Annotated Bibliography
For
Conserving Native Ecosystems

Swan View Coalition and Friends of the Wild Swan
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Scientific Findings on Roads and Roadless Lands

Virtually without exception, science is finding that ecological integrity remains highest in areas that remain unroaded and unmanaged and is lowest in areas that have been roaded and managed. As the density of roads increases, aquatic integrity and wildlife security decreases, while the risk of catastrophic wildfire and the occurrence of exotic weeds increases. The simplest and most cost-effective thing the Forest Service can do to maintain and restore aquatic and ecosystem integrity is to stop building roads and to obliterate in an environmentally sound manner as many roads as possible. This conclusion is supported by the following:

"Areas that are more highly roaded actually have a higher potential for catastrophic wildfires than inventoried roadless areas. Other national assessments have arrived at the same conclusions. [] The fire occurrence data revealed the following key points:

- Nationally, the average size of a large wildfire is greater on NFS lands outside of an inventoried roadless area;

- Nationally, the average size of a large wildland fire started by humans is greater on land outside of inventoried roadless areas;

- Regardless of the cause, a wildland fire ignition was nearly 2 times as likely to occur outside of an inventoried roadless area;

- A human ignited wildland fire is nearly 4 times as likely to occur outside of an inventoried roadless area." (Forest Service Roadless Area Conservation DEIS, page 3-157; hereafter USFS 2000).

"The U.S. Fish and Wildlife Service [] found that bull trout are exceptionally sensitive to the direct, indirect, and cumulative effects of roads. Dunham and Rieman [] demonstrated that disturbance from roads was associated with reduced bull trout occurrence. They concluded that conservation of bull trout should involve protection of larger, less fragmented, and less disturbed (lower road density) habitats to maintain important strongholds and sources for naturally recolonizing areas where populations have been lost." (USFS 2000, page 3-82, parenthesis in original).

"Hitt and Frissell [] showed that over 65% of waters that were rated as having high aquatic biological integrity were found within wilderness-containing subwatersheds. [] Trombulak and Frissell [] concluded that [] the presence of roads in an area is associated with negative effects for both terrestrial and aquatic ecosystems including changes in species composition and population size." (USFS 2000, pages 3-80-81).

"High integrity [forests] contain the greatest proportion of high forest, aquatic, and hydrologic integrity of all [] are dominated by wilderness and roadless areas [and] are the least altered by management. [] Low integrity [forests have] likely been altered by past management [] are extensively roaded and have little wilderness." (USFS 1996a, pages 108, 115 and 116).

"Much of this [overly dense forest] condition occurs in areas of high road density where the large, shade-intolerant, insect-, disease- and fire-resistant species have been harvested over the past 20 to 30 years. [] Fires in unroaded areas are not as severe as in the roaded areas because of less surface fuel, and after fires at least some of the large trees survive to produce seed that regenerates the area. Many of the fires in the unroaded areas produce a forest structure that is consistent with the fire regime, while the fires in the roaded areas commonly produce a forest structure that is not in sync with the fire regime. [] In general, the effects of wildfires in these areas are much lower and do not result in the chronic sediment delivery hazards exhibited in areas that have been roaded." (USFS 1997a, pages 281-282).

"Increasing road density is correlated with declining aquatic habitat conditions and aquatic integrity [] An intensive review of the literature concludes that increases in sedimentation [of streams] are unavoidable even using the most cautious roading methods." (USFS 1996b, page 105).

"This study suggests the general trend for the entire Columbia River basin is toward a loss in pool habitat on managed lands and stable or improving conditions on unmanaged lands." (McIntosh et al 1994).

"The data suggest that unmanaged systems may be more structurally intact (i.e., coarse woody debris, habitat diversity, riparian vegetation), allowing a positive interaction with the stream processes (i.e., peak flows, sediment routing) that shape and maintain high-quality fish habitat over time." (McIntosh et al 1994).

"Although precise, quantifiable relationships between long-term trends in fish abundance and land-use practices are difficult to obtain (Bisson et al. 1992), the body of literature concludes that land-use practices cause the simplification of fish habitat []." (McIntosh et al 1994).

"Land management activities that contributed to the forest health problem (i.e., selective harvest and fire suppression) have had an equal or greater effect on aquatic ecosystems. If we are to restore and maintain high quality fish habitat, then protecting and restoring aquatic and terrestrial ecosystems is essential." (McIntosh et al 1994).

"Native fishes are most typically extirpated from waters that have been heavily modified by human activity, where native fish assemblages have already been depleted, disrupted, or stressed []." (Moyle et al 1996).

"Restoration should be focused where minimal investment can maintain the greatest area of high-quality habitat and diverse aquatic biota. Few completely roadless, large watersheds remain in the Pacific Northwest, but those that continue relatively undisturbed are critical in sustaining sensitive native species and important ecosystem processes (Sedell, et. al 1990; Moyle and Sato 1991; Williams 1991; McIntosh et al. 1994; Frissell and Bayles 1996). With few exceptions, even the least disturbed basins have a road network and history of logging or other human disturbance that greatly magnifies the risk of deteriorating riverine habitats in the watershed." (Frissell undated).

"[A]llocate all unroaded areas greater than 1,000 acres as Strongholds for the production of clean water, aquatic and riparian-dependent species. Many unroaded areas are isolated, relatively small, and most are not protected from road construction and subsequent timber harvest, even in steep areas. Thus, immediate protection through allocation of the unroaded areas to the production of clean water, aquatic and riparian-dependent resources is necessary to prevent degradation of this high quality habitat and should not be postponed." (USFWS et al 1995).

"Because of fire suppression, timber harvest, roads, and white pine blister rust, the moist forest PVG has experienced great changes since settlement of the project area by Euroamericans. Vast amounts of old forest have converted to mid seral stages." (USFS/BLM 2000, page 4-58).

"Old forests have declined substantially in the dry forest PVG []. In general, forests showing the most change are those that have been roaded and harvested. Large trees, snags, and coarse woody debris are all below historical levels in these areas." (USFS/BLM 2000, page 4-65).

"High road densities and their locations within watersheds are typically correlated with areas of higher watershed sensitivity to erosion and sediment transport to streams. Road density also is correlated with the distribution and spread of exotic annual grasses, noxious weeds, and other exotic plants. Furthermore, high road densities are correlated with areas that have few large snags and few large trees that are resistant to both fire and infestation of insects and disease. Lastly, high road densities are correlated with areas that have relatively high risk of fire occurrence (from human caused fires), high hazard ground fuels, and high tree mortality." (USFS 1996b, page 85, parenthesis in original).

In simpler terms, the Forest Service has found that there is no way to build an environmentally benign road and that roads and logging have caused greater damage to forest ecosystems than has the suppression of wildfire alone. These findings indicate that roadless areas in general will take adequate care of themselves if left alone and unmanaged, and that concerted reductions in road densities in already roaded areas are absolutely necessary.

Indeed, other studies conducted by the Forest Service indicate that efforts to "manage" our way out of the problem are likely to make things worse. By "expanding our efforts in timber harvests to minimize the risks of large fire, we risk expanding what are well established negative effects on streams and native salmonids. [] The perpetuation or expansion of existing road networks and other activities might well erode the ability of [fish] populations to respond to the effects of large scale storms and other disturbances that we clearly cannot change." (Reiman et al 1997).

The following quotes demonstrate that trying to restore lower severity fire regimes and forests through logging and other management activities may make the situation worse, compared to allowing nature to reestablish its own equilibrium. These statements are found in "An Assessment of Ecosystem Components in the Interior Columbia Basin and Portions of the Klamath and Great Basins, Volume 3 (ICBEMP):

"Since past timber harvest activities have contributed to degradation in aquatic ecosystems, emphasis on timber harvest and thinning to restore more natural forests and fire regimes represent risks of extending the problems of the past." (ICBEMP page 1340).

"Proposed efforts to reduce fuel loads and stand densities often involve mechanical treatment and the use of prescribed fire. Such activities are not without their own drawbacks -- long-term negative effects of timber harvest activities on aquatic ecosystems are well documented (see this chapter; Henjum and others 1994; Meehan 1991; Salo and Cundy 1987)." (ICBEMP page 1340).

"Species like bull trout that are associated with cold, high elevation forests have probably persisted in landscapes that were strongly influenced by low frequency, high severity fire regimes. In an evolutionary sense, many native fishes are likely well acquainted with large, stand-replacing fires." (ICBEMP page 1341).

"Attempts to minimize the risk of large fires by expanding timber harvest risks expanding the well-established negative effects on aquatic systems as well. The perpetuation or expansion of existing road networks and other activities might well erode the ability of populations to respond to the effects of fire and large storms and other disturbances that we cannot predict or control (National Research Council 1996). (ICBEMP page 1342).

"Watersheds that support healthy populations may be at greater risk through disruption of watershed processes and degradation of habitats caused by intensive management than through the effects of fire." (ICBMP page 1342).

"Timber harvest, through its effects on forest structure, local microclimate, and fuels accumulation, has increased fire severity more than any other recent human activity. If not accompanied by adequate reduction of fuels, logging (including salvage of dead and dying trees) increases fire hazard by increasing surface dead fuels and changing the local microclimate. Fire intensity and expected fire spread rates thus increase locally and in areas adjacent to harvest". (USFS 1996c, pages 4-61-72).

"Logged areas generally showed a strong association with increased rate of spread and flame length, thereby suggesting that tree harvesting could affect the potential fire behavior within landscapes...As a by-product of clearcutting, thinning, and other tree-removal activities, activity fuels create both short- and long-term fire hazards to ecosystems. Even though these hazards diminish over time, their influence on fire behavior can linger for up to 30 years in dry forest ecosystems of eastern Oregon and Washington". (Huff et al 1995).

The answer, therefore, is not to try managing our way out of this situation with more roads and timber harvest/management. In summary:

- Roads have adverse effects on aquatic ecosystems. They facilitate timber sales which can reduce riparian cover, increase water temperatures, decrease recruitment of coarse woody debris, and disrupt the hydrologic regime of watersheds by changing the timing and quantity of runoff. Roads themselves disrupt hydrologic processes by intercepting and diverting flow and contributing fine sediment into the stream channels which clogs spawning gravels. High water temperatures and fine sediment degrade native fish spawning habitat.

According to the U.S. Forest Service 82% of all bull trout populations and stream segments range-wide are threatened by degraded habitat conditions. Roads and forest management are a major factor in the decline of native fish species on public lands in the Northern Rockies and Pacific Northwest.

- An open road density (ORD) of one mile per square mile of land reduces elk habitat effectiveness to only 60% of potential. When ORD increases to six miles per square mile, habitat effectiveness for elk decreases to less than 20%. (Lyon 1984).

- Black bears in southern Appalachia begin avoiding Forest Service roads when the density exceeds 0.8 miles per square mile. (Brody 1984). Grizzly bears use habitats less than expected when ORD exceeds one mile per square mile and total road density (TRD) exceeds two miles per square mile. (Mace and Manley 1993). Open roads contribute to grizzly bear mortality by poaching and, especially during the black bear hunting season, by mistaken killing. (Holland 1985).

- Roads have a similar, devastating effect on wolves. Studies show that wolves fail to survive in areas where ORD exceeds 0.93 miles per square mile. (Thiel 1985).

- Sediment from roads, both open and closed, damages the environment. In northwest Montana, for instance, 80-90% of the sediment produced by logging and road construction generally is attributable to the road (USFS 1985). The Flathead National Forest estimates that, on one of its most pervasive and sensitive land types, one mile of road produces 98 tons of sediment, 80% of which reaches the stream bed (USFS undated).

In addition, the Forest Service estimates that only a 10% increase in fine sediment deposition in spawning gravel decreases the spawning success of bull trout by 50%. (USFS 1986). A road cut across a hillside intercepts subsurface water flow and runs it down ditches and through culverts. There it is joined by sediment-laden runoff from the roadbed and cut banks before running into a stream. Hence, subsurface water which would have once welled up from below a stream to clean bull trout spawning gravels now carries sediment from the road and land surface and deposits it onto the spawning gravels, where it smothers the eggs and fry.

"Rehabilitation of road-miles cannot be accomplished alone by gating, berming, or otherwise blocking the entrance to a road permanently or temporarily, or seasonally closing roads, but will require obliteration, recontouring, and revegetating." (U.S. Fish and Wildlife Service Regions 1 and 6. 1998a).

"Reduction of total miles of forest roads is an important component of watershed restoration. . . Many miles of roads must be 'put to bed', by pulling culverts, resloping road beds, pulling fill and replanting." (U.S. Fish and Wildlife Service. 1998b).

“Recontoured and abandoned sites displayed similar aboveground properties but exhibited notable differences in belowground properties, including soil hydraulic conductivity, organic matter, total carbon, and total nitrogen, among others. Our findings suggest that recontouring can dramatically accelerate recovery of above- and belowground properties so they resemble never-roaded reference conditions. In contrast, abandoning roads generates above- and belowground properties that follow a different path to recovery.” (Lloyd et al 2013).

“Roots on A30 [abandoned] roads were constrained to the upper 15 cm (10 ± 0.45 cm). In contrast, never-roaded sites and recontoured roads had rooting depths that extended below the limits of soil pit excavations (>60–75 cm).” (Lloyd et al 2013).

“The simulated time to runoff generation after a 1-hour storm event was significantly different between treatments, with runoff occurring in the first 0.2 hours of the storm on A30 [abandoned] roads and never on R10 [recontoured] roads.” (Lloyd et al 2013).

“In our study, the trajectory of plant succession on abandoned roads and recontoured roads followed similar trends to other research conducted on passively restored roads (Madej 2001; Foltz et al. 2009), although our data suggest that vegetation succession to shrubs and trees may be slower on abandoned roads as compared with recontoured roads. However, ecosystem recovery belowground differed markedly from that aboveground. The strong differences in belowground properties following road abandonment result in an effective decoupling of the recovery trajectories of above- and belowground ecohydrological properties (Figure 3). Together, these findings support the prediction that recontouring accelerates the rehabilitation of key ecohydrologic properties toward reference dynamics.” (Lloyd 2013).

“After treatment, we conservatively estimate soil TC [carbon] storage increased sixfold, to 6.5 x107 g C per road kilometer (to 25-cm depth). The same trends are seen for soil N [nitrogen]. Abandoned roads have approximately 6.96 x 105 g N per road kilometer, and this amount increases by an order of magnitude to 7.16 x 106 g N (to 25-cm depth). These major differences in soil C and N storagexhave potentially important implications for climate-changexmitigation.” (Lloyd et al 2013).

"Although more expensive as compared with road abandonment, recontouring may be the only way to restore both above- and belowground ecosystem processes, accelerating the recovery of these forest ecosystems by decades to millennia. . . Restoration techniques that fail to restore above- and belowground properties and processes may lead to an altered ecosystem with different functional processes and potential (Kardol and Wardle 2010)." (Lloyd et al 2013).

Comprehensive Management of Human Access

The following citations show that all human access to fish and wildlife habitat has negative impacts, including the existence of roads and trails regardless of use levels. The magnitude of impacts from human use generally occurs in descending order from motorized use of roads and trails to use by bicycles and finally foot or horse use. While many of these citations contend with research and opinions on Flathead Forest Plan Amendment 19, similar methods of quantifying the impacts of motorized and high levels of non-motorized use have been applied to other National Forests via guidance from the Interagency Grizzly Bear Committee.

"We have . . . created technologies that make virtually every place on this planet accessible to us. With our curiosity, money, leisure time, and motorized contraptions, we can invade any corner of the earth with impunity. . . That we can alter human behavior to protect wildland ecosystems and wild animals is reason for hope." (Salwasser 1997).

"The simplicity of A19 [Flathead Forest Plan Amendment 19] and its ability to permanently secure areas for grizzly bears makes it a powerful tool in the conservation of the grizzly bear in the NCDE." (McLellan et al 2000, page 11).

"Private roads were excluded from road density calculations and, if federal land was <75% of the sub-unit, 'no net loss' rather than the numerical guideline values was used. These, and other rules that relaxed road density guidelines were established in sub-units with private lands even when it was shown that a bear's level of risk was 30.27 times as great in rural areas as in backcountry areas. It would appear that in sub-units with private holdings that stricter, not reduced, access controls would be necessary to offset higher levels of mortality." (McLellan et al 2000, page 11).

"Based on the best information available, the current and planned distribution of roads and core area, large portions of roadless areas, and known grizzly bear distribution within the recovery zone portion of the [Flathead National] Forest reveal a pattern and trend in access management that is improving, is based on ecosystem-specific information, and will be conducive to supporting grizzly bears at numbers that promote recovery." (USFWS 2005, page 132).

"The Service believes that grizzly bears in the NCDE would benefit from continued application of the [Flathead National] Forest's access management strategy, as proposed. Efforts to reduce open road density, especially in seasonally important resource areas, and reducing roads to provide core habitat in subunits with high road densities should be pursued and included in all project planning." (USFWS 2005, page 139).

"As human population centers expand and increased dispersed human activity and development ensues, risks to grizzly bears may increase. Public lands will remain important to the recovery and sustainability of the NCDE grizzly bear population." (USFWS 2005, page 140).

The northern Swan Range population of grizzly bear is likely decreasing at over 2% per year, enough to halve the population in about 30 years. (Mace and Waller 1997, errata to page 112).

"[The northern Swan Range] population was semi-isolated because of human development including hydroelectric development. . . until effective management programs are developed on private lands, federal lands should be considered invaluable source areas and managed to reduce man-caused mortality. This would be accomplished by establishing effective areas of high security that transcend seasonal habitats, and where access is regulated." (Mace and Waller 1997, Chapter 9).

"Additional road restrictions and reductions required by A19 [Flathead Forest Plan Amendment 19] are important to reduce displacement (and indirect mortality) and ensure adequate habitat available for continued reproduction and population growth over the long term." (USFWS 2005, page 145).

"It is the Service's biological judgment that 'harm' of grizzly bears is likely to occur in the following conditions: 1. The precise open motorized access densities exceeds 1 mile per square mile in over 19 percent of a subunit. . . 2. The precise total motorized access density exceeds 2 miles per square mile in over 19 percent of a subunit. . . 3. Security core is less than 68% of a subunit." (USFWS 2005, page 150).

"Security core area . . . is at least 0.3 miles from open roads and high-intensity, non-motorized trails. . . The number of restricted roads in security core should be minimized . . . and may not receive high levels of non-motorized use . . . defined as receiving 20 or greater parties per week . . . reclamation of roads [is] the preferred treatment. (USFS 1995).

"Habitat security conditions cannot be defined entirely by motorized access route density. . . heavily used non-motorized trails and areas of high levels of dispersed human use will also influence the effectiveness of area in regards to habitat security." (IGBC 1998).

"[W]e determined that grizzly bears were significantly further than expected from [hiking only] trails, and from lakes with camp-sites during spring, summer, and autumn. . . Therefore, while in the JBHA [Jewel Basin Hiking Area], grizzly bears minimized their interaction with recreationists by spatially avoiding high use areas." (Mace and Waller 1997, Chapter 7.2).

"Direction [is] for reclaiming/obliterating roads including removal of culverts which greatly reduces the risk of future sedimentation problems resulting from culvert failures on reclaimed roads. . . the long term effect of implementing this direction should be beneficial to fish [due] to reduced sediment and routing of surface water once reclaimed and restricted roads have stabilized, and greatly reduced risk of future impacts from culverts left in place and inadequate treatment of closed or reclaimed roads." (Hair 1995).

"The Forest Service estimates a $10 billion backlog in needed road reconstruction and maintenance. . . Fewer roads will be built and those that are built will minimize environmental impacts. Roads that are no longer needed or that cause significant environmental damage will be removed. (Dombeck 1998).

"[T]his points to a smaller road system than our current one . . ." (Holtrop 2010).

The Flathead National Forest needs $6.2 million each year to maintain its road system, but receives less than $1 million. (USFS 2004).

"Roads that are not maintained can become an environmental liability on the watershed. . . It's not a matter of if a culvert is going to fail, it's a matter of when. . . It is cheaper to reclaim a road than to maintain it." (Rowley 1998a and 1998b).

"Reduction of total miles of forest roads is an important component of watershed restoration [but] cannot be accomplished by gating, berming, or otherwise blocking the entrance to a road. . . Many miles of roads must be 'put to bed' by pulling culverts, resloping road beds, pulling fill and replanting." (USFWS 1998a and 1998b).

"The management of roads is the most powerful tool available to balance the needs of bears and all other wildlife with the activities of humans. . . Roads closed to public use through the use of only signs or gates are often not effective. . . The optimum situation to maintain grizzly bear habitat effectiveness and minimize mortality risk is to obliterate the road." (USFWS 1993).

"Roads are the single biggest problem on the landscape for elk. It's well documented, and everything else pales in comparison. . . The more roads you have, the less elk you have." (Stouder 2002).

"Elk travel time [displacement] was highest during ATV exposure, followed by exposure to mountain biking, hiking, and horseback riding. . . A comprehensive approach for managing human activities to meet elk objectives should include careful management of off-road recreational activities, particularly ATV riding and mountain biking, which caused the largest reductions in feeding time and increases in travel time." (Naylor et el. 2009).

Old Growth Forests

Old-growth forest habitat is a diminishing resource on public lands due to many factors. Maintaining existing old-growth stands and providing for recruitment of future old growth is necessary to provide for the viability of old-growth associated wildlife species. While not perfect, the Old-Growth Forest Types of the Northern Region (Green et al, 1992) is probably the best reference available for these forests and should be used as a guide to determine old-growth forest habitat.

We strongly caution though that the minimum characteristics in Green et al, are not the recommended standards, but merely the starting point by which to determine whether a stand is classified as old growth. It is NOT to be used to "manage" old growth down to these minimum characteristics. Also, it is important to note that old-growth attributes such as decadence, large trees, old trees, snags, canopy structure, coarse woody debris, etc. are critical components of old-growth forest habitat. Stands that may not have the minimum number of large trees but contain these other important attributes should be considered "recruitment" or future old-growth and allowed to progress towards meeting the Green et al definition.

Old-growth stands function best as habitat when they are connected to other stands. Connectivity can be achieved by corridors of actual old growth or by suitable closed-canopy or mature condition of the matrix between old-growth stands (Thomas, et al. 1990, Bennett, 1999). Stands designated as future old growth that are presently mature may be suitable (Pfister, et al 2000). Linkages, should whenever possible, contain a large fraction of interior forest (i.e., 100 meters from a high contrast edge, Bennett 1999).

Interior old growth habitat (>100 meters from edge of an opening or stand of lesser age or a road) is the most important component of old-growth habitat (Baker and Knight 2000). In general larger stands are more effective as habitat than smaller stands (Pfister 2000). Fragmentation of existing patches of old growth by roads, timber harvesting or other created openings will decrease effectiveness of the patch as habitat due to the reduction in amount of interior old-growth conditions (Baker and Knight 2000).

Stands that met the Green et al definition of old growth but are burned in a forest fire do not cease to provide a valuable function to wildlife and the forest ecosystem and should not be salvage logged. This burned old growth may function differently but it is still important habitat because burned snags stand much longer than beetle-killed trees, and the fact that it burned does not change its age and age is a primary factor in old growth habitat (Pers. comm. R. McClelland).

Management Recommendations to Protect Old Growth

To protect remaining old growth, provide for recruitment of future old growth, and link these currently small and isolated patches, we suggest the following management standards.

- Use the Old-Growth Forest Types of the Northern Region as a first step in identifying old growth stands.

- All existing old growth must be preserved. Historically old-growth habitat was 15% to 60% (source Amendment #21). Current old growth averages 11.6% across the Forest and ranges between 6.9% to 12.7% (source 1999 – 2007 Forest Plan Monitoring Report). Old-growth forest habitat must be increased to the historical range by allowing mature stands to develop old growth characteristics (snags, down woody material, decadence and age). The Forest Service must calculate how much old growth there is on a watershed (i.e., approximately 10,000 acres) and forest-wide basis. Recruitment old growth must be identified on a watershed and forest-wide basis. Recruitment old growth is subject to the same protections as designated current old growth.

- Designate the existing old growth and future old growth, map it and connect these stands with linkages as described above.

- Place longer-rotation or less intensive uses adjacent to designated old growth, so that a lower-intensity managed zone serves as a buffer for the old-growth system (Noss and Cooperrider 1994). Avoid placing high intensity land uses (e.g. clearcuts, roads) next to designated old growth (Pfister 2000).

- Integrate future recruitment old growth into the network. Where otherwise equivalent replacement stands exist, choose those adjacent to designated old growth as future old growth.

- No logging should take place in old growth stands. Under limited and extraordinary circumstances some thinning of sapling and pole-sized timber less than 6 inches in diameter may be appropriate but only in ponderosa pine habitat type, without using heavy equipment, and when there are no adverse effects to old-growth dependent, management indicator, sensitive, threatened or endangered species.

Native Fish and Water Quality

The best available scientific information on bull trout supports the following specific, numeric and measurable standards for protection of the Primary Constituent Elements of bull trout habitat. Protecting these PCEs in all watersheds will provide benefits for westslope cutthroat trout and other native aquatic species.

Clean- The bull trout is virtually synonymous with water quality. Bull trout require very clean water and favor streams with upwelling groundwater for spawning (Fraley & Shepard 1989; Baxter & Hauer 2000). Of the many threatened and endangered fish species, bull trout are the most sensitive to changes in water quality, particularly from fine sediments generated by logging and grazing activities. Fine sediments can smother spawning beds and degrade other habitat components. A key determinant is the level of fine sediment ≤ 6.35 mm (Weaver & Fraley 1991) and protecting upwelling groundwater. Protection of critical habitat includes standards to maintain and improve water quality and control lethal sediments. For example, fine sediments < 6.4 mm in diameter must be limited to less than 20% in spawning habitat (Espinosa 1996) and standards must be developed to maintain groundwater.

Cold- Bull trout also require colder water than other native fish. Rieman & McIntyre (1993) reported that researchers recognize temperature more consistently than any other factor influencing bull trout distribution (see also, Pratt 1992). Habitat protection efforts must seek to maintain or reacquire natural cold water conditions. Specifically, stream temperatures in current and historic spawning, rearing and migratory corridor habitats should not exceed 6-8 C for spawning, with the optimum for incubation from 2-4 C (McPhail & Murray 1979); 10-12 C for rearing habitat, with 7-8 C being optimal (Goetz 1989); migratory stream corridors should be 12 C or less.

Complex- Critical habitat for bull trout isn't just a set of places, but rather a complex arrangement of environmental conditions. Noting that "watersheds must have specific physical characteristics to provide habitat requirements for bull trout to successfully spawn and rear," in its 1998 listing rule the Service listed the habitat components: "water temperature, cover, channel form and stability, valley form, spawning and rearing substrates, and migratory corridors." Implicit in this list of habitat requirements is the understanding that habitat critical to bull trout viability consists of a specific set of physical conditions in addition to particular places. For example, the Service explained that "[m]aintaining bull trout habitat requires stream channel and flow stability." And further explained that "[a]ll life history stages of bull trout are associated with complex forms of cover, including large woody debris, undercut banks, boulders and pools." Bull trout not only need clean, cold water, they need places to rest, hide, feed and travel.

Intact forests, which provide bank stability, shade and woody debris for formation and maintenance of pool habitat, are essential. Climate change will have implications for species such as bull trout because they require cold, clean water. Isaak et al (2010) state: "Riparian vegetation, for example, strongly affects near stream microclimates and minimizing near-stream disturbances associated with grazing, roadbuilding and timber harvest, or facilitating rapid vegetative recovery after these disturbances, could help buffer many streams from additional warming."

Climate change will also increase rain on snow events resulting in stream scour. Shelburg et al's (2010) study of bull trout redd scour emphasized the importance of habitat heterogeneity and refugia availability in sustaining salmonid populations at multiple spatial scales. Loss of complex fluvial spawning habitat such as large woody debris contributes to redd scour after rain on snow events. They conclude: "Processes that form complex habitat in association with LWD may partially mitigate against unfavorable discharge regimes, water and sediment yield alterations due to land-use, or future climate change."

Espinosa (1996) recommends that all streams should average ≥ 90% bank stability and that cobble embeddedness in summer rearing habitat should be < 30% and < 25% in winter rearing habitats. Additional indices include channel morphology including large woody debris, pool frequency, volume and residual pool volumes.

The Flathead Lake Biological Station has been studying the aquatic environment in the Crown of the Continent ecosystem for decades. Hauer et al (2007) found that:

> "Streams of watersheds with logging have increased nutrient loading, first as SRP and NO3, which is rapidly taken up by stream periphyton. This leads to increased algal growth that is directly correlated with the quantity of logging within the watershed. The increased periphyton increases particulate organic matter in transport as the algal biomass is sloughed into the stream. We observed this as increased TP and TN in logged watershed streams. Other studies in the CCE

> have shown that increased sediment loading and an incorporation of fines into spawning gravel, especially during the summer and fall base flow period, has a dramatic effect on the success of spawning by bull trout (Salvelinus confluentus). Experiments have shown that as the percentage of fines increases from 20% to 40% there is >80% decrease in successful fry emergence."

Hauer, et al. (1999) also found that bull trout streams in wilderness habitats had consistent ratios of large to small and attached to unattached large woody debris. However, bull trout streams in watersheds with logging activity had substantial variation in these ratios. They identified logging as creating the most substantive change in stream habitats.

> "The implications of this study for forest managers are twofold: (i) with riparian logging comes increased unpredictability in the frequency of size, attachment, and stability of the LWD and (ii) maintaining the appropriate ratios of size frequency, orientation, and bank attachment, as well as rate of delivery, storage, and transport of LWD to streams, is essential to maintaining historic LWD characteristics and dynamics. Our data suggest that exclusion of logging from riparian zones may be necessary to maintain natural stream morphology and habitat features. Likewise, careful upland management is also necessary to prevent cumulative effects that result in altered water flow regimes and sediment delivery regimes. While not specifically evaluated in this study, in general, it appears that patterns of upland logging space and time may have cumulative effects that could additionally alter the balance of LWD delivery, storage, and transport in fluvial systems. These issues will be critical for forest managers attempting to prevent future detrimental environmental change or setting restoration goals for degraded bull trout spawning streams."

Wherever possible, critical habitat protection should extend to the entire hydrologic watershed. Frissell (1999) reported complex interactions between near-surface groundwater and surface waters in bull trout streams, suggesting a more comprehensive approach to watershed protection. Baxter and Hauer (2000) reported that geomorphology and hyporheic groundwater exchange have a strong influence on bull trout redd locations.

Connected- The sciences of conservation biology and conservation genetics show that bull trout have naturally occurred throughout the Northern Rockies and Pacific Northwest in a system of connected watersheds comprising migratory meta-populations of bull trout (Rieman & McIntyre 1993). Blockages to historic migration routes, both physical and thermal, must be addressed to provide access to spawning streams and protect the genetic integrity of the bull trout. Historically occupied, but currently unoccupied habitat must be protected and reoccupied to reconnect bull trout populations throughout their range.

In addition to these standards, roadless and low road density watersheds deserve special protection measures. Numerous scientific studies and reviews have consistently reported that bull trout strong populations, presence and biomass are inversely related to road densities (Huntington 1995; Quigley, et al. 1996; Rieman, et al. 1997). Bader (2000) found that 78% of bull trout "strong populations" were in roadless area with most of the remainder directly downstream from roadless area. Quigley, et al. (1996) reported that roadless and wilderness areas can provide "strong anchors" for salmonid recovery. In recognition of this strong body of scientific evidence, the U.S. Fish & Wildlife Service (1998) recommended that remaining roadless areas within bull trout range be maintained in roadless condition.

Muhlfeld, et al. (2009) evaluated the association of local habitat features (width, gradient, and elevation), watershed characteristics (mean and maximum summer water temperatures, the number of road crossings, and road density), and biotic factors (the distance to the source of hybridization and trout density) with the spread of hybridization between native westslope cutthroat trout *Oncorhynchus clarkii lewisi* and introduced rainbow trout *O. mykiss* in the upper Flathead River system in Montana and British Columbia.

They found that hybridization was positively associated with mean summer water temperature and the number of upstream road crossings and negatively associated with the distance to the main source of hybridization. Their results suggest that hybridization is more likely to occur and spread in streams with warm water temperatures, increased land use disturbance, and proximity to the main source of hybridization.

Lynx

The Fish and Wildlife Service designated critical habitat for lynx that includes the Flathead National Forest. They determined the physical and biological features that are the primary constituent elements (PCEs) or, in other words, the elements of physical or biological features that, when laid out in the appropriate quantity and spatial arrangement to provide for a species' life-history processes, are essential to the conservation of the species. They determined that the PCE specific to lynx in the contiguous United States is:

1) Boreal forest landscapes supporting a mosaic of differing successional forest stages and containing:

(a) Presence of snowshoe hares and their preferred habitat conditions, which include dense understories of young trees, shrubs or overhanging boughs that protrude above the snow, and mature multistoried stands with conifer boughs touching the snow surface;

(b) Winter conditions that provide and maintain deep fluffy snow for extended periods of time;

(c) Sites for denning that have abundant coarse woody debris, such as downed trees and root wads; and

(d) Matrix habitat (e.g., hardwood forest, dry forest, non-forest, or other habitat types that do not support snowshoe hares) that occurs between patches of boreal forest in close juxtaposition (at the scale of a lynx home range) such that lynx are likely to travel through such habitat while accessing patches of boreal forest within a home range.

Lynx in the Rocky Mountains of Montana selected mature, multistoried forests composed of large-diameter trees with high horizontal cover[1] during winter. These forests were composed of mixed conifers that included lodgepole pine, Douglas-fir, and western larch, but predominately consisted of Englemann spruce and subalpine fir in the overstory and midstory. (Squires et al. 2010)

Squires et al. (2010) studied den selection in western Montana. They found that lynx denned in preexisting sheltered spaces created by downed logs (62%), root-wads from wind-thrown trees (19%), boulder fields (10%), slash piles (6%) and live trees (4%). Lynx overwhelmingly prefer preexisting sheltered spaces created by downed logs in mature forests.

Squires also found that lynx generally denned in mature spruce-fir forests with high horizontal cover and abundant coarse woody debris. Eighty percent of dens were in mature forest stands and 13% in mid seral regenerating stands; young regenerating (5%) and thinned (either naturally sparse or mechanically thinned) stands with discontinuous canopies (2%) were seldom used.

Maintaining mature and mid-seral regenerating spruce-fir forests with high horizontal cover and abundant woody debris would be most valuable for denning when located in drainages or in concave, drainage-like basins. Management actions that alter spruce-fir forests to a condition that is sparsely stocked (e.g. mechanically thinned) and with low canopy closure (<50%) would create forest conditions that are poorly suitable for denning.

Squires et al. (2006) results also indicate that lynx preferentially forage in spruce-fir forests with high horizontal cover, abundant hares, deep snow, and large-diameter trees during winter. The high horizontal cover found in multistory forest stands is a major factor affecting winter hare densities. Lynx tend to avoid sparse, open forests and forest stands dominated by small-diameter trees during the winter.

They also sampled vegetative characteristics at kill sites and compared these to other locations along lynx travel routes. Lynx killed prey in areas of even higher horizontal cover than they generally encountered along their snow-tracks.

During winter, lynx preferentially foraged in mature, multilayer forests with Engelmann spruce (Picea engelmannii) and subalpine fir (Abies lasiocarpa) in the overstory and midstory, but these forests also included lodgepole pine, Douglas-fir, and western larch. Forests used during winter were composed of larger diameter trees with higher horizontal cover, more abundant snowshoe hares (Lepus americanus), and deeper snow compared to random availability; multilayer, spruce–fir forests provided high horizontal cover with tree branching that touched the snow surface. During

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[1] Horizontal cover is low hanging conifer boughs that touch the snow, small trees that are tall enough to protrude through the snow and herbaceous vegetation in the understory.

winter, lynx killed prey at sites with higher horizontal cover than that along foraging paths. Lynx were insensitive to snow depth or penetrability in determining where they killed prey.

During summer, lynx broadened their resource use to select younger forests with high horizontal cover, abundant total shrubs, abundant small-diameter trees, and dense saplings, especially spruce–fir saplings. Based on multivariate logistic-regression models, resource selection occurred primarily at a fine spatial scale as was consistent with a sight-hunting predator in dense forests. However, univariate comparisons of patch-level metrics indicated that lynx selected homogenous spruce–fir patches, and avoided recent clear-cuts or other open patches. Given that lynx in Montana exhibit seasonal differences in resource selection, we encourage managers to maintain habitat mosaics. Because winter habitat may be most limiting for lynx, these mosaics should include abundant multistory, mature spruce–fir forests with high horizontal cover that are spatially well-distributed.

Montana is near the southern extent of the lynx's current North American distribution. Here, boreal forests are fragmented into patches of suitable habitat at higher elevations, separated by valleys of open grasslands and dry forest types. Southern lynx populations tend to be small and relatively isolated. Therefore, movement and connectivity among groups is particularly important to maintain persistent populations and to recolonize unoccupied habitat.

Research by Dr. John Squires et al. (2012) modeled movements that indicated lynx selected home ranges at mid-elevations with low surface roughness, high canopy cover and little open grassland vegetation. They found that connectivity between lynx habitat in Canada and the conterminous U.S. is facilitated by only a few putative corridors that extend south from the international border.

They identified a primary lynx corridor from Canada that extends from the Whitefish Range, along the western front of the Swan Range ending near Seeley Lake. And a second corridor along the east side of Glacier National Park to the Bob Marshall Wilderness Complex.

Snowmobile trails may facilitate coyote movements into areas with deeper snow during the winter. (Gese et al. 2013) While direct impacts of snowmobiles on lynx were not documented, the potential impacts of a main competitor, the coyote, are worth mentioning. Due to their use of snowmobile trails, coyotes have the potential to access areas of habitat that might normally be too energetically difficult to access in deep snow. Lynx, with their superior body mass to footload, can access habitats containing deep snow that coyotes might typically avoid. In addition, expansion of current winter recreation use areas may create persistent travel corridors that could be utilized by coyotes. Since coyote use of snowmobile trails was related to how much was available, coyote movements could possibly be altered by limiting snow compaction. Researchers suggest the use of snowmobiles may result in consistent compacted trails within lynx conservation areas which may be detrimental to local lynx populations in the Intermountain West. (Id.)

Threats to lynx and their habitat

Excerpts from the 2013 Lynx Conservation Assessment and Strategy

Climate Change

Several possible effects of climate change on lynx can reasonably be anticipated. These include:
1) potential upward shifts in elevation or latitudinal distribution of lynx and their prey;

2) changes in the periodicity or loss of snowshoe hare cycles in the north;

3) reductions in the amount of lynx habitat and associated lynx population size due to changes in precipitation, particularly snow suitability and persistence, and changes in the frequency and pattern of disturbance events (e.g., fire, hurricanes, insect outbreaks);

4) changes in demographic rates, such as survival and reproduction; and

5) changes in predator-prey relationships. In addition, it is possible that interactions between these variables may intensify their effects.

Timber Harvest

Commercial timber management of conifer forests traditionally has been designed to: reduce tree density and promote tree growth (e.g., precommercial thinning), especially in young regenerating forests; improve growth and vigor of mature trees (e.g., commercial thinning, thinning from below); reduce the vulnerability of commercially-valuable trees to insects and disease (e.g., commercial thinning, group selection); and harvest forest products (e.g., regeneration harvest). Timber management practices may mimic natural disturbance processes but often are not an exact ecological substitute. Some practices, such as use of herbicides to suppress hardwood regeneration, do not have an historical analogue. Timber harvest may differ from natural disturbances by:

- Removing most standing biomass from the site, especially larger size classes of trees, and down logs, which alters microsite conditions and nutrient cycling;

- Creating smaller, more dispersed patches and concentrating harvest at lower elevations in mountainous regions and on more nutrient rich soils, resulting in habitat fragmentation;

- Causing soil disturbance and compaction by heavy equipment, which may result in increased water runoff and slower tree growth at the site; or

- Giving a competitive advantage to commercially-valuable tree species and reducing the structural complexity of the forest through the application of harvest, planting, thinning, and herbicide treatments.

Precommercial thinning has been shown to reduce hare numbers by as much as 2- and 3-fold due to reduced densities of sapling and shrub stems and decreased availability of browse. Researchers believe that the practice of precommercial thinning could significantly reduce snowshoe hares across the range of lynx.

There are anecdotal examples of precommercially thinned stands that subsequently "filled in" with understory trees. Some have suggested this could be a technique to extend the time that understory trees and low limbs provide the dense horizontal cover that constitutes snowshoe hare habitat. At this time, no other data are available to quantify the re-establishment of snowshoe hare habitat and over what time period, or the response by snowshoe hares, as compared with sites that were not precommercially thinned, so this remains an unproven management technique.

Uneven-aged management (single tree and small group selection) practices can be employed in stands where there is a poorly developed understory, but have the potential to produce dense horizontal cover for snowshoe hares. Removal of select large trees can create openings in the canopy that mimic gap dynamics and help to maintain and encourage multi-story attributes within the stand.

If removal of large trees opens the canopy to the extent that the patch functions as an opening, this may discourage use by lynx. Removal of larger trees from mature multi-story forest stands to reduce competition and increase tree growth or resistance to forest insects may reduce the horizontal cover (e.g., boughs on snow), thus degrading the quality of winter habitat for lynx. Similarly, removing understory trees from mature multi-story forest stands reduces the dense horizontal cover selected by snowshoe hares, and thus reduces winter habitat for lynx.

Lynx habitats in higher-elevation spruce-fir forests have been less affected by past fire suppression and are mostly within the historical range of variability.

In much of the Rocky Mountains, the fire regime was more variable in lynx habitat, with both frequent (35–100 years) stand-replacing or mixed-severity fires, and infrequent (200+ years) stand-replacement fires (Hardy et al. 1998).

Fragmentation

Fragmentation of the naturally patchy pattern of lynx habitat in the contiguous United States can affect lynx by reducing their prey base and increasing the energetic costs of using habitat within their home ranges. Direct effects of fragmentation on lynx include creation of openings that potentially increase access by competing carnivores, increasing the edge between early-successional habitat and other habitats, and changes in the structural complexities and amounts of seral forests within the landscape. At some point, landscape-scale fragmentation can make patches of foraging habitat too small and too distant from each other to be effectively accessed by lynx as part of their home range. Maintaining preferred habitat patches for lynx and hares within a mosaic of young to old stands in patterns that are representative of natural ecological processes and disturbance regimes would be conducive to long-term conservation.

Recommendations

- Increase the amount of old growth and mature multi-story habitat on the Flathead. Historically old-growth habitat was 15% to 60% (source Amendment #21). Current old-growth averages 11.6% across the Forest and ranges between 6.9% to 12.7% (source 1999 – 2007 Forest Plan Monitoring Report). Old-growth forest habitat must be increased to the historical range. Winter habitat may be most limiting for lynx, so maintaining and recruiting abundant multistory, mature forests with high horizontal cover is especially important.

- Reduce fragmentation of mature multi-story habitat. Forest patch size in late successional forest structure has been significantly reduced from historical levels. Horizontal cover is especially important for snowshoe hare habitat and winter lynx habitat.

- Pay special attention to maintaining or recruiting high horizontal cover and mature stands in the corridors identified by Dr. Squires that extend from Canada through the Whitefish Range, along the western front of the Swan Range ending near Seeley Lake. And the second corridor along the east side of Glacier National Park to the Bob Marshall Wilderness Complex.

Fisher

New research shows that the Rocky Mountain Fisher selects for large, old trees, snags and dense overhead cover more than had been previously thought. Research also shows that Fisher do not select and use riparian areas as much as biologists had hypothesized. Retention and recruitment of connected old-growth forest habitats is very important to maintain viability of fisher; relying on riparian buffer zones is not adequate.

From: Meta-analysis of habitat selction at resting sites by fishers in the pacific coastal states and provinces (Aubry et al. 2013)

Thus, throughout their Pacific coastal range, fishers exhibited clear and remarkably consistent selection for resting sites that had steeper slopes; cooler microclimates; denser overhead cover; greater volume of logs; greater basal area of large conifers, hardwoods, and snags; and larger diameter conifers and hardwoods than were generally available.

That is, fishers appear to be selective of relatively dense overhead cover and large forest structures at resting sites simply because they use relatively large trees, snags, and logs for resting, and the forest conditions around such structures differ from those that occur randomly in the forest.

Even with this sampling design, however, they were able to demonstrate selection of denser canopy cover and larger trees and snags at resting sites than were generally available, indicating that fishers are actively selecting specific environmental conditions around resting structures.

From Conservation of Fishers (Martes pennanti) in South-Central British Columbia, Western Washington, Western Oregon, and California–Volume III: Threat Assessment (Naney et al. 2012)

All known fisher reproductive dens are in cavities in live trees or snags. Reproductive dens are typically in the oldest and largest trees available. These den trees require extensive time periods to develop, because of size and time for ecological processes to occur that create cavities (Volume I, Chapters 7 and 8). Structural elements (e.g., large trees with cavities and platforms) are also used extensively by males and females for resting (Volume I, Chapter 7). There are no reported empirical thresholds at which reduction of structural elements may begin to negatively affect fishers.

Moderate to dense canopy closure provides key habitat features, and overstory trees provide one of the key components of this cover. They also contribute to the structural diversity of forested environments. Overstory trees also contribute to current and future structural elements and prey species abundance and diversity. One of the most consistent predictors of fishers appears to be expanses of forest with moderate to high canopy cover (Volume I, Chapter 7).

Evaluating the effects of fragmentation on any species is a function of several interacting factors: 1) the scale of fragmentation in relation to the scales at which an animal interacts with its environment, 2) the pattern and extent of fragmentation within a given scale, and 3) the degree of contrast between the focal habitat and the surrounding areas (Franklin et al. 2002b). Fishers have relatively large home ranges, use habitat at multiple spatial scales, and typically avoid areas with little or no contiguous cover (Volume I, Chapter 7). Fragmented landscapes may affect landscape permeability, either permanently through vegetation type conversion or temporarily until vegetation recovery occurs (Green et al. 2008). Anthropogenic (e.g., urban development) and natural features (e.g., large rivers; Wisely et al. 2004) can also act as filters to fisher movements. We concluded that fragmentation can affect fishers' use of the landscape because moderate to high amounts of contiguous cover are a consistent predictor of fisher occurrence at large spatial scales (Volume I, Chapter 7).

From Biology and conservation of martens, sables, and fishers: a new synthesis (Raley et al. 2012)

However, available evidence indicates that the incidence of heartwood decay and cavity development is more important to fishers for denning than is the tree species. Other characteristics, such as the size and height of the cavity opening and the interior dimensions of the cavity, may also influence females' choice of natal and pre-weaning den structures. The cavity must be large enough to accommodate an adult female and 1–4 growing kits, and have a relatively small opening (just large enough for a female to fit through) high off the ground (15–26 m on average; e.g., Aubry and Raley 2006; Weir and Corbould 2008; Thompson et al. 2010). These characteristics may be important for excluding potential predators and aggressive male fishers.

Presumably, the cavity must also have adequate thermal properties to protect kits from weather extremes. Compared with ambient temperatures, tree cavities provide stable microclimates with narrow temperature fluctuations (Sedgeley 2001; Weir and Corbould 2008; Coombs et al. 2010). Most (75%) of the dens used by reproductive female fishers were in live trees. Cavities in relatively large live trees appear to have more stable temperatures during the day, and stay warmer at night, than those in relatively small snags (Wiebe 2001; Coombs et al. 2010). Other factors, such as the orientation of the cavity and exposure to sunlight (i.e., amount of canopy cover), may also influence the thermal properties of cavities, but quantitative evidence is lacking.

Fisher resting habitat in western North America is also strongly tied to forest structure. Fishers typically rest in large deformed or deteriorating live trees, snags, and logs, and forest conditions around the rest structures (i.e., the rest site) frequently include structural elements characteristic of late-seral forests.

Fishers rested primarily in deformed or deteriorating live trees (54–83% of all rest structures identified in individual studies), and secondarily in snags (6–26%) and logs (3–20%; e.g., Weir and Harestad 2003; Zielinski et al. 2004b; Aubry and Raley 2006; Purcell et al. 2009). The species of trees and logs used for resting appeared to be less important than the presence of cavities, platforms, and other microstructures. In live trees, fishers rested primarily in rust brooms in more northern study areas (Weir and Harestad 2003; Weir and Corbould 2008; Davis 2009) and mistletoe brooms or other platforms elsewhere (e.g., Self and Kerns 2001; Yaeger 2005; Aubry and Raley 2006). In contrast, fishers primarily used cavities when resting in snags (e.g., Self and Kerns 2001; Zielinski et al. 2004b; Purcell et al. 2009). Fishers used hollow portions of logs or subnivean spaces beneath logs more frequently in regions with cold winters (e.g., Weir and Harestad 2003; Aubry and Raley 2006; Davis 2009) than those with milder winters (e.g., Yaeger 2005; Purcell et al. 2009; Thompson et al. 2010). These results suggest that fishers use structures associated with subnivean spaces to minimize heat loss during cold weather (Weir et al. 2004; Weir and Corbould 2008).

When engaged in active behaviors (e.g., foraging, traveling), fishers in western North America were frequently associated with complex forest structure. In general, active fishers were associated with the presence, abundance, or a greater size of ^{3} 1 of the following characteristics: logs, snags, live hardwood trees, and shrubs (e.g., Carroll et al. 1999; Slauson and Zielinski 2003; Weir and Harestad 2003; Campbell 2004).

Fisher habitat in western North America is intricately linked to a complex web of ecological processes that include natural disturbances (e.g., wind, fire), tree pathogens, and other organisms (e.g., primary excavators) that create and influence the distribution and abundance of microstructures (e.g., cavities, mistletoe brooms) in live trees, snags, and logs. Because female fishers rely exclusively on tree cavities for reproduction, we conclude that heartwood decay by heart-rot fungi, the process by which most reproductive den cavities are created, is an essential component of fisher denning habitat in western North America. This ecological process is also important for creating the microstructures that fishers use for resting (cavities in live trees and snags, and hollows in logs).

In western North America, a moderate to dense forest canopy is one of the strongest and most consistent predictors of fisher distribution and habitat use or selection at all spatial scales. The association of fishers with high amounts of canopy cover is further demonstrated by their avoidance of open environments.

Similarly, fisher occurrence in the Rocky Mountain region was positively correlated with canopy cover up to an apparent threshold of 60% (Carroll et al. 2001).

Previously, it was thought that fishers in western North America may favor riparian forests (Buskirk and Powell 1994; Powell and Zielinski 1994); however, results from recent studies do not support this hypothesis. Although riparian forests were important to fishers in some locales (e.g., black cottonwood [Populus balsamifera trichocarpa] forests provided denning habitat in British Columbia; Weir and Corbould 2008), consistent use or selection for riparian forests has not been demonstrated.

From Stand- and landscape-scale selection of large trees by fishers in the Rocky Mountains of Montana and Idaho (Schwartz et al. 2013)

Perhaps the most compelling result from this study was the consistent selection by female fishers for large trees at both stand and landscape scales

Thus, we recommend that silvicultural treatments of stands consider not only the retention of large trees, but consider the larger landscape when managing for fishers.

These results are similar to Jones and Garton (1994) who found fishers selecting mature and old growth forests during the summer in Idaho. Yet, during the winter, they found fishers using a wider array of habitats, although still selecting for the larger diameter trees compared to random (Jones and Garton, 1994). Zielinski et al. (2004) studied West Coast fisher habitat selection at resting locations in the Coastal Mountains and Sierra Nevada of California. They found that standing trees of California black oak and Douglas-fir of the largest diameter available were used in each area, respectively. In their Sierra study area their resource selection function showed that fishers selected sites nearby water, on steeper slopes, with larger maximum DBH trees at sites with more variable tree DBH than random. They interpreted these results to suggest that managers can maintain fisher resting habitat by retaining large trees and using forest management practices that aid in the recruitment of trees that achieve the largest sizes. They also recommend increasing structural diversity at these sites. We concur with these forest management recommendations in reference to NRM fishers as well.

Fishers likely avoid the ponderosa pine stands as they reflect the drier environments in the study area and generally have less understory cover to offer protection (Graham and Jain, 2005; Keeling et al., 2006). Avoidance of lodgepole pine is likely related to the relatively small diameter of even the oldest trees (i.e., mature sizes of lodgepoles in the Northern US Rocky Mountains is between 18 and 33 cm DBH; Burns and Honkala, 1990). This is consistent with evidence for fisher's selection for western red cedar stands, a species with large DBH and associated with wetter, more structure filled environments.

We recommend retention of large decadent trees and snags in areas with large trees to provide denning habitat for female fishers. While we identified univariate patterns of selection for variables that indicate structure, we also found avoidance of variables such as landscapes with a high proportion of grass, suggesting the corollary – avoidance of open areas - is also true. This is similar to results from Weir and Corbould (2010), where fishers avoided open areas, non-forested ecosystems, and areas with recent logging.

In this study, we found that females are indeed selecting habitat at two scales: a stand scale as indicated by stands that have large mean and maximum DBH trees (as well as a large variation in tree size) and a landscape scale as indicated by the preference for landscapes with a high proportion of large trees. Thus, it appears that while fishers can be detected in riparian stringers that bisect open landscapes, this habitat may not be sufficient for persistence. The converse is also likely true. Landscapes that do not have variation in large trees, snags, and cavities, and drier landscapes (i.e., landscapes with ponderosa and lodgepole pine) are probably not sufficient for fisher persistence either. Forest activities that promote the growth of multi-stage stands with ample structure and variation in tree widths and ages will provide the best habitat for fishers. Retaining trees that have decadence, disease, or defects will help provide some of this habitat.

From Factors affecting landscape occupancy by fishers in north-central British Columbia (Weir and Corbould, 2010)

Fishers showed strong selection for where they established home ranges within the landscape, avoiding establishing home ranges in areas with high densities of open areas. Being that fishers establish home ranges only where there is a sufficient concentration of suitable habitat (Powell 1994), our observation that fishers excluded wetland ecosystems and recently logged stands from their home range may be linked to the low densities of resources found in these areas. Wetlands and recently logged areas typically have little overhead cover, which likely exposes fishers to greater risk from aerial predators (Powell and Zielinski 1994). Further more, escape cover, such as trees for climbing, is farther apart in these environments, making fishers further susceptible to terrestrial predators.

The relationship between the extent of open areas and probability of home range occupancy suggests that past and proposed forest harvesting can strongly affect the ability of the landscape to support fishers, especially in landscapes in which wetland ecosystems are common. Landscapes with previous widespread and intensive forest harvesting may lose their ability to support fishers until these harvested areas regenerate sufficiently. Depending on the residual density of fishers in the harvested landscape, fishers need to disperse from adjacent areas with less forest harvesting for these landscapes to support resident fishers again. Intensive forest harvesting in the future may exacerbate the already diminished ability of modified landscapes to support fishers, particularly in forests that are slated for salvage harvest of diseased or damaged trees.

Because salvage harvest of beetle-killed trees typically involves clear cut harvesting, whereby all tree species (including spruce and fir) and secondary structure within the harvest unit are felled or cleared, our results suggest that this expedited harvest will gravely affect the ability of these landscapes to be occupied by fishers.

Soils

Soils are the foundation of terrestrial life. Forest productivity is directly tied to soil conditions. Soil takes thousands of years to develop and is not ‘renewable’ on a human time scale. Soil is an ecosystem in itself that must be healthy in order to provide for healthy forests, grasslands, and aquatic systems. Actions impacting such complex systems are prone to unintended consequences. Given the life-support role soils play, special care and prudence are essential.

The National Forest Management Act (NFMA) prohibits “irreversible damage” to soils as well as “substantial and permanent impairment of productivity of land”. Loss of soil (erosion) and displacement clearly cause “irreversible damage” and “permanent impairment of productivity of land”. Loss of coarse woody debris causes soil damage that can last a century or more. Soil compaction negatively impacts soil productivity, overland flow, erosion, stream sedimentation, and late season flows. Soil compaction from logging can persist 50 – 80 years. (ICBEMP, Assessment of Ecosystem Components, 1997)

Avoiding soil damage is the only option; full restoration of soil damage is not generally possible. Compacted soils are not completely mechanically restorable. Mechanized decompaction is only partially effective at decompacting and can compound problems by mixing rock and mineral soil with topsoil resulting in long term reduced productivity. Replacing eroded or displaced soil is problematic. Artificial coarse woody debris replacement is not practical over large areas such as burned clearcuts.

Timber harvest practices including road building, log skidding and slash disposal have caused most soil damage on forest lands.

Nutrient recycling is a critical function of soils that historically has been damaged by treatments that negatively affect the amounts, types, and distribution of organic matter retained on site. (Graham, R. T., 1990) Many years of piling and windrowing of slash using dozer blades has removed not only the litter plus duff layers but also the thin layer of organic rich mineral soil (A horizon) from large acreages of forested lands. (McBride, personal communication) Guidelines for retaining adequate coarse woody debris should be developed based on the site potential and be within the historic range of variability for the fire regime of the site. Coarse woody debris needs to be maintained at natural levels in the interface zone, with exception granted immediately around structures and residences. (Harvey, 1987).

Control of livestock concentration, especially in sensitive riparian areas is essential to maintaining soil porosity and bulk density. The moist soils in these areas become compacted by concentrations of cattle in only a few days. (Warren, S.D., 1986; BNF soil monitoring reports) Gentle upland ridge tops and swales are other “gathering places” for cattle that require special efforts to control their distribution to protect soils from detrimental compaction.

The process of nutrient cycling on the forest lands is primarily effected through fire; this recycling is key to forest and grassland ecosystem health. Therefore, the use of fire when treating vegetation should be in accordance with the natural fire regime for the site, and organic matter left on site should be within the natural historic range of variability for the site type. (Fischer, W. C., 1987)

Mycorrhizal fungi are an essential component of productive soil. (Amaranthus, M. P., 1996) Most regeneration failures may be due to problems with mycorrhizae. Monitoring mycorrhizae needs to be part of soil condition assessments. Mycorrhizae are very temperature sensitive, so soil temperatures need to be monitored.

Monitoring of detrimental soil disturbances needs to include: compaction, displacement, rutting, severe burning, erosion, loss of surface organic matter (especially coarse woody debris), soil mass movement, soil temperature, and damage to micro-biological components of soil (especially mycorrhizal fungi).

Given that monitoring has demonstrated an extensive legacy of soil damage, it is time to include that information in watershed health assessments. There needs to be an inventory of where these highly damaged soils occur and the extent to which they are damaged. The Forest Plan needs to quantify the acreages by watershed and do cumulative effects analysis, including the road systems to understand the full impact management has had on watershed health.

Elk

Elk and other big game require secure habitat, low road densities, winter and summer thermal cover and special features such as wet sites, riparian habitat, licks, and movement corridors.

From Defining Elk Security: The Hillis Paradigm. 1991 Proceedings of a Symposium on Elk Vulnerability, Montana Chapter of the Wildlife Society (Hillis et al. 1991)

- Guidelines for elk security are a minimum of 250 acres for providing security under favorable conditions; under less favorable conditions the minimum must be >250 acres. Effective security areas may consist of several cover-types of the block is relatively unfragmented. Among security areas of the same size, one with the least amount of edge and the greatest width generally will be the most effective. Wallows, springs and saddles may require more cover than other habitats.

- Generally, security areas become more effective the farther they are from an open road. The minimum distance between a security area and an open road should be one half mile. The function of this ≥ one half mile “buffer” is to reduce and disperse hunting pressure and harvest that is concentrated along open roads. Failure to accomplish this function will reduce the effective size of the security area and may render it ineffective. When cover is poor and terrain is gentle, it may require > one half mile from open roads before security is effective.

- Roads may be closed to motorized travel to provide security and a buffer between security areas and open roads. However, the minimum distance between open roads and security areas increases as closed-road densities increase within both the security area and buffer.

- To be biologically meaningful, analysis unit boundaries should be defined by the elk herd home-range, and more specifically by the local herd home-range during hunting season. Elk vulnerability increases when less than 30% of analysis unit is comprised of security area.

- These guidelines represent minimums and do not necessarily justify reducing security to meet these levels (i.e., if 50% of an analysis unit is security, do not assume that 20% of the unit is excess security).

Hillis, J. Michael, Michael J. Thompson, Jodie E. Canfield, L. Jack Lyn, C. Les Marcum, Patricia M. Dolan, David W. McCleerey; Defining Elk Security: The Hillis Paradigm. 1991 Proceedings of a Symposium on Elk Vulnerability, Montana Chapter of the Wildlife Society.

From Elk Management in the Northern Region: Considerations in Forest Plan Updates or Revisions (Christensen et al. 1993)

- Considerations for Forest Plans Related to Habitat Effectiveness
  - Roads: density (miles/square mile), construction standards, seasons of use, method of closure. Roads are undoubtedly the most significant consideration on elk summer range. Any motorized vehicle use on roads will reduce habitat effectiveness (including administrative use).
  - Special features: wet sites, riparian habitat, licks, movement corridors. These sites are highly desirable for forage, water, temperature regulation, movement or a combination. Such sites should be recognized and protected; avoid damaging these features where elk are a benefiting resource.
  - Cover: extent, shape, size, connectiveness. Cover analysis includes maintenance of security, landscape management of coniferous cover and monitoring elk use. Cover unit size, patterns on a landscape basis, connectiveness with other cover, the amount of cover available to elk and know use patterns by elk should be considered in prescriptions.
  - Scale of analysis: site specific, herd unit, habitat analysis unit
  - Spatial relationships: intermingled ownerships, adjacent administrative units, district or forest “averaging”
  - Domestic livestock: forage and spatial competition.

- Levels of habitat effectiveness:
  a. For areas intended to benefit elk summer range and retain high use, habitat effectiveness should be 70% or greater.
  b. For areas where elk are one of the primary resource considerations habitat effectiveness should be 50% or greater.
  c. Areas where habitat effectiveness is retained at lower than 50% must be recognized as making only minor contributions to elk management goals.
  d. Reducing habitat effectiveness should never be considered as a means of controlling elk populations.

- Considerations for Forest Plans Related to Elk Vulnerability
  - Roads: season of use, density.
  - Security areas: distance from roads, size, cover characteristics, closures (area), topographic characteristics.
  - Cover management: description, connectiveness, scale, terrain relationships.

- Mortality models: demonstrated predictors of elk mortality based on habitat quality, hunter density, or other factors.

Wildfire And Salvage Logging

Salvage logging after wildfires has significant detrimental impacts to soils, wildlife habitat, birds, water quality and fish.

From Wildfire and salvage logging: Recommendations for ecologically-sound post-fire salvage management and other post-fire treatments on federal lands in the West (Beschta et al 1995):

POST-FIRE PRINCIPLES

We recommend that management of post-fire landscapes should be consistent with the following principles:

1) Allow natural recovery and recognize the temporal scales involved with ecosystem evolution.

Human intervention on the post-fire landscape may substantially or completely delay recovery, remove the elements of recovery, or accentuate the damage. In this light there is little reason to believe that post-fire salvage logging has any positive ecological benefits, particularly for aquatic ecosystems. There is considerable evidence that persistent, significant adverse environmental impacts are likely to result from salvage logging, based on many past cases of salvage projects, plus our growing knowledge of ecosystem functions and land-aquatic linkages. These impacts include soil compaction and erosion, loss of habitat for cavity nesting species, loss of structurally and functionally important large woody debris. Human intervention should not be permitted unless and until it is determined that natural recovery processes are not occurring.

2) No management activity should be undertaken which does not protect soil integrity.

Soil loss and soil compaction are associated with both substantial loss of site productivity and with off-site degradation. Decreased infiltration, increased overland flow, and excess sedimentation all directly contribute to the degradation of forest soils and the off-site degradation of aquatic systems and reduced survival of aquatic species, including salmonids. Reduction of soil loss is associated with maintaining the litter layer. Although post-burn soil conditions may vary depending upon fire severity, steepness of slopes, inherent erodibility, and others, soils are particularly vulnerable in a burned landscape. Soil and soil productivity are irreplaceable in human timescales; therefore, post-burn management activities that accelerate erosion or create soil compaction must be prohibited.

3) Preserve species' capability to naturally regenerate.

From an ecological perspective, there is frequently no need for artificial regeneration. Artificial reintroduction of species will circumvent natural successional changes, are often unsuccessful and will have unanticipated side effects even if successful. If native species are failing to reestablish naturally, that failure will frequently be associated with other reasons than the absence of seed sources or colonists. If warranted, artificial regeneration should use only species and seed sources native to the site, and should be done in such a way that recovery of native plants or animals is unhampered.

4) Do not impede the natural recovery of disturbed systems.

Delays in recovery may increase the likelihood of extirpation of stressed populations, or may alter the pathway of recovery altogether. As a practical example, areas that have experienced the effects of a severe burn and are likely to exhibit high erosion should not be subjected to additional management activities likely to contribute to yet more sedimentation. Efforts should focus on reducing erosion and sedimentation from existing human-caused disturbances, e.g., roads, grazing, salvage logging.

RECOMMENDATIONS ON POST-FIRE PRACTICES

1) Salvage logging should be prohibited in sensitive areas.

Logging of sensitive areas is often associated with accelerated erosion and soil compaction (Marston and Haire 1990), and inherently involves the removal of large wood which in itself has multiple roles in recovery. Salvage logging may decrease plant regeneration, by mechanical damage and change in micro-climate. Finally, logging is likely to have unanticipated consequences concerning micro-habitat for species that are associated with recovery, e.g., soil microbes. Salvage logging by any method must be prohibited on sensitive sites, including:

- in severely burned areas (areas with litter destruction),
- on erosive sites,
- on fragile soils,
- in roadless areas,
- in riparian areas,
- on steep slopes,
- any site where accelerated erosion is possible.

2) On portions of the post-fire landscape determined to be suitable for salvage logging, limitations aimed at maintaining species and natural recovery processes should apply.

Dead trees (particularly large dead trees) have multiple ecological roles in the recovering landscape including providing habitat for a variety of species, and functioning as an important element in biological and physical processes (Thomas 1979). In view of these roles, salvage logging must:

- leave at least 50% of standing dead trees in each diameter class;
- leave all trees greater than 20 inches dbh or older than 150 years;
- generally, leave all live trees.

Because of soil compaction and erosion concerns, conventional types of ground-based yarding systems (tractors and skidders) should be generally prohibited. . .

3) Building new roads in the burned landscape should be prohibited. . .

4) Structural post-fire restoration is generally to be discouraged.

Frequently, post-fire restoration efforts involve the installation of hard structures including sediment traps, fish habitat alterations, bank stabilization, hay bales, weirs, check dams, and gabions. Such hard structures are generally not modeled or sited on the basis of natural processes, and their ability to function predictably may be particularly low in dynamic post-fire landscapes. Hard structures have high rates of both failure and unanticipated side effects. Therefore, structures are generally an undesirable and unsuccessful method for controlling adverse environmental impacts. . .

5) Post-fire management requires reassessment of existing management.

For example, the condition of a transportation system (i.e., pre-existing roads and landings) should be reassessed after a fire. By increasing runoff, erosion, and sedimentation, fires may increase the risks posed by existing roads. Therefore, post-fire analysis is recommended to determine the need for undertaking road maintenance, improvement, or obliteration.

6) Continued research efforts are needed to help address ecological and operational issues.

There is a need to research certain questions in order to guide post-fire management decisions. For example, some argue that salvage logging is needed because of the perceived increased likelihood that an area may reburn. It is the fine fuels that carry fire, not the large dead woody material. We are aware of no evidence supporting the contention that leaving large dead woody material significantly increases the probability of reburn." (Beschta et al 1995)

From Forest Service report PNW-GTR-486 "Environmental Effects of Postfire Logging: Literature Review and Annotated Bibliography" (USFS 2000) which reviewed the literature on salvage logging after fire focusing on environmental effects of logging and removal of large woody structure. Following are some of the references used and conclusions drawn:

a) Working on the Entiat burn of 1970 (Wenatchee National Forest), Klock (1975) and Helvey and others (1985) compared five different log retrieval systems (after hand felling) with respect to soil disturbance and erosion: tractor skidding over bare ground (<30 percent slope), tractor skidding over snow (<40 percent), cable skidding over bare ground, skyline (Wyssen skycrane), and helicopter. Klock (1975) found that tractor skidding over bare ground caused the greatest percentage of area of severe soil disturbance (36 percent), followed by cable skidding (32 percent), tractor skidding over snow (9.9 percent), skyline (2.8 percent), and helicopter (0.7 percent).

b) Evidence that logging can affect vegetative production in the absence of significant ground disturbance was collected by Sexton (1994) in a study in central Oregon in postfire ponderosa pine stands, logged over snow. Sexton found that biomass of vegetation produced 1 and 2 years after postfire logging was 38 percent and 27 percent of that produced in postfire unlogged stands. He also found that postfire logging decreased canopy cover, increased exotic plant species, increased graminoid cover, and reduced overall plant species richness. Pine seedlings grew 17 percent taller on unlogged sites in this short-term study.

c) Postfire logging normally removes a great percentage of large dead woody structure and thus has the potential for significantly changing postfire habitat for wildlife (Lindenmayer and Possingham 1995, 1996). These changes include "structural" effects, such as removal of existing and future snags and large woody material, and "functional" effects, such as reduction in insect populations that serve as food for various wildlife species (Blake 1982, Saab and Dudley 1998, Sallabanks and McIver 1998).

d) In four recent independent studies conducted in the intermountain West, postfire logging caused significant changes in abundance and nest density of cavity-nesting birds, although the effect differed somewhat by location (Caton 1996, Hejl and McFadzen 1998, Hitchcox 1996, Saab and Dudley 1998). Most cavity-nesters showed consistent patterns of decrease after logging, including the mountain bluebird and the black-backed, hairy, and three-toed woodpeckers; abundance of the Lewis' woodpecker increased after logging.

e) No studies have specifically looked at how postfire logging alters the size distribution of fuel and the concomitant changes in future fire risk. Work examining fuels on harvested green tree stands suggests that postfire logging may increase short-term fuel loads and fire risk, owing to increased fine activity fuels, but reduce intermediate and long-term fire risk through removal of larger dead structure (Brown 1980).

f) Proper recovery and rehabilitation techniques by managers may be capable of mitigating soil loss and erosion problems associated with postfire logging (Simon and others 1994). For example, ground disturbance caused by postfire logging could disrupt water-repellent layers, increase infiltration, and thus decrease overland flow and sediment transport to streams, which could be a benefit during severe hydrological events. This hypothesis, however, has not been tested experimentally.

From Toward Meaningful Snag-Management Guidelines for Postfire Salvage Logging in North American Conifer Forests (Hutto 2006):

a) Birds in burned forests have very different snag-retention needs from those cavity nesting bird species that have served as the focus for the development of existing snag-management guidelines. Specifically, many postfire specialists use standing dead trees not only for nesting purposes but for feeding purposes as well. Woodpeckers, in particular, specialize on wood-boring beetle larvae that are superabundant in fire-killed trees for several years following severe fire. Species such as the Black-backed Woodpecker (Picoides arcticus) are nearly restricted in their habitat distribution to severely burned forests. Moreover, existing postfire salvage-logging studies reveal that most postfire specialist species are completely absent from burned forests that have been (even partially) salvage logged. I call for the long-overdue development and use of more meaningful snag-retention guidelines for postfire specialists, and I note that the biology of the most fire-dependent bird species suggests that even a cursory attempt to meet their snag needs would preclude postfire salvage logging in those severely burned conifer forests wherein the maintenance of biological diversity is deemed important.

b) The ecological cost of salvage logging speaks for itself, and the message is powerful. I am hard pressed to find any other example in wildlife biology where the effect of a particular land-use activity is as close to 100% negative as the typical postfire salvage-logging operation tends to be.

c) Existing science-based data suggest that there is little or no biological or ecological justification for salvage logging. McIver and Starr (2000) note that because of this, the justification for salvage logging has begun to shift toward arguments related to rehabilitation or restoration, but those sorts of justifications also reflect a lack of appreciation that severe fires are themselves restorative events and that rehabilitation occurs naturally as part of plant succession (Lindenmayer et al. 2004). Interference with the natural process of plant succession by planting or spraying to speed the process of succession toward narrow timber-producing or old-growth goals, as some suggest (e.g., Sessions et al. 2004), is also incompatible with a holistic public-land-management goal of working within the constraints of a natural system. All things that characterize a severe disturbance event, including soil erosion and sometimes insufferably slow plant recovery, are precisely the things that constitute “rehabilitation” for those organisms that need those aspects of disturbance events at infrequent intervals to sustain their populations.

d) The profound failure of many decision makers to appreciate the ecological value of burned forests stems from their taking too narrow a view of what forests provide. The general belief that “dead and dying timber ought to be harvested and put to use” (Schwennesen 1992) prevailed prior to the infamous salvage rider of 1995 (U.S. Congress 1995), and it apparently still prevails today in many management circles. Land managers, politicians, and the public-at-large need to gain a better appreciation of the unique nature of burned forests as ecological communities, how sensitive the process of succession is to conditions immediately following the disturbance event (Platt & Connell 2003), and how important the legacy of standing deadwood is to the natural development of forests (Franklin et al. 2000). Nowhere are soils, special plants, or wildlife more sensitive to the proposition of tree harvesting than in a burned forest. And nowhere is the consideration of ecology more blatantly absent than in decisions to salvage log.

From Wildlife and Native Fish: Issues of Forest Health and Conservation of Sensitive Species (Rieman and Clayton 1997):

a) Although wildfires may create important changes in watershed processes often considered harmful for fish or fish habitats, the spatial and temporal nature of disturbance is important. Fire and the associated hydrologic effects can be characterized as "pulsed" disturbances (*sensu* Yount and Niemi 1990) as opposed to the more chronic or "press" effects linked to permanent road networks. Species such as bull trout and redband trout appear to have been well adapted to such pulsed disturbance. The population characteristics that provide for resilience in the face of such events, however, likely depend on large, well-connected, and spatially complex habitats that can be lost through chronic effects of other management. Critical elements to resilience and persistence of many populations for these and similar species will be maintaining and restoring complex habitats across a network of streams and watersheds. Intensive land management could make that a difficult job.

From Reducing Fire Risks to Save Fish – A Question of Identifying Risk. A position Paper by the Western Montana Level I Bull Trout Team (Riggers et al 2001):

a) Habitat conditions are another factor that has changed significantly. In general, fish habitat quality is much less diverse and complex than historic, and native fish populations are therefore less fit and less resilient to watershed disturbances. Roads, more than any other factor, are responsible for the majority of stream habitat degradation on National Forest Lands in this area (USDA 1997). Historically roads were not present in watersheds and did not affect hydrologic or erosional patterns. Now, however, extensive road networks in many of our watersheds contribute chronic sediment inputs to stream systems and these effects are exacerbated when fires remove the vegetation that filters road runoff.

b) … the real risk to fisheries is not the direct effects of fire itself, but rather the existing condition of our watersheds, fish communities, and stream networks, and the impacts we impart as a result of fighting fires. There, attempting to reduce fire risk as a way to reduce risks to native fish populations is really subverting the issues. If we are sincere about wanting to reduce risks to fisheries associated with future fires, we ought to be removing barriers, reducing road densities, reducing exotic fish populations, and re-assessing how we fight fires. At the same time, we should recognize the vital role that fires play in stream systems and attempt to get to a point where we can let fire play a more natural role in these ecosystems.

c) Salvage of burned trees is often proposed to reduce future fuel loading. While salvage can be accomplished with minimal impacts in some areas, many burned areas are already extremely sensitive to ground disturbance due to the loss of vegetation. Further disturbance can result in increased erosion, compacted soils and a loss of nutrients from these areas (USDA 2000, Beschta et al. 1995).

d) …we believe, in most cases, proposed projects that involve large-scale thinning, construction of large fuel breaks, or salvage logging as tools to reduce fuel loadings with the intent of reducing negative effects to watersheds and the aquatic ecosystem are largely unsubstantiated. Post-fire activities such as these that increase the probability of chronic sediment inputs to aquatic systems pose far greater threats to both salmonid and amphibian populations and aquatic ecosystem integrity than do fires and other natural events that may be associated with undesired forest stand condition (Frissell and Bayles 1996).

From Factors Influencing Occupancy of Nest Cavities in Recently Burned Forests (Saab et al 2004).

a) Recently burned forests in western North America provide nesting habitat for many species of cavity-nesting birds. Year after fire had the greatest influence on occupancy of nest cavities for both groups, while site of the burn was secondarily important in predicting occupancy by strong excavators and less important for weak excavators. Predicted probability of cavity occupancy was highest during the early years (1–4) after fire, declined over time (5–7 years after fire), and varied by site, with a faster decline in the smaller burned site with a greater mosaic of unburned forest.

From Postfire Management on Forested Public Lands of the Western United States (Beschta et al 2004):

a) Scientific assessments of the current condition of forested systems in the western United States consistently yield the same broad conclusions: a century or more of road building, logging, grazing, mining, fire suppression, and water withdrawals, in conjunction with the loss of key species and the introduction of exotic species have degraded watersheds, modified streamflows and water quality, altered ecosystem processes and decreased biological diversity. Past and present actions limit the capacity for ecosystem recovery and reduce the range and abundance of many native species. Although postfire landscapes are often portrayed as “disasters” in human terms, from an ecological perspective they are the result of vital disturbance processes in forests.

b) Following a wildland fire, a common assumption is that immediate actions are needed to rehabilitate or restore the “fire-damaged” landscape. Yet abundant scientific evidence suggests that commonly applied postfire treatments may compound ecological stresses. Perhaps the most critical step in undertaking ecological restoration in the postfire environment is to forgo those activities and land uses that either cause additional damage or prevent reestablishment of native species, ecosystem processes, or plant succession.

c) To protect aquatic ecosystems in areas with moderate to high-severity burns, postfire management should not increase soil erosion or reduce soil productivity. Furthermore, onsite impacts to early successional native plant species during postfire logging, where such species are nitrogen fixers, can significantly affect a major pathway of nutrient replenishment in the postfire environment. Evidence continues to mount of a direct relationship between mechanical disturbance to the postfire environment and accelerated erosion. Soil compaction can persist for 50-80 years in many forest soils.

d) Postfire salvage logging has sometimes been justified on the assumption that >50% crown scorch results in tree mortality. However, trees within low and mid-elevation forests of the western United States possess a suite of adaptations that facilitate fire survival. Stephens and Finney (2000) found that the probability of conifer mortality is low when the percentage of the crown scorch was <60%. For trees greater than or equal to 50 cm dbh, they determined that the probability of mortality of ponderosa pine, incense cedar and white fir was <40% when crown scorch was as high as 80%. The multiple ecological roles of large trees and their high probability of survival supports the need to retain them in burned areas. Postfire salvage logging, based primarily on economic values, typically removes only the largest trees and…

e) Both ground-based yarding systems (tractors and skidders) and, to a lesser degree, cable systems can cause significant soil disturbance and compaction. Such practices should be prohibited in burned areas whenever they are likely to accelerate onsite erosion.

f) Accelerated surface erosion from roads is typically greatest within the first years following construction, although in most situations sediment production remains elevated over the life of a road. Thus, even "temporary" roads can have enduring effects on aquatic systems. Similarly, major reconstruction of unused roads can increase erosion for several years and potentially reverse reductions in sediment yields that occurred with disuse.

g) It is perhaps widely accepted that "best management practices" (BMPs) can reduce damage to aquatic environments from roads. Time trends in aquatic habitat indicators indicate, however, that BMPs fail to protect salmonid habitats from cumulative degradation by roads and logging. Ziemer and Lisle (1993) note a lack of reliable data showing that BMPs are cumulatively effective in protecting aquatic resources from damage.

From other sources, as noted:

"[S]everely burned forest conditions have probably occurred naturally across a broad range of forest types for millennia. These findings highlight the fact that severe fire provides an important ecological backdrop for fire specialists like the Black-backed Woodpecker, and that the presence and importance of severe fire may be much broader than commonly appreciated." (Hutto 2008).

"Whether forests that have been 'restored' through nontraditional harvest methods still retain the characteristics needed by Black-backed Woodpeckers after they burn severely under extreme weather conditions is currently unknown.

The second reason why we cannot assume that suitable postfire habitat will always be ample is that, even though severely burned forests will always be plentiful, postfire logging (a common postfire management practice) also reduces the suitability of burned forests to fire specialists like the Black-backed Woodpecker (Kotliar et al. 2002, Hutto 2006, Hutto and Gallo 2006, Koivula and Schmiegelow 2007, Saab et al. 2007)." (Hutto 2008).

"In contrast, the patterns of distribution and abundance for several other bird species (black-backed woodpecker [Picoides arcticus], buff-breasted flycatcher [Empidonax fulvifrons], Lewis' woodpecker [Melanerpes lewis], northern hawk owl [Surnia ulula], and Kirtland's warbler [Dendroica kirtlandii]) suggest that severe fire has been an important component of the fire regimes with which they evolved. Patterns of habitat use by the latter species indicate that severe fires are important components not only of higher-elevation and high-latitude conifer forest types, which are known to be dominated by such fires, but also of mid-elevation and even low-elevation conifer forest types that are not normally assumed to have had high-severity fire as an integral part of their natural fire regimes. . .

The ecology of selected species (in the present case, fire-dependent species) should be used to understand and embrace the natural processes that prehistorically produced conditions necessary for their maintenance, and not be used to devise artificial means to circumvent those natural processes." (Hutto et al 2008).

"An appreciation of the biological uniqueness of severely burned forests is important because if we value and want to maintain the full variety of organisms with which we share this Earth, we must begin to recognize the healthy nature of severely burned forests. We must also begin to recognize that those are the very forests targeted for post-fire logging activity. Unfortunately, post-fire logging removes the very element — dense stands of dead trees — upon which many fire-dependent species depend for nest sites and food resources.

With respect to birds, the effects of post-fire salvage harvesting are uniformly negative. In fact, most timber-drilling and timber-gleaning bird species disappear altogether if a forest is salvage-logged. Therefore, such places are arguably the last places we should be going for our wood." (Hutto 2013).

"Although the Black-backed Woodpecker is the most extreme species in terms of its restriction to, and evolutionary history with, burned forests, many additional bird species reach their greatest abundance in burned forests (15 of 87 species detected in burned forests, as I noted above). These include the Three-toed Woodpecker, Hairy Woodpecker, Olive-sided Flycatcher, Clark's Nutcracker, Mountain Bluebird, American Robin, Townsend's Solitaire, Cassin's Finch, Dark-eyed Junco, Chipping Sparrow, and Red Crossbill." (Hutto 2011).

"One of the most common management activities following forest fires is salvage logging (Figure 8). Perhaps we need to change our thinking when it comes to logging after forest fires. With respect to birds, no species that is relatively restricted to burned-forest conditions has ever been shown to benefit from salvage harvesting. In fact, most timber-drilling and timber-gleaning bird species disappear altogether if a forest is salvage-logged. Therefore, if we want our land-use decisions to be based, at least in part, on whether a proposed activity affects the ecological integrity of our forest systems, burned forests should be the LAST, rather than the first places we should be going for our wood.

For birds, standing dead trees are one of the most special biological attributes of burned forests. They house equally unique beetle larvae that become abundant because they feast on the wood beneath the bark of trees that have died and are, therefore, defenseless against attack. If we value and want to maintain the full variety of organisms with which we share this Earth, we must not only recognize that burned forests are quite "healthy," but must also begin to recognize that post-fire logging removes the very element — standing dead trees — upon which each of those special bird species depend for nest sites and food resources. "(Hutto 2011).

"Patches of high-intensity fire (where most or all trees are killed) support the highest levels of native biodiversity of any forest type in western U.S. conifer forests, including many rare and imperiled species that live only in high-intensity patches. Even Spotted Owls depend upon significant patches of high-intensity fire in their territories in order to maintain habitat for their small mammal prey base. These areas are ecological treasures." (Hanson 2010).

Beetle-Killed Trees

Beetle killed trees are a natural part of forest ecosystems and promote development of habitat attributes necessary for many other species.

"'But beetle kill is very different. Change induced by beetles is less abrupt, and, unless beetle-killed trees are cut, they remain part of the overstory for years.' Both of these traits have important implications for how a stand regenerates and how watersheds respond." (USFS 2012, quoting Research Biogeochemist Chuck Rhoades).

"'But the sick and dead trees are also losing needles that fall to the ground and help retain soil moisture. And, as trees decay, they release nutrients back into the system.'" (Id., quoting Research Biogeochemist Chuck Rhoades).

"[R]esearchers are already finding that beetles may impart a characteristic critically lacking in many pine forests today: structural complexity and species diversity." (Id.)

"As these infested trees die their diminutive competitors respond vibrantly. Healthy understory plants stand poised, like a carpet of dry sponges, ready to soak up the water, sun, and fertility liberated by the assault around them. Uptake by the surviving understory strongly dampens runoff and nutrient input into waterways downslope." (Id.)

"[T]otal understory plant cover declined in treated sites compared to those where no cutting took place. The difference was apparently driven by the negative responses of several key native species to mechanical harvest. 'Species in the genus Vaccinium declined markedly in our clearcut sites,' she said. 'That genus includes shrubs related to blueberries that are important to some wildlife. They generally suffer in response to disturbance and copious direct sunlight.'" (Id., quoting researcher Paula Fornwalt).

Aside from promoting mixed age structure and helping to maintain native understory communities, retention of the dead [lodgepole] overstory favors a shift in tree species composition. . . 'Those include lodgepole pine, subalpine fir, and aspen, with subalpine fir as the most abundant species of new recruit. (Id., quoting researcher Paula Fornwalt).

Although an increase in subalpine fir may elevate fire risk in forests recovering from beetle infestation, untreated beetle-killed stands may be of great benefit to non-human forest inhabitants. The prevalence of fir following beetle outbreaks could be a boon for wildlife species that rely on the complex vertical structure that is generally lacking in lodgepole pine-dominated stands. The same low fir limbs that can carry fire into the canopy provide food, thermal cover, and protection from predators for a host of wildlife including snowshoe hare, favorite prey for the Canada lynx. Species of conservation concern ranging from Mexican spotted owls to the Canada lynx could respond positively to the structural complexity induced by mountain pine beetles. By driving these shifts at a huge spatial scale, beetles might even be viewed as a biological mechanism for creating the habitats that now limit some of the species we care most about. (Id.)

"[T]he most informative and striking lesson thus far may be the response that occurs in our absence. Apparently without posing serious threats to water quality or long-term ecosystem viability, mountain pine beetles may increase the structural complexity and species diversity of high elevation forests. These characteristics could have substantial benefits in the near term and, perhaps more importantly, they are the keys to improved resilience in our future forests." (Id.)

"A model of nitrate release from Colorado watersheds calibrated with field data indicates that stimulation of nitrate uptake by vegetation components unaffected by beetles accounts for significant nitrate retention in beetle-infested watersheds." (Rhoades et al 2013).

"The lack of a large streamwater nitrate response after extensive canopy mortality caused by bark beetles may be explained by some combination of two factors. Heterogeneous mortality (spatial and temporal) would be expected to reduce the amount of nitrate loss at any given time over the progression of infestation. In addition, compensatory responses by residual live vegetation are likely to respond to the increased resources available following overstory mortality. . . A second step in adaptation of the model is to assume that beetle-induced mortality, although killing much or most of the original canopy, does not disturb beetle-resistant overstory trees and the understory vegetation that would be lost or damaged during tree harvest." (Id.)

"While research is ongoing and important questions remain unresolved, to date most available evidence indicates that bark beetle outbreaks do not substantially increase the risk of active crown fire in lodgepole pine (Pinus contorta) and spruce (Picea engelmannii)- fir (Abies spp.) forests under most conditions. Instead, active crown fires in these forest types are primarily contingent on dry conditions rather than variations in stand structure, such as those brought about by outbreaks. Preemptive thinning may reduce susceptibility to small outbreaks but is unlikely to reduce susceptibility to large, landscape-scale epidemics. Once beetle populations reach widespread epidemic levels, silvicultural strategies aimed at stopping them are not likely to reduce forest susceptibility to outbreaks. Furthermore, such silvicultural treatments could have substantial, unintended short- and long-term ecological costs associated with road access and an overall degradation of natural areas." Black et al 2013.

Post-disturbance harvest is common practice on forest lands and is designed to remove trees or other biomass in order to produce timber or other resources. This type of resource extraction has the potential to inadvertently lead to heightened insect activity (Nebeker 1989; Hughes and Drever 2001; Romme et al. 2006). In particular, snags and fallen logs contribute to the protection of soils and water quality and provide habitat for numerous cavity and snag-dependent species (Romme et al. 2006), many of which prey on bark beetles and other economically destructive insects. Therefore, outbreaks could be prolonged because of a reduction in the beetle's natural enemies (Nebeker 1989), including both insects and bird species that feed on mountain pine beetles (Koplin and Baldwin 1970; Shook and Baldwin 1970; Otvos 1979). Furthermore, post-disturbance harvest can damage soil and roots by compacting them (Lindenmayer et al. 2008) leading to greater water stress in trees, which may reduce conifer regeneration by increasing sapling mortality (Donato et al. 2006) and, in general, may cause more damage to forests than that caused by natural disturbance events (DellaSala et al. 2006). (Id.)

"Ton for ton, dead trees ('snags') are far more important ecologically than live trees, and there are too few large snags and logs to support native wildlife in most areas. Recent anecdotal reports of forest 'destroyed' by beetles are wildly misleading and inaccurate." (Hanson 2010)

Helicopters

Helicopter logging can negatively affect grizzly bears and other wildlife.

"Activities Generally Resulting in a 'Likely to Adversely Affect' Determination: The available scientific literature suggests that high frequency helicopter use, particularly at low altitudes, in habitat occupied by grizzly bears can negatively affect the bears . . . These effects may include disturbance resulting in behavioral changes, such as fleeing from the disturbance; physiological changes, such as increased heart rate; displacement to lower quality habitat; and increased energetic demands." (Summerfield et al 2006).

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