Friends of the Wild Swan
P.O. Box 103
Bigfork, MT 59911

February 8, 2018

Objection Reviewing Officer
USDA Forest Service, Northern Region
26 Fort Missoula Road
Missoula, MT 59804
Via e-mail to: appeals-northern-regional-office@fs.fed.us

Friends of the Wild Swan is objecting to the Draft Record of Decision for the Final Environmental Impact Statement and Forest Plan for the Flathead National Forest.

We incorporate by reference the objections being submitted separately by Swan View Coalition, Brian Peck, Alliance for the Wild Rockies and the Flathead-Lolo-Bitterroot Citizens Task Force. Objections can be found at:
http://www.swanview.org/reports/Brian_Peck_Forest_Plan_Objection.pdf
http://www.swanview.org/reports/SVC_Forest_Plan_Objection.pdf
http://www.swanview.org/reports/AWR_Forest_Plan_Objection.pdf

Friends of the Wild Swan has been involved in projects and planning on the Flathead National Forest since 1987. We have been involved throughout the entire Forest Plan revision process. We participated in numerous public meetings, submitted comments on the Wilderness Suitability Inventory on June 20, 2014, the Proposed Action on May 14, 2015, and the Draft Environmental Impact Statement on September 29, 2016.

In March 2014, along with Swan View Coalition we presented the Flathead with our *Citizen reVision* based on sound scientific and economic principles that defined a sustainable future for the Flathead National Forest emphasizing the outstanding wild, natural and recreational values while taking advantage of the opportunity to create new jobs through restoration work. We asked that this be developed into an alternative in the Environmental Impact Statement.

The main contact for this objection is:

Arlene Montgomery

Arlene Montgomery
Program Director
arlene@wildswan.org
406-886-2011

1) OBJECTION STATEMENT:

The Draft Forest Plan fails to contain measurable habitat objectives or standards for aquatic ecosystems.

Our comments stated

The draft revised forest plan eliminates Riparian Management Objectives for key indicators of native fish habitat such as water temperature, large woody debris, bank stability, lower bank angle, width/depth ratio and pool frequency that were in INFISH. Nor is there a sediment standard even though research in the Flathead watershed by MDFWP has determined that fine sediment levels (>6.35mm) results in bull and westslope cutthroat trout embryo mortality.

Rationale for Objection

The draft Forest Plan is eliminating the Inland Native Fish Strategy's (INFISH) Riparian Management Objectives and not replacing them with any measurable habitat objectives or standards. Instead the Flathead will monitor to determine trends in habitat condition. However, by the time a trend is detected or apparent, degradation has already occurred.

The Flathead admits that pool frequency, water temperature, large woody debris and width/depth ratio in the current Flathead RMOs are applicable on the Forest. Yet will not have a standard or objective for those parameters. A flaw in the INFISH RMOs was that there was no standard or objective for sediment, a key habitat element in bull trout spawning streams. In addition, the Primary Constituent Elements (PCEs) that were designated for bull trout critical habitat and correspond to some of the INFISH RMOs have no equivalent standard for monitoring in the Forest Plan. Instead, the Plan relies on narrative habitat objectives that are subjective and cannot be measured.

In our comments on the draft EIS we noted that the PCE's for bull trout critical habitat were not analyzed. The Flathead's response was that they were analyzed in the FEIS section 3.2.4, the Biological Assessment and Biological Opinion. There is no analysis of the PCEs in FEIS section 3.2.4. The BA and BO are not NEPA documents.

The Forest Plan relies on continuing the Pacfish/Infish Biological Opinion (PIBO) monitoring in lieu of habitat standards and Riparian Management Objectives, but the INFISH BO is replaced by a new BO for the Forest Plan that does not include the PIBO monitoring as a term and condition. So the Flathead could discontinue PIBO monitoring at any time due to funding constraints or any other reason.

Furthermore, INFISH is being replaced with a Northern Region Aquatic and Riparian Conservation Strategy that isn't even developed yet!

REMEDY

Develop numeric Riparian Management Objectives for the Flathead based on local conditions and that will be consistent with maintaining or restoring the Primary Constituent Elements for bull trout.

2) OBJECTION STATEMENT

The draft Forest Plan does not properly delineate lands not suitable for timber production.

Our comments stated
The draft revised Forest Plan eliminates the riparian management area allocation. RMZs were minimally modeled for future vegetation treatments even though they are not in the suitable timber base. Since there are no riparian Management Areas the RMZs may be in 6a, 6b and 6c MAs which allow varying intensities of logging. The Forest Plan needs riparian MAs.

Rationale for Objection
Management areas 6b and 6c are suitable for timber production, salvage logging, wheeled motorized use and over-snow vehicle use. Moderate and high levels of logging are anticipated in them. There are no exceptions to this suitability for riparian areas. Management area 6a is theoretically not suitable for timber production (and supposedly timber harvest will not be scheduled) but it can be logged.

The Flathead claims that riparian areas are not suitable for timber harvest, yet allows logging in them, in FW-GDL-RMZ 08 (If tree harvest activities occur within riparian management zones…), FW-GDL-RMZ 09 (If new openings are created in riparian management zones through even-aged regeneration harvest or fuel reduction activities…), FW-GDL-RMZ 10 (If harvest activities occur within riparian zones…) Also, ground based logging equipment is allowed in the inner riparian zones during winter logging periods (see FW-GDL-RMZ 12). Even road building to facilitate logging is not expressly prohibited (see FW-GDL-RMZ 11 and 14) but can be done when necessary for a road to cross a stream or other exceptions to be determined during project development.

Riparian areas in MA 6a, 6b and 6c are in the timber base and can be logged.

Similarly, the Conservation Watershed Network is defined in the Forest Plan as:

> A conservation watershed network is a collection of watersheds where management emphasizes habitat conservation and restoration to support native fish and other aquatic species. The goal of the network is to sustain the integrity of key aquatic habitats to maintain long-term persistence of native aquatic species. (Page E-5)

Many of the CWN are in MA 6b and 6c. The FEIS discloses that Alternative B modified would potentially have the highest risk of impact to aquatic species based on the proportion of regeneration harvest. (Page 137) Clearly, the management emphasis in MA 6b and 6c is not to emphasize habitat conservation and restoration but to emphasize logging and road building (even temporary roads have significant impacts). It is hard to fathom how selecting an alternative that has the highest risk of impacts to aquatic species is consistent with the CWN goal to sustain the integrity of key aquatic habitats. [Note that Alternative C has the least risk for logging runoff and sedimentation to streams because it has the least amount of regeneration logging.]

We asked that the Forest Plan Appendix E contain a table that lists the streams, native fish occupancy and status. This was not done. However, after reviewing Van Eimeren and Gardner, 2017 we see that integrated rating for important native fish watersheds in the CWN are not up to par. For example (and this is not a complete list but just to illustrate), Beaver, Cold and Red

Meadow watersheds are Functioning at Unacceptable Risk. Jim, Lion, Piper, Lower Spotted Bear River, Sullivan, Quintonkin and Wheeler are Functioning at Risk. And portions of these watersheds are in MA 6b and 6c.

While we don't disagree that the designation of conservation watershed networks may represent a good long-term conservation strategy for native fishes and their habitat, selection of Alternative B modified, lack of numeric Riparian Management Objectives, and including riparian areas in timber management areas will not meet the goals of the CWN, protect native fish or their habitat.

REMEDY
Delineate a management area for riparian areas that definitively excludes them from the timber base because they are unsuitable for logging.

Remove Conservation Watershed Networks from MA 6a, 6b and 6c.

3) OBJECTION STATEMENT
The revised Forest Plan has no standards or provisions for reducing road densities on the Flathead National Forest.

Our comments stated
The most degraded sediment occurs on the Swan and Tally Lake Ranger Districts yet there is no provision for reducing road densities in the revised Forest Plan.

The 1998 USFWS Biological Opinion for bull trout stated: "there is no positive contribution from roads to physical or biological characteristics of watersheds. Under present conditions, roads represent one of the most pervasive impacts of management activity to native aquatic communities and listed fish species."

The DEIS disregards the large body of science regarding the impacts of roads on aquatic ecosystems and contains one guideline…

The DEIS does not incorporate the USFWS Biological Opinion of the Effects to Bull Trout and Bull Trout Critical Habitat from Road Management Activities on National Forest System and Bureau of Land Management Lands in Western Montana, (2015).

Rationale for objection
In spite of the well documented impacts of roads on water quality and aquatic life, the Flathead is abandoning the current Forest Plan's Amendment 19 that would reduce open and total motorized access density for grizzly bears but would also remove stream aligned culverts on decommissioned roads to benefit aquatic habitat. Instead the Flathead claims that it will have a no net increase in road densities because the baseline road level will be "frozen" at 2011 levels.

This is misleading for a number of reasons.

1. In watersheds that may have reduced road densities below 2011 levels, these can now be increased to 2011 levels.

2. The Flathead is relying on intermittent stored roads, rather than decommissioning roads and in some cases is leaving culverts on stored roads.

3. There is no limit on the miles of temporary roads that can be constructed for projects which can lead to an increase in road densities for 5 years or more in some cases.

4. Some watersheds (especially in the Swan Valley) have very high road densities due to the previous checkerboard ownership or extensive logging by the Forest Service. There is no requirement in the Forest Plan to reduce those road densities even though some of those are bull trout critical habitat or westslope cutthroat trout spawning streams that are Functioning at Risk or at Unacceptable Risk.

5. The Flathead is abandoning the requirement in the USFWS Biological Opinion of the Effects to Bull Trout and Bull Trout Critical Habitat from Road Management Activities on National Forest System and Bureau of Land Management Lands in Western Montana, (2015) to annually inspect and maintain each stream-crossing structure left in place. If annual inspection and maintenance is not feasible remove all stream crossing structures when the road is closed. Instead the Flathead has come up with a new 6-year culvert monitoring scheme that will put water quality and fish habitat in jeopardy because it allows at-risk culverts on closed roads to remain without annual monitoring. [Note, this new culvert monitoring scheme was not available to us when we commented on the DEIS.]

The history of culvert failures on the Flathead due to lack of monitoring and maintenance in addition to best available science showing the harmful impacts of forest roads and culvert failures on water quality, bull trout, and bull trout critical habitat demonstrate it would be arbitrary and capricious for the Forest Service and FWS to modify the Flathead's culvert monitoring requirements. Yet this is exactly what is being done with the new culvert monitoring scheme.

In addition, the Forest Service and FWS have historically under-estimated the number of high-risk culverts on the forest. As early as 2006, FWS found their assumption that 10-15% of culverts would be high risk was incorrect based on Forest Service monitoring that identified 35-40% of culverts as high risk. The Flathead is jeopardizing native fish and water quality by not removing culverts from closed roads and then only monitoring the culverts on those roads every six years. [Exhibit 1 Notice of Intent regarding culverts and bull trout]

REMEDY

Fully comply with and apply the conditions in the USFWS Biological Opinion of the Effects to Bull Trout and Bull Trout Critical Habitat from Road Management Activities on National Forest System and Bureau of Land Management Lands in Western Montana, (2015) to all roads in all watersheds on the Flathead National Forest.

4) OBJECTION STATEMENT

The revised Forest Plan does not contain adequate standards to protect aquatic ecosystems from the effects of roads and the Flathead does not have the budget to maintain its road system.

<u>Our comments stated</u>

The DEIS disregards the large body of science regarding the impacts of roads on aquatic ecosystems and contains one guideline: "Project specific BMPs should be incorporated into road maintenance activities as principle mechanisms for protecting water resources." First, there is no evidence that application of BMPs actually protects fish habitat and water quality. Second, BMPs are only maintained on a small percentage of roads or when there is a logging project. Third, the Flathead is putting hundreds of miles of roads into Maintenance Level 1 intermittent storage which does not require that the road bed be hydrologically secure by removing culverts. Fourth, unmaintained roads with culverts have a higher chance of contributing sediment to streams.

Objection rationale

The Forest Plan relies on several schemes to keep roads on the landscape. None of them will protect water quality and aquatic habitat.

- Best Management Practices

Reliance on Best Management Practices (BMPs) to limit sediment to streams from roads has limitations. First and foremost is regularly maintaining BMPs on roads. For the most part the Flathead National Forest applies BMPs when they have a timber sale and need the roads for hauling. When there is no logging going on, most roads are not maintained to BMP standards.

The Flathead has 3,559 miles of roads with 2,130 miles closed to motorized use and 1,427 miles open to the public for motorized use. Of the closed roads 2,101 miles are in Basic Custodial Care which is Maintenance Level 1, or placed in storage between intermittent uses. Planned road deterioration may occur at this level. In essence these roads will not have BMPs applied.

In fact, in 2015 the Flathead only maintained 494 miles of its total road system or 13%. And only about 34% of its open roads were maintained. So BMPs are not even being applied to 66% of the open roads on the Flathead. The rest are left to languish without maintenance or culvert monitoring.

The Forest Service routinely fails to monitor the effectiveness of BMPs. Without proper monitoring it is impossible to evaluate the cumulative effects of repeatedly relying on the untested and unmonitored effectiveness of the BMPs.

The Flathead references a 2016 report to justify the effectiveness of best management practices related to NFS roads as follows: "Based on the results of **most** of these studies, the case can be made that **most** BMPs [best management practices] result in **some** level of effectiveness in terms of reduced sediment generation or transport" (Edwards, Wood, & Quinlivan, 2016, p. 136) (FEIS Volume IV page 8-107 – emphasis added)

This is hardly a full throated endorsement of BMPs, especially if you happen to be a fish in one of the streams that doesn't get "some" level of BMP effectiveness.

- Total Motorized Route Density (TMRD)

The Forest Plan does not have a standard to limit TMRD on the Forest. It allows an unquantified amount of temporary roads to facilitate timber sales. It caps the TMRD at 2011 levels which in grizzly bear subunits in the Swan Valley are extremely high -- there is no requirement to lower road densities to protect aquatic habitat and water quality in either standards for aquatic life or wildlife (i.e., grizzly bears or elk).

Evaluations of watersheds in the Watershed condition framework found three of the class 2 watersheds are in the Swan Valley: Cold, Jim and Beaver Creek. The other two (Meadow and Middle Logan) are on the Tally Lake Ranger District which also has high road densities. Clean Water Act 303(d) listed impaired waters on the Flathead (Coal, Goat, Jim, Big and Sheppard) are are important bull and westslope throat trout streams (and yes there are high road densities).

Costs to maintain roads in intermittent stored service (ISS) are just avoided in the short term; impacts from the roads and risks to natural resources and wildlife remain. In contrast, road decommissioning may temporarily increase sediment to streams but has dramatic reductions in the long run. The Forest Service's Rocky Mountain Research Station has spent over a decade monitoring the effectiveness of road treatments. A 2012 report evaluating pre and post treatment of roads showed an 80% reduction in sediment delivery to streams when roads were decommissioned.

The Forest Service should also consider decommissioning more roads to achieve its goal of establishing a resilient future forest. Decommissioned roads, when seeded with native species, can reduce the spread of invasive species and help restore fragmented forestlands. Closed roads remain on the landscape and therefore would still present a risk to the ecosystem. Closed roads will continue to fragment wildlife habitat. Little to no maintenance is planned for roads while in storage. In contrast, returning expensive, deteriorating, and seldom used forest roads to the wild would significantly reduce the risks those roads pose to the ecosystem. Decommissioning more road miles would better achieve the needs for the forest.

A strategic reduction in road miles does not necessarily equate to a loss of access. Some roads are already functionally closed, either due to washouts, lack of use, or natural vegetation growth. Other roads receive limited use and are costly to maintain. Resources can be better spent on roads providing significant access than to spread resources thinly to all roads.

The FEIS discloses that road decommissioning repurposes the road area back to productive land base and this reallocation would largely be positive. (Page 101) This results in less weed infestations, less road maintenance costs, more wildlife habitat and cleaner water/fish habitat.

- Culvert monitoring

On top of high road densities and failure to apply BMPs the Flathead is now adding another threat to native fish streams. Instead of complying with a current Biological Opinion that requires culverts on closed roads be monitored annually, the new scheme is to only monitor culverts every six years.

REMEDY

The Forest Plan must contain standards for total road density, must annually monitor culverts and if BMPs are relied on they must be rigorously used (not on just a small segment of the roads).

5) OBJECTION STATEMENT
The Forest Plan does not provide enough old growth forest to support the diversity of wildlife that require this habitat.

Our comments stated
The Flathead really has no idea how much old-growth forest habitat is on the forest, where it is, whether it's connected or enough for old-growth dependent wildlife. Yet, the revised draft Forest Plan proposes vegetation treatments to "promote old growth." The DEIS provides no science to support the logging your way to old growth theory.

Also see the *Citizen reVision* (March 2014) and Friends of the Wild Swan's comments on the proposed action submitted on May 15, 2015.

Objection rationale
The Forest Plan allows current old-growth forest habitat to be reduced to the Green et al. definition minimum amounts and utilizes the untested hypothesis that logging can produce more old growth. See FW-STD-TE&V-01 "In old-growth forest, vegetation management activities must not modify the characteristics of the stand to the extent that stand density (basal area) and trees per acre above a specific size and age class are reduced to below the minimum criteria in Green et al. (2011)." It then lists actions that can occur in old growth habitat that include reducing fuels in the wildland urban interface and addressing human safety. So, in essence old growth can be logged for reasons unrelated to promoting old growth forests characteristics and increasing resilience (although we take issue with the assumption that logging can promote better old growth).

We continue to caution that the minimum characteristics in Green et al, are merely a 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 basal areas. The above standard also does not take into consideration the other attributes that comprise the old growth ecosystem and how logging will impact them. The FEIS mentions studies that illuminate the uncertainty associated with treating old growth forest for the purpose of improving forest conditions and resilience but plows forward with this untested assumption.

The FEIS cites a monitoring report (Renate Bush 2015) of the Meadow Smith Project in the Swan Valley to justify old growth improvement logging but this report only looked at whether the unit's logging prescriptions and treatments were achieved. Neither this report nor the Forest Plan contain monitoring for occupancy and/or abundance of old growth associated wildlife, it's all monitoring for vegetation. Just because logging prescriptions were met or old growth basal area was logged down to the minimum Green et al. amounts does not mean that wildlife are using the old growth in the same way or at all.

The 1986 Forest Plan monitoring was deficient, the Flathead's last monitoring report was in 2010 and even that did not contain adequate monitoring for wildlife. The current Forest Plan's Amendment 21 required monitoring for:

> Occupancy of old growth habitat by old growth associated wildlife species, forest bird distribution, productivity and survivorship; forest carnivore distribution, nesting territories and productivity of bald eagles and peregrine falcons,; vegetation composition structure and pattern in relation to the historical range of variability; proportion of old growth forest and patch sizes by subbasin and watershed; and success in implementing the structural retention standards (large live trees, snags, and coarse woody debris.) (A21 ROD at page 5)
>
> Additional Data Requirements and Accomplishments Schedule:
> Continue old growth survey to fill in data gaps and to verify conditions within candidate old growth stands.
>
> Conduct Forest-wide analysis of reference conditions and trends in landscape patterns.
>
> Assess current and reference conditions to define landscape patterns including patch size, distribution, and connectivity at the watershed scale. (A21 EIS Appendix A page 17)

The Flathead failed to conduct the required Forest Plan monitoring and continues to propose projects that will impact wildlife and its habitat without the benefit of actual data. And where carnivore monitoring was conducted the Flathead has not detected one fisher on the whole Forest. The revised Forest Plan continues this gross omission by not designating even one old growth associated wildlife species as a focal species.

In fact, the Flathead has NO wildlife species designated as a focal species which is defined as:

> A small subset of species whose status permits inferences related to the integrity of the larger ecological system to which it belongs and provides meaningful information regarding the effectiveness of a land management plan in maintaining or restoring the ecological conditions to maintain the diversity of plant and animal communities in the plan area. Focal species are commonly selected on the basis of their functional role in ecosystems (36 § CFR 219.19).

Old-growth forest ecosystems are unique and scarce, by not designating a focal species to monitor the effects of management and natural events on the Forest the Forest Plan is not maintaining the diversity of plant and animal communities in the plan area. Old growth associated wildlife play a functional role in the old growth ecosystem.

This revised Forest Plan should use adaptive management to correct mistaken assumptions from the earlier plan, the revised plan should maintain continuity from the old plan to the new plan based on effects and monitoring but it does not. Rather it continues its abandonment of any wildlife monitoring, management indicator species, sensitive species, does not designate focal wildlife species, designates only three species of conservation concern and forges on as if the landscape is a clean slate.

The Forest Plan allows three trees to be left in a clearcut to contribute to the maintenance and/or development over time of very large desired tree species. This will do little to recruit large trees when many other trees are brought to the mill.

Old growth forest habitat is about 9.5%[1] which is below historic levels and it is severely fragmented. Roads can be constructed in and adjacent to old growth. Forest Plan models indicate that very large tree size class will steadily decline over the next 50 years. Yet the Forest Plan does not contain any provisions to recruit old growth or connect it. The Flathead blames fire, a natural ecosystem process, as the reason for decline yet touts logging as the panacea to have more old growth – this is disingenuous because the Flathead will salvage log any areas that burned further setting back the ecological processes that these forests evolved with.

The Forest Plan does not contain any standards or guidelines for distribution of old growth forest habitat elevationally across the forest.

Research from the Forest Service Pacific Research Station indicates that in order to provide quality woodpecker habitat there needs to be more snags than the Forest Plan standards. If you want to provide 4-14 snags per acre as habitat, you have to leave at least 100 snags per acre. (Exhibit 2. The role of wood hardness in limiting nest site selection in avian cavity excavators.)

Weeds impact native plant and wildlife diversity. The FEIS reveals Alternative C has the least potential for invasive weed establishment and spread associated with motorized uses and ground-disturbing timber activities because of the reduced area suitable for timber production, the lowest proportion of the Forest in summer motorized recreation opportunity spectrum classes and the reduction of motorized roads and trails over time.

The Forest Plan eliminates distance to cover standards. Only retains snags at a minimum level. Allows unlimited temporary road construction and increases system roads that the Flathead cannot afford to maintain. Spreads weeds. And then doesn't even monitor wildlife to see what the impacts are! This is not maintaining or protecting wildlife viability and diversity.

REMEDY
The Forest Plan must contain a standard for the future desired amount of old growth forest habitat that is connected and well-distributed across the Flathead National Forest.

Designate old-growth associated wildlife as focal species to be monitored.

6) OBJECTION STATEMENT
The Forest Plan does not maintain or restore connectivity throughout the Flathead National Forest.

<u>Our comments stated</u>
The NRLMD does not have any connectivity criteria.

---

[1] FEIS at page 240 states 9.2% old growth forest; page 243 states 9.5% with a range between 8% and 20%. The Proposed Action for the Forest Plan document estimated old growth at 11% forestwide with historic amount between 15% and 60%. Clearly, the Flathead doesn't know how much old growth there was or is.

The revised Forest Plan must contain a provision for travel habitat.

The revised Forest Plan must identify a landscape-wide desired future habitat condition for lynx.

The PA fails to address fragmentation and connectivity for terrestrial wildlife.

Objection rationale

Linkage zones are a key factor that must be considered for carnivores, old-growth associated species and ungulates. This includes but is not limited to grizzly bear, wolves, lynx, fisher, pine marten, wolverine, migratory songbirds, woodpeckers, resident birds, northern goshawk, elk, deer, and mountain goats.

Rather than connect habitat across the forest the Forest Plan Alternative B modified has 465,200 acres suitable for timber production in MA 6b and 6c and approximately half of these acres are comprised of inventoried roadless areas. Add in the logging that can occur in other management areas that are considered not suitable for timber production and logging can occur on approximately 912,400 acres. All of this logging will be piecemealed with individual projects that do not consider the cumulative impacts outside of a particular project area and across the Forest.

The mature forest that is currently present on 35% of connectivity areas would drop to 28% in 50 years.

The Forest Plan purports to rely on FW-STD-TE&V-01 and 03 and FW-GDL-TE&V-06 – 09. However, as noted in Objection #5, these allow logging, road construction, only retain 3 live reserve trees in clearcuts and retain the minimum number of snags. While the desired conditions may sound good, there are no standards to achieve them.

There are no adequate standards, guidelines, or objectives to maintain or protect corridors. Corridors must be useable for wildlife to live in, not just the travel through like humans do on a highway. Corridors must connect to core habitat. There is no plan for wildlife connectivity in the Forest Plan.

REMEDY

Develop an over-arching plan for wildlife to move across the Flathead National Forest, map it, and monitor wildlife usage.

7) OBJECTION STATEMENT

The Forest Plan's draft Record of Decision to select Alternative B modified will negatively impact fish and wildlife.

Our comments stated

The Forest Service's actions must lead to recovery of threatened and endangered species – not just survival.

Objection rationale

The Biological Assessments for grizzly bear, Canada lynx and bull trout determined that Alternative B modified "may affect, is likely to adversely affect" those threatened species. The purposes of the Endangered Species Act are to provide a means for conserving the ecosystems upon which endangered and threatened species depend and a program for the conservation of such species. It is unconscionable that the Flathead National Forest would manage some of the most important habitat for these imperiled species in a manner that will adversely affect them.

The Forest Plan abandons road density and secure core standards for grizzly bears. Best available science found that a grizzly bear subunit should have no more than 19% open and total motorized route density and no less than 68% secure core.

The Forest Plan Northern Rockies Lynx Management Direction does not have any connectivity habitat criteria. It does not have a limit on how much of a lynx home range could be in a stand initiation stage when the best available science (Kosterman) found it should be no more than 10-15%. The Forest Plan doesn't protect or maintain mature multi-story forest habitat.

The National Forest Management Act requires maintaining the viability and diversity of native wildlife and fish. The current Forest Plan did not complete the Conservation Strategies required for sensitive, management indicator species and did not monitor for them. The revised Forest Plan eliminates management indicator species, does not require Conservation Strategies, and does not even designate focal species.

Alternative B modified does not maintain viability and diversity of sensitive and threatened species.

REMEDY

Develop a Forest Plan that actually benefits the rare wildlife on the Flathead National Forest.

8) OBJECTION STATEMENT

The Forest Plan does not maintain the wilderness character of roadless areas.

Our comments stated

The PA only proposes 188,206 acres for wilderness designation. It parses out inventoried roadless areas for lesser designations such as backcountry non-motorized, motorized year round, over snow vehicle motorized and summer motorized. By doing so areas in the North Fork, Middle Fork and Hungry Horse are chopped up to accommodate users. Coupled with the logging designations the Forest is a fragmented without any thought to wildlife and connectivity.

The revised Forest Plan does not provide any rationale for the reduction in recommended wilderness for Alternative C in DEIS Appendix 4 and those that were analyzed in the August 2014 Wilderness Evaluation Process. The Wilderness Evaluation Process identified 644,899 acres as potential wilderness, Alternative C recommends 506,900 acres for wilderness designation.

Objection rationale

Alternative B modified only recommends wilderness for 190,400 acres. The Wilderness Evaluation Process identified 644,899 acres as potential wilderness. The EIS admits that "Wilderness does provide the ultimate degree of resource protection for aquatic resources." Wilderness is also the most cost effective management of public lands. Yet less than 1/3 of potential wilderness will have its wilderness character preserved until official Wilderness is designated.

The Forest Plan does not designate key roadless sections adjacent to the Mission Mountain Wilderness that will provide greater protection for wildlife, fish and water quality. Instead those roadless sections are slated for motorized vehicle use, logging in MA 6b and road building in the already heavily roaded and logged Swan Valley.

The Forest Plan ignores the Northern Rockies Ecosystem Protection Act that would designate all roadless areas as Wilderness. It currently has 54 co-sponsors in the House of Representatives (HR 2135) and 9 in the Senate (S 936). The EIS failed to even develop an alternative that protected all of these roadless areas as recommended wilderness.

This failure forecloses options for future generations.

REMEDY
Protect all roadless areas as recommended wilderness.

9) OBJECTION STATEMENT
The Forest Plan does not adequately address the impacts of climate change on forest and aquatic ecosystems.

<u>Our comments stated</u>
Eliminating RMOs ignores the best available science and stringent needs of bull trout for cold clean water in the face of climate change.

The best-buffered systems for coldwater species in the face of climate change are likely to be those with a high proportion of very high elevation terrain and some well-developed alluvial floodplains, as well as a lot of natural sinuosity and channel complexity in the mid-reaches that promote entrainment of spring runoff into the local alluvial aquifers, then slow discharge delayed 2-4 months, offsetting summer warm flows with cold hyporheic discharges.

The DEIS fails to analyze the impacts of reducing shade and cover in riparian areas and how that exacerbates the climate change impacts the streams will already be subjected to.

The DEIS relies on the Climate Shield Model, however those results must be viewed with caution. Frissell advised: Climate change modeling projection studies, especially including several at Rocky Mountain Research Station, Young, Isaak, and Luce PIs. Note that predictions from climate forcing models can be seriously inaccurate to predict instream conditions if they do not explicitly take in to account for the routing of flows through shallow groundwater and hyporheic flow compartments.

The management strategies in the draft revised Forest Plan's Appendix C don't reflect the role of fire, insects and other natural processes on the landscape. Management is based on how humans interpret nature, however, we don't know what trees contain the genetic adaptations necessary to survive in a changing climate.

Approaches focusing on resistance often require massive interventions and increasing physical and financial investments over time. Such approaches may set forests up for future outbreaks [136] and even catastrophic failure as they surpass thresholds in a warming climate [140].

To protect lynx and wolverine denning habitat late season snowmobiling should not be permitted. This is especially important due to climate change impacts that can reduce the amount of snowpack leading to conflicts between snowmobiler's wants and wildlife's needs.

Objection rationale

The Forest Plan relies on the same failed policies of more logging and more roads. The mantra of fuels is pervasive but doesn't consider the impacts that logging and thinning have on drying out the forest floor, reducing mychorrizal and other soil fungi, impacts to wildlife food sources, timing of stream runoff including peak flows in the fall from rain events, the fact that we don't know what trees will be resistant to insects and disease, the interactions between groundwater and surface water, impacts of displacement of wildlife from important habitats and food sources, among others.

Forests affect the climate, climate affects the forests, and, just as in the race between climate dynamics and climate policy, the climate may be gaining the upper hand. Overall, climate effects have been increasingly well documented for aquatic, marine, and terrestrial species and systems (Walther et al, 2002). In her review of over 800 research reports, Parmesan (2006) noted that "A surprising result is the high proportion of species responding to recent, relatively mild climate change (global average warming of 0.6 C)." (Excerpts from the comments: A referenced review of combined land development and climate impact on grizzly bears. By Lance Olsen – last revised/updated 1-2-2018. Exhibit 3)

What we do know from past management is that roads negatively impact wildlife, fish and water quality. Clearcut logging does not mimic wildfire and fragments wildlife habitat. Yet this is precisely what the Forest Plan proposes: more logging and more roads.

REMEDY

Select an alternative that incorporates recommending all potential roadless areas as wilderness; maintains the current Forest Plan's Amendment 19 road density and grizzly bear standards; maintains INFISH standards, Riparian Management Objectives and continued PIBO monitoring; management area allocations for riparian and big game thermal and snow interception; connects and recruits old-growth forest habitat and provides for connectivity for wildlife.

10) OBJECTION STATEMENT

The Forest Plan allows snowmobiles and late season snowmobiling in lynx and wolverine habitat without analyzing the impacts of how that will affect the species.

Our comments stated
To protect lynx and wolverine denning habitat late season snowmobiling should not be permitted. This is especially important due to climate change impacts that can reduce the amount of snowpack leading to conflicts between snowmobiler's wants and wildlife's needs.

Objection rationale
Climate change will impact the amount of snowpack and timing of snowmelt. This can lead to more areas being free of snow earlier in the spring and later in the winter which will impact wolverine and lynx. The Forest Plan continues to allow late season snowmobiling in important roadless areas such as Six Mile and Lost Johnny. The 2016 Flathead DEIS (Page 413) revealed that between Dec.1 to March 31 the Flathead Forest provides 788 miles and 513,654 acres for snowmobile use. The FNF allows late-season snowmobiling on 666 miles of routes.

As snow covered areas become more sparse, snow-dependent wildlife such as lynx and wolverine will be left to compete with snowmobilers for denning and foraging in the late winter and spring.

REMEDY
Eliminate late season snowmobiling from the Flathead National Forest. Map areas of winter use by lynx and wolverine and limit snowmobiling in them.

11) OBJECTION STATEMENT
The Forest Plan does not have adequate monitoring to allow for adaptive management and diversity of fish and wildlife.

Our comments stated
The revised Forest Plan must require that conservation strategies be developed for all MIS and sensitive species. This should include monitoring for species presence, not just habitat as proxy, in order to show a positive correlation between species populations and habitat.

Forest Plan revisions should use adaptive management to correct mistaken assumptions from the earlier plan, the revised plans should maintain continuity from the old plan to the new plan based on effects and monitoring.

The Proposed Action allows the agency to claim that logging will improve lynx habitat without providing any research or monitoring data.

The revised Forest Plan must have robust monitoring to ensure that lynx habitat is not degraded and lynx populations are not declining.

Also see Monitoring section of our comments on the Proposed Action.

Objection rationale
The Forest Plan does not contain adequate monitoring for fish and wildlife or their habitat.

It relies on a Region 1 mesocarnivore monitoring that is not yet developed. The current Forest Plan relied on Conservation Strategies for sensitive species being developed by Region 1 but they never were. For example, the Flathead keeps proposing projects in fisher habitat using habitat as a proxy for a species that is not being detected in the sparse monitoring that has been done in the Swan Valley. The fisher conservation strategy required by Amendment 21 was never developed. Rather than develop monitoring for sensitive species the Flathead has eliminated them as Species of Conservation Concern and has not designated one wildlife species as a focal species. Guess that's one way to get around the failure to conduct monitoring that was in the current Forest Plan, eliminate any species monitoring.

There is no monitoring to determine whether logging will improve lynx habitat, if it doesn't conservation of this species will not be protected.

There is no monitoring for key grizzly bear foods.

There is no monitoring for snowpack, whether it is diminishing and how that impacts lynx and wolverine.

Culvert monitoring will only be required every six years, not annually.

There is no monitoring for old growth forest habitat or old growth associated species.

INFISH is being replaced with a Northern Region Aquatic and Riparian Conservation Strategy that isn't even developed yet.

PIBO monitoring is no longer required so could be eliminated at any time.

REMEDY
Develop a comprehensive monitoring strategy for fish and wildlife and their habitat.

Designate wildlife focal species.

Designate sensitive species as species of conservation concern.

November 15, 2017

Via Certified Mail, Return Receipt Requested

Secretary Ryan Zinke
U.S. Department of the Interior
1849 C Street, N.W.
Washington, D.C. 20240

Greg Sheehan, Acting Director
U.S. Fish and Wildlife Service
1849 C. Street N.W.
Washington, D.C. 20240

Chief Tony Tooke
U.S. Forest Service
1400 Independence Ave., S.W.
Washington, D.C. 20250

Supervisor Chip Weber, Forest Supervisor
Flathead National Forest
650 Wolfpack Way
Kalispell, MT 59901

Sixty-Day Notice of Intent to Sue Under § 7 of the Endangered Species Act

Dear Secretary Zinke, Chief Tooke, Acting Director Sheehan, and Supervisor Weber:

In accordance with the sixty-day notice requirement of the Endangered Species Act ("ESA"), 16 U.S.C. § 1540(g), you are hereby notified that the following organizations intend to bring a civil action against the U.S. Forest Service and the officers and supervisors to whom this letter is directed (collectively the "Forest Service") for violating Section 7 of the ESA, 16 U.S.C. § 1536.

The name and address of the organizations giving Notice of Intent to Sue:

WildEarth Guardians
80 SE Madison, Suite 210
Portland, OR 97206

Swan View Coalition
3165 Foothill Road
Kalispell, MT 59901

Friends of the Wild Swan
P.O. Box 103
Bigfork, MT 59911

As described herein, the Forest Service has violated and is violating the ESA by failing to reinitiate Section 7 consultation with the U.S. Fish and Wildlife Service ("FWS") concerning the effects of its amendment to the requirement to annually monitor forest road culverts on bull trout (*Salvelinus confluentus*) and bull trout critical habitat. *See* 16 U.S.C. § 1536(a)(2). The Forest Service is also violating the ESA by failing to comply with the reasonable and prudent measures or terms and conditions set out in FWS's biological opinions that require annual culvert monitoring. This change to the Forest Service's road-related activities causes an effect to bull trout and its critical habitat, such as culvert failures, that was not considered in the original biological opinions. Thus the Forest Service has violated and is violating the ESA by failing to reinitiate consultation. We will file suit after the 60-day period has run unless the violations described in this notice are remedied.

LEGAL BACKGROUND

Section 2(c) of the ESA establishes that it is "the policy of Congress that all Federal . . . agencies shall seek to conserve endangered species and threatened species and shall utilize their authorities in furtherance of the purposes of" the ESA. 16 U.S.C. § 1531(c)(1). The purpose of the ESA is to "provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, [and] to provide a program for the conservation of such endangered and threatened species . . . " 16 U.S.C. § 1531(b).

To implement this policy, Section 7(a)(2) of the ESA requires that each federal agency consult with FWS[1] to ensure that any action authorized, funded, or carried out by such agency is not likely to (1) jeopardize the continued existence of any threatened or endangered species or (2) result in the destruction or adverse modification of the critical habitat of such species. *See* 16 U.S.C. § 1536(a)(2).

The ESA's consultation requirement applies "to all actions in which there is discretionary Federal involvement or control." 50 C.F.R. § 402.03. Agency actions requiring consultation are broadly defined by regulation to mean "all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies" and include "actions directly or indirectly causing modifications to the land, water, or air." 50 C.F.R. § 402.02.

If listed species may be present in the area of agency action, the action agency must prepare a Biological Assessment ("BA") to determine whether the listed species may be affected by the proposed action. *See* 16 U.S.C. § 1536(c)(1); 50 C.F.R. § 402.12. If the agency determines that its proposed action "may affect" any listed species, the agency must engage in "formal consultation" with FWS. 50 C.F.R. § 402.14; *see also* 51 Fed. Reg. 19,926, 19,949 (June 3, 1986) (explaining that "may affect" broadly includes "[a]ny possible effect, whether beneficial, benign, adverse, or of an undetermined character").

The threshold for a "may affect" determination is very low, and ensures "actions that have any chance of affecting listed species or critical habitat—even if it is later determined that the actions are not likely to do so—require at least some consultation under the ESA." *Karuk Tribe of Cal. v. U.S. Forest Serv.*, 681 F.3d 1006, 1028 (9th Cir. 2012). Under the FWS Consultation handbook, the "may affect" threshold is met if "a proposed action may pose *any* effects on listed species or designated critical habitat." U.S. Fish and Wildlife Serv. & Nat'l Marine Fisheries Serv., *Endangered Species Consultation Handbook: Procedures for Conducting Consultation and Conference Activities Under Section 7 of the Endangered Species Act* at xvi (1998) (emphasis in original). The regulations implementing the ESA require an examination of both the direct effects of the action as well as the indirect effects of the action, which are defined as "those effects that are caused by or will result from the proposed action and are later in time, but are still reasonably certain to occur." 50 C.F.R. § 402.02. Therefore, an agency must consult in every situation except when a proposed action will have "no effect" on a

---

[1] The bull trout is a species under FWS's jurisdiction and was listed under the ESA subject to that jurisdiction.

listed species or critical habitat.

If the action agency concludes in a BA that the activity is not likely to adversely affect the listed species or adversely modify its critical habitat, and FWS concurs with that conclusion in a Letter of Concurrence, then the consultation is complete. 50 C.F.R. §§ 402.12, 402.14(b). If, however, the action agency determines that the activity is likely to adversely affect the listed species or its critical habitat, then FWS completes a biological opinion ("BiOp") to determine whether the activity will jeopardize the species or result in destruction or adverse modification of critical habitat. *Id.* § 402.14. If FWS determines that an action will jeopardize the species or adversely modify critical habitat, it may propose reasonable and prudent alternative actions intended to avoid such results. 16 U.S.C. § 1536(b)(3)(A); 50 C.F.R. § 402.14(g)(5). If FWS determines the proposed action will "take" a species, the BiOp must include an incidental take statement that: (1) specifies the extent and impact of that take; (2) specifies reasonable and prudent measures necessary or appropriate to minimize such impact; (3) sets forth terms and conditions to implement those measures; and (4) contains a monitoring and reporting requirement to report impacts to FWS. 16 U.S.C. § 1536(b)(4); 50 C.F.R. § 402.14.

However, an agency's Section 7 duties do not end with the issuance of a BiOp. The action agency "cannot abrogate its responsibility to ensure that its actions will not jeopardize a listed species; its decision to rely on a FWS biological opinion must not have been arbitrary or capricious." *Pyramid Lake Paiute Tribe of Indians v. U.S. Dep't of Navy*, 898 F.2d 1410, 1415 (9th Cir. 1990). *See also Defenders of Wildlife v. EPA*, 420 F.3d 946, 976 (9th Cir. 2005) (rev'd on other grounds).

Further, once the consultation is complete, the agencies have a duty to ensure that it remains valid. To this end, an agency must re-initiate consultation if certain "triggers" occur. 50 C.F.R. § 402.16. The ESA's implementing regulations require the Forest Service to re-initiate consultation where discretionary federal involvement or control over the action has been retained or is authorized by law, and:

> (a) If the amount or extent of taking specified in the incidental take statement is exceeded;
>
> (b) If new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered;
>
> (c) If the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the biological opinion; or
>
> (d) If a new species is listed or critical habitat designated that may be affected by the identified action.

50 C.F.R. § 402.16. The duty to reinitiate consultation lies with the action agency and the consulting agency.

After consultation is initiated or reinitiated, ESA Section 7(d) prohibits the agency or any permittee from "mak[ing] any irreversible or irretrievable commitment of resources" toward a project that would "foreclos[e] the formulation or implementation of any reasonable and prudent alternative measures . . . " 16 U.S.C. § 1536(d). The 7(d) prohibition "is in force during the consultation process and continues until the requirements of section 7(a)(2) are satisfied." 50 C.F.R. § 402.09.

FACTUAL BACKGROUND

Bull Trout and its Critical Habitat

Bull trout (*Salvelinus confluentus*) was listed as threatened under the ESA throughout the coterminous United States in 1999. Bull trout are a cold-water fish of relatively pristine streams and lakes. They have specific habitat requirements: cold, clean, complex and connected habitat. Primary threats to bull trout include habitat degradation and fragmentation, blockage of migratory corridors, poor water quality, past fisheries management, and the introduction of non-native species such as brown, lake, and brook trout. Effects resulting from climate change also threaten bull trout, because a warming climate is expected to shrink cool spawning and rearing areas. Bull trout occur over a large area, but their distribution and abundance has declined and scientists have documented several local extinctions. Remaining populations tend to be small and isolated from each other, making the species more susceptible to local extinctions.

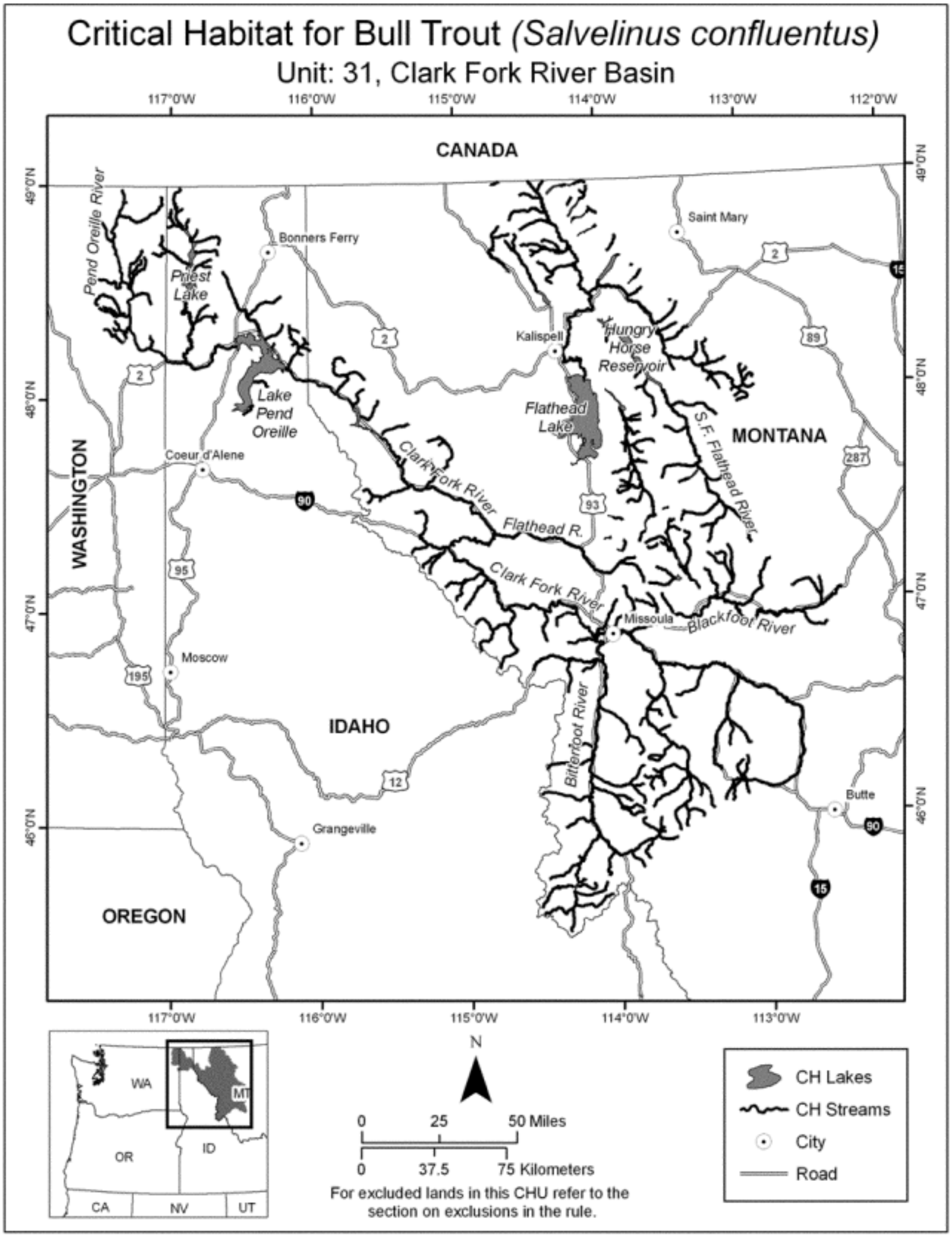
In 1995, Forest Service Regions 1, 4 and 6 adopted the Interim Strategy for Managing Fish-Producing Watersheds ("INFISH") to provide interim direction to protect habitat and population of resident native fish. INFISH is a broad-reaching aquatic habitat conservation strategy for the northwestern United States and was incorporated into Forest Plans, including the Flathead's Forest Plan, in a single Record of Decision.

In 1998, FWS issued a BiOp assessing the effects of implementing all affected Forest Plans as amended by INFISH ("1998 BiOp"). The 1998 BiOp analyzed the effects to bull trout from the Flathead Forest Plan, among others. In the 1998 BiOp, FWS noted, "within the range of the DPSs of bull trout, [Forest Plans] provide direction and standards for broad classes of project activities and land and water management practices that may affect bull trout. [Forest Plans] provide policy guidance for various federal activities carried out on the forest or management area." The programmatic 1998 BiOp ultimately concluded that continued implementation of the Forest Plans is not likely to jeopardize the continued existence of bull trout. However, the 1998 BiOp also concluded that because "[n]o critical habitat has been designated for the species [….] none will be affected."

After years of legal and political wrangling, critical habitat for bull trout was most recently designated on October 18, 2010. 75 Fed. Reg. 63898 (Oct. 18, 2010). The rule designated a total of 19,729 miles of stream and 488,251.7 acres of reservoirs and lakes in the States of Washington, Oregon, Nevada, Idaho, and Montana as critical habitat for the bull trout.

Bull Trout on the Flathead National Forest

Bull trout and bull trout critical habitat exist on the Flathead National Forest. The following map shows Unit 31 of the bull trout critical habitat that was designated in 2010, 75 Fed. Reg. at 64,067, and includes the Flathead National Forest:

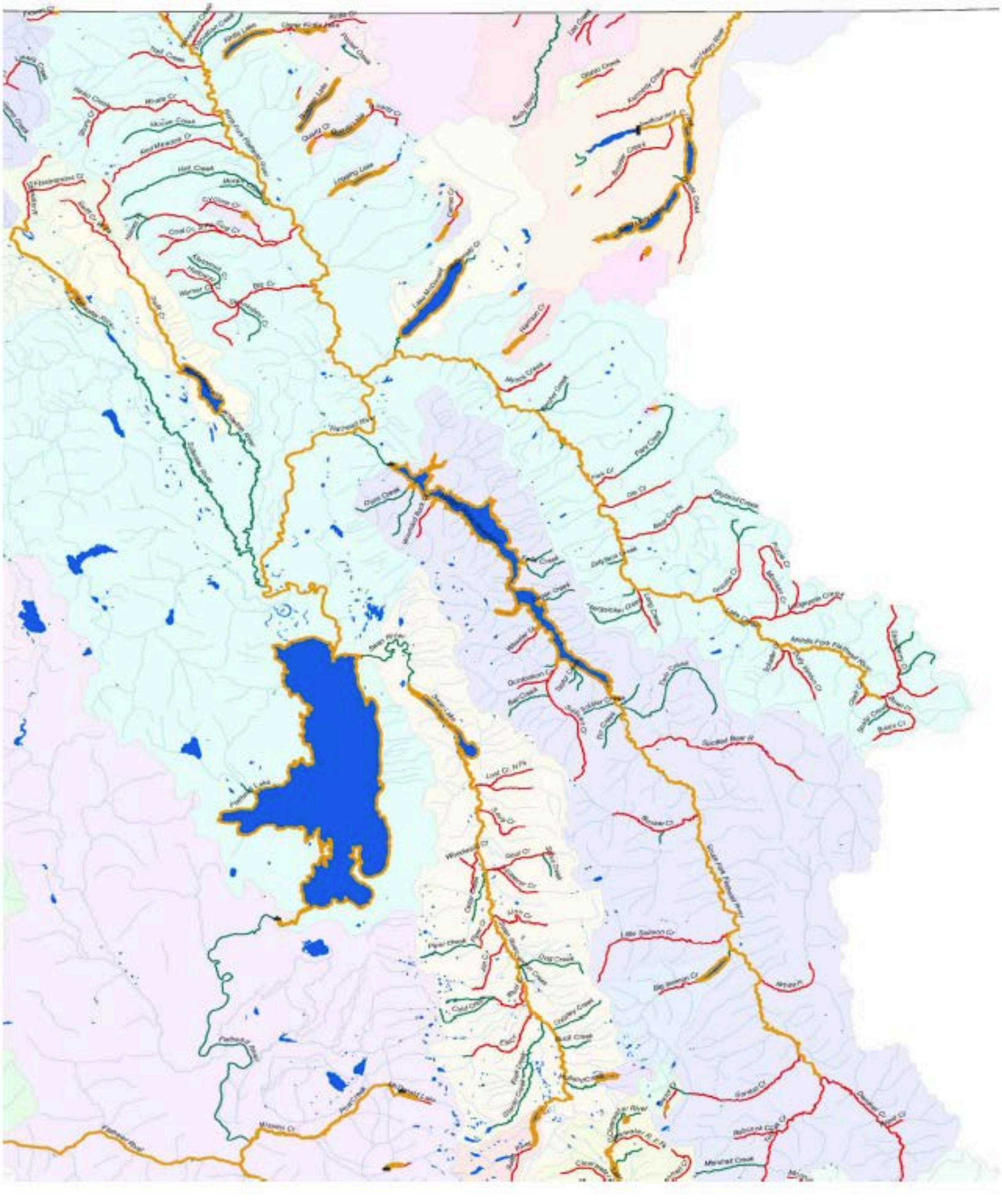


Critical Habitat for Bull Trout *(Salvelinus confluentus)*

Unit: 31, Clark Fork River Basin

For excluded lands in this CHU refer to the section on exclusions in the rule.

The following map shows spawning and occupied bull trout streams in the Flathead Forest Plan Amendment 19 project area in the Swan Lake and Flathead Lake bull trout core areas of northwest Montana:



See U.S. Fish and Wildlife Service Montana Ecological Services Office, Biological Opinion on Amendment 19 (A-19) Revised Implementation Schedule, Bull Trout (*Salvelinus confluentus*) (Nov. 22, 2010) (hereafter, 2010 Amendment 19 BiOp), page 7, Figure 1.

Impacts to Bull Trout from Forest Roads & Culverts

The best available science shows that roads cause significant adverse impacts to National Forest resources. A 2014 literature review from The Wilderness Society surveys the extensive and best available scientific literature—including the Forest Service's General Technical Report synthesizing the scientific information on forest roads (Gucinski 2001)—on a wide range of road-related impacts to ecosystem processes and integrity on National Forest lands. *See* The Wilderness Society,*Transportation Infrastructure and Access on National Forests and Grasslands: A Literature Review* (May 2014) (Attachment A). Erosion, compaction, and other alterations in forest geomorphology and hydrology associated with roads seriously impair water quality and aquatic species viability. Roads disturb and fragment wildlife habitat, altering species distribution, interfering with critical life functions such as feeding, breeding, and nesting, and resulting in loss of biodiversity. Roads facilitate increased human intrusion into sensitive areas, resulting in poaching of rare plants and animals, human-ignited wildfires, introduction of exotic species, and damage to archaeological resources.

Roads often contribute to degraded baseline conditions in watersheds containing bull trout. Roads are a primary source of sediment impacts to developed watersheds. Accumulation of fine sediment is detrimental to bull trout habitat. Lee et al. (1997) found a pattern of decreasing strong populations of bull trout with increasing road density. Sediment delivered to streams is greatest in riparian areas where roads cross the streams. Fords and approaches to the crossings deliver sediment directly to streams. Roads and trails paralleling streams can interfere with large wood reaching the stream and cause increased erosion and decreased stream bank condition.

Culverts can deliver large amount of sediment to receiving waters when the culvert plugs and fails. A 2006 phone log of a discussion between the Forest Service and FWS shows the agencies identified addressing the existing road system on the Flathead as the key opportunity to conserve bull trout. *See* Attachment B (provided to us from FWS in response to a Freedom of Information Act (FOIA) request). The agencies recognized that harms to bull trout from un-maintained forest roads and culverts behind gates and berms are legitimate concerns, and allowing culverts to remain increases the risk of losing a fish population and degrading water quality, as shown in the literature.

FWS's 2015 BiOp on the effects to bull trout and bull trout critical habitat from road-related activities in Western Montana states:

> Culverts that remain in the road behind gates and berms that are not properly sized, positioned, and inspected . . . have an increased risk for failure by reducing awareness of potential maintenance needs. The accumulation of debris has the potential to obstruct culverts and other road drainage structures. Without maintenance and periodic cleaning, these structures can fail, resulting in sediment production from the road surface, ditch, and fill slopes. The design criteria to address drainage structures left behind gates and berms require annual monitoring of these structures.

See U.S. Fish and Wildlife Service Montana Ecological Services Office, Biological Opinion on the Effects to Bull Trout and Bull Trout Critical Habitat From the Implementation of Proposed Actions Associated with Road-related Activities that May Affect Bull Trout and Bull Trout Critical Habitat in Western Montana (April 15, 2015) (hereafter, 2015 Roads Programmatic BiOp), pages 45-46.

In 2006, the Forest Service and FWS affirmed that high-risk culverts (or "pipes") left behind berms and gates on forest roads was the primary issue affecting bull trout habitat on the Flathead National Forest. *See* Meeting notes Seeley Lake 11/30/06 T&C Reporting (Attachment C). The attached maps—prepared by a GIS contractor from the Forest Service's own data—show that many forest roads and culverts directly affect, or affect waters upstream of, bull trout critical habitat. *See* Attachment D.

Actions & Consultation: Flathead Forest Plan & Site-Specific Projects Requiring Culvert Monitoring

Since 2002, FWS has issued seven bull trout BiOps to the Flathead National Forest that include no jeopardy determinations based on reasonable and prudent measures or terms and conditions requiring annual or biannual culvert monitoring on gated or closed roads for the purpose of identifying high risk culverts and repairing or removing them to reduce the risk of failure. *See, e.g.*, Nov. 9, 2016 Letter from Chip Weber, Forest Supervisor, Flathead National Forest to Jodie Bush, U.S. Fish and Wildlife Service. For at least five of these BiOps, FWS based its no jeopardy determination in part on the Forest Service's commitment to annually inspect culverts on closed roads in bull trout habitat. For the Moose Post-Fire Project, FWS based its conclusions in part on the Forest Service's commitment to inspect culverts annually for the first two years following the project, and biannually thereafter. Although FWS did not explicitly base its no jeopardy determination for the West Side Reservoir Project on annual inspections of closed road culverts, reliance on this requirement is implicit given the requirement for the Forest Service to propose a culvert monitoring program and annually submit monitoring reports.

1. Chilly James Restoration Project (Jan. 2016)

In 2015, the Forest Service proposed the Chilly James Restoration Project, which included decommissioning 2.3 miles of road, placing 9 miles of road into intermittent stored service, implementing best management practices for 20.9 miles of road, and re-aligning 0.2 miles of road. *See* U.S. Fish and Wildlife Service Montana Field Office, Biological Opinions on the Effects of the Chilly James Restoration Project on Grizzly Bears, Bull Trout, and Bull Trout Critical Habitat (Jan. 20, 2016) (hereafter, 2016 Chilly James BiOp), page 5. FWS determined that the actions as proposed were not likely to jeopardize the continued existence of bull trout, and were not likely to destroy or adversely modify bull trout critical habitat. *Id.* at 46, 47. It based that determination, in part, on the Forest Service's commitment to comply with the conservation recommendations and design criteria identified in the 2015 Roads Programmatic BiOp. *Id.* at 45.

As explained below, the design criteria require all culverts behind road gates and permanent barriers be inspected annually and, if annual monitoring behind barriers is not feasible, require the Forest Service to remove all stream crossing structures when the road is closed. They also require all stream crossing structures be removed when a road is reclaimed or decommissioned so that annual inspections are not necessary.

FWS anticipated implementation of the Chilly James Restoration Project would likely impart a level of adverse effect, and thus incidental take would occur. *Id.* at 48. To minimize the impact of incidental take that might otherwise result, FWS identified non-discretionary reasonable and prudent measures with implementing terms and conditions, including annual monitoring in the same format as is required by the 2015 Roads Programmatic BiOp. *Id.* at 49-51.

2. Roads Programmatic BiOp (April 2015)

In its 2015 Roads Programmatic BiOp, FWS concluded that the proposed road-related maintenance activities would not appreciably reduce the survival and recovery of bull trout based on the information presented, including the Forest Service's commitment to implement design criteria for all road-related activities. 2015 Roads Programmatic BiOp at 61-63. *See also id* at 65 ("The proposed action requires that each land management unit will monitor projects to assure design criteria are implemented and findings are documented"). Design criteria, listed in Appendix A of the 2015 Roads Programmatic BiOp, expressly incorporate Appendix E as detailing the design criteria for road decommissioning and road storage or closure. *Id.* at 92 (Appendix A, Detailed Description of Road-Related Activities Included in the Proposed Action). Those design criteria require all culverts behind road gates and permanent barriers be inspected annually and, if annual monitoring behind barriers "is not feasible, remove all stream crossing structures when the road is closed." *Id.* at 99 (Appendix E, Standards for Road Closures). They also require removal of all stream crossing structures when a road is reclaimed or decommissioned so that annual inspections are not necessary. *Id.* at 100.

3. Amendment 19 Revised Implementation (Nov. 2010)

In 2010, the Forest Service sought to delay implementation of road-related projects identified in Amendment 19 to the Flathead's Forest Plan (referred to as A-19 projects) through 2009. *See* 2010 Amendment 19 BiOp at 15. This meant further delaying the decommissioning of 16.5 miles of roads in four Grizzly Bear Management Unit (GBMU) watersheds (Red Meadow Creek, Granite Creek, Morrison Creek, and North Fork Lost Creek). *Id.* FWS estimated those roads to contain 28 culverts and two bridges in bull trout drainages, failure of which could produce approximately 476 tons of sediment. *Id.* at 15, 53. FWS affirmed that leaving roads that remain on the landscape without appropriate maintenance adversely affects bull trout. *Id.* at 48.

FWS determined the revised implementation schedule was not likely to jeopardize the continued existence of bull trout, would not appreciably reduce the survival or recovery of bull trout in the wild, and was not likely to destroy or adversely modify bull trout critical habitat. *Id.* at 60-62. Those determinations were based in part on the Forest Service's commitment to, *inter alia*: (1) implement minimization measures to reduce sediment generated by the project; (2) reduce sediment delivery as a result of road related improvements, road decommissioning, and culvert removal and or replacement elsewhere in the A-19 project area; and (3) eventually implement A-19 projects to reduce sediment delivery in the identified GBMU watersheds. *Id.* at 61. As part of its incidental take statement, FWS outlined non-discretionary measures the Forest Service must undertake. *Id.* at 64-69 (including reasonable and prudent measures and terms and conditions that require annual culvert inspection and maintenance for all inventoried culverts, and a plan and schedule to remove or upgrade high risk culverts).

4. Robert-Wedge Post-Fire Project (Nov. 2004)

In 2004, the Forest Service proposed broad scale treatment of forested land and associated land management activities under the Robert and Wedge Post Fire Project. *See* U.S. Fish and Wildlife Service Montana Field Office, Biological Opinion for Bull Trout, Flathead National Forest Robert-Wedge Post-Fire Project 2004 (Nov. 22, 2004) (hereafter, 2004 Robert-Wedge BiOp), pages 4-5. FWS determined the project as proposed was not likely to jeopardize the continued existence of the

Columbia Basin DPS of bull trout. *Id.* at 40. As part of its proposal, the Forest Service committed to monitoring bermed or gated roads that remain on the system if funding allowed. *Id.* at 9.

FWS anticipated implementation of the Robert-Wedge Post-Fire Project activities may result in incidental take of bull trout. *Id.* at 42. To limit sediment delivery from those activities, the Forest Service proposed mitigation that included specific road maintenance mitigation activities identified in the *Biological Assessment of Road Related Actions on Western Montana's Federal Lands that are likely to Adversely Affect Bull Trout* (USDA 2001). *Id.* at 42. FWS also required the Forest Service to comply with non-discretionary reasonable and prudent measures and their implementing terms and conditions, including development of a proposal for monitoring culverts on bermed roads and reporting monitoring activities annually. *Id.* at 46.

5. West Side Reservoir Post-Fire Project (Dec. 2004)

In 2004, as part of the West Side Reservoir Post-Fire Project the Forest Service proposed post-fire logging, road activities, and restoration. *See* U.S. Fish and Wildlife Service Montana Field Office, Biological Opinion for Bull Trout, Flathead National Forest, West Side Reservoir Post-Fire Project 2004 (Dec. 21, 2004) (hereafter, 2004 West Side BiOp), pages 5-6. As part of its proposal, the Forest Service committed to monitoring bermed or gated roads that remain on the system if funding allowed. *Id.* at 9. FWS noted concerns with the Forest Service's proposal to berm 36 miles of road due to the likelihood that culverts would be left in place behind berms, limiting access to clean, repair, or monitor high risk culverts. *Id.* at 36. FWS determined the project as proposed was not likely to jeopardize the continued existence of bull trout. *Id.* at 46. It based that determination in part on minimization measures the Forest Service committed to. *Id.*

FWS anticipated implementation of the West Side Reservoir Project might result in incidental take of bull trout. *Id.* at 47. To minimize incidental take of bull trout, FWS required the Forest Service to comply with non-discretionary reasonable and prudent measures and their implementing terms and conditions, including submission of a proposal for monitoring culverts on bermed roads with annual reports. *Id.* at 51-52.

6. Moose Post-Fire Project (Nov. 2002)

Under the Moose Post-Fire Project, the Forest Service proposed salvage harvest, alternative bark beetle control measures, fuels reduction, and road management. *See* U.S. Fish and Wildlife Service Montana Field Office, Biological Opinion on the Effects of the Moose Post-Fire Project on Bull Trout, Flathead National Forest (Nov. 14, 2002) (hereafter, 2002 Moose BiOp), page 4. The incidental take statement noted that regular monitoring and maintenance of all culverts—not just culverts on actively used roads—is necessary to reduce the potential for culverts to plug or fail and thereby reduce the risk of sediment delivery to bull trout streams. *Id.* at 45. FWS determined the project was not likely to result in jeopardy of bull trout. *Id.* at 42. FWS based its determination in part on the Forest Service's commitment to annually monitor culverts in the project area for the first two years, and then every-other year thereafter. *Id.* at 47 (terms and conditions), 61 (Appendix A).

7. Spotted Beetle Project (March 2002).

In 2002, the Forest Service proposed vegetation management and road management actions, including closing 29 miles of road with an earthen berm or gate and maintenance of all culverts on those closed roads, as part of the Spotted Beetle Resource Management Project. *See* U.S. Fish and Wildlife Service Montana Field Office, Biological Opinion, Bull Trout, Spotted Beetle Resource Management Project (Mar. 8, 2002) (hereafter, 2002 Spotted Beetle BiOp), page 2. FWS determined the project as proposed was not likely to jeopardize the continued existence of bull trout. *Id.* at 30.

As part of its proposed actions, the Forest Service proposed to inspect the culverts remaining on the 29 miles of closed roads to ensure they did not jam with debris and cause road bed erosion to occur. *Id.* at 25. It also committed to implementing the standards and guidelines for conducting road maintenance activities contained in the *Biological Assessment of Road Related Actions on Western Montana's Federal Lands that are Likely to Adversely Affect Bull Trout* (Forest Service and Bureau of Land Management 2001). *Id.* at 28.

FWS anticipated implementation of the Spotted Beetle Project would result in incidental take of bull trout. *Id.* at 31. To minimize incidental take of bull trout, FWS required the Forest Service to comply with non-discretionary reasonable and prudent measures and their implementing terms and conditions, including annual inspections of culverts on roads closed by gates or berms. *Id.* at 32.

Changes to Identified Actions & New Information

Failure to Monitor Culverts

The Forest Service has failed to monitor forest road culverts as required by the terms and conditions of the seven BiOps, a commitment that FWS relied on in its original consultations. *See, e.g.*, Nov. 9, 2016 Letter from Chip Weber, Forest Supervisor, Flathead National Forest to Jodie Bush, U.S. Fish and Wildlife Service (noting that "[s]ince 2009, engineering budgets have declined and monitoring has been inconsistent and incomplete.").

For example, the Forest Service failed to comply with the terms and conditions of its incidental take permit on the West Side Reservoir Post-Fire Project. Under that decision, the agency committed to identify all high-risk culverts behind berms and gates and remove any high-risk culverts within one year, but failed to follow through on this commitment. *See* Attachment C ("the Forest was to identify which pipes are high risk (done) and fix high risk within a year (not done??)"). The agency later documented two major water events and culvert failure, highlighting the issue of abandoned culverts and impacts to water quality and bull trout habitat. *Id.* For the Forest Service, it was not a matter of whether the agency was failing to comply with the BiOp terms and conditions requiring culvert monitoring, but "how far have we missed the mark (i.e., by not meeting the commitments in the BA has take occurred over and above what was assessed in the BO?"). *See* Attachment C.

Based on the Forest Service's responses to a series of FOIA requests as well as meetings with the Forest Service staff between November 2014 and February 2016, the Forest Service has continued to fail to annually monitor stream-crossing culverts behind road closures in bull trout habitat forest-wide as required by the 2015 Roads Programmatic BiOp. *See, e.g.*, K. Hammer, Roads to Ruin: The Flathead National Forest Shirks Its Road Reclamation Duties (May 2016) (Attachment E), pages 18-20 nn.25-30. For example, the Forest Service has failed to conduct annual monitoring of ten culverts remaining on Raghorn Road (10802). *Id.* at 19 n. 32. The road is located upstream of Coal Creek, which is designated bull trout critical habitat. As another example, the Forest Service has failed to annually monitor 24 culverts remaining on Sullivan Creek Road above a 2014 mass road failure. *Id.* at 22 n.52. One of the culverts remaining on Sullivan Creek Road includes a three-foot "high risk" culvert that the agency identified as "a critical situation" in June of 2015. *Id.* Sullivan Creek Road parallels bull trout critical habitat for spawning. Also based on the agency's response (or lack of response) to FOIA requests, it has failed to develop a single culvert monitoring plan for roads closed by berms to provide Grizzly Bear Security Core. *Id.* at 18 n.27.

The Forest Service has failed to annually monitor culverts on North Lost Creek Road (5206), including two stream-aligned culverts located behind the berm that closes the road. Lost Creek is one of the four streams identified as requiring annual culvert monitoring to prevent failures per the 2010 Amendment 19 BiOp. It is a major tributary to North Lost Creek, which is designated critical habitat. The agency's INFRA database incorrectly shows no culverts exist beyond the berm at milepost 4.77. But a Fish Passage Assessment dated 8/12/02 identifies a 72" x 45" squash culvert as low risk for blockage but as impassable to fish due to a free-fall at the culvert outlet. The same form is later marked and red-flagged as "Pulled Prior to 2010." Based on our own surveys from June of 2016, the huge culvert remains, as well as a smaller live-stream culvert.

In 2007, the Forest Service surveyed 120 culverts on just 38 miles of road. In 2008, it surveyed 203 culverts on 47 miles of road. And in 2009 it surveyed 148 culverts on 65 miles of road. *See* Terms and Conditions Monitoring Report, Bull Trout Biological Opinions for Post-fire Salvage Operations, Flathead National Forest 2007-2009, Appendix A (Oct. 28, 2009).

As explained above, FWS relied on the Forest Service's compliance with the reasonable and prudent measures and terms and conditions requiring the Forest Service to annually monitor culverts—as well as commitments to annually monitor culverts—as part of the basis for its determination in at least five of the seven BiOps that the Forest Service's actions would not result in jeopardy to bull trout or destruction or adverse modification of critical habitat. The Forest Service is in violation of its duty under the ESA to reinitiate consultation because the agency subsequently modified its action in a manner that has and is continuing to cause effects to bull trout and bull trout critical habitat that was not considered in the seven BiOps.[2]

Culvert Failures

Based on the limited culvert monitoring in 2004 and the number of culvert failures, the agency underestimated the rate of "high risk" culverts and culvert failures.[3] In 2005 and 2006, the Forest Service documented three failed culverts and one road slump in the West Side Reservoir project

---

[2] *See, e.g.*, 2015 Roads Programmatic BiOp at 68 ("If, during the course of the action, proposed action is not adhered to, the level of incidental take anticipated in the biological opinion may be exceeded; such incidental take represents new information requiring reinitiation of consultation and review of the reasonable and prudent measures provided."); 2010 Amendment 19 BiOp at 69 ("If during the course of the proposed action, the Forest does not adhere to TC1(c), or other terms and conditions above, this would represent new information requiring reinitiation of consultation.").

[3] *See* Monitoring Plan for Culverts on Closed Roads, Robert-Wedge and West Side Reservoir Projects (2004), page 8 ("In 2004, we monitored 89 miles of roads and 234 stream crossings within the West Side Project . . . we found 7 failed culverts, 5 partially plugged culverts and 1 failed bridge. Once again, 15% of the culverts were identified as high risk to fail. There is an additional 19 miles of roads closed by vegetation, 38 miles closed by berms and 53 miles of gated roads that still need to be inventoried as a base level inventory to identify potential risks.")

area. The failed culverts were 48", 36" and 18" in diameter. Monitoring determined that 48% of the culverts inspected and rated[4] were "high risk." *See* R. Stevens and C. Kendall, Biological Opinion Terms and Conditions Monitoring Report for Bull Trout, Flathead National Forest, 2006 (Mar. 22, 2007), pages 16, 21, 23. This type of monitoring results led FWS to conclude: "[We need to t]ry and determine the level/extent outside the take already issued. Remember that the [West Side Project] BO does not cover what was discovered. We based analysis on 10 to 15% of the culverts in the action area are at high risk of failure the[n] discovered its more like 35 to 40%." *See* FWS's Notes from 12/4/06 Conference Call.

In 2006, the Forest Service and FWS documented at least seven major culvert failures and expected that number to increase. *See* Attachment B; *see also* Pre Meeting Notes: By Dan Brewer, For the meeting with Steve Phillips of the Flathead National Forest (Seeley Lake Ranger District 11/30/06) (Attachment F). Between 2007 and 2009, the Flathead observed 12 culvert failures (based on only a subset of stream culverts inventoried) as part of the agency's monitoring program to assess roads and culverts behind berms. *See* Terms and Conditions Monitoring Report, Bull Trout Biological Opinions for Post-fire Salvage Operations, Flathead National Forest 2007-2009, Appendix A (Oct. 28, 2009).

Another example is a culvert failure identified in 2014 on Bunker Creek Road (549), behind a closed road with a berm. *See* Attachment E at 7. The culvert blew out into a tributary that feeds directly into the main fork of Bunker Creek, which is designated bull trout critical habitat. The culvert monitoring was not annual, apparently not thorough, and essentially in 2010. *Id.* at 16-18 n.24. Our own monitoring identified a four-foot diameter culvert almost entirely plugged in 2014 on a tributary also feeding the main fork of Bunker Creek. *Id.* Survey crews in 2010 had been unable to remove "large immovable logs" that were partially blocking this culvert inlet. *Id.* Road 2820 runs up the Middle Fork of Bunker Creek, which is not designated critical habitat for bull trout, but flows into the main fork Bunker Creek, which is designated bull trout critical habitat. The Forest Service's culvert survey in 2010 and our own survey in 2014 found numerous plugged and partially failed culverts. *See id.*

FWS relied on the Forest Service's compliance with terms and conditions requiring the Forest Service to annually monitor culverts to minimize sediment releases into bull trout habitat and critical habitat as part of the basis for its determination in at least five of the seven BiOps that the Forest Service's actions would not result in jeopardy to bull trout or destruction or adverse modification of critical habitat. The agency's failure to monitor culverts as required by the terms and conditions of the BiOps has resulted in culvert failures that degrade bull trout critical habitat and harm bull trout. The Forest Service is therefore in violation of its duty under the ESA to reinitiate consultation because the agency subsequently modified its action in a manner that has and is continuing to cause effects to bull trout and bull trout critical habitat that was not considered in the seven BiOps.[5]

---

[4] The Forest Service identified 319 culverts for inspection, but inspected and rated only 231, with 112 (48%) being high risk. *Id.* The agency removed nine more culverts and did not rate them. The agency apparently mistakenly divided 112 by 319 to arrive at the 35% high risk it reported.

[5] *See, e.g.*, 2015 Roads Programmatic BiOp at 68; 2010 Amendment 19 BiOp at 69 ("in the unlikely event of a large runoff event causing massive or widespread culvert failures, and more than one culvert fails, the level of take exempted in this biological opinion would be exceed, and reinitiation of consultation would be required.").

Modifications to Culvert Monitoring Plan

In 2016, the Flathead National Forest requested to amend the terms and conditions of the seven BiOps requiring annual (or biannual) forest road culvert monitoring. *See, e.g.*, Nov. 9, 2016 Letter from Chip Weber, Forest Supervisor, Flathead National Forest to Jodie Bush, U.S. Fish and Wildlife Service (requesting to "amend these Terms and Conditions such that the proposed monitoring plan would function in lieu of existing monitoring requirements."). Under its proposed rotating panel design, the Forest Service would monitor culverts on closed or gated roads in bull trout watersheds every sixth year instead of annually.

The Forest Service failed to reinitiate consultation to assess these proposed changes to the reasonable and prudent measures and terms and conditions of the road-related BiOps identified above.

Even if the Forest Service does reinitiate consultation on its proposed changes to the culvert monitoring requirements, monitoring culverts once every six years is not adequate to assess the risk of and prevent culvert failures. The history of culvert failures on the Flathead due to lack of monitoring and maintenance in addition to best available science showing the harmful impacts of forest roads and culvert failures on water quality, bull trout, and bull trout critical habitat demonstrate it would be arbitrary and capricious for the Forest Service and FWS to modify the Flathead's culvert monitoring requirements. In response to FOIA requests, the Forest Service and FWS did not provide any records supporting the Forest Service's conclusions that annual culvert monitoring may be duplicative, or that a 5-10 year period may be reasonable to detect changes in culvert conditions or trends.

The Forest Service and FWS have historically under-estimated the number of high-risk culverts on the forest. As early as 2006, FWS found their assumption that 10-15% of culverts would be high risk was incorrect based on Forest Service monitoring that identified 35-40% of culverts as high risk. *See* Attachment E. Based on additional monitoring information available to us in response to FOIA requests, the Forest Service later found 67% of culverts are at high-risk. Because of these false assumptions, FWS noted it had concerns about the impacts of culvert management on bull trout and bull trout habitat across the Flathead. *See* Attachment E.

In its request to modify the culvert monitoring requirements set forth in the BiOps outlined above, the Forest Service pointed to field tests of the monitoring approach in the Sullivan Creek watershed. *See, e.g.*, Nov. 9, 2016 Letter from Chip Weber, Forest Supervisor, Flathead National Forest to Jodie Bush, U.S. Fish and Wildlife Service. But based on the culvert monitoring spreadsheet, provided as an example of culvert monitoring done using the proposed new culvert monitoring plan, the surveyors did not abide by the culvert monitoring plan protocol when assessing culverts in the Sullivan Creek watershed. *Compare* Sullivan Creek Monitoring Results 2016 *with* FNF Culvert Monitoring Plan 7-2016.

Of the 13 culverts identified, the surveyors found only one culvert had damage due to rust, even though three other culverts should have been marked as "damaged" due to blocked inlets and the stream flowing underneath the culvert. *See* FNF Culvert Monitoring Plan 7-2016 at 8 n.*. Moreover, six of the 13 culverts had upstream floatable material. It is very possible for that material to migrate and block the six downstream culvert inlets during the six-year period before this area would be surveyed again. The survey reported only two of the 13 culverts had no issues with proper installment, flow or maintenance.

On May 10, 2017, our organizations submitted a letter to the Forest Service outlining our concerns about the Flathead National Forest's efforts to change its monitoring program for road culverts given the history of culvert failures on the forest landscape. The letter highlighted the harms culvert failures have on water quality and bull trout habitat. Our organizations have also submitted comments on the Flathead's forest-wide Travel Analysis Report and its draft revised Forest Plan, describing how the Flathead's road system is too large to adequately fund, maintain and monitor in order to protect listed species of fish and wildlife.

Climate Change Science

New studies regarding the impacts of climate change reveal that the actions assessed in the seven bull trout BiOps may affect bull trout and its designated critical habitat in a way or to an extent not previously considered in the earlier BiOps. New information shows climate change is expected to lead to more extreme weather events, resulting in increased flood severity, more frequent landslides, altered hydrographs, and changes in erosion and sedimentation rates and delivery processes.[6] Forest roads that were designed for storms and water flows typical of past decades may fail under future weather scenarios, further exacerbating adverse ecological impacts, public safety concerns, and maintenance needs.[7]

New information shows that climate change is affecting bull trout and its critical habitat by warming stream temperatures, altering stream hydrology, and changing the frequency, magnitude, and extent of climate-induced events like floods, droughts, and wildfires. These new studies document the larger role of climate change in affecting the status of bull trout throughout their range:

1) Luce, C. H, J. T. Abatzoglou, and Z. A. Holden. 2013. The Missing Mountain Water: Slower Westerlies Decrease Orographic Enhancement in the Pacific Northwest USA. Science 342: 1360-1364 (Attachment G) (documenting declining trends in streamflow timing and volume attributed to orographic precipitation enhancement, in addition to increased temperatures).

2) Isaak, D. J., *et al.* 2016. Slow climate velocities of mountain streams portend their role as refugia for cold-water biodiversity. Proc Natl Acad Sci, DOI: 10.1073/pnas.1522429113 (Attachment H) (showing temperature resistance of mountain streams and highlighting their importance in buffering cold-water species from climate change).

The Forest Service's own Climate Shield website provides a wealth of new information identifying colder, high-elevation streams that serve as a refugia for native bull trout with the goal of improving

---

[6] *See, e.g.*, Halofsky, J.E. *et al eds.*, USDA, Forest Service, Pacific Northwest Research Station, *Adapting to Climate Change at Olympic National Forest and Olympic National Park*, PNW-GTR-844 (2011), pages 21-27.

[7] *See, e.g.*, Strauch, R.L. *et al.*, *Adapting transportation to climate change on federal lands in Washington State*, Climate Change 130(2), 185-199 (2015) (noting the biggest impacts to roads and trails are expected from temperature-induced changes in hydrologic regimes that enhance autumn flooding and reduce spring snowpack).

the odds of preserving native trout populations:

3) U.S. Forest Service Rocky Mountain Research Station, Climate Shield Cold-Water Refuge Streams for Native Trout, *available at* http://www.fs.fed.us/rm/boise/AWAE/projects/ClimateShield.html (last accessed June 23, 2016).

The Forest Service predicts cold-water refuge streams will play an important role in the future protection of bull trout in light of anticipated climate change-related temperature increases.

In addition, new methods of documenting bull trout, new documentation, and new studies on management and restoration efforts indicate the Forest Service's actions may affect the species to a greater extent than previously considered:

4) Auerbach, N. A., K. A. Wilson, A. I. T. Tulloch, J. R. Rhodes, J. O. Hanson, and H. P. Possingham. 2015. Effects of threat management interactions on conservation priorities. Conservation Biology 29:1626-1635 (Attachment I) (concluding species conservation management that does not consider interactions between actions may result in misplaced investments or misguided expectations of the effort to mitigate threats to species).

5) Barnas, K. A., *et al.* 2015. Is habitat restoration targeting relevant ecological needs for endangered species? Using Pacific Salmon as a case study. Ecosphere 6(7), art 110 (Attachment J) (identifying improvements for habitat management to improve efficiencies in matching identified needs for conserving a species with explicit management actions).

6) Meyer, K.A. *et al.* 2014. Bull trout trends in abundance and probabilities of persistence in Idaho. North American Journal of Fisheries Management 34:202-214 (Attachment K) (describing bull trout population trends and probability of persistence in Idaho).

7) Wilcox, T. M. *et al.* 2014. A blocking primer increases specificity in environmental DNA detection of bull trout (*Salvelinus confluentus*). Conservation Genetics Resources 6:283-284 (Attachment L) (newly developed environmental DNA survey methods are improving agencies' ability to assess bull trout distribution and identify watersheds where bull trout are at risk of extirpation).

The Montana Climate Assessment (MCA), an effort to synthesize, evaluate, and share credible and relevant scientific information about climate change in Montana, is another source of new information regarding climate change that the Forest Service failed to consider in its current BiOps. *See* http://montanaclimate.org.

This wealth of significant new information reveals the agency's actions may affect bull trout and its designated critical habitat in a manner not previously considered in several of the BiOps. The more recent studies were not available for the 2002, 2004, and 2010 BiOps. Climate change effects were not considered as a factor affecting bull trout at the time of listing in 1999. U.S. Fish and Wildlife Service, Recovery Plan for the Coterminous United States Population of Bull Trout (*Salvelinus confluentus*) (Sept. 2015), page iv. The Forest Service is in violation of its duty under the ESA to reinitiate consultation because new information about the effects of climate change reveals the effects of the agency's actions, in the cumulative, may affect threatened bull trout and its critical habitat to an extent not previously considered.

Failure to Consult or Reinitiate

Failing to reinitiate consultation despite changes to the identified action in a manner that causes effects to the listed species or critical habitat that was not considered in the BiOps, and despite new information revealing effects of the actions that were not previously considered, violates ESA regulation 50 C.F.R. § 402.16.

Potential "No Effect" Determination

Based on information available to us and received in response to FOIA requests to the Forest Service and FWS, the Forest Service did not make any further determinations regarding the affects of its actions on bull trout or designated bull trout critical habitat. If the Forest Service did make a "no effect" determination, based on the information set forth above, that determination would be arbitrary and capricious, and contrary to law.

ESA VIOLATIONS

1. The Forest Service has violated the ESA by failing to reinitiate consultation under Section 7 regarding the impacts of its road-related activities on bull trout and its critical habitat despite proposing to eliminate the requirement to annually monitor forest road culverts. This change to culvert monitoring affects bull trout and its critical habitat in a way that was not considered in any of the seven BiOps. 50 C.F.R. § 402.16(c).

2. The Forest Service has violated the ESA by failing to reinitiate consultation under Section 7 regarding the impacts of its road-related activities on bull trout and its critical habitat. The Forest Service failed to reinitiate consultation over effects to bull trout and its critical habitat from road-related activities, despite the agency's multiple failures to implement key aspects of the 2016 Chilly James BiOp, 2015 Roads Programmatic BiOp, 2010 Amendment 19 BiOp, 2004 Robert-Wedge BiOp, 2004 West Side BiOp, 2002 Moose BiOp, and 2002 Spotted Beetle BiOp. The resulting culvert failures show that effects to bull trout and its critical habitat from the road-related activities are greater than what was considered in those BiOps. 50 C.F.R. § 402.16(c). In addition, the Forest Service failed to reinitiate consultation over effects to bull trout and its critical habitat from its road-related activities despite new information since completion of those BiOps show that effects to bull trout and its critical habitat from the road-related activities are greater than what was considered in those BiOps. 50 C.F.R. § 402.16(b).

3. The Forest Service is in violation of Section 7(d) of the ESA by adopting changes to and implementing the road-related activities and reduced culvert monitoring before adequate and lawful consultation is complete. Such actions constitute an "irreversible and irretrievable commitment of resources" and warrant an injunction. See 16 U.S.C. §1536(d).

WildEarth Guardians, Swan View Coalition, and Friends of the Wild Swan will initiate litigation over the Forest Service's ESA violations unless the Forest Service consults, or reinitiates consultation, on the modifications to the culvert monitoring plans. Further, reinitiation of consultation is not sufficient to cure these violations of the ESA. Rather, the Forest Service must complete the Section

7 consultation process after reinitiation has been initiated.

For the above stated reasons, the Forest Service has violated and remains in ongoing violation of the ESA. The 60-day notice requirement is intended to provide you an opportunity to correct the actions in violation of the ESA.

We appreciate your consideration of the ESA violations outlined in this notice and hope that you will take action to resolve them. Please contact me if the Forest Service or FWS is interested in meeting, or if you have any questions or concerns regarding this notice of intent to sue.

Sincerely,

Marla Fox, Rewilding Attorney
WildEarth Guardians

cc: Jeff Sessions, U.S. Attorney General

Attachments

Attachment A: The Wilderness Society, *Transportation Infrastructure and Access on National Forests and Grasslands: A Literature Review* (May 2014).

Attachment B: Phone Log 11/17/06 (Dan Brewer, FWS and Steve Phillips, Forest Service).

Attachment C: Meeting notes Seeley Lake 11/30/06 T&C Reporting.

Attachment D: Maps of bull trout critical habitat, Flathead National Forest roads, barriers, and gates by Ranger District.

Attachment E: K. Hammer, Roads to Ruin: The Flathead National Forest Shirks Its Road Reclamation Duties (May 2016).

Attachment F: Pre Meeting Notes: By Dan Brewer. For the meeting with Steve Phillips of the Flathead National Forest (Seeley Lake Ranger District 11/30/06).

Attachment G: Luce, C. H, J. T. Abatzoglou, and Z. A. Holden. 2013. The Missing Mountain Water: Slower Westerlies Decrease Orographic Enhancement in the Pacific Northwest USA. Science 342: 1360-1364.

Attachment H: Isaak, D. J., *et al.* 2016. Slow climate velocities of mountain streams portend their role as refugia for cold-water biodiversity. Proc Natl Acad Sci, DOI: 10.1073/pnas.1522429113.

Attachment I: Auerbach, N. A., K. A. Wilson, A. I. T. Tulloch, J. R. Rhodes, J. O. Hanson, and H. P. Possingham. 2015. Effects of threat management interactions on conservation priorities. Conservation Biology 29:1626-1635.

Attachment J: Barnas, K. A., *et al.* 2015. Is habitat restoration targeting relevant ecological needs for endangered species? Using Pacific Salmon as a case study. Ecosphere 6(7), art 110.

Attachment K: Meyer, K.A. *et al.* 2014. Bull trout trends in abundance and probabilities of persistence in Idaho. North American Journal of Fisheries Management 34:202-214.

Attachment L: Wilcox, T. M. *et al.* 2014. A blocking primer increases specificity in environmental DNA detection of bull trout (*Salvelinus confluentus*). Conservation Genetics Resources 6:283-284.

Transportation Infrastructure and Access on National Forests and Grasslands
A Literature Review
May 2014

Introduction

The Forest Service transportation system is very large with 374,883 miles (603,316 km) of system roads and 143,346 miles (230,693 km) of system trails. The system extends broadly across every national forest and grasslands and through a variety of habitats, ecosystems and terrains. An impressive body of scientific literature exists addressing the various effects of roads on the physical, biological and cultural environment – so much so, in the last few decades a new field of "road ecology" has emerged. In recent years, the scientific literature has expanded to address the effects of roads on climate change adaptation and conversely the effects of climate change on roads, as well as the effects of restoring lands occupied by roads on the physical, biological and cultural environments.

The following literature review summarizes the most recent thinking related to the environmental impacts of forest roads and motorized routes and ways to address them. The literature review is divided into three sections that address the environmental effects of transportation infrastructure on forests, climate change and infrastructure, and creating sustainable forest transportation systems.

I. Impacts of Transportation Infrastructure and Access to the Ecological Integrity of Terrestrial and Aquatic Ecosystems and Watersheds

It is well understood that transportation infrastructure and access management impact aquatic and terrestrial environments at multiple scales, and, in general, the more roads and motorized routes the greater the impact. In fact, in the past 20 years or so, scientists having realized the magnitude and breadth of ecological issues related to roads; entire books have been written on the topic, e.g., Forman et al. (2003), and a new scientific field called "road ecology" has emerged. Road ecology research centers have been created including the Western

Transportation Institute at Montana State University and the Road Ecology Center at the University of California - Davis.[1]

Below, we provide a summary of the current understanding on the impacts of roads and access allowed by road networks to terrestrial and aquatic ecosystems, drawing heavily on Gucinski et al. (2000). Other notable recent peer-reviewed literature reviews on roads include Trombulak and Frissell (2000), Switalski et al. (2004), Coffin (2007), Fahrig and Rytwinski (2009), and Robinson et al. (2010). Recent reviews on the impact of motorized recreation include Joslin and Youmans (1999), Gaines et al. (2003), Davenport and Switalski (2006), Ouren et al. (2007), and Switalski and Jones (2012). These peer-reviewed summaries provide additional information to help managers develop more sustainable transportation systems

Impact on geomorphology and hydrology

The construction or presence of forest roads can dramatically change the hydrology and geomorphology of a forest system leading to reductions in the quantity and quality of aquatic habitat. While there are several mechanisms that cause these impacts (Wemple et al. 2001 , Figure 1), most fundamentally, compacted roadbeds reduce rainfall infiltration, intercepting and concentrating water, and providing a ready source of sediment for transport (Wemple et al. 1996, Wemple et al. 2001). In fact, roads contribute more sediment to streams than any other land management activity (Gucinski et al. 2000). Surface erosion rates from roads are typically at least an order of magnitude greater than rates from harvested areas, and three orders of magnitude greater than erosion rates from undisturbed forest soils (Endicott 2008).

---

[1] See http://www.westerntransportationinstitute.org/research/roadecology and http://roadecology.ucdavis.edu/

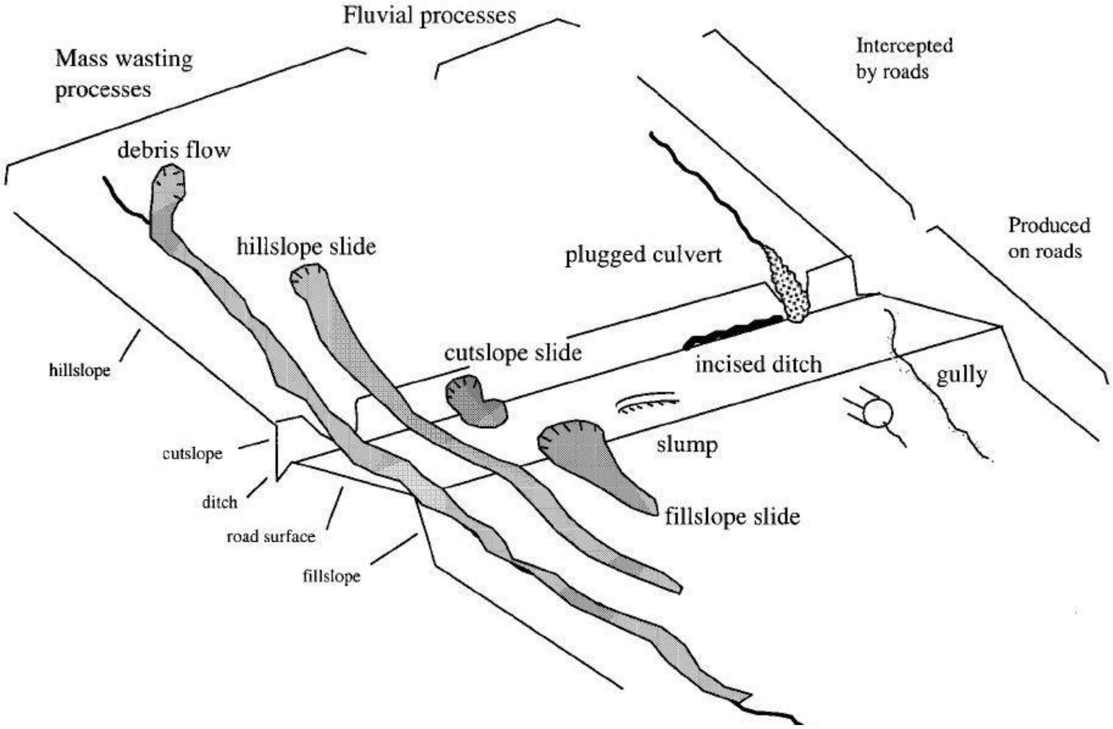


Figure 1: Typology of erosional and depositional features produced by mass-wasting and fluvial processes associate with forest roads (reprinted from Wemple et al. 2001)

Erosion of sediment from roads occurs both chronically and catastrophically. Every time it rains, sediment from the road surface and from cut- and fill-slopes is picked up by rainwater that flows into and on roads (fluvial erosion). The sediment that is entrained in surface flows are often concentrated into road ditches and culverts and directed into streams. The degree of fluvial erosion varies by geology and geography, and increases with increased motorized use (Robichaud et al. 2010). Closed roads produce less sediment, and Foltz et al. (2009) found a significant increase in erosion when closed roads were opened and driven upon.

Roads also precipitate catastrophic failures of road beds and fills (mass wasting) during large storm events leading to massive slugs of sediment moving into waterways (Endicott 2008; Gucinski et al. 2000). This typically occurs when culverts are undersized and cannot handle the volume of water, or they simply become plugged with debris. The saturated roadbed can fail entirely and result in a landslide, or the blocked stream crossing can erode the entire fill down to the original stream channel.

The erosion of road- and trail-related sediment and its subsequent movement into stream systems affects the geomorphology of the drainage system in a number of ways. The magnitude of their effects varies by climate, geology, road age, construction / maintenance practices and storm history. It directly alters channel morphology by embedding larger gravels as well as filling pools. It can also have the opposite effect of increasing peak discharges and scouring channels, which can lead to disconnection of the channel and floodplain, and lowered base flows (Furniss et al. 1991; Joslin and Youmans 1999). The width/depth ratio of the stream changes which then can trigger changes in water temperature, sinuosity and other geomorphic factors important for aquatic species survival (Joslin and Youmans 1999; Trombulak and Frissell 2000).

Roads also can modify flowpaths in the larger drainage network. Roads intercept subsurface flow as well as concentrate surface flow, which results in new flowpaths that otherwise would not exist, and the extension of the drainage network into previously unchannelized portions of the hillslope (Gucinski et al. 2000; Joslin and Youmans 1999). Severe aggradation of sediment at stream structures or confluences can force streams to actually go subsurface or make them too shallow for fish passage (Endicott 2008; Furniss et al. 1991).

Impacts on aquatic habitat and fish

Roads can have dramatic and lasting impacts on fish and aquatic habitat. Increased sedimentation in stream beds has been linked to decreased fry emergence, decreased juvenile densities, loss of winter carrying capacity, and increased predation of fishes, and reductions in macro-invertebrate populations that are a food source to many fish species (Rhodes et al. 1994, Joslin and Youmans 1999, Gucinski et al. 2000, Endicott 2008). On a landscape scale, these effects can add up to: changes in the frequency, timing and magnitude of disturbance to aquatic habitat and changes to aquatic habitat structures (e.g., pools, riffles, spawning gravels and in-channel debris), and conditions (food sources, refugi, and water temperature) (Gucinski et al. 2000).

Roads can also act as barriers to migration (Gucinski et al. 2000). Where roads cross streams, road engineers usually place culverts or bridges. Culverts in particular can and often interfere with sediment transport and channel processes such that the road/stream crossing becomes a barrier for fish and aquatic species movement up and down stream. For instance, a culvert may scour on the downstream side of the crossing, actually forming a waterfall up which fish cannot move. Undersized culverts and bridges can infringe upon the channel or floodplain and trap sediment causing the stream to become too shallow and/or warm such that fish will not migrate past the structure. This is problematic for many aquatic species but especially for anadromous species that must migrate upstream to spawn. Well-known native aquatic species affected by roads include salmon such as coho (*Oncorhynchus kisutch*), chinook (*O. tshawytscha*), and chum (*O. keta*); steelhead (*O. mykiss*); and a variety of trout species including bull trout (*Salvelinus confluentus*) and cutthroat trout (*O. clarki*), as well as other native fishes and amphibians (Endicott 2008).

Impacts on terrestrial habitat and wildlife

Roads and trails impact wildlife through a number of mechanisms including: direct mortality (poaching, hunting/trapping) changes in movement and habitat use patterns (disturbance/avoidance), as well as indirect impacts including alteration of the adjacent habitat and interference with predatory/prey relationships (Wisdom et al. 2000, Trombulak and Frissell 2000). Some of these impacts result from the road itself, and some result from the uses on and around the roads (access). Ultimately, roads have been found to reduce the abundance and distribution of several forest species (Fayrig and Ritwinski 2009, Benítez-López et al. 2010).

Table 1: Road- and recreation trail-associated factors for wide-ranging carnivores (Reprinted from Gaines et al. (2003)[2]

---

[2] For a list of citations see Gaines et al. (2003)

Focal species	**Road-associated factors**	**Motorized trail-associated factors**	**Nonmotorized trail-associated factors**
Grizzly bear	Poaching Collisions Negative human interactions Displacement or avoidance	Poaching Negative human interactions Displacement or avoidance	Poaching Negative human interactions Displacement or avoidance
Lynx	Down log reduction Trapping Collisions Disturbance at a specific site	Disturbance at a specific site Trapping	Disturbance at a specific site
Gray wolf	Trapping Poaching Collisions Negative human interactions Disturbance at a specific site Displacement or avoidance	Trapping Disturbance at a specific site	Trapping Disturbance at a specific site
Wolverine	Down log reduction Trapping Disturbance at a specific site Collisions	Trapping Disturbance at a specific site	Trapping Disturbance at a specific site

Direct mortality and disturbance from road and trail use impacts many different types of species. For example, wide-ranging carnivores can be significantly impacted by a number of factors including trapping, poaching, collisions, negative human interactions, disturbance and displacement (Gaines et al. 2003, Table 1). Hunted game species such as elk (*Cervus canadensis*), become more vulnerable from access allowed by roads and motorized trails resulting in a reduction in effective habitat among other impacts (Rowland et al. 2005, Switalski and Jones 2012). Slow-moving migratory animals such as amphibians, and reptiles who use roads to regulate temperature are also vulnerable (Gucinski et al. 2000, Brehme et al. 2013).

Habitat alteration is a significant consequence of roads as well. At the landscape scale, roads fragment habitat blocks into smaller patches that may not be able to support successfully interior forest species. Smaller habitat patches also results in diminished genetic variability, increased inbreeding, and at times local extinctions (Gucinski et al. 2000; Trombulak and Frissell 2000). Roads also change the composition and structure of ecosystems along buffer zones, called edge-affected zones. The width of edge-affected zones varies by what metric is being discussed; however, researchers have documented road-avoidance zones a kilometer or more away from a road (Table 2). In heavily roaded landscapes, edge-affected acres can be a significant fraction of total acres. For example, in a landscape area where the road density is 3 mi/mi^2 (not an uncommon road density in national forests) and where the edge-affected zone is estimated to be 500 ft from the center of the road to each side, the edge-affected zone is 56% of the total acreage.

Table 2: A summary of some documented road-avoidance zones for various species (adapted from Robinson et al. 2010).

Species	Avoidance zone m (ft)	Type of disturbance	Reference
Snakes	650 (2133)	Forestry roads	Bowles (1997)
Salamander	35 (115)	Narrow forestry road, light traffic	Semlitsch (2003)
Woodland birds	150 (492)	Unpaved roads	Ortega and Capen (2002)
Spotted owl	400 (1312)	Forestry roads, light traffic	Wasser et al. (1997)
Marten	<100 (<328)	Any forest opening	Hargis et al. (1999)
Elk	500–1000 (1640-3281)	Logging roads, light traffic	Edge and Marcum (1985)
	100–300 (328-984)	Mountain roads depending on traffic volume	Rost and Bailey (1979)
Grizzly bear	3000 (9840)	Fall	Mattson et al. (1996)
	500 (1640)	Spring and summer	
	883 (2897)	Heavily traveled trail	Kasworm and Manley (1990)
	274 (899)	Lightly traveled trail	
	1122 (3681)	Open road	Kasworm and Manley (1990)
	665 (2182)	Closed road	
Black bear	274 (899)	Spring, unpaved roads	Kasworm and Manley (1990)
	914 (2999)	Fall, unpaved roads	

Roads and trails also affect ecosystems and habitats because they are also a major vector of non-native plant and animal species. This can have significant ecological and economic impacts when the invading species are aggressive and can overwhelm or significantly alter native species and systems. In addition, roads can increase harassment, poaching and collisions with vehicles, all of which lead to stress or mortality (Wisdom et al. 2000).

Recent reviews have synthesized the impacts of roads on animal abundance and distribution. Fahrig and Rytwinski (2009) did a complete review of the empirical literature on effects of roads and traffic on animal abundance and distribution looking at 79 studies that addressed 131 species and 30 species groups. They found that the number of documented negative effects of roads on animal abundance outnumbered the number of positive effects by a factor of 5. Amphibians, reptiles, most birds tended to show negative effects. Small mammals generally showed either positive effects or no effect, mid-sized mammals showed either negative effects or no effect, and large mammals showed predominantly negative effects. Benítez-López et al. (2010) conducted a meta-analysis on the effects of roads and infrastructure proximity on mammal and bird populations. They found a significant pattern of avoidance and a reduction in bird and mammal populations in the vicinity of infrastructure.

Road density[3] thresholds for fish and wildlife

---

[3] We intend the term "road density" to refer to the density all roads within national forests, including system roads, closed roads, non-system roads administered by other jurisdictions (private, county, state), temporary roads and motorized trails. Please see Attachment 2 for the relevant existing scientific information supporting this approach.

It is well documented that beyond specific road density thresholds, certain species will be negatively affected, and some will be extirpated. Most studies that look into the relationship between road density and wildlife focus on the impacts to large endangered carnivores or hunted game species, although high road densities certainly affect other species – for instance, reptiles and amphibians. Gray wolves (*Canis lupus*) in the Great Lakes region and elk in Montana and Idaho have undergone the most long-term and in depth analysis. Forman and Hersperger (1996) found that in order to maintain a naturally functioning landscape with sustained populations of large mammals, road density must be below 0.6 km/km² (1.0 mi/mi²). Several studies have since substantiated their claim (Robinson et al. 2010, Table 3).

A number of studies at broad scales have also shown that higher road densities generally lead to greater impacts to aquatic habitats and fish density (Table 3). Carnefix and Frissell (2009) provide a concise review of studies that correlate cold water fish abundance and road density, and from the cited evidence concluded that "1) no truly "safe" threshold road density exists, but rather negative impacts begin to accrue and be expressed with incursion of the very first road segment; and 2) highly significant impacts (e.g., threat of extirpation of sensitive species) are already apparent at road densities on the order of 0.6 km/km^2 (1.0 mi/mi²) or less" (p. 1).

Table 3: A summary of some road-density thresholds and correlations for terrestrial and aquatic species and ecosystems (reprinted from Robinson et al. 2010).

Species (Location)	Road density (mean, guideline, threshold, correlation)	Reference
Wolf (Minnesota)	0.36 km/km2 (mean road density in primary range); 0.54 km/km^2 (mean road density in peripheral range)	Mech et al. (1988)
Wolf	>0.6 km/km^2 (absent at this density)	Jalkotzy et al. (1997)
Wolf (Northern Great Lakes region)	>0.45 km/km^2 (few packs exist above this threshold); >1.0 km/km^2 (no pack exist above this threshold)	Mladenoff et al. (1995)
Wolf (Wisconsin)	0.63 km/km^2 (increasing due to greater human tolerance	Wydeven et al. (2001)
Wolf, mountain lion (Minnesota, Wisconsin, Michigan)	0.6 km/km^2 (apparent threshold value for a naturally functioning landscape containing sustained populations)	Thiel (1985); van Dyke et al. (1986); Jensen et al. (1986); Mech et al. (1988); Mech (1989)
Elk (Idaho)	1.9 km/km^2 (density standard for habitat effectiveness)	Woodley 2000 cited in Beazley et al. 2004
Elk (Northern US)	1.24 km/km^2 (habitat effectiveness decline by at least 50%)	Lyon (1983)
Elk, bear, wolverine, lynx, and others	0.63 km/km^2 (reduced habitat security and increased mortality)	Wisdom et al. (2000)
Moose (Ontario)	0.2-0.4 km/km2 (threshold for pronounced response)	Beyer et al. (2013)
Grizzly bear (Montana)	>0.6 km/km^2	Mace et al. (1996); Mattson et al. (1996)
Black bear (North Carolina)	>1.25 km/km^2 (open roads); >0.5 km/km2 (logging roads); (interference with use of habitat)	Brody and Pelton (1989)
Black bear	0.25 km/km^2 (road density should not exceed)	Jalkotzy et al. (1997)
Bobcat (Wisconsin)	1.5 km/km^2 (density of all road types in home range)	Jalkotzy et al. (1997)

Large mammals	>0.6 km/km^2 (apparent threshold value for a naturally functioning landscape containing sustained populations)	Forman and Hersperger (1996)
Bull trout (Montana)	Inverse relationship of population and road density	Rieman et al. (1997); Baxter et al. (1999)
Fish populations (Medicine Bow National Forest)	(1) Positive correlation of numbers of culverts and stream crossings and amount of fine sediment in stream channels (2) Negative correlation of fish density and numbers of culverts	Eaglin and Hubert (1993) cited in Gucinski et al. (2001)
Macroinvertebrates	Species richness negatively correlated with an index of road density	McGurk and Fong (1995)
Non-anadromous salmonids (Upper Columbia River basin)	(1) Negative correlation likelihood of spawning and rearing and road density (2) Negative correlation of fish density and road density	Lee et al. (1997)

Where both stream and road densities are high, the incidence of connections between roads and streams can also be expected to be high, resulting in more common and pronounced effects of roads on streams (Gucinski et al. 2000). For example, a study on the Medicine Bow National Forest (WY) found as the number of culverts and stream crossings increased, so did the amount of sediment in stream channels (Eaglin and Hubert 1993). They also found a negative correlation with fish density and the number of culverts. Invertebrate communities can also be impacted. McGurk and Fong (1995) report a negative correlation between an index of road density with macroinvertebrate diversity.

The U.S. Fish and Wildlife Service's Final Rule listing bull trout as threatened (USDI Fish and Wildlife Service 1999) addressed road density, stating:

> "… assessment of the interior Columbia Basin ecosystem revealed that increasing road densities were associated with declines in four non-anadromous salmonid species (bull trout, Yellowstone cutthroat trout, westslope cutthroat trout, and redband trout) within the Columbia River Basin, likely through a variety of factors associated with roads (Quigley & Arbelbide 1997). Bull trout were less likely to use highly roaded basins for spawning and rearing, and if present, were likely to be at lower population levels (Quigley and Arbelbide 1997). Quigley et al. (1996) demonstrated that when average road densities were between 0.4 to 1.1 km/km^2 (0.7 and 1.7 mi/mi^2) on USFS lands, the proportion of subwatersheds supporting "strong" populations of key salmonids dropped substantially. Higher road densities were associated with further declines" (USDI Fish and Wildlife Service 1999, p. 58922).

Anderson et al. (2012) also showed that watershed conditions tend to be best in areas protected from road construction and development. Using the US Forest Service's Watershed Condition Framework assessment data, they showed that National Forest lands that are protected under the Wilderness Act, which provides the strongest safeguards, tend to have the healthiest watersheds. Watersheds in Inventoried Roadless Areas – which are protected from road building and logging by the Roadless Area Conservation Rule – tend to be less healthy than watersheds in designated Wilderness, but they are considerably healthier than watersheds in the managed landscape.

Impacts on other resources

Roads and motorized trails also play a role in affecting wildfire occurrence. Research shows that human-ignited wildfires, which account for more than 90% of fires on national lands, is almost five times more likely in areas with roads (USDA Forest Service 1996a; USDA Forest Service 1998). Furthermore, Baxter (2002) found that off-road vehicles (ORVs) can be a significant source of fire ignitions on forestlands. Roads can affect where and how forests burn and, by extension, the vegetative condition of the forest. See Attachment 1 for more information documenting the relationship between roads and wildfire occurrence.

Finally, access allowed by roads and trails can increase of ORV and motorized use in remote areas threatening archaeological and historic sites. Increased visitation has resulted in intentional and unintentional damage to many cultural sites (USDI Bureau of Land Management 2000, Schiffman 2005).

II. Climate Change and Transportation Infrastructure including the value of roadless areas for climate change adaptation

As climate change impacts grow more profound, forest managers must consider the impacts on the transportation system as well as from the transportation system. In terms of the former, changes in precipitation and hydrologic patterns will strain infrastructure at times to the breaking point resulting in damage to streams, fish habitat, and water quality as well as threats to public safety. In terms of the latter, the fragmenting effect of roads on habitat will impede the movement of species which is a fundamental element of adaptation. Through planning, forest managers can proactively address threats to infrastructure, and can actually enhance forest resilience by removing unneeded roads to create larger patches of connected habitat.

Impact of climate change and roads on transportation infrastructure

It is expected that climate change will be responsible for more extreme weather events, leading to increasing flood severity, more frequent landslides, changing hydrographs (peak, annual mean flows, etc.), and changes in erosion and sedimentation rates and delivery processes. Roads and trails in national forests, if designed by an engineering standard at all, were designed for storms and water flows typical of past decades, and hence may not be designed for the storms in future decades. Hence, climate driven changes may cause transportation infrastructure to malfunction or fail (ASHTO 2012, USDA Forest Service 2010). The likelihood is higher for facilities in high-risk settings—such as rain-on-snow zones, coastal areas, and landscapes with unstable geology (USDA Forest Service 2010).

Forests fragmented by roads will likely demonstrate less resistance and resilience to stressors, like those associated with climate change (Noss 2001). First, the more a forest is fragmented (and therefore the higher the edge/interior ratio), the more the forest loses its inertia characteristic, and becoming less resilient and resistant to climate change. Second, the more a forest is fragmented characterized by isolated patches, the more likely the fragmentation will interfere with the ability of species to track shifting climatic conditions over time and space. Noss (2001) predicts that weedy species with effective dispersal mechanisms might benefit from fragmentation at the expense of native species.

Modifying infrastructure to increase resilience
To prevent or reduce road failures, culvert blow-outs, and other associated hazards, forest managers will need to take a series of actions. These include replacing undersized culverts with larger ones, prioritizing maintenance and upgrades (e.g., installing drivable dips and more outflow structures), and obliterating roads that are no longer needed and pose erosion hazards (USDA Forest Service 2010, USDA Forest Service 2012a, USDA Forest Service 2011, Table 4).

Olympic National Forest has developed a number of documents oriented at oriented at protecting watershed health and species in the face of climate change, including a 2003 travel management strategy and a report entitled Adapting to Climate Change in Olympic National Park and National Forest. In the travel management strategy, Olympic National Forest recommended that 1/3rd of its road system be decommissioned and obliterated (USDA Forest Service 2011a). In addition, the plan called for addressing fish migration barriers in a prioritized and strategic way – most of these are associated with roads. The report calls for road decommissioning, relocation of roads away from streams, enlarging culverts as well as replacing culverts with fish-friendly crossings (USDA Forest Service 2011a, Table 4).

Table 4: Current and expected sensitivities of fish to climate change on the Olympic Peninsula, associated adaptation strategies and action for fisheries and fish habitat management and relevant to transportation management at Olympic National Forest and Olympic National Park (excerpt reprinted from USDA Forest Service 2011a).

Current and expected sensitivites	Adaptation strategies and actions
Changes in habitat quantity and quality	• Implement habitat restoration projects that focus on re-creating watershed processes and functions and that create diverse, resilient habitat.
Increase in culvert failures, fill-slope failures, stream adjacent road failures, and encroachment from stream-adjacent road segments	• Decommission unneeded roads. • Remove sidecast, improve drainage, and increase culvert sizing on remaining roads. • Relocate stream-adjacent roads.
Greater difficulty disconnecting roads from stream channels	• Design more resilient stream crossing structures.
Major changes in quantity and timing of streamflow in transitional watersheds	• Make road and culvert designs more conservative in transitional watersheds to accommodate expected changes.
Decrease in area of headwater streams	• Continue to correct culvert fish passage barriers. • Consider re-prioritizing culvert fish barrier correction projects.
Decrease in habitat quantity and connectivity for species that use headwater streams	• Restore habitat in degraded headwater streams that are expected to retain adequate summer streamflow (ONF).

In December 2012, the USDA Forest Service published a report entitled "Assessing the Vulnerability of Watersheds to Climate Change." This document reinforces the concept expressed by Olympic National Forest that forest managers need to be proactive in reducing erosion potential from roads:

> “Road improvements were identified as a key action to improve condition and resilience of watersheds on all the pilot Forests. In addition to treatments that reduce erosion, road improvements can reduce the delivery of runoff from road segments to channels, prevent diversion of flow during large events, and restore aquatic habitat connectivity by providing for passage of aquatic organisms. As stated previously, watershed sensitivity is determined by both inherent and management-related factors. Managers have no control over the inherent factors, so to improve resilience, efforts must be directed at anthropogenic influences such as instream flows, roads, rangeland, and vegetation management….
>
> [Watershed Vulnerability Analysis] results can also help guide implementation of travel management planning by informing priority setting for decommissioning roads and road reconstruction/maintenance. As with the Ouachita NF example, disconnecting roads from the stream network is a key objective of such work. Similarly, WVA analysis could also help prioritize aquatic organism passage projects at road-stream crossings to allow migration by aquatic residents to suitable habitat as streamflow and temperatures change” (USDA Forest Service 2012a, p. 22-23).

Reducing fragmentation to enhance aquatic and terrestrial species adaptation

Decommissioning and upgrading roads and thus reducing the amount of fine sediment deposited on salmonid nests can increase the likelihood of egg survival and spawning success (McCaffery et al. 2007). In addition, this would reconnect stream channels and remove barriers such as culverts. Decommissioning roads in riparian areas may provide further benefits to salmon and other aquatic organisms by permitting reestablishment of streamside vegetation, which provides shade and maintains a cooler, more moderated microclimate over the stream (Battin et al. 2007).

One of the most well documented impacts of climate change on wildlife is a shift in the ranges of species (Parmesan 2006). As animals migrate, landscape connectivity will be increasingly important (Holman et al. 2005). Decommissioning roads in key wildlife corridors will improve connectivity and be an important mitigation measure to increase resiliency of wildlife to climate change. For wildlife, road decommissioning can reduce the many stressors associated with roads. Road decommissioning restores habitat by providing security and food such as grasses and fruiting shrubs for wildlife (Switalski and Nelson 2011).

Forests fragmented by roads and motorized trail networks will likely demonstrate less resistance and resilience to stressors, such as weeds. As a forest is fragmented and there is more edge habitat, Noss (2001) predicts that weedy species with effective dispersal mechanisms will increasingly benefit at the expense of native species. However, decommissioned roads when seeded with native species can reduce the spread of invasive species (Grant et al. 2011), and help restore fragmented forestlands. Off-road vehicles with large knobby tires and large undercarriages are also a key vector for weed spread (e.g., Rooney 2006). Strategically closing and decommissioning motorized routes, especially in roadless areas, will reduce the spread of weeds on forestlands (Gelbard and Harrison 2003).

Transportation infrastructure and carbon sequestration

The topic of the relationship of road restoration and carbon has only recently been explored. There is the potential for large amounts of carbon (C) to be sequestered by reclaiming roads. When roads are decompacted during reclamation, vegetation and soils can develop more rapidly and sequester large amounts of carbon. A recent study estimated total soil C storage increased 6 fold to 6.5 x 107g C/km (to 25 cm depth) in the northwestern US compared to untreated abandoned roads (Lloyd et al. 2013). Another recent study concluded that reclaiming 425 km of logging roads over the last 30 years in Redwood National Park in Northern California resulted in net carbon savings of 49,000 Mg carbon to date (Madej et al. 2013, Table 5).

Kerekvliet et al. (2008) published a Wilderness Society briefing memo on the impact to carbon sequestration from road decommissioning. Using Forest Service estimates of the fraction of road miles that are unneeded, the authors calculated that restoring 126,000 miles of roads to a natural state would be equivalent to revegetating an area larger than Rhode Island. In addition, they calculate that the net economic benefit of road treatments are always positive and range from US$0.925-1.444 billion.

Table 5. Carbon budget implications in road decommissioning projects (reprinted from Madej et al. 2013).

Road Decommissioning Activities and Processes	Carbon Cost	Carbon Savings
Transportation of staff to restoration sites (fuel emissions)	X	
Use of heavy equipment in excavations (fuel emissions)	X	
Cutting trees along road alignment during hillslope recontouring	X	
Excavation of road fill from stream crossings		X
Removal of road fill from unstable locations		X
Reduces risk of mass movement		X
Post-restoration channel erosion at excavation sites	X	
Natural revegetation following road decompaction		X
Replanting trees		X
Soil development following decompaction		X

Benefits of roadless areas and roadless area networks to climate change adaptation

Undeveloped natural lands provide numerous ecological benefits. They contribute to biodiversity, enhance ecosystem representation, and facilitate connectivity (Loucks et al. 2003; Crist and Wilmer 2002, Wilcove 1990, The Wilderness Society 2004, Strittholt and Dellasala 2001, DeVelice and Martin 2001), and provide high quality or undisturbed water, soil and air (Anderson et al. 2012, Dellasalla et al. 2011). They also can serve as ecological baselines to help us better understand our impacts to other landscapes, and contribute to landscape resilience to climate change.

Forest Service roadless lands, in particular, are heralded for the conservation values they provide. These are described at length in the preamble of the Roadless Area Conservation Rule (RACR)[4] as well as in the Final Environmental Impact Statement (FEIS) for the RACR[5], and

---

[4] Federal Register .Vol. 66, No. 9. January 12, 2001. Pages 3245-3247.

include: high quality or undisturbed soil, water, and air; sources of public drinking water; diversity of plant and animal communities; habitat for threatened, endangered, proposed, candidate, and sensitive species and for those species dependent on large, undisturbed areas of land; primitive, semi-primitive non- motorized, and semi-primitive motorized classes of dispersed recreation; reference landscapes; natural appearing landscapes with high scenic quality; traditional cultural properties and sacred sites; and other locally identified unique characteristics (e.g., include uncommon geological formations, unique wetland complexes, exceptional hunting and fishing opportunities).

The Forest Service, National Park Service, and US Fish and Wildlife Service recognize that protecting and connecting roadless or lightly roaded areas is an important action agencies can take to enhance climate change adaptation. For example, the Forest Service National Roadmap for Responding to Climate Change (USDA Forest Service 2011b) establishes that increasing connectivity and reducing fragmentation are short and long term actions the Forest Service should take to facilitate adaptation to climate change.[6] The National Park Service also identifies connectivity as a key factor for climate change adaptation along with establishing "blocks of natural landscape large enough to be resilient to large-scale disturbances and long-term changes" and other factors. The agency states that: "The success of adaptation strategies will be enhanced by taking a broad approach that identifies connections and barriers across the landscape. Networks of protected areas within a larger mixed landscape can provide the highest level of resilience to climate change."[7] Similarly, the National Fish, Wildlife and Plants Climate Adaptation Partnership's Adaptation Strategy (2012) calls for creating an ecologically-connected network of conservation areas.[8]

---

[5] Final Environmental Impact Statement, Vol. 1, 3–3 to 3–7

[6] Forest Service, 2011. *National Roadmap for Responding to Climate Change*. US Department of Agriculture. FS-957b. Page 26.

[7] National Park Service. *Climate Change Response Program Brief.* http://www.nature.nps.gov/climatechange/adaptationplanning.cfm. Also see: National Park Service, 2010. *Climate Change Response Strategy*. http://www.nature.nps.gov/climatechange/docs/NPS_CCRS.pdf. Objective 6.3 is to "Collaborate to develop cross-jurisdictional conservation plans to protect and restore connectivity and other landscape-scale components of resilience."

[8] See http://www.wildlifeadaptationstrategy.gov/pdf/NFWPCAS-Chapter-3.pdf. Pages 55- 59. The first goal and related strategies are:

> Goal 1: Conserve habitat to support healthy fish, wildlife, and plant populations and ecosystem functions in a changing climate.
>
> > Strategy 1.1: identify areas for an ecologically-connected network of terrestrial, freshwater, coastal, and marine conservation areas that are likely to be resilient to climate change and to support a broad range of fish, wildlife, and plants under changed conditions.
> >
> > Strategy 1.2: Secure appropriate conservation status on areas identified in Strategy 1.1 to complete an ecologically-connected network of public and private conservation areas that will be resilient to climate change and support a broad range of species under changed conditions.
> >
> > Strategy 1.4: Conserve, restore, and as appropriate and practicable, establish new ecological connections among conservation areas to facilitate fish, wildlife, and plant migration, range shifts, and other transitions caused by climate change.

Crist and Wilmer (2002) looked at the ecological value of roadless lands in the Northern Rockies and found that protection of national forest roadless areas, when added to existing federal conservation lands in the study area, would 1) increase the representation of virtually all land cover types on conservation lands at both the regional and ecosystem scales, some by more than 100%; 2) help protect rare, species-rich, and often-declining vegetation communities; and 3) connect conservation units to create bigger and more cohesive habitat "patches."

Roadless lands also are responsible for higher quality water and watersheds. Anderson et al. (2012) assessed the relationship of watershed condition and land management status and found a strong spatial association between watershed health and protective designations. Dellasalla et al. (2011) found that undeveloped and roadless watersheds are important for supplying downstream users with high-quality drinking water, and developing these watersheds comes at significant costs associated with declining water quality and availability. The authors recommend a light-touch ecological footprint to sustain the many values that derive from roadless areas including healthy watersheds.

III. Sustainable Transportation Management in National Forests as Part of Ecological Restoration

At 375,000 miles strong, the Forest Service road system is one of the largest in the world – it is eight times the size of the National Highway System. It is also indisputably unsustainable – that is, roads are not designed, located, or maintained according to best management practices, and environmental impacts are not minimized. It is largely recognized that forest roads, especially unpaved ones, are a primary source of sediment pollution to surface waters (Endicott 2008, Gucinski et al. 2000), and that the system has about 1/3rd more miles than it needs (USDA Forest Service 2001). In addition, the majority of the roads were constructed decades ago when road design and management techniques did not meet current standards (Gucinski et al. 2000, Endicott 2008), making them more vulnerable to erosion and decay than if they had been designed today. Road densities in national forests often exceed accepted thresholds for wildlife.

Only a small portion of the road system is regularly used. All but 18% of the road system is inaccessible to passenger vehicles. Fifty-five percent of the roads are accessible only by high clearance vehicles and 27% are closed. The 18% that is accessible to cars is used for about 80% of the trips made within National Forests.[9] Most of the road maintenance funding is directed to the passenger car roads, while the remaining roads suffer from neglect. As a result, the Forest Service currently has a $3.7 billion road maintenance backlog that grows every year. In other words, only about 1/5th of the roads in the national forest system are used most of the time, and the fraction that is used often is the best designed and maintained because they are higher level access roads. The remaining roads sit generally unneeded and under-maintained – arguably a growing ecological and fiscal liability.

Current Forest Service management direction is to identify and implement a sustainable transportation system.[10] The challenge for forest managers is figuring out what is a sustainable road system and how to achieve it – a challenge that is exacerbated by climate change. It is

---

[9] USDA Forest Service. Road Management Website Q&As. Available online at http://www.fs.fed.us/eng/road_mgt/qanda.shtml.

[10] See Forest Service directive memo dated March 29, 2012 entitled "Travel Management, Implementation of 36 CFR, Part 202, Subpart A (36 CFR 212.5(b))"

reasonable to define a sustainable transportation system as one where all the routes are constructed, located, and maintained with best management practices, and social and environmental impacts are minimized. This, of course, is easier said than done, since the reality is that even the best roads and trail networks can be problematic simply because they exist and usher in land uses that without the access would not occur (Trombulak and Frissell 2000, Carnefix and Frissell 2009, USDA Forest Service 1996b), and when they are not maintained to the designed level they result in environmental problems (Endicott 2008; Gucinski et al. 2000). Moreover, what was sustainable may no longer be sustainable under climate change since roads designed to meet older climate criteria may no longer hold up under new climate scenarios (USDA Forest Service 2010, USDA Forest Service 2011b, USDA Forest Service 2012a, AASHTO 2012).

Forest Service efforts to move toward a more sustainable transportation system

The Forest Service has made efforts to make its transportation system more sustainable, but still has considerable work to do. In 2001, the Forest Service tried to address the issue by promulgating the Roads Rule[11] with the purpose of working toward a sustainable road system (USDA 2001). The Rule directed every national forest to identify a minimum necessary road system and identify unneeded roads for decommissioning. To do this, the Forest Service developed the Roads Analysis Process (RAP), and published Gucinski et al. (2000) to provide the scientific foundation to complement the RAP. In describing the RAP, Gucinski et al. (2000) writes:

> "Roads Analysis is intended to be an integrated, ecological, social, and economic approach to transportation planning. It uses a multiscale approach to ensure that the identified issues are examined in context. Roads Analysis is to be based on science. Analysts are expected to locate, correctly interpret, and use relevant existing scientific literature in the analysis, disclose any assumptions made during the analysis, and reveal the limitations of the information on which the analysis is based. The analysis methods and the report are to be subjected to critical technical review" (p. 10).

Most national forests have completed RAPs, although most only looked at passenger vehicle roads which account for less than 20% of the system's miles. The Forest Service Washington Office in 2010 directed that forests complete a Travel Analysis Process (TAP) by the end of fiscal year 2015, which must address all roads and create a map and list of roads identifying which are likely needed and which are not. Completed TAPs will provide a blueprint for future road decommissioning and management, they will not constitute compliance with the Roads Rule, which clearly requires the identification of the minimum roads system and roads for decommissioning. Almost all forests have yet to comply with subpart A.

The Forest Service in 2005 then tried to address the off-road portion of this issue by promulgating subpart B of the Travel Managemenr Rule,[12] with the purpose of curbing the most serious impacts associated with off-road vehicle use. Without a doubt, securing summer-time travel management plans was an important step to curbing the worst damage. However, much work remains to be done to approach sustainability, especially since many national forests used the travel management planning process to simply freeze the footprint of motorized routes, and did not try to re-design the system to make it more ecologically or socially sustainable. Adams

---

[11] 36 CFR 215 subpart A

[12] 36 CFR 212 subpart B

and McCool (2009) considered this question of how to achieve sustainable motorized recreation and concluded that:

> As the agencies move to revise [off-road vehicle] allocations, they need to clearly define how they intend to locate routes so as to minimize impacts to natural resources and other recreationists in accordance with Executive Order 11644....[13]
>
> …As they proceed with designation, the FS and BLM need to acknowledge that current allocations are the product of agency failure to act, not design. Ideally, ORV routes would be allocated as if the map were currently empty of ORV routes. Reliance on the current baseline will encourage inefficient allocations that likely disproportionately impact natural resources and non-motorized recreationists. While acknowledging existing use, the agencies need to do their best to imagine the best possible arrangement of ORV routes, rather than simply tinkering around the edges of the current allocations.[14]

The Forest Service only now is contemplating addressing the winter portion of the issue, forced by a lawsuit challenging the Forest Service's inadequate management of snowmobiles. The agency is expected to issue a third rule in the fall of 2014 that will trigger winter travel management planning.

Strategies for identifying a minimum road system and prioritizing restoration

Transportation Management plays an integral role in the restoration of Forestlands. Reclaiming and obliterating roads is key to developing a sustainable transportation system. Numerous authors have suggested removing roads 1) to restore water quality and aquatic habitats Gucinski et al. 2000), and 2) to improve habitat security and restore terrestrial habitat (e.g., USDI USFWS 1993, Hebblewhite et al. 2009).

Creating a minimum road system through road removal will increase connectivity and decrease fragmentation across the entire forest system. However, at a landscape scale, certain roads and road segments pose greater risks to terrestrial and aquatic integrity than others. Hence, restoration strategies must focus on identifying and removing/mitigating the higher risk roads. Additionally, areas with the highest ecological values, such as being adjacent to a roadless area, may also be prioritized for restoration efforts. Several methods have been developed to help prioritize road reclamation efforts including GIS-based tools and best management practices (BMPs). It is our hope that even with limited resources, restoration efforts can be prioritized and a more sustainable transportation system created.

GIS-based tools

---

[13] Recent court decisions have made it clear that the minimization requirements in the Executive Orders are not discretionary and that the Executive Orders are enforceable. See

- *Idaho Conservation League v. Guzman ,* 766 F. Supp. 2d 1056 (D. Idaho 2011) (Salmon-Challis National Forest TMP) .
- *The Wilderness Society v. U.S. Forest Service*, CV 08-363 (D. Idaho 2012) (Sawtooth-Minidoka district National Forest TMP).
- *Central Sierra Environmental Resource Center v. US Forest Service*, CV 10-2172 (E.D. CA 2012) (Stanislaus National Forest TMP).

[14] Page 105.

Girvetz and Shilling (2003) developed a novel and inexpensive way to analyze environmental impacts from road systems using the Ecosystem Management Decision Support program (EMDS). EMDS was originally developed by the United States Forest Service, as a GIS-based decision support tool to conduct ecological analysis and planning (Reynolds 1999). Working in conjunction with Tahoe National Forest managers, Girvetz and Shilling (2003) used spatial data on a number of aquatic and terrestrial variables and modeled the impact of the forest's road network. The network analysis showed that out of 8233 km of road analyzed, only 3483 km (42%) was needed to ensure current and future access to key points. They found that the modified network had improved patch characteristics, such as significantly fewer "cherry stem" roads intruding into patches, and larger roadlessness.

Shilling et al. (2012) later developed a recreational route optimization model using a similar methodology and with the goal of identifying a sustainable motorized transportation system for the Tahoe National Forest (Figure 2). Again using a variety of environmental factors, the model identified routes with high recreational benefits, lower conflict, lower maintenance and management requirements, and lower potential for environmental impact operating under the presumption that such routes would be more sustainable and preferable in the long term. The authors combined the impact and benefit analyses into a recreation system analysis "that was effectively a cost-benefit accounting, consistent with requirements of both the federal Travel Management Rule (TMR) and the National Environmental Policy Act" (p. 392**).**

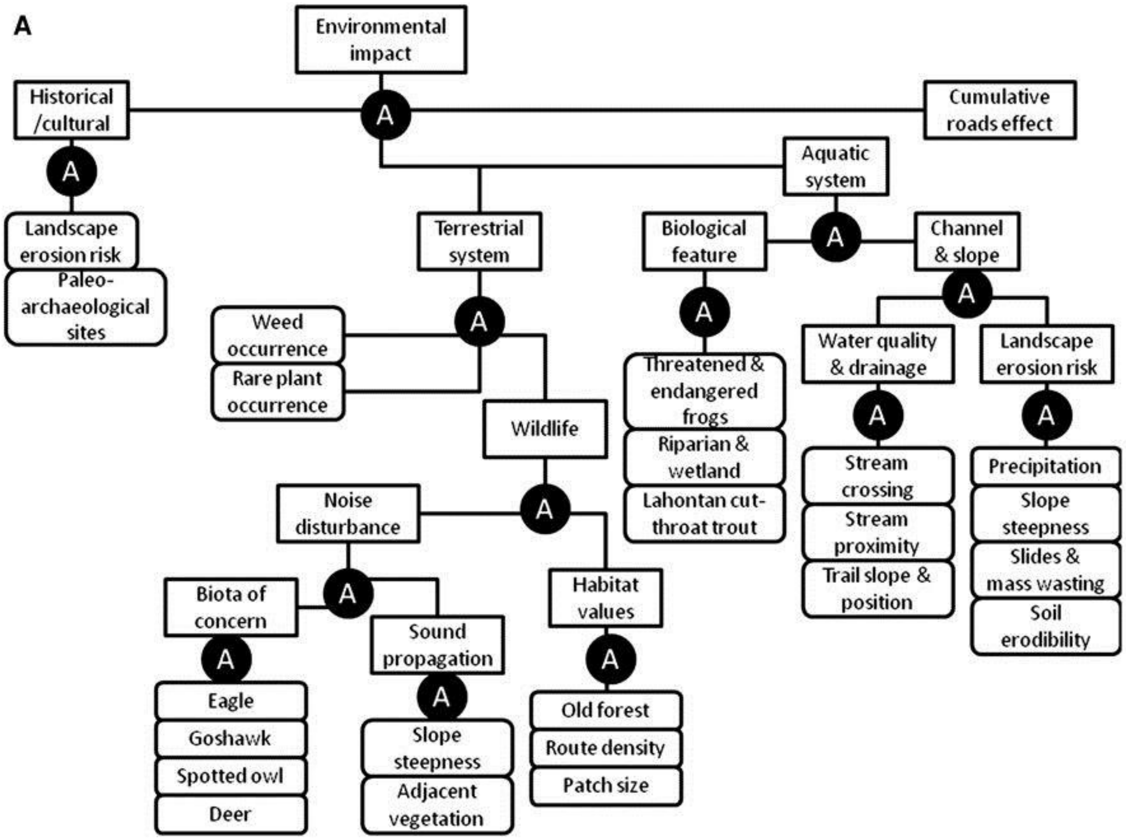


Figure 2: A knowledge base of contributions of various environmental conditions to the concept ‘‘environmental impact’’ [of motorized trails]. Rectangles indicate concepts, circles indicate Boolean logic operators, and rounded rectangles indicate sources of environmental data. (Reprinted from Shilling et al. 2012)

The Wilderness Society in 2012 also developed a GIS decision support tool called “RoadRight” that identifies high risk road segments to a variety of forest resources including water, wildlife, and roadlessness (The Wilderness Society 2012, The Wilderness Society 2013). The GIS system is designed to provide information that will help forest planners identify and minimize road related environmental risks. See the summary of and user guide for RoadRight that provides more information including where to access the open source software.[15]

---

[15] The Wilderness Society, 2012. Rightsizing the National Forest Road System: A Decision Support Tool. Available at http://www.landscapecollaborative.org/download/attachments/12747016/Road+decommissioning+model+-overview+2012-02-29.pdf?version=1&modificationDate=1331595972330.

The Wilderness Society, 2013.
RoadRight: A Spatial Decision Support System to Prioritize Decommissioning and Repairing Roads in

Best management practices (BMPs)

BMPs have also been developed to help create more sustainable transportation systems and identify restoration opportunities. BMPs provide science-based criteria and standards that land managers follow in making and implementing decisions about human uses and projects that affect natural resources. Several states have developed BMPs for road construction, maintenance and decommissioning practices (e.g., Logan 2001, Merrill and Cassaday 2003, USDA Forest Service 2012b).

Recently, BMPs have been developed for addressing motorized recreation. Switalski and Jones (2012) published, "*Off-Road Vehicle Best Management Practices for Forestlands: A Review of Scientific Literature and Guidance for Managers*." This document reviews the current literature on the environmental and social impacts of off-road vehicles (ORVs), and establishes a set of Best Management Practices (BMPs) for the planning and management of ORV routes on forestlands. The BMPs were designed to be used by land managers on all forestlands, and is consistent with current forest management policy and regulations. They give guidance to transportation planners on where how to place ORV routes in areas where they will reduce use conflicts and cause as little harm to the environment as possible. These BMPs also help guide managers on how to best remove and restore routes that are redundant or where there is an unacceptable environmental or social cost.

References

AASHTO. 2012. Adapting Infrastructure to Extreme Weather Events: Best Practices and Key Challenges. Background Paper. AASHTO Workshop. Traverse City, Michigan, May 20, 2012. Available at: http://climatechange.transportation.org/pdf/adapt_background5-20-12.pdf.

Adams, J.C., and S.F. McCool. 2009. Finite recreation opportunities: The Forest Service, the Bureau of Land Management, and off-road vehicle management. Natural Areas Journal 49: 45–116.

Anderson, H.M., C. Gaolach, J. Thomson, and G. Aplet. 2012. Watershed Health in Wilderness, Roadless, and Roaded Areas of the National Forest System. Wilderness Society Report. 11 p.

Battin J., M.W. Wiley, M.H. Ruckelshaus, R.N. Palmer, E. Korb, K.K. Bartz, and H. Imaki. 2007. Projected impacts of climate change on salmon habitat restoration. Proceedings of the National Academy of Sciences of the United States of America 104: 6720–6725.

Baxter, C.V., C.A. Frissell, and F.R. Hauer. 1999. Geomorphology, logging roads, and the distribution of bull trout spawning in a forested river basin: implications for management and conservation. Transactions of the American Fisheries Society 128: 854–867.

Baxter, G. 2002. All terrain vehicles as a cause of fire ignition in Alberta forests. Advantage (Publication of the Forest Engineering Research Institute of Canada) 3(44): 1-7.

National Forests User Guide. RoadRight version: 2.2, User Guide version: February, 2013. Available at http://www.landscapecollaborative.org/download/attachments/18415665/RoadRight%20User%20Guide%20v22.pdf?api=v2

Beazley, K., T. Snaith, F. MacKinnon, and D. Colville. 2004. Road density and the potential impacts on wildlife species such as American moose in mainland Nova Scotia. Proceedings of the Nova Scotia Institute of Science 42: 339-357.

Benítez-López , A., R. Alkemade, and P.A. Verweij. 2010. The impacts of roads and other infrastructure on mammal and bird populations: a meta-analysis. Biological Conservation 143: 1307-1316.

Beyer, H.L., R. Ung, D.L. Murray, and M.J. Fortin. 2013 Functional responses, seasonal variation and thresholds in behavioural responses of moose to road density. Journal of Applied Ecology 50: 286–294.

Brehme, C.S., and J.A. Tracey, L.R. McClenaghan, and R.N. Fisher. 2013. Permeability of roads to movement of scrubland lizards and small mammals. Conservation Biology 27(4): 710–720.

Bowles, A.E. 1997. Responses of wildlife to noise. In Wildlife and recreationists: coexistence through management and research. Edited by R.L. Knight and K.J. Gutzwiller. Island Press, Washington, DC. p. 109–156.

Brody, A.J., and M.R. Pelton. 1989. Effects of roads on black bear movements in western North Carolina. Wildlife Society Bulletin 17: 5-10.

Carnefix, G., and C. A. Frissell. 2009. Aquatic and Other Environmental Impacts of Roads: The Case for Road Density as Indicator of Human Disturbance and Road-Density Reduction as Restoration Target; A Concise Review. Pacific Rivers Council Science Publication 09-001. Pacific Rivers Council, Portland, OR and Polson, MT. Available at: http://www.pacificrivers.org/science-research/resources-publications/road-density-as-indicator/download

Coffin, A. 2006. From roadkill to road ecology: A review of the ecological effects of roads. Journal of Transport Geography 15: 396-406.

Crist, M.R., and B. Wilmer. 2002. Roadless Areas: The Missing Link in Conservation. The Wilderness Society, Washington D.C.

Davenport, J., and T.A. Switalski. 2006. Environmental impacts of transport related to tourism and leisure activities. In: The ecology of transportation: managing mobility for the environment, editors: J Davenport and Julia Davenport. Dordrecht, Netherlands: Kluwer Academic Publishers. 333-360. Available at: http://www.wildlandscpr.org/files/uploads/PDFs/d_Switalski_2006_Enviro_impacts_of_transport.pdf

DellaSala, D., J. Karr, and D. Olson. 2011. Roadless areas and clean water. Journal of Soil and Water Conservation, vol. 66, no. 3. May/June 2011.

DeVelice, R., and J.R. Martin. 2001. Assessing the extent to which roadless areas complement the conservation of biological diversity. Ecological Applications 11(4): 1008-1018.

Endicott, D. 2008. National Level Assessment of Water Quality Impairments Related to Forest Roads and Their Prevention by Best Management Practices. A Report Prepared by the Great Lakes Environmental Center for the Environmental Protection Agency, Office of Water, December 4, 2008. 259 pp.

Edge, W.D., and C.L. Marcum. 1985. Movements of elk in relation to logging disturbances. Journal of Wildlife Management 49(4): 926–930.

Fahrig, L., and T. Rytwinski. 2009. Effects of roads on animal abundance: an empirical review and synthesis. Ecology and Society 14(1): 21.
Available at: http://www.ecologyandsociety.org/vol14/iss1/art21/.

Foltz, R.B. N.S. Copeland, and W.J. Elliot. 2009. Reopening abandoned forest roads in northern Idaho, USA: Quantification of runoff, sediment concentration, infiltration, and interrill erosion parameters. Journal of Environmental Management 90: 2542–2550.

Forman, R. T. T., and A.M. Hersperger. 1996. Road ecology and road density in different landscapes, with international planning and mitigation solutions. Pages 1–22. IN: G. L. Evink, P. Garrett, D. Zeigler, and J. Berry (eds.), Trends in Addressing Transportation Related Wildlife Mortality. No. FLER- 58-96, Florida Department of Transportation, Tallahassee, Florida.

Foreman, R.T.T., D. Sperling, J.A. Bissonette et al. 2003. Road Ecology – Science and Solutions. Island Press. Washington, D.C. 504 p.

Furniss, M.J., T.D. Roelofs, and C.S. Yee. 1991. Road construction and maintenance. In: Meehan, W.R., ed. Influences of forest and rangeland management on salmonid fishes and their habitats. Spec. Publ. 19. Bethesda, MD: American Fisheries Society. p. 297-323.

Gaines, W.L., P. Singleton, and R.C. Ross. 2003. Assessing the cumulative effects of linear recreation routes on wildlife habitats on the Okanogan and Wenatchee National Forests. Gen. Tech. Rep. PNW-GTR-586. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 79 p. Available at: http://www.montanawildlife.com/projectsissues/Assessingthecumulativeeffectsoflinearrecreationroutesonwildlifehabitats.pdf

Gelbard, J.L., and S. Harrison. 2003. Roadless habitats as refuges for native grasslands: interactions with soil, aspect, and grazing. Ecological Applications 13(2): 404-415.

Girvetz, E., and F. Shilling. 2003. Decision Support for Road System Analysis and Modification on the Tahoe National Forest. Environmental Management 32(2): 218–233

Grant, A., C.R. Nelson, T.A. Switalski, and S.M. Rinehart. 2011. Restoration of native plant communities after road decommissioning in the Rocky Mountains: effect of seed mix composition & soil properties on vegetatative establishment. Restoration Ecology 19: 160-169.

Gucinski, M., J. Furniss, R. Ziemer, and M.H. Brookes. 2000. Forest Roads: A Synthesis of Scientific Information. Gen. Tech. Rep. PNWGTR-509. Portland, OR: U.S. Department of

Agriculture, Forest Service, Pacific Northwest Research Station. 103 p. Available at: http://www.fs.fed.us/pnw/pubs/gtr509.pdf.

Hargis, C.D., J.A. Bissonette, and D.T. Turner. 1999. The influence of forest fragmentation and landscape pattern on American martens. Journal of Applied Ecology 36(1): 157–172.

Hebblewhite, M., R.H. Munro, E.H Merrill. 2009. Trophic consequences of postfire logging in a wolf-ungulate system. Forest Ecology and Management 257(3): 1053-1062.

Holman, I.P., R.J. Nicholls, P.M. Berry, P.A. Harrison, E. Audsley, S. Shackley, and M.D.A. Rounsevell. 2005. A regional, multi-sectoral and integrated assessment of the impacts of climate and socio-economic change in the UK. Part II. Results. Climatic Change 71: 43-73.

Jalkotzy, M.G., P.I. Ross, and M.D. Nasserden. 1997. The effects of linear developments on wildlife: a review of selected scientific literature. Prepared for Canadian Association of Petroleum Producers. Arc Wildlife Services, Ltd., Calgary, AB. 115 p.

Jensen W.F., T.K. Fuller, and W.L. Robinson. 1986. Wolf (*Canis lupus*) distribution on the Onterio-Michigan border near Sault Ste. Marie. Canadian Field-Naturalist 100: 363-366.

Joslin, G., and H. Youmans, coordinators. 1999. Effects of recreation on Rocky Mountain wildlife: A Review for Montana. Committee on Effects of Recreation on Wildlife, Montana Chapter of The Wildlife Society. 307 p. Available at: http://joomla.wildlife.org/Montana/index

Kasworm, W.F., and T.L. Manley. 1990. Road and trail influences on grizzly bears and black bears in northwest Montana. International Conference on Bear Research and Management 8: 79-84.

Kerkvliet, J., J. Hicks, and B. Wilmer. 2008. Carbon Sequestered when Unneeded National Forest Roads are Revegetated. The Wilderness Society Briefing Memo. Available at: http://wilderness.org/sites/default/files/legacy/brief_carbonandroads.pdf.

Lee, D., J. Sedell, B.E. Rieman, R. Thurow, and J. Williams. 1997. Broad-scale assessment of aquatic species and habitats. In: An assessment of ecosystem components in the interior Columbia basin and portions of the Klamath and Great Basins. Edited by T.M. Quigley and S.J. Arbelbide. General Technical ReportPNW-GTR-405. USDA Forest Service, Pacific Northwest Research Station, Portland, OR. Vol III. p. 183–196.

Lloyd, R., K. Lohse, and T.P.A. Ferre. 2013. Influence of road reclamation techniques on forest ecosystem recovery. Frontiers in Ecology and the Environment 11(2): 75-81.

Loucks, C., N. Brown, A. Loucks, and K. 2003. USDA Forest Service roadless areas: potential biodiversity conservation reserves. Conservation Ecology 7(2): 5. Available at: http://www.ecologyandsociety.org/vol7/iss2/art5/

Logan, R. 2001. Water Quality BMPs for Montana Forests. Montana Department of Environmental Quality. Missoula, MT. 60p. Available at:

https://dnrc.mt.gov/Forestry/Assistance/Practices/Documents/2001WaterQualityBMPGuide.pdf

Lyon, L.J. 1983. Road density models describing habitat effectiveness for elk. Journal of Forestry 81: 592-595.

Mace, R.D., J.S. Waller, T.L. Manley, L.J. Lyon, and H. Zuuring. 1996. Relationships among grizzly bears, roads and habitat in the Swan Mountains, MT. Journal of Applied Ecology. 33: 1395-1404.

Madej, M., J. Seney, and P. van Mantgem. 2013. Effects of road decommissioning on carbon stocks, losses, and emissions in north coastal California. Restoration Ecology 21(4): 439–446.

Mattson, D.J., S. Herrero, R.G. Wright, and C.M. Pease. 1996. Science and management of Rocky Mountain grizzly bears. Conservation Biology 10(4): 1013-1025.

McCaffery M., T.A. Switalski, and L. Eby. 2007. Effects of road decommissioning on stream habitat characteristics in the South Fork Flathead River, Montana. Transactions of the American Fisheries Society 136: 553-561.

McGurk, B.J., and D.R. Fong, 1995. Equivalent roaded area as a measure of cumulative effect of logging. Environmental Management 19: 609-621.

Mech, L D. 1989. Wolf population survival in an area of high road density. American Midland Naturalist 121: 387-389.

Mech, L. D., S.H. Fritts, G.L. Radde, and W.J. Paul. 1988. Wolf distribution and road density in Minnesota. Wildlife Society Bulletin 16: 85-87.

Merrilll, B.R., and E. Cassaday. 2003. Best Management Practices for Road Rehabilitation – Road – Stream Crossing Manual. California State Parks. Eureka, CA. 25p. Available at: http://www.parks.ca.gov/pages/23071/files/streamcrossingremovalbmp5_03.pdf

Mladenoff, D.J., T.A. Sickley, R.G. Haight, and A.P. Wydeven. 1995. A regional landscape analysis and prediction of favorable gray wolf habitat in the Northern Great Lakes region. Conservation Biology 9: 279-294.

Moore, T. 2007. [unpublished draft]. National Forest System Road Trends, Trends Analysis Submitted to Office of Management and Budget. United States Department of Agriculture, Forest Service, Engineering Staff, Washington Office, Washington, DC.

National Fish, Wildlife and Plants Climate Adaptation Partnership (NFWPCAP). 2012. National Fish, Wildlife and Plants Climate Adaptation Strategy. Association of Fish and Wildlife Agencies, Council on environmental Quality, Great Lakes Indian Fish and Wildlife Commission, National Oceanic and Atmospheric Administration, and U.S. Fish and Wildlife Service. Washington, DC.

Noss, R.F. 2001. Beyond Kyoto: forest management in a time of rapid climate change. Conservation Biology 15(3): 578-590.

Ortega, Y.K., and D.E. Capen. 2002. Roads as edges: effects on birds in forested landscapes. Forest Science 48(2): 381–396.

Ouren, D.S., C. Haas, C.P. Melcher, S.C. Stewart, P.D. Ponds, N.R. Sexton, L. Burris, T. Fancher, and Z.H. Bowen. 2007. Environmental effects of off-highway vehicles on Bureau of Land Management lands: A literature synthesis, annotated bibliographies, extensive bibliographies, and internet resources: U.S. Geological Survey, Open-File Report 2007-1353, 225 p.

Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. Annual Review of Ecology, Evolution, and Systematics 37: 637-669.

Quigley, T.M., and S.J. Arbelbide, tech. eds. 1997. An assessment of ecosystem components in the interior Columbia basin and portions of the Klamath and Great Basins: volume 1 and volume 3. Gen. Tech. Rep. PNW-GTR-405. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Available at: http://www.fs.fed.us/pnw/publications/pnw_gtr405/.

Reynolds, K. 1999. Netweaver for EMDS user guide (version1.1); a knowledge base development system. General technical Report PNW-GTR-471. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Rhodes, J.J., McCullough, D.A., and F.A. Espinosa. 1994. A coarse screening process for evaluation of the effects of land management activities on salmon spawning and rearing habitat in ESA consultations. Tech. Rep. 94-4. Portland, OR: Columbia River Intertribal Fish Commission. 127 p.

Rieman, B., D. Lee, G. Chandler, and D. Myers. 1997. Does wildfire threaten extinction for salmonids? Responses of Redband Trout and Bull Trout Following Recent Large Fires on the Boise National Forest, in Greenlee, J. M., Proceedings: First Conference on Fire Effects on Rare and Endangered Species and Habitats. Coeur d'Alene, Idaho. International Association of Wildland Fire. Fairfield, WA. p. 47-57.

Robichaud, P.R., L.H. MacDonald, and R.B. Foltz. 2010. Fuel management and Erosion. In: Cumulative Watershed Effects of Fuels Management in the Western United States. USDA Forest Service RMRS-GTR-231. P. 79-100. Available at: http://www.fs.fed.us/rm/pubs/rmrs_gtr231/rmrs_gtr231_079_100.pdf

Robinson, C., P.N. Duinker, and K.F. Beazley. 2010. A conceptual framework for understanding, assessing, and mitigation effects for forest roads. Environmental Review 18: 61-86.

Rooney, T.P. 2006. Distribution of ecologically-invasive plants along off-road vehicle trails in the Chequamegon National Forest, Wisconsin. The Michigan Botanist 44:178-182

Rost, G.R., and J.A. Bailey. 1979. Distribution of mule deer and elk in relation to roads. Journal of Wildlife Management 43(3): 634–641.

Rowland, M.M., M.J. Wisdom, B.K. Johnson, and M.A. Penninger. 2005. Effects of roads on elk: implications for management in forested ecosystems. Pages 42-52. IN: Wisdom, M.J., technical editor, The Starkey Project: a Synthesis of Long-term Studies of Elk and Mule Deer. Reprinted from the 2004 Transactions of the North American Wildlife and Natural Resources Conference, Alliance Communications Group, Lawrence, KS.

Schiffman, L. 2005. Archaeology, Off-Road Vehicles, and the BLM. Published online April 20, 2005. Archeaology.
Available at: http://www.archaeology.org/online/features/southwest/

Semlitsch, R.D., T.J. Ryan, K. Hamed, M. Chatfield, B. Brehman, N. Pekarek, M. Spath, and A. Watland. 2007. Salamander abundance along road edges and within abandoned logging roads in Appalachian forests. Conservation Biology 21: 159-167.

Shilling, F., J. Boggs, and S. Reed. 2012. Recreational System Optimization to Reduce Conflict on Public Lands. Environmental Management 50: 381–395.

Strittholt, J., and D. Dellasala. 2001. Importance of Roadless Area Conservation in Forested Ecosystems: Case Study of the Klamath-Siskiyou Region of the United States. In Conservation Biology 15(6): 1742-1754.

Switalski, T.A., J.A. Bissonette, T.H. DeLuca, C.H. Luce, and M.A. Madej. 2004. Benefits and impacts of road removal. Frontiers in Ecology and the Environment. 2(1): 21-28.
Available at: http://www.fs.fed.us/rm/pubs_other/rmrs_2004_switalski_t001.pdf

Switalski, T.A., and C.R. Nelson. 2011. Efficacy of road removal for restoring wildlife habitat: black bear in the Northern Rocky Mountains, USA. Biological Conservation 144: 2666-2673.

Switalski, T.A., and A. Jones. 2012. Off-road vehicle best management practices for forestlands: A review of scientific literature and guidance for managers. Journal of Conservation Planning 8: 12-24.

The Wilderness Society. 2004. Landscape Connectivity: An Essential Element of Land Management. Policy Brief. Number 1.

The Wilderness Society. 2012. Rightsizing the National Forest Road System: A Decision Support Tool. Available at: http://www.landscapecollaborative.org/download/attachments/12747016/Road+decommissioning+model+-overview+2012-02-29.pdf?version=1&modificationDate=1331595972330.

The Wilderness Society. 2013. RoadRight: A Spatial Decision Support System to Prioritize Decommissioning and Repairing Roads in National Forests User Guide. RoadRight version: 2.2, User Guide version: February, 2013.

Available at: http://www.landscapecollaborative.org/download/attachments/18415665/RoadRight%20User%20Guide%20v22.pdf?api=v2

Thiel, R.P. 1985. The relationships between road densities and wolf habitat in Wisconsin. American Midland Naturalist 113: 404-407.

Trombulak S., and C. Frissell. 2000. Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities. Conservation Biology 14(1): 18-30.

USDA Forest Service. 1996a. National Forest Fire Report, 1994. Washington DC.

USDA Forest Service. 1996b. Status of the interior Columbia basin: summary of scientific findings. Gen. Tech. Rep. PNW-GTR-385. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station; U.S. Department of the Interior, Bureau of Land Management. 144 p.

USDA Forest Service. 1998. 1991-1997 Wildland Fire Statistics. Fire and Aviation Management, Washington, D.C.

USDA Forest Service. 1999. Roads Analysis: Informing Decisions about Managing the National Forest Transportation System. Misc. Rep. FS-643. Washington, D.C.: USDA Forest Service. 222 p. Available at: http://www.fs.fed.us/eng/road_mgt/DOCSroad-analysis.shtml

USDA Forest Service. 2001a. Final National Forest System Road Management Strategy Environmental Assessment and Civil Rights Impact Analysis. U.S. Department of Agriculture Forest Service Washington Office, January 2001.

USDA Forest Service. 2010. Water, Climate Change, and Forests: Watershed Stewardship for a Changing Climate, PNW-GTR-812, June 2010, 72 p.
Available at: http://www.fs.fed.us/pnw/pubs/pnw_gtr812.pdf.

USDA Forest Service. 2011a. Adapting to Climate Change at Olympic National Forest and Olympic National Park. Forest Service Pacific Northwest Research Station General Technical Report, PNW-GTR-844, August 2011.
Available at: http://www.fs.fed.us/pnw/pubs/pnw_gtr844.pdf

USDA Forest Service. 2011b. National Roadmap for Responding to Climate Change. US Department of Agriculture. FS-957b. 26 p.
Available at: http://www.fs.fed.us/climatechange/pdf/Roadmap_pub.pdf.

USDA Forest Service. 2012a. Assessing the Vulnerability of Watersheds to Climate Change: Results of National Forest Watershed Vulnerability Pilot Assessments. Climate Change Resource Center.

USDA Forest Service. 2012b. National Best Management Practices for Water Quality Management on National Forest System Lands. Report# FS-990. 177p. Available at:

http://www.fs.fed.us/biology/resources/pubs/watershed/FS_National_Core_BMPs_April2012.pdf

USDI Fish and Wildlife Service. 1993. Grizzly bear recovery plan. Missoula, MT. 181p.

USDI Fish and Wildlife Service. 1999. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for Bull Trout in the Coterminous United States; Final Rule. Federal Register Volume 64, Number 210 (Monday, November 1, 1999). p. 58922.

USDI Bureau of Land Management. 2000. Strategic paper on cultural resources at risk. Bureau of Land Management, Washington, D.C. 18 p.

USDI National Park Service. 2010. Climate Change Response Strategy. National Park Service Climate Change Response Program, Fort Collins, Colorado.
Available at: http://www.nature.nps.gov/climatechange/docs/NPS_CCRS.pdf.

van Dyke, F.G., R.H. Brocke, H.G. Shaw, B.B Ackerman, T.P. Hemker, and F.G. Lindzey. 1986. Reactions of mountain lions to logging and human activity. Journal of Wildlife Management. 50(1): 95–102.

Wasser, S.K., K. Bevis, G. King, and E. Hanson. 1997. Noninvasive physiological measures of disturbance in the northern spotted owl. Conservation Biology 11(4): 1019–1022.

Wemple, B.C., J.A. Jones, and G.E. Grant. 1996. Channel network extension by logging roads in two basins, western Cascades, OR. Water Resources Bulletin 32: 1195-1207.

Wemple, B.C., F.J. Swanson, and J.A. Jones. 2001. Forest Roads and geomorphic process interactions, Cascade Range, Oregon. Earth Surface Process and Landforms 26: 191-204.
Available at: http://andrewsforest.oregonstate.edu/pubs/pdf/pub2731.pdf

Wilcove, D.S. 1990. The role of wilderness in protecting biodiversity. Natural Resources and Environmental Issues: Vol. 0, Article 7.

Wisdom, M.J., R.S. Holthausen, B.C. Wales, C.D. Hargis, V.A. Saab, D.C. Lee, W.J. Hann, T.D. Rich, M.M. Rowland, W.J. Murphy, and M.R. Eames. 2000. Source habitats for terrestrial vertebrates of focus in the interior Columbia basin: Broad-scale trends and management implications. Volume 1 – Overview. Gen. Tech. Rep. PNW-GTR-485. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.
Wydeven, A.P, D.J. Mladenoff, T.A. Sickley, B.E. Kohn, R.P. Thiel, and J.L. Hansen. 2001. Road density as a factor in habitat selection by wolves and other carnivores in the Great Lakes Region. Endangered Species Update 18(4): 110-114.

Attachments

Attachment 1: Wildfire and Roads Fact Sheet

Attachment 2: Using Road Density as a Metric for Ecological Health in National Forests: What Roads and Routes should be Included? Summary of Scientific Information

ATTACHMENT A

Roads and Fire: A Proven Relationship

Photo: Lou Anegli Digital

Roaded Forests Are at a Greater Risk of Experiencing Wildfires than Unroaded Forests

- A wildland fire ignition is almost twice as likely to occur in a roaded area than in a roadless area. (USDA 2000, Table 3-18)
- The location of large wildfires is often correlated with proximity to busy roads. (Sierra Nevada Ecosystem Project, 1996)
- High road density increases the probability of fire occurrence due to human-caused ignitions. (Hann, W.J., et al. 1997)
- Unroaded areas have lower potential for high-intensity fires than roaded areas because they are less prone to human-caused ignitions. (DellaSala, et al. 1995)
- The median size of large fires on national forests is greater outside of roadless areas. (USDA 2000, Table 3-22)
- A positive correlation exists between lightning fire frequency and road density due to increased availability of flammable fine fuels near roads. (Arienti, M. Cecilia, et al. 2009)
- Human caused wildfires are strongly associated with access to natural landscapes, with the proximity to urban areas and roads being the most important factor (Romero-Calcerrada, et al. 2008)

For more information, contact Gregory H. Aplet, Ph.D., Senior Forest Scientist, at greg_aplet@tws.org or 303-650-5818 x104.

HUMAN ACTIVITY AND WILDFIRE

- Sparks from cars, off-road vehicles, and neglected campfires caused nearly 50,000 wildfire ignitions in 2000. (USDA 2000, Fuel Management and Fire Suppression Specialist Report, Table 4.)
- More than 90% of fires on national lands are caused by humans (USDA 1996 and 1998)
- Human-ignited wildfire is almost 5 times more likely to occur in a roaded area than in a roadless area (USDA 2000, Table 3-19).

There are 375,000 miles of roads in our national forests.

ATTACHMENT A

Roads and Fire: A Proven Relationship

Photo: USDA Forest Service, Coconino National Forest

References

Arienti, M. Cecilia; Cumming, Steven G., et al. 2009. Road network density correlated with increased lightning fire incidence in the Canadian western boreal forest. International Journal of Wildland Fire 2009, 18, 970–982

DellaSala, D.A., D.M. Olson and S.L. Crane. 1995. Ecosystem management and biodiversity conservation: Applications to inlandPacific Northwest forests. Pp. 139-160 in: R.L. Everett and D.M. Baumgartner, eds. Symposium Proceedings: Ecosystem Management inWestern Interior Forests. May 3-5, 1994, Spokane, WA. Washington State University Cooperative Extension, Pullman, WA.

Hann, W.J., et al. 1997. An Assessment of Ecosystem Components in the Interior Columbia Basin and Portions of the Klamath and Great Basins: Volume II, Ch. 3, p. 882

Romer-Calcerrada, Raul. 2008. GIS analysis of spatial patterns of human-caused wildfire ignoition risk in the SW of Madrid (Central Spain). Landscape Ecol. 23:341-354.

Sierra Nevada Ecosystem Project. 1996. Status of the Sierra Nevada: Sierra Nevada Ecosystem Project, Final Report to Congress Volume I: Assessment summaries and management strategies. Wildland Resources Center Report No. 37. Center for Water and Wildland Resources, Unversity of California, Davis, CA.

USDA Forest Service. 1996. National Forest Fire Report 1994.Washington, D.C.

USDA Forest Service. 1998. 1991-1997 Wildland fire statistics. Fire and Aviation Management, Washington, D.C.

USDA. 2000. Forest Service Roadless Area Conservation Rule Final Environmental Impact Statement, Ch. 3,.

THE WILDERNESS SOCIETY 75 YEARS
1935 – 2010

Attachment 2: Using Road Density as a Metric for Ecological Health in National Forests: What Roads and Routes should be Included?

Summary of Scientific Information

Last Updated, November 22, 2012

I. Density analysis should include closed roads, non-system roads administered by other jurisdictions (private, county, state), temporary roads and motorized trails.

Typically, the Forest Service has calculated road density by looking only at open system road density. From an ecological standpoint, this approach may be flawed since it leaves out of the density calculations a significant percent of the total motorized routes on the landscape. For instance, the motorized route system in the entire National Forest System measures well over 549,000 miles.[1] By our calculation, a density analysis limited to open system roads would consider less than 260,000 miles of road, which accounts for less than half of the entire motorized transportation system estimated to exist on our national forests.[2] These additional roads and motorized trails impact fish, wildlife, and water quality, just as open system roads do. In this section, we provide justification for why a road density analysis used for the purposes of assessing ecological health and the effects of proposed alternatives in a planning document should include closed system roads, non-system roads administered by other jurisdictions, temporary roads, and motorized trails.

Impacts of closed roads

It is crucial to distinguish the density of roads physically present on the landscape, whether closed to vehicle use or not, from "open-road density" (Pacific Rivers Council, 2010). An open-road density of 1.5 mi/mi² has been established as a standard in some national forests as protective of some terrestrial wildlife species. However, many areas with an open road density of 1.5 mi/mi² have a much higher inventoried or extant hydrologically effective road density, which may be several-fold as high with significant aquatic impacts. This higher density occurs because many road "closures" block vehicle access, but do nothing to mitigate the hydrologic alterations that the road causes. The problem is

---

[1] The National Forest System has about 372,000 miles of system roads. The forest service also has an estimated 47,000 miles of motorized trails. As of 1998, there were approximately 130,000 miles of non-system roads in our forests. Non-system roads include public roads such as state, county, and local jurisdiction and private roads. (USFS, 1998) The Forest Service does not track temporary roads but is reasonable to assume that there are likely several thousand miles located on National Forest System lands.

[2] About 30% of system roads, or 116,108 miles, are in Maintenance Level 1 status, meaning they are closed to all motorized use. (372,000 miles of NFS roads - 116,108 miles of ML 1 roads = 255,892). This number is likely conservative given that thousands of more miles of system roads are closed to public motorized use but categorized in other Maintenance Levels.

further compounded in many places by the existence of "ghost" roads that are not captured in agency inventories, but that are nevertheless physically present and causing hydrologic alteration (Pacific Watershed Associates, 2005).

Closing a road to public motorized use can mitigate the impacts on water, wildlife, and soils only if proper closure and storage technique is followed. Flow diversions, sediment runoff, and illegal incursions will continue unabated if necessary measures are not taken. The Forest Service's National Best Management Practices for non-point source pollution recommends the following management techniques for minimizing the aquatic impacts from closed system roads: eliminate flow diversion onto the road surface, reshape the channel and streambanks at the crossing-site to pass expected flows without scouring or ponding, maintain continuation of channel dimensions and longitudinal profile through the crossing site, and remove culverts, fill material, and other structures that present a risk of failure or diversion. Despite good intentions, it is unlikely given our current fiscal situation and past history that the Forest Service is able to apply best management practices to all stored roads,[3] and that these roads continue to have impacts. This reality argues for assuming that roads closed to the public continue to have some level of impact on water quality, and therefore, should be included in road density calculations.

As noted above, many species benefit when roads are closed to public use. However, the fact remains that closed system roads are often breached resulting in impacts to wildlife. Research shows that a significant portion of off-road vehicle (ORV) users violates rules even when they know what they are (Lewis, M.S., and R. Paige, 2006; Frueh, LM, 2001; Fischer, A.L., et. al, 2002; USFWS, 2007.). For instance, the Rio Grande National Forest's Roads Analysis Report notes that a common travel management violation occurs when people drive around road closures on Level 1 roads (USDA Forest Service, 1994). Similarly, in a recent legal decision from the Utah District Court , *Sierra Club v. USFS*, Case No. 1:09-cv-131 CW (D. Utah March 7, 2012), the court found that, as part of analyzing alternatives in a proposed travel management plan, the Forest Service failed to take a hard look at the impact of continued illegal use. In part, the court based its decision on the Forest Service's acknowledgement that illegal motorized use is a significant problem and that the mere presence of roads is likely to result in illegal use.

In addition to the disturbance to wildlife from ORVs, incursions and the accompanying human access can also result in illegal hunting and trapping of animals. The Tongass National Forest refers to this in its EIS to amend the Land and Resources Management Plan. Specifically, the Forest Service notes in the EIS that Alexander Archipelego wolf mortality due to legal and illegal hunting and trapping is related not only to roads open to motorized access, but to all roads, and that *total road densities* of 0.7-1.0 mi/mi^2 or less may be necessary (USDA Forest Service, 2008).

As described below, a number of scientific studies have found that ORV use on roads and trails can have serious impacts on water, soil and wildlife resources. It should be expected that ORV use will continue to

---

[3] The Forest Service generally reports that it can maintain 20-30% of its open road system to standard.

some degree to occur illegally on closed routes and that this use will affect forest resources. Given this, roads closed to the general public should be considered in the density analysis.

Impacts of non-system roads administered by other jurisdictions (private, county, state)

As of 1998, there were approximately 130,000 miles of non-system roads in national forests (USDA Forest Service, 1998). These roads contribute to the environmental impacts of the transportation system on forest resources, just as forest system roads do. Because the purpose of a road density analysis is to measure the impacts of roads at a landscape level, the Forest Service should include all roads, including non-system, when measuring impacts on water and wildlife. An all-inclusive analysis will provide a more accurate representation of the environmental impacts of the road network within the analysis area.

Impacts of temporary roads

Temporary roads are not considered system roads. Most often they are constructed in conjunction with timber sales. Temporary roads have the same types environmental impacts as system roads, although at times the impacts can be worse if the road persists on the landscape because they are not built to last.

It is important to note that although they are termed temporary roads, their impacts are not temporary. According to Forest Service Manual (FSM) 7703.1, the agency is required to "Reestablish vegetative cover on any unnecessary roadway or area disturbed by road construction on National Forest System lands within 10 years after the termination of the activity that required its use and construction." Regardless of the FSM 10-year rule, temporary roads can remain for much longer. For example, timber sales typically last 3-5 years or more. If a temporary road is built in the first year of a six year timber sale, its intended use does not end until the sale is complete. The timber contract often requires the purchaser to close and obliterate the road a few years after the Forest Service completes revegetation work. The temporary road, therefore, could remain open 8-9 years before the ten year clock starts ticking per the FSM. Therefore, temporary roads can legally remain on the ground for up to 20 years or more, yet they are constructed with less environmental safeguards than modern system roads.

Impacts of motorized trails

Scientific research and agency publications generally do not decipher between the impacts from motorized trails and roads, often collapsing the assessment of impacts from unmanaged ORV use with those of the designated system of roads and trails. The following section summarizes potential impacts resulting from roads and motorized trails and the ORV use that occurs on them.

Aquatic Resources

While driving on roads has long been identified as a major contributor to stream sedimentation (for review, see Gucinski, 2001), recent studies have identified ORV routes as a significant cause of stream sedimentation as well (Sack and da Luz, 2004; Chin et al.; 2004, Ayala et al.; 2005, Welsh et al;. 2006). It has been demonstrated that sediment loss increases with increased ORV traffic (Foltz, 2006). A study by

Sack and da Luz (2004) found that ORV use resulted in a loss of more than 200 pounds of soil off of every 100 feet of trail each year. Another study (Welsh et al., 2006) found that ORV trails produced five times more sediment than unpaved roads. Chin et al. (2004) found that watersheds with ORV use as opposed to those without exhibited higher percentages of channel sands and fines, lower depths, and lower volume – all characteristics of degraded stream habitat.

Soil Resources [4]

Ouren, et al. (2007), in an extensive literature review, suggests ORV use causes soil compaction and accelerated erosion rates, and may cause compaction with very few passes. Weighing several hundred pounds, ORVs can compress and compact soil (Nakata et al., 1976; Snyder et al., 1976; Vollmer et al., 1976; Wilshire and Nakata, 1976), reducing its ability to absorb and retain water (Dregne, 1983), and decreasing soil fertility by harming the microscopic organisms that would otherwise break down the soil and produce nutrients important for plant growth (Wilshire et al., 1977). An increase in compaction decreases soil permeability, resulting in increased flow of water across the ground and reduced absorption of water into the soil. This increase in surface flow concentrates water and increases erosion of soils (Wilshire, 1980; Webb, 1983; Misak et al., 2002).

Erosion of soil is accelerated in ORV-use areas directly by the vehicles, and indirectly by increased runoff of precipitation and the creation of conditions favorable to wind erosion (Wilshire, 1980). Knobby and cup-shaped protrusions from ORV tires that aid the vehicles in traversing steep slopes are responsible for major direct erosional losses of soil. As the tire protrusions dig into the soil, forces far exceeding the strength of the soil are exerted to allow the vehicles to climb slopes. The result is that the soil and small plants are thrown downslope in a “rooster tail” behind the vehicle. This is known as mechanical erosion, which on steep slopes (about 15° or more) with soft soils may erode as much as 40 tons/mi (Wilshire, 1992). The rates of erosion measured on ORV trails on moderate slopes exceed natural rates by factors of 10 to 20 (Iverson et al., 1981; Hinckley et al., 1983), whereas use on steep slopes has commonly removed the entire soil mantle exposing bedrock. Measured erosional losses in high use ORV areas range from 1.4-242 lbs/ft^2 (Wilshire et al., 1978) and 102-614 lbs/ft^2 (Webb et al., 1978). A more recent study by Sack and da Luz (2003) found that ORV use resulted in a loss of more than 200 lbs of soil off of every 100 feet of trail each year.

Furthermore, the destruction of cryptobiotic soils by ORVs can reduce nitrogen fixation by cyanobacteria, and set the nitrogen economy of nitrogen-limited arid ecosystems back decades. Even small reductions in crust can lead to diminished productivity and health of the associated plant community, with cascading effects on plant consumers (Davidson et al., 1996). In general, the deleterious effects of ORV use on cryptobiotic crusts is not easily repaired or regenerated. The recovery time for the lichen component of crusts has been estimated at about 45 years (Belnap, 1993). After this time the crusts may appear to have regenerated to the untrained eye. However, careful observation will reveal that the 45 year-old crusts will not have recovered their moss component, which will take an additional 200 years to fully come back (Belnap and Gillette, 1997).

---

[4] For a full review see Switalski, T. A. and A. Jones (2012).

Wildlife Resources [5]

Studies have shown a variety of possible wildlife disturbance vectors from ORVs. While these impacts are difficult to measure, repeated harassment of wildlife can result in increased energy expenditure and reduced reproduction. Noise and disturbance from ORVs can result in a range of impacts including increased stress (Nash et al., 1970; Millspaugh et al., 2001), loss of hearing (Brattstrom and Bondello, 1979), altered movement patterns (e.g., Wisdom et al. 2004; Preisler et al. 2006), avoidance of high-use areas or routes (Janis and Clark 2002; Wisdom 2007), and disrupted nesting activities (e.g., Strauss 1990).

Wisdom et al. (2004) found that elk moved when ORVs passed within 2,000 yards but tolerated hikers within 500 ft. Wisdom (2007) reported preliminary results suggesting that ORVs are causing a shift in the spatial distribution of elk that could increase energy expenditures and decrease foraging opportunities for the herd. Elk have been found to readily avoid and be displaced from roaded areas (Irwin and Peek, 1979; Hershey and Leege, 1982; Millspaugh, 1995). Additional concomitant effects can occur, such as major declines in survival of elk calves due to repeated displacement of elk during the calving season (Phillips, 1998). Alternatively, closing or decommissioning roads has been found to decrease elk disturbance (Millspaugh et al., 2000; Rowland et al., 2005).

Disruption of breeding and nesting birds is particularly well-documented. Several species are sensitive to human disturbance with the potential disruption of courtship activities, over-exposure of eggs or young birds to weather, and premature fledging of juveniles (Hamann et al., 1999). Repeated disturbance can eventually lead to nest abandonment. These short-term disturbances can lead to long-term bird community changes (Anderson et al., 1990). However when road densities decrease, there is an observable benefit. For example, on the Loa Ranger District of the Fishlake National Forest in southern Utah, successful goshawk nests occur in areas where the localized road density is at or below 2-3 mi/mi^2 (USDA, 2005).

Examples of Forest Service planning documents that use total motorized route density or a variant

Below, we offer examples of where total motorized route density or a variant has been used by the Forest Service in planning documents.

- The Mt. Taylor RD of the Cibola NF analyzed open and closed system roads and motorized trails together in a single motorized *route* density analysis. Cibola NF: Mt. Taylor RD Environmental Assessment for Travel Management Planning, Ch.3, p 55. http://prdp2fs.ess.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5282504.pdf.

- The Grizzly Bear Record of Decision (ROD) for the Forest Plan Amendments for Motorized Access

---

[5] For a full review see:Switalski, T. A. and A. Jones (2012).

Management within the Selkirk and Cabinet-Yaak Grizzly Bear Recovery Zones (Kootenai, Lolo, and Idaho Panhandle National Forests) assigned route densities for the designated recovery zones. One of the three densities was for Total Motorized Route Density (TMRD) which includes open roads, restricted roads, roads not meeting all reclaimed criteria, and open motorized trails. The agency's decision to use TMRD was based on the Endangered Species Act's requirement to use best available science, and monitoring showed that both open and closed roads and motorized trails were impacting grizzly. Grizzly Bear Plan Amendment ROD. Online at cache.ecosystem-management.org/48536_FSPLT1_009720.pdf.

- The Chequamegon-Nicolet National Forest set forest-wide goals in its forest plan for both open road density and total road density to improve water quality and wildlife habitat.

> *I decided to continue reducing the amount of total roads and the amount of open road to resolve conflict with quieter forms of recreation, impacts on streams, and effects on some wildlife species.* ROD, p 13.

Chequamegon-Nicolet National Forest Land and Resource Management Plan Record of Decision. Online at http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5117609.pdf.

- The Tongass National Forest's EIS to amend the forest plan notes that Alexander Archipelago wolf mortality due to legal and illegal hunting and trapping is related not only to roads open to motorized access, but to all roads, and that *total road densities* of 0.7-1.0 mi/mi^2 or less may be necessary.

> *Another concern in some areas is the potentially unsustainable level of hunting and trapping of wolves, when both legal and illegal harvest is considered. The 1997 Forest Plan EIS acknowledged that open road access contributes to excessive mortality by facilitating access for hunters and trappers. Landscapes with open-road densities of 0.7 to 1.0 mile of road per square mile were identified as places where human-induced mortality may pose risks to wolf conservation. The amended Forest Plan requires participation in cooperative interagency monitoring and analysis to identify areas where wolf mortality is excessive, determine whether the mortality is unsustainable, and identify the probable causes of the excessive mortality.*
>
> *More recent information indicates that wolf mortality is related not only to roads open to motorized access, but to all roads, because hunters and trappers use all roads to access wolf habitat, by vehicle or on foot. Consequently, this decision amends the pertinent standard and guideline contained in Alternative 6 as displayed in the Final EIS in areas where road access and associated human caused mortality has been determined to be the significant contributing factor to unsustainable wolf mortality. The standard and guideline has been modified to ensure that a range of options to reduce mortality risk will be considered in these areas, and to specify that total road densities of 0.7 to 1.0 mile per square mile or less may be necessary.* ROD, p 24.

Tongass National Forest Amendment to the Land and Resource Management Plan Record of Decision and Final EIS. January 2008. http://tongass-fpadjust.net/Documents/Record_of_Decision.pdf

References

Anderson, D.E., O.J. Rongstad, and W.R. Mytton. 1990. Home range changes in raptors exposed to increased human activity levels in southeastern Colorado. Wildlife Bulletin 18:134-142.

Ayala, R.D., P. Srivastava, C.J. Brodbeck, E.A. Carter, and T.P. McDonald. 2005. Modeling Sediment Transport from an Off-Road Vehicle Trail Stream Crossing Using WEPP Model. American Society of Agricultural and Biological Engineers, 2005 ASAE Annual International Meeting, Paper No: 052017.

Belnap, J. 1993. Recovery rates of cryptobiotic crusts: inoculant use and assessment methods. Great Basin Naturalist 53:89-95.

Belnap, J. and D.A. Gillette. 1997. Disturbance of biological soil crusts: impacts on potential wind erodibility of sandy desert soils in SE Utah. Land Degradation and Development 8: 355-362.

Brattstrom, B.H., and M.C. Bondello. 1979. The effects of dune buggy sounds on the telencephalic auditory evoke response in the Mojave fringe-toed lizard, Uma scoparia. Unpublished report to the U.S. Bureau of Land Management, California Desert Program, Riverside, CA. 31p.

Chin, A., D.M. Rohrer, D.A. Marion, and J.A. Clingenpeel. 2004. Effects of all terrain vehicles on stream dynamics. Pages:292-296 in Guldin, J.M. technical compiler, Ovachita and Ozark Mountains Symposium: ecosystem management research. General technical report SRS-74. Ashville, NC: USDA, FS, Southern Research Station.

Davidson, D.W, W.D. Newmark, J.W. Sites, D.K. Shiozawa, E.A. Rickart, K.T. Harper, and R.B. Keiter. 1996. Selecting Wilderness areas to conserve Utah's biological diversity. Great Basin Naturalist 56: 95-118.

Dregne, H.E. 1983. Physical effects of off-road vehicle use. Pages 15-30 in R.H. Webb and H.G. Wilshire. Environmental Effects of Off-Road Vehicles: Impacts and Management in Arid Regions. Springer-Verlag, New York.

Foltz, R.B. 2006. Erosion from all terrain vehicle (ATV) trails on National Forest lands. The American Society of Agricultural and Biological engineers (ASABE). Paper# 068012. St. Joseph, MI.

Frueh, LM. 2001. Status and Summary Report on OHV Responsible Riding Campaign. Prepared by Monaghan and Associates for the Colorado Coalition for Responsible OHV Riding. Available at http://www.wildlandscpr.org/files/CO%20OHV%20Focus%20Group%20StatusSummaryReport_1.pdf.

Gucinski, H., M. J. Furniss, R. R. Ziemer, and M. H. Brookes. 2001. Forest roads: a synthesis of scientific information. Gen. Tech. Rep. PNWGTR-509. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR. http://www.fs.fed.us/pnw/pubs/gtr509.pdf

Hamann, B., H. Johnston, P. McClelland, S. Johnson, L. Kelly, and J. Gobielle. 1999. Birds. Pages 3.1-3.34 in Joslin, G. and H. Youmans, coordinators Effects of Recreation on Rocky Mountain Wildlife: A Review for Montana.

Hershey, T.J., and T.A. Leege. 1982. Elk movements and habitat use on a managed forest in north-central Idaho. Idaho Department of Fish and Game. 32p.

Hinckley, B.S., Iverson, R.M. and B. Hallet. 1983. Accelerated water erosion in ORV-use areas. Pages 81-96 in Webb, R.H. and H.G. Wilshire, editors, Environmental Effects of Off-Road Vehicles. Springer-Verlag, New York.

Irwin, L.L., and J.M. Peek. 1979. Relationship between road closure and elk behavior in northern Idaho. Pages 199-205 in Boyce, M.S. and L.D. Hayden-Wing, editors, North American Elk: Ecology, Behavior, and Management. Laramie, WY: University of Wyoming.

Iverson, R.M., Hinckley, B.S., and R.H. Webb. 1981. Physical effects of vehicular disturbance on arid landscapes. Science 212: 915-917.

Janis, M.W., and J.D. Clark. 2002. Responses of Florida panthers to recreational deer and hog hunting. Journal of Wildlife Management 66(3): 839-848.

Lewis, M.S., and R. Paige. 2006. Selected Results From a 2006 Survey of Registered Off-Highway Vehicle (OHV) Owners in Montana. Responsive Management Unit Research Summary No. 21. Prepared for Montana Fish, Wildlife and Parks. http://fwp.mt.gov/content/getItem.aspx?id=19238

Millspaugh, J.J. 1995. Seasonal movements, habitat use patterns and the effects of human disturbances on elk in Custer State Park, South Dakota. M.S. Thesis. Brookings, SD: South Dakota State University.

Millspaugh, J.J., G.C. Brundige, R.A. Gitzen, and K.J. Raedeke. 2000. Elk and hunter space-use sharing in South Dakota. Journal of Wildlife Management 64(4): 994-1003.

Millspaugh, J.J., Woods, R.J. and K.E. Hunt. 2001. Fecal glucocorticoid assays and the physiological stress response in elk. Wildlife Society Bulletin 29: 899-907.

Misak, R.F., J.M. Al Awadhi, S.A. Omar, and S.A. Shahid. 2002. Soil degradation in Kabad area, southwestern Kuwait City. Land Degradation & Development. 13(5): 403-415.

Nakata, J.K., H.G. Wilshire, and G.G. Barnes. 1976. Origin of Mojave Desert dust plumes photographed from space. Geology 4(11): 644-648.

Nash, R.F., G.G. Gallup, jr., and M.K. McClure. 1970. The immobility reaction in leopard frogs (Rana pipiens) as a function of noise induced fear. Psychonometric Science 21(3): 155-156.

Ouren, D.S., Haas, Christopher, Melcher, C.P., Stewart, S.C., Ponds, P.D., Sexton, N.R., Burris, Lucy, Fancher, Tammy, and Bowen, Z.H., 2007, Environmental effects of off-highway vehicles on Bureau of Land Management lands: A literature synthesis, annotated bibliographies, extensive bibliographies, and internet resources: U.S. Geological Survey, Open-File Report 2007-1353, 225 p.

Pacific Rivers Council. 2010. Roads and Rivers 2: An Assessment of National Forest Roads Analyses. Portland, OR http://pacificrivers.org/science-research/resources-publications/roads-and-rivers-ii/download

Pacific Watershed Associates. 2005. Erosion Assessment and Erosion Prevention Planning Project for Forest Roads in the Biscuit Fire Area, Southern Oregon. Prepared for Pacific Rivers Council and The Siskiyou Project. Pacific Watershed Associates, Arcata, California. http://pacificrivers.org/files/post-fire-management-and-sound-science/Final%20Biscuit%20PWA%20Report.pdf

Phillips, G.E. 1998. Effects of human-induced disturbance during calving season on reproductive success of elk in the upper Eagle River Valley. Dissertation. Fort Collins, CO: Colorado State University.

Preisler, H.K., A.A. Ager, and M.J. Wisdom. 2006. Statistical methods for analyzing responses of wildlife to human disturbance. Journal of Applied Ecology 43: 164-172.

Rowland, M.M., M.J. Wisdom, B.K. Johnson, and M.A. Penninger. 2005. Effects of roads on elk: implications for management in forested ecosystems. Pages 42-52. IN: Wisdom, M.J., technical editor, The Starkey Project: a Synthesis of Long-term Studies of Elk and Mule Deer. Reprinted from the 2004 Transactions of the North American Wildlife and Natural Resources Conference, Alliance Communications Group, Lawrence, KS.

Sack, D., and S. da Luz, Jr. 2003. Sediment Flux and Compaction Trends on Off-Road Vehicle (ORV) and other Trails in an Appalachian Forest Setting. Physical Geography 24 (6): 536-554.

Snyder, C.T., D.G. Frickel, R.E. Hadley, and R.F. Miller. 1976. Effects of off-road vehicle use on the hydrology and landscape of arid environments in central and southern California. U.S. Geological Survey Water-Resources Investigations Report #76-99. 45p.

Switalski, T. A. and A. Jones. 2012. Off-road Vehicle Best Management Practices for Forestlands: A Review of Scientific Literature and Guidance for Managers. Journal of Conservation Planning. Vol. 8 (2014). Pages 12 – 24.

USFWS, Nevada Fish and Wildlife Office. 2007. 12-Month Finding on a Petition to List the Sand Mountain Blue Butterfly (Euphilotes pallescens ssp. arenamontana) as Threatened or Endangered with Critical Habitat. Federal Register, Vol. 72, No. 84. See pages 24260-61. http://www.wildlandscpr.org/denial-petition-list-sand-mountain-blue-butt....

USDA Forest Service (USFS) 1994. Rio Grande National Forest Roads Analysis Process Report. See pages 76-77 and 118.

USDA Forest Service. (USFS) 1998. National Forest System Roads and Use. Available online at http://www.fs.fed.us/eng/road_mgt/roadsummary.pdf.

USDA Forest Service. (USFS) 2008. Tongass National Forest Amendment to the Land and Resource Management Plan Record of Decision and Final EIS. http://tongass-fpadjust.net/Documents/Record_of_Decision.pdf

Vollmer, A.T., B.G. Maza, P.A. Medica, F.B. Turner, and S.A. Bamberg. 1976. The impact of off-road vehicles on a desert ecosystem. Environmental Management 1(2):115-129.

Webb, R.H., Ragland, H.C., Godwin, W.H., and D. Jenkins. 1978. Environmental effects of soil property changes with off-road vehicle use. Environmental Management 2: 219-233.

Webb, R.H.. 1983. Compaction of desert soils by off-road vehicles. Pages 51-79 in: Webb, R.H. and Wilshire, H.G., editors, Environmental Effects of Off-Road Vehicles. Springer-Verlag, New York.

Welsh, M.J., L.H. MacDonald, and E. Brown, and Z. Libohova. 2006. Erosion and sediment delivery from unpaved roads and off-highway vehicles (OHV). Presented at AGU fall meeting. San Francisco, CA.

Wilshire, H.G., G.B. Bodman, D. Broberg, W.J. Kockelman, J. Major, H.E. Malde, C.T. Snyder, and R.C. Stebbins. 1977. Impacts and management of off-road vehicles. The Geological Society of America. Report of the Committee on Environment and Public Policy.

Wilshire, H.G., Nakata, J.K., Shipley, S., and K. Prestegaard. 1978. Impacts of vehicles on natural terrain at seven sites in the San Francisco Bay area. Environmental Geology 2: 295-319.

Wilshire, H.G. 1980. Human causes of accelerated wind erosion in California's deserts. Pages 415-433 in D.R. Coates and J.B. Vitek, editors, Thresholds in Geomorphology. George Allen & Unwin, Ltd., London.

Wilshire, H.G. 1992. The wheeled locusts. Wild Earth 2: 27-31.

Wisdom, M.J., R.S. Holthausen, B.C. Wales, C.D. Hargis, V.A. Saab, D.C. Lee, W.J. Hann, T.D. Rich, M.M. Rowland, W.J. Murphy, and M.R. Eames. 2000. Source habitats for terrestrial vertebrates of focus in the interior Columbia basin: Broad-scale trends and management implications. Volume 1 – Overview. Gen. Tech. Rep. PNW-GTR-485. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. http://www.fs.fed.us/pnw/pubs/gtr485/gtr485vl.pdf

Wisdom, M.J., H.K. Preisler, N.J. Cimon, and B.K. Johnson. 2004. Effects of off-road recreation on mule deer and elk. Transactions of the North American Wildlife and Natural Resource Conference 69.

Wisdom, M.J. 2007. Shift in Spatial Distribution of Elk Away from Trails Used by All-Terrain Vehicles. Report 1, May 2007, USDA Forest Service, Pacific Northwest Research Station, La Grande, OR.

Phone log 11/17/06 (Dan Brewer Steve Phillips)

Steve indicated that with these new plans the key issue we could do for bull trout is to deal with the existing roads system. Steve indicated that we need a mechanism to obligate the Forest into doing the right thing a MOU or something. Roads behind gates and berms continues to be an impact to bull trout and wct, currently we keep replacing culverts on roads. This has become a huge issue case in point the recent rain events. Often time it's pointed out that pulling culverts is expansive and the timber folks would like to keep these roads for future use.

Although these are legitimate concerns un-maintained roads and culverts will fail and the lack of maintenance put other resources at risk. So the decision to leave a culverts and roads behind a gate or berm is really a decision to increase the risk a losing a population of fish degrade water quality the has been shown over and over again in the literature. This has been an issue the Service and FS bio's have been warning the decisions makers about since Moose Fire, and now with the recent rain events this very issue is playing itself out. The Flathead had at least 7 major culvert failures, and after this last storm I would expect that number to increase.

Meeting notes Seeley Lake 11/30/06 T&C Reporting

Steve would like to address the T&C broadly and than "dial in" on the things that need a more specific focus:

All most all of the fire related BOs contain similar T&Cs . So for BOs that have:

BMP T&Cs: Steve will provide a map of the road segments that received BMPs, and provide addition narrative on what BMPs were field reviewed (similar to what the Bitterroot NF does). For example Steve Dan and Pat reviewed the Quinton Cr road on October 28 (?), 2006. The road BMPs appeared to be effective in reducing potential sediment delivery, no riling was observed in the road bed, cross drains were functioning and road was well graveled minimizing potential surface erosion. We also reviewed a log landing site, at this site a large pond of standing water was observed, causing people to drive around expanding the roaded area, and could cause the road to slump and has the potential to deliver sediment to the stream.

Decom Road T&C: For decommissioning Steve would like to use the A19 reporting, but include a statement of if pipes are left in the road or not. I think this needs to be in a separate report for bull trout?

High Risk Pipes T&C: This is the primary issues affecting BT habitat in the FNF. Leaving pipes behind berms/gates was a major in issue Moose we had several T&Cs to attempt to minimize this impact. For Westside the Forest was to identify which pipes are high risk (done) and fix high risk within a year (not done??). Forest will provide map of how many pipes are behind berms/gates. The Forest ID the high risk pipes but did not replace these within a year (we since had two major water events and pipe failure). The water events highlighted the issue and subsequent impacts of culverts. To address Steve would like to display on a map what was inventoried and what was treated and how and what remains. How do we address missing the mark not meeting this T&C. Currently the Service does not have the information to determine either way. The question is how far have we missed the mark (i.e., by not meeting the commitments in the BA has take occurred over and above that was assessed in the BO?) Steve will provide a map of bermed and to be bermed roads.

T&C Imp INFISH (Fish Barriers) Will provide map of barriers and barriers that were replaced (In Moose the upper Warner Creek pipe has not been fixed still in court).

T&C use the LAA Roads Programmatic form to report. We fell that the BMP map will address this. Steve will high light any minimization that should have occurred that did not.

T&C "Tell use what your going to do by March 1" The intent of that was to demonstrate that BT needs/money was going to BT watersheds issue. This T&C was a fall out of analyzing the worst case scenario. Steve will report general hopes, the forest usually does not know what they are going to do in April.

ATTACHMENT C

Project Status T&C several T&C ask this question. Steve will report general what's happen, focus on the thing what reduce sediment to reduce thing for bull trout. Again this is what happens when worst case scenario is analyzed, and numerous comments are given based on what is proposed (so when the proposed action changes usually harvest units dropped etc. then the other sometimes beneficial action are dropped which were analyzed as a long term beneficial effects (the example would be doing BMPs/culvert up grades on a section of road that access a harvest unit if the harvest unit is dropped than usually the improvement are dropped as well, weather these action occur or not effects the Baseline.

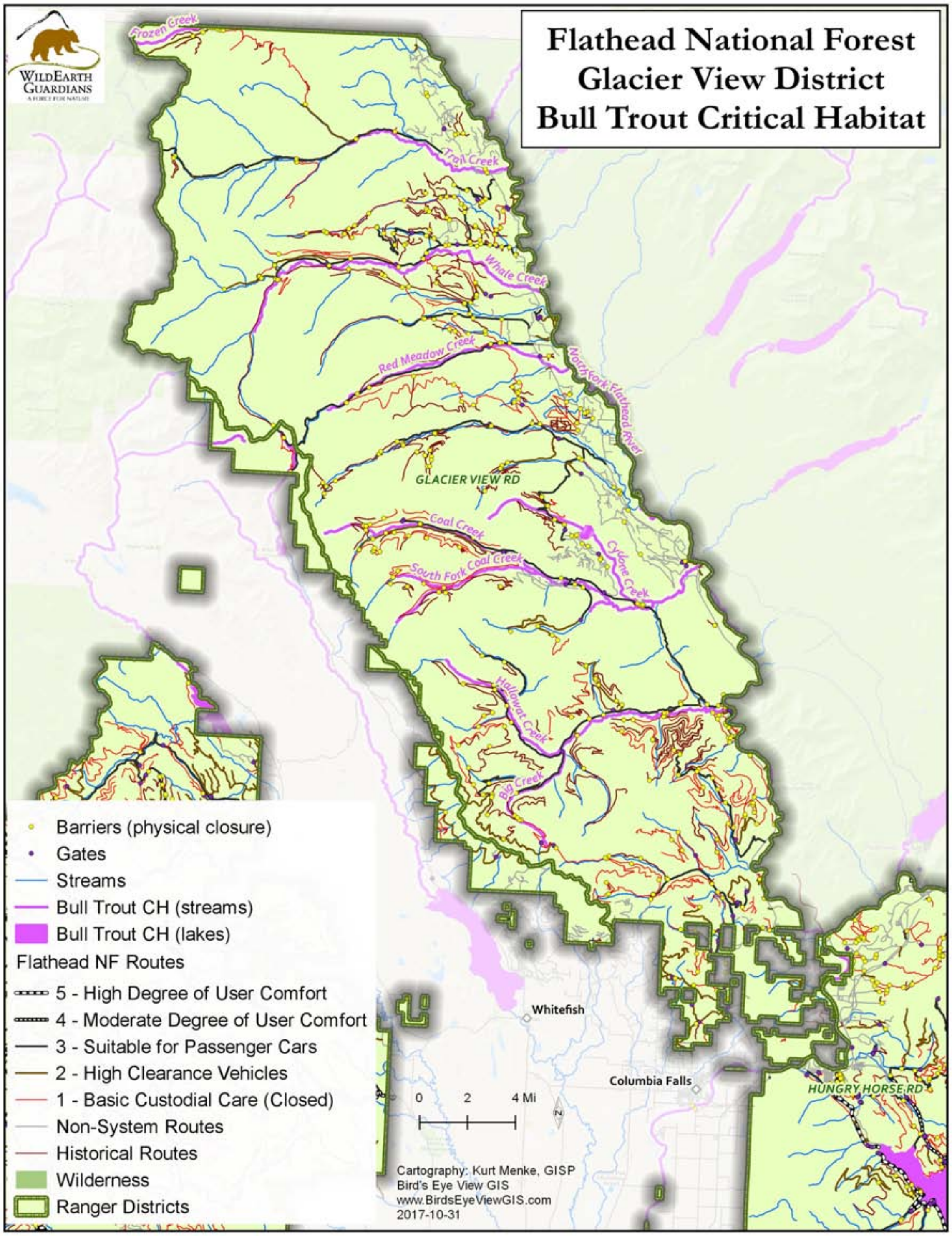
What we need to EMPHASIS. I think this is wear we have to get project specific. For Example Moose Fire 7 culvert left in Skookoleel drainage 5 on 316E and 2 on 5286) the Forest is to reduce the potential effects meaning up size INFISH…,

In December Steve will ID what needs to be emphasized. In mid Feb Steve would like share a draft report.

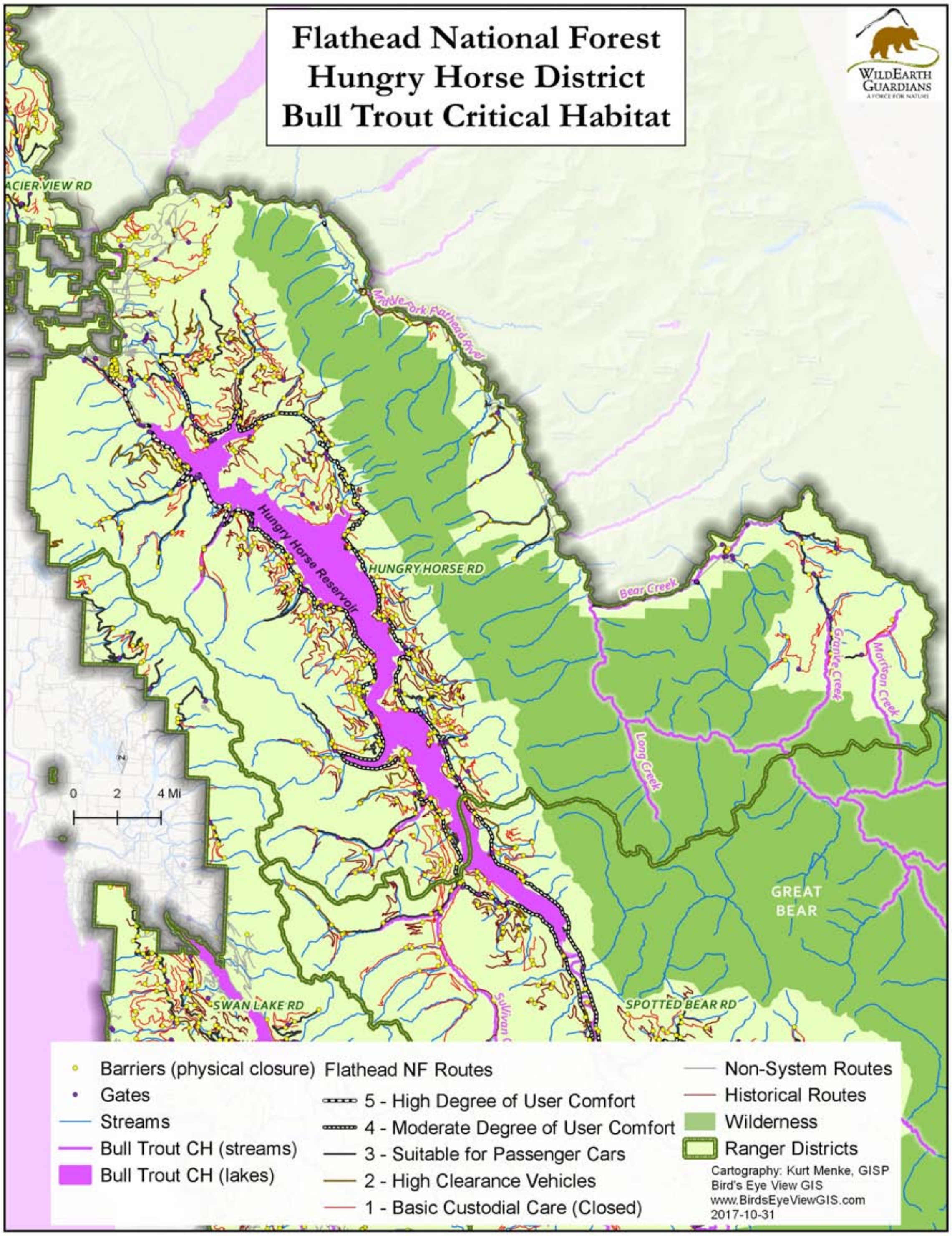
If its "decommissioned" there no pipes in the road unless its snowmobile Road ?

How are we going to handle reporting leaving pipes, would need to adjust the baseline?

ATTACHMENT D

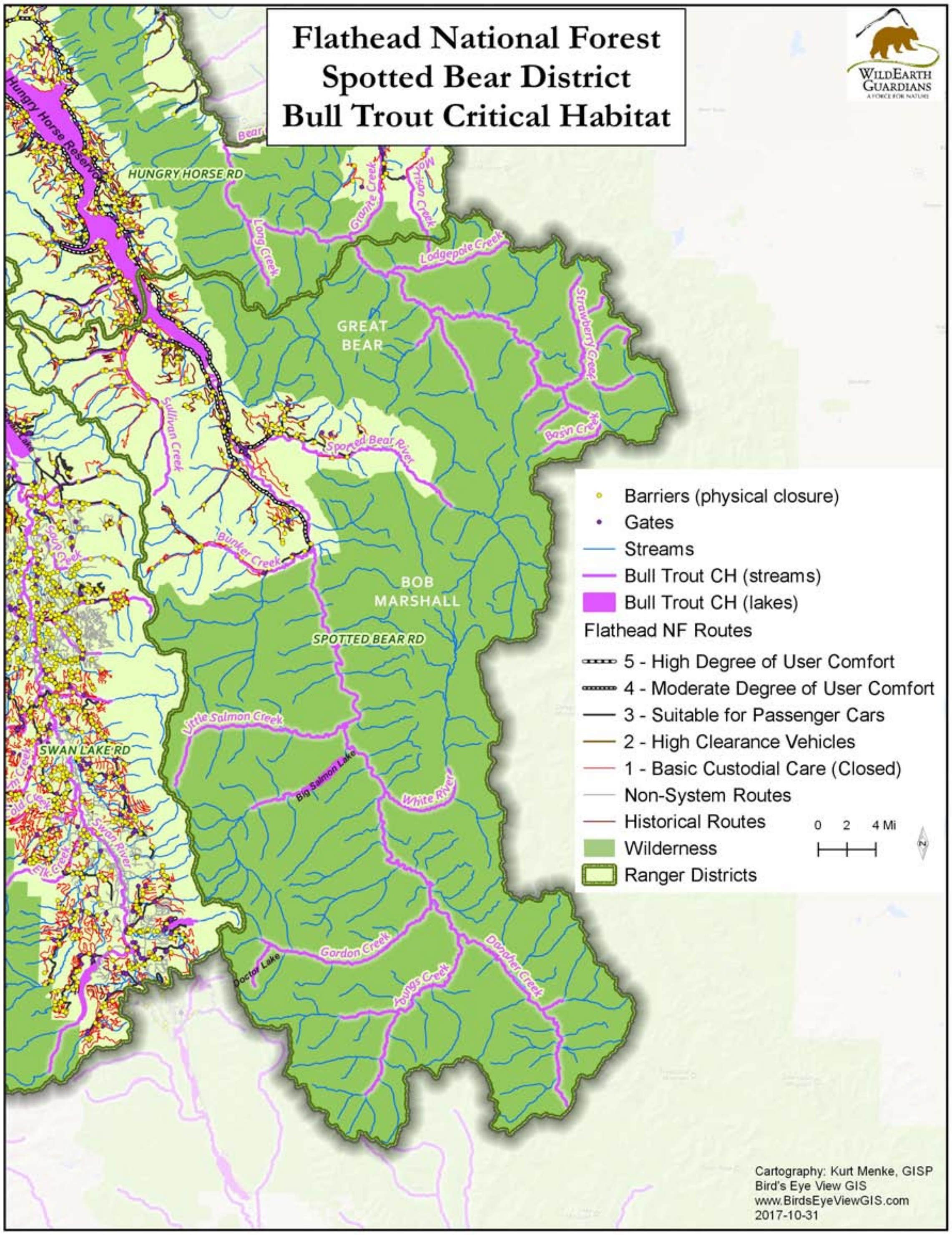


ATTACHMENT D



Cartography: Kurt Menke, GISP
Bird's Eye View GIS
www.BirdsEyeViewGIS.com
2017-10-31

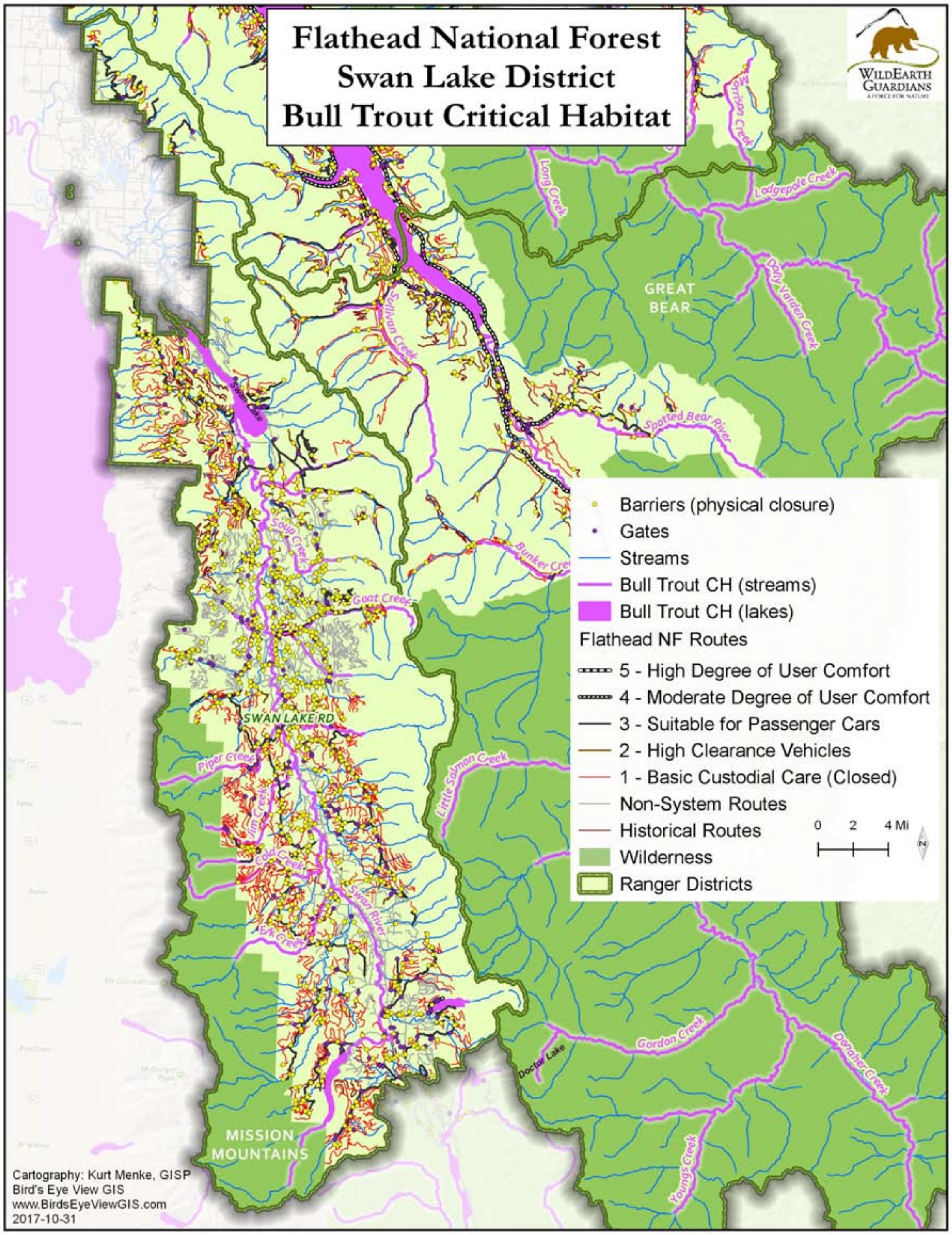
ATTACHMENT D



Flathead National Forest
Spotted Bear District
Bull Trout Critical Habitat

Cartography: Kurt Menke, GISP
Bird's Eye View GIS
www.BirdsEyeViewGIS.com
2017-10-31

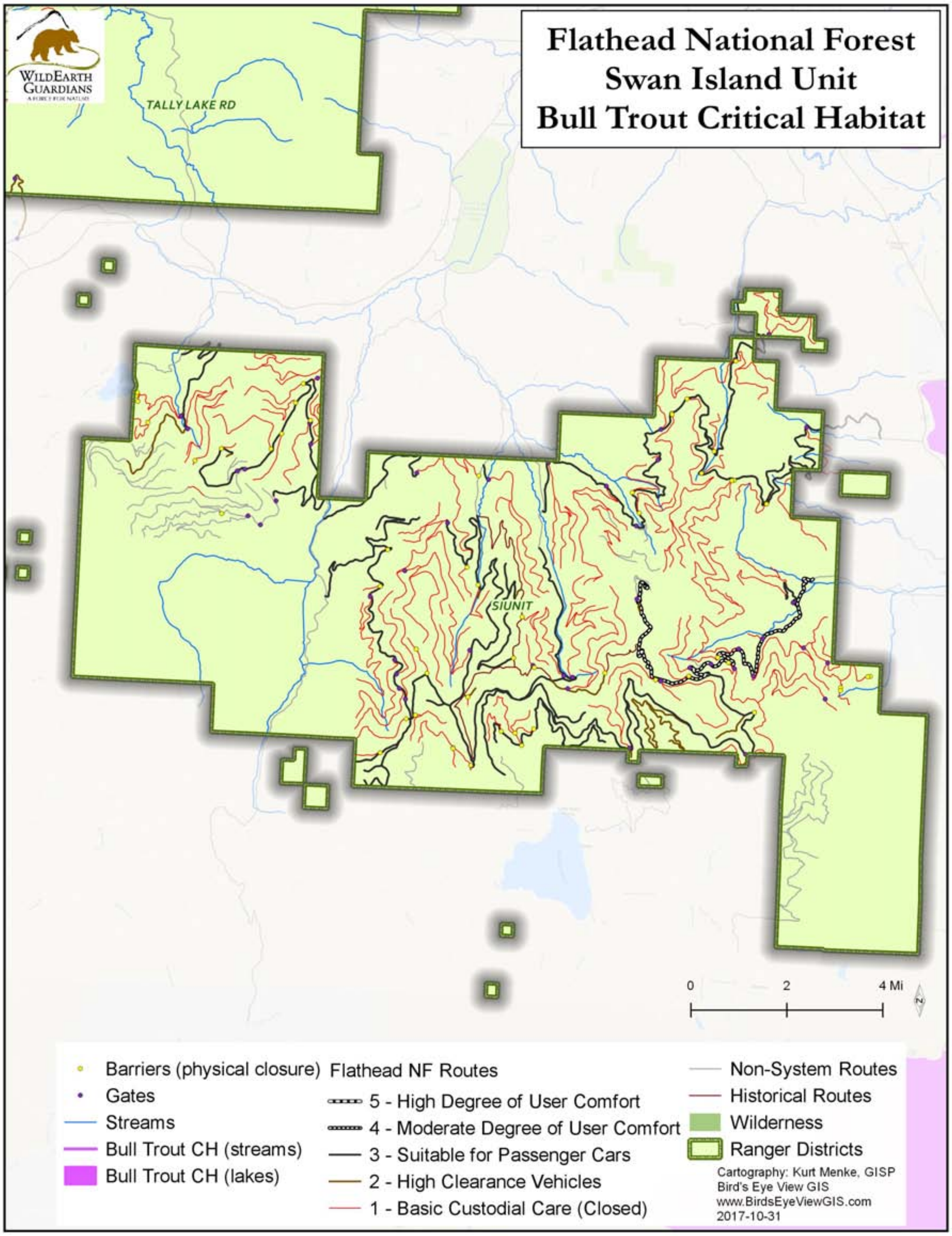
ATTACHMENT D



Flathead National Forest
Swan Lake District
Bull Trout Critical Habitat

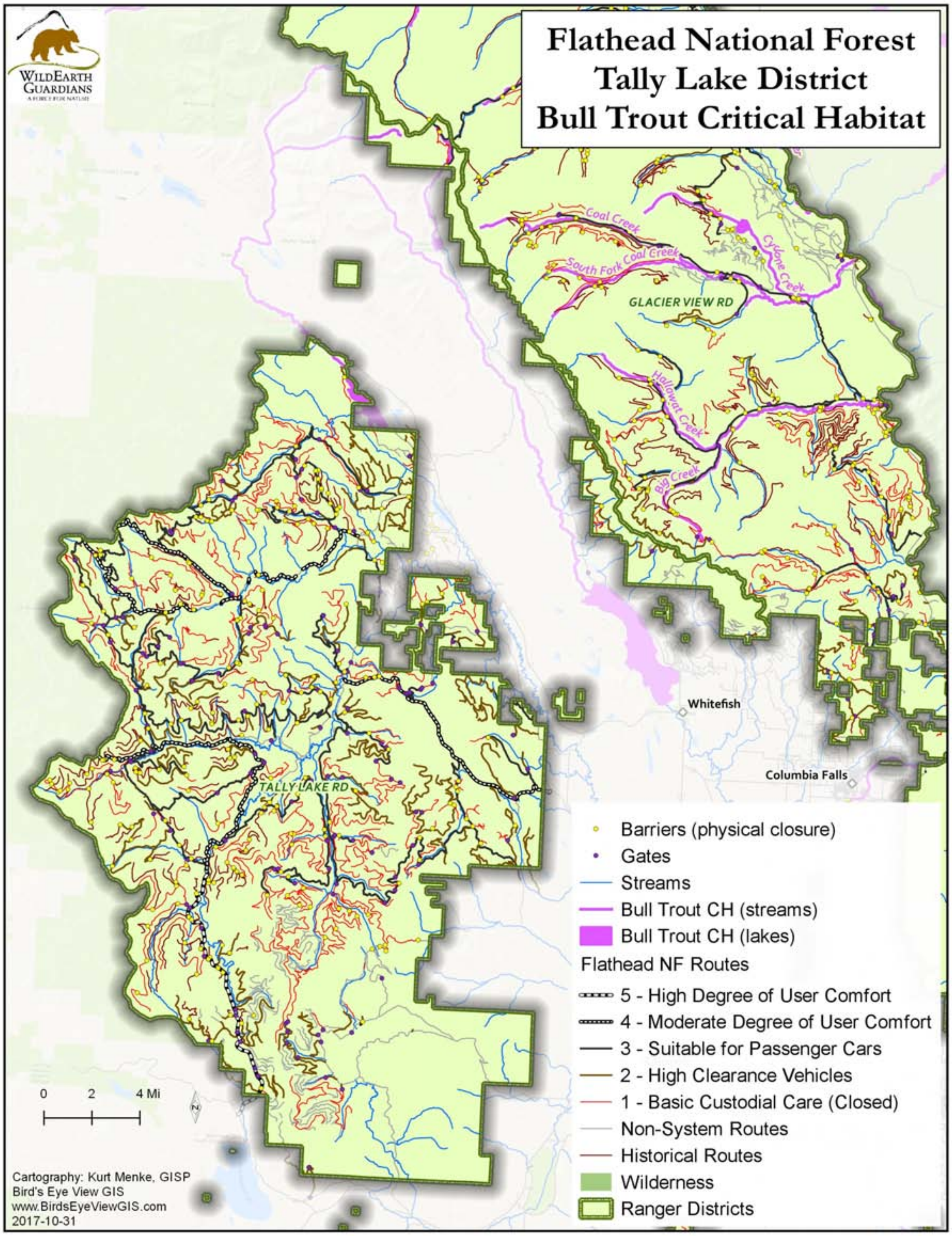
Cartography: Kurt Menke, GISP
Bird's Eye View GIS
www.BirdsEyeViewGIS.com
2017-10-31

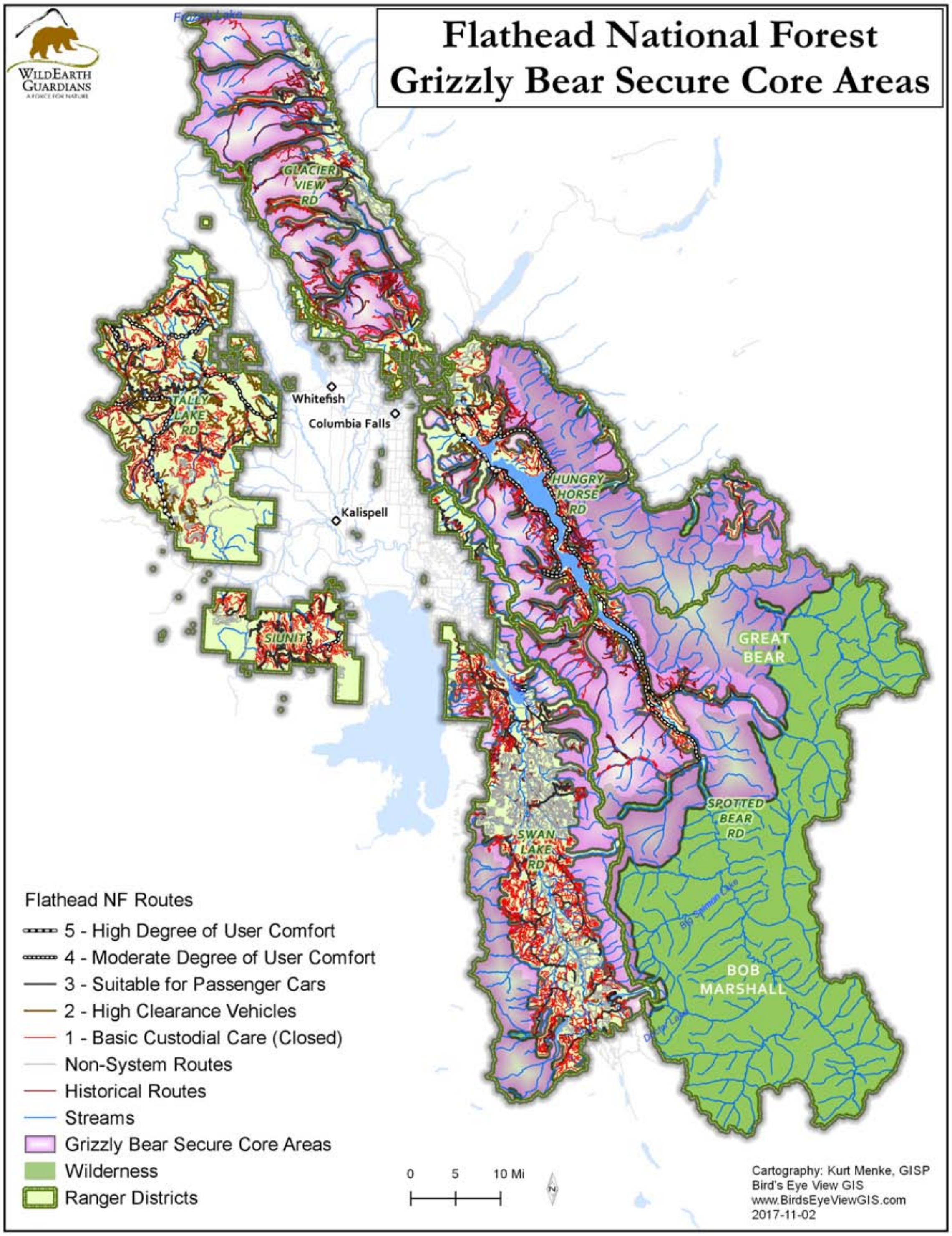
ATTACHMENT D



Cartography: Kurt Menke, GISP
Bird's Eye View GIS
www.BirdsEyeViewGIS.com
2017-10-31

ATTACHMENT D




WildEarth Guardians
A Force for Nature
Flathead National Forest
Grizzly Bear Secure Core Areas
Frozen Lake
GLACIER VIEW RD
TALLY LAKE RD
Whitefish
Columbia Falls
Kalispell
HUNGRY HORSE RD
SIUNIT
GREAT BEAR
SPOTTED BEAR RD
SWAN LAKE RD
Big Salmon Lake
BOB MARSHALL
Doctor Lake
Flathead NF Routes
5 - High Degree of User Comfort
4 - Moderate Degree of User Comfort
3 - Suitable for Passenger Cars
2 - High Clearance Vehicles
1 - Basic Custodial Care (Closed)
Non-System Routes
Historical Routes
Streams
Grizzly Bear Secure Core Areas
Wilderness
Ranger Districts
0
5
10 Mi
N
Cartography: Kurt Menke, GISP
Bird's Eye View GIS
www.BirdsEyeViewGIS.com
2017-11-02

May 2016

Roads to Ruin:

The Flathead National Forest Shirks Its Road Reclamation Duties

by
Keith Hammer

Swan View Coalition
3165 Foothill Road
Kalispell, MT 59901
keith@swanview.org

Easy-to-access culverts on open roads can blow out, like this one, while culverts on closed roads get inspected even less often. Though the Flathead National Forest has found up to half of its culverts on closed roads at high risk of failing, it has neither inspected them regularly nor removed them as promised.   *(Forest Service photo, Nokio Creek, 1999)*

Executive Summary

In order to protect water quality and fish, the Flathead National Forest is required to either remove or monitor annually all culverts and bridges in roads closed in threatened bull trout habitat. Similarly, the Flathead is required to develop a monitoring plan for each road it chooses to simply close in providing Security Core habitat for threatened grizzly bear, rather than conducting the preferred reclamation by removing all stream-crossing structures.

Our investigation finds the Flathead has developed none of the required stream-crossing monitoring plans for roads closed to provide Security Core. Nor has it annually monitored stream-crossing structures on closed roads in bull trout habitat.

Though the Forest Service (FS) set forth these requirements and the need for them, the Flathead has failed to implement them. Rather than correct the problem, it has instead set upon a course to do away with such requirements - as culverts and bridges continue to fail on roads both open and closed to motor vehicles.

This report will discuss how the Flathead tracks its roads and stream-crossing structures, discuss how it does and does not monitor them, and provide examples of the consequences when it fails to adequately manage them. It will conclude with recommendations on how to get the effort back on track rather than abandon it to the detriment of fish, wildlife and taxpayers.

Reclamation of 60 miles of road in the Big Creek watershed removed culverts and restored native stream channels, like this reclaimed crossing. This resulted in Big Creek being the first watershed in Montana restored and removed from its list of watersheds "impaired" by logging and road-building. *(Forest Service photo)*

Why the Fuss About Roads and Culverts?

Grizzly bear research indicates bears are displaced by motorized vehicles and other human uses of bear habitat. They are displaced from habitat near roads, even roads closed by gates to motorized vehicles, due to vehicle trespass and non-motorized uses of the road behind the gate. Moreover, female bears raising young need 68% of their habitat to be essentially free of roads. [1]

MT Dept. Fish, Wildlife and Parks photo

Flathead Forest Plan Amendment 19 (A19) was issued in 1995 to incorporate this research and includes limits on Open Motorized Route Density (OMRD) and Total Motorized Route Density (TMRD) - and a required minimum of 68% Security Core. A gate can be placed on a road to reduce OMRD but the road must be reclaimed/ decommissioned and removed from the road "system" in order to not count as a road and reduce TMRD. Road reclamation requires that all stream-aligned culverts and bridges be removed so they can't plug or fail during indefinite long-term closure.

While road reclamation is preferred to increase Security Core habitat, permanent road barriers like earthen berms are allowed and culverts may remain, but a culvert "monitoring plan must be developed and its implementation assured." [2, 3]

Requirements for maintaining FS roads in bull trout habitat place even more emphasis on not leaving stream-crossing structures to fail behind road closure devices. Biological Opinions (BiOps) issued by Fish and Wildlife Service (FWS) require that all culverts behind gates and permanent barriers be monitored annually and that, if annual monitoring behind barriers "is not feasible, remove all stream crossing structures when the road is closed." The BiOps require the removal of all stream-crossing structures when roads are reclaimed, so annual inspections shouldn't be an issue. [4]

In other words, when done properly, road closures and reclamation benefit bears, other wildlife, water quality, fish, and the American taxpayer. The FS and FWS agree that road reclamation that removes all stream-crossing structures, as well as the ditch-relief culverts that channel ditch water under the road, "offers the greatest long-term benefit by reducing sediment delivery, reducing the risk of culvert failure, and the need for maintenance. [5]

Joel Sartore Nat. Geo. Stock w/ Wade Fredenburg photo

Are Culvert and Bridge Failures That Big a Problem?

FWS finds all abandoned culverts eventually fail. More broadly, plugging by stream bedload and woody debris was the most common cause in cited studies of culverts. Those smaller than 24″ diameter accounted for 81% of the plugged culverts. [6]

Even a small stream in an 18″ dia. culvert can do a lot of damage, as shown in our 2015 photos on this page of such a crossing on Pinnacle Ridge Road 1673. Steep streams like this tributary move bedload downhill. It in this case entirely fills the culvert catch basin, plugs the culvert, and sends the stream over the road where it carries away the road fill and fine sediments that can choke trout spawning beds.

The author witnessed this same culvert plugged with bedload and failing in 1973 as an employee of the Flathead National Forest. The Flathead reports roads have increased sediment levels in Pinnacle Creek nearly twelve-fold over natural levels! [7]


Road 1673 looking upstream at plugged catchment.


Road 1673 looking downstream at road-fill erosion.

Large culverts like the 54″ dia. culvert pictured on the cover of this report can still overflow. The one pictured sent 1,000 cubic yards of road fill downstream. [8] A rust line greater than one-third the height of the culvert indicates this culvert was undersized and at increased risk of failure. [9]

Bridges are not immune to washing out, especially during high flows in Spring or with rain falling on fresh snow. A 1990 report by the Flathead documents $319,000 in necessary repairs to roads, culverts and bridges in the South Fork Flathead and Spotted Bear areas damaged during a rain-on-snow event in November 1989. [10]

As A19 was being written, Montana Department of Fish, Wildlife and Parks (MDFWP) used a helicopter to survey culverts on closed roads in the South Fork Flathead and Spotted Bear area, finding 52 culverts partially plugged or undermined and 13 culverts that had failed in bull trout streams. [11] Such findings are among the reasons A19 and FWS's Road Maintenance BiOps include requirements to either remove culverts from closed roads or monitor them regularly to prevent blowouts. [12]

How Aware is the Forest Service of this Problem?

The Forest Service is well aware of the problems associated with roads, culverts and bridges. Following is what the Forest Service wrote in its 2014 Biological Assessment (BA) of road-related activities in bull trout habitat:

"Existing roads are considered a primary source of sediment related impacts to bull trout in developed watersheds (USFS 1998, page 38), and the degraded baseline conditions caused by roads and sediment were part of the rationale for listing bull trout as threatened. . .

<u>The road related activities addressed in this BA . . . are necessary to . . . reduce the risk of damage to watersheds realizing that significant environmental events are likely to occur</u>. . .

<u>The activities described in this BA can occur on a routine basis</u> . . .

The BTCS [Bull Trout Conservation Strategy] recognized that road interactions and activities associated with roads are a high concern. Road densities have been demonstrated as an effective proxy for departure from historic condition, the state of current condition, and ostensibly past management (Rieman et al. 2000). The correlation of higher road densities with fewer bull trout is repeated throughout the planning area, the Columbia River Basin, and other areas where native fisheries and land management issues overlap (Ripley et al. 2005, Quigley and Arbelbide 1997, Riggers and Mace 1997). . .

Road related activities include maintaining the driving surface, <u>reducing the environmental impacts of existing roads</u>, and decommissioning roads. . .

<u>Appendix E addresses how roads placed in a closed or stored status, or decommissioned, are to be treated</u>. . .

Culverts that remain in the road behind gates and berms that are not properly sized, positioned, and inspected will be considered for removal. These have an increased risk for failure by reducing awareness of potential maintenance needs. The accumulation of debris has the potential to obstruct culverts and other road drainage structures. Without maintenance and periodic cleaning, these structures can fail, resulting in sediment production from the road surface, ditch, and fill slopes. <u>The design criteria to address drainage structures left behind gates and berms require annual monitoring of these structures.</u> This programmatic BA recognizes that as the number of closed roads grows (as anticipated), the burden of annual inspection will increase. . .

In the recent past these land management units have maintained an average of approximately 19 percent of the <u>open</u> road system, or 3727 miles each year . . . <u>The</u> overall condition of the existing road network and <u>amount of maintenance needed to maintain the entire road network is unknown</u>. . .

<u>Road decommissioning will result in long-term benefits by reducing sediment sources, reducing the risk of culvert failure, and eliminating the need for maintenance."</u>

[13, parenthesis in original, emphasis added; 14].

So the Forest Service Must be Pursuing Road Decommissioning to Eliminate Culverts and Maintenance Costs?

Rather than continuing to embrace its road decommissioning obligations, the Flathead's decommissioning program has come nearly to a standstill. [15] FWS initially required the Flathead to meet its A19 OMRD objectives within 5 years and its TMRD and Security Core within 10 years as mandatory terms and conditions of its 1995 BiOp. [16] When the Flathead failed to meet those conditions, FWS began issuing BiOps allowing the Flathead to simply make some bit of progress as it plans timber sales and other projects. [17]

Road decommissioning removes culverts, restores streambed gradients, removes road fill, and stabilizes slopes. Paul Harvey photo

When the Flathead began revision of its current (1986) Forest Plan in 2006, it proposed to halve its timber sale program and the "suitable timber base" acreage supporting it. This was partly due to recognizing the Flathead was receiving only 15% of the funds needed to properly maintain its road system, which was built primarily for logging access, and that it needed to continue decommissioning up to 500 miles of road over the coming decade to further reduce impacts to fish and wildlife. [14; 18; 19]

The 2006 Forest Plan revision effort was suspended, then taken up again in late 2013. The Flathead's 2014 Planning Assessment concludes "During the past two decades, appropriated funding for roads construction and maintenance has decreased. . . The overall trend affecting the Flathead NF transportation system is that budgets for repairs and maintenance are expected to continue to decrease . . . [20]

Regardless of failing budgets, the Flathead's 2015 Proposed Forest Plan would increase the suitable timber base half-again over the 2006 proposal, requiring more roads be retained for logging access. It would do away with further implementation of the A19 road management program and treat grizzly bear as a species no longer protected by the Endangered Species Act. [21]

Similarly, the Flathead's 2014 Travel Analysis Report finds only 54 miles of its 3,518-mile road system should be decommissioned, in spite of A19's legally required objectives for grizzly bear never being met to provide the promised bear habitat security. The TAR also portends a shift to "storing" roads rather than decommissioning them, claiming that storing a road is cheaper, largely because the culverts need not be removed for "storage." [22]

Is the Delay in Road Decommissioning Hurting Anything?

Here, in part, is what the Flathead wrote FWS about the effects to bull trout of its delayed implementation of A19's road closure and decommissioning objectives:

"The delay in achieving the implementation schedule has resulted in roads existing on the landscape longer than anticipated. . .

A blown-out culvert in the long-closed Bunker Creek Road 549 in 2014, upstream of bull trout critical habitat.

In 2007, 30 miles [of closed roads] were surveyed and <u>9 failed culverts were found and about 50% of the culverts were at a high risk of failure.</u> It is estimated that there are about 760 miles of bermed roads on the Forest and until these roads are surveyed, it is reasonable to state that conditions exist on them that could contribute sediment to stream networks downstream. . .

These surveys do not exist for every road [so we] infer from the surveys that have occurred that the retention of roads have resulted in unwanted culvert failures or debris slumps that have entered streams and have impacted bull trout habitat. . .

<u>Retention of these roads and lack of maintenance has resulted in culvert failures that have contributed sediment into bull trout waters . . . and is 'likely to adversely affect' bull trout</u>. . .

<u>If the A19 objectives were achieved we would have more roads that would have been reclaimed</u> (i.e. culverts removed, stream channels restored, road surface water barred and treatment that would put that road in a self-maintaining state) <u>and fewer potential effects. Decommissioning . . . would result in a long-term reduction of sediment and improve watershed and stream conditions.</u>" [23, emphasis added]

Shown on this page are just two of the problems we found behind the closure berm on Bunker Creek Road 549 the last two summers, in a bull trout watershed. [24]

Wildfire burned this Road 549 bridge over Bunker Creek in 2015, stranding 3 bridges and 30 culverts beyond!

Then Certainly Culverts are Being Removed or Monitored!

Though the Forest Service is well aware of the damage being cause by failing culverts, culvert failures remain a common occurrence. Though it long ago set forth its own requirements for monitoring culverts annually on closed roads in bull trout watersheds, and FWS agreed it must do so, it has not done so. [4; 5; 24; 25; 26]

Though the Flathead required that it either remove culverts or develop a monitoring plan for each road it closes with a berm to provided grizzly bear Security Core habitat, the Flathead has not prepared a single such monitoring plan! [2, 27] This even though it has bermed or simply abandoned several hundred roads to increase Security Core (and even more to lower TMRD). [28]

Monitoring culverts on closed roads is not an easy task, which is why it is best to remove them instead.

The Flathead, like other National Forests, uses an INFRA database to track culverts, bridges and other travel route infrastructure. The 2015 INFRA data it provided us lists 14,460 culverts and 231 bridges on its National Forest System Roads (NFSR). Not all culverts are listed in INFRA, however, especially smaller diameter culverts. [29]

The failure to include smaller culverts in INFRA compounds the problem of trying to track culverts at risk of blowing out. This is especially true given that studies show 81% of plugged culverts are less than 24” diameter. [6] The culvert size issue aside, we found the 2015 INFRA data extremely inconsistent in tracking problem culverts and those that had been replaced due to problems. [24; 30]

In short, the Flathead does not know with certainty how many culverts it has, where they are all located, what condition they are in, or which have failed. This lack of culvert surveys and adequate database make it difficult to determine the Forest-wide and system-wide effects on water quality and fish.

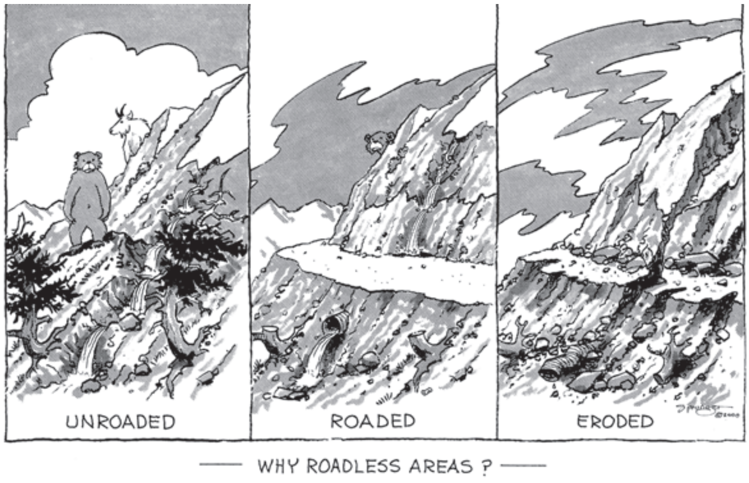
Indeed, the Flathead finds “If road surveys existed on every road system, we would be better able to determine if culverts have failed on closed roads and what the associated affects would be on streams and bull trout.” [23] The Forests in Western Montana in 2014 were left to conclude “The overall condition of the existing road network and amount of maintenance needed to maintain the entire road network is unknown.” [5]

Rather than proposing to significantly reduce the size of its road system to be more fiscally and environmentally responsible, the Flathead intends to make it larger by beginning to rebuild roads it previously decommissioned! [Appendix A; 31]

What's the Problem?

It has become increasingly clear the FNF simply doesn't want to take full responsibility for either removing culverts from closed roads or inspecting them annually to insure they do not plug and fail - as required by the programmatic bull trout BiOp. While the FNF, when challenged, recently agreed to an annual culvert monitoring program in its Chilly James Restoration Project, it simultaneously claims it need not do this elsewhere in bull trout habitat. [26]

This is akin to how the FNF failed to implement its programmatic A19 road closure and decommissioning objectives, leaving 126 miles of road decommissioning scheduled but never implemented and much of the Forest never scheduled to meet A19 objectives. [15, 17] Now the FNF is trying to cheat A19, leaving unattended culverts in “impassable” and other “stored” or abandoned roads from which culverts were promised to be removed! [32]



While the FNF claims A19 has since 1995 allowed it to not count “impassable” or “stored” roads in TMRD, it only began doing so in 2012. [33, 34] When pressured, the FNF now states there “is no forest policy concerning [stored road] treatments and TMRD calculations” and that it is up to the District Ranger whether or not to include “stored” roads in TMRD. [35]

In a broader context, the Forest Service appears to be favoring politics over science and trying to keep its admittedly bloated road system. Whereas its initial directive to arrive at a “minimum road system” clearly “points to a smaller road system,” subsequent directives and travel planning like that on the FNF show that the road system may instead get even larger. [36]

The agency's recently released Ecosystem Restoration Policy could not be more telling. The word “road” appears not at all in the policy, as though roads do not compromise ecosystem resilience and we needn't do anything about them to restore damaged ecosystems. [37]

Such notions run contrary to the primary findings of the Interior Columbia Basin Ecosystem Management Project, which essentially found that ecosystems with roads and management were generally less resilient than those remaining roadless and without management. Many studies caution that trying to restore ecosystems through more management could do more harm than good. [38]

Simply put, the Forest Service is retaining its bloated road system so it can argue for more funds to feign “restoration” by logging, thinning, and burning in ways that require retention of the very roads that cause and enable the ecosystem damage! [37, 38]

Aren't Collaborative Groups Coming to the Rescue?

Unfortunately, collaborative groups have been used on the FNF to promote the myth that the primary problem with forest ecosystems is that there are too many trees rather than too many logging roads. In spite of plentiful scientific research and advice to the contrary, some collaborative groups have outright lied that logging is needed to restore forests and then argued that stream-aligned culverts be left in "reclaimed/decommissioned" roads.

The Southwest Crown Collaborative visits a completed logging unit in the Meadow Smith timber sale in 2012.

The collaborative group Flathead Common Ground was launched on the FNF by Defenders of Wildlife, National Wildlife Federation and Intermountain Forest Industries Association. An invited panel of scientists reviewed the collaborative's "ecologically driven" logging proposal and reported back in 1997.

The panel did not agree that the logging was ecologically driven and concluded "the desire to harvest timber products should be explicitly recognized here as the driving force." The panel also found it was "unclear the extent to which road closure entails gating only, gating plus culvert removal, or reclamation/obliteration." [39]

The collaborative's final proposal nonetheless still called its logging "ecologically driven." DOW and NWF in particular refused to abide by A19's requirement that all stream-aligned culverts be removed from the 120 miles of road the FNF said needed to be reclaimed in the Paint-Emery Project area. Indeed, they argued against it. [40]

The Collaborative Forest Landscape Restoration Program (CFLRP) says plenty about logging as restoration but barely mentions decommissioning existing roads. [41] This bias is similarly reflected in its accomplishments. Its 5-year report finds CFLRP exceeding its logging goals but falling far short in removing roads and the weeds they spread. [42]

The Southwest Crown Collaborative (SWCC), which is partly funded by CFLRP, on 9/11/12 recorded the FNF Supervisor as saying the Swan Lake Ranger District "has already decommissioned 800 miles of roads due to grizzly bears, so there aren't as many opportunities today" for decommissioning. [43] Swan View Coalition showed this to be in error and the District Ranger subsequently agreed only 74 miles have been decommissioned in the District - about half of that in the SWCC area. [44]

Meanwhile, other collaborators are urging Congress to fund them and to ignore those who may have a better grip on the facts and resort to litigation when necessary. [45]

In Plain Language, What's Going On?

The Forest Service complains it doesn't get enough funding to maintain its roads yet refuses to significantly reduce its road network. Instead it simply blocks more roads shut to save on maintenance while largely ignoring the culverts and bridges on those closed roads as though they'll maintain themselves. [46, 47]

When it does get funding for road maintenance, it skims 55% off the top of that and uses it instead for "timber support." [48] Though timber sales are supposed to then help maintain the roads used to haul the logs, a vicious downward spiral is set in motion as timber sales are used to justify more roads and roads are used to justify more timber sales! [49]

The conservation community has helped lobby Congress to provide funds to repair or decommission roads via the Legacy Roads and Trails Program. [50] This once independent budget line item, however, has now been combined with other budget sources into an Integrated Resource Restoration budget line item. This makes it harder to insure that money to fix or decommission roads is not instead used to accomplish logging targets and other logging-as-restoration objectives - concerns expressed by the Forest Service itself. [51]

On the FNF, its choices for decades have been crystal clear, especially in bull trout habitat: either remove all the culverts from closed roads or commit to monitoring and maintaining them annually. This it has not done, nor has it met similar requirements when closing roads to provide grizzly bear Security Core habitat. As roads, culverts and bridges continue to wash out and collapse, as pictured on this page and page 7, it becomes even harder to monitor culverts and bridges stranded further up the road. [52]


Water collecting in the ditch of this closed road contributed to mass failure into Sullivan Creek, a key bull trout spawning stream.

The FNF is attempting a revisionist history of A19, as though it did not require "reclaimed" roads to be treated as "decommissioned" roads to be removed from the road system. Its increasing reliance instead on simply calling roads "impassable" and "stored" to decrease road densities reneges on promises it made its biologists, the courts and the American public. [53]

No National Forest should need the additional force of law afforded threatened and endangered species to make it do the right thing. Simple common sense and fiscal responsibility indicate the Forest Service needs to decommission a significant portion of its road system in order to adequately manage the remainder in an ecologically sound manner. [54]

Recommendations

Based on our investigations, we recommend the following to the Forest Service:

1. Continue A19 as an integrated road management program and reduce the Suitable Timber Base and Allowable Sale Quantity accordingly, as proposed in 2006. [55]

2. Recognize that A19 dovetails with requirements for managing roads in bull trout habitat and the agency's duty to arrive at an environmentally and fiscally sustainable "minimum road system."

The last three miles of Bunker Creek Road 549 was decommissioned under Clinton's 1998 Clean Water Action Plan. Here a bridge was removed at Warrior Creek.

3. Apply the road closure, reclamation and culvert monitoring programs developed for bull trout and grizzly bear across the entire Flathead National Forest, so the benefits are extended to all fish and wildlife and are not dependent upon Endangered Species Act listings and protections. [56]

4. Inventory all stream-crossing structures on the Forest and include them in the INFRA database, in a manner that insures inspections, problems and repairs are fully accounted for and easily traceable. [57]

5. Commit to the annual inspection and necessary cleaning of all stream-crossing structures. If this is unrealistic, reduce the size of the road system to a size that is realistic. [58]

6. Quit skimming 55% off the top of road maintenance funds for "timber support" and put it directly to work maintaining roads where needed most. [59]

7. Recognize that calling logging and other vegetative treatments requiring roads "restoration" is at odds with considerable science and at odds with ecosystem restoration requiring the removal of roads. [60]

8. Recognize removing culverts from roads is cheaper than maintaining them in the long term. [61]

9. Work with the public to secure funding and independent budget line items for decommissioning roads - and keep them independent line items. [62]

10. Recognize litigation is as important as collaboration in helping guide the agency. [63]

> *"The simplicity of A19 and its ability to permanently secure areas for grizzly bears makes it a powerful tool in the conservation of the grizzly bear."*
>
> Dr. Bruce McLellan, Dr. M. A. Sanjayan
> and Dr. Nova Silvy
> 9/19/2000

Acknowledgements

The author wishes to acknowledge the assistance of Flathead Forest Supervisor Chip Weber and members of his staff as we conducted our investigations and submitted numerous Freedom of Information Act requests for data and documents. Michele Dragoo was of particular help as she handled the FOIA requests and collected various documents from District offices as well as the Supervisor's office. Our thanks extend to those who helped get the documents to Michele Dragoo.

We met several times with Rob Carlin, Kathy Ake and Trisha Cassner and wish to thank them for their efforts to answer our questions and to provide INFRA and other infrastructure data to us in formats we could use in Excel and Google Earth.

We also wish to thank Spotted Bear District Ranger Deb Mucklow, Ron Krueger and other FNF staff who followed up on our numerous reports of plugged or partially plugged culverts, in some cases removing the debris before further damage could occur and in others confirming our discovery of culverts where they were thought not to exist.

Disclaimer and Need for Further Study

This investigation and report were made without the benefit of full access to the INFRA database. It nonetheless reports on a handful of the problems found by comparing INFRA data using Excel and Google Earth to field observations. Space here does not allow a discussion of every problem found. We reserve for another time a discussion of the stream-aligned culverts found in decommissioned, "impassable/stored" and other roads where they should not exist either by definition, requirement, common sense, or because they were specifically reported as having been removed.

With full access to the INFRA data and its database capabilities, more could be gleaned concerning the adequacy of the data and its ability or inability to indicate where culverts and bridges have been stranded beyond culverts and bridges that have been removed by act or nature. Such further study could also produce recommendations for improving how INFRA could track the history of each structure and when it was last inspected, cleaned, identified as a problem, repaired, or scheduled for further action.

Notes and Sources

1. See generally Fish and Wildlife Service's 1/6/95 Biological Opinion on Flathead Forest Plan Amendment 19, as amended 2/17/95, for the biological rationale adapting research to Forest Plan objectives and standards, including the BiOp's Incidental Take Statement. Kemper McMaster, Field Supervisor, Montana Field Office.

2. Flathead Forest Plan Amendment #19: Allowable sale quantity and objectives and standards for grizzly bear habitat management. Decision Notice signed 3/1/95 by Joel Holtrop, Flathead Forest Supervisor. See also Amendment 19 Appendix D: Forest Plan Appendix TT Definitions and implementation direction for restricted roads, reclaimed roads, and security core areas.

3. For more information regarding how Amendment 19 has been dovetailed with the work of the Interagency Grizzly Bear Committee and implemented on the Flathead National Forest, see Keith Hammer's white paper "Only decommissioned roads removed from the Forest Development Road System may be omitted from calculations of Total Motorized Route Density on the Flathead National Forest. Dated 6/4/15 and updated by addendum 2/7/16. This white paper is also included as Appendix A to this report.

4. Biological Opinion on the effects to bull trout and bull trout critical habitat from the implementation of proposed actions associated with road-related activities that may affect bull trout and bull trout critical habitat in Western Montana. Jodi Bush, Field Supervisor, Ecological Services Montana Field Office of Fish and Wildlife Service. April 15, 2015. The 2015 BiOp follows similar BiOps dated 4/26/99, 8/1/01, and 4/29/08. All these BiOps, and the Forest Service Biological Assessments they respond to, express concerns about continued failure of culverts. The 8/1/01 BiOp and all that follow require the annual inspection of culverts on closed roads.

5. Biological Assessment of Road related activities that affect bull trout and bull trout critical habitat in Western Montana. Prepared by USDA Forest Service Northern Region and UDI Bureau of Land Management Missoula Field Office. Dated 5/5/14, revised 12/15/14.

6. Biological Opinion on the Effects of the Moose Post-Fire Project on bull trout. U.S. Fish and Wildlife Service, Montana Field Office. Dated 11/14/02. Citing Copstead, R. L. and D. K. Johansen. 1998. Water/road interaction: examples from three flood assessment sites in Western Oregon. USDA Forest Service, San Dimas Technology and Development Center, San Dimas, California.

7. Due to a switchback in Pinnacle Ridge Road 1673, another 18" dia. culvert carries the same small stream under the road immediately uphill of the crossing shown in the photos. While the upper culvert was not failing in 1973 when the author inspected it then as a Forest Service employee, its catch basin was filled with bedload and the culvert was overflowing the road when inspected on 6/26/15, sending more bedload and road fill downhill to fill the catchbasin at the lower crossing and contributing to its failure also.

The Flathead's August 1993 DEIS for the Middle Fork Ecosystem Management Project, reported another "recent culvert washout and repair" in the Pinnacle Creek watershed, but did not specify exactly where. The DEIS did note lower Pinnacle Creek was in the worst condition of all streams in the Project area. It noted a 1,177% increase in sediment over natural conditions and concluded "The existing sediment yield increase is from roads. Roads will continue to generate sediment indefinitely unless they are restored to pre-road condition."

When Road Management Objectives for this road were established in 2009, the two 18" dia. culverts weren't even listed as existing, let alone included under "Special Maintenance Criteria Details." A Forest Service Avalanche Ranger reported the 2015 failures in late winter and both culverts with a history of failure on the small tributary to Pinnacle Creek are reported to have since been replaced with 48" dia. culverts.

8. Counting culverts: An assessment of integrated road and culvert management on the Flathead National Forest. Keith Hammer. December 2000. Available at
http://www.swanview.org/reports/Culvert-Report.pdf

9. Culvert Monitoring Form 5/2005 provided by the Flathead National Forest on 2/5/16.

10. See Note 8, citing Flathead NF Flood Damage report to the Regional Forester, 4/4/90.

11. See Note 8, citing MDFWP survey report to Flathead NF by Tom Weaver, 12/18/95.

12. See Notes 2 and 4.

13. See Note 5.

14. In preparation for revision of the Flathead, Lolo and Bitterroot Forest Plans, Forest Service fisheries biologists in 2000 conducted "baseline bull trout risk assessments." These risk assessments were made on a 6th Code Hydrologic Unit Code (HUC6) basis and detailed among other things the miles of roads and streams in each HUC, the density of roads, the proximity of those roads to the streams, and the number stream crossings by roads.

We analyzed this risk data and found, based on road density and its location relative to streams, that the Flathead National Forest rated 70% of its HUC6 sub-watersheds to be Functioning at Risk or Functioning at Unacceptable Risk to bull trout. It found 30% of the sub-watersheds Function Appropriately. Our analysis of the data is presented in our May 2004 report "Watersheds at Risk: Roads threaten bull trout on the Bitterroot, Flathead and Lolo National Forests." The report is available at:
http://www.swanview.org/reports/Watersheds_at_Risk_report.pdf

We also applied a "Road:Stream Ratio" analysis to this same HUC6 data. We found that only 23% of the HUC6 sub-watersheds within the Flathead National Forest boundary remain roadless and that, on the whole, the developed sub-watersheds had 20% more miles of road than streams (9,092 miles of road compared to 7,607 miles of streams). We also found that 92% of the developed sub-watersheds had road densities in excess of levels where most bull trout populations occur and in excess of recommended standards for grizzly bear recovery. This analysis is detailed in our April 2003 report "Off the Charts: Roads outnumber streams in developed Flathead watersheds." The report is available at:
http://www.swanview.org/reports/Off_the_Charts_report.pdf

15. The Flathead National Forest tracks its Road Decommissioning Projects in a spreadsheet updated annually. These are roads intended to be decommissioned, removed from the "road system," and tracked instead as "historic" roads once the decommissioning work and re-vegetation become effective. The spreadsheet also tracks decisions to decommission roads where the decommissioning has not yet occurred.

The 2/18/16 spreadsheet concludes decisions have been made since 1992 to decommission 889 miles of road; that 162 of those miles needed no work as they were naturally re-vegetated, that 601 of those miles needed work and were actively decommissioned, but that 126 of those miles remain in the road system and have not been decommissioned as planned. The spreadsheets and other Flathead documents show that the Flathead decommissioned an average of 43 miles of road per year from 2003 - 2013 [see Note 19, below] while decommissioning only 12 miles total in 2014 and 2015.

As discussed in Appendix A to this report, where A19 used the term "reclaimed," the A19 EA made clear that reclaimed roads would also be removed from the road system, also known as "decommissioned."

16. See the Incidental Take Statement in Fish and Wildlife Service's 1/6/95 Biological Opinion on Flathead Forest Plan Amendment 19, as amended 2/17/95. Kemper McMaster, Field Supervisor, Montana Field Office.

17. FWS's 2015 BiOps and Incidental Take Statements regarding the Forest-wide effects of Amendment 19 to grizzly bear [see Note 15] were replaced by successive BiOps and Incidental Take Statements on 10/25/05 and 1/31/14 to address revised A19 implementation schedules. Currently, FWS prohibits the Flathead from making any net increase in OMRD or TMRD or any net decrease in Security Core; to abide by any access management implementation schedules made a part of individual projects; and to otherwise proceed "with reductions of access densities and increases in core as authorized by project decisions without time tables, as funding allows." This is followed by the Conservation Recommendation that the Flathead "Continue to manage access on the Forest to maintain or achieve lower road densities . . . low road densities would also benefit other wildlife and public resources. Low road densities may result in lower maintenance costs that free up funding for other resource needs."

18. US Forest Service Western Montana Planning Zone. 2004. Analysis of the management situation for the Bitterroot, Flathead and Lolo National Forests. 3/2/2004. Missoula, MT

19. Flathead National Forest. 2006. Proposed Land Management Plan. April 2006.

20. Flathead National Forest. 2014. Assessment of the Flathead National Forest - Part 2. April 2014.

21. Flathead National Forest. 2015. Proposed Action - Revised Forest Plan. March 2015.

22. Flathead National Forest. 2014. Travel Analysis Report for Flathead National Forest. The final TAR includes the same economic analysis as the draft TAR and suffers from the same flaws described in Swan View Coalition's comments on the draft TAR.

Namely, the TAR: 1) compares the cost of decommissioning to the cost of ML-1 road maintenance, not to the true costs of properly "storing" a road with no risk of culvert or bridge failures and no need for maintenance, falsely concluding "You can store the road forever cheaper than decommissioning" and 2) presumes that the road will be rebuilt or reconditioned in the future, making decommissioning appear all the more costly and short-circuiting the whole purpose of the TAR in helping determine which roads should never be rebuilt in order to arrive at a fiscally and environmentally sustainable "minimum road system."

Our full comments on and other documents related to the draft TAR can be found at:
http://www.swanview.org/articles/newsletter-alerts/help_decommission_old_logging_roads_that_are_trashing_the_environment/194

23. Flathead National Forest. 2010. Fisheries Biological Assessment: Amendment 19 objectives and standards for grizzly bear habitat management revised implementation schedule. Pat Van Eimeren - Flathead National Forest Fisheries Biologist. 6/2/10.

24. Bunker Creek Road 549 (and its spur Middle Fork Road 2820) have been closed yearlong to protect wildlife habitat since 3/26/96, initially with a gate and then with an earth berm at Milepost (MP) 3.7 on Road 549. In 1998 and 1999, Road 549 was decommissioned above its junction with Road 2820, from MP 9.7 to its end MP 12.9, using funds provided by President Clinton's 1998 Clean Water Action Plan, which called for the decommissioning of 5,000 miles of road a year by 2002 on federal lands. (See Note 15. The Clean Water Action Plan is at https://www.epa.gov/aboutepa/president-clinton-announces-clean-water-action-plan)

Bunker Creek, below its confluence with Middle Fork Creek, has since been designated bull trout "critical habitat." The Road 549 bridge burned in 2015 and pictured on page 7 of this report is 50 yards upstream from the confluence with Middle Fork Creek and the beginning of downstream "critical habitat." The bridge debris and the worst of the slumping road fill has since been removed.

Similarly, the burned bridge is 50 yards from the junction with Road 2820 and 175 yards from the decommissioned portion of Road 549. We surveyed the decommissioned portion of Road 549 in 2014. This appears to be a good job of decommissioning and not a single bridge or culvert remains.

Road 2820, on the other hand, has relied on the earth berm on Road 549 for its closure to motor vehicles and had motorcycle tracks evident during our visit in 2014. According to the Flathead's INFRA database, which is used Forest Service-wide to track travel route infrastructure, Road 2820 still has 3 bridges and 30 culverts in place. (The Flathead in 2015 provided us with Excel spreadsheets and Google Earth KML files containing INFRA and other data relative to National Forest System Roads, decommissioned/historic/non-system roads, "impassable" NFSR roads, road barriers, road gates, existing culverts and bridges, and disposed/removed culverts and bridges on the Flathead).

When we requested pursuant to the Freedom of Information Act (FOIA) all culvert inspection plans and forms for Road 2820, the only ones provided were 12 stream-bearing culvert inspection forms from a 2010 survey, along with the survey log noting the cleaning of additional cross-drain culverts. Although this is a bull trout watershed, no requisite annual culvert inspections were provided. Although this is a bermed road in grizzly bear Security Core, no requisite monitoring plan for the road and culverts was ever prepared. The 2010 survey reported three plugged and failed stream-bearing culverts, another half-dozen partially plugged culverts cleaned during the survey, and rated half of the dozen stream-bearing culverts as medium or high risk of blockage or failure.

On 8/28/14 we found two of these Road 2820 culverts again partially plugged with woody debris and noted one had overflowed and sent part of the roadbed downstream toward Middle Fork Creek. We alerted the District Ranger, who sent a couple employees up with hand tools to clean the woody debris out.

On 8/28/14 we also encountered a Forest Service employee and "Call When Needed" backhoe contractor digging out the failed 24" dia. culvert at MP 6.2 in Road 549, as pictured on page 7 of this report, and laying in a second 24" dia. culvert alongside it. The 2015 INFRA data shows two culverts now at this location, but no remarks to indicate one of them had failed or why a second culvert was necessary. A 2010 culvert survey log for Road 549 indicates this culvert was at that time a "washout, deposition upstream of road, downstream side of road washout is 5-10 ft deep."

We alerted this 8/28/14 crew, which had temporarily removed the earth berm closure to get equipment in to make the repair at MP 6.2, to a 4' dia. culvert at MP 6.9 that was nearly completely plugged with logs and bed load and would likely fail with the next big storm or Spring runoff. They ran the backhoe up the road and cleaned the culvert inlet, heading off another culvert failure and sediment load into Bunker Creek. The 2015 INFRA data contains no remarks that this culvert nearly failed and needed cleaning in 2014. Nor does the 2015 INFRA data note the 2010 culvert survey log indicated the crew had at that time cleared the culvert of all but "large immovable logs," which are perhaps among the logs that trapped bedload against the culvert inlet as shown in our 2014 photo below, left. The small remaining hole into the 4' dia. culvert inlet was smaller than a volleyball. The culvert pictured on the right is provided for comparison and is a Forest Service photo of a 4' dia. culvert blowing out in 2014 behind a gate on Emery Creek Road 546.

We requested pursuant to the FOIA all culvert inspection plans and forms for Road 549. The only ones provided for the road behind the closure berm were 2 stream-bearing culvert inspection forms from a 2010 survey, along with the survey log. The 2010 survey log accounts for only 36 of the 51 culverts that the 2015 INFRA data list as existing behind the closure berm. Although this is a bull trout watershed, no requisite annual culvert inspections were provided. Although this is a bermed road in grizzly bear Security Core, no requisite monitoring plan for the road and culverts was ever prepared.

25. Through a series of FOIA requests and meetings with FNF staff spanning from November 2014 through February 2016, we learned that annual monitoring of stream-crossing culverts behind road closures in bull trout habitat is not being conducted Forest-wide. When we asked for such culvert monitoring records for five specific closed roads in bull trout habitat, FNF could provide no annual inspection reports for those roads. Though we were provided INFRA road infrastructure data for FNF culverts and bridges, we were informed the INFRA data would not show when a culvert was last inspected (personal communication with Kathy Ake and Trisha Kassner, 6/24/15) - which it indeed does not.

26. The FNF insists "The Forest is not required to monitor every stream crossing in every bull trout watershed across the forest [and the annual culvert monitoring requirement on closed roads does not apply until] a project utilizes the programmatic [Biological] Opinion." (Chilly James Restoration Project Decision Notice and Finding of No Significant Impact, Appendix 4 Response to Public Comments, Richard Kehr, 4/15/16).

On the other hand, the Chilly James DN cited above then continues: "Roads with stream crossings that are closed by a berm or gate in bull trout watersheds in the project area will have annual culvert monitoring and reporting as required by the bull trout biological opinion . . . The Chilly James project is very similar to work described in the 2015 programmatic Biological Opinion for road-related work . . . However the project does have more actual activity (number of cross-drains to be cleared and culverts removed) than normally allotted and thus a stand-alone Biological Opinion was prepared."

The Chilly James DN essentially claims that the annual culvert monitoring requirement in the programmatic BiOp does not apply until the Forest Service says it does. We will let the referenced 2008 Biological Opinion speak for itself, along with its 2015 updated Biological Opinion (see Note 4 and page 3 of this report). Similarly, we will let the Forest Service's Biological Assessment prepared for the 2015 update speak for itself (see Note 5 and the summary of the BA provided on page 5 of this report).

27. On 7/15/15, we submitted a FOIA request and asked the FNF to provide copies of all the culvert monitoring plans required for each road closed, rather than decommissioned, to provided grizzly bear Security Core habitat - as required by A19 since 1995. In his FOIA response dated 9/22/15, FNF Supervisor Chip Weber responded: "as was mentioned in our August 6th meeting, there are no monitoring plans as you requested in your July 15th request."

28. We utilized INFRA data and Google Earth kml road files provided by the FNF to determine how many roads have been simply closed, rather than decommissioned, to increase grizzly bear Security Core habitat. Bermed ML-1 roads numbered 228, Impassable TMRD roads numbered 48, and Impassable Not TMRD roads numbered 45, for a total of 321 roads. [See Appendix A to this report for a discussion of ML-1 and Impassable roads]. For comparison purposes, 435 of FNF's decommissioned roads also serve to increase Security Core.

29. Personal communication with Kathy Ake and Trisha Kassner, 6/24/15. Our Counting Culverts report in 2000 estimated 80,000 culverts may exist on the FNF. The report is accessible via Note 8.

30. The INFRA data provided by the FNF included 14,460 culverts. In the "Remarks" data column, only 110 culverts were mentioned as having problems and similarly, though not the same culverts, 110 were mentioned as having been replaced. This appears to be a gross under-representation of problem culverts, given some individual culvert surveys have reported up to 65 failed or failing culverts on the handful of

roads surveyed (see Notes 11 and 24, for example). If there exists a portion of the INFRA database that better tracks problem culverts, we were not provided nor made aware of it by the FNF.

31. Though FNF's implementation of A19 road decommissioning has been sluggish, it has recently come nearly to a standstill. While the FNF proposed in 2006 to decommission up to another 500 miles of road, assessments in the past couple of years call for only 54 miles of road decommissioning ever and the elimination of A19 altogether (see page 6 of this report). More recently, FNF logging proposals like the Trail Creek Fire Salvage Project have begun proposing to rebuild previously decommissioned roads, bring them back into the roads "system" and keep them there - to the detriment of water quality, fish and wildlife (see pages 11 - 14 of Appendix A to this report).

32. A particularly egregious example of leaving unattended culverts in "impassable" roads is the recently "waterproofed" Raghorn Road 10802 in the Coal Creek watershed, which is "critical habitat" for bull trout and an "impaired" Water Quality Limited Stream. Road 10802 was among many roads initially scheduled for decommissioning in 1992 but for which implementation languished for decades. Finally, a 2010 decision was issued to remove all 13 culverts from the "long abandoned" Road 10802. But in 2012 only three culverts were removed, stranding numerous stream-crossing culverts beyond! More details can be found on pages 12-14 of Appendix A to this report.

33. Protocol paper for motorized access analyses application rule. Draft NCDE Grizzly Bear Conservation Strategy Appendix 5. Kathy Ake. February 2013.

34. 2012 Annual Flathead National Forest Plan Amendment 19 implementation monitoring report and responses to Amendment 19 revised implementation schedule terms and conditions. June 2013. Flathead National Forest. This announcement that the FNF was not including many "impassable" roads in calculations of TMRD coincides with the significant slowdown in the FNF's road decommissioning, which is required by A19 to remove a road from TMRD calculations. Decommissioning dropped from an average of 43 miles per year to only 6 miles per year (see Note 15).

35. See the Chilly James DN cited in Note 26. In its Appendix 4 Response to Comments, the DN more fully states: "There is no forest policy concerning ISS treatments and TMRD calculations. Roads and specific treatments are assessed by the Interdisciplinary Team at the project area scale as described in the EA. Whether or not a road will be managed to meet 'reclaimed' status under Amendment 19 and contribute or not contribute towards TMRD is specifically addressed within the EA . . ."

This District-level discretion was confirmed by Mark Ruby during an informal Objection resolution meeting for the Chilly James Restoration Project on 4/5/16, stating that the District Ranger has the discretion to either include or not include an ISS road that otherwise meets "reclaimed" status (though not removed from the transportation "system" and considered decommissioned) in TMRD calculations. For more detail on ISS, impassable, reclaimed, and decommissioned roads and their inclusion in or exclusion from calculations of TMRD, see Appendix A to this report.

In short, it does little good to have a well-written program like A19 or the programmatic bull trout BiOp for road-related activities if it is going to be cherry-picked and rendered piecemeal at every project. Rather than a program, this is called "making it up as we go along."

36. Deputy Chief Joel Holtrop's 11/10/10 directive for implementing Travel Management, Implementation of 36 CFR 212, Subpart A stated that the travel management process "points to a smaller road system." Deputy Chief Leslie Weldon on 3/29/12 replaced Holtrop's directive and, among other things, removed the phrase "points to a smaller road system." The FNF is now proposing to reconstruct previously decommissioned roads and keep them in the road system (see Note 31).

37. Forest Service Ecosystem Restoration Policy. RIN 0596-AC82. Notice of Final Directive. Thomas Tidwell. 4/18/16 as reported in the Federal Register, Vol. 81, No. 81, 4/27/16, pages 24785-24793. The Policy notes

"Ecosystem restoration can be achieved by a range of management activities, such as forest thinning to reduce tree density, prescribed fire to reduce fuel buildup, replacing culverts to better connect streams, or fencing to restrict disturbances." No mention is made of removing culverts or roads to restore ecosystems. The policy goes on to promote tree- and carbon-removing "forest treatments" with the expectation that "more carbon will continue to be sequestered than would otherwise occur without the treatment" - while acknowledging "research on whether restoration increases carbon stocks is inconclusive."

38. See our annotated bibliography at http://www.swanview.org/reports/Annotated_Bibliography.pdf The first nine pages contend with roads. For convenience, we include several relevant citations here:

"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." (U. S. Forest Service. 1996. Integrated Scientific Assessment for Ecosystem Management in the Interior Columbia Basin and Portions of the Klamath and Great Basins. General technical report PNW-GTR-382. September 1996. Pages 108, 115 and 116).

"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." (U. S. Forest Service. 1996b. Status of the Interior Columbia Basin: Summary of Scientific Findings. General technical report PNW-GTR-385. November 1996. Page 85).

"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 . . .

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 . . .

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 . . .

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."
(An Assessment of Ecosystem Components in the Interior Columbia Basin and Portions of the Klamath and Great Basins, Volume 3 (ICBEMP): pages 1340-1342).

"Fire and the associated hydrologic effects can be characterized as pulsed disturbances as opposed to the more chronic 'press' effects linked to permanent roads or extended timber harvest activities . . . It also is not clear that attempts to manipulate the structure and processes of whole ecosystems (i.e. beneficially manipulate the fire regime) can ever be successful . . . The perpetuation or expansion of existing road networks, and other activities might well erode the ability of populations to respond to the effects of large scale storms and other disturbances that we clearly cannot change." (Bruce Reiman, Danny Lee, Gwynne Chandler and Deborah Meyers. 1997. Does Wildfire Threaten Extinction for Salmonids? Responses of Redband Trout and Bull Trout Following Recent Large Fires on the Boise National Forest. USDA Forest Service, Intermountain Research Station; Boise, Idaho. 1997.)

"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. Biological Opinion for the Effects to Bull Trout from Continued Implementation of Land and Resource Management Plans and Resource Management Plans as Amended by the Interim Strategy for Managing Fish-producing Watersheds in Eastern Oregon and Washington, Idaho, Western Montana, and Portions of Nevada (INFISH), and the Interim Strategy for Managing Anadromous Fish-producing Watersheds in Eastern Oregon and Washington, Idaho, and Portions of California (PACFISH). 8/14/98.

39. University of Montana Science Advisory Committee letter to Intermountain Forest Industry Association's Brendan Moynahan and Defenders of Wildlife's Hank Fisher regarding its review of Flathead Common Ground's Draft Proposal. Daniel Pletscher. 1/3/97.

40. Flathead Common Ground [Final] Recommendations. 2/24/97.

In an 8/4/99 email response to criticism from Swan View Coalition and others, National Wildlife Federation's Tom France and Sterling Miller, along with Defenders of Wildlife's Hank Fisher, state that leaving some stream-aligned culverts in roads to be reclaimed/decommissioned would save the FNF money, acknowledge NWF and DOW don't know "how many culverts would be left and what their locations are," agree "a watershed inventory should have been completed," and yet conclude leaving unidentified stream-aligned culverts "poses little risk to fish populations." They concluded this would "achieve important security for grizzly bears sooner rather than later, both in Paint Emery and across the entire forest."

Indeed, only a few months earlier, the FNF decided to attempt this "let's not and say we did" approach to A19 road reclamation in its 5/6/99 "Implementation Note #13." Swan View Coalition and others filed notice they would sue and reminded the FNF of its A19 duties to remove all stream-aligned culverts from reclaimed roads in order to protect water quality and fish as it secured bear habitat. FNF rescinded Note 13, stating "We talked it over with our attorneys and we decided they [Swan View Coalition and Friends of the Wild Swan] were right." This matter is more thoroughly discussed on page 7 of Appendix A to this report.

41. The CFLRP is set forth in Title IV of the Omnibus Public Land Management Act of 2009, available at:
https://www.gpo.gov/fdsys/pkg/PLAW-111publ11/pdf/PLAW-111publ11.pdf

42. Collaborative Forest Landscape Restoration Program 5-Year Report. USDA Forest Service. FS-1047. March 2015. Available at:
https://gallery.mailchimp.com/1947d6cd971c70f8ef837d21a/files/CFLR_5_Year_Report_USFS_lowres_4_6_15.pdf

43. Initial meeting notes of the 9/11/12 SWCC Executive Committee, prior to updating/correction on 12/11/12.

44. Keith Hammer email to Chip Weber and the SWCC, dated 11/28/12 re: the SWCC meeting notes cited in Note 43, above. Richard Kehr email to Matthew Koehler, dated 8/4/15. Keith Hammer email to Richard Kehr and the SWCC, dated 8/11/15. Keith Hammer's 8/11/15 email attached a letter to the SWCC, which included a Google Earth map using FNF road data layers to demonstrate the plethora of roads in the Swan Valley from which to choose for decommissioning. This letter and map are available at:
http://www.swanview.org/reports/SLRD_Road_Decommissioning.pdf

45. Joint letter from 43 Montana collaborators to Senator Steve Daines. Julia Altemus, Montana Wood Products Association, et al. 1/14/15. Available at:
http://www.swanview.org/reports/FinalPartnersLetter_1_14_15_Final.pdf

The above letter is also included in a packet of information prepared by Keith Hammer on 9/27/15 detailing "How Congress and the Forest Service are Paying Collaborative Partners." The packet includes links to the SWCC web site, which lists its collaborative partners and provides a listing of CFLRP and other funds provided some of those partners, often in exchange for little more than an in-kind contribution in labor worth one-fifth the amount of cash the partner may receive from the federal government. This packet is available at: http://www.swanview.org/reports/Full_Packet_2.pdf

46. Flathead National Forest. 2014. Travel Analysis Report for Flathead National Forest. Page 5: "Current and projected funding is far reduced from the funding needed to maintain the needed road system. . . Approximately 3,465 miles of roads [are] 'likely needed for future use' [and] 55 miles of road were identified as 'likely not needed for future use'."

47. Legacy Roads and Trails Program FAQS: "The Forest Service generally has the funding to maintain 20% of our road network each year. In 2011, the Forest Service maintained 16% of its road network [and] decommissioned 581 miles" of its 375,000 mile road network. Available at http://www.fs.fed.us/restoration/Legacy_Roads_and_Trails/faqs.shtml

48. Flathead National Forest. 2014. Travel Analysis Report for Flathead National Forest: Appendix E.

49. The Forest Service has a long history of using taxpayer "capital investment" funds to build roads into remote areas where the timber industry refused to bid on the timber, often multiple times. Our "A Tale of Two Subsidies" details two such "hard money" projects totally $840,000 to build 27 miles of new road and reconstruct 14 miles of existing roads when no timber sale bids were received. The Bent Flat and Sunset Beaver roads were built into sensitive areas, including grizzly bear habitat, and it was subsequently necessary to decommission some of these roads. In the Bent Flat area, FNF is now proposing to rebuild 7 miles of previously decommissioned roads to log trees burned in 2015. See pages 10-11 of Appendix A to this report for more about the Trail Creek Fire Salvage Project. "A Tale of Two Subsidies" is available at:
http://www.swanview.org/reports/A_Tale_of_Two_Subsidies.pdf

50. See Note 47 for source.

51. Evaluating the Integrated Resource Restoration Line Item: Results from Phase 1. 2014. Ecosystem Workforce Program Working Paper #47. Courtney Schultz, Katherine Mattor and Cassandra Moseley. Spring 2014. Available at http://ewp.uoregon.edu/sites/ewp.uoregon.edu/files/WP_47.pdf

52. INFRA data provided by the FNF indicates there are 24 culverts remaining in Sullivan Creek Road 547 above the 2014 mass failure at MP 3.5, with 5 of them larger than 18" diameter. FNF on 2/5/26 could provide only 4 culvert monitoring reports for this road in a bull trout watershed, rather than the requisite annual reports. The reports provided were written after the mass failure that occurred in 2014. A 3' dia. culvert at MP 4.26 was rated as "high risk" because it had a rust line greater than one-third the height of the culvert, had floatable debris upstream and is located less than 600 feet above a bull trout spawning reach. An old wooden bridge over Sullivan Creek and more culverts on Road 2801 are also stranded beyond the mass failure on Road 547.

The FNF has refused to decommission Road 547 and claims the mass failure was a natural occurrence caused by Sullivan Creek eating away at the toe of the slope. This even though the toe of the slope remains largely in place, still supporting some of the slumped hillside, and the apex of the slump is located in the road bed. When inspected in 2015, the apex has further collapsed, removing the entire width of the road bed. Links to our requests that all culverts and bridges be removed above the mass failure, FNF's response, and relevant new articles are available at:
http://www.swanview.org/articles/whats-new/help_decommission_old_logging_roads_that_are_trashing_the_environment/194

See Note 24 for information on the culverts and bridges stranded beyond the burned bridge in Bunker Creek Road 549, as pictured on page 7 of this report.

53. See Appendix A to this report, particularly pages 2-3, which explain how the A19 EA accounted for reclaimed roads miles by removing them from the road system, which is also the definition of a decommis-

sioned road. See also pages 6-7 of Appendix A, which describe the conditions placed on A19 by the Forest's fisheries biologist (and later incorporated into A19's Appendix D).

Though the FNF reported to the Flathead Basin Commission and others that it "decommissioned" South Coal Ridge Road 1604, it instead has retained it in its road system as an "impassable/stored" road not included in the calculation of TMRD. The Flathead Basin Commission makes clear in a footnote: "Decommissioning of a Forest Service road means that it will be removed from the official transportation system." FNF hydrologist Craig Kendall confirms the road has been "decommissioned" by removing culverts and installing 75 water bars along the road surface, noting that "sediment delivery is expected to be reduced from an annual average of 558 lbs to 8.5 lbs in locations where ditch lengths are reduced from 500 feet to 50 feet . . . due primarily to shortening of ditch lengths by constructing water bars." (Final Report: Coal Creek Restoration Project. DEQ Contract No. 205042. Flathead Basin Commission. 7/30/08).

Google Earth KML road files and INFRA data provided by the FNF, however, show Road 1604 has been retained in the road system as a "stored" Maintenance Level 1 road not included in calculations of TMRD, rather than removed from the system as "decommissioned." This is important because it signals an intent on the part of the FNF to rebuild the road in the future, which would remove the water bars and largely negate the reductions in sediment delivery to Coal Creek intended to meet the Coal Creek TMDL, a plan intended to help remove Coal Creek from the list of streams "impaired" by sediment. Coal Creek is also suffering low bull trout spawning success.

Google Earth KML road files provided by the FNF indicate 110 road segments are considered "impassable" and <u>are not included</u> in calculations of TMRD. Another 174 road segments are considered "impassable" and <u>are included</u> in calculations of TMRD. Roads in either category of "impassable road" may exist in grizzly bear Security Core. All "impassable" roads are retained in the "system" as Maintenance Level 1 "stored" roads.

54. See Note 47. The FAQ responses include the following: "The 'Travel Management' analysis effort that is currently under way will help the Forest Service identify how to best 'right-size' our vast road network . . . The Forest Service recognizes that a significant number of roads need to be removed to bring the road system down to a manageable, maintainable system that still meets the needs of the agency and forest users."

55. The FNF led an effort by the Interagency Grizzly Bear Committee NCDE Subcommittee to replace A19's road reclamation, permanent road barriers and Security Core habitat with an approach dependent instead on road gates and Seasonally Secure Areas that fluctuate as gates are swung open and shut. This "Proposed Approach" was submitted for peer review and the reviewers found the "simplicity of A19 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 . . . The proposed approach's added complexity unfortunately necessitated several additional assumptions, some of which are tenuous . . . we caution against any relaxation of establishing permanently secure areas . . ." Dr. Bruce McLellan, Dr. M. A. Sanjayan and Dr. Nova Silvy. 2000. Peer review of the motorized access management strategies for grizzly bear habitat in the Northern Continental Divide Ecosystem. 9/19/2000.

Moreover, and as detailed on page 3 and in Appedix A to this report, FNF's fisheries biologists insured that A19 road closures and reclamation to benefit grizzly bears would also protect water quality and fish by requiring all stream-aligned culverts be removed from reclaimed roads and all culverts in closed roads be either removed or inspected regularly. Indeed, page 12 of the A19 Decision Notice summarizes its multiple-resource benefits as follows: "Motorized access restrictions and road reclamation will provide other benefits in addition to increased habitat security for grizzly bears. Decreased motorized access density will improve the habitat effectiveness for numerous species of wildlife, including wolves, fisher, lynx, elk, wolverine, and marten. Motorized access restrictions will change hunting opportunities from roaded to unroaded in some portions of the Forest. This is expected to increase the proportion of older bulls and bucks in elk and deer populations. Road reclamation, while likely causing some short-term increases in sediment, will in the long-term improve water quality and fish habitat by reducing fine sediment and stream channel erosion." (See Note 2).

56. The replacement of failed culverts in westslope cutthroat trout habitat and subsequent requirements that they then be monitored annually is not without precedent on the FNF. A Decision Memo for several Emery Creek Culvert Replacements, for example, notes Emery Creek "has one of the highest densities of [westslope cutthroat] trout tributary to Hungry Horse Reservoir." It also documents the failure of a 4' dia. culvert "during the 2014 spring runoff," as pictured in this report, in the lower right of Note 24. (Emery Creek Culvert Replacements Decision Memo. Robert Davies. 8/25/14).

Montana Dept. of Fish, Wildlife and Parks issued Stream Protection Act "124" Permits for these culvert replacements on several Emery Creek tributaries, requiring that the new culverts be inspected annually, post-runoff and/or during runoff "to insure that the new pipe arch is effectively moving water and debris and that any new failures are avoided." (Leo Rosenthal. MDFWP Stream Protection Act 124 Permits dated 9/22/14 for Remington Creek, 9/22/14 for Royal Creek, and 10/9/14 for Emery Creek).

57. Culvert inspection reports currently occupy some 45 file cabinet drawers on the FNF. A similar or larger number of file drawers contain information on bridges, road engineering and road work contracts. (Personal communication with Michele Dragoo and Rob Carlin, 8/6/15). Only in rare instances was culvert inspection information included in the INFRA data provided us by the FNF. Moreover, we were told that INFRA would not indicate the date of the last culvert inspection (see Note 25).

It is important that stream-crossing structures be fully inventoried and their inspection and repair tracked in a searchable database. This would help, among other things, to identify culverts like those that repeatedly failed in Pinnacle Ridge Road 1673 due to significant bedload movement and undersized culverts (see page 4 of this report). Pinnacle Ridge Road 1673 is a seasonally open road, so its not like these culverts never get driven by or can't be inspected from the comfort and convenience of a motor vehicle. Indeed, the focus on monitoring culverts on closed roads per A19 and the bull trout BiOps for road-related activities is intended to address the issue of more difficult inspection and less likely discovery of plugged culverts. This should not be construed to indicate that stream-crossing structures on open roads don't plug and fail and hence need not be inspected annually.

58. See note 57.

59. See page 11 of this report and Note 48.

60. See pages 9 and 10 of this report and Note 38.

61. FNF's Allen Rowley in 1998 told the Missouian newspaper that it is cheaper to reclaim a road than continually maintain it (see our Counting Culverts report via Note 8). In proposing road "storage" for 9 miles of road in a manner that would remove all stream-aligned culverts, Swan Lake Ranger District notes "Rather than investing in BMPs [Best Management road maintenance Practices] now, it is more cost-efficient to remove any potential impact it has to aquatic resources up front [and be] placed in a condition that does not require maintenance." (Request for public input: Chilly James Restoration Project. Richard Kehr. 2/14/14.)

62. See page 11 of this report.

63. Were it not for lawsuits filed by Swan View Coalition and others, the 1986 Flathead Forest Plan would have built 75 miles of road per year until its already abundant 4,000 miles of roads was increased to 6,000. Because the 1986 Plan did not have adequate road density standards and all five Ranger Districts reported they could not produce the Allowable [Timber] Sale Quantity [ASQ] without violating the Plan's grizzly bear standards, we went to court. The court told the agency to rework its Plan to provide adequate grizzly bear security and the FNF wrote A19. Besides the motorized access management discussed in the report, A19 also lowered FNF's ASQ from 100 MMBF/year to 54, although only 10MMBF of that reduction was due to grizzly bear standards and the rest was due to improved planning for the protection of old growth forests, elk winter range, whitetail deer winter range, etc. (See Note 2). A more detailed accounting of these lawsuits is provided in our Counting Culverts report accessible via Note 8 of this report.

A19 was precedent-setting. A19's form of managing motorized access was applied to the other National Forests in the NCDE, though it is unfortunate the culvert removal and monitoring requirements were not. Because of those culvert removal requirements, the FNF has demonstrated and been able to claim progress in making things better for threatened bull trout. The FNF has consequently reclaimed/decommissioned 763 miles of road and has only built 13 miles of road in roadless areas since 1986. Especially when considered within the context of broader agency initiatives like the Roadless Rule and Travel Planning Rule, A19 has made it easier for the FNF to adjust to initiatives aimed at minimizing roads and their environmental effects. How much of this progress would have been made without litigation?

More recently, Swan View Coalition and others filed a lawsuit against the Glacier Loon Fuels Reduction and Forest Health Project. In it they also challenged the continued logging of now-federal former Plum Creek lands by The Nature Conservancy for Plum Creek without the full application of A19, federal law and ESA consultation requirements. When the Court said Plum Creek and TNC must apply all federal law, they chose instead to cancel their "timber supply agreement." So the FS is no longer constrained from decommissioning former Plum Creek roads until the agreement would have expired in 2018 or until logging cleanup by TNC was completed as late as 2021. As a result, the Chilly James Restoration Project will begin decommissioning roads in the "impaired," Water Quality Limited Jim Creek in Summer 2016. (See *Swan View Coalition v Weber*, CV 13-129-M-DWM, Court Order dated 9/25/14. See also the Chilly James Decision Notice cited in Note 26).

Litigation could have been avoided. The FNF could have followed the plain language of A19 and the law and perhaps the SWCC would have rallied around it. But the FNF instead refused. Swan View Coalition and others were there in SWCC meetings and letters urging compliance, but it took a lawsuit instead. The bottom line is that old Plum Creek roads in a heavily damaged watershed can be decommissioned in Summer 2016 because a lawsuit helped clear that path. The Forest Service needs to acknowledge the essential constructive path, checks and balances provided by litigation rather than demonize those who work to enforce land management laws and help insure collaborative groups have access to accurate information.

Photo Credits

The photos used in this report are by Keith Hammer/Swan View Coalition unless otherwise noted in the text or caption.

Appendix A

Keith Hammer's white paper "Only decommissioned roads removed from the Forest Development Road System may be omitted from calculations of Total Motorized Route Density on the Flathead National Forest, dated 6/4/15 and updated by addendum 2/7/16, begins on the following page.

ATTACHMENT E

Swan View Coalition *Nature and Human Nature on the Same Path*

3165 Foothill Road, Kalispell, MT 59901 swanview.org & swanrange.org ph/fax 406-755-1379

Only Decommissioned Roads Removed from the Forest Development Road System May be Omitted from Calculations of Total Motorized Route Density On the Flathead National Forest

Keith Hammer
June 4, 2015

Updated by Including Addendum
February 7, 2016

Executive Summary

This paper is written in response to attempts by the Flathead National Forest and the Draft NCDE Grizzly Bear Conservation Strategy to omit from calculations of Total Motorized Route Density (TMRD) roads that may be impassable to motorized vehicles but have not been adequately decommissioned and removed from the Forest Development Road System (System).

The administrative record and the plain language of Flathead Forest Plan Amendment 19 (A19) show that a road must be reclaimed/obliterated/decommissioned (hereafter "Reclaimed") and removed from the System before it is no longer considered a road that must be included in calculations of TMRD.

TMRD standards require road reclamation and removal of the road from the System, while Security Core standards do not. Road reclamation is A19's preferred method of increasing Grizzly Bear Security Core because it simultaneously protects water quality and fish through required culvert removals and other hydrologic stabilization work. Reclamation of roads is not absolutely required in Security Core and roads restricted by berms, boulders or dense vegetation may suffice, provided "a monitoring plan to detect any erosion or culvert blockage problems" is implemented.

The A19 administrative record does not support the notion that a road can remain in the System as a road and yet not be counted as a road in calculations of TMRD. As long as the road remains in the System, even if placed in Intermittent Stored Service (ISS) or any other "storage" or "impassable" category, it is considered a road and must be included in the calculation of total road miles and TMRD.

Current and past attempts to exclude System roads from calculations of TMRD appear to arise from interpretations like those guided by the ill-fated and short-lived Implementation Note #13 in 1999 - which ran counter to the A19 administrative record.

Rather, implementation must be guided by the plain language of Amendment 19, as clarified by its Appendix D definitions and the administrative record discussed below.

Amended EA for Amendment 19

The essential question of whether open and restricted roads need to be reclaimed and removed from the System in order to meet TMRD and other A19 standards was resolved, according to the Flathead National Forest, in the Amended A19 Environmental Assessment and its Appendix D. This Appendix was also issued as Appendix D to A19 and as Flathead Forest Plan Unbound Appendix TT. In the Amended EA's Response to Public Comments, the Flathead responds:

> Total motorized access density objectives must be met after including open and restricted motorized roads and trails, except for those that have been reclaimed . . . In response to comments that the definitions of restricted and reclaimed roads and core areas did not adequately express our intent, additional text . . . has been included as Appendix D [and] would be incorporated into the Forest Plan as Unbound Appendix TT.

(Forest Plan Amendment 19 Amended Environmental Assessment. February 1995. Page 107.) The Amended EA continues in its Response to Public Comments:

> Comment(s): The preferred alternative should make clear that meeting the Total Motorized Access Density (TMAD) objective will require reclaiming open and restricted roads.
>
> Response: Chapter III of the EA describes the miles of road reclamation and road restrictions estimated to result from implementation of each alternative. In addition, Appendix D has been added to the EA. This Appendix defines in detail "reclaimed road" and "restricted road."

(Forest Plan Amendment 19 Amended Environmental Assessment. February 1995. Page 133.) Indeed Chapter III of the Amended EA, in describing the chosen Alternative 3C, concludes:

> To meet the standards and short-term objectives in MS-1 and MS-2 areas, approximately 350 miles of open roads and 125 miles of currently restricted roads would need to be reclaimed in the short term (5 years). To meet long term (10 years) standards and objectives, another 175 miles of already-restricted roads would need to be reclaimed.

(Forest Plan Amendment 19 Amended Environmental Assessment. February 1995. Page 95.)

Also, apparently in response to public comments including ours, the Amended A19 EA reworked Figures 22 and 23 to reflect the reclamation of Chapter III's estimated 475 miles of road and their removal from the road System to meet the 5-year A19 standards. Figure 23 shows no category for "stored" or "impassable" System roads that would not be counted in calculating TMRD. Reclaimed roads are accounted for in the reduction of total road miles in the System.

In other words, if it remains a System road, it gets counted as a road. That this common sense understanding predated A19 is confirmed by Figure 22's notation of 420 miles of roads that were in 1990 "obliterated and removed from the forest inventory."

Amendment 19 and Interagency Grizzly Bear Committee Definitions

The A19 process and the Interagency Grizzly Bear Committee (IGBC) process on which it is based include the same three classifications of roads: Open, Restricted, and Reclaimed. Neither includes a category for "stored" or "impassable" roads that remain on the System yet would not be counted as roads in calculations of TMRD.

In part the definitions of Restricted and Reclaimed roads are as follows, first from A19:

> RESTRICTED ROAD . . .
>
> A road on which motorized vehicle use is restricted during the entire non-denning period. The road requires physical obstruction and motorized vehicle use in the non-denning period is legally restricted by order . . .
>
> Outside of security core areas, motorized administrative use is acceptable at low intensity levels . . .
>
> All restricted roads will be included in calculating total motorized access route density . . .
>
> RECLAIMED ROAD . . .
>
> A reclaimed road has been treated in such a manner so as to no longer function as a road or trail and has a legal closure order until reclamation is effective. This can be accomplished through one or a combination of treatments including: recontouring to original slope, placement of natural debris, or revegetation with shrubs or trees . . .
>
> Administrative use of reclaimed roads may not occur . . .
>
> The entire road will receive treatment such that maintenance or entries to maintain "road drainage" is not needed. This will require removal of culverts or other water passage structures that are aligned with stream channels. In most cases this will also require that road related sediment sources be repaired and the road reworked to eliminate ditch water flow without the aid of cross drain culverts . . .
>
> Reclaimed roads that fully satisfy the definition of a reclaimed road will not be included in calculations of open road density, total motorized access density, or

> security core area. Roads that have been treated, but that do not yet fully satisfy the definition of a reclaimed road will be included in calculations for total motorized access route density . . .
>
> The acceptable lag time for the treatment to become effective and the expected persistence of people to continue to use a road should dictate the amount and type of initial, and perhaps follow-up, treatment required . . .

(Flathead Forest Plan Appendix TT; a.k.a. Appendix D to Amendment 19.)

Now, according to the IGBC:

> Reclaimed/Obliterated Road -- a route which is managed with the long term intent for no motorized use, and has been treated in such a manner so as to no longer function as a road. An effective means to accomplish this is through one or a combination of several means including: recontouring to original slope, placement of logging, or forest debris, planting of shrubs or trees, etc. . .
>
> Total Motorized Route Density calculations will include open roads, restricted roads, roads not meeting all restricted or obliterated criteria, and all motorized trails.

(Interagency Grizzly Bear Committee Task Force Report: Grizzly Bear/Motorized Access Management; Interagency Grizzly Bear Committee; July 29, 1998; emphasis added.)

Protocol Papers for Amendment 19 and the IGBC Task Force Report

Protocol Papers prepared for both A19 and the IGBC Task Force over the years consistently document the use of only the initial three classifications of roads: Open, Restricted, and Reclaimed. None include a category for roads to remain in the System yet not be counted in calculations of TMRD:

> . . . each road was classified as open, restricted, or reclaimed.

(Kathy Ake and Nancy Warren. 9/1/94 updated 2/17/95.) In 2001, the Protocol Paper provides a bit more specific definition of road, as follows, but repeats the three allowed classifications of roads:

> Definitions are based upon the IGBC Motorized Access Management report with verbal clarification from individual committee members (see Amendment 19 project file) . . .
>
> ROAD . . . All created or evolved routes that are >500 feet long (minimum inventory standard for the Forest Service INFRA data base), which are or were reasonably and prudently drivable with a conventional passenger car or pickup. Within the three classes below . . . OPEN ROAD . . . RESTRICTED ROAD . . . RECLAIMED/OBLITERATED ROAD.

(Protocol paper. Kathy Ake; 11/20/01; emphasis added).

Even the 2013 draft Protocol Paper Kathy Ake prepared as Appendix 5 to the Draft NCDE Grizzly Bear Conservation Strategy starts off on the right foot by clarifying that:

> Sometimes referred to as a reclaimed or obliterated road, a historical road has been treated in such a manner so as to no longer function as a road or trail, and the road is no longer considered part of the agency's road system.

When the 2013 Protocol Paper begins discussing the Draft Grizzly Bear Conservation Strategy, however, it introduces a new and fourth classification of roads as "Closed Yearlong Impassable" (hereafter "Impassable"):

> Similar to historical roads, roads that are naturally revegetated, have the entrance obliterated for >0.1 miles, or have the bridge or large >4ft culvert removed are also not included in the analyses, i.e. they do not count in OMRD or TMRD, nor are they buffered in the Secure Core analysis. These roads are impassable by any vehicle (passenger car, truck, 4WD vehicle, ATV, motorcycle, etcetera). These roads are still on the system. Revegetated roads defined as so grown-in that they are no longer drivable. The vegetation is such that it is easier to walk on the side-hill as opposed to down the center of the road bed.

(Protocol Paper for Motorized Access Analyses Application Rule. Draft NCDE Grizzly Bear Conservation Strategy Appendix 5. Kathy Ake. February 2013.)

This new, fourth classification of roads is introduced to the public for the first time in the 2013 draft Grizzly Bear Conservation Strategy while simultaneously stating it "Has been incorporated this way since IGBC motorized access or Flathead NF's A19 started." This interpretation is not supported by the administrative record.

In an 8/18/94 letter to the A19 Interdisciplinary Team Leader, Flathead Forest Wildlife Biologist Nancy Warren documented her clarification on this very issue with members of the IGBC Motorized Access Task Force:

> Is it correct to classify all bermed, barricaded, tank-trapped, or overgrown (to just a path) roads as restricted roads, even though they may not be "reasonably and prudently driveable with a conventional passenger or pickup", even though use by all-terrain vehicles may not be restricted?
>
> Tom Puchlerz [IGBC Task Force Chair] indicated that the intent was to classify as "restricted" roads that could easily be re-opened by removing a barricade or tank trap. If the road was so overgrown or rough that reconstruction would be needed [and] if there were no access, then it would be <u>classified as reclaimed/obliterated</u>. Tom Wittinger and Chris Servheen agreed with this interpretation.

(Nancy Warren to Jim Morrison; letter dated 8/18/94; emphasis added).

The IGBC Task Force did not suggest a new, fourth classification of road. Nancy Warren instead reports that, if the road is so overgrown and rough as to require reconstruction to become passable again, it should be classified as Reclaimed. The Flathead's A19, however, requires among other things that all stream-bearing culverts be removed from that road and that it be removed from the System in order to be fully Reclaimed.

Moreover, as detailed above and summarized below, the A19 administrative record does not support use of a fourth classification of Impassable road. In response to public comment, the Amended A19 EA estimates the miles of open road that will need to be closed to motor vehicles and the miles of open and already restricted roads that will need to be reclaimed to meet A19 standards. Nowhere does it mention that roads can be simply rendered "impassable" and retained as part of the System while not being counted in calculations of TMRD.

Nor do any of the Protocol Papers prior to 2013 highlight that "impassable" roads can simply be omitted from calculations of TMRD. Nor does either the 1994 or 1998 IGBC Task Force Report say or allow this. Indeed, they make it clear that a road must meet all of the criteria for a Reclaimed road to not be counted in calculations of TMRD. Simply put, under A19, an Impassable road that remains on the road System is a Restricted road and must be counted in calculations of TMRD until it has all of its stream-bearing culverts and bridges removed, fully meets all other Reclaimed road criteria, and is removed from the System.

Road Treatments Required by the Amendment 19 Fisheries Biological Evaluation

A19 reluctantly allows stream-bearing culverts and bridges to remain behind berms, concrete and boulder barriers on Restricted roads in Security Core, provided "a monitoring plan to detect any erosion or culvert blockage problems" is implemented. However, A19 expressly requires that all those stream crossing structures be removed from Reclaimed roads that will no longer be included in calculations of TMRD. This is due in large part to the Fisheries Biological Evaluation for A19:

> Implementation of the preferred alternative would result in the following: . . .
>
> Direction for reclaiming/obliterating roads including removal of culverts which greatly reduces the risk of future sedimentation problems resulting from culvert failure on reclaimed roads.
>
> Direction for restricted roads in core habitat areas to implement road drainage treatments similar to reclaimed roads, or to develop and implement a monitoring plan to detect any erosion or culvert blockage problems . . .
>
> The determination [of effects on fish] assumes incorporation of the proposed definitions and minimum treatment requirements for reclaimed and restricted roads.

(Biological Evaluation for Bull Trout, Cutthroat Trout, and Shorthead Sculpin: Potential Effects from Implementing Amendment 19, Alternative 3 to the Forest Plan. Donald E. Hair. 2/4/95.)

The Fisheries Biological Evaluation, like all the other A19 and IGBC documents, contends with the effects of Open roads, Restricted roads, and Reclaimed roads. It does not mention a fourth classification of Impassable roads, let alone say that they are considered separate from Restricted roads. Nor does it say Impassable roads can be excluded from calculations of TMRD while leaving stream-bearing culverts to blow out behind an obliterated entrance, the first already blown-out or otherwise removed >4ft culvert, or in a roadbed grown thick with vegetation but still harboring stream-bearing culverts.

Indeed, this fourth classification of Impassable roads appears to have all the trappings of an under-the-radar, end-run around the clear language and requirements of A19. We don't doubt the Flathead has done this. We simply disagree that this is allowed by A19 - for all the reasons provided above.

Implementation Note #13

On May 6, 1999 the Flathead issued Implementation Note #13 under the guise of clarifying A19's Appendix D definitions. It in fact contradicted them, in part by allowing stream-bearing culverts to remain in Reclaimed roads in violation of the conditions of the Fisheries Biological Assessment and the plain language of A19.

Swan View Coalition and Friends of the Wild Swan on September 23, 1999 filed a 60-day notice of intent to file suit under the Endangered Species Act and the Forest Supervisor rescinded Implementation Note #13 on November 19, 1999. Flathead Forest spokesman Allen Rowley was quoted in the November 24, 1999 Missoulian: "We talked it over with our attorneys and we decided they (conservation groups) were right."

So here we are in 2014 with the Flathead claiming it can simply render or find a road impassable, keep it on its road System, not remove all stream-bearing culverts, and yet not count it in calculations of TMRD either. (Personal communication with Kathy Ake 10/15/14 and Kathy Ake's Appendix 5 to the draft Grizzly Bear Conservation Strategy.) Indeed, connected Roads #10753 and #10754 in the Flathead's Canyon Creek drainage have seven washed out culverts, have never been adequately repaired or reclaimed, and yet are not included in the Flathead's calculation of TMRD. (Terms and Conditions Monitoring Report: Bull Trout Biological Opinions for Post-fire Salvage Operations, Flathead National Forest, 2007-2009; Craig Kendall; October 28, 2009; Appendix A Summary of Road and Culvert Surveys - checked against "Impassable" road data files provided by Kathy Ake 1/27/15). A19 certainly did not intend for the Flathead to allow culverts to blow out and to then take credit for the reduction in TMRD as though the blown-out roads had been properly reclaimed!

Leaving culverts to potentially blow out in roads not counted in TMRD would have been allowed by Implementation Note #13. It appears the Flathead formally rescinded Note #13, then went ahead and implemented portions of its intent anyway - in clear violation of the plain language of A19 and in spite of assurances by the Forest Supervisor that the plain language of Flathead Forest Plan Appendix TT/A19 Appendix D would be implemented:

> . . . I have reviewed the language of LRMP Implementation Note #13 and the existing Forest Plan Appendix TT and have determined to rescind Implementation Note #13 to avoid any confusion or misunderstanding with the implementation of Appendix TT . . . The definitions and direction contained in Appendix TT will be used by the Flathead National Forest unless and until the Forest Plan is subsequently amended or revised and any consultation obligations are satisfied with the U.S. Fish and Wildlife Service.

(Letter of Supervisor Cathy Barbouletos to attorney Dan Rohlf. 11/19/99.)

No such amendments or revisions have taken place and Appendix TT/D remains the law of A19. A19's requirements to protect fish are not at odds with its requirements to protect grizzly bear. A19's requirements to remove stream-bearing culverts from Reclaimed roads and to regularly inspect and clean culverts on Restricted roads are indeed common sense measures required by Fish and Wildlife Service in numerous biological opinions regarding bull trout. Rather than graciously comply with the multiple-species requirements of A19, it appears the Flathead has instead employed a shrouded classification of Impassable road to reportedly benefit bears while ducking corresponding requirements to protect water quality, bull trout and other aquatic life.

The Flathead's Road Decommissioning Spreadsheet

The Flathead's Road Decommissioning Spreadsheet lists "Road Decommissioning Projects" since A19 was first issued in 1995. It tracks five categories of Reclaimed roads:

Category 1 - System roads reclaimed and moved to Historic but still monitor for A19

Category 2 - System roads reclaimed and moved to Historic = revegetated - no monitoring

Category 3 - Roads reclaimed and left as System roads, still monitor for A19

Category 4 - Moved to Historic, naturally revegetated, no contract work needed, no monitoring

The fifth category is "Only Has Decision," meaning reclamation plans have yet to be implemented on those miles of road.

This spreadsheet shows clearly that the goal is to remove Reclaimed Roads from the System as the reclamation treatments become effective. Interestingly, all roads from Category 3 were shifted to other categories in 1999, the same year as the short-lived Implementation Note #13, and it has remained at zero road miles ever since.

A19 allows only three classifications of roads. Open and Restricted roads must be included in calculations of TMRD and only Reclaimed roads are excused from those calculations. Like all the other documents in the A19 administrative record, the spreadsheet does not contain a classification or category for Impassable roads excused from calculations of TMRD while remaining on the System.

According to A19 and Appendix TT/D, the only roads excused from calculations of TMRD should be included in this spreadsheet of Reclaimed roads. But they aren't all included because a shrouded classification of Impassable roads exists, though contrary to A19. (Personal communication with Kathy Ake 10/15/14; Kathy Ake's Appendix 5 to the draft Grizzly Bear Conservation Strategy; and "Impassable" road data files provided by Kathy Ake 1/27/15.)

Conclusion

At every turn, A19 NEPA documents and the Flathead National Forest have pointed to Forest Plan Appendix TT/A19 Appendix D as the guiding light and requirements of A19. Appendix TT/D provides for only three classifications of roads: Open, Restricted, and Reclaimed. It provides no classification for Impassable roads. Under A19, if a road is rendered impassable by either an act of nature or by human intervention, it remains an Open or Restricted road until it meets all criteria for a Reclaimed road and is removed from the road System.

This interpretation describes the publicly observable practice of implementing A19. This interpretation has been the Forest Service's direct response to public comments raising these very questions since 1995. This interpretation is consistent with the Forest Service itself asking these very questions of the IGBC Motorized Access Task Force. This is also the only interpretation of Appendix TT/D supported by the A19 administrative record.

The public discovery of the Flathead's shrouded category of Impassable roads that need not be included in calculations of TMRD came about only due to its disclosure in Appendix 5 of the 2013 Draft NCDE Grizzly Bear Conservation Strategy. Even then, its disclosure is largely obscured by footnotes attempting to detail the differences in motorized access management between the Flathead and the four other Forests in the NCDE - partly because the other Forests apparently do not require all stream-bearing culverts and bridges to be removed from Reclaimed roads.

Simply put, and for the reasons provided above, the Flathead must consider its Impassable roads to be Restricted or Open roads, include them in calculations of TMRD, and set about either repairing or reclaiming these roads to adequately protect water quality, fisheries and wildlife. It violates A19 and a wide variety of conservation laws for the Flathead to retain what at this juncture appears to be a "junk pile" of unattended old roads. It adds insult to injury to suggest that these roads are environmentally benign by implying they have been managed according to A19's standards for protecting water quality, fish and wildlife.

Addendum Added February 7, 2016

"Storing" Roads is Not the Functional Equivalent of "Decommissioning"

The preceding portions of this paper remain unchanged. The preceding explains why "impassable" roads can't be omitted from Total Motorized Route Density (TMRD) under Forest Plan Amendment 19 (A19). This addendum explains why neither "impassable" nor "stored" roads are the functional equivalent of decommissioned roads. The Flathead is proposing to reconstruct previously decommissioned "non-system" road templates for logging, then place them back into the road "system" under "Intermittent Stored Service" (ISS) - as though ISS is the functional equivalent of "decommissioning."

ISS is not the functional equivalent of decommissioning. Nor did the A19 Amended EA assess the effects of road reclamation/decommissioning as though roads removed from the road system would periodically be rebuilt, requiring culverts to be reinstalled and vegetation to be removed from the roadbed each time they are brought back into service under ISS.

The Flathead's Trail Creek Fire Salvage Project proposal, for example, proposes to "construct approximately seven miles of new system roads on existing templates to access proposed harvest units and then place these seven miles, plus approximately an additional mile of road, into storage and classify the roads as intermittent stored service (ISS) roads following salvage harvest operations . . . to facilitate harvest activities and long-term resource management." (Trail Creek Fire Salvage Project proposal released for public review by Spotted Bear District Ranger Debbie Mucklow via cover letter dated 1/26/16).

These roads would largely be rebuilt on "historic" road templates decommissioned and removed from the road system as recently as 2000 and 2004. (Personal communication with Matt Shaffer, FNF, and FNF's 3/23/15 Road Decommissioning Projects spreadsheet). "Upon completion of the project, the first portion of the road would be recontoured to the original hillslope . . . Beyond the first portion of the road (200 - 600 feet) the roadway would be treated to discourage use including sporadic placement of natural debris where available and seeding or planting to encourage re-vegetation." (Trail Creek Fire Salvage Project proposal released for public review by Spotted Bear District Ranger Debbie Mucklow via cover letter dated 1/26/16).

While the Trail Creek proposal says that the new road design would "favor rolling dips over culvert installation," it does not say culverts will not be installed where necessary and it does not say that they would be removed post-project if they are installed. The proposal does make it clear that the road template would be brushed out and the road surface bladed to allow for log hauling.

The proposal does acknowledge it would need site-specific amendments to A19 to allow for summertime heavy equipment work on these road templates, which is not allowed in Security Core during the non-denning period for grizzly bears. The proposal would then simply have the public and other agencies believe that post-project ISS is the functional equivalent of decommissioning and complies with A19.

As described on pages 3 and 4 of this paper, A19 requires that a reclaimed/ decommissioned road be "treated in such a manner so as to no longer function as a road or trail" and the IGBC further emphasizes "the long term intent for no motorized use." To the contrary, ISS designation has the long-term intent of intermittent motorized use of the road and retains it in the road system. This is not the functional equivalent of a decommissioned road that is removed from the system precisely because the long term intent is to eliminate motorize use and render the road environmentally benign in the watershed. This is clearly evident in Amended EA's assessment of the effects of A19 road decommissioning, particularly on pages 65-67:

> Road reclamation can decrease rates of surface erosion by up to 95 percent . . . With road reclamation, culverts will be removed at stream crossings . . . The potential increase in sediment due to culvert removals and other ground disturbance will be balanced by an immediate decrease in peak flows and subsequent stream channel erosion due to dispersing runoff concentrated by the roads . . . Soil compaction on the reclaimed roads will gradually decrease as the roads revegetate with woody shrubs and conifer. After 50 - 100 years, these areas will have increased infiltration and productivity rates similar to undisturbed sites. Water quality and fisheries will improve from the road reclamation activities . . . culvert removal will reduce the risk of culvert failures . . . [and the A19 EA alternative proposing the fewest open roads and the greatest amount of Security Core] would improve watershed conditions more than all other alternatives.

What the A19 Amended EA did not do was assess decommissioned roads as if they were to be ISS roads intermittently used for logging access. While A19 requires that Security Core remain in place and effective for at least 10 years, it did not contemplate nor assess the effects of roads being decommissioned, rebuilt, then decommissioned again on a repeating basis of every 10 years or so, or simply at the whim of the Forest Service. Such a repetitive process clearly has significant negative impacts to vegetation, soils and water quality not contemplated nor assessed in A19. In Trail Creek and other projects, the Flathead is ignoring and shortchanging the benefits to soils, water quality and fish that were fully integrated into A19 grizzly bear security standards.

ISS and Road "Storage"

The Flathead's Travel Analysis Process, as documented in the June 2014 Beaver Creek Analysis and elsewhere, defines ISS as "Closed to traffic. The road is in a condition that THERE IS LITTLE RESOURCE RISK IF maintenance IS NOT PERFORMED (self-maintaining). (FSH 5409.17-94-2)." (Emphasis in original). FSH 5409.17-94-2 in turn defines "Road Storage [as] The process/action of closing a road to vehicle traffic and placing it in a condition that requires minimum maintenance to protect the facility for future use."

This is little more than Maintenance Level 1 “storage,” which is defined in the Flathead’s 2014 Forest-Wide Travel Analysis Report as follows:

> These roads have been placed in storage between intermittent uses. The period of storage must exceed 1 year. Basic custodial maintenance is performed to prevent damage to adjacent resources and to perpetuate the road for future resource management needs. Emphasis is normally given to maintaining drainage facilities and runoff patterns. Planned road deterioration may occur at this level.

A19 road decommissioning requires that “drainage facilities” like stream-aligned culverts be removed, not maintained. A19 decommissioning also requires that “runoff patterns” be “reworked to eliminate ditch water flow without the aid of cross drain culverts,” not to maintain runoff patters through culverts. (A19, Appendix D). Hence, again, ISS and other “stored” roads are not the functional equivalent of an A19 decommissioned road. Properly decommissioned roads, unlike those repeatedly reused, should pose no risk to a watershed, require no maintenance, and are allowed to re-vegetate. That re-vegetation not only deters human use of the old travel-way, it also over time de-compacts any road surface that was not mechanically de-compacted at the time of decommissioning.

The Problems with “Storage” and “Impassable” Exemplified

So, what could possibly go wrong in the Flathead’s pursuit of replacing road decommissioning with road “storage” and/or classifying roads “impassable?” In addition to misrepresentations made to the public and other agencies like Fish and Wildlife Service (FWS), plenty. Take Raghorn Road #10802 in the Coal Creek watershed as an example:

According to the Flathead’s 3/23/15 Road Decommissioning Projects spreadsheet, the Flathead decided to reclaim Road #10802 on 9/25/92 as a part of the North Coal Salvage Timber Sale. The Biological Assessment for this timber sale was supplemented on 4/15/94 and FWS concurred with its findings on 5/5/94, citing the same grizzly bear research and findings soon to be incorporated into A19 in 1995.

Given the importance of Coal Creek to bull trout and westslope cutthroat trout, the Flathead revisited the pre-A19 decisions for Road #10802 and two others in the watershed. The subsequent 7/27/10 decision by District Ranger Jimmy DeHerrera for these roads decided to remove all 15 culverts from the three roads, 13 of them on Road #10802, including all cross-drain culverts:

> These actions are being proposed to protect important bull trout spawning areas. If these culverts fail during a storm event, unnecessary sediment would be transported downstream jeopardizing spawning and rearing habitat for fish and impacting water quality. A TMDL [Total Maximum Daily Load plan for an “impaired water body”] was also completed for Coal Creek in 2005 and road waterproofing was identified to alleviate sediment conditions in Coal Creek.”

On 6/21/2010, FWS concurred with the decision to remove all the culverts. Coal Creek was soon after designated Bull Trout Critical Habitat, adding additional Endangered Species Act prohibitions to damaging threatened bull trout habitat. In 2012, however, the Flathead considered the road "waterproofed" after removing only 3 culverts less than half way up the 3.69-mile-long Road #10802, leaving other culverts in place! (Waterproofing Rd. 10802 map and notes by Pat VanEimeran and John Littlefield, November 2012).

Several of the remaining culverts beyond those removed are stream-aligned and at least two of them were flowing water when I inspected them on 8/20/15! VanEimeran and Littlefield's November 2012 notes cited above also document water flowing across and under the road at these locations!

The Flathead's INFRA database and KML (Google Earth Keyhole Markup Language) road files provide by Kathy Ake in 2015 nonetheless classify the entire road as a Maintenance Level 1 "system" road that is "impassable" and hence not included in A19 calculations of TMRD. This even though the road is not impassable according to the "impassable" criteria Ake listed in the Draft Grizzly Bear Conservation Strategy (see page 5 of this paper): 1) the first portion is not naturally re-vegetated to the degree it hinders motorized or foot travel - in fact the brush was cut back, apparently to provide passage for the culvert-removal machinery in 2012, 2) the entrance to the road has not been obliterated, and 3) the three culverts removed were 36" diameter culverts that don't meet the minimum 4' culvert removal criteria to qualify as an impassable barrier.

When compared to Ake's Conservation Strategy criteria, Road #10802 is not an "impassable" road but a bermed road. Under A19 this bermed road can be and is largely located in Security Core habitat. Though decommissioning the road is preferred under A19, a berm closure of restricted road in Security Core is allowed - **provided** the Forest develops and implements "a monitoring plan to detect any erosion or culvert blockage problems" on each such road. (Biological Evaluation for Bull Trout, Cutthroat Trout, and Shorthead Sculpin: Potential Effects from Implementing Amendment 19, Alternative 3 to the Forest Plan. Donald E. Hair. 2/4/95.)

Hair's culvert monitoring requirement, above, is also repeated in A19's Appendix D definition of a restricted road. In spite of this, the Flathead has not developed a single culvert-monitoring plan for any of the many score of bermed roads in Security Core, let alone for Raghorn Road #10802! (Chip Weber's 9/22/15 response to Swan View Coaltion's 8/7/15 FOIA request).

Whether a bermed road or an "impassable" road, as made clear in this paper, Road #10802 must nonetheless be included in calculations of TMRD. And this brings us back to the plain language interpretation of A19: a road must have all stream-aligned culverts removed, all cross-drain culverts removed or rendered non-essential and harmless, and be removed from the road "system" before it is no longer a road counted in TMRD. Moreover, Road #10802 should have all of its culverts removed because the Flathead promised the public and FWS that it would do so in National Environmental Policy Act and ESA consultation documents!

Raghorn Road #10802 is but one example of what goes wrong when the Flathead fails to follow the plain language of its own Forest Plan and road decommissioning decisions. Instead of a decommissioned road that no longer functions as a road or trail, Road #10802 can be easily walked or ridden on a mountain bike or driven for at least the first mile by violating the berm closure in/on a motorized vehicle. Bears and other wildlife are left with easier human access into their habitat than promised and bull trout are left with culverts that remain ticking time bombs instead of having been removed as promised. FWS has concluded:

> Culverts left in place behind gated and bermed roads . . . pose a risk to bull trout . . . Whatever the design life, any crossing structure would have a 100% chance of failure over its installation life if it is not removed after the road is abandoned.

(FWS's Montana Field Office, Biological Opinion on the Effects of the Moose Post-Fire Project on Bull Trout, 11/14/2002).

Conclusion

The public is left with little reason to trust the Flathead as it repeatedly attempts to end run A19's fiscally responsible program to restore grizzly bear habitat security in a way that provides the same benefits to other wildlife and fish. If the Flathead wants to change A19, it needs to issue a major Forest Plan amendment with full public disclosure and involvement. It cannot lawfully or ethically change A19 by simply claiming that "impassable" and ISS "system" roads are not really roads, are equivalent to decommissioned roads removed from the "system," and need not be included in TMRD.

Pre Meeting Notes: By Dan Brewer. For the meeting with Steve Phillips of the Flathead National Forest (Seeley Lake Ranger District 11/30/06),

Background:

I have been reviewing the Biological Opinions (BO) issued to the FNF in recent years. This is a difficult task as several different biologist authored these documents (Kat Jay Kellie Leslie).

Since 2002 the FNF has been issued 8 BO's for Bull Trout (8 BOs in 4 years). Each BO contained several terms and conditions to minimize impacts to bull trout, in all the FNF has about 102 term and conditions for on-going projects concerning bull trout. Taken in sum this appears to be lot of terms and conditions, however 5 of the 8 BOs were post fire "fast track" consultations. These fast track BOs contain the majority of the T&Cs. This was the result of receiving information and changes to the proposed actions up until the week before the BO was issued in many cases. As a result these BOs tend to contain numerous information requests concerning the what's and how's of implementation, as numerous assumptions were made in the BO analysis about what would occur. This is the repercussion of developing a project based on worst case scenario.

Of the 6 BOs that involved timber harvest and road related actions 63 of the 87 T&Cs attempted to address road and road related issues (culvert removal, upgrades, BMP work of monitoring these activities). That's 72% of the T&C were related to roads.

During the time frame of these 8 consultations 2 larger consultations were occurring A19 and A24. These consultations had the potential to affect bull trout habitat as well. During the Moose Fire BMP/Post Fire consultation the issue of leaving culverts behind berms and gates for snowmobile's and other reasons first arose (10/01/02 email Leslie Kubin, meeting notes, etc.). At that time the Service was informed that A24 was in the process of handling the potential adverse effects to bull trout habitat that could occur outside the Moose project area. At the project level (Moose Post Salvage/BMP) Forest committed to monitor culverts behind gates and berms (September 19, 2002 letter from the Forest) and reduce the amount of fill over the culvert, up size the culverts and armor as necessary. This effort also included a monitoring program and risk assessment. The initial assumptions were that the number of culverts that failed was low, and therefore the amount of culverts at risk of failure was low, between 10 to 15 %. This was largely based on expert opinion. However the most recent culvert risk assessment data suggests that the % of culvert at high risk of failure is closer to 40%. Monitoring would minimize take.

In 2006 the Forest reported that the risk/potential for culvert failure was much higher than previously thought during the Moose Fire Consultation and closer to 40% this is far above the assumed 10-15 % used in the Moose Fires Consultation.

In considering this information the Service has concerns about the impacts of culvert management on bull trout across bull trout waters across the FNF. Culvert that are behind gates and berms typically do not receive “default maintenance” (the type of maintenance that occurs from everyday use) which would only minimize the impact of undersized pipes.

The Issues associated with leaving culverts behind berms was identified in the Moose Fires and Moose BMP projects and extends outside those project areas.

The recent weather events and subsequent culvert failures have highlighted the issue with roads and culverts. Not all natural events can be anticipated and even under the best road management conditions weather events can still lead to culvert and road failure.   Hence the argument for low road density area’s, to minimize impacts to the aquatic environment from both chronic and pulse events.

Ecological Applications, 25(4), 2015, pp. 1016–1033

The role of wood hardness in limiting nest site selection in avian cavity excavators

TERESA J. LORENZ,[1,4] KERRI T. VIERLING,[1] TIMOTHY R. JOHNSON,[2] AND PHILIP C. FISCHER[3]

[1]*Department of Fish and Wildlife Sciences, University of Idaho, P.O. Box 441136, Moscow, Idaho 83844 USA*
[2]*Department of Statistical Sciences, University of Idaho, Moscow, Idaho 83844 USA*
[3]*Retired Civil Engineer, 1405 Jesica Drive, Selah, Washington 98942 USA*

Abstract. Woodpeckers and other primary cavity excavators (PCEs) are important worldwide for excavating cavities in trees, and a large number of studies have examined their nesting preferences. However, quantitative measures of wood hardness have been omitted from most studies, and ecologists have focused on the effects of external tree- and habitat-level features on nesting. Moreover, information is lacking on the role of wood hardness in limiting nesting opportunities for this important guild. Here, we used an information theoretic approach to examine the role of wood hardness in multi-scale nest site selection and in limiting nesting opportunities for six species of North American PCEs. We found that interior wood hardness at nests ($n = 259$) differed from that at random sites, and all six species of PCE had nests with significantly softer interior wood than random trees ($F_{1,517} = 106.15$, $P < 0.0001$). Accordingly, interior wood hardness was the most influential factor in our models of nest site selection at both spatial scales that we examined: in the selection of trees within territories and in the selection of nest locations on trees. Moreover, regardless of hypothesized excavation abilities, all the species in our study appeared constrained by interior wood hardness, and only 4–14% of random sites were actually suitable for nesting. Our findings suggest that past studies that did not measure wood hardness counted many sites as available to PCEs when they were actually unsuitable, potentially biasing results. Moreover, by not accounting for nest site limitations in PCEs, managers may overestimate the amount of suitable habitat. We therefore urge ecologists to incorporate quantitative measures of wood hardness into PCE nest site selection studies, and to consider the limitations faced by avian cavity excavators in forest management decisions.

Key words: Black-backed Woodpecker; nest limitations; nest site selection; primary cavity excavator; resource selection; secondary cavity user; snag decay class; White-headed Woodpecker; wood hardness; wood mass density.

INTRODUCTION

Most woodpeckers (Piciformes: Picidae) are members of an important and influential guild called primary cavity excavators (PCEs). PCEs are ecosystem engineers that are unique among vertebrates because of their ability and propensity to excavate nest cavities in solid wood. They also differ from the majority of birds that construct nests with materials from the external environment surrounding nest sites because the nests of PCEs are entirely constructed by removing wood from a tree's interior. This makes the nest sites of PCEs relatively well protected against environmental variability and predators, and many vertebrates that cannot excavate wood themselves readily use and compete for old, vacant PCE nests (Martin et al. 2004, Aitken and Martin 2008, Gentry and Vierling 2008). This guild of animals, called secondary cavity users (SCUs), is large and diverse. In some regions, SCUs comprise up to one-third of all vertebrate species and include all major taxa (Bunnell et al. 1999). Because of this, many species of PCE are considered both ecosystem engineers and ecological keystones (Daily et al. 1993, Bednarz et al. 2004, Blanc and Walters 2008), and the presence of PCEs has well-documented and far-reaching effects on species richness and ecosystem health (Lindenmayer et al. 2000, Virkkala 2006, Drever et al. 2008).

Given their importance, a great deal of research has focused on PCE nesting ecology, especially nest site selection. Despite this attention, however, research studies have come to different conclusions about influential factors in nest site selection. These differences began more than 50 years ago, when some early studies suggested that PCEs select sites based on external tree- or habitat-level factors, such as tree size, tree species, and vegetation cover (e.g., Lawrence 1967). Others proposed that internal wood density drove PCE nest site selection (Conner et al. 1976, Miller and Miller 1980), and PCEs selected sites with "soft" or "decayed" wood (Kilham 1971, Conner et al. 1976, Miller and

Manuscript received 6 June 2014; revised 24 October 2014; accepted 5 November 2014. Corresponding Editor: J. M. Marzluff.

[4] E-mail: teresajlorenz@gmail.com

Miller 1980, Daily 1993) rather than trees with particular external features or characteristics. More recently, research studies have come to different conclusions even for the same species of PCE. For selection of nest trees within territories (third-order selection; Johnson 1980), Saab et al. (2009) reported that tree size and surrounding snag density were important for selection by Hairy Woodpeckers (*Picoides villosus*), while Schepps et al. (1999) concluded Hairy Woodpeckers select sites based on wood hardness.

Some of this dichotomy may stem from the fact that, while methods for measuring external tree- and habitat-level features have been available for decades, methods for quantifying wood density lagged behind. An economical and practical tool for estimating wood density inside PCE nest trees was not available until Matsuoka (2000) improved on Schepps et al.'s (1999) method for measuring wood hardness. In lieu of quantitative measures, studies have used visual indications of wood decay, such as the presence of fungal conks (Pasinelli 2007, Cockle et al. 2012) or tree decay classes (Martin et al. 2004, Vierling et al. 2008, Bonnot et al. 2009, Wightman et al. 2010) as a surrogate for wood density. However, recent research has revealed two downsides of such visual markers for predicting PCE use. First, PCE nest trees do not always display fungal fruiting bodies even when wood decay fungi are present (Conner et al. 1976). Secondly, when tested in forestry studies, decay classes at best only roughly correlate with wood density (Saint-Germain et al. 2007, Aakala 2010, Strukelj et al. 2013). Probably because of these shortcomings, PCEs reportedly use a variety of decay classes, ranging from entirely live trees with no conks or defects, to trees in advanced decay classes, indicating that fungal conks and decay classes are fairly unreliable indicators of nest site availability.

While past studies have advanced our understanding of PCE nest site selection in multiple ways, incorporating quantitative measures of wood harness might advance our understanding further. In particular, studies are needed that simultaneously consider the effects of external habitat-level factors and wood hardness on nest site selection. We reviewed a large number of studies published since Schepps et al. (1999) and Matsuoka (2000) that modeled habitat-level factors in nest site selection, but did not quantify wood hardness (Martin et al. 2004, Vierling et al. 2008, Bonnot et al. 2009, Saab et al. 2009, Wightman et al. 2010, Hollenbeck et al. 2011). Meanwhile, the only studies we found that quantified wood hardness restricted their analysis of nest site selection to nest tree factors (Schepps et al. 1999), measured hardness but did not specifically examine nest site selection (Matsuoka 2008, Tozer et al. 2009), or measured hardness only at the outer surface of trees (Schepps et al. 1999, Tozer et al. 2009), when early studies indicated that interior wood hardness was more important (Conner et al. 1976, Miller and Miller 1980). Assuming that wood hardness is an influential factor, information is also needed on what proportion of wood in different decay classes is suitable for PCE nesting, and whether external features of trees can be used to estimate nest site availability for PCEs. While forestry studies have measured wood hardness for trees in different decay classes, this information has not been used to estimate PCE nest site availability because there is no quantitative information on the density of wood at nests for any North American PCE. Such information would also be important for determining whether PCEs have nest site limitations similar to SCUs (Newton 1994, Martin et al. 2004, Wiebe 2011).

Given these information gaps, we designed a study to examine the role of wood hardness in PCE nest site selection and in limiting nesting opportunities. We had four primary objectives. First, we compared wood hardness at nests to wood at random sites, to determine whether nest wood was distinctive and limiting in natural systems. Second, we explored variation in wood hardness for nests of different species of PCE, and we tested whether species differed in their excavation abilities. Third, we examined the relative role of wood hardness in nest site selection by PCEs. To do this, we modeled wood hardness in comparison with external tree- and habitat-level features that have been implicated in past studies of nest site selection by PCEs. We tested for selection at two spatial scales: selection of nest trees within territories and selection of nest cavities on trees. Lastly, we examined whether external features of trees were a reliable indicator of interior wood hardness. We did this by comparing wood hardness for random trees within different decay classes and with different external properties.

METHODS

Study area and study species

We conducted this study from 2011 through 2013 in the eastern Cascade Range of Washington State, USA, in Yakima, Kittitas, and Chelan Counties (approximately 47°00′ N and 121°00′ W). Land ownership included private, state, and the United States Forest Service. We searched for nests in all major forest types native to the eastern Cascade Range, including ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), western hemlock (*Tsuga heterophylla*), subalpine fir (*Abies lasiocarpa*), and western larch (*Larix occadentalis*) forests (Lillybridge et al. 1995). Elevation ranged from 350 m to 2000 m, and dominant tree species varied among sites and by elevation. In general, 1350-m elevation marked the division between lower elevation ponderosa pine and Douglas-fir forest types and higher elevation grand fir or western larch forest types (Lillybridge et al. 1995). Some forests had been burned in U.S. Forest Service prescribed burns or wildfires in the last 10 years, and nests were found in patches ranging from unburned to severely burned (100% mortality of overstory trees).

We selected six species of PCEs for our study that occur in forests of western North America: American Three-toed Woodpecker (*Picoides dorsalis*), Black-backed Woodpecker (*P. arcticus*), Hairy Woodpecker, Northern Flicker (*Colaptes auratus*), White-headed Woodpecker (*P. albolarvatus*), and Williamson's Sapsucker (*Sphyrapicus thyroideus*). We chose these species because they represent two presumed but unconfirmed guilds in excavation ability among PCEs. American Three-toed, Black-backed, and Hairy Woodpeckers have been classified as "strong" excavators (Dudley and Saab 2003, Edworthy et al. 2012), compared to Northern Flicker, White-headed Woodpecker, and Williamson's Sapsucker (Saab and Dudley 1998, Schepps et al. 1999, Bunnell 2013).

Field methods

We searched for PCE nests from March through July, 2011–2013, in 10 study sites ~600–3000 ha in size. We searched for nests in both live and dead trees. To make finding nests easier, we used playbacks of calls and drumming to locate adult birds (Johnson et al. 1981) and followed adults until we located their nest cavities. We considered nests occupied if we observed eggs or nestlings using inspection cameras (Cen-tech, Camarillo, California, USA) or if adult behavior indicated that incubation or nestling feeding was underway (Jackson 1977), and we marked the locations of all occupied nests on portable GPS units. PCEs may reuse cavities among years, and for nests that we found after nest excavation, we looked for fresh wood chips on the ground surrounding nests to determine whether nests were current-year excavations.

After the nesting season, we returned to all current-year nests and measured vegetation features that were hypothesized to influence PCE nest site selection in past studies. We measured the diameter at breast height (dbh) of the nest tree, nest and tree height, and noted the species of tree. Most nests were in standing dead trees (hereafter, snags) and for these nests, we examined the remaining bark, tree growth form, and other features to determine species following Parks et al. (1997). We used a compass to determine the orientation of the nest cavity entrance, a spherical densitometer to estimate canopy cover at the nest tree, and estimated the proportion of the ground covered by shrubs within a 5 m radius plot (Martin et al. 1997). We also measured the dbh and noted the species of all trees and snags within 11.3 m of the nest for trees and snags at least 1.4 m height and 8 cm dbh (Martin et al. 1997). These measures were used to calculate tree and snag density at nest sites. We then estimated prefire canopy cover at nest sites because Saab et al. (2009) suggested it is important for nest site selection in Black-backed Woodpeckers. To estimate prefire canopy cover we used Gradient Nearest Neighbor (GNN) Classified Landsat (ETM+) satellite imagery flown between two and eight years prior to each fire (IMAP: Interagency mapping and assessment project, Landscape Ecology Mapping Modeling and Analysis [LEMMA]; *available online*).[5] This data set averaged prefire canopy cover within 30 × 30 m pixels, and for nests we assumed that the canopy cover from each 30 × 30 m pixel was representative of canopy cover at the actual nest site. We used ArcGIS 10 (ESRI 2010) to extract these data for nest sites.

For assessing nest site selection at the territory scale, we measured all of the features mentioned in the previous paragraph at one random tree associated with each nest. We included only snags in our sample of random trees, since only a small proportion of nests occurred in live trees. We selected random snags by walking >75 m from nests in a random orientation until we encountered a snag within ~10 m of the bearing. Following Bonnot et al. (2009), we assumed that nest territories were no greater than 250 m radius. Therefore, if no snag was encountered within 250 m of a nest site, we returned to the nest and selected another random orientation. For random snags, we included only those larger than 20 cm for the large-bodied Northern Flicker and 15 cm for the smaller woodpeckers and sapsuckers, because this corresponded to the smallest dbh trees used in our study by the large- and small-bodied PCEs, respectively.

Characterizing wood hardness at nests and random sites

At each nest site we measured the hardness of wood using a method developed by Matsuoka (2000) in which wood mass density is proportional to the torque required to spin an increment borer into a pre-drilled hole. It is similar to the more commonly used resistograph (Isik and Li 2003, Farris et al. 2004), but requires the operator to manually record torque associated with predetermined distance increments. We accessed cavities >2 m high using climbing ladders, tree climbing spikes, and by felling snags, although we minimized felling to extremely high cavities or unstable snags (<1% of all snags).

As suggested by Matsuoka (2000), we used torque measured in newton meters (N·m) for all statistical analysis involving wood hardness, although we also present summary statistics on wood mass density (Appendix A). In the first year of our study, the horizontal depth of our widest cavity was 14 cm, so we measured hardness at 1-cm increments, beginning at the tree's surface and ending 15 cm deep toward the heartwood, similar to Farris et al. (2004) (Fig. 1). Thus, for each hardness measurement, we measured hardness at one spot on the exterior of the tree, but recorded 16 measures of wood hardness as we drilled in toward the tree's center.

A fundamental problem with this method is that it is impossible to measure the hardness of wood that has already been removed by PCEs (Conner 1977, Matsuo-

---

[5] http://lemma.forestry.oregonstate.edu/data

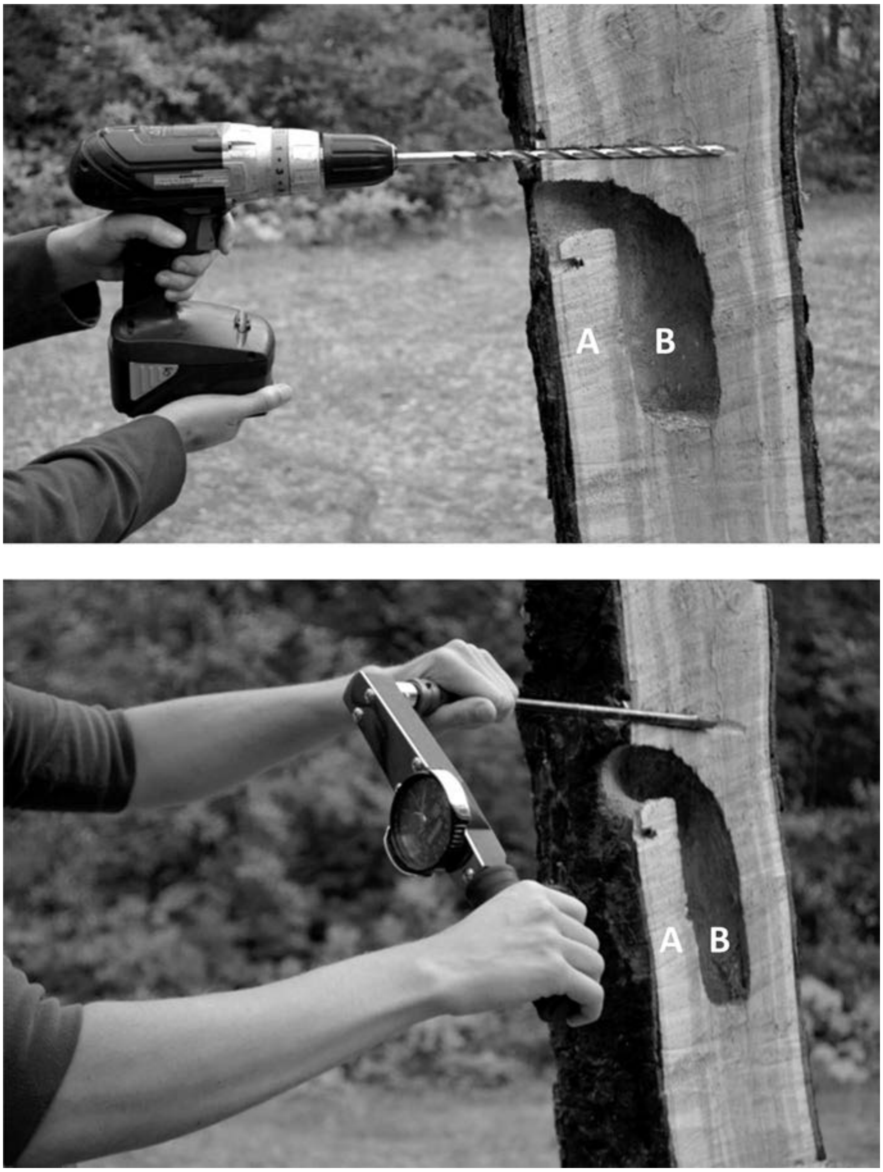


FIG. 1. Longitudinal section of an American Three-toed Woodpecker (*Picoides dorsalis*) nest showing the procedure we used to quantify wood hardness. First, we used a drill to create a 9-mm diameter hole above the nest cavity opening (top), and then recorded the torque (N·m) required to spin an increment borer into the pre-drilled hole (bottom) following Matsuoka (2000). The area marked A represents the nest sill, and the area marked B represents the nest cavity body in our study.

ka 2000). We therefore had to make several assumptions about how hardness of removed wood was best represented by hardness of remaining wood. Results from Matsuoka (2008) suggest that wood 5 cm above the nest cavity opening is similar to wood 10 cm below the cavity body. Furthermore, Matsuoka (2008) implied that this wood should be representative of the excavated wood since it is close in proximity to the nest. We therefore measured wood hardness within 5 cm of the top of the nest cavity entrance. For nests excavated directly under limbs, where the presence of a limb made it impossible to measure from the tree surface, we measured wood hardness within 10 cm of the lowest point of the nest cavity body.

Matsuoka (2008) also showed that hardness can vary across the width of nest sites, particularly between wood excavated for the nest entrance hole (hereafter "sill") and wood excavated for the main cavity chamber, or cavity body (hereafter "body") (Fig. 1). We therefore treated sill and body wood differently in all analyses. For woodpecker nests, we measured horizontal sill and body width using calipers, and then averaged hardness for all wood measured in the sill and body regions. Random sites, of course, lacked nests. Thus, for comparing nest wood with random wood, we assumed that wood in the outer three centimeters of random sites was comparable to the sill wood at PCE nests, since the average sill width in our study was 3 cm. Similarly, we assumed that wood 3 to 13 cm deep was representative of body wood, since across all nests, the average horizontal width of the nest cavity body was 10 cm. For random sites, we measured wood hardness at a random height and orientation on each snag. For logistical reasons, we selected random heights no greater than 12 m, which was the maximum extent of our climbing ladder. Since the average height of nests in our study was much lower than this (mean = 4.26 m; SD = 3.51 m), we assumed that this would not inordinately bias our results.

Pyle and Brown (1999) found that wood hardness varied across the bole of logs, and therefore it is possible that hardness varies across the bole of snags. If this is the case, a measurement taken at one location on random snags may not be representative of hardness throughout the bole. Therefore, at a subsample of 10% of random trees, we compared three measures of hardness within three strata of the tree's height: the upper third, the middle third, and the lower third of the bole. Within each of these strata, we measured hardness at one random height and orientation. Although we conducted this test in order to measure the extent of hardness variation within trees, it is likely that our sample scheme was not extensive enough to detect small or rare pockets of rot within the sampled trees. Therefore, whenever possible we restricted our inferences on wood availability to actual measurement points, rather than assuming that our samples described hardness in the entire bole of random trees.

PCE nest site availability

To calculate the availability of suitable wood, we compared the range of hardness between nest and random sites. We limited this analysis to two focal species, Black-backed and White-headed Woodpeckers, because we did not have time to measure hardness intensively in nest territories for all six PCEs before snowfall limited access to field sites. We chose these two species because they represent both the strong and weak excavator guilds, but are also at-risk species that have been the focus of much research attention recently (Bonnot et al. 2009, Wightman et al. 2010, Hollenbeck et al. 2011, Nappi and Drapeau 2011). For this particular objective, we selected a subsample of 50% of all Black-backed and White-headed Woodpecker nest sites, returned to those nest sites in autumn, and measured the wood hardness at the six nearest unused snags to each nest tree. We then calculated the minimum and maximum hardness values from nest sites for the two species separately. Then, for each of the six nearest nonuse snags, we determined whether the range of hardness values in the sill and body region fell within the range of values for nest sites. If the nonuse site contained harder or softer wood than nests for that species, we considered it unusable (or unsuitable or unavailable) for nesting. Otherwise, we considered the sample usable (or suitable or available). We then computed simple proportions of nonuse samples that fell within each of six categories: (1) sill too hard, body suitable; (2) sill suitable, body too hard; (3) sill too hard, body too hard; (4) sill too soft, body suitable; (5) sill too soft, body too hard; and (6) suitable for nesting (sill and body both suitable). We omitted categories for body wood that was too soft because we found no nests with softer body wood than random sites.

We computed these proportions for all snags together, and then by snag decay class based on the system by Bull et al. (1997). Assuming that hard wood is more common than soft wood, we expected that the strong excavator guild, represented by the Black-backed Woodpecker would be less limited; i.e., they would have a higher proportion of excavatable wood available in nest territories, compared to a weak excavator, the White-headed Woodpecker.

Nest site selection model development

We evaluated multi-scale nest site selection only for species with at least 30 nest locations. We used an information-theoretic approach (Burnham and Anderson 2002) to develop candidate models for each species based on hypotheses of nest site selection from past research. Thus, for territory-scale selection we first conducted a literature search to determine features that were hypothesized to influence PCE nest site selection and nest survival in past studies (Table 1; Appendix B). Some features implicated in past studies were highly correlated in our study because they essentially measured the same thing, but at slightly different scales. For example, Saab et al. (2009) and Forristal (2009) suggested that Black-backed Woodpeckers selected nest sites with high densities of snags >23 cm dbh, whereas Bonnot et al. (2009) reported that they selected sites with high densities of snags >15 cm dbh. For such factors, we selected one parameter to include in our models; generally the factor that was implicated in the largest number of studies. Some other potentially influential features were not present in our study areas. For example, Bonnot et al. (2009) found that Black-backed Woodpeckers selected nest patches with high densities of aspens, which we did not ever record among 821 sampled trees in Black-backed Woodpecker territories. Thus, after combining some factors and omitting others, we retained 11 parameters that we considered might influence territory-scale nest site selection in our study area. We then built candidate models for each species that considered the potential effects of these factors on nest predation, adult foraging opportunities, and ease of excavation (Table 1), and we limited our candidate set to 20 models for all species (Johnson and Omland 2004). Because the literature indicates that the different species respond differently to various habitat features, the

TABLE 1. Description of model parameters used to examine nest site selection by four primary cavity excavators (PCEs) in central Washington, USA, 2011–2013.

Possible variables	Parameter	BBWO	HAWO	NOFL	WHWO	Hypothesized reason	Source
Territory scale							
Nest tree dbh	dbh	x	x	x	x	protection from predation and/or search image	3, 4, 8, 9, 10, 12, 13, 15, 17, 19, 20, 21
Snag decay class from Cline	cline	x	x	x	x	protection from predation, ease of excavation, and/or search image	3, 4, 9, 10, 13, 17, 19
Nest tree sill wood hardness	sill	x	x	x	x	protection from predation, thermoregulation, or ease of excavation	1, 5, 16, 20
Nest tree body wood hardness	body	x	x	x	x	ease of excavation	2, 11
Density of live trees >50 cm dbh near nest	dlive50				x	preferred foraging habitat	8, 18
Density of live trees >10 cm dbh near nest	dlive10	x	x	x		protection from predation	4, 22
Density of snags >23 cm dbh near nest	dsnag	x	x	x		preferred foraging habitat	4, 7, 13, 14, 15, 19, 22
Prefire canopy cover	prefire	x				preferred foraging habitat	15
Shrub cover around nest	shrub				x	protection from predation	22
Percent slope at nest	slope				x	unknown (perhaps related to travel ease and thus predation)	8, 18
Percent canopy cover at nest	canopy			x	x	protection from predation, thermoregulation, and/or preferred foraging habitat	6, 18
Nest tree scale							
Nest cavity orientation	orientation	x	x	x	x	. . .	
Nest cavity height	height	x	x	x	x	. . .	
Nest tree sill wood hardness	sill	x	x	x	x	. . .	
Nest tree body wood hardness	body	x	x	x	x	. . .	

Notes: An "x" indicates that the given parameter was included in models for that species. The PCE species are: BBWO, Black-backed Woodpecker (*Picoides arcticus*); HAWO, Hairy Woodpecker (*P. villosus*); NOFL Northern Flicker (*Colaptes auratus*); and WHWO, White-headed Woodpecker (*P. albolarvatus*). The hypothesized reason for including a given parameter was sometimes based on our interpretation of study results; the sources used to create this table did not always provide a reason for the importance of the different parameters. An ellipsis indicates a lack of research on nest site selection; thus we included all possible parameters and did not attempt to provide a hypothesized reason. Sources are: 1, Conner 1977; 2, Miller and Miller 1980; 3, Raphael and White 1984; 4, Saab and Dudley 1998; 5, Schepps et al. 1999; 6, Wiebe 2001; 7, Saab et al. 2002; 8, Buchanan et al. 2003; 9, Spiering and Knight 2005; 10, Bagne et al. 2008; 11, Matsuoka 2008; 12, Vierling et al. 2008; 13, Bonnot et al. 2009; 14, Forristal 2009; 15, Saab et al. 2009; 16, Tozer et al. 2009; 17, Wightman et al. 2010; 18, Hollenbeck et al. 2011; 19, Nappi and Drapeau 2011; 20, Straus et al. 2011; 21, Cooke and Hannon 2012; and 22, Kozma and Kroll 2012. See Appendix B for sources used to create this table and Appendix C for the set of final models.

number of candidate models differed by species and ranged from 12 to 18 models.

For most species in this study, selection for a site on a tree had not been examined in past research studies. Thus, for the selection of a site on a nest tree, we included four covariates for all species: cavity orientation, cavity height, body wood hardness, and sill wood hardness. For this analysis, orientation was divided into four categories around the ordinal directions: north as 315–45°, east as 46–115°, south as 116–205°, and west as 206–295°. Similar to territory-scale selection, we built models for each species that considered the effects of nest predation, ease of excavation, and also nest thermoregulation on nest site selection.

Tree external appearance and wood hardness

Snag decay classification systems are a common means of grouping snags into categories that are assumed to reflect the underlying wood hardness and associated decay. However, we could find no past woodpecker studies that tested whether snag decay classes provided accurate information on wood hardness in a tree's interior. Therefore, we noted the decay class for every tree and snag sampled in our study using three established classification systems that have been used in past studies with our focal species. For these systems, trees are classified into three (Bull et al. 1997; hereafter Bull), five (Cline et al. 1980; hereafter Cline), or nine classes (Thomas et al. 1979, hereafter Thomas) based on

TABLE 2. Description of snag decay classes by Thomas, Cline, and Bull used to categorize snags in central Washington, USA, 2011–2013.

Class	Description
Thomas	
1	Live tree with no defects
2	Live tree with defects
3	Snag with limbs bark and top present
4	Snag with top remaining, but some bark and limbs absent
5	Snag with top remaining, some limbs absent, and all bark absent
6	Snag with some top missing, and all limbs and bark absent
7	Snag with most of top missing, and all limbs and bark absent
8	Stump-sized snag (no bark or limbs) with top lying at base
9	Stump-sized snag (no bark or limbs) with top disintegrated
Cline	
1	Snag with top, branches, limbs, and bark 100% intact
2	Snag with few limbs, no fine branches, broken top, and variable bark sloughing
3	Snag with limb stubs only, broken top, and variable bark sloughing
4	Snag with few or no limb stubs, broken top, and variable bark sloughing
5	Snag with no limb stubs, broken top, and 20% bark remaining
Bull	
1	Snag retaining 100% of its bark, branches, and top
2	Snag that has lost some bark, branches, and often a portion of the top
3	Snag missing bark, most of the branches, and has a broken top

Note: Data sources for each system are: Bull (Bull et al. 1997), Cline (Cline et al. 1980), and Thomas (Thomas et al. 1979).

whether they are alive or dead, the amount of bark remaining, condition of the top (intact or broken), and condition of the limbs (limbs or branches intact or broken), and higher numbers are supposed to indicate more advanced stages of decay (Table 2). We then tested whether wood hardness varied by decay class.

As noted by others (e.g., Larjavaara and Muller-Landau 2010), snag decay classes are inherently subjective; many trees are difficult to place into categories because they do not lose their bark, top, or limbs following the progression described by the various decay classes. Therefore, for each tree we also noted the approximate percentage of each of these features remaining. We then counted the number of old woodpecker cavities and starts, estimated the proportion of the tree surface that was blackened from fire, and noted the presence of fungal conks and woodpecker foraging evidence, using Farris et al. (2004) as a guide. We then related wood hardness at these trees with their external characteristics to determine if any external features were reliable predictors of internal wood hardness.

Statistical analysis

We used two-way repeated-measures ANOVA to compare hardness between the nest sill and body, and between nests of different species and random samples, where sill and body wood were treated as repeated, or within-subjects factors, and species was treated as a between-subjects factor. For this analysis we combined all random samples into a separate group to compare with samples from the nests of the different PCE species. Thus, our between-subjects factor had seven levels, one for nests of each of the six species of PCE and one for random samples. We used one-way repeated-measures ANOVA to test for differences in wood hardness at different heights within random trees, and simple, one-way ANOVA to compare wood hardness for trees within different snag decay classes. Whenever appropriate, data were assessed for normality. When overall F statistics indicated a significant difference among means, we used post hoc multiple comparison Tukey-Kramer tests.

We used multiple regression to determine whether any external features of random snags were reliable predictors of wood hardness. Variables considered as possible predictors were the percentage of bark, branches, needles, limbs, and top remaining on the snag, percentage of bark that was blackened from fire, and the presence of fungal conks, woodpecker foraging evidence, and old cavities or cavity starts. We looked for correlations among explanatory variables beforehand, and found that branches, needles, and limbs were correlated. Consequently, we omitted limbs and needles from our final model. We assessed model fit using R^2 and looked for violations of model assumptions using standard residual tests and diagnostic plots.

To compare different models of nest site selection by PCEs, we used conditional logistic regression models with matched-pairs case–control sampling, and where the "cases" were nest sites and the "controls" were random sites (Keating and Cherry 2004). Prior to building our models we assessed possible correlations between all pairwise combinations of covariates and omitted covariates if their coefficient > 0.5. We used Akaike's Information Criterion corrected for small sample sizes ($\mathrm{AIC_c}$) to assess the amount of support for the different models. Based on Akaike weights, we considered models in the 90% confidence set of candidate models as the best approximating models given the data. For each variable in the 90% confidence set we computed model averaged parameter estimates, their standard errors, and 95% confidence intervals (± 1.96 SE), following Mazerolle (2006) and Symonds and Moussalli (2011). When confidence intervals did not include 0, we concluded that the associated parameter had an effect on nest site selection. To assess the importance of variables, we computed a relative importance value by summing the Akaike weights (w_i) for all models containing each variable, and for variables with equal representation across models

TABLE 3. Mean and range of sill and body wood hardness at nests for six species of woodpecker compared to random trees in central Washington, USA, 2011–2013.

Species	n	Sill hardness (N·m) Mean	Sill hardness (N·m) Range	Cavity body hardness (N·m) Mean	Cavity body hardness (N·m) Range
American Three-toed Woodpecker	9	5.7^{cd}	0.6–13.8	2.5^{a}	0.6–6.6
Black-backed Woodpecker	39	5.2^{c}	0.0–11.9	1.7^{a}	0.0–6.2
Hairy Woodpecker	60	3.8^{ab}	0.0–9.8	1.8^{a}	0.0–5.0
Northern Flicker	55	2.5^{a}	0.0–9.6	1.1^{a}	0.0–4.7
White-headed Woodpecker	75	2.8^{a}	0.0–14.5	1.7^{a}	0.0–5.1
Williamson's Sapsucker	21	4.2^{bc}	0.1–16.6	1.6^{a}	0.3–4.9
Random trees	259	6.6^{d}	0.0–26.1	9.0^{b}	0.0–27.6

Notes: The PCE species are: American Three-toed Woodpecker (*Picoides dorsalis*), Black-backed Woodpecker (*P. arcticus*), Hairy Woodpecker (*P. villosus*), Northern Flicker (*Colaptes auratus*), White-headed Woodpecker (*P. albolarvatus*), and Williamson's Sapsucker (*Sphyrapicus thyroideus*). Superscript letters indicate results of post hoc multiple comparison tests, and means with the same letter do not differ.

(Burnham and Anderson 2002). For variables that showed quasi-complete separation, we computed parameter estimates using Firth's penalized maximum likelihood method (Firth 1993) following recommendations by Allison (2008).

Goodness-of-fit tests for conditional logistic regression in case–control studies have not been well developed, except for very special cases (Hosmer and Lemeshow 1985, Arbogast and Lin 2004), and the lack of predicted probabilities preclude the use of tools like prediction error and cross-validation. For all models in our 90% confidence set we therefore provided likelihood-based pseudo R^2 measures based on McFadden's proposed measures of goodness of fit (McFadden 1973), with the caveat that these do not necessarily have the same properties as R^2 values in linear regression with least squares estimation, but they are roughly analogous. We computed McFadden's adjusted pseudo R^2, which penalizes models for including too many predictors, and we considered values close to 1 as indicative of adequate model predictive power.

We used SAS version 9.3 statistical software (SAS Institute 2011) for all statistical analyses, and we considered statistical results significant at $\alpha = 0.05$.

RESULTS

General characteristics of nest and random sites

We found 259 PCE nests across a range of forest types and substrates. Most were in dead ponderosa pines (53%) or Douglas-firs (24%). Seven nests (3%) occurred in live trees, including live trembling aspen (*Populus tremuloides*), ponderosa pine, and Douglas-fir. One nest was excavated into the cedar siding of a cabin, two were in cut stumps, and one was in a fallen log on the ground. The remaining 19% of nests were in snags representing seven other tree species: grand fir, subalpine fir, trembling aspen, western red cedar (*Thuja plicata*), western larch, lodgepole pine (*Pinus contorta*), and Engelmann spruce (*Picea engelmannii*). Average cavity height was 4.26 m (range 0.00–23.68 m) and average nest tree dbh was 41.90 cm (range 15.67–104.49 cm). The smallest nest tree in our sample was used by a White-headed Woodpecker (dbh = 15.67 cm) and the largest by a Hairy Woodpecker (dbh = 104.49 cm). For comparison, average height of random sample locations was 4.12 m (range 0.76–16.74 m), and average dbh of random trees was 38.40 cm (range 15.49–108.20 cm).

Characteristics of wood hardness at nests and random sites

Mean wood hardness differed between the nest sill and body regions ($F_{1,517} = 65.66$, $P < 0.0001$), and between nests and random sites ($F_{1,517} = 106.15$, $P < 0.0001$). For all PCE nests, wood in the sill region was harder than wood in the body region, but for random sites wood in the body region was harder (Table 3). This resulted in a different hardness profile between nests and random sites where nests showed a distinctive drop in wood hardness in the tree interior, but samples from random snags increased in hardness from the bark surface until ~9 cm deep, at which point hardness leveled off (Fig. 2). Nest sites also increased in hardness beginning approximately 10 cm deep (Fig. 1), and overall woodpeckers appeared to align the nest cavity body with the patch of softest wood at each site.

For wood in the body region, we found no differences in hardness by species, although random samples had significantly harder body wood than nests for all species (Table 3). For wood in the sill region, on average, American Three-toed Woodpecker nests had the hardest sills among all species, and Northern Flicker had the softest sills. However, we observed considerable overlap in minimum and maximum sill hardness among species. For example, on average, Williamson's Sapsucker and White-headed Woodpecker had sills of intermediate hardness, but they also had the hardest recorded sills of any species (16.61 and 14.46 N·m, respectively; Table 3).

For assessing variation in hardness within trees, we randomly selected a subsample of 23 random trees (~10%) from our larger sample of all random trees. For logistical reasons, we restricted this subsampling to snags within 200 m of roads. For this subsample, wood

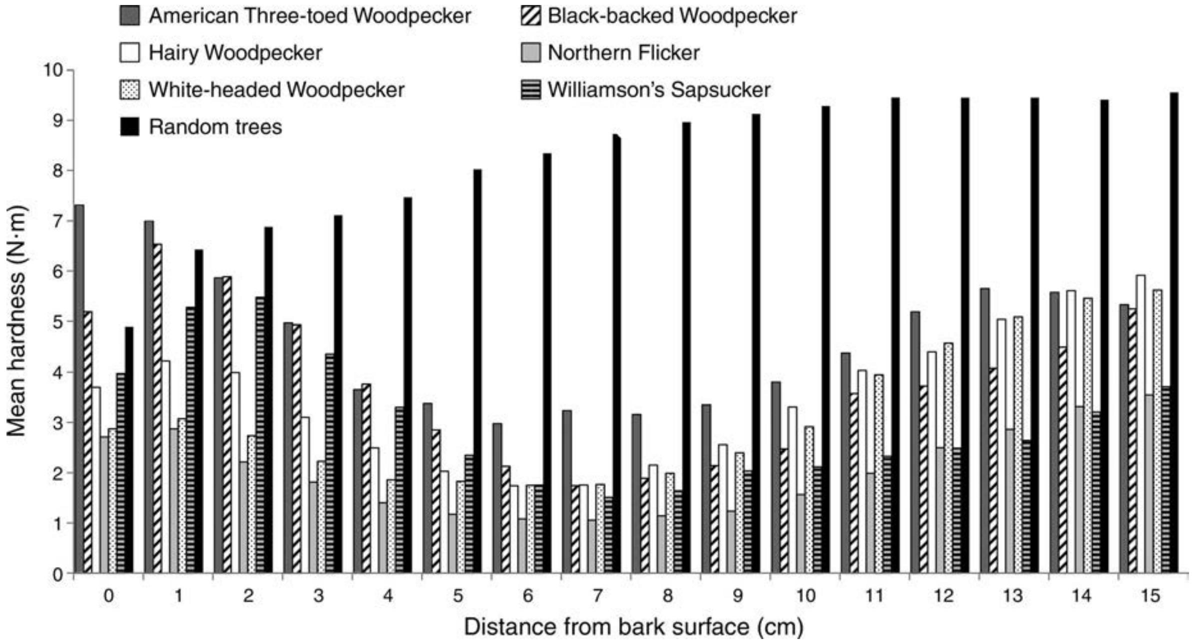


FIG. 2. Mean hardness at nests for six species of woodpecker compared to random sites in central Washington, USA, from 2011 to 2013. See Table 3 notes for full species names.

hardness did not differ within random trees by height ($F_{2,43} = 0.09$, $P = 0.9168$).

PCE nest site availability

Among 360 nonuse snags measured in White-headed and Black-backed Woodpecker territories, we classified 86% and 96% as unsuitable for nesting by these species, respectively (Fig. 3). For both species, the majority of nonuse snags (63% and 78%) were deemed unsuitable because interior wood was too hard to be excavated for a nest cavity body, even though the exterior wood was suitable for nesting.

When considering snag suitability based on decay classification systems, the decay class that provided the

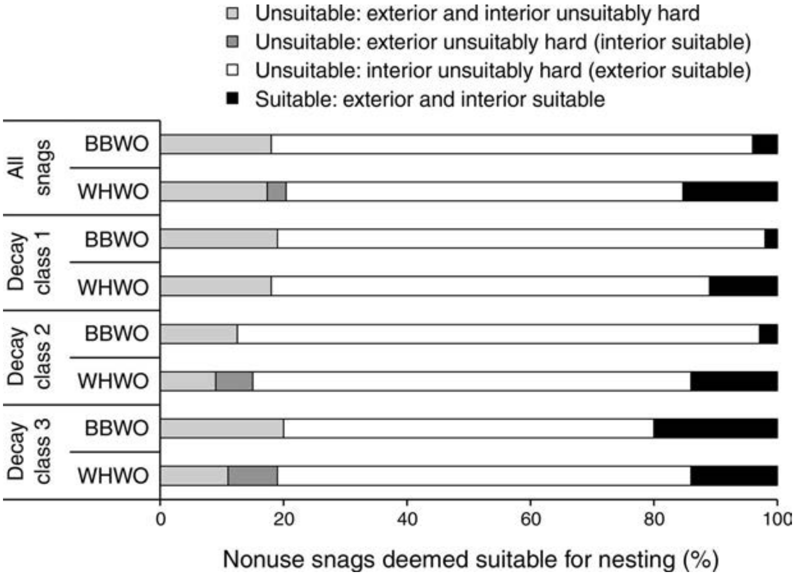


FIG. 3. Percentage of 360 nonuse snags in Black-backed Woodpecker (BBWO) and White-headed Woodpecker (WHWO) nesting territories that were deemed suitable for nesting based on wood hardness in central Washington, USA, 2011–2013. We considered all snags together, and then the percentages in each of three decay classes of Bull et al. (1997). See Table 2 for descriptions of the decay classes.

TABLE 4. Support for models in 90% confidence set explaining multi-scale nest site selection by four species of PCE in central Washington, USA, 2011–2013.

Species and model	k	AIC$_c$	Δ_i	w_i	Pseudo R^2
Territory scale					
Black-backed Woodpecker					
Body	2	2.333	0.000	0.665	0.926
Sill body	3	4.686	2.352	0.205	0.889
Sill body dsnag	4	7.176	4.843	0.059	0.852
Hairy Woodpecker					
Body	2	2.211	0.000	0.647	0.951
Sill body	3	4.429	2.218	0.213	0.928
Sill body dsnag	4	6.727	4.517	0.068	0.904
Northern Flicker					
Body	2	2.231	0.000	0.584	0.947
Sill body	3	4.471	2.240	0.191	0.921
Cline sill body	4	4.800	2.569	0.162	0.895
White-headed Woodpecker					
Sill body	3	4.338	0.000	0.891	0.940
Body	2	8.865	4.527	0.093	0.894
Nest tree scale					
Black-backed Woodpecker					
Body	2	7.120	0.000	0.749	0.837
Sill body	3	9.310	2.189	0.251	0.803
Hairy Woodpecker					
Body orientation	3	4.429	0.000	0.894	0.928
Body	2	9.805	5.376	0.061	0.861
Northern Flicker					
Height sill body orientation	5	33.156	0.000	0.472	0.607
Body	2	33.730	0.573	0.354	0.534
Sill body	3	35.959	2.802	0.116	0.508
White-headed Woodpecker					
Sill body	3	25.364	0.000	0.533	0.729
Body	2	25.805	0.441	0.427	0.723

Note: Variables used in the models are defined in Table 1, and full set of models is listed in Appendix C.

highest proportion of suitable wood was decay class 3 of Bull's system, in which 14–20% of sites were suitable for White-headed and Black-backed Woodpeckers, respectively (Fig. 3). However, when considering average wood hardness for used vs. unused snags, wood from decay class 3 was 4.6 times harder than wood from Black-backed and White-headed Woodpecker nest sites. Additionally, the majority of snags were too hard to be used for nesting by either species based on interior wood hardness and regardless of snag decay class. Decay class 1 of Bull performed especially poorly for Black-backed Woodpecker: 2% of snags in this class were usable, and, on average, wood from snags in this decay class was five times harder than wood at Black-backed Woodpecker nest sites.

Nest site selection

We found at least 30 nest sites for four species: Black-backed Woodpecker, Hairy Woodpecker, Northern Flicker, and White-headed Woodpecker. For territory-scale selection, the best fitting model describing nest site selection included only body wood hardness for all species except White-headed Woodpecker, which also included sill wood hardness in the top model (Table 4). For nest tree selection, the top model included body wood hardness for all species (Table 4). For all species and at both spatial scales, the importance value for body wood hardness was 0.99, and body wood hardness was the only statistically significant parameter estimate in all models (Table 5). McFadden's pseudo R^2 ranged between 0.926 and 0.951 for models explaining nest site selection, and 0.607 and 0.928 for nest tree selection (Table 5), suggesting adequate predictive power for all models.

Tree external appearances and wood hardness

We classified 559 random snags into decay classes based on the systems of Bull, Cline, and Thomas. We had small sample sizes of snags in decay classes 1, 2, 8, and 9 (live trees and stumps) of the system used by Thomas, and therefore only compared decay classes 3–7 for this classification system. Hardness of wood sampled from snags differed among classes for Bull ($F_{2,556} = 10.93$, $P < 0.0001$) and Cline ($F_{4,554} = 6.76$, $P < 0.0001$), but not for Thomas, where we found an overall significant F test ($F_{4,554} = 5.72$, $P = 0.0002$), but no significant pairwise comparisons (Fig. 4). For Bull's system, average wood hardness decreased predictably by decay class. However, for Cline, wood hardness did not decrease predictably among decay classes, and snags in decay class 4 were harder than those in decay class 3. Overall, there was much overlap in hardness within

TABLE 5. Model averaged parameter estimates, unconditional standard errors, 95% confidence intervals, and importance values explaining multi-scale nest site selection by four species of PCE in central Washington, USA, 2011–2013.

Species and parameter	Estimate	SE	Upper CI	Lower CI	Importance
Territory scale					
Black-backed Woodpecker					
Body	−0.412	0.089	−0.237	−0.587	0.99
Sill	−0.045	0.055	0.153	−0.063	0.27
Dsnag	0.001	0.001	0.001	−0.001	0.19
Hairy Woodpecker					
Body	−0.377	0.072	−0.237	−0.518	0.99
Sill	−0.015	0.031	0.075	−0.044	0.29
Dsnag	0.001	0.001	0.002	−0.001	0.14
Northern Flicker					
Body	−0.399	0.082	−0.237	−0.560	0.99
Sill	−0.002	0.061	0.122	−0.119	0.42
Cline 1	−0.037	0.139	0.235	−0.310	0.17
Cline 2	0.020	0.180	0.315	−0.390	0.17
Cline 3	−0.038	0.147	0.307	−0.268	0.17
Cline 4	0.048	0.127	0.297	−0.202	0.17
White-headed Woodpecker					
Body	−0.365	0.060	−0.247	−0.483	0.99
Sill	−0.026	0.099	0.167	−0.219	0.90
Nest tree scale					
Black-backed Woodpecker					
Body	−0.627	0.143	0.908	0.347	0.99
Sill	−0.001	0.044	0.086	−0.086	0.25
Hairy Woodpecker					
Body	−0.502	0.092	0.683	0.321	0.99
Sill	−0.004	0.007	0.011	−0.018	0.04
Northern Flicker					
Body	−0.592	0.155	0.895	0.288	0.99
Sill	−0.044	0.092	0.225	−0.137	0.59
Height	−0.134	0.092	0.046	−0.313	0.47
Orientation east	0.258	0.293	0.833	−0.317	0.53
Orientation north	−0.325	0.392	0.444	−1.095	0.53
Orientation south	0.353	0.360	1.059	−0.353	0.53
White-headed Woodpecker					
Body	−0.537	0.104	0.740	0.333	0.99
Sill	−0.098	0.087	0.072	−0.268	0.55

decay classes. For example, the softest and hardest samples were both from snags in decay class 3 of Bull's system.

We found that the external characteristics of snags were poorly correlated with wood hardness at sample locations ($R^2 = 0.074$). The only significant predictor of wood hardness for random sites was the presence of old woodpecker nest cavities and starts ($\beta = -1.31$, $P = 0.0032$), and for each cavity or start observed on a tree, mean wood hardness decreased by 1.3 N·m (Table 6). Woodpecker foraging evidence and the proportion of blackened bark, intact bark, intact top, and intact branches on a snag were not associated with variation in wood hardness (Table 6). Residuals plots and the Durbin-Watson test ($d = 1.97$) suggested that the model assumptions were not violated. We intended to consider whether the presence of fungal conks was associated with variation in wood hardness, but we found too few snags with conks (3.9%) to include them in our analysis. All of these conks (100%) were fruiting bodies of pouch fungus (*Cryptoporus volvatus*), and they occurred only on blackened and burned conifer snags.

DISCUSSION

Characteristics of nest wood and differences among species

All six species of PCE in our study occupied nests that had a distinctive wood hardness profile in which the nest cavity body was aligned with a patch of interior soft wood. This is similar to qualitative descriptions of wood at woodpecker nests by Conner et al. (1976) and Miller and Miller (1980), and more recent quantitative measures by Matsuoka (2008) for the Eurasian Greater Spotted Woodpecker (*Dendrocopos major*). Our study confirms that soft interior wood is important for many North American PCEs, since we observed this pattern at nest sites for all six species of PCE in our study.

There are several possible reasons for this distinctive profile of wood hardness. A few studies have suggested that woodpeckers do not select soft wood, but rather create soft wood by foraging or drilling starts, introducing fungi on their bills (Farris et al. 2004), and then returning to these locations to nest in later years. But most research indicates that woodpeckers instead locate and select soft spots that were independently created by wood decay fungi (Kilham 1983, Jackson and Jackson 2004, Losin et al. 2006). Our results support this. First, woodpecker foraging evidence was not associated with softened wood on random snags. Second, many woodpeckers were attracted to recent burns (<1 year postfire) for nesting, which almost certainly lacked appreciable numbers of preburn excavations. Third, some snags in our study were monitored as part of a concurrent study on woodpecker space use, and for these snags we knew the locations of past starts and observed woodpeckers creating cavities from start to finish within a single breeding season. Losin et al. (2006) pointed out that even if woodpeckers carry fungi on their bill tips (Farris et al. 2004), cavity starts are an unlikely medium for fungal growth because they are exposed to drying effects of wind and sun. Also, early studies noted the tapping behavior of woodpeckers in spring near future excavations (Kilham 1983, Wilkins and Ritchison 1999), indicating that PCEs search for and detect subtle changes in wood resonance while pecking or climbing trees (Conner et al. 1976). Given the rarity of soft wood in our study and the absence of obvious visual cues associated with soft wood, our findings support these suppositions that PCEs find soft spots as they visit trees and snags, and they possess sensory abilities lacking in humans that enable them to perceive changes in wood density within a tree's interior.

Assuming that PCEs find, rather than create soft spots, Kilham (1968, 1971) suggested that PCEs prefer sites with soft interior wood for excavation ease, but which also had hard exteriors to protect future nest contents from predators. It is also possible that PCEs select sites based on future cavity microclimate. Wood hardness may directly or indirectly (by constraining sill or body thickness, or cavity orientation; Losin et al. 2006) affect microclimate of nests, which in turn may affect clutch size under some environmental conditions (Wiebe 2001). PCEs may also simply prefer wood with the maximum hardness they are capable of excavating. However, they are likely capable of leveraging more power when they are positioned vertically on the outside of the tree rather than when head and body movements are confined and horizontal inside of a cavity start (Miller and Miller 1980). This might force them to select trees with soft interiors. Alternatively, they may instead prefer the softest, easiest sites available and trees with soft interiors often have hard exteriors.

After measuring large numbers of random sites, our findings indicate that ease of excavation is a major factor driving nest wood hardness and site selection. We observed a consistent preference for sites with soft interiors, despite their rarity on the landscape. Additionally, not all nests followed the pattern of hard exterior/soft interior. Some nests had soft exteriors and interiors, although no nests followed the reverse pattern (soft exterior and hard interior). The notion that PCEs select sites that are easy to excavate is supported by Losin et al. (2006), who reported that Red-naped Sapsuckers (*Syphrapicus nuchalis*) preferred nest sites with thin sapwood and that would be easier to excavate. However, within the range of wood hardness that they are physically capable of excavating, PCEs probably also face trade-offs when selecting nest sites, because sites that are easy to excavate could be riskier in terms of nest predation (Kilham 1983, Tozer et al. 2009) and

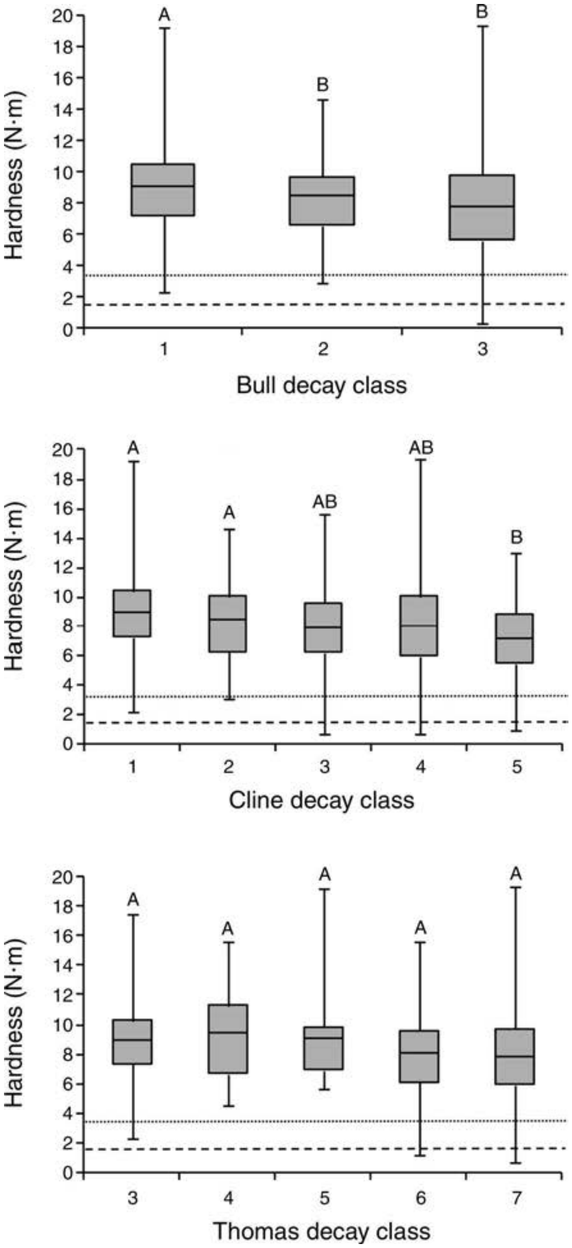


FIG. 4. Variation in wood hardness by snag decay class for 559 random snags in central Washington, USA, 2011–2103, classified by the decay class systems of Bull (top), Cline (center), and Thomas (bottom). See Table 2 for descriptions of the decay classes. Dashed and dotted lines on plots indicate mean body and sill wood hardness at nests, respectively. Letters show the results of post hoc multiple comparison tests, and means with the same letter do not differ.

TABLE 6. Parameter estimates, standard errors, and *P* values for multiple regression associating wood hardness with external features of 559 random snags in central Washington, USA, 2011–2012.

Variable	Estimate	SE	*T*	*P*
Presence of foraging sign	0.368	0.327	1.12	0.261
Presence of cavities	−1.31	0.440	−2.98	0.003
Percentage of blackened bark	−0.003	0.004	−0.84	0.402
Percentage of top missing	−0.009	0.006	−1.58	0.114
Percentage of bark missing	0.011	0.007	1.60	0.110
Percentage of branches missing	−0.004	0.005	−0.71	0.476

more exposed to climate variability. We suggest that future studies examine some of these trade-offs, and determine the extent to which PCEs are limited by excavation abilities that may force them to compromise on thermal benefits and safety. An important first step in this process is to measure wood hardness in available trees to more accurately estimate the number of potential nest sites, which prior to this study has probably been grossly overestimated.

Another important consideration is that species likely differ in their excavation abilities, and this may affect trade-offs in nest site selection decisions. In support of this, while we found no difference in internal wood hardness, we did observe differences in exterior, or sill wood hardness among the six species in this study. On average, nests of three-toed woodpeckers (*P. dorsalis* and *P. arcticus*) had harder sills than those of sapsuckers, which in turn had harder sill wood than Hairy Woodpecker, White-headed Woodpecker, and Northern Flicker nests. Despite these differences and their implications for nest site selection, our results suggest that researchers should be cautious about using excavator guilds (e.g., Ingold 1994, Dudley and Saab 2003, Bunnell 2013) without more study, particularly controlled tests in laboratory settings. This is partly because, despite differences in mean sill hardness, we observed a lot of overlap suggesting excavator guilds are overly simplistic. Moreover, even if guilds reflect biological differences in ability, they may not be realized in natural settings where birds appear most limited by soft interior wood. For example, our results suggest that in some locations, Black-backed Woodpeckers (see Plate 1) may be more limited than White-headed Woodpeckers for nest sites, possibly because Black-backed Woodpeckers nest in recent burns where less wood has had time to soften following death. Thus, even if excavator guilds provide biologically accurate information, they may not provide reliable information for management or conservation purposes, and therefore should be used with caution.

Nest site selection

We found that interior wood hardness was the most important predictor of nest site selection at the nest tree and territory scale for all species examined suggesting that PCEs are limited to a small subset of trees on the landscape for nesting. These findings may explain why some species that do not forage on snags are nevertheless attracted to patches of burned forest, or other areas of high snag density. For example, aerial insectivores like Lewis's Woodpecker (*Melanerpes lewis*), ground-foragers like Northern Flicker, and live-tree specialists like White-headed Woodpecker are all known to converge in burned forests during the nesting season (Saab et al. 2009). If soft wood is rare, then the probability of soft wood occurring in any given area is probably somewhat proportional to the sheer amount of dead or diseased wood. The more snags that occur in an area, the higher the probability that at least a few have suitable soft spots, and these PCEs may be attracted to burns because they provide opportunities for nesting that are not commonly found in nearby unburned forests.

Our findings may also explain previously inexplicable regional variation in woodpecker nesting preferences noted by others. For example, Bonnot et al. (2009) called attention to regional variation in nest tree size for the at-risk Black-backed Woodpecker. In California, USA, Raphael and White (1984) reported that Black-backed Woodpeckers nested in trees with an average dbh of 45 cm, whereas in Quebec, Canada, Nappi and Drapeau (2011) found them nesting in trees half that size (mean dbh = 22 cm). Similarly, large-diameter snags are promoted for nests sites of the declining White-headed Woodpecker based on research from Oregon, USA (Wightman et al. 2010), while we found them selecting trees as small as 16 cm dbh. Since internal wood softening is likely caused by wood-rotting fungi, and since fungi likely grow differently in different trees and regions, woodpeckers in different regions might select sites with highly variable external properties, but to them, very similar internal properties. If this is the case, it is not possible to make generalizations about nest site selection across regions without accounting for wood hardness or decay fungi: Providing large-diameter snags in a region where PCEs are using rot in small-diameter trees could be detrimental. It also suggests that it would be more beneficial for PCEs if managers focus on providing trees with rot, or which are susceptible to rot, rather than trees with particular external features or dimensions.

PLATE 1. A female Black-backed Woodpecker (*Picoides arcticus*) at a nest excavated in a small diameter (22 cm), live ponderosa pine (*Pinus ponderosa*) in central Washington, USA, 2013. While large diameter snags have been promoted for this species in some studies, we found them nesting in both live and dead trees, and across a range of tree diameters (21–86 cm). Despite this variation, woodpeckers consistently selected sites with softened interior wood. Photo credit: T. J. Lorenz.

The notion that wood-rotting fungi are important to PCE nesting ecology is not new. Jackson and Jackson (2004) provided a review of the evidence that wood-rotting fungi are central for PCE nesting ecology, and suggested that woodpeckers select for sites with rot or with fungal conks. However, we propose that PCEs do not select specifically for rot or fungal conks, but rather that they select trees with soft interiors, and soft interior wood is often caused by wood decay fungi. This would explain why PCEs sometimes use manufactured nest boxes or human buildings for nesting, which should contain little or no trace of wood-rotting fungi, but which are filled with soft materials such as wood shavings or insulation. If this is the case, then wood hardness is ultimately the mode by which PCEs select nest sites, and it just so happens that in natural systems, wood-rotting fungi are a common mechanism by which wood is softened.

Nevertheless, we do not intend to downplay the role of wood-rotting fungi in PCE nesting ecology. On the contrary, we agree with Jackson and Jackson (2004) that more research is needed on the species of fungi that cause wood softening at PCE nests and how they can be promoted. This is especially true for coniferous forests. With the exception of the endangered Red-cockaded Woodpecker (*Picoides borealis*) of the southeastern USA, past research has focused on PCE use of heart rot-infected deciduous trees (Conner et al. 1976, Daily 1993, Schepps et al. 1999, Matsuoka 2008). In coniferous forests of the northwestern USA, we observed that many nests were excavated into the sapwood of conifer snags, indicating that sapwood rot is an underappreciated mechanism of wood softening in some regions. Research on rot in coniferous forests is particularly needed because several at-risk PCEs rely on coniferous forests for population persistence, including the White-headed, Black-backed, Lewis's, and American and Eurasian Three-toed Woodpecker (*Picoides tridactylus*) (e.g., Garrett et al. 1996, Dixon and Saab 2000, Vierling et al. 2013).

Tree external appearances and wood hardness

We found that commonly used snag decay classes were a poor predictor of nest site selection compared to wood hardness. There are several reasons why decay classes poorly predict PCE use in this and past studies (Chambers and Mast 2005, Bagne et al. 2008). First, decay classes attempt to categorize and simplify a continuous and complex phenomenon (Creed et al. 2004, Angers et al. 2012). Second, factors that enable trees to compartmentalize decay can function long after a tree's death (Shigo 1984). Thus, indicators of decay class that should be used to identify localized pockets of decay are in practice applied to describe decay in the entire bole of a tree. Third, snag decay classes group snags based on their exterior features, whereas woodpeckers appear to select snags based on internal features, specifically wood hardness. Factors that cause a tree to take on the outward appearance of a snag decay class are not necessarily those that cause fungal colonization and wood softening in the interior. For example, top breakage is often listed as a major factor associated with advanced snag decay (Cline et al. 1980, Bull et al. 1997). Yet, top breakage may occur from factors besides decay, such as from excessive wind, snow, mechanical thinning, or fire, and thus, a broken-top snag may contain hard wood in all of its bole. When tops do break from decay, the portion of bole containing soft wood may fall to the ground. Although dead-topped trees are said to provide a good surface for fungal colonization (Haggard and Gaines 2001), we could not find studies that specifically tested this hypothesis, and fungal growth could be inhibited in some broken-topped trees, because they subject the bole's interior to the drying effects of wind and sun (Losin et al. 2006). In sum, a broken-top tree or snag would be favorable for PCE use only under fairly specific conditions. It is not surprising therefore that, while PCEs consistently selected soft interior wood in our study, nests occurred in sites ranging from entirely live trees to live trees with dead tops and snags with both intact and broken tops.

Snag decay classes have likely enjoyed such popularity because they are easy to use. However, they can be fairly subjective (Larjavaara and Muller-Landau 2010), and their limitations for predicting wood density were appreciated early on by foresters (Gale 1973). Since then, the majority of studies on snag decay classes report findings very similar to ours; for random spots on snags, there is large variation within and overlap among decay classes in wood density. Thus, while decay classes may sometimes point to localized pockets of decay, for describing wood in the entire bole of a tree they only indicate changes in wood mass density at coarse scales; for example, between the two most extreme decay classes within one system, and they poorly describe variation at finer scales (Saint-Germain et al. 2007, Aakala 2010, Paletto and Tosi 2010, Strukelj et al. 2013). This is potentially problematic for studies of PCE nest site selection, since PCEs appear to perceive changes in wood density at very fine scales (Matsuoka 2008, Zahner et al. 2012).

Despite these concerns, we could find no other studies of PCE nest site selection that acknowledged the shortcomings of decay classes and tested their accuracy. Additionally, ours is the first study to relate hardness of snag decay classes with hardness at PCE nests. We found that regardless of snag decay class, the majority of wood in nesting territories was unsuitably hard for nesting by our two focal species, the Black-backed and White-headed Woodpecker. We also found no external features of snags that were associated with interior wood softness at our random measurement points. While we acknowledge that sampling at random spots on snags, rather than near broken tops or limbs, likely led to a conservative estimate of soft wood, we recommend that ecologists avoid using snag decay classifications for determining the suitability of sites for PCE nests until more intensive sampling of snags is done. When decay classes are used, ecologists should recognize that the majority of wood on all snags is likely unsuitable for nesting.

Implications for research and management

Our findings suggest that higher densities of snags and other nest substrates should be provided for PCEs than generally recommended, because past research studies likely overestimated the abundance of suitable nest sites and underestimated the number of snags required to sustain PCE populations. Accordingly, the felling or removal of snags for any purpose, including commercial salvage logging and home firewood gathering, should not be permitted where conservation and management of PCEs or SCUs is a concern (Scott 1978, Hutto 2006). Managers should also take particular care that programs designed to increase the number of nesting substrates do not end up providing large numbers of unusable sites. Several studies attempting to create nest snags for PCEs have reported low use by woodpeckers, indicating that this should be a major concern. For example, Bednarz et al. (2013) inoculated 330 trees with *Fomitopsis pinicola* in western Washington, USA, and found no avian nest cavities eight to nine years later. Likewise, for 883 and 1111 snags created by tree-topping in western Oregon, USA, by Walter and Maguire (2005) and Kroll et al. (2012), only 2–3% were used by woodpeckers for nesting 10 to 12 years later. In these cases, managers may have unknowingly provided large numbers of unsuitably hard snags that PCEs were not physically capable of excavating. Yet the alternative situation could also be detrimental. If managers provide large numbers of unsuitably soft snags, PCEs may experience high depredation rates and be incapable of successfully fledging broods (Conner 1977, Tozer et al. 2009). This second case could have significant population-wide ramifications for rare or sensitive species since it could attract nesting birds to sink habitats. But either situation may be costly for managers while not beneficial for PCEs.

For researchers, future studies of PCE nesting ecology must include quantitative measures of wood hardness for unbiased results. Past research studies that did not measure wood hardness probably counted some trees as available for PCEs that were not actually available. In addition to causing bias (Jones 2001), this may explain "nonideal" selection decisions reported by PCEs in past studies. Sadoti and Vierling (2010) and Frei et al. (2013) reported that woodpeckers selected sites where they experienced low productivity, and then concluded that PCEs made maladaptive or nonideal selection decisions. But these studies did not measure wood hardness, and therefore some sites counted as available were probably not available. In order to determine the extent and frequency of bias, new studies should be conducted to revisit old research questions, and these new studies should quantitatively measure wood hardness to obtain a more accurate assessment of nest site availability. Additionally, until wood hardness is incorporated into nest site selection models, ecologists should remain cautious of interpretations made without measures of wood hardness, at least at the territory scale and smaller. We also encourage researchers to further explore the role of wood hardness in PCE nest site limitations and nest survival (Tozer et al. 2009), and to conduct intensive studies of wood hardness to better estimate the availability of suitable nest wood in different forest types. Lastly, as suggested by Jackson and Jackson (2004), much could be gained by identifying and promoting wood decay fungi associated with PCE nest sites, rather than simply measuring and modeling patterns in external features.

Acknowledgments

This study was partially funded by the U.S. Department of Agriculture, Forest Service. For logistical support, we thank R. Huffman from the Washington Department of Fish and Wildlife, and A. Lyons, K. Mellen-McLean, J. St. Hiliare, and D. Youkey from the U.S. Forest Service. C. Harrington and C. Raley loaned us equipment, and A. Adamson, T. Kogut, J. Kozma, J. Millard, and H. Murphy shared nest locations. We are grateful to J. Millard for also helping with field data collection. C. Coffin, T. Bass, J. Ashbaugh, and the Carlson family allowed access to their land, and Sleeping Lady Resort in Leavenworth, Washington, graciously allowed us to measure a nest in one of their lodges. J. Rachlow, M. Raphael, L. Svancara, and two anonymous reviewers provided comments that improved the manuscript.

Literature Cited

Aakala, T. 2010. Coarse woody debris in late-successional *Picea abies* forests in northern Europe: variability in quantities and models of decay class dynamics. Forest Ecology and Management 260:770–779.

Aitken, K. E. H., and K. Martin. 2008. Resource selection plasticity and community responses to experimental reduction of a critical resource. Ecology 89:971–980.

Allison, P. D. 2008. Convergence failures in logistic regression. SAS Institute, Cary, North Carolina, USA.

Angers, V. A., Y. Bergeron, and P. Drapeau. 2012. Morphological attributes and snag classification of four North American boreal tree species: relationships with time since death and wood density. Forest Ecology and Management 263:138–147.

Arbogast, P. G., and D. Y. Lin. 2004. Goodness-of-fit methods for matched case-control studies. Canadian Journal of Statistics 32:373–386.

Bagne, K. E., K. L. Purcell, and J. T. Rotenberry. 2008. Prescribed fire, snag population dynamics, and avian nest site selection. Forest Ecology and Management 255:99–105.

Bednarz, J. C., M. J. Huss, T. J. Benson, and D. E. Varland. 2013. The efficacy of fungal inoculation of live trees to create wood decay and wildlife-use trees in managed forests of western Washington, USA. Forest Ecology and Management 307:186–195.

Bednarz, J. C., D. Ripper, and P. M. Radley. 2004. Emerging concepts and research directions in the study of cavity-nesting birds: keystone ecological processes. Condor 103:1–4.

Blanc, L. A., and J. R. Walters. 2008. Cavity excavation and enlargement as mechanisms for indirect interactions in an avian community. Ecology 89:506–514.

Bonnot, T. W., J. J. Millspaugh, and M. A. Rumble. 2009. Multi-scale nest-site selection by black-backed woodpeckers in outbreaks of mountain pine beetles. Forest Ecology and Management 259:220–228.

Buchanan, J. B., R. E. Rogers, D. J. Pierce, and J. E. Jacobson. 2003. Nest-site habitat use by white-headed woodpeckers in the eastern Cascade Mountains, Washington. Northwestern Naturalist 84:119–128.

Bull, E. L., C. G. Parks, and T. R. Torgersen. 1997. Trees and logs important to wildlife in the interior Columbia River basin. General Technical Report PNW-GTR-391. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon, USA.

Bunnell, F. L. 2013. Sustaining cavity-using species: patterns of cavity use and implications to forest management. ISRN Forestry 2013:1–33.

Bunnell, F. L., L. L. Kremsater, and E. Wind. 1999. Managing to sustain vertebrate richness in forests of the Pacific Northwest: relationships within stands. Environmental Reviews 7:97–146.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer, New York, New York, USA.

Chambers, C. L., and J. N. Mast. 2005. Ponderosa pine snag dynamics and cavity excavation following wildfire in northern Arizona. Forest Ecology and Management 216:227–240.

Cline, S. P., A. B. Berg, and H. M. Wight. 1980. Snag characteristics and dynamics in Douglas-fir forests, western Oregon. Journal of Wildlife Management 44:773–786.

Cockle, K. L., K. Martin, and G. Robledo. 2012. Linking fungi, trees, and hole-using birds in a Neotropical tree-cavity network: Pathways of cavity production and implications for conservation. Forest Ecology and Management 264:210–219.

Conner, R. N. 1977. The effect of tree hardness on woodpecker nest entrance orientation. Auk 94:369–370.

Conner, R. N., O. K. Miller, Jr., and C. S. Adkisson. 1976. Woodpecker dependence on trees infected by fungal heart rots. Wilson Bulletin 88:575–581.

Cooke, H. A., and S. J. Hannon. 2012. Nest-site selection by old boreal forest cavity excavators as a basis for structural retention guidelines in spatially-aggregated harvests. Forest Ecology and Management 269:37–51.

Creed, I. F., K. L. Webster, and D. L. Morrison. 2004. A comparison of techniques for measuring density and concentrations of carbon and nitrogen in coarse woody debris at different stages of decay. Canadian Journal of Forest Research 34:744–753.

Daily, G. C. 1993. Heartwood decay and vertical distribution of red-naped sapsucker nest cavities. Wilson Bulletin 105:674–679.

Daily, G. C., P. R. Ehrlich, and N. M. Haddad. 1993. Double keystone bird in a keystone species complex. Proceedings of the National Academy of Sciences USA 90:592–594.

Dixon, R. D., and V. A. Saab. 2000. Black-backed Woodpecker (*Picoides arcticus*). The birds of North America online. A. Poole, editor. Cornell Lab of Ornithology, Ithaca, New York, USA.

Drever, M. C., K. E. H. Aitken, A. R. Norris, and K. Martin. 2008. Woodpeckers as reliable indicators of bird richness, forest health, and harvest. Biological Conservation 141:624–634.

Dudley, J., and V. Saab. 2003. A field protocol to monitor cavity-nesting birds. Research Paper RMRS-RP-44. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado, USA.

Edworthy, A. B., K. L. Wiebe, and K. Martin. 2012. Survival analysis of a critical resource for cavity-nesting communities: patterns of tree cavity longevity. Ecological Applications 22:1733–1742.

Esri [Environmental Systems Research Institute]. 2010. ArcGIS 10.0. Esri, Redlands, California, USA.

Farris, K. L., M. J. Huss, and S. Zack. 2004. The role of foraging woodpeckers in the decomposition of ponderosa pine snags. Condor 106:50–59.

Firth, D. 1993. Bias reduction of maximum likelihood estimates. Biometrika 80:27–38.

Forristal, C. D. 2009. Influence of postfire salvage logging on black-backed woodpecker nest-site selection and nest survival. Thesis. Montana State University, Bozeman, Montana, USA.

Frei, B., J. W. Fyles, and J. J. Nocera. 2013. Maladaptive habitat use of a North American woodpecker in population decline. Ethology 119:1–12.

Gale, R. M. 1973. Snags, chainsaws, and wildlife: one aspect of habitat management. Pages 97–112 *in* J. Yoakum, editor. Presentation to the 4th annual joint conference of the American Fisheries Society and Wildlife Society. Wildlife in managed forests: Cal-Nev wildlife 1973 transactions. American Fisheries Society, Bethesda, Maryland, USA

Garrett, K. L., M. G. Raphael, and R. D. Dixon. 1996. White-headed Woodpecker (*Picoides albolarvatus*). *In* A. Poole, editor. The birds of North America online. Cornell Lab of Ornithology, Ithaca, New York, USA.

Gentry, D. J., and K. T. Vierling. 2008. Reuse of woodpecker cavities in the breeding and non-breeding seasons in old burn habitats in the Black Hills, South Dakota. American Midland Naturalist 171:413–429.

Haggard, M., and W. L. Gaines. 2001. Effects of stand-replacement fire and salvage logging on a cavity-nesting bird community in Eastern Cascades, Washington. Northwest Science 75:387–396.

Hollenbeck, J. P., V. A. Saab, and R. W. Frenzel. 2011. Habitat suitability and nest survival of white-headed woodpeckers in unburned forests of Oregon. Journal of Wildlife Management 75:1061–1071.

Hosmer, D. W., and S. Lemeshow. 1985. Goodness-of-fit tests for the logistic regression model for matched case-control studies. Biometrical Journal 27:511–520.

Hutto, R. L. 2006. Toward meaningful snag-management guidelines for postfire salvage logging in North American conifer forests. Conservation Biology 20:984–993.

Ingold, D. J. 1994. Nest-site characteristics of red-bellied and red-headed woodpeckers and northern flickers in east-central Ohio. Ohio Journal of Science 94:2–7.

Isik, F., and B. Li. 2003. Rapid assessment of wood density of live trees using the resistograph for selection in tree improvement programs. Canadian Journal of Forest Research 33:2426–2435.

Jackson, J. A. 1977. How to determine the status of a woodpecker nest. Living Bird 15:205–221.

Jackson, J. A., and B. J. S. Jackson. 2004. Ecological relationships between fungi and woodpecker cavity starts. Condor 106:37–49.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource performance. Ecology 61:65–71.

Johnson, J. B., and K. S. Omland. 2004. Model selection in ecology and evolution. Trends in Ecology and Evolution 19:101–108.

Johnson, R. R., B. T. Brown, L. T. Haight, and J. M. Simpson. 1981. Playback recordings as a special avian censusing technique. Studies in Avian Biology 6:68–75.

Jones, J. 2001. Habitat selection studies in avian ecology: a critical review. Auk 118:557–562.

Keating, K. A., and S. Cherry. 2004. Use and interpretation of logistic regression in habitat-selection studies. Journal of Wildlife Management 68:774–789.

Kilham, L. 1968. Reproductive behavior of hairy woodpeckers II. Nesting and habitat. Wilson Bulletin 80:286–305.

Kilham, L. 1971. Reproductive behavior of yellow-bellied sapsuckers I. Preference for nesting in *Fomes*-infected aspens and nest hole interrelations with flying squirrels, raccoons, and other animals. Wilson Bulletin 83:159–171.

Kilham, L. 1983. Life history studies of woodpeckers of eastern North America. Publication Number 20. Nuttall Ornithology Club, Cambridge, Massachusetts, USA.

Kozma, J. M., and A. J. Kroll. 2012. Woodpecker nest survival in burned and unburned managed ponderosa pine forests of the northwestern United States. Condor 114:1–13.

Kroll, A. J., S. D. Duke, M. E. Hane, J. R. Johnson, M. Rochelle, M. G. Betts, and E. B. Arnett. 2012. Landscape composition influences avian colonization of experimentally created snags. Forest Ecology and Management 152:145–151.

Larjavaara, M., and H. C. Muller-Landau. 2010. Comparison of decay classification, knife test, and two penetrometers for estimating wood density of coarse woody debris. Canadian Journal of Forest Research 40:2313–2321.

Lawrence, L. D. K. 1967. A comparative life-history study for four species of woodpeckers. Ornithological Monographs 5:1–156.

Lillybridge, T. R., B. L. Kovalchik, C. K. Williams, and B. G. Smith. 1995. Field guide to forested plant associations of the Wenatchee National Forest. General Technical Report PNW-GTR-359. USDA Forest Service, Portland, Oregon, USA.

Lindenmayer, D. B., C. R. Margules, and D. B. Botkin. 2000. Indicators of biodiversity for ecologically sustainable forest management. Conservation Biology 14:941–950.

Losin, N., C. H. Floyd, T. E. Schweitzer, and S. J. Keller. 2006. Relationship between aspen heartwood rot and the location of cavity excavation by a primary cavity-nester, the red-naped sapsucker. Condor 108:709–710.

Martin, K., K. E. H. Aitken, and K. L. Wiebe. 2004. Nest-sites and nest webs for cavity-nesting communities in interior British Columbia, Canada: nest characteristics and niche partitioning. Condor 106:5–19.

Martin, T. E., C. R. Paine, C. J. Conway, W. M. Hochachka, P. Allen, and W. Jenkins. 1997. BBIRD field protocol. Montana Cooperative Wildlife Research Unit, University of Montana, Missoula, USA.

Matsuoka, S. 2000. A method to measure the hardness of wood in standing woodpecker nest trees. Japanese Journal of Ornithology 49:151–155.

Matsuoka, S. 2008. Wood hardness in nest trees of the great spotted woodpecker *Dendrocopos major*. Ornithological Science 7:59–66.

Mazerolle, M. J. 2006. Improving data analysis in herpetology: using Akaike's Information Criterion (AIC) to assess the strength of biological hypotheses. Amphibia-Reptilia 27:169–180.

McFadden, D. 1973. Conditional logit analysis of qualitative choice behavior. Pages 104–142 *in* P. Zarembka, editor. Frontiers in econometrics. Academic Press, New York, New York, USA.

Miller, E., and D. R. Miller. 1980. Snag use by birds. Pages 337–356 *in* R. M. DeGraaf, editor. Management for non-game birds. General Technical Report INT-GTR-86. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah, USA.

Nappi, A., and P. Drapeau. 2011. Pre-fire forest conditions and fire severity as determinants of the quality of burned forests for deadwood-dependent species: the case of the black-backed woodpecker. Canadian Journal of Forest Research 41:994–1003.

Newton, I. 1994. The role of nest-sites in limiting the numbers of hole nesting birds: a review. Biological Conservation 70:265–276.

Paletto, A., and V. Tosi. 2010. Deadwood density variation with decay class in seven tree species of the Italian Alps. Scandinavian Journal of Forest Research 25:164–173.

Parks, C. G., E. L. Bull, and T. R. Torgersen. 1997. Field guide for the identification of snags and logs in the interior Columbia River Basin. General Technical Report PNW-GTR-390. USDA Forest Service, Portland, Oregon, USA.

Pasinelli, G. 2007. Nest site selection in middle and great spotted woodpeckers *Dendrocopos medius* and *D. major*: implications for forest management and conservation. Biodiversity and Conservation 16:1283–1298.

Pyle, C., and M. M. Brown. 1999. Heterogeneity of wood decay classes within hardwood logs. Forest Ecology and Management 114:253–259.

Raphael, M. G., and M. White. 1984. Use of snags by cavity-nesting birds in the Sierra Nevada. Wildlife Monographs 86:1–66.

Saab, V. A., R. Brannon, J. G. Dudley, L. Donohoo, D. Vanderzanden, B. Johnson, and H. Lackowski. 2002. Selection of fire-created snags at two spatial scales by cavity-nesting birds. General Technical Report PSW-GTR-181. USDA Forest Service, Pacific Southwest Research Station, Ogden, Utah, USA.

Saab, V. A., and J. G. Dudley. 1998. Responses of cavity-nesting birds to stand-replacement fire and salvage logging in ponderosa pine/Douglas-fir forests of southwestern Idaho. Research Paper PMRS-RP-11. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado, USA.

Saab, V. A., R. E. Russell, and J. G. Dudley. 2009. Nest-site selection by cavity-nesting birds in relation to postfire salvage logging. Forest Ecology and Management 257:151–159.

Sadoti, G., and K. T. Vierling. 2010. Nonideal habitat selection by a North American cavity excavator: pecking up the wrong tree? Canadian Journal of Zoology 88:527–535.

Saint-Germain, M., P. Drapeau, and C. M. Buddle. 2007. Host-use patterns of saproxylic phloeophagus and xylophagous Coleoptera adults and larvae along the decay gradient in standing dead black spruce and aspen. Ecography 30:737–748.

SAS Institute. 2011. SAS 9.3. SAS Institute, Cary, North Carolina, USA.

Schepps, J., S. Lohr, and T. E. Martin. 1999. Does tree hardness influence nest-tree selection by primary cavity nesters? Auk 116:658–665.

Scott, V. E. 1978. Characteristics of ponderosa pine snags used by cavity-nesting birds in Arizona. Journal of Forestry 76:26–28.

Shigo, A. L. 1984. Compartmentalization: a conceptual framework for understanding how trees grow and defend themselves. Annual Review of Phytopathology 22:189–214.

Spiering, D. J., and R. L. Knight. 2005. Snag density and use by cavity-nesting birds in managed stands of the Black Hills National Forest. Forest Ecology and Management 241:40–52.

Straus, M. A., K. Bavrlic, E. Nol, D. M. Burke, and K. E. Elliot. 2011. Reproductive success of cavity-nesting birds in partially harvested woodlots. Canadian Journal of Forest Research 41:1004–1017.

Strukelj, M., S. Brais, S. A. Quideau, V. A. Angers, H. Kebli, P. Drapeau, and S. Oh. 2012. Chemical transformations in downed logs and snags of mixed boreal species during decomposition. Canadian Journal of Forest Research 43:785–798.

Symonds, M. R. E., and A. Moussalli. 2011. A brief guide to model selection, multimodel inference and model averaging in behavioral ecology using Akaike's Information Criterion. Behavioral Ecology and Sociobiology 65:13–21.

Thomas, J. W., R. G. Anderson, C. Maser, and E. L. Bull. 1979. Snags. Pages 60–77 *in* J. W. Thomas, editor. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agriculture Handbook Number 553. USDA Forest Service, Portland, Oregon, USA.

Tozer, D. C., E. Nol, D. M. Burke, K. A. Elliott, and K. J. Falk. 2009. Predation by bears on woodpecker nests: Are nestling begging and habitat choice risky business? Auk 126:300–309.

Vierling, K. T., L. B. Lentile, and N. Nielsen-Pincus. 2008. Preburn characteristics and woodpecker use of burned coniferous forest. Journal of Wildlife Management 72:422–427.

Vierling, K. T., V. A. Saab, and B. W. Tobalske. 2013. Lewis's Woodpecker (*Melanerpes lewis*). *In* A. Poole, editor. The birds of North America online. Cornell Lab of Ornithology, Ithaca, New York, USA.

Virkkala, R. 2006. Why study woodpeckers? The significance of woodpeckers in forest ecosystems. Annales Zoologici Fennici 43:82–85.

Walter, S. T., and C. C. Maguire. 2005. Snags, cavity-nesting birds, and silvicultural treatments in western Oregon. Journal of Wildlife Management 69:1578–1591.

Wiebe, K. L. 2001. Microclimate of tree cavity nests: Is it important for reproductive success in northern flickers? Auk 118:412–421.

Wiebe, K. L. 2011. Nest-sites as limiting resources for cavity-nesting birds in mature forest ecosystems: a review of the evidence. Journal of Field Ornithology 82:239–248.

Wightman, C. S., V. A. Saab, C. Forristal, K. Mellen-McLean, and A. Markus. 2010. White-headed woodpecker nesting ecology after wildfire. Journal of Wildlife Management 74:1098–1106.

Wilkins, H. D., and G. Ritchison. 1999. Drumming and tapping by red-bellied woodpeckers: description and possible causation. Journal of Field Ornithology 70:578–586.

Zahner, V., L. Sikora, and G. Pasinelli. 2012. Heart rot as a key factor for cavity tree selection in the black woodpecker. Forest Ecology and Management 271:98–103.

Supplemental Material

Ecological Archives

Appendices A–C are available online: http://dx.doi.org/10.1890/14-1042.1.sm

A referenced review of combined land development and climate impact on grizzly bears.

By Lance Olsen – last revised/updated 1-2-2018

Summary

Conservation of grizzly bears in the lower 48 US and associated acreage in Canada is and will continue to be adversely affected by simultaneous changes of climate and land development, a.k.a., subdivision, exurban sprawl, housing. Each change – land use or climate change -- is capable of important and even decisive impact on the bear, and, because they are now occurring simultaneously, they require evaluation as an influential, interacting combination.

The recent proposal to de-list the grizzly bear population of the Northern Continental Divide Ecosystem (NCDE) requires an integrated analysis of these important changes in grizzly bear habitat. However, the Habitat-Based Recovery Criteria skim lightly over the fact of two changes with combined effect on the bear via their combined effect on habitat.

Avoiding the worst consequences of climate change will require actions to avoid an accumulation of (even sub-lethal) extremes of heat including the health of any animal, *and I*

want to emphasize here that heat (temperature) itself must be considered a component or condition of habitat as important as any other component or condition.

I’ll also stress here that avoiding the worst consequences of land development will meet head on with the influential and tightly-coupled finance and real estate industries, which may staunchly oppose efforts to limit their impact on land, habitat, and species including but not limited to grizzly bears.

This review is an attempt to be inclusive of land development and climate impacts, but is not intended to be exhaustive. It may, however, emphasize lines of evidence which do not receive equal emphasis in, or are left missing from, other current assessments of the grizzly’s future.

Land development and grizzly bears

In its Winter 1982 issue, the University of Montana forestry school’s magazine, *Western Wildlands,* devoted an entire issue to articles by experts speaking to the status of grizzly bears in the lower 48 states. In his article, US Fish and Wildlife Service biologist Chris Servheen said development and human occupation (i.e., subdivision) was the "most detrimental" thing that could happen to grizzly country.

His summary of ill effects from human range expansion into and occupation of wildlife habitat has seen repeated confirmation in covering many species including the grizzly. Put broadly, assuming that land available for nature = total land area – area under agriculture and settlements (Lambin and Meyfroidt, 2011), a continued expansion of business, industrial and/or residential settlement into grizzly habitat will reduce land available for safe and ready access by wildlife including the grizzly bear. Making much the same basic point, Di Marco and Santini (2015) find that human pressures predict species' geographic range size better than biological traits.

That grizzlies will not be able to occupy towns and cities is clear, and the impact of development at the fringe of cities, and into rural areas, has been understood for some years as a limiting factor for many wild species. For example, Hansen et al (2005) reported that, "Low-density rural home development is the fastest-growing form of land use in the United States since 1950. This 'exurban' development (~6–25 homes/km^2) includes urban fringe development (UFD) on the periphery of cities and rural residential development

(RRD) in rural areas attractive in natural amenities.”

This expansion of human range into attractive wildlife habitat has lasting impact. Hansen et al found that the effects of real estate development “may be manifest for several decades following exurban development, so that biodiversity is likely still responding to the wave of exurban expansion that has occurred since 1950.” The authors also report that, “RRD is more likely than UFD to occur near public lands; hence it may have a larger influence on nature reserves and wilderness species.”

The long lasting impact of human range expansion in the form of land development was again emphasized in a broadly based, global finding that “lag time” from action to later consequence means that land use exerts cumulative influence on the biodiversity of the future, often leaving an “extinction debt” in which extinctions occur long after the conditions that set them in motion (Essl et al, 2015).

These findings lend confirmation to an earlier report that US national parks are too small to offer persisting survival of their signature mammals (Newmark, 1987). Ergo, it is of high interest that Martinuzzi et al (2015) find that “Land use change around protected areas can diminish their conservation value.”

Part of this diminishment for the grizzly bear lies in loss of security from human disturbance, harassment, and killing. That is, when grizzlies show up in an area that has been developed and occupied by human range expansion, the consequences can include a killing of the bears.

The importance of protecting land around protected areas had also been underscored by Prugh et al (2008) whose detailed analysis led to a conclusion that, while protected areas – and their size -- “are indeed important factors,” conservation may get even higher returns by improving the habitat quality of lands around and between them. In their review of Prugh et al, Franklin and Lindenmayer (2009) agreed, saying, “Matrix management matters because formal reserve systems will never cover more than a small fraction of the globe; human-modified land —the matrix— overwhelmingly dominates.”

Given likely future trends, the developed-land matrix adjacent to and near to protected areas will be exerting more not less influence on wildlife including grizzly bears in coming years and decades. Authors of a recent study project that human population growth “will result in a significant anthropogenic environmental change worldwide through increases in developed land (DL) consumption …. an important environmental and socioeconomic process affecting humans and ecosystems (Grekousis and Mountrakis, 2015).”

The authors add this: “Attention has been given to DL modeling inside highly populated cities. However, modeling DL consumption should expand to non-metropolitan areas where arguably the environmental consequences are more significant.” (Grekousis and Mountrakis, 2015).

A related study (Boakes et al) found “extreme contagion” of encroaching land use. That is, when acreage is taken under intense management, that change of the landscape can more readily spread to adjacent acreage. And, again, a key consideration here is not just that this acreage can be lost as habitat, but can also be a source of death for bears.

Nelson et al (2015) stress that, “Urban area and croplands will expand in the future to meet human needs for living space, livelihoods, and food. In order to jointly provide desired levels of urban land, food production, and ecosystem service and species habitat provision the global society will have to become much more strategic in its allocation of intensively managed land uses.”

Because local decisions on land development can soften or worsen local conditions brought by climate change, local support of conservation strategies will be essential even for “iconic” landscapes of national and international interest. (Scheffer et al, 2015). Outcomes are still in the process of being worked out, but it’s too soon to be dancing in the streets over some near-term success in long-term conservation of the grizzly bear in the Northern US Rockies and nearby Canada. Radeloff et al (2010) sum up the uncertainty of the situation: “Future housing patterns will be determined by society—by policies, land use plans, zoning ordinance, and consumer choices.”

One important strategic need seems plain enough for wildlife in general and for grizzlies in particular. Because the coupled finance and real estate industries jointly determine where land development will be placed, and how much will be placed there, any strategic allocation of intensive land use as part of grizzly bear conservation will require the engagement and support of both industries.

Laurance et al (2015) stress 9 key issues in 21st Century expansion of human range, 3 of them related to need for conservation entities and individuals to work with the finance industry -- and for finance to find relationships with conservation agencies and biologists. For example, "Financial institutions need to integrate long-term environmental protection into … the business case of individual projects." Real estate developers, often dependent on loans, face the same need.

Climate change and grizzly bears

Similarly to land development, combustion of fossil fuels imposes long-lasting effects. Although maximum heating made possible by combustion in any one year may be achieved within 10 years (Ricke and Caldeira, 2015), Solomon et al (2009) calculated that effects of elevated CO2 levels will be "irreversible" for as long as 1,000 years. Eby et al (2009) calculated effects lasting up to 10,000 years, which also indicates irreversible and irretrievable impact on species and systems.

Placing limits on the accumulating heat is essential to species and systems because every organism only survives and thrives within thermal limits. A direct implication of thermal limits is that no description or evaluation of habitat is complete without heat included as a key, even decisive, feature of habitat. For example, Dell et al (2013) report that, " … organisms have a physiological response to temperature, and these responses have important consequences" including that, "biological rates and times (e.g. metabolic rate, growth, reproduction, mortality and activity) vary with temperature."

Portner et al (2008) had earlier pointed out that, "All organisms live within a limited range of body temperatures," and that, "Direct effects of climatic warming can be understood through fatal decrements in an organism's performance in growth, reproduction, foraging, immune competence, behaviors and competitiveness."

Portner et al add that, "Performance in animals is supported by aerobic scope, the increase in oxygen consumption rate from resting to maximal," and that only a passive anaerobic existence is possible beyond thermal limits.

Any increased demand for oxygen under increasing heat has *direct* implications for any animal involved in vigorous activity including digging, running in pursuit of prey, mating, and in the frequently vigorous play of cubs. In turn, an animal’s oxygen demand may be linked to its risk of extinction (McAlester, 1970). A recent report indicates that a vertebrate animal’s oxygen demand can impose limits on the animal’s tolerance for heat (Smith et al, 2015).

Meanwhile, we’ve been turning up the heat. Meehl and Tebaldi (2004) reported evidence of “more intense, more frequent, and longer lasting heat waves in the 21st Century.” Only five years later, Gangulya et al (2009) reported that, globally, “Observed heat wave intensities in the current decade are larger than worst-case projections."

Duffy and Tebaldi (2012) detected evidence of an increasing prevalence of extreme summer temperatures in the U.S. Recent findings also include indications that US heat waves may become more long-lasting at mid-latitudes in response to loss of Arctic Ocean ice cover (Commou et al, 2015).

A study at global scale indicates that, for a variety of reasons including drought-driven reduction of the plant food base, a wide variety of species across the globe are already “shrinking” today (e.g., Sheridan and Bickford, 2011). An earlier review cited lines of evidence that large body size has often been a disadvantage in the history of mammalian evolution (Davies et al, 2008)

All of which becomes important when we ask how hot the world will get for large-bodied mammals including the grizzly. Although widely implied in the by-now familiar language of feedback mechanisms, what's typically left unsaid is that boosting the heat to 2C above pre-industrial levels would effectively crank it up to 6C.

As Lynas (2008) describes it, "If … we cross the 'tipping point' of Amazonian collapse and soil carbon release that lies somewhere above two degrees, then another 250 ppm of CO2 would pour into the atmosphere, yielding another 1.5C (2.7F) of warming and taking us straight into the four-degree world. Once we arrive there, the accelerated release of carbon and methane from thawing Siberian permafrost will send even more greenhouse gas into the atmosphere, driving yet more warming, and perhaps pushing us on into the five-degree world. At this level of warming, … organic methane hydrate release becomes a serious possibility, catapulting us into the ultimate mass extinction apocalypse of six degrees. The lesson is as clear as it is daunting: If we are to be confident about saving humanity and the planet from the worst mass extinction of all time, worse even than that at the end of the Permian, we must stop at two degrees."

To determine credibility of the 2C→6C scenario within the climate science community, this discussion should help:

<< http://www.realclimate.org/index.php/archives/2007/11/six-degrees/>>

Can climate affect species and systems?

While biologists faced initial skepticism within IPCC about claims linking climate change to adverse impact on living species and systems, that controversy was effectively resolved following an important synthesis of evidence (Parmesan and Yohe, 2003). Overall, climate effects have been increasingly well documented for aquatic, marine, and terrestrial species and systems (Walther et al, 2002). In her review of over 800 research reports, Parmesan (2006) noted that "A surprising result is the high proportion of species responding to recent, relatively mild climate change (global average warming of 0.6 C)."

Since Parmesan's 2006 report, the heat has increased, with continued combustion of forest and fossil fuel bringing it to 0.85C by 2015. A recent calculation by IPCC scientists lends plausibility to concerns that it's too late for halting the heat at 1.5C (Tschakert, 2015). Equally relevant, one team of researchers found that ecosystems will begin unraveling between 1 and 2C (Leemans and Eickhout, 2004). Since then, Anderson and Bows (2011) cite evidence that 2C should be considered the point at which the world reaches a "very dangerous" rather than merely a dangerous threshhold.

Wherever the threshold lies, Schellenhuber (2008) has said that, "the race between climate dynamics and climate policy will be a close one."

Indications that climate dynamics are gaining the upper hand over policy have shown up in evidence of a long-expected slowing of the Atlantic Meridian Overturning (Rahmstorf et al, 2015). A separate recent study finds slowing of the Amazon's important function as a carbon sink (Brienen et al, 2015). Another independent study found weakening or slowing carbon sinks of land and ocean alike, on a worldwide scale (Raupach et al, 2014).

Possibly most dangerous for forest components of grizzly habitat is "hot drought" (Overpeck, 2013), a combination of drought and extreme heat which has already proven capable of killing trees outright in the U.S. (Breshears et al, 2005) and globally (Allen et al, 2010). Scientists have already been weighing evidence that forests today may well be grasslands or shrublands tomorrow, which would affect grizzlies indirectly by changing the world immediately around them.

One way their world will change with heat and drought will be in the foods available. While one recent report (Ripple et al, 2015) cites evidence that the serviceberry is becoming a more important food source for Yellowstone grizzlies, and while the serviceberry plant itself is widely regarded as drought tolerant, it is difficult to find support for a scenario in which this or any other plant’s production of berries can continue under increased and still increasing drought and heat.

While even a cursory review of threats to Northern US and associated Canadian Rockies grizzlies’ food supply is beyond the scope of this assessment, the case of carpenter ants may be instructive. For example, Frank et al (2015) find that carpenter ants depend on course woody debris, while Peterson et al (2015) find that policy regarding post-fire logging favors removal of woody debris because it can provide fuel for fire.

For one more example, it seems plausible that no inventory and analysis of food diversity for grizzlies can avoid implications of climate change impact on the grasses (Craine, et al 2012). Again, it’s plausibly too soon for confidence in the currently popular assumption that grizzlies will have many alternative foods to support them in the ilimited area where we'll allow them.

For most of lower 48 grizzly country, one climate-driven change of habitat would include a shift away from a region dominated by conifer needles (Westerling, et al 2011) to a region where what's left is the leaves of deciduous species, plausibly including shrubs. Shrubs can provide the bear with important hiding cover where climate eliminates trees. However, Couture et al (2015) find that a high-CO2 world can affect insect consumption of and damage to leaves: "Using a light-use efficiency model, we show that the negative impacts of herbivorous insects on net primary production more than doubled under elevated concentrations of CO2," and "We conclude that herbivorous insects may limit the capacity of forests to function as sinks for anthropogenic carbon emissions in a high CO2 world." Others have cited evidence that forest cover can be replaced not by shrubs, but by grasses, which cannot provide hiding cover.

When paired to observed data regarding weakening or slowing of large scale ocean process such as the Atlantic overturning (Rahmstorf et al, op, cit.), similar slowing of

Amazon carbon capture (Brienen et al, op. cit.), and a possible slowing of carbon capture by land and sea alike (Raupach et al, op. cit.), any insect-driven weakening or slowing of forest carbon sinks fits neatly within growing concerns about “critical slowing down,” a process which can identify the approach of natural systems’ catastrophic-scale collapse before that catastrophic shift becomes fact.

For example, van Nes and Scheffer (2007) reported that, “In all the models we analyzed, critical slowing down becomes apparent quite far from a threshold point, suggesting that it may indeed be of practical use as an early warning signal ” of “catastrophic shift” in natural systems. The following years saw continuing interest in risk of critical slowing down and catastrophic shifts in natural systems (e.g., Biggs et al, 2009; Drake and Griffen, 2010; Carpenter et al, 2011; Dai et al, 2012; Dornelas et al, 2012; Barnovsky et al, 2012, Dakos and Bascompte, 2014).

In continuing concern about risk revealed in these successive studies, Martin et al (2015) could report that catastrophic shift is “a paramount concern” and that examples “can be found in ecology, climate sciences, and economics, to name a few, where regime shifts have catastrophic consequences that are mostly irreversible.”

The documented predictive power of critical slowing down should not be ignored or shrugged off in the case of a slowing in the recovery of threatened or endangered species, including the grizzly bears of the lower 48 United States.

Many maintain that the unreliability of local weather forecasts beyond the next few days is proof that climate science can't reliably show us what to expect in the next few decades. However, Sawyer (1972) set out expectations of CO2 driven heat which were precise enough that, a little over 3 decades later, another observer (Nicholls, 2007) could remark that, "Despite huge efforts, and advances in the science, the scientific consensus on the amount of global warming expected from increasing atmospheric carbon dioxide concentrations has changed little from that in Sawyer's time."

Some interactions of climate and land change

Forests affect the climate, climate affects the forests, and, just as in the race between climate dynamics and climate policy, the climate may be gaining the upper hand. In 1888, the Chief of the Forest Division, U.S. Geological Survey, could report that, "The woodland and forest may be considered … as a physical factor with effects on climate, erosion, and the flow of streams." (Gannet, 1888) However, by 2012 the US Forest Service could report that, “Climate change will alter ecosystem services, perceptions of value, and decisions regarding land uses” (USDA Forest Service, 2012).

Animals are as subject to simultaneous change of climate and land use as forests are. While Di Marco and Santini (2015) reported that human pressures predict species’ geographic range size better than biological traits, they also found that climate joins land use as a deciding factor for species’ decline: “Our model had high predictive ability and showed that climatic variables and human pressures are the most influential predictors of range size,” and “These findings were confirmed when repeating the analyses on large-ranged species, individual biogeographic regions and individual taxonomic groups. Climatic and human impacts have determined the extinction of mammal species in the past and are the main factors shaping the present distribution of mammals.”

Grizzlies have already been among the animals affected by the combination of climate and human expansion around the bears. In a study of drought’s impact on distribution of

Yellowstone grizzlies, Picton et al (1985) found that, “Habitat available to the population is characterized by sporadic and widely fluctuating food production primarily controlled by weather. The natural carrying capacity of the overall habitat fluctuates accordingly. During years of low carrying capacity, bears compensate by using a larger area” and, in using the larger area, “more of them are likely to die, ” because their use of larger areas takes them into conflict with the human occupants of developed areas.

This risk was subsequently supported by the Teitelbaum et al (2015) conclusion that “Resource-poor environments are known to increase the size of mammalian home ranges and territories.” Specifically supporting Picton et al on the effects of drought, Teitelbaum’s team found that, “when all other variables were held constant, animals living in regions that exhibited low vegetation greenness (i.e. mean annual NDVI c. 0.06) had a predicted migration distance of 206 km and animals in regions with relatively high vegetation greenness (i.e. mean annual NDVI c. 0.80) had a predicted migration distance roughly one-tenth as large.”

Drought continues to be a key risk for conservation of wild species including grizzlies. Within Yellowstone Park, for example, a drying trend was found when researchers put their focus on amphibians (McMenamin et al, 2008) and found declining numbers driven by a drying up of wetlands. In the larger region around the park, Leppi et al (2012) found evidence of drought in a fairly widespread decline of late season stream flows, concluding that trends of increasing heat "pose serious concern for aquatic ecosystems" of the region's Rockies. In an assessment of streamflows in the larger Pacific Northwest, Luce et al (2009) also reported declining streamflows.

But drought is not alone in forcing grizzlies to expand their range size. Grizzlies' range expansion and subsequent mortality is also increased when, as Hagen et al (2015) report in a study of Scandanavian grizzlies, "Recovery of natural populations occurs often with simultaneous or subsequent range expansions."

Thus, two pressures combine to force the bear to expand its range, and to do so in the same time that humans expand into the same range. The upshot is that, instead of being the much-touted endgame for North American grizzly recovery from threatened status, an increased number of bears, in an increasingly dry western U.S. has become a beginning of another risk to the bear's habitat needs and to its risks from human disturbance, harassment, and killing.

Biologists had previously failed to convince IPCC that climate change was having impact on living species and systems. Today, it is or should be hard to convince that it isn’t, and is or should be hard to convince that it won’t have adverse consequences for the grizzly bears of the Northern U.S. Rockies and adjacent/nearby grizzly bears in Canada. Especially when combined with land development, the many consequences of increasing worldwide heat will have important, even decisive impact on the bear’s future distribution, population density, reproduction, pursuit of prey, food supply, metabolism including oxygen requirements, and exposure to human-caused mortality.

Because temperature and precipitation are key features of climate -- and of habitat including food supply -- it may be of more than merely incidental interest that, with temperature still at only 0.85C above pre-industrial levels, Griffin et al (2011) could report that “Neonatal elk survival to 3 months declined following hotter previous summers and increased with higher May precipitation, especially in areas with wolves and/or grizzly bears.”

Conclusion

For most of the 20th Century, most scientists assumed that climate change could only occur too slowly for people to notice (Weart, 2003). It’s since become clear that change can come much more quickly, and that the rate of change has often gone unacknowledged. Weart reminded his fellow physicist readers of *Physics Today* that, “A committee of the National Academy of Sciences (NAS) has called this reorientation in the thinking of scientists a veritable 'paradigm shift.' The new paradigm of abrupt global climate change, the committee reported in 2002, 'has been well established by research over the last decade, but this new thinking is little known and scarcely appreciated in the wider community of natural and social scientists and policymakers.' "

Smith et al (2014) stress that the rate of climate change is a crucial variable because, with faster rates of change, there is “less time for human and natural systems to adapt.” Their study focused on risk of near-term acceleration of temperature change, and found temperatures climbing at rates “unprecedented for at least the past 1,000 years.” They add that “Regional rates of change in Europe, North America and the Arctic are higher than the global average.”

Rate of change has been similarly emphasized in Mora et al

(2013), who project that the high extreme temperatures of today will have become the coolest temperatures by 2047-2069, well within the lifetimes of many people.

Because a substantial variety of changes of climate and land development will be combining to influence outcomes, and plausibly at increasing speed, some are raising questions about agency, individual, and organization capacity to deal with it. In a study of “risk aversion,” Tulloch, et al (2014) point out that agencies making decisions about actions to take to save species “frequently face the dilemma of whether to invest in actions with high probability of success and guaranteed benefits or to choose projects with a greater risk of failure that might provide higher benefits if they succeed. The answer to this dilemma lies in the decision maker’s aversion to risk—their unwillingness to accept uncertain outcomes.”

That same concern is raised in a paper asking explicitly if “fear of failure” can influence decisions about conservation of small populations (Meek et al, 2015). And a separate line of inquiry asks whether any current conservation entities are “configured” well enough to accomplish what’s expected of them in a time of complex global change (Armsworth et al, 2015). How well these questions are answered in day-to-day practice, all while keeping the public informed and engaged, will play an important role in shaping the future of grizzly bears.

A large part of the needed answers arise when we see that the finance and land development industries have a shared and substantial influence over where and how much development takes place, and that land development will be taking place alongside the changes also being forced by a topic of longstanding importance in the history of physics: *heat*.

And all that follows in heat's powerful wake.

References

Allen, Craig D., Alison K. Macalady, Haroun Chenchouni, Dominique Bachelet, Nate McDowell, Michel Vennetier, Thomas Kitzberger et al. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management.* 5 February 2010

Anderson, Kevin, and Alice Bows. Beyond 'dangerous' climate change: emission scenarios for a new world.

Philosophical Transactions of the Royal Society A: *Mathematical, Physical and Engineering Sciences* (2011) 369, 20–44 doi:10.1098/rsta.2010.0290

Armsworth, et al. Are conservation organizations configured for effective adaptation to global change? *Frontiers in Ecology and the Environment.* April 2015

Barnovsky et al. Approaching a state shift in Earth's biosphere. *Nature.* June 7, 2012

Boakes, Elizabeth H., Georgina M. Mace, Philip J. K. McGowan and Richard A. Fuller. Extreme contagion in global habitat clearance. *Proceedings of the Royal Society B: Biological Sciences,* published online 25 November 2009

Biggs, Reinette, Stephen R. Carpenter, and William A. Brock. Turning back from the brink: Detecting an impending regime shift in time to avert it. *PNAS*. January 20, 2009

Breshears, David D., Neil S. Cobb, Paul M. Rich, Kevin P. Price, Craig D. Allen et al. Regional vegetation die-off in response to global-change-type drought. *PNAS,* October 10, 2005.

Carpenter, S. R., J. J. Cole, M. L. Pace, R. Batt et al. Early Warnings of Regime Shifts: A Whole-Ecosystem Experiment. *Science*, 27 MAY 2011

Craine, Joseph M. et al. Timing of climate variability and grassland productivity. *Proceedings of the National Academy of Sciences USA* Early Edition, February, 2012, www.pnas.org/cgi/doi/10.1073/pnas.1118438109

Dai, Lei, Daan Vorselen, Kirill S. Korolev, Jeff Gore. Generic Indicators for Loss of Resilience Before a Tipping Point Leading to Population Collapse. *Science,* 1 JUNE 2012

Dakos, Vasilis and Jordi Bascompte. Critical slowing down as early warning for the onset of collapse in mutualistic communities. *PNAS* Published online before print November 24, 2014

Davies, J. et al. Phylogenetic trees and mammalian biodiversity. *Proceedings of the National Academy of Sciences USA*, Aug. 12, 2008.

Dell, Anthony I., Samraat Pawar and Van M. Savage, Temperature dependence of trophic interactions are driven by asymmetry of species responses and foraging strategy. *Journal of Animal Ecology,* May 21, 2013

Di Marco, Moreno and Luca Santini. Human pressures predict species' geographic range size better than biological traits. *Global Change Biology*, Feb 20, 2015

Dornelas, Maria, Anne E. Magurran et al. Quantifying temporal change in biodiversity: challenges and opportunities. *Proceedings of the Royal Society B: Biological Sciences*. Published ahead of print October 24, 2012

Drake, M., and Blaine D. Griffen. Early warning signals of extinction in deteriorating environments. *Nature,* Published online 8 September 2010.

Duffy, P. B. & Tebaldi, C.. Increasing prevalence of extreme summer temperatures in the U.S.A. *Climatic Change*. Published online: 21 January 2012. DOI 10.1007/s10584-012-0396-6

Eby, M. et al. Lifetime of Anthropogenic Climate Change: Millennial Time Scales of Potential CO2 and Surface Temperature Perturbations. *Journal of Climate* 15 MAY 2009

Essl, Franz, Stefan Dullinger, Wolfgang Rabitsch, Philip E. Hulme, Petr Pysek, John R. U. Wilson and David M. Richardson. Historical legacies accumulate to shape future biodiversity in an era of rapid global change. *Diversity and Distributions*, 1–14, a 2015

Frank, Shane C., Sam M.J.G. Steyaert‥ A “clearcut” case? Brown bear selection of coarse woody debris and carpenter ants on clearcuts. *Forest Ecology and Management*. 15 July 2015.

Franklin, Jerry F. and David B. Lindenmayer. Importance of matrix habitats in maintaining biological diversity *PNAS* January 13, 2009 vol. 106 no. 2 349–350

Gangulya, Auroop R. et al. Higher trends but larger uncertainty and geographic variability in 21st century temperature and heat waves. *PNAS*, September 15, 2009.

Gannett, Henry. *Forests of the United States: 19th Annual Report*, Part 5 (1888), pp. 1-3.

Gramling, Carolyn. Arctic Impact: Is the melting Arctic really bringing frigid winters to North America and Eurasia? Scientists struggle to piece together an atmospheric puzzle.

Science, 20 February 2015

Grekousis, George, and Giorgos Mountrakis. Sustainable Development under Population Pressure: Lessons from Developed Land Consumption in the Conterminous U.S. *PlosOne*. March 25, 2015

Griffin, Kathleen A., Mark Hebblewhite, Hugh S. Robinson, Peter Zager, Shannon M. Barber-Meyer et al. Neonatal mortality of elk driven by climate, predator phenology and predator community composition. *Journal of Animal Ecology* 2011, 80, 1246–1257

Hagen, Snorre B. , Alexander Kopatz , Jouni Aspi , Ilpo Kojola , Hans Geir Eiken. Evidence of rapid change in genetic structure and diversity during range expansion in a recovering large terrestrial carnivore. *Proceedings of the Royal Society B: Biological Sciences*. 22 April 2015

Hansen, Andrew J., Richard L. Knight, John M. Marzluff, Scott Powell, Kathryn Brown, Patricia H. Gude, and Kingsford Jones. Effects of Exurban Development on Biodiversity: Patterns, Mechanisms, and Research Needs. *Ecological Applications* 15: 2005

Lambin, Eric F. and Patrick Meyfroidt. Global land use change, economic globalization, and the looming land scarcity. *PNAS,* March 1, 2011

Laurance, William F., Anna Peletier-Jellema, Bart Geenen, Harko Koster, Pita Verweij, Pitou Van Dijck, Thomas E. Lovejoy, Judith Schleicher, Marijke Van Kuijk. Reducing the global environmental impacts of rapid infrastructure expansion. *Current Biology*, March 30, 2015

Leemans, Rik, and Bas Eickhout. Another reason for concern: regional and global impacts on ecosystems for different levels of climate change. *Global Environmental Change*, 10/2004

Leppi, Jason C. et al. Impacts of climate change on August stream discharge in the Central-Rocky Mountains. *Climatic Change.* DOI 10.1007/s10584-011-0235-1

Luce, C. H., and Z. A. Holden (2009), Declining annual streamflow distributions in the Pacific Northwest United States, 1948–2006. *Geophysical Research Letters*, 36, L16401, doi:10.1029/2009GL039407.

Lynas, Mark. *Six Degrees*. 2008. National Geographic Society by arrangement with HarperCollins.

Martín, Paula Villa, Juan A. Bonachel, Simon A. Levin, and Miguel A. Muñozc. Eluding catastrophic shifts. *PNAS,* March 27, 2015

Martinuzzi, Sebastián, Volker C. Radeloff, Lucas N. Joppa, Christopher M. Hamilton, David P. Helmers, Andrew J. Plantinga, David J. Lewis. Scenarios of future land use change around United States' protected areas. *Biological Conservation* 184 (2015) 446–455

McAlester, A. Lee. Animal Extinctions, Oxygen Consumption, and Atmospheric History. *Journal of Paleontology*. Vol. 44, No. 3 (May, 1970), pp. 405-409

McMenamin, Sarah et al. Climatic change and wetland desiccation cause amphibian decline in Yellowstone National Park. *Proceedings of the National Academy of Sciences USA*, November 4, 2008

Meek, Mariah H., Caitlin Wells, Katharine M. Tomalty, Jaime Ashander, Esther M. Cole, Daphne A. Gille , et al. Fear of failure in conservation: The problem and potential solutions to aid conservation of extremely small populations. *Biological Conservation* 184 (2015)

Meehl, Gerald A. and Claudia Tebaldi. More Intense, More Frequent, and Longer Lasting Heat Waves in the 21st Century**.** *Science*, 13 August 2004

Mora, Camilo, Abby G. Frazier, Ryan J. Longman, Rachel S. Dacks, Maya M. Walton et al. The projected timing of climate departure from recent variability. *Nature,* 10 October 2013

Nelson, Erik, Heather Sander et al. Projecting Global Land-Use Change and Its Effect on Ecosystem Service Provision and Biodiversity. *PloSONE* December 15, 2010. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0014327

Newmark, William D. A land-bridge island perspective on mammalian extinction in western North American parks. *Nature.* 29 January 1987

Nicholls, Neville. Climate: Sawyer predicted rate of warming in 1972. *Nature,* 30 August 2007

Overpeck, JONATHAN T. The Challenge of Hot Drought. *Nature.* VOL 503 | 21 NOVEMBER 2013

Parmesan, Camille, and Gary Yohe. A globally coherent fingerprint of climate change impacts across natural systems. *Nature,* 2 JANUARY 2003

Parmesan, Camille. Ecological and Evolutionary Responses to Recent Climate Change. *Annual Review of Ecology Evolution & Systematics.* 2006.

Peterson, David W , Erich K. Dodson, Richy J. Harrod. Post-fire logging reduces surface woody fuels up to four decades following wildfire. *Forest Ecology and Management*. 15 February 2015

Picton, H.D., D.M. Mattson, B.M. Blanchard and R.R. Knight. Climate, Carrying Capacity, and the Yellowstone Grizzly Bear. *Proceedings: Grizzly Bear Habitat Symposium, General Technical Report INT-207,* 1985

Portner, Hans O., and Anthony P. Farrell. Physiology and Climate Change. *Science* 31 October 2008

Prugh, Laura R., Karen E. Hodges, Anthony R. E. Sinclair, and Justin S. Brashares. Effect of habitat area and isolation on fragmented animal populations. *PNAS* 2008 Dec 30; 105(52): 20770–20775.

Rahmstorf, Stefan, Jason E. Box, Georg Feulner, Michael E. Mann, Alexander Robinson, Scott Rutherford & Erik J. Schaffernicht. Exceptional twentieth-century slowdown in Atlantic Ocean overturning circulation. *Nature Climate Change* 23 March 2015

Raupach, M. R., M. Gloor, J. L. Sarmiento, J. G. Canadell, T. L. Frölicher, T. Gasser, R. A. Houghton, C. Le Quéré, and C. M. Trudinger. The declining uptake rate of atmospheric CO2 by land and ocean sinks. *Biogeosciences*, 2 July 2014

OPEN ACCESS
Ricke, Katharine L and Ken Caldeira. Maximum warming occurs about one decade after a carbon dioxide emission. *Environ. Res. Letters.* 2 December 2014

Ripple, William J., Robert L. Beschta, Jennifer K. Fortin and Charles T. Robbins. Wolves trigger a trophic cascade to berries as alternative food for grizzly bears (pages 652–654 *Journal of Animal Ecology*), 3 MAR 2015

Sawyer, J. S. Man-made carbon dioxide and the "greenhouse" effect. *Nature* 239, 23–26; 1972

Scheffer, M., S. Barrett, S. R. Carpenter, C. Folke, A. J. Green, M. Holmgren et al. A safe operating space for iconic ecosystems: Manage local stressors to promote resilience to global change. *Science* 20 MARCH 2015

Schellenhuber, Hans Joachim. Global warming: Stop worrying, start panicking? *Proceedings of the National Academy of Sciences.* September 23, 2008

Smith, Colton , Rory S. Telemeco , Michael J. Angilletta , John M. VandenBrooks. Oxygen supply limits the heat tolerance of lizard embryos. *Biology Letters* April 2015

Smith, Steven J., James Edmonds, Corinne A. Hartin, Anupriya Mundra & Katherine Calvin. Near-term acceleration in the rate of temperature change. *Nature Climate Change*, Published online 09 March 2015

Solomon, Susan**,** Gian-Kasper Plattner, Reto Knutti, and Pierre Friedlingstein**.** Irreversible climate change due to carbon dioxide emissions. *Proceedings of the National*

Academy of Sciences, February 10, 2009

Teitelbaum, Claire S., William F. Fagan, Chris H. Fleming, Gunnar Dressler, Justin M. Calabrese, Peter Leimgruber and Thomas Mueller. How far to go? Determinants of migration distance in land mammals. *Ecology Letters*, (2015) doi: 10.1111/ele.12435

Tschakert, Petra. 1.5°C or 2°C: a conduit's view from the science-policy interface at COP20 in Lima, Peru. *Climate Change Responses* March 27, 2015.

Tulloch, Ayesha I.T., Richard F. Maloney, Liana N. Joseph et al. Effect of Risk Aversion on Prioritizing Conservation Projects. *Conservation Biology*, 2014

van Nes, Egbert H. and Marten Scheffer. Slow Recovery from Perturbations as a Generic Indicator of a Nearby Catastrophic Shift. *The American Naturalist* June 2007

Walther, G. et al**,** Ecological responses to recent climate change. *Nature*, March 28, 2002

Weart, Spencer. The Discovery of Rapid Climate Change. *Physics Today* August 2003.

http://scitation.aip.org/content/aip/magazine/physicstoday/article/56/8/10.1063/1.1611350

Westerling, Anthony L., et al. Continued warming could transform Greater Yellowstone fire regimes by mid-21st century. *PNAS* Early Edition July 25, 2011 www.pnas.org/cgi/doi/10.1073/pnas.1110199108