Project Title: A Guide to Fuels Management in Riparian Areas of the Interior West

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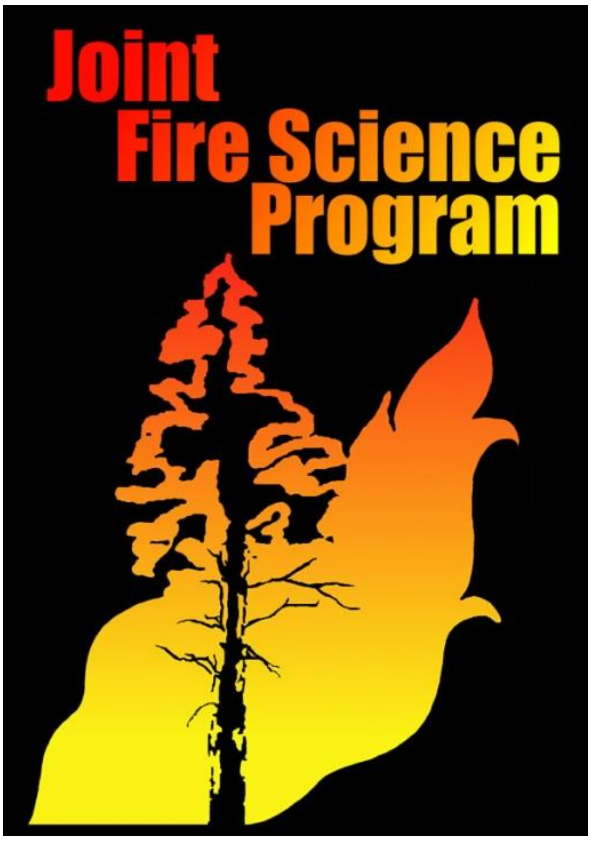


1.0 Abstract

Fuel treatments in riparian areas pose distinct challenges. Riparian areas are protected by administrative regulations, many of which are largely custodial and restrict active management. However, riparian areas have also been affected by fire suppression, land use, and disturbance and manipulative treatments of fuels may be needed to maintain riparian biodiversity and restore valued functions. This project is a synthesis of the current knowledge regarding fuels treatments in riparian areas of the interior western USA. It summarizes the most recent scientific literature, but also incorporates the practical knowledge gained by resource managers who have been utilizing different techniques to reduce riparian fuels. Because riparian fuel treatments are a fairly new management strategy, we set out to document their frequency, extent, efficacy, and potential ecological effects on federal lands in the western U.S. by conducting an on-line survey of resource managers from the USDA Forest Service, and USDI Fish and Wildlife Service, Bureau of Land Management, and National Park Service. We found that active fuels management in riparian areas is increasingly common across all agencies, although about 70% of the treated riparian areas were included as part of upland projects. The most common primary project objectives were hazardous fuel reduction (57% of respondents) and habitat restoration (55% of respondents); however, most projects had multiple objectives. Although prescribed fire is the most frequently used treatment in riparian projects, treatment combinations — which include sequences of burning, mechanical thinning, scattering, and pile burning — are also common. Similar to upland projects, the primary constraint to planning and implementation is the potential occurrence of federally-listed species in the project area. Additional concerns and constraints varied with agency and region.

Treating fuels in riparian areas is a topic where the state of the practice has preceded the state of the science. To incorporate practical knowledge, we selected projects from the survey participants, visited them to highlight as case studies, and present their on-the-ground 'lessons learned'. Our primary deliverable will be a USDA Forest Service General Technical Report (GTR), where we will also present guidelines on how to integrate ecological knowledge and principles into planning and monitoring riparian fuels projects and provide recommendations for post-treatment streamside management.

2.0 Background and Purpose

Two decades of uncharacteristically severe wildfires have caused government resource managers to actively reduce hazardous fuels across western forests to lessen wildfire intensity and effects. As the wildland urban interface (WUI) continues to expand into streamside areas and as concern for severe wildfire risk in sensitive ecosystems increases, a growing number of land managers are exploring options for treating and managing fuels in riparian areas. Although administrative regulations restrict active

management in some riparian areas, manipulative treatments of fuels may be needed to maintain riparian biodiversity and restore valued ecological functions, thus presenting distinct management challenges. To date, limited guidance has been available to assist in the design of riparian fuels treatments and little is known about the effectiveness or ecological impacts of past efforts in reducing riparian fuels.

This project is a synthesis of the current knowledge regarding fuels treatments in riparian areas of the interior western USA (Eastern Oregon and Washington, Idaho, Utah, Nevada, Colorado, Wyoming, and Montana). The synthesis updates existing reviews and summarizes recently released scientific articles and published information. It also incorporates the practical knowledge gained by resource managers who are utilizing different techniques to reduce riparian fuels. Because riparian fuel treatments are a fairly new management strategy, we set out to document their frequency, extent, efficacy, and potential ecological effects on federal lands in the western U.S. by conducting an on-line survey. From the survey participants, we selected and visited several projects to highlight as case studies. Finally, we compiled guidelines on how to integrate ecological knowledge and principles into planning and monitoring fuels projects in riparian areas. In our project deliverable (GTR), we will also provide recommendations for post-treatment management of riparian areas, and address grazing, control of invasive plant species, recreation, and other actions.

The overall goals of the project were to:

(1) review and synthesize the published literature on the role of wildfire and effects of fuel treatments in riparian areas;
(2) conduct a survey of federal agency personnel to gather and analyze information about completed and proposed fuel treatments in riparian areas and wetlands;
(3) assess selected case studies to showcase riparian fuel treatments from planning stages, through implementation, and post treatment monitoring. The case studies were selected from information provided by survey respondents and represent a range of riparian conditions and projects located in different ecoregions;
(4) provide guidelines for pre-and-post treatment monitoring in riparian areas.

3.0 Study Description and Location

This synthesis project has four components: (1) an extensive literature review of the relation between wildfire and riparian areas, and the issues, justification, and effects of fuel reduction treatment in wetlands and riparian areas; (2) results of a online survey of resource managers, summarizing information about fuel reduction practices in the interior west; (3) an examination of 5 case studies, highlighting riparian fuel treatments with different objectives, methods, and vegetation types; (4) suggested guidelines

for pre-and-post project-level monitoring for riparian fuels projects. Each of these components will be presented as a different section in the forthcoming General Technical Report (GTR, in preparation).

3.1 Literature Survey

The literature review presents information from national and international sources, including scientific journals and periodicals, government publications and websites on the role of wildfire and impacts of fuel treatments in stream-riparian corridors. Although the geographic focus of this project is the interior West, we gleaned available literature for all information that may be relevant to managers. We included related fisheries, terrestrial wildlife, forestry, and geomorphology literature that presented recent information on the effects of wildfire and fuel treatments on terrestrial and aquatic habitat in stream-riparian corridors, including riparian vegetation, stream bank stability, stream temperature, stream-riparian food webs, water quality, and large wood dynamics. Influence of fire and fuel treatments on riparian soils, nutrient and sediment fluxes are also covered. In the literature review portion of the GTR, findings from scientific journals and other sources are summarized by five common riparian vegetation types: cottonwood forests, conifer-dominated riparian areas, willow-dominated riparian areas, meadows and wetlands.

3.2 Online Survey of Riparian Fuel Treatments, Interior West

In spring 2010, an online survey was conducted to gather information about completed and proposed fuel treatments in riparian areas and wetlands. The survey targeted fire program managers and other resource professionals from the U.S. Department of Agriculture (USDA), Forest Service (USFS) and the U.S. Department of the Interior (USDI), Bureau of Land Management (BLM), National Park Service (NPS), and Fish and Wildlife Service (USFWS) in the interior western United States. The study area included the entire states of Colorado, Idaho, Montana, Nevada, Utah, and Wyoming, and eastern Oregon and Washington. The Black Hills region of South Dakota and a small area in northern California were also included. The survey questionnaire was administered via a web-based application (SurveyMonkey) and was sent to the entire survey population of over 2,000 potential participants. The survey requested details about complete and proposed fuels management projects in riparian areas and wetlands including treatment types and combinations, vegetation types, specifics of pre-and-post monitoring, and how effective the project was at meeting the objectives. The different sections and flow of the survey questions are shown in Figure 1.

There were 532 respondents (22% response rate) representing a range of resource specialists, including fire managers, hydrologists, fisheries biologists, wildlife biologists, ecologists, and cultural

resource specialists. Responses were received from the four agencies (BLM, NPS, USFS, and USFWS) and from 10 different states (Table 1, Figure 2). Of the 532 respondents, 249 reported having projects in

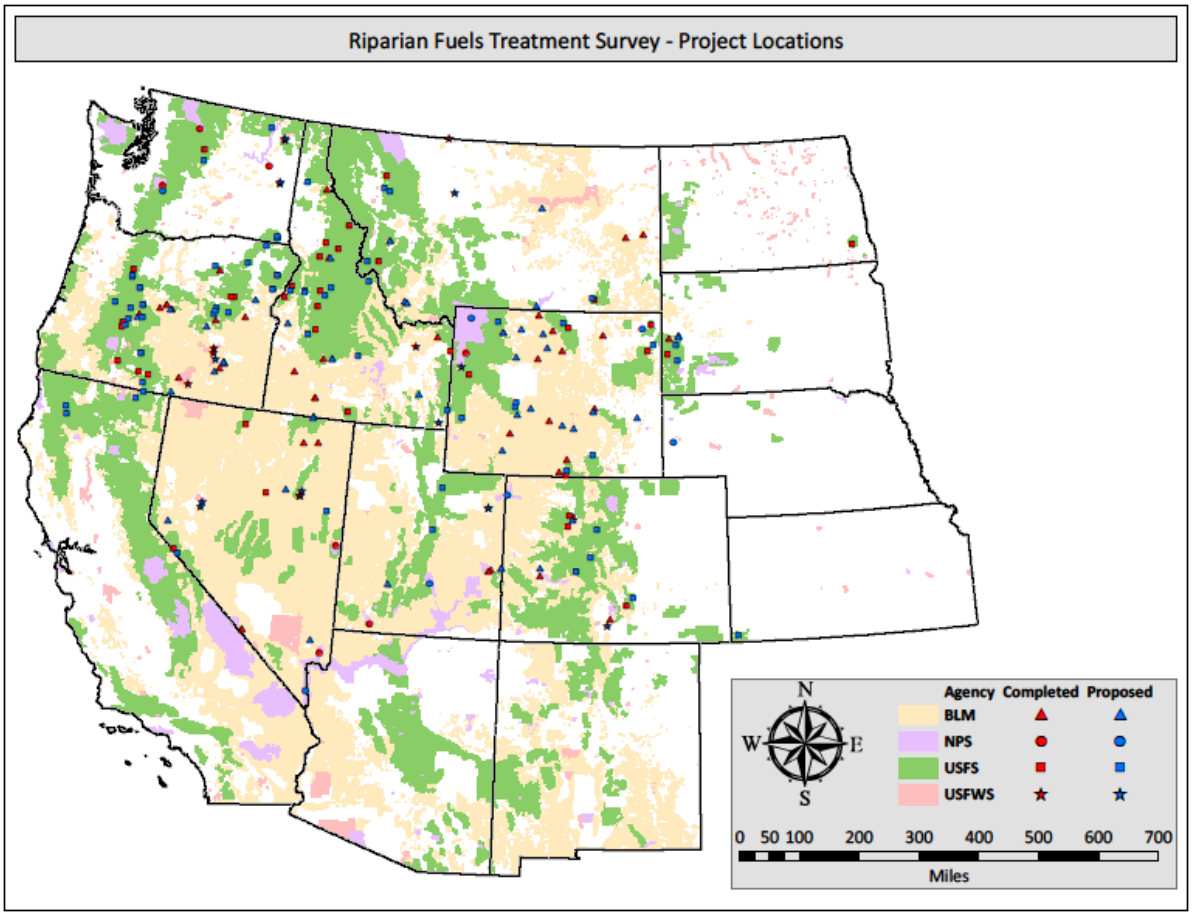
Figure 1. Survey organization and flow.

Table 1. Summary of response rates by agency, resource specialty, and state. All values are expressed as percentages.

	Category	Percent of Survey Population	Overall Response Rate
Agency	BLM	45	19
	NPS	7	18
	USFS	44	26
	USFWS	4	21
Specialty	Chief of Resources Management	<1	15
	Cultural/ Archeology	8	15
	District Ranger	<1	33
	Fire	20	30
	Fisheries/ Aquatic	5	35
	Forestry	6	35
	Hydrology	4	36
	NEPA	3	24
	Range	15	21
	Recreation	7	11
	Refuge Manager	2	10
	Resources/ Biology/ Botany/Ecology	15	16
	Riparian/ Wetlands	<1	20
	Soils	1	15
	Superintendent	<1	20
	Wildlife	13	16
State	California	3	18
	Colorado	13	20
	Idaho	15	25
	Montana	12	23
	Nevada	9	21
	Oregon	15	25
	South Dakota	2	32
	Utah	12	17
	Washington	4	22
	Wyoming	14	22

riparian or wetland areas. Of those, 105 reported on completed projects, 87 reported on projects planned or in progress, and 57 reported both completed and planned projects (Figure 2). Approximately 27% of the completed and proposed projects reported were planned specifically in riparian or wetland areas, while the others included these areas as part of upland projects.

Figure 2. Locations of completed and proposed projects by agency, as described by survey respondents.



3.3 Case Studies

We selected five case studies from information provided by the survey respondents to represent a range of riparian conditions and projects located in different vegetation types. Treating fuels in riparian areas is a topic where much of the on-the-ground work precedes the actual science, somewhat analogous to where we were over 10 years ago with postfire rehabilitation treatments (Robichaud et al. 2000). By focusing on issues and concerns at different stages in project planning and implementation, we will provide specific examples of 'lessons learned' in Section 4 of the GTR to more broadly share information.

Case Study 1: Ponderosa Restoration Broadcast Prescribed Fire and Hazardous Tree Removal; Heber-Kamas Ranger District; Uinta-Wasatch-Cache National Forests; Utah. This project is focused on restoring upland ponderosa pine stands and reducing fuel loads in a highly recreated area of the Uinta-

Wasatch-Cache National Forests. Old-growth ponderosa pines are perceived to be at risk of loss to wildfire and mountain pine beetle attack. The first two phases were conducted in the ponderosa-dominated uplands and entailed mechanical hand-thinning and piling (2006-2007), followed by pile burning (winter 2007). Phase 3 is a broadcast burn of 3,900 acres that includes three streams with high riparian fuel loads; managers intend to treat two of the streamside areas and create a fireline around one stream to protect northern goshawk habitat. Although planned for spring 2011, the burn has been postponed due to high snow loads. This project is representative of treatment combinations (thinning + pile burning + prescribed fire) and sequencing in mountain-pine beetle infested watersheds of the interior west.

Case Study 2: Hazardous Tree Removal along Transportation (Riparian) Corridors in Mountain Pine Beetle Infested Forests; Arapaho-Roosevelt and Medicine Bow-Routt National Forests; Colorado, Wyoming. This project is focused on protecting the forest-wide transportation network from hazardous dead trees (due to mountain pine beetle and other forest insects) falling onto roads and roadside infrastructure. Although similar to *Case Study 1*, it does not include any prescribed fire, only mechanical and hand thinning. The treatment area is nearly forest-wide, and entails tree removal along state highways, as well as county and Forest Service roads, so includes a range of stream sizes and riparian conditions. Protection of roads and other values at risk preempts ecological considerations and resource managers are working to influence treatment prescriptions, contract agreements and implementation. Concerns include loss of shade, degradation of riparian biodiversity and structure, and reduction in the amount and condition of streamside, recruitable large wood.

Case Study 3: Yellowtail Area Coordinated Resource Management: Habitat Restoration and Invasive Plant Management; Bighorn Canyon National Recreation Area, Wyoming. This project entails multiple treatments and partners and is an example of collaboration among federal, state, and local agencies and entities. The treatments — ranging from mechanical cutting and mulching (using a Gyro-Trac mulching machine) to carefully managed pasture-scale grazing by goats — are focused on removal of invasive species and restoration of native cottonwood communities along the Shoshone and Bighorn Rivers. One aspect of the project was mechanical removal of Russian olive and saltcedar, followed by chemical treatments of stumps to prevent sprouting and reestablishment, and had mixed results. Much practical knowledge was gained in this project regarding treatment combinations and sequencing in large floodplain riparian areas.

Case Study 4: Prescribed Burning in Willow Stands; Fontenelle allotment, Kemmerer Ranger District, Bridger-Teton National Forest, Wyoming; Teton National Park, Wyoming. In western Wyoming, resource managers from the USFS, NPS, and Wyoming Game and Fish have been using prescribed fire to manage willow-dominated riparian areas for wildlife benefit for nearly 20 years. In general, willows respond very favorably to spring burns (prior to leaf-out), and regenerate vigorously for several years following treatment. Although differences among *Salix* species have been noted, current annual growth of most willow branches (leaders) can be increased dramatically with managed fire. However, browsing pressure by native ungulates, including elk, deer, and moose, can be very heavy, so relative costs and benefits need consideration. Also, the ability to conduct an effective burn depends largely on soil and fuel moisture, so treatments can be difficult to schedule and implement successfully.

Case Study 5: Management of Woody Encroachment into Riparian Meadows; Fremont-Winema and Deschutes National Forests, Oregon. Dry, mesic and wet streamside meadows are valuable habitats throughout the Interior west, and encroachment by woody species, especially conifers, is a serious management concern in some locations. Woody encroachment is thought to be a consequence of fire suppression, past management practices, and possibly climate change. In the past, wildfire likely kept tree invasion in check but livestock grazing may have facilitated successful tree establishment and reduced fine fuels, thus decreasing the capacity of fire to carry into encroaching conifer stands. In eastern Oregon, resource managers have utilized prescribed fire and thinning treatments to maintain open meadows for recreation, to regenerate willows and other riparian hardwoods, and to improve wildlife and rare plant habitat. Although treatments have been successfully implemented, woody regeneration is high, and maintenance of treatment results may not be cost effective over the long-term.

Other: At least three other types of projects will be described in detail. Although we did not conduct site visits for these types of projects, they have been identified as local or regional projects of interest. We will discuss concerns and lessons learned for (1) treatments in conifer-dominated riparian areas with conflicting issues of high riparian fuel loads AND water temperature-dependent fish species (Payette NF, Idaho); (2) in Great Basin portions of Nevada, Utah, and Idaho, sagebrush and western juniper habitats are being treated with different methods and commonly include riparian areas (many focused on removal of juniper from streamside zones); (3) wetland habitat where the herbaceous vegetation is managed with prescribed fire and other methods for waterfowl habitat.

3.4 Guidelines for Monitoring Riparian Fuel Treatments

Each agency has protocols for monitoring stream habitat and riparian vegetation and condition (USDA Forest Service and USDA Bureau of Land Management 1995; Elzinga et al. 1998; Kershner et al. 2001, Kershner 2002; Reeves et al. 2002; Burton et al. 2008). Separate monitoring methods have also been developed for monitoring fuel characteristics and impacts of wildfire (USDI National Park Service 1992, 2001; USDI Fish and Wildlife Service 2005; Lutes et al. 2006). We review existing methods, including metrics assessed, strengths and limitations for application in different riparian vegetation types, and estimated costs, when available. We provide a range of approaches that build on and integrate existing methods, but with a focus on riparian fuel assessment and evaluation of effectiveness of riparian fuel reduction. These monitoring guidelines will be presented in Section 5 of the GTR.

4.0 Key Findings

4.1 Key Findings: Literature Survey

Past reviews have summarized research on the role of fire as a natural disturbance in stream-riparian ecosystems, especially in mountainous environments (Bisson et al, 2003, Dwire and Kauffman 2003, Petitt and Naiman 2009); recent work has advanced understanding of post-fire recovery in different stream-riparian environments (Mellon et al. 2008, Jackson and Sullivan 2009, Malison and Baxter 2010). However, the implications and effects of fuels management practices in riparian areas are not well studied (Dwire et al. 2010; Stone et al. 2010). Published research results are limited to a few localized studies along conifer-dominated stream segments (Bêche et al. 2005, Arkle and Pilliod 2010). Findings suggest that certain stream parameters, including substrates and benthic macroinvertebrate composition, do not appear to be affected by riparian fuel treatments (Miller 2009). However, recent reports also indicate that shade is reduced and water temperatures have warmed over the short-term following treatments (Martin and DeJuilio 2009, Volpe 2009). Agency specialists have limited information to assist in their decision-making process when planning fuels reduction treatments in riparian and wetland areas. Both concerns and justifications for conducting treatments are largely derived from anecdotal experience or studies that have investigated effects of forest harvest or wildland fire (Dwire et al. 2010).

4.2 Key Findings: Online Survey of Riparian Fuel Treatments, Interior West

Active fuels management in riparian areas is increasingly common.

The survey confirmed that there is increased interest in actively managing fuels in riparian and wetland areas. Numerous fuel reduction treatments are being conducted and planned throughout the interior west (Figure 2). Survey respondents provided information on 100 completed projects, and over a

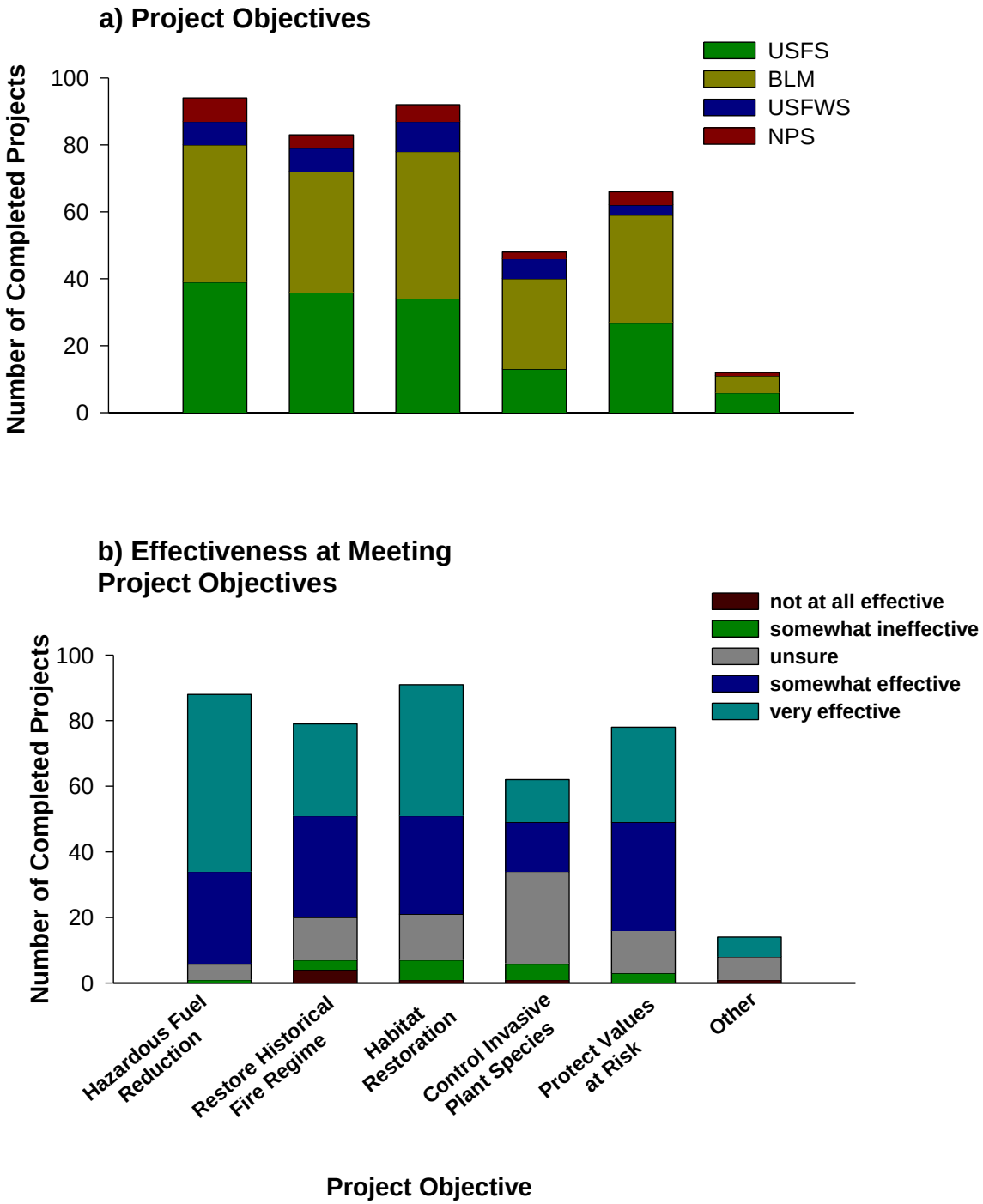
third (35%) of the respondents had worked on three or more completed projects in the last 10 years. Respondents also provided information on 130 proposed projects, and over 40% noted that they had three or more projects either in progress or planning stages. Although over 70% of these fuel reduction projects are part of larger upland projects and not specific to riparian areas, managers are intentionally including streamside areas. Respondents indicated that inclusion of riparian areas in larger upland projects was one mechanism for reducing streamside fuels; facilitated project planning and implementation; more realistically mimicked the natural fire regime; and reduced costs. Higher numbers of completed and proposed projects were located in Eastern Oregon, Idaho, and Wyoming than in Nevada, Utah or Colorado (Figure 2).

USFS had the highest survey response rate (26%), and USFS respondents reported on the largest number of projects (40 completed, 67 proposed) followed by BLM (44 completed, 46 proposed). In a few cases, two respondents reported on the same project. Far fewer NPS (7 complete, 7 proposed) and USFWS projects (10 complete, 11 proposed) were described, primarily reflecting the smaller amount of public land administered by these agencies relative to USFS and BLM, rather than the response rate (Table 1). Interagency participation was a component of both completed (23%) and proposed projects (63%); for reporting purposes, we assigned these projects to the agency of the respondent. The USFWS projects were primarily focused on natural wetlands or the areas adjacent to reservoirs rather than riparian areas associated with streams. USFS, BLM, and NPS projects included some wetlands, but were primarily focused on streamside areas.

Most riparian fuel reduction projects had multiple objectives; in general, objectives were effectively met.

In the survey, respondents could select up to six different objectives that applied to their project and assign a rank of primary, secondary, or tertiary to each. In Figure 3a, we summarize the objectives recorded for completed projects by agency, regardless of ranking. Over half of the respondents described projects with more than one primary objective, and nearly all had secondary and tertiary objectives. The most common primary objectives for both the completed and planned projects were hazardous fuels reduction (57%) and habitat restoration (55%). Virtually all of the USFWS projects included habitat restoration as a primary objective. The NPS had the most projects with hazardous fuels reduction as the sole primary objective (86%) followed by the USFS (59%). Restoring the historic fire regime was the most common secondary objective (35%), and was recorded as an objective for most projects. Treatment of invasive species was a primary objective in only a few projects, and the least common objective overall. Protecting values at risk was an objective that included protection of campgrounds, roads and

Figure 3. (a) Project objectives by agency; and (b) effectiveness (5 point scale) at meeting project objectives.



other infrastructure located in the WUI or wildland-urban intermix, cultural resources, and sensitive ecosystems. In the 'other' category, survey respondents noted the following additional project objectives: rangeland improvement; greater recreational access and opportunities for hunting and fishing; reduction of the influence of mountain pine beetle; salvage logging; and enhancement of aspen regeneration.

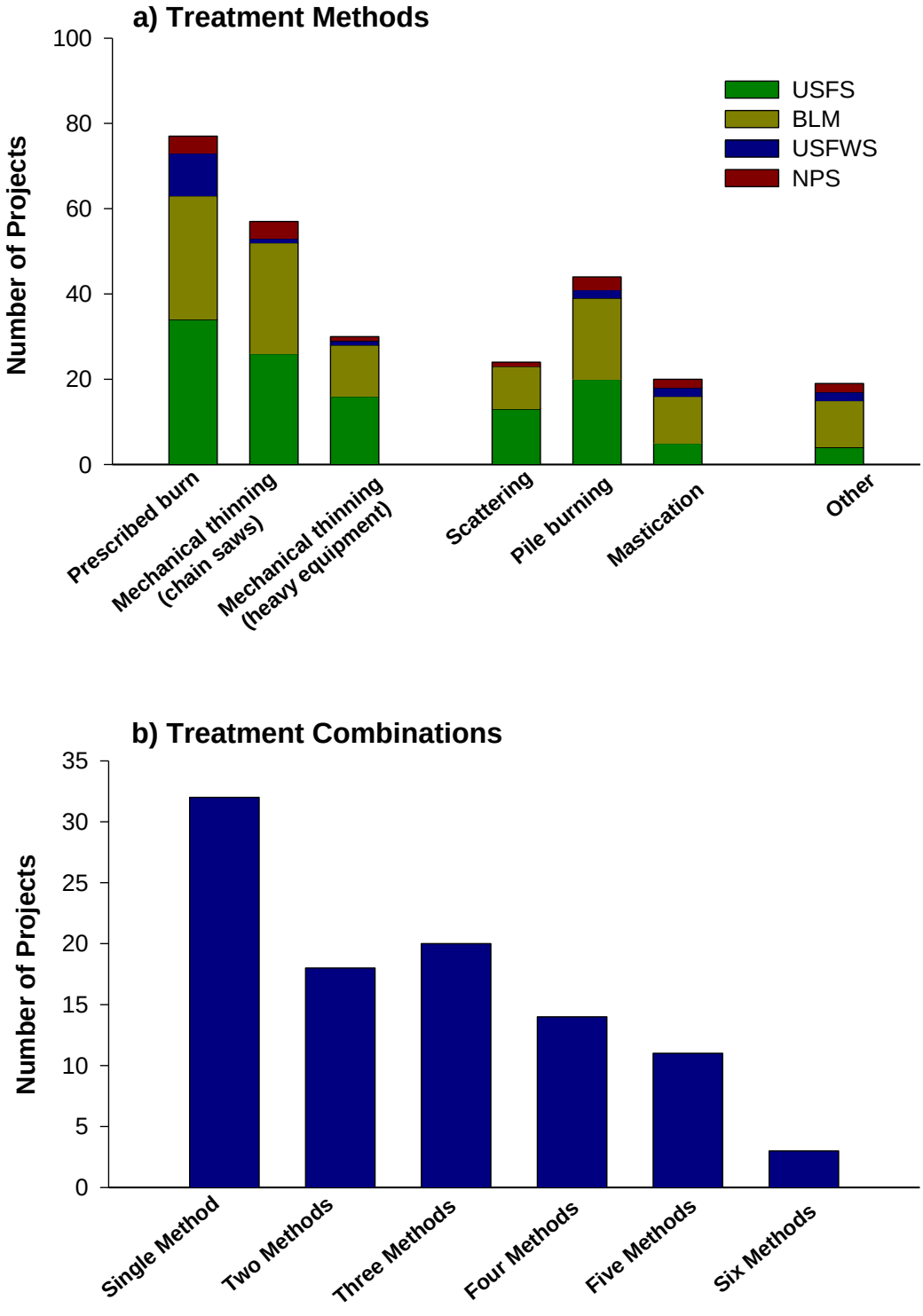
For completed projects, survey participants were asked to rank project effectiveness at meeting objectives (Figure 3b). Projects were most successful at reducing hazardous fuels and this objective scored the highest effectiveness rating (average effectiveness = 4.53, out of a 5-point rating scale). The objectives 'habitat restoration' and 'protection of values at risks' were also effectively met by most projects. For 'control of invasive plant species', it may be too early to determine project effectiveness, as reflected in the higher number of 'not sure' rankings. In general, most of the projects were 'somewhat effective' to 'very effective' at reaching the objectives analyzed in this study.

Prescribed fire is the most commonly used treatment in riparian projects, although combined treatments are common.

Prescribed fire was the primary tool for fuels treatments used by all agencies in riparian and wetland areas (Figure 4a). The USFWS used prescribed fire on all of the projects they reported. For the 32 completed projects (all agencies) that used a single treatment method, 29 used prescribed fire (Figure 4b). It was clear, though, that most projects combined treatment methods; more than two-thirds of the completed projects used multiple treatments. Prescribed fire and hand thinning (with chain saws) were the methods most frequently combined with scattering, pile burning, and mastication. Mechanical treatments (heavy equipment) were included in many projects implemented by the USFS and the BLM. Other treatments reported by survey respondents were: follow-up herbicide application or tamarisk beetle release, mowing, flooding to reduce cattail re-establishment, and seeding of desirable species.

When we designed the survey, we had intended to evaluate effectiveness of individual treatments, i.e. relate effectiveness ratings to both objectives and treatments used. However, because multiple treatment combinations were frequently employed (Figure 4b), it was not possible to evaluate the relative effectiveness of individual treatments.

Figure 4. (a) Number of projects that used different fuel treatments by agency; (b) number of projects that used a single treatment method (prescribed fire = 29; mechanical thinning = 1; mastication = 1), or combined more than one treatment.



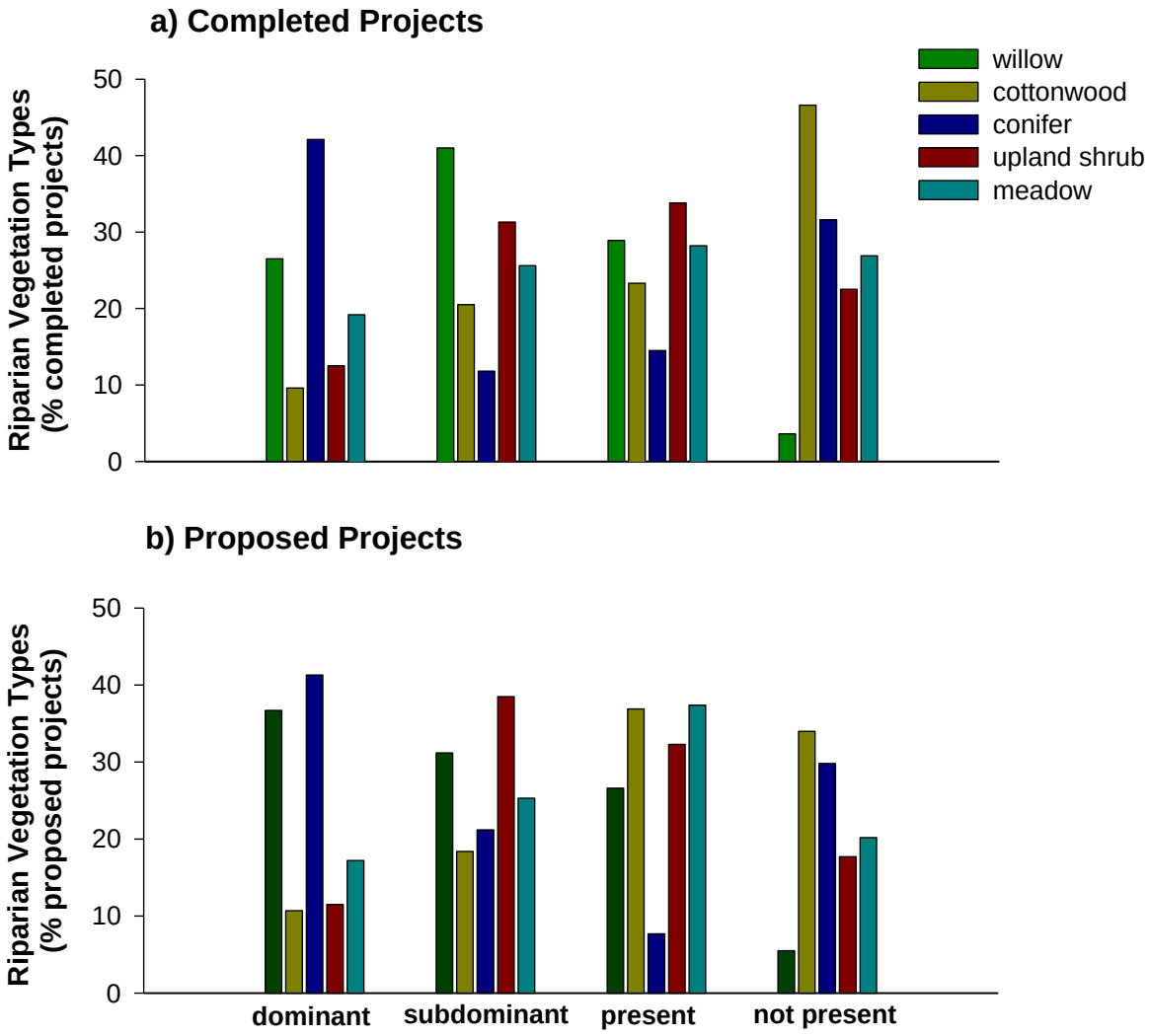
Most projects are being conducted in conifer or willow dominated riparian areas.

The survey also examined vegetation types reported in the fuels treatment project areas. Most projects, both completed and proposed, were located in conifer-dominated riparian areas, followed by willow-dominated (Figure 5). However, there were trends among the four agencies, reflecting the ecology of the lands each administers. Projects in conifer and willow dominated riparian areas were most common on USFS lands; projects in riparian areas dominated by upland shrubs were most common on BLM lands. Conifers were rarely present on the USFWS projects, which were largely conducted in wetlands and riparian meadows, dominated by herbaceous, emergent vegetation, such as cattails, sedges, and bulrushes. Approximately 27% of the completed projects included some palustrine habitat (wetlands, marshes), and while these were located on public lands administered by all agencies, most were on USFWS lands. Nearly 70% of the projects were conducted in riverine habitats, and the remaining 4% were located on the margins of lakes or ponds in lacustrine habitat. Cottonwoods occurred at numerous project sites and a few projects focused on cottonwood restoration; however, cottonwoods were not present at many of the project areas (Figure 5). Other vegetation that was noted in the project areas included aspen and birch; boxelder; invasive species such as tamarisk, Russian olive, and whitetop; greasewood; and upland shrubs, such as rabbitbrush and juniper (primarily on BLM lands).

Fuels and vegetation are the most frequently monitored attributes for riparian fuels projects, although limited quantitative data are collected.

Most respondents reported that project-related monitoring was conducted or planned for both their completed (71%) and proposed (82%) projects to determine the effectiveness at meeting project objectives. The most common ecological variables monitored in the completed projects were vegetation attributes and fuels, both before and after treatment implementation (Table 2). Terrestrial wildlife, primarily bird species that commonly use streamside areas, was monitored by 40% of the respondents. Over half of the respondents did no monitoring of water quality, erosion, or stream biota. For the projects that were monitored, the most common methods were rapid assessment techniques, with only about one-third collecting aquatic biota samples or quantitatively sampling vegetation. In the survey, we asked detailed questions about project monitoring, including duration, frequency, and methods used. We had hoped to evaluate the different monitoring methods and possibly compile monitoring data to better evaluate treatments being used in streamside areas. However, few respondents provided sufficient information to allow analysis of the monitoring information. From the limited response, however, it was clear that most managers do not have the resources to conduct monitoring beyond the first year or two following treatments.

Figure 5. Percentage of projects completed (a) or proposed (b) in five different riparian vegetation types.



The occurrence of TES species is the most common constraint/ concern for managing riparian fuels; other concerns vary by agency and region.

There are multiple challenges to conducting and planning fuels treatments in all vegetation types, but wetlands and riparian areas pose additional concerns (Figure 6, Table 3). Responses from the survey indicated that the most significant constraint for all agencies was the potential presence of threatened, endangered or sensitive species in the project area. While this is also a major concern for upland fuels projects, inclusion of aquatic and riparian obligate species increases the number of species of concern and is critical when conducting and planning projects in streamside areas. Cultural resources were an

Table 2. Summary of responses (from on-line survey) to questions regarding project related monitoring. All values are expressed as percentages of completed projects.

	Monitoring? (% of respondents)		**Type of Monitoring** (% of respondents who conducted monitoring)			
Ecological Variable	**Yes**	**No**	**Pre- and – post Treatment Monitoring**	**Visual Rapid Assessment**	**Sample Collection**	**Quantitative Data Collection**
Water quality and/ or Quantity	27	54	51	25	10	5
Erosion / runoff	29	56	59	61	0	6
Stream Biota	19	62	29	20	33	0
Vegetation attributes (e.g. rare plants, invasives, utilization)	**87**	8	**76**	34	4	36
Fuel types and Loads	**71**	21	**76**	40	5	21
Terrestrial wildlife	40	38	61	39	13	26
Other	26	60	27	50	0	17

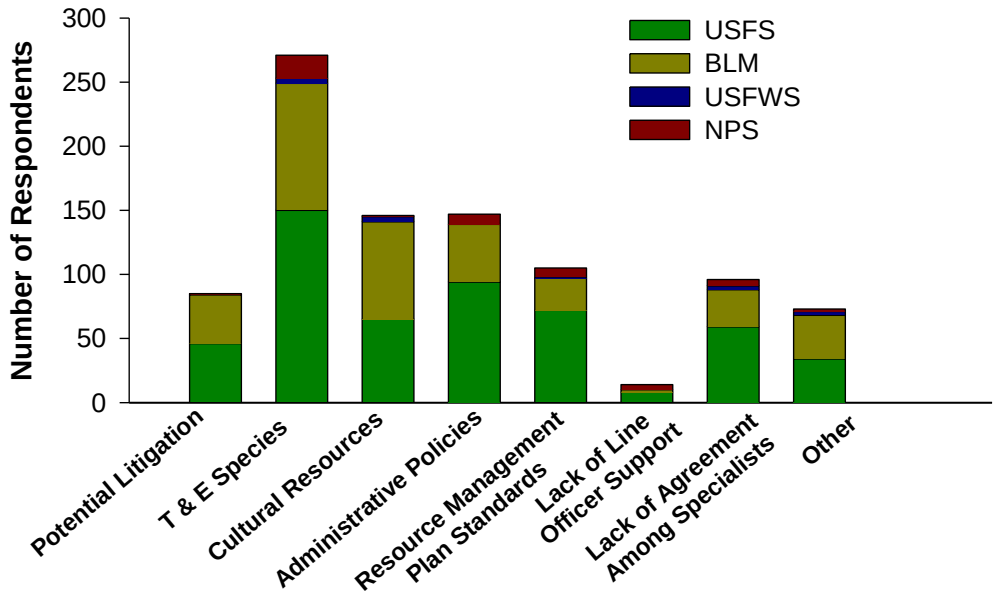
issue in planning riparian fuels projects in riparian areas, particularly in the Great Basin region, where archeological sites are concentrated in stream-riparian corridors. BLM and USFS respondents from Nevada and Utah most frequently noted this constraint. Administrative policies, resource management plans, and lack of agreement among resource specialists were commonly encountered constraints among USFS, BLM, and NPS respondents (Figure 6, Table 3). Surprisingly, only 19% of the respondents, evenly divided between BLM and USFS, recorded potential litigation as a constraint to riparian fuels projects. Limited support from line officers was the least common constraint noted (3% of survey respondents).

Several additional constraints were recorded by survey respondents, most notably funding. Budgets generally do not target riparian areas as priority treatment areas, so managers interested in treating riparian fuels include streamside areas as part of larger projects. As noted above, approximately 70% of the projects (completed and planned) were part of predominantly upland projects. Much of the funding available for fuels treatments is focused in the WUI; 56% of the completed and planned projects reported by the participants were located in the WUI.

Another noteworthy concern is unknown or unpredictable effects to riparian habitat, both during treatment and recovery phases. This lack of scientific knowledge limits managers and resource specialists in their ability to make informed decisions regarding treatment designs in riparian areas. Effects of treatments and prescribed fire in riparian areas included concerns about reduced water quality due to erosion and sedimentation, decreased shade, and spread of invasive species. Some survey respondents

mentioned that the protection of existing cottonwood galleries, which are not resistant to fire, and avoidance of damage to riparian communities were significant reasons to exclude prescribed fire from riparian areas. Other constraints listed by respondents were: burn windows, difficulties in gathering adequate fire resource support, landownership patterns around riparian areas, visual and recreation conflicts, and politics and public perception.

Figure 6. Number of respondents (by agency) who recorded different constraints to planning and conducting fuel reduction treatments in riparian areas.



4.3 Key Findings: Case Studies

Common themes for success of riparian fuel treatments were identified. Examination of five different case studies revealed the ecological complexity of treating riparian fuels, the need for more quantitative monitoring over time, and the benefit of sharing planning and implementation experiences.

Each of the case studies highlighted specific challenges to conducting *and* maintaining treatments in riparian areas. However, there were also some common themes. Below, we first note factors that were important for success across all projects, then mention specific findings from each case study.

Table 3. Responses to yes/no questions in the online survey. Percentage of respondents is shown for each question; note that the number of respondents (in parentheses) varied with the question.

Question	Yes	No	Not Sure
Under your forest/ fire management plan, are prescribed fires permitted to burn into riparian or wetland areas outside of the prescribed fire boundary?	27% (107)	37% (146)	35% (138)
Under your forest/ fire management plan, are fires designated as "Wildland Fire Managed for Resource Benefit" (now ="wildfire") permitted to burn into riparian or wetland areas?	42% (165)	20% (77)	38% (149)
During a prescribed burn, are ignitions allowed in riparian areas?	26% (102)	44% (170)	30% (119)
Are Fire Regime Condition Classes (FRCCs) applicable to the riparian or wetland areas within your administrative unit?	46% (41)	18% (16)	36% (32)
Were invasive/ noxious plant species prevalent in *riparian/ wetland* habitats within the project area at the time of project implementation?	42% (37)	48% (43)	10% (9)
Were invasive/ noxious plant species prevalent in *uplands* within the project area at the time of project implementation?	42% (37)	53% (47)	6% (5)
Were insects and / or disease prevalent in *riparian/ wetland* habitats within the project area at the time of project implementation?	16% (14)	65% (58)	19% (17)
Were insects and / or disease prevalent in *upland* habitats within the project area at the time of project implementation?	32% (28)	58% (52)	10% (9)

Good coordination across disciplines, agencies, and multiple stakeholders increases the probability of funding as well as success in planning, implementation and maintenance of riparian fuel projects. While this can be said for most projects, coordination and some level of consensus is critical for management of streamside areas. Active manipulation of riparian areas has the potential to affect numerous biological and physical resources and processes, and it is particularly important to plan projects with input from a range of resource professionals including fisheries biologists, wildlife biologists, hydrologists, and both fire ecologists and fire management staff. Coordinated planning includes clearly defining objectives and designing projects accordingly. Seasonality, fuel/soil moisture conditions, and existing vegetation must be carefully considered in planning riparian projects to meet objectives. For example, if the objective is to reduce hazardous fuels or achieve a certain amount of canopy opening, it may be best to burn areas with a backing fire rather than a head fire during times of the year when lower

riparian fuel moistures will maximize consumption of vegetation and fuels. If planning does not account for riparian conditions, the project may not achieve all objectives. Some managers reported that riparian treatments did not burn as hot as planned and did not result in sufficient canopy opening or fuel reduction. Later, these streamside areas burned during wildfires that were stand-replacing, despite the specific project goal to avoid such events.

Case Study 1: Ponderosa Restoration Broadcast Prescribed Fire and Hazardous Tree Removal; Heber-Kamas Ranger District; Uinta-Wasatch-Cache National Forests.

To date, the lessons learned from this project focus on the challenges of collaborative treatment design, given the limited information on effects of riparian fuels treatments. In this case, the treatment is prescribed fire in fuel-heavy riparian areas, and the district wildlife biologist was concerned about potential treatment effects on northern goshawk nesting and breeding habitat. The negotiated project design excludes fire along the stream containing a tree with an existing nest. As noted above, the first two phases were conducted in the ponderosa-dominated uplands and entailed mechanical hand-thinning and piling, followed by pile burning. The third phase is a broadcast burn of 3,900 acres; although planned for spring 2011, it has been postponed due to high snow loads. Aspects of this project that will inform future riparian prescriptions are (1) the fire management officer is willing to ignite in riparian areas, and will document how well this works; (2) fire behavior in the riparian areas may be monitored during the treatment (depends on resources); (3) pre-fire data on riparian fuels and instream large wood have been collected, with the potential to compare to post-fire conditions once the treatment is implemented.

Case Study 2: Hazardous Tree Removal along Transportation (Riparian) Corridors in Mountain Pine Beetle Infested Forests; Medicine Bow-Routt National Forest; Colorado, Wyoming.

Hazard tree removal along transportation networks in national forests has raised concerns about unknown consequences, which currently outnumber 'lessons learned'. Resource managers are reducing fuels and hazards posed by dead timber along miles of riparian areas and perennial fish-bearing streams to decrease threats to human life and property. However, there is limited understanding of instream large wood dynamics in Rocky Mountain streams, including natural volumes and distributions, and how current riparian management will ultimately affect the form and function of stream habitats for decades to come. In the near future, managers will be faced with episodic inputs of instream large wood in beetle-infested watersheds that may be hazardous to infrastructure (culverts, bridges, road crossings) in managed watersheds. However, they also wish to retain instream large wood to improve channel habitat. Other concerns include loss of shade and degradation of riparian plant diversity and structure for terrestrial

wildlife. The overriding message from field visits during examination of this case study was a plea for research and assistance in the establishment of demonstration areas to monitor the impacts of this unprecedented type of riparian management.

Case Study 3: Yellowtail Area Coordinated Resource Management: Habitat Restoration and Invasive Plant Management; Bighorn Canyon National Recreation Area, Wyoming.

Lessons learned in this complex, cottonwood floodplain project included; (1) burnt slash piles either remained as burned-out, unvegetated areas or allowed for expansion of invasive, undesirable plants; avoid burning slash piles in floodplains; (2) leave some big material (large woody limbs and branches) for wildlife habitat structure; (3) a Gyrotrac was used for mechanical tree removal, and created considerable ground disturbance; use only in winter to minimize ground disturbance; (4) mechanical treatments of Russian Olive require several years of follow-up maintenance to reduce/ manage resprouting; most effective follow-up was repeated application of chemical herbicide; (5) re-establishment of native vegetation is necessary to foster conversion back to native communities; plantings of bare root stock for buffalo-berry and cottonwood pole plantings were reasonably successful; (6) although there were some small prescribed burns (60 acres) and natural burns (NPS and WYG&F) in the project area, prescribed fire was not a big component of this project; (7) goats were used in a rotational fashion to reduce cover of herbaceous invasive species in treated areas; although successful in the short-term, they must be intensely managed.

Case Study 4: Prescribed Burning in Willow Stands; Fontenelle allotment, Kemmerer Ranger District, Bridger-Teton National Forest, Wyoming; Teton National Park, Wyoming.

Spring broadcast burns have been used in extensive willow stands to foster new leader growth and improve forage and habitat for moose and elk. Successful treatments have been administered before willows have broken dormancy (i.e. prior to vulnerable bud-break), and before spring run-off has saturated the floodplain soils. Although fall burning is also possible and has been tried, conditions must be cold and dry to get a decent burn without damage to the plants. Multiple agencies have been involved, including USFS, NPS, and Wyoming Game and Fish. Resource management objectives have sometimes been contradictory between the agencies that share common boundaries, so adaptive coordination and cooperation has been necessary, including prioritization of hazardous fuel management versus habitat objectives. In general, resource managers agree that use of fire is perhaps the best way to reintroduce natural disturbance into willow or hardwood-dominated riparian habitats in this region.

Lessons learned are: (1) burn a large area (or several areas), so that ungulate grazing/browsing pressure is distributed; otherwise, the post-treatment browse levels may retard willow regrowth; (2) treatments are most successful when/ where ungulate populations are relatively low; in areas of high population densities, post-treatment browsing pressure may slow the rates of regrowth, while in areas of moderate-low population densities, prescribed fire regenerated the willows; (3) if the treated area is part of a livestock grazing allotment, restrict grazing until willows have recovered; (4) in general, the recovery of willows following fire is rapid, but must also be closely monitored; use caution with recovering vegetation for at least 5 years.

Case Study 5: Management of Woody Encroachment into Riparian Meadow; Deschutes and Fremont-Winema National Forests, Oregon.

Lessons learned from different meadow fuel reduction projects were (1) short and long-term (10 years or longer) treatment results are influenced by the surface and subsurface hydrology of different portions of the meadow; (2) plant species of concern (rare plants and desirable meadow natives) have responded well to treatments; (3) tree regeneration is high, and maintenance of treatment results requires longer-term investment.

5.0 Management Implications

5.1 Management Implications: Literature Review

Limited published information, particularly results of studies that specifically address riparian fuel loads and the ecological effects of riparian fuel treatments, continues to hamper fuels management near streams. The riparian literature clearly indicates that streamside areas have evolved with disturbance (Naiman et al., 2005), including fire (Dwire et al. 2003, Pettit and Naiman 2009), and basic and traditional knowledge of riparian species shows that most are well adapted to fire (Anderson 2005, www.fs.fed.us/database/feis/plants). However, the scarcity of fire-related research in different riparian vegetation types combined with protective administrative policies makes it difficult for managers in some regions to justify streamside fuel treatments, despite their concerns for severe fire risk.

5.2 Management Implications: Online Survey Findings

Active management of fuels in riparian areas is increasingly common.

Increased, active management of riparian vegetation and fuels implies a shift from custodial, 'hands off' approaches to incorporation of riparian corridors into broader-scale (watershed-scale or larger) treatments. This has likely resulted from recent information on large-scale fire behavior, fire return

intervals, and greater appreciation of linkages between riparian areas and uplands. Although riparian functions and characteristics need distinct consideration, stream-riparian corridors are part of the larger landscape, and need to be integrated into landscape level planning. Managers are concerned about riparian fuel loads, and perceive them to be high along many streams in the interior West. They are reluctant to leave high streamside fuel loads while uplands are treated, so they include these areas to protect them from high severity fire, and to exert some influence on fire behavior.

Most riparian fuel reduction projects have multiple objectives; in general, objectives were effectively met.

In many cases, managers are using fuel treatments as restoration projects both in uplands and riparian areas. This may be a consequence of funding, i.e. funds are available for fuel reduction, so managers make use of these resources to simultaneously restore habitat and historical fire regimes, and, in some locations, to control invasive plant species. Prioritization of objectives may be necessary, so some may be achieved more effectively than others. Also, without quantitative monitoring, achievement of some objectives is difficult to assess.

Prescribed fire is the most commonly used treatment in riparian projects, but combined treatments are common.

Despite the difficulty of getting some riparian areas to burn, most fire managers appear to be confident in managing prescribed fire in riparian areas, and many resource professionals feel that burning is the best method to treat fuel-heavy streamside corridors. In discussions during field visits (case studies), we also learned that managers are selecting the methods and approaches that are most cost effective and available to them, designing treatments based on the characteristics and condition of upland and riparian vegetation and fuel loads, and budget constraints. Treatment combinations were chosen on a site-specific basis depending on the habitat characteristics, feasibility, and protective regulations (e.g. heavy equipment cannot be used in wilderness and some streamside areas). As noted above, the use of multiple treatment combinations makes it difficult to evaluate effectiveness of different treatments or phases/ sequencing of treatments.

Most projects are being conducted in conifer or willow dominated riparian areas.

Although this finding suggests that more conifer and willow-dominated riparian areas require treatment, it may also be that these vegetation types are either easier to treat or more frequently included in the perimeters of upland fuel treatments. To the extent possible, we will examine the survey

information to further explore this finding. The limited number of treatments conducted in or near cottonwood galleries may imply hesitancy to treat these valued resources.

Fuels and vegetation are the most frequently monitored attributes for riparian fuels projects, although limited quantitative data are collected.

The limited quantitative monitoring on riparian fuels projects restricts the ability to conduct adaptive management and to share results, both beneficial and detrimental. Pre-and-post treatment photos can be compelling, but data are also needed to inform follow-up management over the short and-long term (years to decades). Resource managers are limited by budget constraints that do not prioritize monitoring and many rely on the monitoring programs implemented by their administrative units (e.g. district offices, forests, or regions). However, in most cases, they may not be able to use this information to assess the effects or outcomes of specific projects. Limited quantitative monitoring also makes agencies vulnerable to litigation. Although not one of the most common constraints to riparian fuel treatments, potential litigation was noted by 74 of the survey respondents (Figure 6). Environmental assessments and other NEPA documents for streamside riparian fuel projects have been challenged due to lack of specificity in monitoring descriptions, especially near fish-bearing streams with sensitive species (personal communication, Payette National Forest, ID).

The occurrence of TES species is the most common constraint/ concern for managing riparian fuels; other concerns vary by agency and region.

This finding reinforces the dilemma of finding the balance between species protection versus habitat conservation, particularly for aquatic TES species. Management choices (and implications of management choices) have become increasingly complex given emerging information on climate change, and impacts on stream temperature and fire frequency (Isaak et al. 2010, Rieman and Isaak 2010). Even though the occurrence of TES species is a major constraint, however, some managers are proceeding with streamside fuel treatments to avert the potential damage of severe wildfire. Several other constraints, such as potential litigation and administrative policies, may be related to issues involving TES species (Figure 6). Others may reflect regional variations and concerns regarding riparian management.

5.3 Management Implications: Findings from the Case Studies

The importance of good coordination across disciplines, agencies, and multiple stakeholders is worth repeating because it has strong implications for successful project management and highlights the

need for strong leadership and commitment. This was reiterated during site visits, but also noted in survey comments.

Regarding riparian fuel treatments, the state of the practice has preceded the state of the science. Currently, there is no mechanism for sharing field experiences, 'lessons learned', what worked and what failed. Management implications are that mistakes may be repeated and good options or solutions to common obstacles may not be communicated. The deliverable for this project (GTR) will partially serve that purpose, but additional forums for information sharing are recommended.

6.0 Relationship to other recent findings and ongoing work on this topic

The results of a 2007 phone survey of USFS Fire Management Officers in 11 western states found that 43% of the respondents were conducting fuels treatments in riparian areas, primarily for hazardous fuels reduction and ecological restoration or habitat improvement goals (Stone et al. 2010). We conducted an expanded survey that included wetlands, and also incorporated the experience of a variety of resource professionals in four agencies across the interior portion of the western United States. Our goals were similar to the previous survey, but we also wanted more detailed information on the ecology of the treated areas, differences among agencies, and contrasts between completed and proposed projects. Most results were consistent between the 2 surveys (2007 vs. 2010). However, more USFS riparian projects are being planned and conducted than found in 2007, suggesting a shift from 'hands-off' riparian protection to more active manipulation of riparian areas. Although resource managers are experiencing similar constraints as in 2007, another indication of shifting administrative policy is that the level of line officer support for treating riparian fuels appears to be growing.

The concern for transfer of knowledge regarding treatment of riparian areas is pervasive throughout the western US. We were recently contacted by social scientists at Oregon State University who are working with colleagues in the USFS Pacific Northwest Research Station. They are conducting a fish and fire science communication network study to identify obstacles to science-based decision-making that "arise from gaps in communication of knowledge rather than gaps in the availability of knowledge". Their sample population includes federal agency employees who produce or use information about the effects of fire and fuels management on riparian systems in the Pacific Northwest; their methods will include surveys and interviews. We collaborated with them by sharing the contact lists of practitioners who were actively managing for riparian fuels (i.e. those with completed and proposed projects) in their study area (Oregon, Washington, Idaho), and agreed to participate in survey test trials. While the effective sharing and transfer of scientific knowledge is critical and needs to be strengthened, knowledge gaps continue to be a major issue regarding riparian management.

Concerns surrounding treatment of riparian areas have gained increasing attention as severe fire behavior has been reported in streamside areas. This is not a recent finding – the influence of canyons and streamside terrain on fire behavior has been reported by the fire management community for many years (Barrows 1951, Countryman 1971). If fire suppression, custodial riparian management, or natural processes have contributed to higher accumulations of fuel loads in streamside areas relative to uplands, and if pre-fire moisture levels are low due to drought or season, riparian fire severity may be greater than adjacent uplands. High riparian fuel loads, especially if uplands have been harvested or actively managed for fuel reduction, can influence fire spread by serving as 'wicks' (Agee 1998, Skinner 2003). This fire behavior was documented during the Angora Fire, Tahoe National Forest, CA in late June 2007 (Murphy et al. 2007). Prior to ignition, the Angora Creek Stream Environment Zone (SEZ, or riparian area) contained heavy dead woody fuel loads. A retrospective evaluation of the Angora Fire behavior noted that "dense stands of trees in the Angora SEZ likely contributed to the rapid spread upslope to Angora Ridge and across the slope to the base of Tahoe Mountain" (Murphy et al. 2007). This fire burned over 250 structures on private property, cost approximately $160,000,000 in property loss and suppression costs, and has drawn attention to the role of riparian corridors and fuel conditions on fire behavior (Murphy et al. 2007, Safford et al. 2009).

A related synthesis project, also funded by the Joint Fire Sciences Program, is titled "Fire and Aquatic Ecosystems in the Context of Climate Change: A Synthesis for Improved Management" (JFSP 08-2-1-15; Principal Investigator-Charles Luce; Co-principal investigators – Penny Morgan, Bruce Rieman, Kate Dwire, John Buffington, Matt Dare, Zack Holden, Claire McGrath). Results of this project will also be published as a GTR with focus on (1) summarizing recent research that addresses larger spatial and temporal scales for fire and fish management; (2) integrating discussion of physical and biological processes to provide a more holistic understanding of terrestrial and aquatic responses to wildfire and fuel management; (3) framing approaches to aquatic species conservation within climate change scenarios that include alterations to hydrologic systems that affect both landscapes and riverscapes and exacerbate fire regimes. There is some overlap between our two projects; however, Luce et al. (in preparation) is focused on integrating climate change predictions into management considerations for forests, wildfire, and aquatic species conservation.

7.0 Future work needed

Ecological justification for fuels treatments in riparian areas is not yet supported by empirical evidence, although qualitative information regarding high riparian fuel loads and observations of fire behavior in streamside areas has begun to focus attention on the topic. The build-up of streamside fuels is

a concern in most riparian vegetation types; however, in conifer dominated watersheds, recent beetle infestations have resulted in considerable canopy mortality, affecting fuel loads in both upland and riparian areas. As more upland acreage is treated, untreated riparian areas may be at even greater risk of severe wildfire behavior. Vegetation metrics have been shown to be strong indicators of riparian burn severity (Halofsky and Hibbs 2008); however, there is limited published information available to managers on riparian fuel loads relative to uplands or the ecological effects of fuel reduction treatments in riparian areas.

Existing tools, models, and databases have limited applicability for many riparian areas. Because riparian plant communities may differ considerably from upland vegetation, and riparian reference conditions are difficult to define, the application of Fire Regime Condition Class (FRCC) ratings, which were derived for dominant upland vegetation types, is questionable for some riparian areas (Table 3). There is no fuel model for willow-dominated areas, and fuel models for some conifer-dominated vegetation types may not be apply to riparian areas, where overstory species composition and understory vegetation structure (ladder fuels) differ from surrounding uplands. LANDFIRE, also known as Landscape Fire and Resource Management Planning Tools (www.landfire.gov), shows riparian areas as unburnable, linear segments on the landscape where fuels cannot be mapped. Although a tremendous resource with fire ecology information on native plant species, the Fire Effects Information System does not include many riparian species, including some common willow species (www.fs.fed.us/database/feis/plants).

Both positive and negative impacts of riparian fuel treatments remain largely undocumented in the literature, highlighting the need for a rigorous evaluation of different treatments, treatment combinations, and treatment sequencing. For example, what are the potential risks and benefits of active ignitions in riparian areas? In addition to the parameters currently monitored, improved assessment of pre-and-post treatment fuel characteristics is needed to evaluate short and long-term changes to terrestrial and aquatic habitat. Although we recognize that all projects cannot be extensively monitored, the establishment of treatment demonstration areas in different riparian vegetation types to track immediate effects and recovery rates over time could inform managers from different agencies. In these demonstration areas, monitoring needs to be conducted using statistically defensible methods, which would allow inferences to be made regarding the success or effectiveness of fuel reduction activities. Dissemination of monitoring results, collected to assess the effectiveness of riparian-specific burn plans, would assist in planning or modifying projects and advance discussions regarding the benefits, risks, and challenges of conducting treatments in riparian areas.

Given the level of existing information, riparian treatments are essentially experimental, thus underscoring the need for more rigorous monitoring and basic research. To increase understanding of the ecological role of fuel reduction treatments, assessment of effects need to be considered at a landscape or watershed-scale that incorporates fire history, past fire suppression, and wildfire for riparian and adjacent upland areas. Assessment of riparian conditions and fuel loads need to be better integrated with upland evaluations. Other research needs include: determination of reference fuel conditions for a range of riparian forests and plant associations, effectiveness comparisons of different treatment types (e.g. prescribed fire, thinning, combinations), evaluation of using fuel treatments as surrogates for low-intensity wildland fire in riparian areas, risk assessment of 'no action' options for cases in which riparian fuel loads are perceived as hazardous, and rigorous examination of treatment effects on aquatic and riparian biota and habitat.

Deliverable Crosswalk Table

Proposed	**Accomplished / Status**
Literature synthesis	Completed; will be published as Section 2 in the GTR.
Conduct survey of riparian fuel treatments of the Interior West	Completed.
Summarize survey results	Completed. Survey data are compiled in an ACCESS database; frequency analyses and summarization are completed, and will be published in Section 3 of the GTR.
Field visits (case studies)	Completed; 9 different projects were visited in 2010; findings are being integrated into detailed descriptions of 5 different project types as Section 4 in the GTR.
Field tour of riparian fuel treatments	Planned as part of USFS R2 Annual Meeting of Hydrologists, Fish Biologists, and Soil Scientists. However, meeting was cancelled due to budget constraints; may occur in summer 2011.
Monitoring- guidelines for assessing riparian fuels treatments.	In preparation; will be published as Section 5 in the GTR.
Presentations	Completed; please see list of presentations below.
A Guide to Fuels Management in Riparian Areas of the Interior West (GTR) (peer-review; not refereed)	In preparation and will be submitted summer-fall, 2011.
Burning Questions for Managers: Fuel Management Practices in Riparian Areas (peer-review; not refereed).	Manuscript is undergoing internal review and will be submitted in summer 2011 to *Fire Management Today*.
Treating Fuels in Riparian Areas of the Interior West: Objectives, Methods, and Effectiveness (peer-review; refereed).	The majority of the survey data has been processed and analyzed. Manuscript preparation will occur spring-summer 2011, with expected submission (*Environmental Management*) in fall 2011.

Presentations (additional deliverables)

Dwire, K. A. 2009. Wildfire and fuel reduction in riparian areas of the interior west. Presented at the *2009 Restoring the West Conference: Peaks to Valleys: Innovative Land Management for the Great Basin*, Logan UT, October 27-28, 2009. Sponsored by Utah State University, USDA Rocky Mountain Research Station, and the Western Aspen Alliance.

Dwire, K.A. 2010.Wildfire and fuel treatments in riparian areas of the Interior West. Presented at the USFS Region 4 Annual Meeting (fish biologists, hydrologists, soils scientists, range ecologists); April 12-15, 2010, Ogden, UT.

Dwire, K.A. 2011. Research in progress on wetland and riparian ecosystems; fire, fuels, flows, and fens. Presented at the USFS Region 2 Annual Meeting for Botanists, Range Ecologists and Wildlife Biologists; Ft. Collins, Colorado; March 22-24, 2011

Dwire, K.A. 2011. Wildfire and fuel reduction treatments in riparian areas. Presented at Colorado State University, College of Forest, Rangeland, and Watershed Stewardship; March 21, 2011.

Dwire, K.A. 2011. Fuel reduction treatments in riparian areas of the Interior West: management in the context of climate change. Presented at the Klamath Fire Ecology Symposium, Orleans, CA. April 26-28, 2011. Sponsored by Region 5 USDA Forest Service, The Nature Conservancy's Fire Learning Network, Humboldt State University, Mid-Klamath Watershed Council, the Hoopa and Karuk Tribes of California, and the Orleans-Somes Bar Fire Safe Council.

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Literature Cited

Agee, J.K. 1998. The landscape ecology of western forest fire regimes. *Northwest Science* 72, 24-34 (special issue).

Agee, J.K. and C.N. Skinner. 2005. Basic principles of forest fuel reduction treatments. *Forest Ecology and Management* 211: 83-96.

Anderson, M.K. 2002. From burns to baskets: Californian Indian Women's Influence on ecosystems with the use of fire and other horticultural techniques. Association for Fire Ecology Misc. Pub. 1: 1-9.

Arkle, R.S. and D.S. Pilliod. 2010. Prescribed fire as ecological surrogates for wildfires: a stream and riparian perspective. *Forest Ecology and Management* 259: 893-903.

Arkle, R.S., D.S. Pilliod, and K. Strickler. 2009. Fire, flow, and dynamic equilibrium in stream macroinvertebrate communities. *Freshwater Biology* 55: 299-314.

Barrows, J.S. 1951. Fire behavior in Northern Rocky Mountain Forests. Station Paper 29. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 134 pages.

Bêche, L.A., S.L. Stephens, and V.H. Resh. 2005. Effects of prescribed fire on a Sierra Nevada (California, USA) stream and its riparian zone. *Forest Ecology and Management* 218: 37-59.

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

Burton, T.A., S.J. Smith, and E.R. Cowley. 2008. Monitoring stream channels and riparian vegetation; Multiple indicators. Interagency Technical Bulletin Version 5.0, April 2008. USDA Forest Service, USDI Bureau of Land Management; Idaho State Office, BLM, Intermountain Region, USFS.

Countryman, C.M. 1971. Fire whirls…why, when, and where. Station Paper. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 11 pages.

Dombeck, M.P., J.E. Williams, and C.A. Wood. 2004. Wildfire policy and public land: scientific understanding with social concerns across landscapes. *Conservation Biology* 18: 883-889.

Dwire, K.A. and J.B. Kauffman. 2003. Fire and riparian ecosystems in landscapes of the western USA. *Forest Ecology and Management* 178 (1-2):61- 74.

Dwire, K.A., C.C. Rhoades, M.K. Young. 2010. Potential effects of fuel management activities in riparian areas. Pages 176 -206. In: Elliot, W.J., Miller, I.S., and Audin, L. (eds), Cumulative watershed effects of fuel management in the western United States. General Technical Report RMRS-GTR-231. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 299 p.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby 1998. Measuring and monitoring plant populations. Tech Reference 1730-1, BLM/RS/ST-98/005+1730 Denver, CO: Bureau of Land Management, National Business Center.

Fire Effects Information System; USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Available at http://www.fs.fed.us/database/feis/plants.

Halofsky, J.E. and D.E. Hibbs 2008. Determinants of riparian fire severity in two Oregon fires, USA. *Canadian Journal of Forest Research* 38: 1959-1973.

Hudak, A.T., I. Rickert, P. Morgan, E. Strand, A.A. Lewis, P.R. Robichaud, C. Hoffman, and A.A. Holden. 2011. Review of fuel treatment effectiveness in forests and rangelands and a case study from the 2007 megafires in central Idaho, USA. Gen. Tech. Rep. RMRS-GTR-252 Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 60 p.

Isaak, D.J., C. Luce, B.E. Rieman, D. Nagel, E. Peterson, D. Horan, S. Parkes, and G. Chandler. 2010. Effects of climate change and wildfire on stream temperatures and salmonid thermal habitat in a mountain river network. Ecological Applications 20: 1350-1371.

Jackson, B.K. and S.M.P Sullivan. 2009. Influence of wildfire severity on riparian plant heterogeneity in an Idaho, USA wilderness. *Forest Ecology and Management*. 259:24-32.

Kershner, J.L. 2002. Effectiveness monitoring of aquatic and riparian resources in the areas of PACFISH/INFISH and the biological opinions for bull trout, salmon, and steelhead. Final Plan. Logan, UT: US Department of Agriculture, Forest service. 56 p.

Kershner, J.L. E. Cowley, R. Henderson, K. Kratz, D. Martin, D. Quimby, K. Stein, D. Turner, L. Ulmner, M. C. Vison, and D. Young. 2001. Effectiveness monitoring of aquatic and riparian resources in the areas of PACFISH/INFISH and the biological opinions for bull trout, salmon, and steelhead. Draft Plan. Logan, UT: USDA Forest Service and USDI Bureau of Land Management 50 p.

Lutes, D. C., R.E. Keane, J.F. Caratti, C.H. Key, N.C. Benson, S. Sutherland, and L.J. Gangi. 2006. FIREMON: Fire effects monitoring and inventory system. Gen. Tech. Rep. RMRS-GTR-164-CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 1CD.

Malison, R.L. and C.V.Baxter. 2010. The fire pulse: wildfire stimulates flux of aquatic prey to terrestrial habitats driving increases in riparian consumers. *Canadian Journal of Fisheries and Aquatic Sciences* 67: 570-579.

Martin, C. and J. DeJuilio. 2009. An examination of prescribed fire effects and fuel treatment effectiveness within headwater riparian corridors in the Middle Rogue River Basin of southwest Oregon. Report to the Joint Fire Sciences Program.

Mellon, C.D., M.S. Wipfli, and J.L. Li. 2008. Effects of forest fire on headwater macroinvertebrate communities in eastern Washington, USA. *Freshwater Biology* 53: 2331-2343.

Miller, S. 2009. Macroinvertebrate responses to riparian and upland fuels treatments in the Applegate and Middle Rogue River watersheds, OR. Report to the Joint Fire Sciences program.

Murphy, K., T. Rich, and T. Sexton. 2007. An assessment of fuel treatment effects on fire behavior, suppression effectiveness, and structure ignition on the Angora Fire. USDA Forest Service. R5-TP-025.

Naiman, R.J.; Decamps, H.; McClain, M.E. 2005. Riparia: Ecology, conservation, and management of streamside communities. Elsevier, Inc. London, UK. 430 pages.

Petitt, N.E. and R.J. Naiman. 2007. Fire in the riparian zone: characteristics and ecological consequences. *Ecosystems* 10: 673-687.

Reeves, G.H., D.B. Hohler, D.P. Larsen, K. Kratz, K. Reynolds, K.F. Stein, D.E. Busch, P. Hays, M. Tehan, T. Atzet. 2004. Aquatic and riparian effectiveness monitoring program for the Northwest Forest Plan. Corvallis, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Rieman, B. and D. Isaak. 2010. Climate change, aquatic ecosystems, and fishes in the Rocky Mountain West: implications and alternatives for management. U.S.D.A. Forest Service, Rocky Mountain Research Station, GTR-RMRS-250, Fort Collins, CO.

Robichaud, P.R., J.L. Beyers, and D.G. Neary. 2000. Evaluating the effectiveness of postfire rehabilitation treatments. Gen. Tech. Rep. RMRS-GTR-63. Fort Collins, USDA Forest Service, Rocky Mountain Research Station. 85 p.

Safford, H.D., D.A. Schmidt, and C. Carlson. 2009. Effects of fuel treatments on fire severity in an area of wildland-urban interface, Angora Fire, Lake Tahoe basin, California. *Forest Ecology and Management* 258:773-787.

Skinner, C.N. 2003. A tree-ring based fire history of riparian reserves in the Klamath Mountains, northwestern California. *In*: Proceedings of the Riparian Habitat and Floodplains Conference, 12-15 March 2001, Sacramento, CA. The Wildlife Society, Western Section.

Stone, K., D.S. Pilliod, K.A. Dwire, C.C. Rhoades, S.P. Wollrab, M.K.Young. 2010. Fuel reduction management practices in riparian areas of the western USA. *Environmental Management* 46:91-100. DOI10.1007/s00267-010-9501-7.

USDA Forest Service and USDA Bureau of Land Management. 1995. Environmental assessment for the implementation of interim strategies for managing anadromous fish-producing watersheds in eastern Oregon, and Washington, Idaho, and portions of California. Washington, DC. (SS/X.A. 1.3).

USDI Fish and Wildlife Service. Grace, S. and D. Brownlie, eds. [Draft]. Fuel and fire effects monitoring guide, [Online]. http://fire.fws.gov/ifcc/monitor/RefGuide/default.htm.

USDI National Park Service. 1992. Western Region fire monitoring handbook. San Francisco, CA: U.S. Department of the Interior, National Park Service, Western Region. 89 p.

USDI National Park Service. 2001. Fire monitoring handbook. Boise, ID: National Interagency Fire Center. 283 p.

Volpe, C.J. 2009. Effects of prescribed riparian fire in small headwater streams in the Rogue River basin, southwest Oregon. USDI-BLM agency report. Bureau of Land Management, Medford, OR.