great effects on stream channel structure, water quality, and the aquatic biota.

Kaushal, S.S.; Likens, G.E.; Jaworski, N.A.; Pace, M.L.; Sides, A.M.; Seekell, D.; Belt, K.T.; Secor, D.H.; Wingate, R.L. 2010. Rising stream and river temperatures in the United States. Frontiers in Ecology and the Environment. 8(9): 461-466. doi:10.1890/090037

Abstract: Water temperatures are increasing in many streams and rivers throughout the US. We analyzed historical records from 40 sites and found that 20 major streams and rivers have shown statistically significant, long-term warming. Annual mean water temperatures increased by 0.009-0.077 °C yr^{-1}, and rates of warming were most rapid in, but not confined to, urbanizing areas. Long-term increases in stream water temperatures were typically correlated with increases in air temperatures. If stream temperatures were to continue to increase at current rates, due to global warming and urbanization, this could have important effects on eutrophication, ecosystem processes such as biological productivity and stream metabolism, contaminant toxicity, and loss of aquatic biodiversity.

Kay, C.E. 1994. The impact of native ungulates and beaver on riparian communities in the intermountain West. Natural Resources and Environmental Issues. 1: 23-44.

Abstract: This paper reviews the impact native ungulates, primarily elk and moose, and beaver can have on riparian communities in the western United States. In Yellowstone National Park and in other areas where ungulates are not managed, repeated browsing has reduced tall willow, aspen, and cottonwood communities by approximately 95 percent since the late 1800s. Native ungulates can also severely reduce or eliminate palatable grasses and forbs from herbaceous riparian communities. By eliminating woody vegetation and security cover and by altering plant-species composition, native ungulates can alter bird, mammal, and aquatic communities. They can even negatively affect endangered species like grizzly bears for which riparian areas provide critical habitat. In many respects, excessive use by native ungulates is similar to overgrazing by domestic livestock. Beaver is a keystone species that alters the hydrology, energy flow, and nutrient cycling of aquatic systems. Unlike ungulates, which tend to degrade riparian habitats, beaver actually create and maintain riparian areas. Beaver dams not only impound water but they also trap sediments that raise the water table and allow the extension of riparian communities into former upland areas. By trapping silt over thousands of years, beaver have actually created many of the West's fertile valleys. Prior to the arrival of Europeans, Western streams supported large populations of beaver. During one five-day period in 1825, Peter Skene Ogden's fur brigade trapped 511 beaver. Today, state and federal land-management agencies are using beaver to restore damaged riparian areas. Beaver, however, can become a nuisance when they dam irrigation facilities, plug highway culverts, or fell streamside trees valued by landowners.

Kenwick, R.A.; Shammin, M.R.; Sullivan, W.C. 2009. Preferences for riparian buffers. Landscape and Urban Planning. 91(2): 88-96. doi:10.1016/j.landurbplan.2008.12.005

Abstract: Intensive management of riparian zones in the mid-western United States has long involved clearing vegetation, straightening meandering streams, and lining earthen banks with stone or concrete. Recently, however, scholars have begun to document the ecological costs of such practices. Replacing barren stream edges with more natural alternatives such as vegetated buffers can improve the visual appeal, environmental services, and ecological health of these ecosystems. Despite their potential benefits, these alternatives are rarely

employed. Is it because individual landowners dislike these management strategies or is it that professional planners disapprove of such options? This paper examines the approval of various riparian buffer types by landowners and planners in Illinois using a photo-questionnaire. Participants rated their preferences for tree buffers, grass buffers, and a 'no buffer' condition along waterways in rural and suburban landscapes. They also rated their preferences for meandering streams in rural areas and earthen banks in the suburbs. The results show substantial support for tree buffers by both residents and planners. Participants also demonstrated considerable approval for meandering streams in rural areas. These findings add to the growing body of literature on preferences for buffers in different landscape settings and provide ample evidence for planners and policy-makers to take necessary steps to preserve or restore vegetated riparian buffers and meandering channels along Mid-western waterways. These natural alternatives to existing strategies are not only visually attractive and ecologically beneficial, they are also positive steps towards more sustainable riparian management practices.

Keppeler, E.T. 1998. The summer flow and water yield response to timber harvest. In: Ziemer, R.R., tech. coord. Proceedings of the conference on coastal watersheds: the Caspar Creek story. Gen. Tech. Rep. PSW-GTR-168. Albany, CA: USDA Forest Service, Pacific Southwest Research Station: 35-43. http://www.treesearch.fs.fed.us/pubs/7791

Abstract: Continuous measurement of streamflow at the Caspar Creek watersheds has led to several analyses of the effects of two harvest methods (selection and clearcut) on summer flows and annual yield. Although all Caspar Creek analyses have indicated an increase in runoff after timber removal, the magnitude and duration of the response depend on the nature and extent of the logging and site preparation, climatic conditions, as well as the definition of the hydrologic parameter at issue. Regression analysis using a calibration period of 1963 to 1971 was used to compare annual yield, summer flow volume, and minimum streamflow between the South Fork (SFC) and the North Fork (NFC) of Caspar Creek for a 35-year period.

Kinley, T.A.; Newhouse, N.J. 1997. Relationship of riparian reserve zone width to bird density and diversity in southeastern British Columbia. Northwest Science. 71(2): 75-86.

Abstract: British Columbia forestry guidelines require riparian management areas of 20 to 50 m width between small streams and cutblocks, composed of reserve zones (no timber harvest) and/or management zones (limited timber harvest). Guidelines in Kootenai National Forest, Montana, limit forest harvesting for 30 m adjacent to permanent streams. As one step in providing a basis to assess such guidelines, we compared (1) habitat structure between spruce-dominated riparian forest and pine-dominated upland forest, (2) breeding bird characteristics (density of detections, species richness, species diversity and species equitability) between riparian and upland forest, and (3) breeding bird characteristics between riparian reserve zones of various widths (averaging 70, 37, or 14 m wide). The study occurred in the Montane Spruce biogeoclimatic zone of southeastern British Columbia. In relation to upland forest, riparian forest had greater tall shrub and canopy cover, but fewer live trees. Snag density, low shrub cover, and coarse woody debris did not differ at $P<0.05$. The two habitat types did not differ in mean bird species richness per site, but riparian forest

had greater species diversity and species equitability, greater density of all species combined, and greater density of three individual species. The density of all birds combined, all riparian-associated birds combined, and three of the four riparian-associated species increased with increasing reserve zone width. Species diversity and species equitability did not differ significantly among treatments. The widths of riparian management areas required under current British Columbia and Kootenai National Forest guidelines are considerably narrower than the widest category of reserves investigated in this study (70 m). Our data indicate that prescribed riparian management areas under current guidelines will have lower densities of total birds and of riparian-associated birds than if reserves were required to average 70 m in width.

Kline, J.D.; Alig, R.J.; Johnson, R.L. 2000. Forest owner incentives to protect riparian habitat. Ecological Economics. 33(1): 29-43. doi:10.1016/S0921-8009(99)00116-0

Abstract: Private landowners increasingly are asked to cooperate with landscape-level management to protect or enhance ecological resources. We examine the willingness of nonindustrial private forest owners in the Pacific Northwest (USA) to forego harvesting within riparian areas to improve riparian habitat. An empirical model is developed describing owners' willingness to accept an economic incentive to adopt a 200-foot harvest buffer along streams as a function of their forest ownership objectives and socioeconomic characteristics. Results suggest that owners' willingness to forego harvest varies by their forest ownership objectives. Mean incentive payments necessary to induce owners to forego harvest in riparian areas are higher for owners possessing primarily timber objectives ($128-137/acre/year) than for owners possessing both timber and nontimber objectives ($54-69/acre/year) or primarily recreation objectives ($38-57/acre/year).

Kobziar, L.N.; McBride, J.R. 2006. Wildfire burn patterns and riparian vegetation response along two northern Sierra Nevada streams. Forest Ecology and Management. 222(1-3): 254-265. doi:10.1016/j.foreco.2005.10.024

Abstract: Riparian vegetation plays an integral role in the ecology of the streams it borders, and in many western US forests, is subjected to frequent wildfire disturbances. Many questions concerning the role of natural fire in the dynamics of riparian zone vegetation remain unanswered. This case study explores the relationships between wildfire burn patterns, stream channel topography, and the short-term response of riparian vegetation to fire along two creeks in the northern Sierra Nevada mixed-conifer forest. Post-fire sampling along 60, 3 m wide transects across riparian zones was used to document the topography, species distribution, sprouting response, and seedling recruitment 1 year after the Lookout fire in the Plumas National Forest, CA. Our results indicate that larger riparian zones acted as natural fire breaks, limiting the progression of the predominantly backing fire downhill toward the stream. On Fourth Water creek's steeper first terraces, where crown fires occurred, the percentage of burned plants that sprouted was higher than in the less-severely burned and more extensive first terraces of Third Water creek (93% versus 33%, $P < 0.05$). Total seedling recruitment was higher along Fourth Water creek (69 versus 35 seedlings, $P < 0.05$), while plant regeneration along Third Water creek was primarily vegetative. Along Fourth Water creek, the percent of burned hardwoods that sprouted increased with proximity to the wa-

ter's edge from 33% on the slope above the riparian zone to 95% on the gravel bar, suggesting that moisture content plays a role in riparian species response to fire. An influx of white fir (*Abies concolor* Gordon & Glend. (Lindl.)) seedlings on the second terraces of Third Water creek may indicate a shift in species composition if future fires are suppressed and regeneration trends do not change significantly in the next few years. These results contribute to the limited research on natural fire in riparian zones, and can inform management strategies designed to restore and maintain riparian vegetation in the fire-prone forests of the Sierra Nevada.

Kovalchik, B.L.; Chitwood, L.A. 1990. Use of geomorphology in the classification of riparian plant associations in mountainous landscapes of central Oregon, U.S.A. Forest Ecology and Management. 33-34: 405-418. doi:10.1016/0378-1127(90)90206-Q

Abstract: Resource managers are increasingly interested in the importance, unique values, classification, and management of riparian zones. Understanding the ecology of the riparian zone is complicated by extreme variation in geology, climate, terrain, hydrology, and disturbances by humans. As a result, it is often difficult to determine the vegetation potential of riparian sites and develop management options. A recent riparian classification in central Oregon uses geomorphology in addition to traditional floristic classification to help identify vegetation potential in the riparian zone. A four-level geomorphic/floristic classification is proposed. Geomorphology is especially useful on riparian sites where the natural vegetation composition, soils, and/or water regimes have been altered by past disturbance, either natural or human-induced.

Kovalchik, B.L.; Clausnitzer, R.R. 2004. Classification and management of aquatic, riparian, and wetland sites on the national forests of eastern Washington: series description. Gen. Tech. Rep. PNW-GTR-593. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 354 p. http://www.treesearch.fs.fed.us/pubs/7405

Abstract: This is a classification of aquatic, wetland, and riparian series and plant associations found within the Colville, Okanogan, and Wenatchee National Forests. It is based on the potential vegetation occurring on lake and pond margins, wetland fens and bogs, and fluvial surfaces along streams and rivers within Forest Service lands. Data used in the classification were collected from 1,650 field plots sampled across the three forests. This classification identifies 32 series separated into four physiognomic classes: coniferous forests, deciduous forests, shrubs, and herbaceous vegetation. In addition, keys to the identification of 163 plant associations or community types are presented. The report includes detailed descriptions of the physical environment, geomorphology, ecosystem function, and management of each series. This classification supplements and expands information presented in upland forest plant association classifications previously completed for the three eastern Washington forests. It is a comprehensive summary of the aquatic, riparian, and wetland series and contributes to the understanding of ecosystems and their management in eastern Washington.

Koyama, A.; Stephan, K.; Kavanagh, K.L. 2012. Fire effects on gross inorganic N transformation in riparian soils in coniferous forests of central Idaho, USA: wildfires v. prescribed fires. International Journal of Wildland Fire. 21(1): 69-78. doi:10.1071/WF10132

Abstract: We investigated differences between wildfires and prescribed fires in their effects on nitrogen (N) dynamics in mineral soils collected from riparian coniferous forests of central Idaho, USA. Specifically, we investigated how the two types of fires affected inorganic N concentrations, microbial biomass N and gross transformation rates of inorganic N in mineral soils relative to their corresponding unburned controls. There was no significant difference in soil NH_4^+ concentrations between burnt and control soils in either type of fires. However, wildfires significantly reduced gross ammonification and microbial NH_4^+ uptake rates relative to their controls ($P = 0.05$ and 0.08). No such effect was found in soils burnt by the prescribed fires relative to their controls. Burnt soils had significantly higher NO_3^- concentrations than control soils when all the data were pooled ($P = 0.08$). The elevated NO_3^- concentrations in the soils burnt by either type of fire were not caused by increased gross nitrification, but likely by significantly reduced microbial NO_3^- uptake ($P \leq 0.02$). We concluded that controlled prescribed fires conducted in early spring had less of an effect on soil N dynamics than wildfires in the region.

Kreutzweiser, D.P.; Capell, S.S. 2001. Fine sediment deposition in streams after selective forest harvesting without riparian buffers. Canadian Journal of Forest Research. 31(12): 2134-2142. doi: 10.1139/x01-155

Abstract: Fine sediment accumulation was measured in streams in low-order forest watersheds across a gradient of selective harvesting with no protective riparian buffers. Comparisons were made among sites in selection-cut (40% canopy removal), shelterwood-cut (50% canopy removal), diameter limit cut (about 85% canopy removal), and undisturbed tolerant hardwood catchments. These were further compared with a headwater stream catchment not harvested but affected by logging road activities. The greatest increases in fine inorganic sediment occurred at the road-improvement site with mean bedload estimates more than 4000 times higher than pre-manipulation values. Sediment bedload was still significantly elevated 2 years after the road-improvement activities. Significant increases (up to 1900 times the pre-harvest average) in inorganic sediment also occurred at the highly disturbed diameter-limit site as a result of heavy ground disturbance and channeled flow paths from skidder activity in riparian areas. Similar increases were detected at the selection-cut site but were attributable to secondary road construction in the runoff area. In the shelterwood harvest area, where logging roads were not a factor, no measurable increases in sediment deposition were detected. There was little indication that harvesting activities at any site affected the organic fraction or the particle size distribution of fine sediments. The results of this study suggest that riparian buffer zones may not be necessary for selective harvesting in hardwood forests at up to 50% removal, at least in terms of reducing sediment inputs.

Lamb, E.G.; Mallik, A.U. 2003. Plant species traits across a riparian-zone/forest ecotone. Journal of Vegetation Science. 14(6): 853-858. doi:10.1658/1100-9233(2003)014[0853:PSTAAR]2.0.CO;2

Abstract: We examined the changes in prevalence of nine plant traits – including the presence of woody stem tissue, leaf longevity, nitrogen fixation, seed longevity, dispersal vector, pollination vector, and clonal growth form – across a riparian/forest-understory ecotone. This ecotone, found along headwater streams in boreal mixed-wood forests, supports four

distinct vegetation zones: streambank, riparian, transition, and upland forest understory. The objective of this study was to identify specific trait patterns that may indicate functional responses to the changes in environmental factors such as nutrient availability and wind exposure that occur across the ecotone. The suites of plant species traits found in each zone were distinct, with a strong change in the prevalence of several traits. Wind and insect pollination, wind and vertebrate diaspore dispersal, and deciduous and evergreen leaves showed the greatest change in prevalence between the vegetation types. Some traits, including insect pollination and vertebrate diaspore dispersal, were strongly correlated within species. The consistent co-occurrence of pairs of traits in the same species suggests common responses by very different traits to the same environmental factor. This study demonstrates that an ecotone can be characterized not only as a discontinuity in species distributions or environmental factors, but also as a discontinuity in the trait spectrum. Examining ecotones from a trait perspective has strong potential for identifying the environmental factors and associated species functional responses that encourage the development of distinct vegetation boundaries.

Liquori, M.K. 2006. Post-harvest riparian buffer response: Implications for wood recruitment modeling and buffer design. Journal of the American Water Resources Association. 42(1): 177-189. doi:10.1111/j.1752-1688.2006.tb03832.x

Abstract: Despite the importance of riparian buffers in providing aquatic functions to forested streams, few studies have sought to capture key differences in ecological and geomorphic processes between buffered sites and forested conditions. This study examines post-harvest buffer conditions from 20 randomly selected harvest sites within a managed tree farm in the Cascade Mountains of western Washington. Post-harvest wind derived treefall rates in buffers up to three years post-harvest averaged 268 trees/km/year, 26 times greater than competition-induced mortality rate estimates. Treefall rates and stem breakage were strongly tied to tree species and relatively unaffected by stream direction. Observed treefall direction is strongly biased toward the channel, irrespective of channel or buffer orientation. Fall direction bias can deliver significantly more wood recruitment relative to randomly directed treefall, suggesting that models that utilize the random fall assumption will significantly under-predict recruitment. A simple estimate of post-harvest wood recruitment from buffers can be obtained from species specific treefall and breakage rates, combined with bias corrected recruitment probability as a function of source distance from the channel. Post-harvest wind effects may reduce the standing density of trees enough to significantly reduce or eliminate competition mortality and thus indirectly alter bank erosion rates, resulting in substantially different wood recruitment dynamics from buffers as compared to unmanaged forests.

Lisle, T.E. 2002. How much dead wood in stream channels is enough? In: Laudenslayer, W.F., Jr.; Shea, P.J.; Valentine, B.E.; Weatherspoon, C.P.; Lisle, T.E., eds. Proceedings of the symposium on the ecology and management of dead wood in western forests. Gen. Tech. Rep. PSW-GTR-181. Albany, CA: USDA Forest Service, Pacific Southwest Research Station: 85-93. http://www.treesearch.fs.fed.us/pubs/6718

Abstract: Private forest managers often seek guidelines on how much dead wood should be retained in streams in order to adequately fulfill ecosystem functions. There are three approaches to answering this question for a particular reach of channel. The first approach uses an understanding of ecologic functions of dead wood in streams to determine the amount needed to fulfill ecologic and geomorphic functions. This approach fails because the complexities of sizes, shapes, and arrangements of dead wood in a variety of lotic ecosystems overwhelm any scientific specification of target loadings. Another approach uses reference loadings to evaluate departures in amounts of dead wood in streams from reference amounts in unaltered systems. A precise threshold cannot be defined using this approach because dead wood volumes are highly variable, even within pristine channels in similar settings, and distributions for managed and pristine channels overlap. A third approach constructs a wood budget by evaluating past, present, and projected supplies in streams and riparian areas. This is a cumulative-effects analysis that shifts the focus from channels to riparian forests. In combination, the three approaches provide the best information to determine how much wood is enough, but they do not offer simple, formulaic prescriptions. The demands for performing the necessary analyses before harvesting riparian wood suggest that management of riparian forests will continue to be guided most often by general prescriptions.

Lytle, D.A.; Poff, N.L. 2004. Adaptation to natural flow regimes. Trends in Ecology and Evolution. 19(2): 94-100. doi:10.1016/j.tree.2003.10.002

Abstract: Floods and droughts are important features of most running water ecosystems, but the alteration of natural flow regimes by recent human activities, such as dam building, raises questions related to both evolution and conservation. Among organisms inhabiting running waters, what adaptations exist for surviving floods and droughts? How will the alteration of the frequency, timing and duration of flow extremes affect flood- and drought-adapted organisms? How rapidly can populations evolve in response to altered flow regimes? Here, we identify three modes of adaptation (life history, behavioral and morphological) that plants and animals use to survive floods and/or droughts. The mode of adaptation that an organism has determines its vulnerability to different kinds of flow regime alteration. The rate of evolution in response to flow regime alteration remains an open question. Because humans have now altered the flow regimes of most rivers and many streams, understanding the link between fitness and flow regime is crucial for the effective management and restoration of running water ecosystems.

Macdonald, E.; Burgess, C.J.; Scrimgeour, G.J.; Boutin, S.; Reedyk, S.; Kotak, B. 2004. Should riparian buffers be part of forest management based on emulation of natural disturbance? Forest Ecology and Management. 187(2-3): 185-196. doi:10.1016/S0378-1127(03)00330-X

Abstract: Riparian communities (those near open water) have often been shown to display high structural and compositional diversity and they have been identified as potentially serving a keystone role in the landscape. Thus, they are the focus of specific management guidelines that attempt to protect terrestrial and aquatic ecosystems. We used a digital forest inventory database for a portion of the boreal mixed-wood forest in Alberta, Canada, to examine whether proximity to a lake affects forest composition, age, or configuration. Two analyses were employed: (1) forest composition (dominant canopy species, proportional composition of different species) and age (decade-of-origin) in bands of 50 m width and varying distance from small lakes were compared to forest in a similar spatial configuration but away from open water and (2) forest composition, dominant canopy species, age, and stand shape metrics were examined along transects emanating out from lakes in two regions, which varied in topography and dominant forest cover. We found no effect of distance from lake on forest age. The proportion of the landscape covered by forest of the predominant canopy species increased with distance from lake, but this was largely due to a corresponding decline in cover of non-forest vegetation rather than a change in forest canopy composition. At the spatial resolution of forest management planning, riparian forests in this region are of similar age and composition as those away from lakes. Since there is no natural analogue for riparian buffer strips around lakes, they may not be justified in the context of ecosystem management following the natural disturbance paradigm. Management of riparian forests should focus on meeting defined management and conservation objectives through, for example, protection of finer scale features of riparian zones and landscape-level planning for allocation of uncut forest.

Mahlum, S.K.; Eby, L.A.; Young, M.K.; Clancy, C.G.; Jakober, M. 2011. Effects of wildfire on stream temperatures in the Bitterroot River Basin, Montana. International Journal of Wildland Fire. 20(2): 240-247. doi:10.1071/WF09132

Abstract: Wildfire is a common natural disturbance that can influence stream ecosystems. Of particular concern are increases in water temperature during and following fires, but studies of these phenomena are uncommon. We examined effects of wildfires in 2000 on maximum water temperature for a suite of second- to fourth-order streams with a range of burn severities in the Bitterroot River basin, Montana. Despite many sites burning at high severity, there were no apparent increases in maximum water temperature during the fires. One month after fire and in the subsequent year, increases in maximum water temperatures at sites within burns were 1.4-2.2°C greater than those at reference sites, with the greatest differences in July and August. Maximum temperature changes at sites >1.7 km downstream from burns did not differ from those at reference sites. Seven years after the fires, there was no evidence that maximum stream temperatures were returning to pre-fire norms. Temperature increases in these relatively large streams are likely to be long-lasting and exacerbated by climate change. These combined effects may alter the distribution of thermally sensitive aquatic species.

Marcus, W.A.; Marston, R.A.; Colvard, C.R., Jr.; Gray, R.D. 2002. Mapping the spatial and temporal distributions of woody debris in streams of the Greater Yellowstone Ecosystem, USA. Geomorphology. 44(3-4): 323-335. doi:10.1016/S0169-555X(01)00181-7

Abstract: The objectives of this study were: (1) to document spatial and temporal distributions of large woody debris (LWD) at watershed scales and investigate some of the controlling processes; and (2) to judge the potential for mapping LWD accumulations with airborne multispectral imagery. Field surveys were conducted on the Snake River, Soda Butte Creek, and Cache Creek in the Greater Yellowstone Ecosystem, USA. The amount of woody debris per kilometer is highest in 2nd order streams, widely variable in 3rd and 4th order streams, and relatively low in the 6th order system. Floods led to increases in woody debris in 2nd order streams. Floods redistributed the wood in 3rd and 4th order streams, removing it from the channel and stranding it on bars, but appeared to generate little change in the total amount of wood throughout the channel system. The movement of woody debris suggests a system that is the reverse of most sediment transport systems in mountains. In 1st and 2nd order tributaries, the wood is too large to be moved and the system is transport-limited, with floods introducing new material through undercutting, but not removing wood through downstream transport. In the intermediate 3rd and 4th order channels, the system displays characteristics of dynamic equilibrium, where the channel is able remove the debris at approximately the same rate that it is introduced. The spatial distribution and quantity of wood in 3rd and 4th order reaches varies widely, however, as wood is alternatively stranded on gravel bars or moved downstream during periods of bar mobilization. In the 6th order and larger channels, the system becomes supply-limited, where almost all material in the main stream can be transported out of the central channel by normal stream flows and deposition occurs primarily on banks or in eddy pool environments. Attempts to map woody debris with 1-m resolution digital four-band imagery were generally unsuccessful, primarily because the imagery could not distinguish the narrow logs within a pixel from the surrounding sand and gravel background and due to problems in precisely coregistering imagery and field maps.

Marczak, L.B.; Sakamaki, T.; Turvey, S.L.; Deguise, I.; Wood, S.L.R.; Richardson, J.S. 2010. Are forested buffers an effective conservation strategy for riparian fauna? An assessment using meta-analysis. Ecological Applications. 20(1): 126-134. doi:10.1890/08-2064.1

Abstract: Historically, forested riparian buffers have been created to provide protection for aquatic organisms and aquatic ecosystem functions. Increasingly, new and existing riparian buffers are being used also to meet terrestrial conservation requirements. To test the effectiveness of riparian buffers for conserving terrestrial fauna, we conducted a meta-analysis using published data from 397 comparisons of species abundance in riparian buffers and unharvested (reference) riparian sites. The response of terrestrial species to riparian buffers was not consistent between taxonomic groups; bird and arthropod abundances were significantly greater in buffers relative to unharvested areas, whereas amphibian abundance decreased. Edge-preferring species were more abundant in buffer sites than reference sites, whereas species associated with interior habitat were not significantly different in abundance. The degree of buffer effect on animal abundance was unrelated to buffer width; wider buffers did not result in greater similarity between reference and buffer sites. However, responses to buffer treatment were more variable in buffers <50 m wide, a commonly prescribed width in many management plans. Our results indicate that current buffer prescriptions do not maintain most terrestrial organisms in buffer strips at levels comparable to undisturbed sites.

McAllister, L.S. 2008. Reconstructing historical riparian conditions of two river basins in eastern Oregon, USA. Environmental Management. 42(3): 412-425. doi:10.1007/s00267-008-9127-1

Abstract: As land use continues to alter riparian areas, historical information is increasingly needed to help establish reference conditions for monitoring and assessment. I developed

and applied a procedure in the John Day and Deschutes river basins of eastern Oregon for synthesizing historical documentary records available across broad spatial areas to reconstruct 19th-century riparian conditions. The study area was stratified by ecoregion and stream physical characteristics to partition regional variability. Three primary data sources—General Land Office survey notes, historical photographs, and written accounts—provided descriptive records, which were grouped by topic to develop common riparian attributes. The number of records for each attribute was tallied by stratum to compare and contrast riparian structure and composition across strata and ecoregions. Detailed descriptions of historical riparian conditions using the original documentary records further illustrated the unique riparian conditions in each stratum. Similarities and differences in historical riparian structure and composition at the stratum and ecoregion levels were evident based on the distributional pattern and numbers of records of attributes across strata. A high number of repeated observations within and among primary data sources helped to corroborate descriptive data. Although these reference data cannot provide the detail needed for rigorous quantitative assessments, they do describe a range of conditions approaching a minimally disturbed condition and provide an important perspective for conducting riparian assessments in highly disturbed regions where least-disturbed reference sites are often poor examples of a desired condition.

McGreer, D.J. 1996. Considerations in development of riparian management strategies: potential consequences of wildfire on riparian and aquatic systems. Unpublished report (prepublication manuscript). Lewiston, ID: Western Watershed Analysts. 37 p.

Abstract: This paper examines the comparative benefits and risks of active versus passive management within riparian areas given the unnaturally fire-prone conditions currently common in the Interior Columbia River Basin. Because riparian ecosystems are naturally subject to periodic disturbance, they exhibit a diversity of structural and developmental stages across the landscape and through time. Riparian areas evolve as mosaics of varying habitat conditions that reflect the disturbance patterns and processes of the surrounding landscape. To successfully provide properly functioning riparian and aquatic systems, aquatic conservation strategies should be consistent with these disturbance-based riparian systems. The key riparian functions of benefit to aquatic systems – shade, provision of large woody debris (LWD), root structure for bank stability, nutrient flux, and organic litter input – are provided within a distance equal to the height of one site-potential tree from the aquatic area. Site specific riparian area conditions and ecological opportunities influence the extent to which these riparian functions are in effect. Riparian areas may also provide an important sediment trapping function, but control of sediment requires control of erosion and sediment delivery processes throughout the entire watershed, not just within riparian areas. Fire exclusion policies have caused many forested areas of the Intermountain and Interior Columbia River Basin (ICRB) regions to become unnaturally dense, have shifted composition towards fire intolerant species, and have caused heavy accumulations of fuels. Wildfire hazards have become extreme, with catastrophic results in many watersheds and riparian systems. Soils subject to the extreme heat of intense wildfires become water repellent, and overland flow of surface waters from rainfall has produced floods of historic proportions.

Riparian vegetation for shade and LWD recruitment has been destroyed, instream large woody debris has been consumed by fire, and hillsides and stream channels have become unstable. These effects have all too often caused destructive stream channel debris torrents and extensive fish mortality. The effects are sometimes repeated when accumulations of burned standing and downed snags and young tree and brush regrowth are consumed several years later in reburns. Landscape-sized efforts are needed to reverse deterioration of the region's forested riparian areas and to reduce their susceptibility to severe wildfire. The silvicultural practices of selective thinning and prescribed burning will be necessary, and are well suited for reduction of potential environmental impacts of wildfire and long-term risks of reburn. Timber salvage will also be needed to minimize effects of wildfire. Active management strategies that incorporate and carefully manage disturbance processes to achieve desired future vegetation and habitat conditions within watersheds and their riparian areas provide the highest potential for restoring and maintaining ecosystem functions and processes, and for achieving fully functioning riparian systems. Passive riparian management strategies allow riparian vegetation to become unnaturally dense and fire-prone, inevitably and unnecessarily predisposing riparian and aquatic systems to destruction by catastrophic wildfire.

Meehan, W.R. 1996. Influence of riparian canopy on macroinvertebrate composition and food habits of juvenile salmonids in several Oregon streams. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 14 p. http://www.treesearch.fs.fed.us/pubs/2877

Summary (from report): Eight streams in Oregon were selected to study the community composition of macroinvertebrates and the feeding habits of juvenile salmonids. The streams were in coastal Oregon, along the west side of the Cascade Range, in central Oregon, and in eastern Oregon [Meadow Creek and McCoy Creek were the eastern OR sample streams]; thus they generally transected the State from west to east. The streams were second- to third-order streams and representative of the many small streams that provide rearing habitat for young salmon and trout. In each of the four geographical areas studied, two streams were sampled, and each had a reach with a canopy of vegetation over the stream and a reach without riparian canopy.

Benthic, drift, sticky trap, and water trap samples, along with stomach samples of the fish, were taken throughout the year over a 3-year period. The data used in this analysis resulted from compositing the samples of invertebrates into four distinct categories: diets of fish in canopied and non-canopied stream sections, and the populations of macroinvertebrates present in the stream environment in canopied and non-canopied sections.

Two simple main effects were considered—one associated with canopied versus non-canopied stream conditions, and the other with fish diet versus presence of the invertebrates in the environment. The interaction of these two effects also was evaluated.

In all aquatic sample types, including fish stomachs, Diptera and Ephemeroptera were the predominant invertebrates collected. In sticky trap and water trap samples, Diptera and Collembola were the predominant orders, reflecting the input of terrestrial invertebrates.

Both main effects—fish diet versus invertebrates in the environment, and canopied versus non-canopied stream condition—were highly significant (P≤0.01), but in terms of the amount of preferred fish food organisms available, the presence or absence of riparian canopy did not seem to be a major concern.

Merrill, A.G.; Benning, T.L.; Fites, J.A. 2006. Factors controlling structural and floristic variation of riparian zones in a mountainous landscape of the western United States. Western North American Naturalist. 66(2): 137-154. doi:10.3398/1527-0904(2006)66[137:FCSAFV]2.0.CO;2

Abstract: We examined landscape patterns in the physical conditions and vegetative composition of montane riparian zones to identify their most important sources of variation. Information on plant species cover and on physical characteristics that occur at coarse, medium, and fine scales was collected for 144 riparian plots located throughout the Lake Tahoe Basin, which straddles the California-Nevada border in the western United States. Constrained and unconstrained ordination analyses were used to identify the most important correlates of physical form and plant species composition. Through multivariate analysis of environmental variables (principal components analysis), vegetation data (detrended correspondence analysis), and the combined relationship between the environmental and vegetation data (canonical correspondence analysis), we consistently found that the greatest variation occurred along a gradient of decreasing valley width, decreasing stream sinuosity, and increasing stream slope. Although surface characteristics reflected a 2^{nd} important source of variation in physical conditions, plant species distribution was not strongly correlated with riparian surface conditions. Strong correlations among physical variables that occur at different scales, such as between valley form and geofluvial surface and between geofluvial surface and surface conditions, support the use of a physically based hierarchical framework for organizing riparian zones within the landscape. Such a hierarchical framework would be useful for interpreting patterns in riparian structure and process at different scales and could be applied to riparian zones in other mountain landscapes of the western United States and elsewhere. Moreover, our finding that riparian plant species composition is most strongly correlated with environmental variables that occur at coarse to moderate scales, most of which can be derived from existing data, supports the idea that modeling montane riparian community distribution using topographic and remotely sensed data could be useful; however, a large degree of species variation, unexplained by the variables we collected, indicates that other variables, perhaps disturbance regime, should be included in such a venture.

Merritt, D.M.; Scott, M.L.; LeRoy Poff, N.; Auble, G.T.; Lytle, D.A. 2010. Theory, methods and tools for determining environmental flows for riparian vegetation: riparian vegetation-flow response guilds. Freshwater Biology. 55(1): 206-225. doi:10.1111/j.1365-2427.2009.02206.x

Abstract: 1. Riparian vegetation composition, structure and abundance are governed to a large degree by river flow regime and flow-mediated fluvial processes. Streamflow regime exerts selective pressures on riparian vegetation, resulting in adaptations (trait syndromes) to specific flow attributes. Widespread modification of flow regimes by humans has resulted in extensive alteration of riparian vegetation communities. Some of the negative effects of altered flow regimes on vegetation may be reversed by restoring components of the natural flow regime. 2. Models have been developed that quantitatively relate components of the flow regime to attributes of riparian vegetation at the individual, population and community levels. Predictive models range from simple statistical relationships, to more complex stochastic matrix population models and dynamic simulation models. Of the dozens of predictive models reviewed here, most treat one or a few species, have many simplifying assumptions such as stable channel form, and do not specify the time-scale of response. In many cases, these models are very effective in developing alternative streamflow management plans for specific river reaches or segments but are not directly transferable to other rivers or other regions. 3. A primary goal in riparian ecology is to develop general frameworks for prediction of vegetation response to changing environmental conditions. The development of riparian vegetation-flow response guilds offers a framework for transferring information from rivers where flow standards have been developed to maintain desirable vegetation attributes, to rivers with little or no existing information. 4. We propose to organise riparian plants into non-phylogenetic groupings of species with shared traits that are related to components of hydrologic regime: life history, reproductive strategy, morphology, adaptations to fluvial disturbance and adaptations to water availability. Plants from any river or region may be grouped into these guilds and related to hydrologic attributes of a specific class of river using probabilistic response curves. 5. Probabilistic models based on riparian response guilds enable prediction of the likelihood of change in each of the response guilds given projected changes in flow, and facilitate examination of trade-offs and risks associated with various flow management strategies. Riparian response guilds can be decomposed to the species level for individual projects or used to develop flow management guidelines for regional water management plans.

Messier, M.S.; Shatford, J.P.A.; Hibbs, D.E. 2012. Fire exclusion effects on riparian forest dynamics in southwestern Oregon. Forest Ecology and Management. 264: 60-71. doi:10.1016/j.foreco.2011.10.003

Abstract: Euro-American settlement and organized fire suppression have been associated with structural and compositional changes in many upland forests of the western United States, but little is known about the impacts on riparian forests, portions of the landscape protected for habitat and water quality. In this study, we used dendroecological methods to characterize the pre-settlement disturbance and tree recruitment processes of riparian forests in the Rogue River basin of southwestern Oregon and to identify changes to the forest structure and composition post-settlement. Our results suggest riparian forests in our study area developed with frequent disturbance by fire and that Euro-American land management shifted these forests onto a new successional trajectory. Our findings indicate the current hands-off management regime for riparian forests under the Northwest Forest Plan will continue along this altered trajectory and have ecologically undesirable consequences. We suggest that the restoration of pre-settlement forest dynamics in fire-prone forests of southwestern Oregon will be most effective where it includes density reductions in overstory trees and prescribed fire in both upland and riparian forests.

Meyer, K.E.; Dwire, K.A.; Champ, P.A.; Ryan, S.E.; Riegel, G.M.; Burton, T.A. 2012. Burning questions for managers: fuels management practices in riparian areas. Fire Management Today. 72(2): 16-23.
Abstract: Vegetation treatment projects for fuel reduction in riparian areas can pose distinct challenges to resource managers. Riparian areas are protected by administrative regulations, many of which are largely custodial and restrict active management. Like uplands, however, riparian areas have been affected by fire suppression, land use, and multiple types of disturbance. Also, many streamside areas are part of the expanding wildland-urban interface (WUI) or wildland-urban intermix that may be at high risk of wildfire. In some cases, manipulative treatments of fuels may be needed to maintain riparian biodiversity, restore or protect valued riparian functions, and reduce wildfire risk. A growing number of Federal, State, and local land managers are exploring options for managing fuels in streamside areas. Because vegetation treatments to reduce fuels in riparian areas are fairly new and untested, limited information is available on where, why, and what practices land managers are implementing (Stone and others 2010), and what management strategies are most effective in different riparian types.
Miller, D.; Luce, C.; Benda, L. 2003. Time, space, and episodicity of physical disturbance in streams. Forest Ecology and Management. 178(1-2): 121-140. doi:10.1016/S0378-1127(03)00057-4
Abstract: Storm-driven episodes of gully erosion and landsliding produce large influxes of sediment to stream channels that have both immediate, often detrimental, impacts on aquatic communities and long-term consequences that are essential in the creation and maintenance of certain channel and riparian landforms. Together, these effects form an important component of river ecosystems. In this paper, we describe issues involved in characterizing and predicting the frequency, magnitude, spatial extent, and synchrony of these sediment influxes. The processes that drive sediment fluxes exhibit spatial and temporal variability over a large range of scales. Disregard of this variability can have unanticipated consequences for efforts to quantify process rates, as we illustrate using landslide densities observed for a storm event in western Oregon. Multiple factors interact to create the temporal and spatial patterns of erosional and mass-wasting events that affect stream channels. Fires, in particular, enhance susceptibility to erosional and mass-wasting processes, and thus affect the timing and magnitude of sediment-mobilizing events. We use examples from west-central Idaho to show how fires, storms, and topography interact to create spatially distinct patches of intense erosional activity. We require quantitative descriptions of these controlling factors to make quantitative predictions of how differences or changes in topography, fire regime, and climate will affect the regime of sediment fluxes. The stochastic and heterogeneous nature of these factors leads us to quantify them in probabilistic terms. The effects of future fire and storm sequences are governed in part by the past sequence of events over time frames spanning centuries and spatial extents spanning entire river basins. Empirical characterization of past events poses a considerable challenge, given that our observational record typically spans several decades at most. Numerical models that simulate mul-

tiple event sequences provide an alternative means for estimating the influence of antecedent conditions and for quantifying the role of different controlling factors.

Minshall, G.W. 2003. Responses of stream benthic macroinvertebrates to fire. Forest Ecology and Management. 178(1-2): 155-161. doi:10.1016/S0378-1127(03)00059-8

Abstract: Synthesis of published research on the responses of stream benthic macroinvertebrates to fire in western United States indicates a consistent pattern of response that can guide resource management and future research. Direct effects of fire generally are minor or indiscernible. Indirect effects, resulting primarily from increased rates of runoff and channel alteration, have the greatest impacts on macroinvertebrate community metrics and food web responses. Postfire effects are variable in time and space, but in smaller size streams (first to fourth order) that are otherwise undisturbed, changes generally are restricted to the first 5-10 years following fire and are associated with the more intense burns (crown fires with ≥ 50% of the catchment involved). In unfragmented habitats, initially supporting intact, functioning stream ecosystems, recovery from fire appears to be relatively rapid and to contribute to enhanced aquatic productivity and biodiversity. However, in poorly managed watersheds and those subjected to indiscriminate salvage logging, impacts from fire are expected to be greater and recovery of the macroinvertebrate communities and stream ecosystems more protracted.

Moore, R.D.; Richardson, J.S. 2012. Natural disturbance and forest management in riparian zones: comparison of effects at reach, catchment, and landscape scales. Freshwater Science. 31(1): 239-247. doi:10.1899/11-030.1

Abstract: Forest disturbance agents, such as wildfire and windthrow, often differ in magnitude and frequency between upland and riparian zones. Riparian forests may be subject to additional disturbance agents that do not affect uplands, including debris flows, floods, bank erosion, and avulsions. Forest harvesting, with or without a streamside buffer, is an additional riparian disturbance agent in managed landscapes. The effects of riparian harvesting on stream habitat and ecology are qualitatively similar to those of wildfire, with the important exception of recruitment of large in-stream wood. For most other disturbance agents, current knowledge is insufficient to assess the degree to which natural disturbance can be emulated via riparian forest harvesting. In particular, the effects of the spatial patterns and frequencies of disturbance on the trajectories and rates of post-disturbance recovery are poorly understood for many landscapes and are complicated by the potential for propagation of effects down the stream network. Broadly based, long-term research on riparian disturbance regimes is needed to provide the scientific basis required for designing strategies for sustainable streamside forest management.

Moore, R.D.; Wondzell, S.M. 2005. Physical hydrology and the effects of forest harvesting in the Pacific Northwest: a review. Journal of the American Water Resources Association. 41(4): 763-784. doi:10.1111/j.1752-1688.2005.tb03770.x

Abstract: The Pacific Northwest encompasses a range of hydrologic regimes that can be broadly characterized as either coastal (where rain and rain on snow are dominant) or interior (where snowmelt is dominant). Forest harvesting generally increases the fraction of precipitation that is available to become streamflow, increases rates of snowmelt, and modifies the runoff pathways by which water flows to the stream channel. Harvesting may potentially decrease the magnitude of hyporheic exchange flow through increases in fine sediment and clogging of bed materials and through changes in channel morphology, although the ecological consequences of these changes are unclear. In small headwater catchments, forest harvesting generally increases annual runoff and peak flows and reduces the severity of low flows, but exceptions have been observed for each effect. Low flows appear to be more sensitive to transpiration from vegetation in the riparian zone than in the rest of the catchment. Although it appears that harvesting increased only the more frequent, geomorphically benign peak flows in several studies, in others the treatment effect increased with return period. Recovery to pre-harvest conditions appeared to occur within about 10 to 20 years in some coastal catchments but may take many decades in mountainous, snow dominated catchments.

Moore, R.D.; Spittlehouse, D.L.; Story, A. 2005. Riparian microclimate and stream temperature response to forest harvesting: A review. Journal of the American Water Resources Association. 41(4): 813-834. doi:10.1111/j.1752-1688.2005.tb03772.x
Abstract: Forest harvesting can increase solar radiation in the riparian zone as well as wind speed and exposure to air advected from clearings, typically causing increases in summertime air, soil, and stream temperatures and decreases in relative humidity. Stream temperature increases following forest harvesting are primarily controlled by changes in insolation but also depend on stream hydrology and channel morphology. Stream temperatures recovered to pre-harvest levels within 10 years in many studies but took longer in others. Leaving riparian buffers can decrease the magnitude of stream temperature increases and changes to riparian microclimate, but substantial warming has been observed for streams within both unthinned and partial retention buffers. A range of studies has demonstrated that streams may or may not cool after flowing from clearings into shaded environments, and further research is required in relation to the factors controlling downstream cooling. Further research is also required on riparian microclimate and its responses to harvesting, the influences of surface/subsurface water exchange on stream and bed temperature regimes, biological implications of temperature changes in headwater streams (both on site and downstream), and methods for quantifying shade and its influence on radiation inputs to streams and riparian zones.

Nagle, G. 1998. Report on research project on environmental history of riparian areas in the Umatilla basin. Unpublished Report. [Place of publication unknown]: USDA Forest Service, Pacific Northwest Research Station, Aquatic/Land Interaction Program. 14 p.
Abstract: No abstract available.

Naiman, R.J.; Décamps, H. 1997. The ecology of interfaces: riparian zones. Annual Review of Ecology and Systematics. 28(1): 621-658. doi:10.1146/annurev.ecolsys.28.1.621
Abstract: Riparian zones possess an unusually diverse array of species and environmental processes. The ecological diversity is related to variable flood regimes, geographically unique channel processes, altitudinal climate shifts, and upland influences on the fluvial corridor. The resulting dynamic environment supports a variety of life-history strategies, biogeochemical cycles and rates, and organisms adapted to disturbance regimes over broad spa-

tial and temporal scales. Innovations in riparian zone management have been effective in ameliorating many ecological issues related to land use and environmental quality. Riparian zones play essential roles in water and landscape planning, in restoration of aquatic systems, and in catalyzing institutional and societal cooperation for these efforts.

Naiman, R.J.; Décamps, H.; Pollock, M. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecological Applications. 3(2): 207-212. doi:10.2307/1941822

Abstract: Riparian corridors possess an unusually diverse array of species and environmental processes. This "ecological" diversity is related to variable flood regimes, geomorphic channel processes, altitudinal climate shifts, and upland influences on the fluvial corridor. This dynamic environment results in a variety of life history strategies, and a diversity of biogeochemical cycles and rates, as organisms adapt to disturbance regimes over broad spatio-temporal scales. These facts suggest that effective riparian management could ameliorate many ecological issues related to land use and environmental quality. We contend that riparian corridors should play an essential role in water and landscape planning, in the restoration of aquatic systems, and in catalyzing institutional and societal cooperation for these efforts.

Nilsson, C.; Svedmark, M. 2002. Basic principles and ecological consequences of changing water regimes: Riparian plant communities. Environmental Management. 30(4): 468-480. doi:10.1007/s00267-002-2735-2

Abstract: Recent research has emphasized the importance of riparian ecosystems as centers of biodiversity and links between terrestrial and aquatic systems. Riparian ecosystems also belong among the environments that are most disturbed by humans and are in need of restoration to maintain biodiversity and ecological integrity. To facilitate the completion of this task, researchers have an important function to communicate their knowledge to policy-makers and managers. This article presents some fundamental qualities of riparian systems, articulated as three basic principles. The basic principles proposed are: (1) The flow regime determines the successional evolution of riparian plant communities and ecological processes. (2) The riparian corridor serves as a pathway for redistribution of organic and inorganic material that influences plant communities along rivers. (3) The riparian system is a transition zone between land and water ecosystems and is disproportionately plant species-rich when compared to surrounding ecosystems. Translating these principles into management directives requires more information about how much water a river needs and when and how, i.e., flow variables described by magnitude, frequency, timing, duration, and rate of change. It also requires information about how various groups of organisms are affected by habitat fragmentation, especially in terms of their dispersal. Finally, it requires information about how effects of hydrologic alterations vary between different types of riparian systems and with the location within the watershed.

Nitschke, C.R. 2005. Does forest harvesting emulate fire disturbance? A comparison of effects on selected attributes in coniferous-dominated headwater systems. Forest Ecology and Management. 214(1-3): 305-319. doi:10.1016/j.foreco.2005.04.015

Abstract: The emulation of natural disturbances is seen by many as an important management paradigm for achieving sustainable ecosystem management. To successfully emulate

natural disturbances, managers must first have an understanding of the complex interactions that occur to the biophysical and chemical attributes of an ecosystem for both the natural and the "emulating" disturbance. The management of riparian ecosystems is an important issue faced by managers since the type of harvesting treatment can have a significant influence on the aquatic component. The removal or retention of riparian forests can have a direct influence on water quality and quantity, particularly on the smaller systems that are found at the headwaters of catchments, but do these treatments invoke a similar response as wildfire? To determine if emulation occurs, the effects of forest harvesting treatments and wildfire on temperature, water chemistry, summer stream flow, and sedimentation in headwater systems were compared using a meta-analysis. A statistically significant difference was found for temperature response between partial/selective harvesting and wildfire, but not after clearcut harvesting. Water chemistry showed statistically significant differences for 11 out of 14 tested attributes, with dissolved organic carbon exhibiting the most marked difference. A significant difference was identified between clearcut harvesting and wildfire for summer stream flow but not between wildfire and partial/selective harvest systems. Forest harvesting operations were found to emulate sedimentation through forest roads but not harvest treatment. Partial/selective harvest systems may offer the greatest emulation congruency versus clearcut harvest systems in terms of overall headwater response and recovery. Partial/selective harvest systems combined with prescribed burning may provide managers with the best solution when attempting to emulate wildfire in headwater systems and reduce the detrimental impact of perturbation on these systems.

Obedzinski, R.A.; Shaw, C.G.I.; Neary, D.G. 2001. Declining woody vegetation in riparian ecosystems of the western United States. Western Journal of Applied Forestry. 16(4): 169-181.
<u>Abstract</u>: Riparian ecosystems serve critical ecological functions in western landscapes. The woody plant components in many of these keystone systems are in serious decline. Among the causes are invasion by exotic species, stress-induced mortality, increases in insect and disease attack, drought, beaver, fire, climatic changes, and various anthropogenic activities. The latter include agricultural development, groundwater depletion, dam construction, water diversion, gravel mining, timber harvesting, recreation, urbanization, and grazing. This article examines the factors implicated in the decline and discusses the importance of interactions among these factors in causing decline. It also clarifies issues that need to be addressed in order to restore and maintain sustainable riparian ecosystems in the western United States, including the function of vegetation, silvics of the woody plant species involved, hydrologic condition, riparian zone structure, and landscape features, geomorphology, and management objectives.

Ober, H.K.; Hayes, J.P. 2008. Influence of forest riparian vegetation on abundance and biomass of nocturnal flying insects. Forest Ecology and Management. 256(5): 1124-1132. doi:10.1016/j.foreco.2008.06.010
<u>Abstract</u>: Despite widespread recognition of linkages between vegetation and insects, understanding of the ecological mechanisms underlying these relationships is limited. Better comprehension of relationships linking abundance and biomass of insects to vegetation

would increase accuracy of predictions of the effects of forest management activities on insect communities. This knowledge could also be pivotal to understanding predator-prey dynamics linked to insect populations. We sampled nocturnal flying insects and measured vegetation characteristics in 34 stream reaches in conifer-dominated forests of the Oregon Coast Range in the Pacific Northwest of the United States. We considered five a priori hypotheses (resource quality, resource diversity, resource abundance, resource concentration, and stream cover hypotheses) that could explain mechanisms underlying associations between riparian vegetation and nocturnal flying insects, and used an information-theoretic approach to determine the relative strength of evidence for each. The resource quality hypothesis, which predicts that abundance and biomass of insects increases with cover of deciduous vegetation, explained substantial variation for nearly every order of insect investigated, whereas the remaining hypotheses explained relatively little. Abundance and biomass of insects had stronger associations with characteristics of canopy trees than with characteristics of shrub or understory trees, suggesting that deciduous trees are an important habitat element for nocturnal flying insects in these areas. Resource managers planning riparian vegetation management in conifer-dominated forests should be aware that manipulation of the cover of deciduous trees in riparian areas could have a large impact on these insects and their vertebrate predators. By providing information on forest canopy composition, remote sensing may offer a low-cost tool for identifying areas with high abundance and biomass of insects during conservation planning.

O'Laughlin, J. 2005. Conceptual model for comparative ecological risk assessment of wildfire effects on fish, with and without hazardous fuel treatment. Forest Ecology and Management. 211(1-2): 59-72. doi:10.1016/j.foreco.2005.01.028

Abstract: Wildfire poses risks to fish and wildlife habitat, among other things. Management projects to reduce the severity of wildfire effects by implementing hazardous fuel reduction treatments also pose risks. How can land managers determine which risk is greater? Comparison of risks and benefits from fuel treatment projects to risks from severe wildfire effects is consistent with policies requiring public land managers to analyze short- and long-term environmental effects. However, formulating the problem as a comparison of temporal considerations often results in decisions to reject fuels treatment projects near imperiled species habitat, even though the adverse effects of short-term project actions may result in substantial long-term net benefits from reducing the severity of wildfire effects. Consistent with widely accepted ecological risk assessment methods, the problem is formulated in a conceptual model. Salmonid fish populations are the risk assessment endpoint, and one stressor adversely affecting them is sediment from wildfire or logging. The model compares short-term effects of implementing fuels reduction treatments to longer-term wildfire effects with and without fuel treatments, including risk reduction benefits. Used quantitatively or qualitatively, the model may contribute to sustainable resource management decisions by improving communication among stakeholders, risk managers in land and resource management agencies, and risk assessors in agencies responsible for enforcing the Endangered Species Act.

Olson, D.L. 2000. Fire in riparian zones: a comparison of historical fire occurrence in riparian and upslope forests in the Blue Mountains and southern Cascades of Oregon. Master of Science thesis. Seattle, WA: University of Washington. 274 p.
Abstract: Despite the ecological importance of fire in Pacific Northwest forests, its role in riparian forests is not well documented. This study reconstructed the historical occurrence of fire within riparian forests along different stream sizes within three different national forests in Oregon. Two study areas were located in mostly dry, low-severity fire regime forests in the Blue Mountains of northeastern Oregon (Dugout and Baker) and the third study area was located in more mesic, moderate-severity fire regime forests on the western slopes of the southern Oregon Cascades (Steamboat). Fire scar dates and tree establishment dates were determined from a total of 424 fire scarred tree wedges and 81 increment cores taken from 67 riparian and upslope plots. Based on the data from this study, fire was common historically in the riparian zones of all three study areas. Weibull median probability fire return intervals (WMPIs) for riparian forests in Dugout ranged between 13 and 14 years, and were only slightly longer than those for upslope forests (averaging one year longer). In Baker, differences between riparian and upslope forest WMPIs were greater, ranging between 13 and 36 years for riparian WMPIs, compared to 10 to 20 years for upslope WMPIs. However, further analyses suggested that forest type and slope aspect play a larger role than proximity to a stream when it came to differentiating fire regimes in this study area. For both Dugout and Baker it appeared that stream channels did not necessarily act as fire barriers during the more extensive fire years. Steamboat riparian WMPIs were somewhat longer (ranging from 35-39 years) than upslope WMPIs (ranging from 27-36), but these differences were not significant. Fires were probably more moderate in severity and likely patchy, considering the incidence of fires occurring only at a riparian plot or an upslope plot within a pair, but not at both. It is possible that fire return interval lengths were associated with aspect, but more sampling would need to be done to show this. Based on the results from this study, it is evident that: 1) restoring fire, or at least conducting fuel reduction treatments, will be necessary to protect riparian forests in comparable forest ecosystems, 2) forests should be managed according to forest type, not just by proximity to a stream, and 3) historical recruitment of large woody debris was likely small but continuous for low-severity fire regime riparian forests, with a relatively short residence time, and patchy and more pulsed for the more moderate-severity fire regime forests.
Osborne, T.Z.; Kobziar, L.N.; Inglett, P.W. 2013. Fire and water: New perspectives on fire's role in shaping wetland ecosystems. Fire Ecology. 9(1): 1-5. doi:10.4996/fireecology.0901001
Abstract: This special issue of Fire Ecology is dedicated to furthering scientific understanding of the role fire plays in the development and functioning of wetland ecosystems. While not initially intuitive, the concept of fire exerting significant influence on how wetland environments function has only recently become a prominent topic of discussion among researchers, although it has been recognized by the management community for some time. This new interest in determining how large scale disturbances modulate ecological processes in wetlands led to a series of invited talks at a Fire in Wetlands session during the 9th International Association for Ecology (INTECOL) meeting in Orlando, Florida, USA, in 2012. The col-

lection of work presented here is the product of that special session, and includes research covering diverse topics such as fire effects on wetland biogeochemistry, vegetation community structure, and wildlife dynamics. Managers' perspectives, while presented in multiple talks during the INTECOL session, are captured here in discussions of the management implications of the research presented. This introduction summarizes each of the papers included in this special issue and is organized into topics of biogeochemistry, vegetation, community dynamics, and wildlife dynamics. The summarizing comments include key messages for management and future directions for research on fire in wetlands.

Padgett, W.G. 1981. Ecology of riparian plant communities in southern Malheur National Forest. Master of Science thesis. Corvallis, OR: Oregon State University. 143 p.

Abstract: Riparian communities in the southern portion of Malheur National Forest were intensively studied with the objective of designing an approach for classifying disturbed riparian areas into units of similar potential. Not all riparian community types in this portion of the Blue Mountains were sampled due to time limitations. Some of the major community types sampled included: Baltic rush (*Juncus balticus*) communities; Kentucky bluegrass (*Poa pratensis*) communities; beaked sedge (*Carex rostrata*) communities; water sedge (*Carex aquatilis*) communities; mountain alder (*Alnus incana*) communities; and various willow communities (*Salix geyeriana*, *Salix exigua* ssp. *exigua*, *Salix rigida* var. *mackenziana*, and *Salix lemmonii*). Sites were selected to maximize geographic variation. Piezometers were placed at each site to determine depth to water table. Soil temperature at depths of 15 cm and 50 cm and water table depth were measured semi-weekly. Plant frequency and understory cover by species were determined using 25 cm square plot frames along three 10 m transects in each community sampled. Belt transects were run to determine tree and shrub densities. Tree cover was determined using a hand-held densiometer and the line-intercept method was used for shrub cover. Soils were described and samples were collected from each horizon for laboratory determination of percent organic carbon, soil texture, and reaction (pH). Ordinations of plant communities and plant species were calculated using the DECORANA program for detrended correspondence analysis. The first axis of ordination arranged both species and communities along a moisture gradient. This was verified by correlation analysis as well as through canonical correlation of a species matrix and an environmental matrix. Stand ordination tables combined with water table and soils data were employed in separating these communities into units of similar vegetative potential (Riparian dominance types). Use of these riparian dominance types may improve management of riparian zones in this part of the Blue Mountains and the use of these types is encouraged.

Palmer, M.A.; Bernhardt, E.S.; Allan, J.D.; Lake, P.S.; Alexander, G.; Brooks, S.; Carr, J.; Clayton, S.; Dahm, C.N.; Follstad Shah, J.; Galat, D.L.; Loss, S.G.; Goodwin, P.; Hart, D.D.; Hassett, B.; Jenkinson, R.; Kondolf, G.M.; Lave, R.; Meyer, J.L.; O'Donnell, T.K.; Pagano, L.; Sudduth, E. 2005. Standards for ecologically successful river restoration. Journal of Applied Ecology. 42(2): 208-217. doi:10.1111/j.1365-2664.2005.01004.x

Abstract: Increasingly, river managers are turning from hard engineering solutions to ecologically based restoration activities in order to improve degraded waterways. River restoration projects aim to maintain or increase ecosystem goods and services while protecting down-

stream and coastal ecosystems. There is growing interest in applying river restoration techniques to solve environmental problems, yet little agreement exists on what constitutes a successful river restoration effort. We propose five criteria for measuring success, with emphasis on an ecological perspective. First, the design of an ecological river restoration project should be based on a specified guiding image of a more dynamic, healthy river that could exist at the site. Secondly, the river's ecological condition must be measurably improved. Thirdly, the river system must be more self-sustaining and resilient to external perturbations so that only minimal follow-up maintenance is needed. Fourthly, during the construction phase, no lasting harm should be inflicted on the ecosystem. Fifthly, both pre- and post-assessment must be completed and data made publicly available. Determining if these five criteria have been met for a particular project requires development of an assessment protocol. We suggest standards of evaluation for each of the five criteria and provide examples of suitable indicators. Billions of dollars are currently spent restoring streams and rivers, yet to date there are no agreed upon standards for what constitutes ecologically beneficial stream and river restoration. We propose five criteria that must be met for a river restoration project to be considered ecologically successful. It is critical that the broad restoration community, including funding agencies, practitioners and citizen restoration groups, adopt criteria for defining and assessing ecological success in restoration. Standards are needed because progress in the science and practice of river restoration has been hampered by the lack of agreed upon criteria for judging ecological success. Without well-accepted criteria that are ultimately supported by funding and implementing agencies, there is little incentive for practitioners to assess and report restoration outcomes. Improving methods and weighing the ecological benefits of various restoration approaches require organized national-level reporting systems.

Parsons, C.T.; Momont, P.A.; Delcurto, T.; McInnis, M.; Porath, M.L. 2003. Cattle distribution patterns and vegetation use in mountain riparian areas. Journal of Range Management. 56(4): 334-341.

Abstract: To quantify the effects of season of use on beef cattle distribution relative to the riparian area, 52 cow/calf pairs were used to evaluate 1) early summer grazing (mid-June to mid-July), and 2) late summer grazing (mid-August to mid-September) during the summers of 1998 and 1999. Within a block, cow/calf pairs used during early summer were also used during late summer grazing periods. Pastures were stocked to achieve 50% utilization of herbaceous vegetation after a 28-day grazing trial. Livestock location and ambient air temperature were recorded hourly during two, 4-day periods in each season of use. Locations were transcribed to a geographical information system for the study area. Ocular vegetation utilization estimates, forage quality, and fecal deposits within 1-m of the stream were recorded post-grazing. During early summer, cattle were further from the stream ($P < 0.01$) than late summer, averaging 161 and 99-m, respectively. Cows were observed closer ($P < 0.01$) to the stream when ambient air temperatures were higher. Fecal deposits within 1-m of the stream were similar ($P = 0.13$) following early and late summer grazing. Forage quality varied ($P < 0.01$) between seasons, with early summer forages having lower dry matter, greater crude protein, lower fiber, and greater in situ dry matter disappearance compared

with late summer forages. Utilization of riparian vegetation was lower and use of upland vegetation greater during early summer than late summer (P < 0.05). In summary, season of use affected cattle distribution relative to the riparian area, with late summer pastures having more concentrated use of riparian vegetation. [This study was conducted on 109 ha of the Eastern Oregon Agricultural Research Center's Hall Ranch located in the foothills of the Wallowa Mountains in northeastern Oregon.]

Pettit, N.; Naiman, R. 2007. Fire in the riparian zone: characteristics and ecological consequences. Ecosystems. 10(5): 673-687. doi:10.1007/s10021-007-9048-5

Abstract: We review the current understandings of the frequency, spatial distributions, mechanisms, and ecological consequences of fire in riparian zones. Riparian zones are well known for influencing many ecological processes at local to landscape scales, and fire can have an important ecosystem-scale influence on them. Riparian zones differ from surrounding uplands in their biophysical templates, moisture regimes and disturbance regimes; as a consequence the characteristics and effects of fire are different than in adjacent uplands. Fire impacts on riparian zones vary proportionally with the severity and extent of burning in the catchment and are affected by stream size. Riparian zones can act as a buffer against fire and therefore as a refuge for fire-sensitive species. However, under some circumstances, such as dry pre-fire climatic conditions and the accumulation of dry fuel, riparian areas become corridors for fire movement. Fire incursion into riparian zones creates canopy gaps and drier conditions, which allow subsequent buildup of dead wood and establishment of fire adapted species. In concert, this increases fuel loads and the probability of another fire. Secondary effects of riparian fire include altering nutrient fluxes and cycling, increasing sediment loads, and stimulating erosion. We conclude that riparian fires are potentially important in shaping ecological characteristics in many regions, but this is poorly quantified. A better understanding of riparian fire regimes is essential to assess the effects of fire in helping shape the complex ecological characteristics of riparian zones over the longer-term.

Platts, W.S.; Armour, C.L.; Booth, G.D.; Bryant, M.; Bufford, J.L.; Cuplin, P.; Jensen, S.; Lienkaemper, G.W.; Minshall, G.W.; Monsen, S.B.; Nelson, R.L.; Sedell, J.R.; S., T.J. 1987. Methods for evaluating riparian habitat with applications to management. Gen. Tech. Rep. INT-221. Ogden, UT: USDA Forest Service, Intermountain Research Station. 177 p.

Abstract: This report develops a standard way of measuring and evaluating riparian conditions. These methods will be helpful to those persons documenting, monitoring, predicting, or evaluating riparian, stream or range conditions, and how this relates to their biotic resources, especially those conditions needed to relate to impacts from land uses.

Poff, B.; Koestner, K.A.; Neary, D.G.; Merritt, D. 2012. Threats to western United States riparian ecosystems: A bibliography. Gen. Tech. Rep. RMRS-GTR-269. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 78 p.
http://www.treesearch.fs.fed.us/pubs/42463

Abstract: This bibliography is a compendium of state-of-knowledge publications about the threats affecting western U.S. riparian ecosystems and is a companion to the website: http://www.rmrs.nau.edu/awa/ripthreatbib. The website contains abstracts and access to many of the publications via PDFs, or it directs the readers to websites where PDFs of the

publication can be viewed or obtained. The bibliography is ordered alphabetically and the type of threats discussed in each publication is highlighted. These threats include agriculture, climate change, dam construction, disease, drought, invasive species, fire, floods, flow regulation, forest harvesting, grazing, groundwater depletion, insects, mining, recreation, roads, water diversions, urbanization, and water quality.

Pollock, M.M.; Beechie, T.J.; Jordan, C.E. 2007. Geomorphic changes upstream of beaver dams in Bridge Creek, an incised stream channel in the interior Columbia River basin, eastern Oregon. Earth Surface Processes and Landforms. 32(8): 1174-1185. doi:10.1002/esp.1553

Abstract: Channel incision is a widespread phenomenon throughout the dry interior Columbia River basin and other semi-arid regions of the world, which degrades stream habitat by fundamentally altering natural ecological, geomorphological and hydrological processes. We examined the extent of localized aggradation behind beaver dams on an incised stream in the interior Columbia River basin to assess the potential for using beaver, *Castor canadensis*, dams to restore such channels, and the effect of the aggradation on riparian habitat. We estimated aggradation rates behind 13 beaver dams between 1 and 6 years old on Bridge Creek, a tributary to the John Day River in eastern Oregon. Vertical aggradation rates are initially rapid, as high as 0.47 m yr^{-1}, as the entrenched channel fills, then level off to 0.075 m yr^{-1} by year six, as the sediment begins accumulating on adjacent terraces. We found that a 0.5 m elevation contour above the stream channel approximately coincided with the extent of new riparian vegetation establishment. Therefore, we compared the area surrounding reaches upstream of beaver dams that were within 0.5 m elevation of the stream channel with adjacent reaches where no dams existed. We found that there was five times more area within 0.5 m elevation of the channel upstream of beaver dams, presumably because sediment accumulation had aggraded the channel. Our results suggest that restoration strategies that encourage the recolonization of streams by beaver can rapidly expand riparian habitat along incised streams.

Pollock, M.M.; Beechie, T.J.; Imaki, H. 2012. Using reference conditions in ecosystem restoration: an example for riparian conifer forests in the Pacific Northwest. Ecosphere. 3(11): art98 (23 p). doi:10.1890/ES12-00175.1

Abstract: Quantifying the attributes of reference sites is a crucial problem in the restoration of ecosystems, driving both the evaluation of current conditions and the setting of management targets for specific points in the future. Restoration of riparian ecosystems, particularly those dominated by conifers, has become a priority because of the numerous ecosystem services they provide, including a high number of vertebrate species in population decline that utilize these structurally complex forests. By way of example, we illustrate a three-step process to assess the effects of proposed riparian ecosystem restoration efforts: (1) identify reference sites (2) quantify metrics that describe the reference sites, and (3) use models to predict the likely effects of restoration actions relative to reference conditions. To this end, we identified 117 natural, late-successional conifer dominated stands from existing forest inventories in the Pacific Northwest for the purpose of establishing reference conditions. We did this to establish quantitative metrics for structural attributes essential to the maintenance of biodiversity in these forests, and to assess whether there were any important quantitative differences between upland and riparian forests or whether upland and riparian forest reference sites could be used interchangeably. Both forest types were generally similar, but riparian stands had higher average live tree wood volumes and basal areas, suggesting they may be growing on sites that are more productive. Both riparian and upland forests had abundant large diameter (>50 cm) live trees and snags. Collectively, our data suggest that mature, late-successional conifer dominated forests have well developed structural characteristics in terms of abundant large trees in the overstory, abundant large snags, and a well-developed understory of shade-tolerant trees. We modeled the growth of young conifer stands to assess whether a common restoration treatment would accelerate development of structural characteristics typical of reference conditions. We found that left untreated, the stands followed a trajectory towards developing forest structure similar to the average reference condition. In contrast, the restoration treatment followed a developmental trajectory along the outside range of reference conditions.

Poulin, V.A.; Simmons, B.; Harris, C. 2000. Riparian silviculture: An annotated bibliography for practitioners of riparian restoration. Victoria, BC: B.C. Ministry of Forests, Watershed Restoration Program. 32 p.

Summary (from Introduction to report): This annotated bibliography was prepared to help direct watershed restoration specialists in British Columbia to information about riparian silviculture and to papers and web sites that provide the scientific rationale for the riparian restoration of watersheds. This work was part of a study undertaken by the authors to improve future planning and implementation of riparian restoration projects funded through Forest Renewal BC (Poulin et al. 2000). That study found that the most significant barrier to riparian restoration in the province was a fundamental lack of understanding about why and how riparian forests must be restored to renew fish habitat, water quality and channel stability. Over 65 of the citations here address that barrier.

Quigley, T.M. 1981. Estimating contribution of overstory vegetation to stream surface shade. Wildlife Society Bulletin. 9(1): 22-27.

Abstract: A method for estimating the contribution of forest overstory to stream surface shade is presented. Characteristics that must be known to estimate stream surface shade are width of stream, distance from vegetation to stream, orientation of stream, height of overstory, density of vegetation, crown measurement, location, date, and time. Examples and a technique for determining the sensitivity of stream surface shade to changes in stream characteristics and vegetation are given.

Rashin, E.B.; Clishe, C.J.; Loch, A.T.; Bell, J.M. 2006. Effectiveness of timber harvest practices for controlling sediment related water quality impacts. Journal of the American Water Resources Association. 42(5): 1307-1327. doi: 10.1111/j.1752-1688.2006.tb05303.x

Abstract: Timber harvest best management practices (BMPs) in Washington State were evaluated to determine their effectiveness at achieving water quality standards pertaining to sediment related effects. A weight-of-evidence approach was used to determine BMP effectiveness based on assessment of erosion with sediment delivery to streams, physical disturbance of stream channels, and aquatic habitat conditions during the first two years following harvest. Stream buffers were effective at preventing chronic sediment delivery to

streams and physical disturbance of stream channels. Practices for ground-based harvest and cable yarding in the vicinity of small streams without buffers were ineffective or only partially effective at preventing water quality impacts. The primary operational factors influencing BMP effectiveness were: the proximity of ground disturbing activities to streams; presence or absence of designated stream buffers; the use of special timber falling and yarding practices intended to minimize physical disturbance of stream channels; and timing of harvest to occur during snow cover or frozen ground conditions. Important site factors included the density of small streams at harvest sites and the steepness of inner stream valley slopes. Recommendations are given for practices that provide a high confidence of achieving water quality standards by preventing chronic sediment delivery and avoiding direct stream channel disturbance.

Reeves, G.H.; Duncan, S.L. 2009. Ecological history vs. social expectations: managing aquatic ecosystems. Ecology and Society. 14(2): art8 (14 p).
http://www.ecologyandsociety.org/vol14/iss2/art8/
Abstract: The emerging perspective of ecosystems as both non-equilibrium and dynamic fits aquatic ecosystems as well as terrestrial systems. It is increasingly recognized that watersheds historically passed through different conditions over time. Habitat conditions varied in quantity and quality, primarily as a function of the time since the last major disturbance and the legacy of that disturbance. Thus, to match the effects of historical processes, we would expect a variety of conditions to exist across the watersheds in a region at any time. Additionally, watersheds have different potentials to provide habitat for given fish species because of variation in physical features. This developing ecological understanding is often preempted by social desires to bring all watersheds to a "healthy" condition, which in turn is reflected in a common regulatory approach mandating a single condition as the long-term goal for all watersheds. Matching perceptions and regulations to the way aquatic systems actually change and evolve through time will be a major challenge in the future.

Reeves, G.H.; Bisson, P.A.; Rieman, B.E.; Benda, L.E. 2006. Postfire logging in riparian areas. Conservation Biology. 20(4): 994-1004. doi:10.1111/j.1523-1739.2006.00502.x
Abstract: We reviewed the behavior of wildfire in riparian zones, primarily in the western United States, and the potential ecological consequences of postfire logging. Fire behavior in riparian zones is complex, but many aquatic and riparian organisms exhibit a suite of adaptations that allow relatively rapid recovery after fire. Unless constrained by other factors, fish tend to rebound relatively quickly, usually within a decade after a wildfire. Additionally, fire and subsequent erosion events contribute wood and coarse sediment that can create and maintain productive aquatic habitats over time. The potential effects of postfire logging in riparian areas depend on the landscape context and disturbance history of a site; however, available evidence suggests two key management implications: (1) fire in riparian areas creates conditions that may not require intervention to sustain the long-term productivity of the aquatic network and (2) protection of burned riparian areas gives priority to what is left rather than what is removed. Research is needed to determine how postfire logging in riparian areas has affected the spread of invasive species and the vulnerability of upland forests to insect and disease outbreaks and how postfire logging will affect the frequency and be-

havior of future fires. The effectiveness of using postfire logging to restore desired riparian structure and function is therefore unproven, but such projects are gaining interest with the departure of forest conditions from those that existed prior to timber harvest, fire suppression, and climate change. In the absence of reliable information about the potential consequence of postfire timber harvest, we conclude that providing postfire riparian zones with the same environmental protections they received before they burned is justified ecologically. Without a commitment to monitor management experiments, the effects of postfire riparian logging will remain unknown and highly contentious.

Rheinhardt, R.; Brinson, M.; Meyer, G.; Miller, K. 2012. Integrating forest biomass and distance from channel to develop an indicator of riparian condition. Ecological Indicators. 23: 46-55. doi:10.1016/j.ecolind.2012.03.017

Abstract: Living and detrital biomass in a riparian buffer zones ameliorate diffuse-source pollution originating from adjacent landscapes, with higher nutrient removal potential, particularly with respect to nitrogen and sediments, associated with more biomass (i.e., older forests). Pollution removal is mediated by sediment trapping and uptake of nitrogen by plants and by denitrification by microbial communities in root zones using organic matter and root exudates as energy sources. However, as a consequence of various land management activities, the amount of biomass of most forest riparian zones is much lower than its potential, which is mature forest. This makes restoration of riparian buffer zones to mature forest an ideal way to both improve water quality and increase carbon sequestration. This study measures the amount of biomass aboveground and in soils for a variety of common, age-related condition-types associated with riparian buffer zones along low order (headwater) streams in agricultural landscapes of Coastal Plain North Carolina. The data are used to determine pollution removal potential in relation to stand age and distance from channel and a basis for developing an indicator of riparian condition. Mean biomass for common riparian cover types were Mature Forest (>50 y old): 483 Mg/ha; Young Forest (25-50 y old): 257 Mg/ha; Regenerating Forest (5-25 y old): 205 Mg/ha; recently Harvested Forest (0-5 y old): 165 Mg/ha; Perennial Herb: 67 Mg/ha; Shrub/Sapling: 63 Mg/ha; and Annual Rowcrop: 36 Mg/ha. Trees contained >96% of all aboveground biomass and >58% of total biomass present in the forested conditions. Biomass in recently harvested forests were >97% detrital, mostly due to the large amount of slash left after harvesting and the mostly intact soil organic matter. Most (>80%) of the biomass in non-forest cover types was stored in the detrital pool. By partitioning the riparian zone into inverse distance-weighted subzones based on distance from stream channel, we developed an indicator for determining riparian condition based on both biomass and proximity of biomass to channel.

Richardson, J.S.; Naiman, R.J.; Bisson, P.A. 2012. How did fixed-width buffers become standard practice for protecting freshwaters and their riparian areas from forest harvest practices? Freshwater Science. 31(1): 232-238. doi:10.1899/11-031.1

Abstract: Riparian buffers provide improved protection for water quality and biota, and narrow, fixed-width buffers of native vegetation along streams have been used to mitigate the effects of forest harvest at least since the 1960s. The practice of leaving unmanaged strips of vegetation along water courses in agricultural lands had been used before the 1960s in southern Europe and in eastern North America, but the scientific basis for leaving riparian buffers on forested lands came from observations in the coastal temperate rainforests of western North America. Those observations often were applied to other forested landscapes without further considerations. Fixed-width buffers are administratively simple to implement and assess, and have come to be the norm for streamside protection from forestry. Most guidelines for streamside protection allow some local modification for site and watershed-scale considerations, but frequently, the option to deviate from fixed-width buffers is not exercised because of uncertainty about outcomes. Few experiments have been done to test the efficacy of buffers of a particular width or of site- or landscape-specific modifications.

Rieman, B.E.; Lee, D.C.; Thurow, R.F.; Hessburg, P.F.; Sedell, J.R. 2000. Toward an integrated classification of ecosystems: defining opportunities for managing fish and forest health. Environmental Management. 25(4): 425-444. doi:10.1007/s002679910034

Abstract: Many of the aquatic and terrestrial ecosystems of the Pacific Northwest United States have been simplified and degraded in part through past land-management activities. Recent listings of fishes under the Endangered Species Act and major new initiatives for the restoration of forest health have precipitated contentious debate among managers and conservation interests in the region. Because aggressive management activities proposed for forest restoration may directly affect watershed processes and functions, the goals of aquatic and terrestrial conservation and restoration are generally viewed as in conflict. The inextricable links in ecological processes and functions, however, suggest the two perspectives should really represent elements of the same problem; that of conserving and restoring more functional landscapes. We used recent information on the status and distribution of forest and fish communities to classify river subbasins across the region and explore the potential conflict and opportunity for a more integrated view of management. Our classification indicated that there are often common trends in terrestrial and aquatic communities that highlight areas of potential convergence in management goals. Regions where patterns diverge may emphasize the need for particular care and investment in detailed risk analyses. Our spatially explicit classification of subbasin conditions provides a mechanism for progress in three areas that we think is necessary for a more integrated approach to management: (1) communication among disciplines; (2) effective prioritization of limited conservation and restoration resources; and (3) a framework for experimentation and demonstration of commitment and untested restoration techniques.

Rieman, B.E.; Gresswell, R.E.; Young, M.K.; Luce, C.H. 2003a. Introduction to the effects of wildland fire on aquatic ecosystems in the western USA. Forest Ecology and Management. 178(1-2): 1-3. doi:10.1016/S0378-1127(03)00050-1

Abstract: [This is an editorial.] The management of wildfire has long been controversial. The role of fire and fire-related management in terrestrial and aquatic ecosystems has become an important focus in recent years, but the general debate is not new. In his recent book, Stephen Pyne (2001) describes the political and scientific debate surrounding the creation of the U.S. Forest Service and the emergence of fire suppression as a central tenet of wildland management. Essentially, views in the first decade of the 20th century focused on fire as

good or evil: a tool that might benefit other resources or interests (e.g. Indian burning) and mitigate larger more destructive fires, or a threat to the recruitment and productivity of newly designated forest reserves. The "great fires" in the Western USA in 1910 and the associated loss of human life and property largely forged the public and political will to suppress fire on a massive scale.

Rieman, B.; Lee, D.; Burns, D.; Gresswell, R.; Young, M.; Stowell, R.; Rinne, J.; Howell, P. 2003b. Status of native fishes in the western United States and issues for fire and fuels management. Forest Ecology and Management. 178(1-2): 197-211. doi:10.1016/S0378-1127(03)00062-8

Abstract: Conservation of native fishes and changing patterns in wildfire and fuels are defining challenges for managers of forested landscapes in the western United States. Many species and populations of native fishes have declined in recorded history and some now occur as isolated remnants of what once were larger more complex systems. Land management activities have been viewed as one cause of this problem. Fires also can have substantial effects on streams and riparian systems and may threaten the persistence of some populations of fish, particularly those that are small and isolated. Despite that, major new efforts to actively manage fires and fuels in forests throughout the region may be perceived as a threat rather than a benefit to conservation of native fishes and their habitats. The management of terrestrial and aquatic resources has often been contentious, divided among a variety of agencies with different goals and mandates. Management of forests, for example, has generally been viewed as an impact on aquatic systems. Implementation of the management-regulatory process has reinforced a uniform approach to mitigate the threats to aquatic species and habitats that may be influenced by management activities. The problems and opportunities, however, are not the same across the landscapes of interest. Attempts to streamline the regulatory process often search for generalized solutions that may oversimplify the complexity of natural systems. Significant questions regarding the influence of fire on aquatic ecosystems, changing fire regimes, and the effects of fire-related management remain unresolved and contribute to the uncertainty. We argue that management of forests and fishes can be viewed as part of the same problem, that of conservation and restoration of the natural processes that create diverse and productive ecosystems. We suggest that progress toward more integrated management of forests and native fishes will require at least three steps: (1) better integration and development of a common conceptual foundation and ecological goals; (2) attention to landscape and ecological context; and (3) recognition of uncertainty.

Riparian Habitat Subcommittee. 1979. Managing riparian ecosystems (zones) for fish and wildlife in eastern Oregon and eastern Washington. Unpublished, spiral-bound report. [Place of publication unknown]: Oregon/ Washington Interagency Wildlife Committee, Riparian Habitat Subcommittee. 44 p.

Abstract: Riparian ecosystems are defined as streams, lakes, and wet areas, and adjacent vegetative communities which are predominantly influenced by their association with water. Optimum fish and wildlife habitat conditions are described for this ecosystem in eastern Oregon and Washington. A process is outlined to evaluate the present conditions of riparian

ecosystems, to project potentials for enhancement, and to establish recommended habitat conditions for managing fish and wildlife within riparian ecosystems.

Roath, L.R.; Krueger, W.C. 1982. Cattle grazing influence on a mountain riparian zone. Journal of Range Management. 35(1): 100-103.

Abstract: A combination of management and physical topographic constraints caused cattle to concentrate on the riparian zone early in the grazing season in 1977 and 1978. A large percentage of cattle days and vegetation utilization on the riparian zone occurred in the first 4 weeks of the grazing period. Utilization on herbaceous vegetation was 76% and 72% in 1977 and 1978, respectively. Impact of grazing on the most prevalent species, Kentucky bluegrass, was minimal. Shrub use increased with increased maturity of herbaceous vegetation. Utilization of major shrubs was not excessive in either year, and very likely had no long-term effects on either the abundance or vigor of the shrubs. [This research was conducted on one unit of a U.S. Forest Service allotment in the southern Blue Mountains, approximately 55 km south of John Day, Oregon.]

Robichaud, I.; Villard, M.-A.; Machtans, C.S. 2002. Effects of forest regeneration on songbird movements in a managed forest landscape of Alberta, Canada. Landscape Ecology. 17(3): 247-262. doi:10.1023/A:1020247118426

Abstract: Recent studies have shown that barrier effects exist even in relatively vagile species such as forest songbirds. The objectives of this study were to determine whether a 560 × 100 m riparian buffer strip of mature forest was used as a movement corridor by forest songbirds and, if so, to what extent corridor effects persisted as woody vegetation regenerated in the adjacent clearcut. Over a 4-yr period, juvenile movement rates decreased in the riparian buffer strip and increased in the regenerating clearcut. Adult movement rates increased in the riparian buffer strip in the first year after logging, then gradually decreased, while still increasing in the regenerating clearcut. However, both juvenile and adult movement rates were higher in the buffer strip than in an undisturbed control site. Results suggest that most adults we captured held territories in the vicinity of the net lanes,and that most of the juveniles captured were dispersing away from their natal territory. Four years after harvest, juvenile movement rates were higher in the regenerating clearcut than in the riparian buffer strip, but several species had not yet been captured or detected in the regeneration. Our results suggest that the use of the riparian buffer strip as a movement corridor decreased with forest regeneration for both adults and juveniles. However, the buffer strip still acted as a movement corridor for the following species: Philadelphia and Red-eyed Vireos, Red-breasted Nuthatch, and Ovenbird.

Robison, E.G.; Beschta, R.L. 1990. Identifying trees in riparian areas that can provide coarse woody debris to streams. Forest Science. 36(3): 790-801.

Abstract: The natural fall of trees into mountain streams provides coarse woody debris that can improve fish habitat and influence stream morphology. Geometric and empirical equations, based on tree size and distance from the stream, were used to determine the conditional probability of a tree's adding coarse woody debris to a stream. Additional equations were developed to relate this probability to basal area factor. For conditions in the Pacific Northwest, Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) was selected to illustrate how

the equations can be used for varying tree sizes and probabilities. After selecting a probability and determining basal area factor by these equations, resource managers can use prisms or wedge devices before timber harvesting in riparian areas to identify specific trees that can potentially add woody debris to the stream.

Roby, K.; Azuma, D. 1995. Changes in a reach of a northern California stream following wildfire. Environmental Management. 19(4): 591-600. doi:10.1007/bf02471970

Abstract: One reach of a northern California stream, burned by intense wildfire in 1979, was studied to monitor changes and recovery from the fire. Benthic macroinvertebrates collected three weeks and one to four, six, eight, and 11 years following the wildfire were used to assess stream condition and compared to samples from a reach of a nearby unburned stream. Transportable sediment was measured 11 years following the fire. The fire was also used as a worst case example to compare results with a standard cumulative watershed effects assessment methodology. Benthic invertebrate density and taxa richness of the burned reach were both low compared to the unburned reach three weeks after the fire. Mean density was significantly higher in the burned reach in the three years following the fire, while taxa richness was significantly lower in the burned reach over the same time period. Higher density and lower richness in the burned reaches persisted throughout the study period but were not significant after three years. Mean Shannon diversity of the burned reach was significantly lower than that of the unburned reach for each year of the study, although absolute differences diminished throughout the 11-year study period. Transportable sediment was significantly higher in the burned reach than the unburned comparison. Pearson correlations between sediment and biological metrics were weak. Although the correlation between invertebrate diversity and a measure of watershed disturbance (equivalent roaded acres) was high (r =0.95) for the burned watershed, the measure appeared to be a poor indicator of cumulative effects on stream condition. The measure (ERA) was poorly correlated with invertebrate diversity in the unburned reach and, while the ERA calculations indicated substantial recovery, biological and physical measures indicated recovery of the burned stream reach was incomplete.

Roche, L.M.; Kromschroeder, L.; Atwill, E.R.; Dahlgren, R.A.; Tate, K.W. 2013. Water quality conditions associated with cattle grazing and recreation on national forest lands. PLoS ONE. 8(6): e68127 (14 p). doi: 10.1371/journal.pone.0068127

Abstract: There is substantial concern that microbial and nutrient pollution by cattle on public lands degrades water quality, threatening human and ecological health. Given the importance of clean water on multiple-use landscapes, additional research is required to document and examine potential water quality issues across common resource use activities. During the 2011 grazing-recreation season, we conducted a cross sectional survey of water quality conditions associated with cattle grazing and/or recreation on 12 public lands grazing allotments in California. Our specific study objectives were to 1) quantify fecal indicator bacteria (FIB; fecal coliform and *E. coli*), total nitrogen, nitrate, ammonium, total phosphorus, and soluble-reactive phosphorus concentrations in surface waters; 2) compare results to a) water quality regulatory benchmarks, b) recommended maximum nutrient concentrations, and c) estimates of nutrient background concentrations; and 3) examine relationships between water quality, environmental conditions, cattle grazing, and recreation. Nutrient concentrations observed throughout the grazing-recreation season were at least one order of magnitude below levels of ecological concern, and were similar to U.S. Environmental Protection Agency (USEPA) estimates for background water quality conditions in the region. The relative percentage of FIB regulatory benchmark exceedances widely varied under individual regional and national water quality standards. Relative to USEPA's national *E. coli* FIB benchmarks – the most contemporary and relevant standards for this study – over 90% of the 743 samples collected were below recommended criteria values. FIB concentrations were significantly greater when stream flow was low or stagnant, water was turbid, and when cattle were actively observed at sampling. Recreation sites had the lowest mean FIB, total nitrogen, and soluble-reactive phosphorus concentrations, and there were no significant differences in FIB and nutrient concentrations between key grazing areas and non-concentrated use areas. Our results suggest cattle grazing, recreation, and provisioning of clean water can be compatible goals across these national forest lands.

Rood, S.B.; Gourley, C.R.; Ammon, E.M.; Heki, L.G.; Klotz, J.R.; Morrison, M.L.; Mosley, D.A.N.; Scoppettone, G.G.; Swanson, S.; Wagner, P.L. 2003. Flows for floodplain forests: a successful riparian restoration. BioScience. 53(7): 647-656. doi:10.1641/0006-3568(2003)053[0647:ffffas]2.0.co;2

Abstract: Throughout the 20th century, the Truckee River that flows from Lake Tahoe into the Nevada desert was progressively dammed and dewatered, which led to the collapse of its aquatic and riparian ecosystems. The federal designation of the endemic cui-ui sucker (*Chasmistes cujus*) as endangered prompted a restoration program in the 1980s aimed at increasing spring flows to permit fish spawning. These flows did promote cui-ui reproduction, as well as an unanticipated benefit, the extensive seedling recruitment of Fremont cottonwood (*Populus fremontii*) and sandbar willow (*Salix exigua*). Recruitment was scattered in 1983 but extensive in 1987, when the hydrograph satisfied the riparian recruitment box model that had been developed for other rivers. That model was subsequently applied to develop flow prescriptions that were implemented from 1995 through 2000 and enabled further seedling establishment. The woodland recovery produced broad ecosystem benefits, as evidenced by the return by 1998 of 10 of 19 riparian bird species whose populations had been locally extirpated or had declined severely between 1868 and 1980. The dramatic partial recovery along this severely degraded desert river offers promise that the use of in-stream flow regulation can promote ecosystem restoration along other dammed rivers worldwide.

Rood, S.B.; Samuelson, G.M.; Braatne, J.H.; Gourley, C.R.; Hughes, F.M.R.; Mahoney, J.M. 2005. Managing river flows to restore floodplain forests. Frontiers in Ecology and the Environment. 3(4): 193-201. doi:10.1890/1540-9295(2005)003[0193:MRFTRF]2.0.CO;2

Abstract: River damming has dramatic environmental impacts and while changes due to reservoir flooding are immediate, downstream impacts are more spatially extensive. Downstream environments are influenced by the pattern of flow regulation, which also provides an opportunity for mitigation. We discuss impacts downstream from dams and recent case studies where collaborative efforts with dam operators have led to the recovery of more

natural flow regimes. These restoration programs, in Nevada, USA, and Alberta, Canada, focused on the recovery of flow patterns during high flow years, because these are critical for riparian vegetation and sufficient water is available for both economic commitments and environmental needs. The restoration flows were developed using the "Recruitment Box Model", which recommends high spring flows and then gradual flow decline for seedling survival. These flow regimes enabled extensive recruitment of cottonwoods and willows along previously impoverished reaches, and resulted in improvements to river and floodplain environments. Such restoration successes demonstrate how instream flow management can act as a broadly applicable tool for the restoration of floodplain forests.

Rood, S.B.; Goater, L.A.; Mahoney, J.M.; Pearce, C.M.; Smith, D.G. 2007. Floods, fire, and ice: disturbance ecology of riparian cottonwoods. Canadian Journal of Botany. 85(11): 1019-1032. doi:10.1139/B07-073

Abstract: Cottonwoods are poplar trees that are well adapted to dynamic riparian, or streamside, zones throughout the Northern Hemisphere. Here we assess the influences of three prominent physical disturbances, floods, fire, and ice, on cottonwood population ecology. We emphasize cottonwoods along rivers from the "Crown of the Continent", the central Rocky Mountain zone around the Canada – United States border, where five Populus species overlap and four hybridize. Moderate to major floods scour banks and deposit bars, creating barren and moist colonization sites that are essential for cottonwood seedling recruitment. Floods also scarify shallow roots, thus promoting clonal suckering, especially for the section Tacamahaca species: narrowleaf cottonwood (*Populus angustifolia* James), balsam poplar (*Populus balsamifera* L.), and black cottonwood (*Populus trichocarpa* Torr. & A. Gray). Fire would naturally be less frequent in some riparian zones because of the moist conditions and firebreaks provided by the streams, but with human use, floodplain forest fires have probably increased. Following fire, regrowth through clonal root and shoot suckers can be prolific for the Tacamahaca species, but is limited for the section Aigeiros, prairie cottonwood (*Populus deltoides* Bartr.). River ice, and especially ice drives that accompany winter or spring break-up, provide powerful riparian disturbances that have often been neglected. Ice drives generate barren sites for seedling colonization, shear shoots, and scarify roots promoting shoot and root suckering, and sever branches, enabling dispersive clonal branch propagation. Following studies along many regional rivers, we conclude that: (i) riparian cottonwoods are tolerant of, and dependent upon, occasional physical disturbance for population rejuvenation; (ii) differing disturbance responses contribute to niche differentiation across the Populus species; (iii) different disturbances enable varied spatial and temporal patterns of cottonwood establishment, including fringe, general, and patch recruitment; and (iv) natural disturbance regimes probably favor native cottonwoods and disfavor some invasive, woody plants. River damming and flow regulation often attempt to attenuate flood and ice disturbance, a management objective that may hinder the perpetuation of native floodplain forests. We recommend that river resource managers seek to allow flood and ice disturbance, and additionally, fire may provide a managed disturbance that could rejuvenate overmature cottonwood groves along some regulated rivers.

Ruel, J.-C.; Pin, D.; Cooper, K. 2001. Windthrow in riparian buffer strips: effect of wind exposure, thinning and strip width. Forest Ecology and Management. 143(1-3): 105-113. doi:10.1016/S0378-1127(00)00510-7
Abstract: This paper discusses the effects of topography, riparian buffer strip width and thinning on the amount of windthrow over 9 years in balsam fir (*Abies balsamea*) stands. Monitoring of windthrow was conducted in 25 riparian areas representing five treatments: uncut control, thinned 20 m strip, unthinned 20, 40 and 60 m strips. Wind tunnel measurements were made on a topographical model of the study area to provide an estimate of local wind behavior. A cluster analysis performed on the wind speed data led to the identification of four major topographic units of similar wind behavior. Wind speed in valleys varied greatly depending upon the direction of the approaching winds and the presence of small topographic features. When the wind blows perpendicularly to the valley, wind speed tends to be lower but more variable than when it blows parallel to the valley. Windthrow was not related to strip width or thinning. The field study showed that windthrow 5 years after cutting was found to be correlated with the speed of winds blowing roughly perpendicular to the strips. Windthrow after 7 and 9 years, following an unusual wind event that occurred between years 5 and 7, was no longer correlated with this wind direction. High levels of damage were observed where the valley widened, offering less shelter to the buffer strips.
Russell, W.H.; McBride, J.R. 2001. The relative importance of fire and watercourse proximity in determining stand composition in mixed conifer riparian forests. Forest Ecology and Management. 150(3): 259-265. doi:10.1016/s0378-1127(00)00586-7
Abstract: Factors related to the composition of riparian forest stands on three streams in the northern Sierra Nevada mixed conifer forest type were related to proximity to the water course and years since fire. Using a linear regression analysis 46 variables were correlated to the natural log of distance from the thalweg "ln(distance)" including a highly significant positive correlation to dominance and percent canopy cover of conifers, and a significant negative correlation to the same variables when applied to hardwoods. Twenty six variables were correlated to years since fire "years" including similar correlations to the dominance and cover of hardwood and conifer species. However, the significance of the correlation and the degree of sample variability described by fire age was relatively low in comparison to that found for distance from the thalweg. In addition the relative frequency of fire scars increased in a linear fashion with distance from the watercourse. The results of this study indicate that the importance of fire as a determining influence on forest composition declines in proximity to the riparian zone.
Samuelson, G.M.; Rood, S.B. 2004. Differing influences of natural and artificial disturbances on riparian cottonwoods from prairie to mountain ecoregions in Alberta, Canada. Journal of Biogeography. 31(3): 435-450. doi:10.1111/j.0305-0270.2003.01052.x
Aim: Ecoregions represent biophysical zones where environmental factors enable the development of particular plant communities. Ecoregions are generally large but abrupt transitions occur in areas with rapid physical change. A particularly abrupt transitional sequence occurs in the Rocky Mountain region of south-western Alberta where fescue prairie, aspen parkland and mountain ecoregions occur within 15 km. To investigate plant adaptation

across ecoregions, our study investigated the influences of a natural disturbance (flooding) and an artificial disturbance (cattle grazing) on reproductive and population processes of black cottonwood (*Populus balsamifera* subsp. *trichocarpa*, Torr. & Gray), the dominant riparian tree.

Location: We studied cottonwoods throughout their elevational range along two free-flowing, first-order streams, Yarrow and Drywood creeks. Cottonwood was the only prominent tree in the prairie ecoregion, the dominant riparian tree in the parkland and extended upward through the montane ecoregion where it was a pioneer species for the mixed coniferous-deciduous woodland. Cottonwoods did not occur in the higher elevation subalpine ecoregion.

Methods: Thirty-six cross-sectional sampling transects were located across the three ecoregions with cottonwoods, and in ungrazed and grazed areas of each ecoregion. Rectangular 100 m^2 tree and 2 m^2 seedling quadrats were positioned along the transects, and substrate and vegetation were assessed. Historic hydrological data were analyzed relative to flood recurrences and seasonal flow patterns.

Results: Overall, the cottonwoods displayed a sawtooth shaped 'punctuated progressive age structure' with many young trees, progressively fewer older trees, and about four pulses of increased recruitment over the past century. This was considered to provide a healthy cottonwood population and recruitment pulses were apparently associated with flood events with appropriate peak timing and magnitude and a gradual post-flood stage recession. However, analyses of tree, sapling and seedling data indicated that flood-associated seedling recruitment was less important and clonal processes were more important for cottonwood recruitment in the montane ecoregion, the highest ecoregion with cottonwoods. The correlation between flood events and cottonwood recruitment was strongest in the mid-elevation parkland ecoregion suggesting greater reliance on flood-associated seedling recruitment. There was little correlation with flooding and limited recruitment in the fescue prairie ecoregion in recent decades and the disturbed age structure probably results from cattle impacts that have prevented recruitment and produced a decrepit cottonwood forest population.

Main conclusions: These analyses suggested that a healthy cottonwood population displayed a sawtooth shaped 'punctuated progressive age structure' and that cottonwood reproduction processes varied across ecoregions with increased clonality in the highest montane ecoregion. Cattle grazing impacts on reproduction were most severe in the lowest prairie ecoregion that is treeless except for the riparian zone. We conclude that appropriate strategies of instream flow regulation, land-use policies and practices, and conservation and restoration efforts should be refined according to ecoregion to recognize the differences in cottonwood reproductive and population ecology.

Scott, M.L.; Shafroth, P.B.; Auble, G.T. 1999. Responses of riparian cottonwoods to alluvial water table declines. Environmental Management. 23(3): 347-358. doi:10.1007/s002679900191

Abstract: Populus species typically dominate riparian ecosystems throughout arid and semiarid regions of North American and efforts to minimize loss of riparian Populus requires an

integrated understanding of the role of surface and groundwater dynamics in the establishment of new, and maintenance of existing, stands. In a controlled, whole-stand field experiment, we quantified responses of Populus morphology, growth, and mortality to water stress resulting from sustained water table decline following in-channel sand mining along an ephemeral sandbed stream in eastern Colorado, USA. We measured live crown volume, radial stem growth, annual branch increment, and mortality of 689 live *Populus deltoides* subsp. *monilifera* stems over four years in conjunction with localized water table declines. Measurements began one year prior to mining and included trees in both affected and unaffected areas. Populus demonstrated a threshold response to water table declines in medium alluvial sands; sustained declines ≥1 m produced leaf desiccation and branch dieback within three weeks and significant declines in live crown volume, stem growth, and 88% mortality over a three-year period. Declines in live crown volume proved to be a significant leading indicator of mortality in the following year. A logistic regression of tree survival probability against the prior year's live crown volume was significant (−2 log likelihood = 270, χ2 with 1 df = 232, P < 0.0001) and trees with absolute declines in live crown volume of ≥30 during one year had survival probabilities <0.5 in the following year. In contrast, more gradual water table declines of ~0.5 m had no measurable effect on mortality, stem growth, or live crown volume and produced significant declines only in annual branch growth increments. Developing quantitative information on the timing and extent of morphological responses and mortality of Populus to the rate, depth, and duration of water table declines can assist in the design of management prescriptions to minimize impacts of alluvial groundwater depletion on existing riparian Populus forests.

Shaw, J.R.; Cooper, D.J. 2008. Linkages among watersheds, stream reaches, and riparian vegetation in dryland ephemeral stream networks. Journal of Hydrology. 350(1-2): 68-82. doi:10.1016/j.jhydrol.2007.11.030

<u>Abstract</u>: Ephemeral streams are common features of landscapes around the world, and are the predominant fluvial environment in arid zones. Current understanding of dryland riparian ecology is derived primarily from perennial stream environments, and little is known about the factors controlling vegetation along ephemeral streams. This study describes relationships between the physical characteristics of watersheds and stream reaches, and their effects on riparian plant communities, for 14 ephemeral stream reaches in the semi-arid southern Colorado Plateau, USA. Interactions of watershed properties produce gradients of hydro-geomorphic regimes throughout stream networks, which give rise to spatial patterns in the structure and composition of perennial woody plant and grass dominated communities. As watershed and network magnitudes increased, and basin slope decreased, stream reaches exhibited reduced erosive capacities and more attenuated alluvial groundwater variability. Decreased disturbance potential and increased moisture availability in the downstream direction was related to greater abundance of obligate riparian taxa, and increasing structural importance of shrub and tree species. Divisions in watershed and stream reach physical properties corresponded with riparian plant community types, implying that progress in dryland fluvial ecology could be made from research within a watershed or network context. These concepts are integrated to form a stream classification system that describes

functional linkages between watersheds, stream reaches, and riparian plant ecology. Type I streams drain watersheds less than 10 km^2, exhibit the greatest disturbance potential and most xeric alluvial groundwater regime, and are occupied by upland plant associations. Type II streams have watersheds between 10 and 100 km^2, and have more moderate shear stresses and more persistent alluvial groundwater. Plant communities consisting of a mix of upland and riparian species occur in Type II reaches. Type III reaches drain watersheds of more than 100 km^2 and hydrologic regimes are controlled mainly by upstream hydro-climatic conditions. These streams have the lowest bank full shear stresses and perennial water tables that span expansive floodplains. Wetland tree and shrub communities dominate Type III reaches, and upland plants are a minor ecological component.

Sibley, P.K.; Kreutzweiser, D.P.; Naylor, B.J.; Richardson, J.S.; Gordon, A.M. 2012. Emulation of natural disturbance (END) for riparian forest management: synthesis and recommendations. Freshwater Science. 31(1): 258-264. doi:10.1899/11-094.1

Abstract: Designing management strategies based on the emulation of natural disturbance (END) to promote long-term sustainability of riparian forests and their adjacent aquatic ecosystems is an evolving process. Conceptually, the goal of END in riparian forest management is to mimic, to the extent possible, natural disturbance processes within the range of natural variability of the ecosystem while accounting for both temporal (frequency) and spatial (size) scales of the disturbance. The application of END in riparian forests has been evaluated in a limited but growing number of studies. From these studies, the idea has emerged that END could be used as a *tool* to enhance forest complexity and resilience capacity through carefully implemented management strategies. In practice, however, this tool presents a formidable challenge, constrained by scientific and social uncertainty. In this *BRIDGES* cluster we have critically examined: 1) the historical, scientific, and practical foundations of applying END in riparian forest management as an alternative to fixed-width buffers, and 2) the extent to which mimicking natural disturbance and renewal processes can protect aquatic ecosystems through conservation of riparian and aquatic biodiversity. In this synthesis paper, we identify some of the outstanding questions and uncertainties that constrain the integration of END into riparian forest management, provide some initial guiding principles for applying END in riparian areas, and offer recommendations for future research.

Sobota, D.J. 2003. Fall directions and breakage of riparian trees along streams in the Pacific Northwest. Master of Science thesis. Corvallis, OR: Oregon State University. 126 p.

Abstract: In the Pacific Northwest, regulatory agencies have recently implemented management strategies for restoration and maintenance of wood recruitment to streams over time. This allochthonous organic material is a critical component in the geomorphic and biological structure of forested streams. Mathematical models are commonly used to evaluate long-term wood dynamics in stream ecosystems. Accuracy and applicability of these models in a wide range of forest, geomorphic and regional conditions are limited by current understanding of tree fall patterns. I quantified fall directions and breakage of riparian trees at 21 second- to fourth-order stream sites in the Pacific Northwest, USA. These patterns influence rates, amounts and spatial distribution of wood delivered to streams. Riparian tree fall di-

rections strongly differed by species, rooting position away from the stream and side slope steepness adjacent to the channel. Though average tree fall directions oriented towards stream regardless species, rooting position, and side slope, variance of fall directions significantly declined between valley bottoms and hillslopes and between gentle and steep side slopes. Standard deviation of fall directions, as calculated from circular statistical techniques, was two times greater on gentle slopes (0-10% steepness) than on extremely steep slopes (> 90% steepness) (± 80° versus ± 40°). A similar pattern occurred based on rooting position away from the stream (valley bottom versus hillslopes). Valley constraint, forest structure, forest age and region (west of the Cascades Mountains crest versus the interior Columbia Basin) were not associated with variation in fall directions ($p>0.10$ in all cases). Several sites with relatively thin trees (height/dbh > 50 m/m) had overall upstream fall directions. Over half (58%) of the riparian trees measured in this study did not break when they fell. Of riparian trees that were broken, 62% of breaks could not be attributed to physical features of the stream or riparian zone. Percent of trees with breaks slightly increased with forest age ($p=0.08$). More significantly, percent of trees with fall breaks increased with tree height ($p<0.0001$). Models indicated slight differences among species except for western larch (*Larix occidentalis* Nutt.), which had a significantly higher rate of breakage than other species. Trees that broke when they fell typically produced 2 to 3 pieces (geometric mean of 2.7 pieces with 42% coefficient of variation) and the first break typically occurred at half height (average of 0.50 with ± 0.24 standard deviation; proportion of height from base to top). Effects of species type were insignificant on pieces produced or location of first break. These results have several important implications for riparian zone management of forested streams in the Pacific Northwest. Topographic influences on tree growth patterns and rooting conditions could affect stream wood loading rates and patterns where riparian forest dynamics dominate input pathways. Stream sections with side slopes > 90% on both banks potentially receive 1.5 times more falling trees (by numbers) than sections with slopes 0-10% and 2.5 times more than what is expected from a random fall pattern. Breakage by falling trees on impact needs to be considered in simulations of wood recruitment from riparian forests. Large channel-spanning wood pieces that have potential to form pools and jams also have the highest probability to break when initially falling into the channel. A simple model of wood recruitment based on field data and riparian forest dynamics of an old growth forest in the West Cascades of Oregon indicated that fall breakage might reduce numbers of channel spanning wood pieces entering a 10-m wide stream by 7 to 79% over a 100-year time period. At the same time, breakage may amplify absolute number of wood pieces entering a stream channel by 1.1 to 1.8 times. Overall, results presented in this thesis may improve accuracy and calibration of stream wood recruitment models for use in riparian management in the Pacific Northwest.

Stephens, J.L.; Alexander, J.D. 2011. Effects of fuel reduction on bird density and reproductive success in riparian areas of mixed-conifer forest in southwest Oregon. Forest Ecology and Management. 261(1): 43-49. doi:10.1016/j.foreco.2010.09.022

Abstract: Studies in southwest Oregon suggest that riparian areas within mixed-conifer forests historically burned with frequencies and intensities similar to upland areas and that fire played an important role in maintaining both of these ecosystems. Currently, most fuel reduction projects do not include riparian, due to the perception that these riparian areas are negatively affected by anthropogenic disturbance. However, there is very little information on the ecological consequences of including riparian areas in fuel reduction projects. We compared the effects of non-commercial thin and hand-pile treatments followed by prescribed burns in riparian areas of intermittent and perennial streams that were treated to the streamside (unbuffered), to the typical prescription in which sites were treated only in the adjacent upland (buffered). Unbuffered fuel reduction treatments have the potential to affect bird density and reproductive success differently than buffered treatments by altering (1) available nest habitat, (2) predator and nest parasite abundance, and (3) food availability in riparian areas. This study assessed whether unbuffered fuel reduction treatments yielded similar bird response as buffered treatments by quantifying differences in density and reproductive success of five bird species, vegetation structure, the frequency of occurrence of predators and a nest parasite, and arthropod biomass. Density was greater for the shrub and tree-nesting Pacific-slope Flycatcher in buffered streams post treatment. Reproductive success showed a minimal, near-term effect for the shrub-nesting Black-headed Grosbeak. For potential causal factors, we found differences between buffered and unbuffered streams only for available nest habitat in the upper-ground strata and frequency of occurrence of raptors. Overall, results suggest that fuel reduction in riparian areas as compared with typical upland treatments with buffers had a small effect on bird density and a near-term effect on reproductive success. Additional study of fuel reduction in riparian areas is warranted because of its effectiveness in reducing the risk of unnaturally severe wildfire and, correspondingly, the potential benefit to bird communities over the long-term.

Stoddard, J.L.; Larsen, D.P.; Hawkins, C.P.; Johnson, R.K.; Norris, R.H. 2006. Setting expectations for the ecological condition of streams: the concept of reference condition. Ecological Applications. 16(4): 1267-1276. doi:10.1890/1051-0761(2006)016[1267:SEFTEC]2.0.CO;2

Abstract: An important component of the biological assessment of stream condition is an evaluation of the direct or indirect effects of human activities or disturbances. The concept of a reference condition is increasingly used to describe the standard or benchmark against which current condition is compared. Many individual nations, and the European Union as a whole, have codified the concept of reference condition in legislation aimed at protecting and improving the ecological condition of streams. However, the phrase reference condition has many meanings in a variety of contexts. One of the primary purposes of this paper is to bring some consistency to the use of the term. We argue the need for a reference condition term that is reserved for referring to the naturalness of the biota (structure and function) and that naturalness implies the absence of significant human disturbance or alteration. To avoid the confusion that arises when alternative definitions of reference condition are used, we propose that the original concept of reference condition be preserved in this modified form of the term: reference condition for biological integrity or RC(BI). We further urge that these specific terms be used to refer to the concepts and methods used in individual bioassessments to characterize the expected condition to which current conditions are compared: minimally disturbed condition (MDC); historical condition (HC); least disturbed condi-

tion (LDC); and best attainable condition (BAC). We argue that each of these concepts can be narrowly defined, and each implies specific methods for estimating expectations. We also describe current methods by which these expectations are estimated including: the reference-site approach (condition at minimally or least-disturbed sites); best professional judgment; interpretation of historical condition; extrapolation of empirical models; and evaluation of ambient distributions. Because different assumptions about what constitutes reference condition will have important effects on the final classification of streams into condition classes, we urge that bioassessments be consistent in describing the definitions and methods used to set expectations.

Stone, K.R.; Pilliod, D.S.; Dwire, K.A.; Rhoades, C.C.; Wollrab, S.P.; Young, M.K. 2010. Fuel reduction management practices in riparian areas of the western USA. Environmental Management. 46(1): 91-100. doi:10.1007/s00267-010-9501-7

Abstract: Two decades of uncharacteristically severe wildfires have caused government and private land managers to actively reduce hazardous fuels to lessen wildfire severity in western forests, including riparian areas. Because riparian fuel treatments are a fairly new management strategy, we set out to document their frequency and extent on federal lands in the western U.S. Seventy-four USDA Forest Service Fire Management Officers (FMOs) in 11 states were interviewed to collect information on the number and characteristics of riparian fuel reduction treatments in their management district. Just under half of the FMOs surveyed (43%) indicated that they were conducting fuel reduction treatments in riparian areas. The primary management objective listed for these projects was either fuel reduction (81%) or ecological restoration and habitat improvement (41%), though multiple management goals were common (56%). Most projects were of small extent (93% < 300 acres), occurred in the wildland-urban interface (75%), and were conducted in ways to minimize negative impacts on species and habitats. The results of this survey suggest that managers are proceeding cautiously with treatments. To facilitate project planning and implementation, managers recommended early coordination with resource specialists, such as hydrologists and fish and wildlife biologists. Well-designed monitoring of the consequences of riparian fuel treatments on fuel loads, fire risk, and ecological effects is needed to provide a scientifically-defensible basis for the continued and growing implementation of these treatments.

Swanson, D.K.; Schmitt, C.L.; Shirley, D.M.; Erickson, V.; Schuetz, K.J.; Tatum, M.L.; Powell, D.C. 2010. Aspen biology, community classification, and management in the Blue Mountains. Gen. Tech. Rep. PNW-GTR-806. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 117 p. http://www.treesearch.fs.fed.us/pubs/35257

Abstract: Quaking aspen (*Populus tremuloides* Michx.) is a valuable species that is declining in the Blue Mountains of northeastern Oregon. This publication is a compilation of over 20 years of aspen management experience by USDA Forest Service workers in the Blue Mountains. It includes a summary of aspen biology and occurrence in the Blue Mountains, and a discussion of aspen conservation and management techniques such as fencing, conifer removal, and artificial propagation. Local data on bird use of aspen stands, insects and diseases in aspen, and genetic studies of aspen are also included. An aspen community classifica-

tion developed from over 200 sample plots is presented, with plant species composition and cover, environment and soils, and management considerations.

Sweeney, B.W.; Czapka, S.J. 2004. Riparian forest restoration: why each site needs an ecological prescription. Forest Ecology and Management. 192(2-3): 361-373. doi:10.1016/j.foreco.2004.02.005

Abstract: Although restoration of riparian forests improves water and habitat quality of streams, it can be a slow and difficult process, particularly in landscapes where competition from non-native invasive plants and mammalian herbivores produces high seedling mortality. We experimentally evaluated the short-term (1 year) and long-term (5 years) effects on seedling survival and growth of measures to reduce both herbivory (tree shelters) and plant competition (herbicides, tree mats, and mowing) for five species of deciduous trees in two riparian sites in the coastal plain of eastern Maryland, USA. Study species included: *Quercus palustris* (pin oak), *Quercus rubra* (red oak), *Quercus alba* (white oak), *Acer rubrum* (red maple), and *Liriodendron tulipifera* (tulip poplar). Results show that: (1) seedlings protected by tree shelters exhibit on average about 39% higher survival and 300% greater growth after 5 years than seedlings without shelters; (2) tree shelters alter the relative growth relationships among species of seedlings; (3) controlling plant competition may be less important for increasing survival in optimal sites than in marginal sites and more effective when used in conjunction with other measures (e.g. tree shelters) for improving seedling survival and growth; (4) local herbivores preferred certain species of seedlings (tulip poplar and red maple) over others; (5) herbivory can mask the effects of other factors such as site-to-site differences in soil moisture and fertility. Based on these results, we conclude that most prescriptions for restoring a diverse and natural streamside forest need to include a proactive program to enhance the survival and growth of seedlings. This is because local site characteristics (soil moisture and fertility, light and temperature regime, etc.) will not be optimal for all species of seedlings, and herbivores and non-native invasive plants are at, and will continue to be at, historically unprecedented levels. Furthermore, if money and labor are limited, such a plan (especially in the mid-Atlantic region of North America) should give first priority to protecting seedlings from herbivory and assign protection from plant competition a lower priority.

Tabacchi, E.; Lambs, L.; Guilloy, H.; Planty-Tabacchi, A.-M.; Muller, E.; Décamps, H. 2000. Impacts of riparian vegetation on hydrological processes. Hydrological Processes. 14(16-17): 2959-2976. doi:10.1002/1099-1085(200011/12)14:16/17<2959::AID-HYP129>3.0.CO;2-B

Abstract: The main impacts of riparian vegetation on hydrological processes are briefly reviewed in order to highlight needs and perspectives for research and management goals. This review is based upon three distinct influences of riparian vegetation on hydrological processes: (i) the control of runoff, i.e. the physical impact of living and dead plants on hydraulics, (ii) the impact of plant physiology on water uptake, storage and return to the atmosphere, and (iii) the impact of riparian vegetation functioning on water quality. Riparian vegetation influences runoff through complex hydraulic interactions during baseflows as well as overbank flows. The contribution of fine vegetational structures to landscape hydrological roughness needs to be considered in relation to the spatial complexity (patchiness, vertical stratification, rhizosphere) and temporal variability (phenology, succession) of plant communities. With the exception of some woody species, the uptake, storage and return of water to the atmosphere is poorly known for riparian communities, and therefore the assessment of the regional hydrological importance of the riparian corridor remains difficult to estimate. Although better understood than the above two influences of riparian vegetation on hydrological processes, there are still a number of unresolved issues concerning the role of riparian vegetation in controlling water quality. In particular, little is known about the coupling of microbial and vegetational functions in nutrient cycling and the dynamics of carbon release from coarse and fine plant debris. The influence of vegetation complexity and plant diversity on both qualitative and quantitative aspects of water cycling remains an important area for future research. Fundamental and management issues are identified in relation to the use of riparian vegetation as a model and as a tool.

Teply, M.; McGreer, D. 2013. Simulating the effects of forest management on stream shade in central Idaho. Western Journal of Applied Forestry. 28(1): 37-45. doi:10.5849/wjaf.11-037

Abstract: Uneven-aged stands with multistory, diverse canopies are common throughout the forests of the Inland Northwest, and both current regulations and prescriptions under consideration often promote further diversification. Understanding the potential effects of alternative riparian management prescriptions on stream shade is important, and effects may vary with even-aged versus uneven-aged conditions. For a range of riparian stand conditions in Central Idaho, in this article, we compare shade predictions from two approaches using a widely used model introduced by Chen et al. in 1998, one that accounts for multiple canopies ("canopy-explicit approach") and another that accounts for a single-layer canopy ("canopy-average approach"). We found slight improvements using the canopy-explicit approach when there were distinct overstory and understory canopies. However, we found that both approaches under-predicted shade levels observed in the field. The underestimate is influenced by the Forest Vegetation Simulator (FVS) canopy cover metric that we used to inform the model; this metric underestimates vertical non-overlapping cover, an important input to the shade model. We used the canopy-explicit approach to evaluate effects of the Idaho Forestry Program (IFP), a major conservation agreement that the State of Idaho is currently pursing with federal agencies, on stream shade. For this evaluation, we compared shade predicted to occur through implementation of the IFP with that from passive (no harvest) management. For the IFP, we found that shade reduction would be approximately 5%, on average, largely because of the effect of the 25-ft stream-adjacent no-harvest zone that this alternative requires. We also compared shade produced under the IFP with shade targets developed by the Idaho Department of Environmental Quality. Predicted IFP shade levels were lower than target levels, in large part because of the effect of the FVS cover metric. Overall, these comparisons highlight the usefulness of the approach in comparing the effects of different management alternatives on shade, despite the bias introduced by using the FVS cover metric and problems inherent in comparing results developed through simulation to targets based on different methods.

Theurer, F.D.; Lines, I.; Nelson, T. 1985. Interaction between riparian vegetation, water temperature, and salmonid habitat in the Tucannon River. Water Resources Bulletin. 21(1): 53-64. doi:10.1111/j.1752-1688.1985.tb05351.x

Abstract: This analysis relates physical-process, ecological, and economic models to: (1) analyze the instream water temperatures with respect to existing and proposed riparian vegetation under natural conditions; (2) use these water temperatures to determine salmon and steel-head fish populations that were based upon actual field count and known temperature preference data; and (3) determine the economic worth based upon the estimated carrying capacity of the river, the estimated number of return spawners, and the economic value of commercially caught and sport-caught salmon and steelhead. The economic evaluations are in accordance with procedures outlined by the U.S. Water Resources Council (1983).

Tholen, R.D. 1999. Modeling fire effects on stand composition and structure within riparian buffers in dry Douglas-fir/ponderosa pine forests. Master of Science thesis. Moscow, ID: University of Idaho. 52 p.

Abstract: The USDA, Forest Service and USDI, Bureau of Land Management have adopted riparian buffer systems to maintain and restore cold water fish habitats. The FIRESUM successional model was used to project the long-term effects of these buffers on forest ecological health and aquatic habitat conditions. FIRESUM was calibrated using stand data from sites along the North Fork Boise River, in south central Idaho, along with local weather and fuels information. The model's ability to replicate actual fire mortality as measured on the study plots was tested using chi square, ANOVA comparisons using the F-statistic, and Pearson's correlation statistical tests. These tests suggest that the model, as calibrated, accurately predicts tree mortality from fire within the study area. Following model validation testing, three fire management scenarios were modeled for a 150 year period: low-intensity fire every thirty years, determined to be the historic fire regime; high-intensity fire at year 75; and no fire. Simulated forests were compared for their ability to persist following fire, and their ability to provide large woody debris and shade for aquatic habitats. Model results suggest that reinitiation of the native fire regime of low intensity fire at a 30 year return interval will produce a forest more likely to persist and repeat following fire, and that will provide a more consistent amount of large woody debris recruitment and shade than the other scenarios tested. FIRESUM is a useful tool for managers to better understand the effect of their decisions on forest and aquatic habitats.

Thomas, J.W.; Maser, C.; Rodiek, J.E. 1979. Riparian zones. In: Thomas, J.W., ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Washington, DC: U.S. Department of Agriculture, Forest Service: 40-47.

Summary: Riparian zones can be identified by the presence of vegetation that requires free or unbound water or conditions that are more moist than normal (Franklin and Dyrness 1973, Minore and Smith 1971). Riparian zones can vary considerably in size and vegetative complex because of the many combinations that can be created between water sources and physical characteristics of a site. Such characteristics include gradient, aspect, topography, soil, type of stream bottom, water quality, elevation, and plant community (Odum 1971). All riparian zones within forested areas of the Blue Mountains have these things in common:

(1) they create well-defined habitat zones within the much drier surrounding areas; (2) they make up a minor proportion of the overall area; (3) they are generally more productive in terms of biomass – plant and animal – than the remainder of the area; and (4) they are a critical source of diversity within the forest ecosystem.

Twery, M.J.; Hornbeck, J.W. 2001. Incorporating water goals into forest management decisions at a local level. Forest Ecology and Management. 143(1-3): 87-93. doi:10.1016/S0378-1127(00)00508-9

Abstract: Silvicultural practices are important factors in determining water yield and quality from forested watersheds. Similarly, goals for water yield and quality significantly influence the acceptability of various silvicultural practices. Developed through a process of consulting experts in various subspecialties of natural resource management, the NED decision support software is designed to provide a structure for project-level analysis of management alternatives based on identified goals. Using this software, one can analyze forest conditions in the northeastern United States with respect to water, wildlife, timber production, visual quality, and general ecological goals. Water quantity goals include increasing water flow, maintaining a minimum flow, and limiting peak flow. Water quality goals include intensive watercourse protection, wetlands protection, riparian area management, cold-water fish habitat, and warm-water fish habitat. In all cases, a minimum goal of obeying the law by following statutory best management practices (BMPs) is implied, whether or not one selects another water goal. Given a set of goals, a user of the NED system can analyze which goals are met under alternative silvicultural prescriptions or other activities and resolve which goals may or may not be compatible with each other.

Vande Kamp, K.; Rigge, M.; Troelstrup, N.H.; Smart, A.J.; Wylie, B. 2013. Detecting channel riparian vegetation response to best-management-practices implementation in ephemeral streams with the use of Spot high-resolution visible imagery. Rangeland Ecology and Management. 66(1): 63-70. doi:10.2111/REM-D-11-00153.1

Abstract: Heavily grazed riparian areas are commonly subject to channel incision, a lower water table, and reduced vegetation, resulting in sediment delivery above normal regimes. Riparian and in-channel vegetation functions as a roughness element and dissipates flow energy, maintaining stable channel geometry. Ash Creek, a tributary of the Bad River in western South Dakota contains a high proportion of incised channels, remnants of historically high grazing pressure. Best management practices (BMP), including off-stream watering sources and cross fencing, were implemented throughout the Bad River watershed during an Environmental Protection Agency (EPA) 319 effort to address high sediment loads. We monitored prairie cordgrass (*Spartina pectinata* Link) establishment within stream channels for 16 yr following BMP implementation. Photos were used to group stream reaches (n = 103) subjectively into three classes; absent (estimated < 5% cover; n = 64), present (estimated 5-40% cover; n = 23), and dense (estimated > 40% cover; n = 16) based on the relative amount of prairie cordgrass during 2010 assessments of ephemeral channels. Reaches containing drainage areas of 0.54 to 692 ha were delineated with the use of 2010 National Agriculture Imagery Program (NAIP) imagery. Normalized difference vegetation index (NDVI) values were extracted from 5 to 39 sample points proportional to reach length using a series

of Satellite Pour l'Observation de la Terre (SPOT) satellite imagery. Normalized NDVI (nNDVI) of 2,152 sample points were determined from pre- and post-BMP images. Mean nNDVI values for each reach ranged from 0.33 to 1.77. ANOVA revealed significant increase in nNDVI in locations classified as present prairie cordgrass cover following BMP implementation. Establishment of prairie cordgrass following BMP implementation was successfully detected remotely. Riparian vegetation such as prairie cordgrass adds channel roughness that reduces the flow energy responsible for channel degradation.

Van de Water, K.; North, M. 2010. Fire history of coniferous riparian forests in the Sierra Nevada. Forest Ecology and Management. 260(3): 384-395. doi:10.1016/j.foreco.2010.04.032
Abstract: Fire is an important ecological process in many western U.S. coniferous forests, yet high fuel loads, rural home construction and other factors have encouraged the suppression of most wildfires. Using mechanical thinning and prescribed burning, land managers often try to reduce fuels in strategic areas with the highest fuel loads. Riparian forests, however, are often designated as areas where only limited management action can take place within a fixed-width zone. These highly productive forests have developed heavy fuel loads capable of supporting stand-replacing crown fires that can alter wildlife habitat and ecosystem function, and contribute to stream channel erosion. Objectives of this study were to determine whether adjacent coniferous riparian and upland forests burned historically with different frequencies and seasonalities, and whether these relationships varied by forest, site, and stream characteristics. We measured dendrochronological fire records in adjacent riparian and upland areas across a variety of forest, site and stream conditions at 36 sites in three sampling areas in the northern Sierra Nevada. Riparian fire return intervals (FRI) ranged from 8.4 to 42.3 years under a liberal filter (mean 16.6), and 10.0 to 86.5 years under a conservative filter (mean 30.0). Upland FRI ranged from 6.1 to 58.0 years under a liberal filter (mean 16.9), and 10.0 to 56.3 years under a conservative filter (mean 27.8). Riparian and upland fire return intervals were significantly different in only one quarter of the sites we sampled. Riparian and upland areas did not burn with different seasonalities, and fire events occurred primarily during the late summer-early fall dormant season in both riparian and upland areas (88% and 79% of scars, respectively). FRI was shorter in forests with a higher proportion (>22.7-37.6%) of fire-tolerant pine (*Pinus* spp.), sites east of the Sierra crest, lower elevation sites (<1944 m), and riparian zones bordering narrower, more incised streams (width/depth ratio <6.2). Upland areas exhibited a greater degree of fire-climate synchrony than riparian areas. Our study suggests that Sierra Nevada coniferous riparian forests bordering many montane streams might be managed for fuel loads and fire return intervals similar to adjacent upland forests.

Van de Water, K.; North, M. 2011. Stand structure, fuel loads, and fire behavior in riparian and upland forests, Sierra Nevada Mountains, USA; a comparison of current and reconstructed conditions. Forest Ecology and Management. 262(2): 215-228.
doi:10.1016/j.foreco.2011.03.026
Abstract: Fire plays an important role in shaping many Sierran coniferous forests, but longer fire return intervals and reductions in area burned have altered forest conditions. Productive, mesic riparian forests can accumulate high stem densities and fuel loads, making them

susceptible to high-severity fire. Fuels treatments applied to upland forests, however, are often excluded from riparian areas due to concerns about degrading streamside and aquatic habitat and water quality. Objectives of this study were to compare stand structure, fuel loads, and potential fire behavior between adjacent riparian and upland forests under current and reconstructed active-fire regime conditions. Current fuel loads, tree diameters, heights, and height to live crown were measured in 36 paired riparian and upland plots. Historic estimates of these metrics were reconstructed using equations derived from fuel accumulation rates, current tree data, and increment cores. Fire behavior variables were modeled using Forest Vegetation Simulator Fire/Fuels Extension. Riparian forests were significantly more fire prone under current than reconstructed conditions, with greater basal area (BA) (means are 87 vs. 29 m^2/ha), stand density (635 vs. 208 stems/ha), snag volume (37 vs. 2 m^3/ha), duff loads (69 vs. 3 Mg/ha), total fuel loads (93 vs. 28 Mg/ha), canopy bulk density (CBD) (0.12 vs. 0.04 kg/m^3), surface flame length (0.6 vs. 0.4 m), crown flame length (0.9 vs. 0.4 m), probability of torching (0.45 vs. 0.03), predicted mortality (31% vs. 17% BA), and lower torching (20 vs. 176 km/h) and crowning indices (28 vs. 62 km/h). Upland forests were also significantly more fire prone under current than reconstructed conditions, yet changes in fuels and potential fire behavior were not as large. Under current conditions, riparian forests were significantly more fire prone than upland forests, with greater stand density (635 vs. 401 stems/ha), probability of torching (0.45 vs. 0.22), predicted mortality (31% vs. 16% BA), and lower quadratic mean diameter (46 vs. 55 cm), canopy base height (6.7 vs. 9.4 m), and frequency of fire tolerant species (13% vs. 36% BA). Reconstructed riparian and upland forests were not significantly different. Our reconstruction results suggest that historic fuels and forest structure may not have differed significantly between many riparian and upland forests, consistent with earlier research suggesting similar historic fire return intervals. Under current conditions, however, modeled severity is much greater in riparian forests, suggesting forest habitat and ecosystem function may be more severely impacted by wildfire than in upland forests.

Van Sickle, J.; Gregory, S.V. 1990. Modeling inputs of large woody debris to streams from falling trees. Canadian Journal of Forest Research. 20(10): 1593-1601. doi:10.1139/x90-211

Abstract: A probabilistic model predicts means and variances of the total number and volume of large woody debris pieces falling into a stream reach per unit time. The estimates of debris input are based on the density (trees/area), tree size distribution, and tree-fall probability of the riparian stand adjacent to the reach. Distributions of volume, length, and orientation of delivered debris pieces are also predicted. The model is applied to an old-growth coniferous stand in Oregon’s Cascade Mountains. Observed debris inputs from the riparian stand exceeded the inputs predicted from tree mortality rates typical of similar non-riparian stands. Debris pieces observed in the stream were generally shorter, with less volume per piece, than those predicted by the model, probably because of bole breakage during tree fall. As a second application, predicted debris inputs from riparian management zones of various widths are compared with the input expected from an unharvested stand.

Wales, B.C. 2001. The management of insects, diseases, fire, and grazing and implications for terrestrial vertebrates using riparian habitats in eastern Oregon and Washington. Northwest Science. 75(Special Issue): 119-127.

Abstract: Riparian habitats in eastern Oregon and Washington compose a small percentage of the landscape, and yet these habitats are essential for many species of vertebrates. Riparian areas are sensitive to disturbance agents, which can pose a formidable challenge to effective management of these habitats. Moreover, few studies have documented the effects of disturbance agents on riparian habitats and associated fauna. In general, disturbances from insects and disease likely have-strong effects on cavity nesters and insect feeders, and use of Bt (*Bacillus thuringiensis*) to control insect pests decreases the food supply for insectivores. Most fire effects on terrestrial vertebrates are through changes in habitat, food, and competitors, and responses to fire are variable and species specific. Salvage logging likely has negative effects for species that use dead and dying trees. Livestock grazing in riparian areas can eliminate nesting substrates, alter habitat structure and composition, compact soil, trample banks, encourage cowbird expansion, and increase exotic plants. The magnitude of these effects depends on the timing and intensity of grazing. There are almost no studies on how landscape-level vegetation patterns (including riparian corridors) contribute to the viability of wildlife populations. Managers have usually chosen to buffer riparian areas from harvest, spraying, and prescribed fire, but there are no decision-support tools or guidelines for management of riparian habitat for terrestrial vertebrates.

Wells, A.F. 2006. Deep canyon and subalpine riparian and wetland plant associations of the Malheur, Umatilla, and Wallowa-Whitman National Forests. Gen. Tech. Rep. GTR-PNW-682. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 277 p. http://www.treesearch.fs.fed.us/pubs/24936

Abstract: This guide presents a classification of the deep canyon and subalpine riparian and wetland vegetation types of the Malheur, Umatilla, and Wallowa-Whitman National Forests. A primary goal of the deep canyon and subalpine riparian and wetland classification was a seamless linkage with the mid-montane northeastern Oregon riparian and wetland classification provided by Crowe and Clausnitzer in 1997. The classification is based on potential natural vegetation and follows directly from the plant association concept for riparian zones. The 95 vegetation types classified across the three national forests were organized into 16 vegetation series, and included some 45 vegetation types not previously classified for northeastern Oregon subalpine and deep canyon riparian and wetland environments. The riparian and wetland vegetation types developed for this guide were compared floristically and environmentally to riparian and wetland classifications in neighboring geographic regions. For each vegetation type, a section was included describing the occurrence(s) of the same or floristically similar vegetation types found in riparian and wetland classifications developed for neighboring geographic regions. Lastly, this guide was designed to be used in conjunction with the mid-montane guide to provide a comprehensive look at the riparian and wetland vegetation of northeastern Oregon.

Welty, J.J.; Beechie, T.; Sullivan, K.; Hyink, D.M.; Bilby, R.E.; Andrus, C.; Pess, G. 2002. Riparian aquatic interaction simulator (RAIS): a model of riparian forest dynamics for the generation

of large woody debris and shade. Forest Ecology and Management. 162(2-3): 299-318. doi:10.1016/S0378-1127(01)00524-2

Abstract: Streams depend on riparian forests to supply many important functions such as delivery of large woody debris (LWD), organic matter, and nutrients into the aquatic ecosystem and to provide shade to help maintain cool water. Both forests and streams are dynamic, and inputs from the riparian forest are constantly replenished as organic matter and nutrients are processed and transported. Forest stand dynamics have been intensively studied and foresters have developed a good understanding of tree growth and mortality to support commercial forest management. In recent years, the relationships between aquatic functions and adjacent forest stand characteristics have been increasingly quantified by ecologists. Management of riparian forests to protect aquatic functions and water quality has received considerable attention in the Pacific Northwest and elsewhere. For scientific knowledge to be useful to decision-makers, the complex set of riparian relationships, increasingly well understood individually, need to be collectively and objectively linked in a form that can be easily used by scientists and non-scientists alike to develop management strategies for riparian forests. In this paper we describe an analytical system that quantitatively links widely used forest growth forecasting systems for coastal Pacific Northwest forest types to the riparian ecological functions of large woody debris recruitment and shade. The riparian aquatic interaction simulator (RAIS), with its user-friendly interface, allows managers to forecast aquatic functions for up to 300 years. RAIS provides these forecasts over a range of critical input variables and produces realistic estimates of riparian functions when compared with published research.

Wilford, D.J.; Sakals, M.E.; Innes, J.L. 2005. Forest management on fans: hydrogeomorphic hazards and general prescriptions. Land Management Handbook No. 57. Victoria, BC: British Columbia Ministry of Forests, Research Branch. 35 p.
http://www.for.gov.bc.ca/hfd/pubs/docs/lmh/Lmh57.pdf

Abstract: Forested alluvial and colluvial fans can be runout zones for debris flows and debris floods, and are subject to floods. Forest management activities on areas of fans with this hydrogeomorphic activity can exacerbate the effects of these events and lead to substantial damage to infrastructure such as roads and bridges, productive forest sites, and fish habitat. This handbook presents a six-step hazard recognition scheme that enables forest practitioners to prepare appropriate strategies and prescriptions. The six steps are: fan identification in an operating area, pre-typing watersheds, aerial photograph interpretation, fieldwork, prescription development, and monitoring. The scheme is applicable to forested fans throughout British Columbia.

Williams, C.A.; Cooper, D.J. 2005. Mechanisms of riparian cottonwood decline along regulated rivers. Ecosystems. 8(4): 382-395. doi:10.1007/s10021-003-0072-9

Abstract: Decline of riparian forests has been attributed to hydrologic modifications to river flows. However, little is known about the physiological and structural adjustments of riparian forests subject to modified flow regimes, and the potential for forest restoration using historic flow regimes is poorly understood. In this paired river study, we compared hydrology, water relations, and forest structure in cottonwood-dominated floodplains of the regulated Green River to those of the unregulated Yampa River. We measured floodplain groundwater levels, soil water availability, cottonwood xylem pressure (ψxp), and leaf-level stomatal conductance (gs) to assess current impacts of river regulation on the water status of adult cottonwoods. We also simulated a flood on the former floodplain of the regulated river to evaluate its impact on cottonwood water relations. Canopy and root structure were quantified with estimates of cottonwood leaf area and percent live canopy and root density and biomass, respectively. Regulation of the Green River has lowered the annual peak flow yet raised minimum flows in most years, resulting in a 60% smaller stage change, and lowered soil water availability by as much as 70% compared to predawn conditions. Despite differences in water availability, daily and seasonal trends in ψxp and gs were similar for cottonwoods on the regulated and unregulated rivers. In addition, soil water added with the experimental flood had little effect on cottonwood water relations, contrary to our expectations of alleviated water stress. Green River cottonwoods had 10%-30% lower stand leaf area, 40% lower root density, and 25% lower root biomass compared with those for Yampa River cottonwoods. Our results suggest that water relations at the leaf and stem level are currently similar for Yampa and Green River trees due to structural adjustments of cottonwood forests along the Green River, triggered by river regulation.

Williamson, N.M. 1999. Crown fuel characteristics, stand structure, and fire hazard in riparian forests of the Blue Mountains, Oregon. Master of Science thesis. Seattle, WA: University of Washington. 98 p.

Abstract: Disturbances are inherent components of all forest ecosystems (White and Pickett 1985, Sprugel 1991). They play an extremely important role in the shaping of populations and communities through the alteration of landscape pattern and subsequent impacts on future ecological processes (White 1979, Oliver 1981, Pickett and White 1985, Rogers 1996, Camp et al. 1997, Agee 1998). The type, timing, extent, and intensity of disturbances can dramatically affect species distributions, successional pathways, and community composition and structure in forest ecosystems (Baker 1992, Agee 1993, Attiwill 1994, Veblen et al. 1994, Huff 1995, Whelan 1995). For example, a relatively frequent patchy or discontinuous disturbance may generate substantial spatial and temporal heterogeneity within a landscape and potentially increase species diversity by creating a variety of different habitats. On the other hand, a less recurrent, more widespread disturbance of greater severity may have the opposite effect, creating a more homogeneous environment (Gregory et al. 1991). Disturbances can both create, and be constrained by, landscape pattern (Swanson et al. 1988, Agee 1993, Hadley 1994, Turner and Romme 1994, Bessie and Johnson 1995, Castello et al. 1995). Any alteration in disturbance regime can, and likely will, result in an alteration in community composition and structure. Successful management of forested communities requires an understanding of disturbance processes. Increasingly there is an interest (and need) within land management to better incorporate natural disturbances into management planning. Of the many disturbance types found in natural systems (e.g. wind, floods, insects, and disease), perhaps the most widespread is that of fire. Fire has played a significant role in the shaping of many of the inland Northwest's diverse plant communities. The current structure, species composition, and dynamics of many ecosystems are often the di-

rect result of past fires or in other cases, the result of other processes that have themselves been affected by fire (Agee 1993). In turn, other processes may have effects on the occurrence of fire across a landscape. An example of the complex relationships between disturbances is that of fire and insect outbreaks. It is hypothesized that fire exclusion has led to more widespread and more severe western spruce budworm (*Choristoneura occidentalis*) outbreaks within this century (McCune 1983, Anderson et al. 1987, Swetnam and Lynch 1989, Wickman 1992, Swetnam and Lynch 1993, Hadley 1994, Powell 1994, Wickman et al. 1994, Swetnam et al. 1995). However, fire-induced stress can also predispose stands to insect attacks (Fischer 1980, Gara et al. 1985). There is a great concern among land managers that the hazard of high-severity wildfires has increased throughout western North America in this century as a result of fire exclusion and various land use practices. High-severity fires are difficult to control and can often result in extensive damage to aquatic systems. This damage can occur directly, as when riparian forests burn, or indirectly as when upslope fires result in large inputs of sediment and debris to aquatic systems (Brown 1989, Minshall et al. 1989, Beschta 1990, Wissmar et al. 1994, Young 1994, Rieman and Clayton 1997). There is a growing interest in the use of prescribed fire and silvicultural treatments to reduce the hazards of stand-replacement fire. Although much is known about the historic role of fire in upland forests, very little attention has been paid to the role of fire in riparian forests. The success of efforts to protect these sensitive areas requires a thorough understanding of the disturbance processes that created and maintained these forests and how these processes have changed over the last century. This study examines a number of factors that influence fire behavior and in particular influence the occurrence of crown fire behavior. This study also compares crown fire hazard between riparian and upslope stands in the Blue Mountains of northeast Oregon. It is hoped that the results of this study will increase our understanding of the fire hazards faced by land managers in the inland Northwest and perhaps contribute to a means of accurately assessing those hazards.

Wilm, H.G. 1943. Determining net rainfall under a conifer forest. Journal of Agricultural Research. 67(12): 501-512.

Summary: This article reports results from a study that examined how much of the total precipitation falling on a forest actually reaches the ground beneath a canopy, and to what extent this quantity is augmented by removal of trees in timber harvest operations. It contains the following sections: introduction; experimental site and plots; sources of variation and sampling; methods of analysis; results; summary and conclusions; and literature cited. It was found that there was a significant relationship between timber harvest and the proportion of precipitation reaching the ground. Net precipitation appeared to vary in linear relation to the intensity of harvest. It was found that light intermediate harvests, such as thinnings or improvement cuts, resulted in no appreciable increase in net precipitation.

Wilm, H.G.; Dunford, E.G. 1948. Effect of timber cutting on water available for stream flow from a lodgepole pine forest. Tech. Bull. No. 968. Washington, DC: U.S. Department of Agriculture. 43 p.

Summary: This bulletin describes the water yield implications associated with timber harvest activities in a lodgepole pine forest type in the central Rocky Mountains. It includes the fol-

lowing sections: introduction; the problem; experimental area and methods; results; discussion and conclusion; summary; and literature cited. It was found that initial snow storage was increased by 26 percent following the heaviest timber harvest, and by 5 percent following timber stand improvement (thinning) activities. Net precipitation, defined as the proportion of precipitation actually reaching the snowpack or the soil surface, was increased by an average of 32% following the heaviest timber harvest. The amount of water available for stream flow was 10.34 inches for the uncut plots and 13.52 inches for the heavy timber harvest treatment, an increase of 31 percent. No visible soil erosion occurred on any of the plots, although some erosion was observed from the logging roads. This study demonstrated that timber cutting in the lodgepole pine type of the central Rocky Mountains resulted in an immediate and real increase in the amount of water available for streamflow.

Winter, T.C. 2007. The role of ground water in generating streamflow in headwater areas and in maintaining base flow. Journal of the American Water Resources Association. 43(1): 15-25. doi:10.1111/j.1752-1688.2007.00003.x

Abstract: The volume and sustainability of streamflow from headwaters to downstream reaches commonly depend on contributions from ground water. Streams that begin in extensive aquifers generally have a stable point of origin and substantial discharge in their headwaters. In contrast, streams that begin as discharge from rocks or sediments having low permeability have a point of origin that moves up and down the channel seasonally, have small incipient discharge, and commonly go dry. Nearly all streams need to have some contribution from ground water in order to provide reliable habitat for aquatic organisms. Natural processes and human activities can have a substantial effect on the flow of streams between their headwaters and downstream reaches. Streams lose water to ground water when and where their head is higher than the contiguous water table. Although very common in arid regions, loss of stream water to ground water also is relatively common in humid regions. Evaporation, as well as transpiration from riparian vegetation, causing ground-water levels to decline also can cause loss of stream water. Human withdrawal of ground water commonly causes streamflow to decline, and in some regions has caused streams to cease flowing.

Winward, A.H. 2000. Monitoring the vegetation resources in riparian areas. Gen. Tech. Rep. RMRS-GTR-47. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 49 p. http://www.treesearch.fs.fed.us/pubs/5452

Abstract: This document provides information on three sampling methods used to inventory and monitor the vegetation resources in riparian areas. The vegetation cross-section method evaluates the health of vegetation across the valley floor. The greenline method provides a measurement of the streamside vegetation. The woody species regeneration method measures the density and age class structure of any shrub or tree species that may be present in the sampling area. Together these three sampling procedures can provide an evaluation of the health of all the vegetation in a given riparian area.

Wissmar, R.C.; Smith, J.E.; McIntosh, B.A.; Li, H.W.; Reeves, G.H.; Sedell, J.R. 1994. A history of resource use and disturbance in riverine basins of eastern Oregon and Washington (early 1800s-1990s). Northwest Science. 68(Special Issue): 1-35.

Abstract: A historical review of human activities influencing stream and riparian ecosystems in eastern Washington and Oregon shows that cumulative effects of resource uses and management over the past two centuries are altering the health of many river basins. Past practices such as livestock grazing and forest harvest near riparian areas and streams became collectively significant over long time periods and are continuing today. Case histories for the Okanogan and Methow River basins (north central Washington), the Naches River (eastern Cascade Mountains), and the Grande Ronde and John Day River basins (eastern and north central Oregon) provide chronologies of events that shaped the present-day landscapes and socio-economic conditions of the region. Historic cumulative effects on stream and riparian ecosystems include livestock grazing and mining from the 1860s until about 1910. Timber harvest, roads, fire management, dams, irrigation, and fisheries increased in importance during the 20th century. Management histories show minimal actions for reducing damage to stream and riparian ecosystems. Managers commonly perpetuate the notion that streams and riparian areas are difficult to manage because little is known about how these ecosystems function. Many agencies strive to develop procedures for treating the symptoms of degraded ecosystems while giving little consideration to the causes. Other agencies and public groups concerned with conflicting issues like water allocations and minimum instream flows for fish usually disagree with plans for resolving these issues. The continuous dissent by these parties only adds to the plight of fish as available water and habitats continue to decline. Alternatively, new basin-wide management strategies of federal and environmental organizations offer hope for improving the ecosystem biodiversity and population levels of fish and wildlife. Priorities include the protection, restoration, and monitoring of habitats and networks that connect stream and riparian ecosystems in degraded and intact watersheds. Intact watersheds (e.g., roadless and wilderness areas) function as critical habitats and refuge areas for fish and wildlife of adjoining ecosystems.

Wissmar, R.C.; Smith, J.E.; McIntosh, B.A.; Li, H.W.; Reeves, G.H.; Sedell, J.R. 1994. Ecological health of river basins in forested regions of eastern Washington and Oregon. Gen. Tech. Rep. PNW-GTR-326. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 65 p. http://www.treesearch.fs.fed.us/pubs/6371

Abstract: A retrospective examination of the history of the cumulative influences of past land and water uses on the ecological health of select river basins in forest regions of eastern Washington and Oregon indicates the loss of fish and riparian habitat diversity and quality since the 19th century. A physiographic framework of the eastern Washington and Oregon in terms of spatial and temporal geologic, climatic and hydrologic conditions provides a regional perspective for reviewing influences of human patterns of settlement, resource development and management on the river basins. The study focuses on impacts of timber harvest, fire management, livestock grazing, mining and irrigation management practices on stream and riparian ecosystems. Extensive reviews of ecosystem damage and fish losses caused by hydroelectric and large irrigation projects, highway and railroad construction and other factors are beyond the scope of this analysis but are summarized. Case histories of the chronology of natural resource uses and health of select river basins, the Okanogan, Methow and Little Naches River basins (Cascade Mountains of Washington) and the Grande

Ronde and John Day River basins (northeastern and central Oregon) show that during European settlement period livestock grazing, mining, and irrigation developments were the major land and water uses impacting streams and riparian ecosystems. After the 1940s, timber harvest, road construction and irrigation were the major management impacts. The examination of past environmental management approaches for assessing stream, riparian, and watershed conditions in forest regions shows numerous advantages and shortcomings. The select management approaches include: instream flow incremental methodology (IFIM) for the evaluation of the effect of water diversion on steam flows and salmonid habitats; the equivalent clear-cut method (ECA) for assessing the hydrologic effects of logging; a watershed cumulative effects model (KWCEA) for evaluating the effects of logging and roads on soil loss; and procedures for addressing soil compaction problems. The study concludes by providing recommendations for ecosystem management with emphasis on monitoring and restoration activities.

Wondzell, S.M.; Hemstrom, M.A.; Bisson, P.A. 2007. Simulating riparian vegetation and aquatic habitat dynamics in response to natural and anthropogenic disturbance regimes in the upper Grande Ronde River, Oregon, USA. Landscape and Urban Planning. 80(3): 249-267. doi:10.1016/j.landurbplan.2006.10.012

Abstract: We developed state and transition models (STMs) to evaluate the effects of natural disturbances and land-use practices on aquatic and riparian habitats. The STMs consisted of discrete states defined by channel morphology and riparian vegetation. Transitions between states resulted from plant succession and from natural and anthropogenic disturbances. Channel conditions and habitat suitability for anadromous salmonids were ranked by using a qualitative four-factor scale for each state in the STMs. Disturbance probabilities were varied to define both historical and current disturbance regimes. Models were run for 120 years with the current disturbance regime to illustrate changes associated with Euro-American settlement, and then run for an additional 50 years under the historical disturbance regime to illustrate the potential for passive recovery. Results suggested that Euro-American settlement dramatically changed riparian vegetation and channel conditions, which resulted in substantial declines in habitat quality. Passive recovery of channel conditions and habitat suitability was quick in some stream types, but slow in others. Overall, our results underestimate the effects of human land uses on streams and overestimate the rate of recovery under passive restoration because the models do not yet include the effects of many management activities, especially those resulting from forest harvest and roads.

Wyman, S.; Bailey, D.; Borman, M.; Cote, S.; Eisner, J.; Elmore, W.; Leinard, B.; Leonard, S.; Reed, F.; Swanson, S.; Riper, L.V.; Westfall, T.; Wiley, R.; Winward, A. 2006. Riparian area management: Grazing management processes and strategies for riparian-wetland areas. Tech. Ref. 1737-20. BLM/ST/ST-06/002+1737. Denver, CO: U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center. 105 p.

Summary (adapted from the Preface): Grazing management in riparian-wetland areas has been a major issue facing rangeland managers for more than three decades. In the late 1960s, growing concern about the environment prompted landowners, land managers, land users, and a highly interested public to take a critical look at land management practices,

with an eye toward reducing adverse environmental consequences resulting from use of the land. That critical look identified management of livestock grazing in riparian-wetland areas as a significant issue that has assumed permanence on both private and public grazing lands. Basic topics covered in this technical reference include riparian-wetland area attributes and processes, resource assessments and inventories of riparian-wetland areas, development of good resource management objectives, management strategy factors, grazing treatments, and collaborative monitoring. Examples of tools, techniques, and treatments are provided, but they do not represent all of the "tools in the toolbox" that are available to resource managers. Although the term riparian is used alone throughout this document, riparian-wetland area is implied. While examples in this document feature running water (lotic) riparian-wetland areas for the most part, these principles are applicable to standing water (lentic) areas as well. This document is intended to provide the background and information necessary to allow managers to develop practices that will help protect riparian area resources while maintaining the viability and economic soundness of the grazing enterprise. Management of the associated uplands can directly affect conditions in the riparian area. Consequently, it is important to consider the entire watershed and its resources when developing a grazing management strategy. A successful grazing management strategy meets the needs of the operator, livestock, wildlife, and upland and riparian resources. Continued success is achieved by monitoring how well the strategy meets these needs and making timely adjustments as necessary.

Young, M.K. 1994. Movement and characteristics of stream-borne coarse woody debris in adjacent burned and undisturbed watersheds in Wyoming. Canadian Journal of Forest Research. 24(9): 1933-1938. doi:10.1139/x94-248

Abstract: Following fire, changes in streamflow and bank stability in burned watersheds can mobilize coarse woody debris. In 1990 and 1991, I measured characteristics of coarse woody debris and standing riparian trees and snags in Jones Creek, a watershed burned in 1988, and in Crow Creek, an unburned watershed. The mean diameter of riparian trees along Jones Creek was less than that of trees along Crow Creek, but the coarse woody debris in Jones Creek was greater in mean diameter. Tagged debris in Jones Creek was three times as likely to move, and moved over four times as far as such debris in Crow Creek. In Jones Creek, the probability of movement was higher for tagged pieces that were in contact with the stream surface. Larger pieces tended to be more stable in both streams. It appears that increased flows and decreased bank stability following fire increased the transport of coarse woody debris in the burned watershed. Overall, debris transport in Rocky Mountain streams may be of greater significance than previously recognized.

Young, K.A. 2000. Riparian zone management in the Pacific Northwest: Who's cutting what? Environmental Management. 26(2): 131-144. doi:10.1007/s002670010076

Abstract: In the Pacific Northwest (PNW) of North America, forestry practices during the last century have degraded the ecological linkages between riparian forests and streams. In an attempt to protect the integrity of lotic ecosystems and associated fisheries resources (primarily anadromous Pacific salmon, *Oncorhynchus* sp.), regional governments now restrict timber harvest in riparian forests. I summarize and assess the riparian zone management

guidelines of the states of California, Oregon, and Washington (USA) and the province of British Columbia (Canada). Only Oregon and British Columbia protect fish-bearing streams with "no-harvest" zones, and only the wider (20-50 m) no-harvest zones for larger fish-bearing streams in British Columbia are likely to maintain near-natural linkages between riparian and stream ecosystems. All four jurisdictions protect most streams with "management zones" of variable width, in which timber harvest activities are restricted. All the management zone guidelines permit the harvest of the largest conifers from riparian forests and will, if applied over a series of timber harvest rotations (60-80 years), result in the continued removal of potential sources of large woody debris from the region's watersheds. All four jurisdictions require additional protection for streams and watersheds that are severely degraded or (in the United States) contain threatened or endangered species. The governments of the PNW have taken a "manage until degraded, then protect" approach to riparian forest management that is unlikely to maintain or restore the full suite of riparian-stream linkages necessary for lotic ecosystems to function naturally at the stream, watershed, basin, or regional scale.

Young, M.K.; Mace, E.A.; Ziegler, E.T.; Sutherland, E.K. 2006. Characterizing and contrasting instream and riparian coarse wood in western Montana basins. Forest Ecology and Management. 226(1-3): 26-40. doi:10.1016/j.foreco.2006.01.021

Abstract: The importance of coarse wood to aquatic biota and stream channel structure is widely recognized, yet characterizations of large-scale patterns in coarse wood dimensions and loads are rare. To address these issues, we censused instream coarse wood (≥2 m long and ≥10 cm minimum diameter) and sampled riparian coarse wood and channel characteristics in and along 13 streams in western Montana. Instream coarse wood tended to be shorter but of larger diameter than riparian pieces, presumably because of fluvial processing. Instream coarse wood also displayed highly variable spatial patterns. Most segments lacked significant spatial correlation in coarse wood abundance in adjacent 50 m reaches and when present, coarse wood patch sizes (100-1200 m) were specific to particular streams. Estimation of instream and riparian piece dimensions within 25% of the mean required samples of 13-314 pieces, whereas estimation of wood loads instream segments required samples of 8-210 reaches (400-10,500 m). If these results are representative of other systems, few previous studies have used sample sizes adequate to characterize instream coarse wood loads.

Zenner, E.K.; Olszewski, S.L.; Palik, B.J.; Kastendick, D.N.; Peck, J.E.; Blinn, C.R. 2012. Riparian vegetation response to gradients in residual basal area with harvesting treatment and distance to stream. Forest Ecology and Management. 283: 66-76. doi:10.1016/j.foreco.2012.07.010

Abstract: The long-term sustainability of riparian management zones (RMZs) depends upon the maintenance of desirable ecosystem conditions within the riparian buffer. We assessed the change in understory vegetation (density and/or biomass of tree seedlings, saplings, woody shrubs, and herbs) in response to different levels of residual basal area within eight northern hardwood RMZs in northeastern Minnesota, USA. Three-year herbaceous cover, diversity, and species composition was investigated in a subset of four of these sites. RMZs were 46 m wide and located next to upland clearcuts. Three overstory harvest treatments were applied in the RMZs: uncut controls with an average overstory basal area of 23 m^2 ha^{-1}, overstory basal area reduction to 16 m^2 ha^{-1} in the medium-retention RMZs, and overstory basal area reduction to 8 m^2 ha^{-1} in the low-retention RMZs. Both partial cut treatments followed best management practices to decrease management intensity towards stream banks, resulting in a gradient of decreasing residual basal area corresponding to increasing light availability with increasing distance from the stream. Understory shrub and sapling biomass, and density of small woody regeneration, including aspen/birch and beaked hazel, all increased in the partially harvested treatments by the third year following treatment, particularly in the low-retention RMZs. In all treatments, along the gradient of decreasing basal area with distance from the stream, small woody biomass and aspen/birch regeneration densities responded positively with distance to stream and increased light availability. Species with higher light requirements increased significantly with more light availability. In contrast, herbaceous species with higher nutrient and heat requirements responded negatively to increased light availability and increased distance to the stream, including in the controls. This response was large due to species differences between the location nearest to the stream and those further from the stream and most likely reflects different species compositions among fluvial landforms. While both partial harvesting treatments resulted in aspen regeneration densities within acceptable ranges for timber production standards, the lower (though not statistically significant) beaked hazel densities following the more conservative partial harvest treatment might be more favorable for the development of longer-lived conifer species in the long run. Further, many of the herbaceous responses were only observed at the extreme ends of the treatment gradient. Regardless of treatment, the edge effect on light availability, which extended at least 5 m into the uncut control RMZ, may reduce the functional width (i.e., effectiveness) of the vegetation buffer.

APPENDIX 2: SILVICULTURE WHITE PAPERS

White papers are internal reports, and they are produced with a consistent formatting and numbering scheme – all papers dealing with Silviculture, for example, are placed in a silviculture series (Silv) and numbered sequentially. Generally, white papers receive only limited review and, in some instances pertaining to highly technical or narrowly focused topics, the papers may receive no technical peer review at all. For papers that receive no review, the viewpoints and perspectives expressed in the paper are those of the author only, and do not necessarily represent agency positions of the Umatilla National Forest or the USDA Forest Service.

Large or important papers, such as two papers discussing active management considerations for dry and moist forests (white papers Silv-4 and Silv-7, respectively), receive extensive review comparable to what would occur for a research station general technical report (but they don't receive blind peer review, a process often used for journal articles).

White papers are designed to address a variety of objectives:

(1) They guide how a methodology, model, or procedure is used by practitioners on the Umatilla National Forest (to ensure consistency from one unit, or project, to another).

(2) Papers are often prepared to address ongoing and recurring needs; some papers have existed for more than 20 years and still receive high use, indicating that the need (or issue) has long standing – an example is white paper #1 describing the Forest's big-tree program, which has operated continuously for 25 years.

(3) Papers are sometimes prepared to address emerging or controversial issues, such as management of moist forests, elk thermal cover, or aspen forest in the Blue Mountains. These papers help establish a foundation of relevant literature, concepts, and principles that continuously evolve as an issue matures, and hence they may experience many iterations through time. [But also note that some papers have not changed since their initial development, in which case they reflect historical concepts or procedures.]

(4) Papers synthesize science viewed as particularly relevant to geographical and management contexts for the Umatilla National Forest. This is considered to be the Forest's self-selected 'best available science' (BAS), realizing that non-agency commenters would generally have a different conception of what constitutes BAS – like beauty, BAS is in the eye of the beholder.

(5) The objective of some papers is to locate and summarize the science germane to a particular topic or issue, including obscure sources such as master's theses or Ph.D. dissertations. In other instances, a paper may be designed to wade through an overwhelming amount of published science (dry-forest management), and then synthesize sources viewed as being most relevant to a local context.

(6) White papers function as a citable literature source for methodologies, models, and procedures used during environmental analysis – by citing a white paper, specialist reports can include less verbiage describing analytical databases, techniques, and so forth, some of which change little (if at all) from one planning effort to another.

(7) White papers are often used to describe how a map, database, or other product was developed. In this situation, the white paper functions as a 'user's guide' for the new product. Examples include papers dealing with historical products: (a) historical fire extents for the Tu-

cannon watershed (WP Silv-21); (b) an 1880s map developed from General Land Office survey notes (WP Silv-41); and (c) a description of historical mapping sources (24 separate items) available from the Forest's history website (WP Silv-23).

The following papers are available from the Forest's website: Silviculture White Papers

Paper #	Title
1	Big tree program
2	Description of composite vegetation database
3	Range of variation recommendations for dry, moist, and cold forests
4	Active management of dry forests in the Blue Mountains: silvicultural considerations
5	Site productivity estimates for upland forest plant associations of the Blue and Ochoco Mountains
6	Fire regimes of the Blue Mountains
7	Active management of moist forests in the Blue Mountains: silvicultural considerations
8	Keys for identifying forest series and plant associations of the Blue and Ochoco Mountains
9	Is elk thermal cover ecologically sustainable?
10	A stage is a stage is a stage…or is it? Successional stages, structural stages, seral stages
11	Blue Mountains vegetation chronology
12	Calculated values of basal area and board-foot timber volume for existing (known) values of canopy cover
13	Created opening, minimum stocking level, and reforestation standards from the Umatilla National Forest land and resource management plan
14	Description of EVG-PI database
15	Determining green-tree replacements for snags: a process paper
16	Douglas-fir tussock moth: a briefing paper
17	Fact sheet: Forest Service trust funds
18	Fire regime condition class queries
19	Forest health notes for an Interior Columbia Basin Ecosystem Management Project field trip on July 30, 1998 (handout)
20	Height-diameter equations for tree species of the Blue and Wallowa Mountains
21	Historical fires in the headwaters portion of the Tucannon River watershed
22	Range of variation recommendations for insect and disease susceptibility
23	Historical vegetation mapping
24	How to measure a big tree
25	Important insects and diseases of the Blue Mountains
26	Is this stand overstocked? An environmental education activity
27	Mechanized timber harvest: some ecosystem management considerations
28	Common plants of the south-central Blue Mountains (Malheur National Forest)
29	Potential natural vegetation of the Umatilla National Forest
30	Potential vegetation mapping chronology

Paper #	Title
31	Probability of tree mortality as related to fire-caused crown scorch
32	Review of the "Integrated scientific assessment for ecosystem management in the interior Columbia basin, and portions of the Klamath and Great basins" – forest vegetation
33	Silviculture facts
34	Silvicultural activities: description and terminology
35	Site potential tree height estimates for the Pomeroy and Walla Walla ranger districts
36	Tree density protocol for mid-scale assessments
37	Tree density thresholds as related to crown-fire susceptibility
38	Umatilla National Forest Land and Resource Management Plan: forestry direction
39	Updates of maximum stand density index and site index for the Blue Mountains variant of the Forest Vegetation Simulator
40	Competing vegetation analysis for the southern portion of the Tower Fire area
41	Using General Land Office survey notes to characterize historical vegetation conditions for the Umatilla National Forest
42	Life history traits for common conifer trees of the Blue Mountains
43	Timber volume reductions associated with green-tree snag replacements
44	Density management field exercise
45	Climate change and carbon sequestration: vegetation management considerations
46	The Knutson-Vandenberg (K-V) program
47	Active management of quaking aspen plant communities in the northern Blue Mountains: regeneration ecology and silvicultural considerations
48	The Tower Fire…then and now. Using camera points to monitor postfire recovery
49	How to prepare a silvicultural prescription for uneven-aged management
50	Stand density conditions for the Umatilla National Forest: a range of variation analysis
51	Restoration opportunities for upland forest environments of the Umatilla National Forest
52	New perspectives in riparian management: Why might we want to consider active management for certain portions of riparian habitat conservation areas?
53	Eastside Screens chronology
54	Using mathematics in forestry: an environmental education activity
55	Silviculture certification: tips, tools, and trip-ups
56	Vegetation polygon mapping and classification standards: Malheur, Umatilla, and Wallowa-Whitman national forests
57	The state of vegetation databases on the Malheur, Umatilla, and Wallowa-Whitman national forests

REVISION HISTORY

March 2014: The first version of this white paper (26 p.) was prepared for a Umatilla NF meeting convened on April 2, 2013 and dealing with the topic of "Mechanical vegetation treatments in RHCAs." As a result of the meeting, a revised version (March 2014) was prepared to: (1) include more literature in appendix 1 dealing particularly with considerations related to range management (domestic livestock grazing) and RHCAs; (2) add abstracts for the literature citations contained in appendix 1 to provide additional information for readers who might want to obtain the full source; (3) highlight literature references in appendix 1 with particular geographical relevance to the Blue Mountains ecoregion (red font color was used to identify them); (4) expand the number of riparian species for which adaptation information was provided in table 2; (5) add RHCA treatment proposal descriptions for the Tollgate project at Walla Walla Ranger District; and (6) add case studies examining historical interactions between wildfire and RHCAs.