HIGH COUNTRY CONSERVATION ADVOCATES
CENTER FOR BIOLOGICAL DIVERSITY
ROCKY SMITH

March 30, 2020

Reviewing Officer
U.S.D.A. Forest Service
Rocky Mountain Region
1617 Cole Blvd. Building 17
Golden, CO 80401
Via Email: SM.FS.r02admin-rev@usda.gov

Re: OBJECTIONS Pursuant to 36 C.F.R. § 218.8 to Taylor Park Vegetation Management Project, Gunnison Ranger District, Gunnison National Forest

Dear Reviewing Officer:

High Country Conservation Advocates (HCCA), the Center for Biological Diversity, and Rocky Smith, collectively "Objectors," hereby submit these objections to the Gunnison National Forest's draft Decision Notice (DDN), Finding of No Significant Impact (FONSI) and final environmental assessment (Final EA) for the Taylor Park Vegetation Management Project.

At the same time, we acknowledge that the Forest Service made some significant improvements between its Preliminary EA and Final EA that should reduce some impacts. We appreciate that the Gunnison Ranger District listened to neighbors, conservationists, and county representatives in reducing some project impacts, especially from new road construction. We find it extremely disappointing, therefore, that near the end of the NEPA process the Forest Service added a contentious, significant, and surprising project expansion with virtually no environmental review. We must regretfully file this objection and hope that the Forest Service will eliminate those eleventh-hour and unanalyzed portions of the project that undercut the modest progress toward a more collaborative project development process. The Forest Service still has a chance to take one step forward if it removes Contingency Treatment Areas and undefined logging areas, as opposed to the two steps back the DDN represents. The Forest Service has also not responded to our concerns about accurately displaying the potential effects on lynx.

<u>Project Objected To</u>
Pursuant to 36 C.F.R. § 218.8(d)(4), HCCA objects to the following project:

> *Project*: Taylor Park Vegetation Management Project, Gunnison Ranger District, Gunnison County, Colorado

Responsible Official and Forest/Ranger District: Matthew McCombs, District Ranger, Gunnison Ranger District, Gunnison National Forest

Timeliness

These objections are timely filed. Notice of the DDN and FONSI was published in the Gunnison Country Times (the newspaper of record) on Thursday, February 27, 2020.

Lead Objector

As required by 36 C.F.R. § 218.8(d)(3), the Objectors designate the "Lead Objector" as follows:

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Interests and Participation of the Objectors

Based out of Gunnison County, **High Country Conservation Advocates** (HCCA) is a non-profit organization with over 1,000 members. HCCA is actively involved in monitoring and scrutinizing National Forest management, overseeing government decision-making and compliance with environmental laws, advocating for better stewardship of natural systems, and working for improvements to environmental health. HCCA members use and plan to use the federal lands in the Gunnison District of the Gunnison National Forest, including specifically the national forest lands included within Taylor Park project area. HCCA members are affected by the proposed project activities.

HCCA has participated in all public processes for this project thus far. We submitted scoping comments on May 21, 2018; submitted comments on the Preliminary EA on May 13, 2019; and submitted comments on supplemental materials made available from the Forest Service on January 15, 2020. HCCA staff attended the Forest Service's public meeting in Tincup on June 21, 2018. Staff are also members of the Taylor Park Adaptive Management Group and have attended most, if not all, of the meetings associated with the Group's formation and implementation.

The **Center for Biological Diversity** is a non-profit environmental organization with over 61,000 members, and 1.6 million activist-supporters nationwide who value wilderness, biodiversity, old growth forests, and the threatened and endangered species which occur on America's spectacular public lands and waters. Center members and supporters use and enjoy the GMUG National Forest, and the lands of the Taylor Park project area for recreation, photography, nature study, and spiritual renewal. Headquartered in Tucson, Arizona, the Center has offices in Denver and Crested Butte, Colorado

The Center for Biological Diversity believes that the welfare of human beings is deeply linked to nature — to the existence in our world of a vast diversity of wild animals and plants. Because diversity has intrinsic value, and because its loss impoverishes society, we work to secure a future for all species, great and small, hovering on the brink of extinction. We do so through science, law and creative media, with a focus on protecting the lands, forests, waters and climate that species need to survive. The Center has and continues to actively advocate for increased protections for species and their habitats in western Colorado and across the American Southwest. The Center submitted scoping comments on May 21, 2018; submitted joint comments with HCCA, as well as their own supplemental comments on the Preliminary EA on May 13, 2019; and submitted joint comments with HCCA on January 15, 2020 on supplemental materials made available from the Forest Service.

Rocky Smith is a forest management analyst and consultant with 40 years' experience in reviewing projects, plans, policies, and legislation concerning the management of national forests. Rocky submitted scoping comments on May 21, 2018 and submitted comments on the Preliminary EA on May 13, 2019.

I. THE FINAL EA VIOLATES NEPA BECAUSE IT FAILS TO DISCLOSE SITE-SPECIFIC IMPACTS.

Objectors raised this issue on page 8 of our joint May 13, 2019 comments on the Preliminary Draft and pages 1-6 of our joint January 15, 2020 comments on the Supplemental EA.

Selected Alternative 2 in the Final EA differs markedly from the proposed action in the preliminary EA, and from project direction contemplated in scoping documents, in that it more than triples the acreage identified for salvage logging in anticipation of potential mortality events, from 8,767 acres to 29,095 acres, while providing little to no baseline data for those acres, nor analysis of direct, indirect, or cumulative impacts of logging any or all of these additional lands. The inclusion of these Contingency Treatment Areas (CTAs), as well as 3,153 acres of "fuel treatments to be determined," where various types of logging could be applied over a to-be-determined timeframe extending potentially two decades, is not accompanied by requisite NEPA analysis. The Final EA is devoid of the site-specific information required under NEPA, and the adaptive management framework contemplated for the project is not a legally-compliant substitute. We would likely not be filing this administrative objection had these CTAs not been added to the project decision at the tail-end of the public process.

A. NEPA Requires Agencies to Take a Hard Look at Site-Specific Impacts.

NEPA is "our basic national charter for protection of the environment."[1] It has two fundamental purposes: "(1) to ensure that the agency will have detailed information on significant environmental impacts when it makes decisions; and (2) to guarantee that this information will be available to a larger audience."[2] As discussed in greater detail in sections below, neither of these are satisfied with the Taylor

[1] 40 C.F.R. § 1500.1.

[2] *Envtl. Prot. Info. Ctr. v. Blackwell*, 389 F. Supp. 2d 1174, 1184 (N.D. Cal. 2004) (quoting *Neighbors of Cuddy Mt. v. Alexander*, 303 F.3d 1059, 1063 (9th Cir. 2002)); *see also Earth Island v. United States Forest Serv.*, 351 F.3d 1291, 1300 (9th Cir. 2003) ("NEPA requires that a federal agency 'consider every significant aspect of the environmental

Park analysis and decision. The agency is making a decision to potentially commit resources without providing detailed information and analysis upon which that decision is based, and without disclosing impacts of possible future actions.

Analyzing and disclosing site-specific impacts is critical because where, when, and how activities occur on a landscape strongly determine the nature of the impact. As the Tenth Circuit Court of Appeals has explained, the actual "location of development greatly influences the likelihood and extent of habitat preservation. Disturbances on the same total surface area may produce wildly different impacts on plants and wildlife depending on the amount of contiguous habitat between them."[3] Indeed, "location, not merely total surface disturbance, affects habitat fragmentation,"[4] and therefore location data is critical to the site-specific analysis NEPA requires. Merely disclosing the existence of particular geographic or biological features is inadequate—agencies must discuss their importance and substantiate their findings as to the impacts.[5] While the EA does show the locations of CTAs,[6] it does not identify what areas within those will be treated, nor by what means, nor by what date, nor what the forest conditions are now, nor what other values may be found within the CTAs, nor what they would be in the future when logging would take place. The Taylor Park decision sanctions logging across a wide and diverse landscape despite the fact that the Forest Service has failed to disclose the where, when, what, and how of that logging.

In *Muckleshoot Indian Tribe v. U.S. Forest Service*,[7] the Court held that the project-specific NEPA analyses that tiered to a programmatic EIS needed to consider the site specific impacts of a federal action because the programmatic EIS could not consider the site-specific impacts of later developed actions. Similarly, the Forest Service must conduct future NEPA analyses for potential projects totaling 29,095 acres of CTAs and 3,153 acres of fuel treatments, and must consider the site-specific impacts of those actions in those future NEPA analyses. The site-specific impacts that would occur as a result of the contingency and fuel treatments sanctioned by this project decision forbid the Forest Service from relying merely on the analysis in the Final EA, analysis that only adequately addresses a subset of that acreage.

Earlier this month, the District Court for the District of Alaska issued a decision underscoring the Forest Service's legal duty to disclose the when, where, and how of logging projects before approving project-level actions. The court found unlawful the agency's analysis of the Prince of Wales timber sale because it failed to disclose site-specific locations for roads and treatments. The District Court explains the approach the Forest Service took in the Prince of Wales EIS, describing that the document "analyzed" four alternatives, but that:

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impact of a proposed action . . . [and] inform the public that it has indeed considered environmental concerns in its decision-making process.'").

[3] *New Mexico ex rel. Richardson*, 565 F.3d at 706.

[4] *Id*.

[5] *Or. Natural Res. Council Fund v. Goodman*, 505 F.3d 884, 892 (9th Cir. 2007).

[6] Final EA at 32.

[7] *Muckleshoot Indian Tribe v. U.S. Forest Service*, 177 F.3d 800 (9th Cir. 1999).

> the alternatives do not provide the specific locations or configurations of harvest or roadbuilding within the LSTA [Logging System Transportation Analysis]. Instead, the Project EIS provides that "site-specific locations and methods" for activities such as timber harvest "will be determined during implementation" over the 15-year lifespan of the Project. It explains that siting decisions and the parameters of actual timber sales will be determined pursuant to an Implementation Plan . . . . However, the EIS makes clear that these subsequent, site-specific decisions will not be subject to additional NEPA review. The Forest Service terms this approach "condition-based analysis."[8]

The Prince of Wales EIS made assumptions "[i]n order to capture the 'maximum effects' of the Project."[9] This is strikingly similar to the Taylor Park Project, whose Final EA states: "For analysis purposes, a mass mortality salvage scenario is assumed to capture the extent of effects for the CTAs. […] Though we analyze this scenario as full treatment of the CTAs, in reality that is extremely unlikely due to design constraints."[10] Despite this statement, the Final EA does not disclose the impacts of the "worst case scenario." It does not disclose the impacts of a beetle kill across nearly 30,000 acres; it does not disclose the impacts of logging the CTAs; and it does not disclose the difference between leaving the CTA areas uncut after a beetle kill in comparison to its proposed action of logging an undefined acreage within those 30,000 acres.

The Taylor Park Final EA states: "The 29,095-acre figure from above is only the gross area of the external boundaries, and does not imply that all of the acres within would be available or practical for salvage harvest.[11] Likewise, the Price of Wales EIS also identified larger areas within which smaller areas of logging would later be identified, and approved the construction of 164 miles of road (the Taylor Park project approves the construction of 109 miles of road), but "the Project EIS does not include a determination—or even an estimate—of when and where the harvest activities or road construction authorized by each alternative will actually occur."[12] This is identical to the Taylor Park project, which "distinguishes contingency treatment areas . . . where treatments could be applied . . . . *These CTAs cover a large acreage to provide for adaptability in the face of potential fast changing or changed forest conditions*. […] [S]alvage treatments could be authorized within these areas."[13]

The court distinguishes its decision from *WildEarth Guardians v. Conner* where the Tenth Circuit upheld an Environmental Assessment (EA) for the Tennessee Creek Vegetation Management Project designed to address a beetle infestation in two national forests.[14] But the issue in that case was limited specifically to the Forest Service's analysis of impacts to lynx, and it was determined that the project was adhering to a scientifically-supported lynx conservation strategy that was included in the relevant forest plan. The

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[8] *See Southeast Alaska Conservation Council v. U.S. Forest Serv.*, 2020 U.S. Dist. LEXIS 43499, Case No. 1:19-cv-00006-SLG (D. Alaska Mar. 11, 2020) at *8 (citations omitted). Exhibit 1.
[9] *Id*. at *7.
[10] Final EA at 28.
[11] *Id.* at 53.
[12] *Southeast Alaska* at *19.
[13] Final EA at 28 (emphasis added).
[14] *WildEarth Guardians v. Conner,* 920 F.3d 1245, 1250-51 (10th Cir. 2019).

deficiencies in the Taylor Park EA extend beyond consideration of impacts to lynx, to the other resources and values that the agency has failed to consider before undertaking a commitment of resources.

The District Court of Alaska emphasized the purpose of preparing an EA: "An EA is meant to determine whether a proposed action will have a significant impact on the environment, such that an EIS is necessary."[15] As described throughout this objection, the Forest Service has not demonstrated – because it has not provided any degree of analysis supporting its determination – that salvage logging almost 30,000 acres would not have a significant impact on the environment. In distinguishing the Prince of Wales EIS from the Tennessee Creek EA, the court noted: "[A]n agency's analysis of a proposed action's maximum potential impacts *may* be appropriate for an EA . . . ."[16] But that appropriateness is predicated on analysis, which the Taylor Park EA lacks. For the project at hand, the Final EA does not sustain its statement that the Forest Service has analyzed a "full treatment"[17] scenario that considers the maximum potential impacts of the proposed action. On the contrary, the EA is not designed to address that scenario, instead providing analysis for a proposed action that does not include full treatments, if any, in CTAs.

The Tennessee Creek Project EA provides a much greater level of detail for its 13,580 acres of proposed treatment, including specific treatment types and acreages. For example:

> The Service's chosen alternative will involve 2,370 acres of clearcutting, 6,765 acres of thinning, 345 acres of precommercial thinning, and 6,040 acres of prescribed burns (some of which will overlap with the clearcutting and thinning), as well as the creation of about 21 miles of temporary roads. The EA also describes how much those treatments—spaced out over 10 to 15 years—will impact each forest type. Of the 9,480 acres of lodgepole pine stands that are treatable (not limited by slope, accessibility, or other factors preventing treatment), 6,765 will be targeted for thinning and 345 will be targeted for precommercial thinning (a process of thinning stands that were clear-cut 20-30 years earlier, so that growth can be concentrated on the more commercially valuable trees). And the Service will use clearcutting and prescribed burns to create openings in lodgepole-pine stands, but on no more than 25% of the 9,480 acres of treatable pine, and with clear-cuts limited to irregularly shaped 40-acre patches.[18]

This level of detail is completely lacking in the Taylor Park EA. Instead, we are only told that 29,095 of Engelmann spruce, lodgepole pine, and Douglas-fir are identified in CTAs for salvage logging, and provided with a single map[19] of these general areas, a map that does not distinguish between forest types. Less than two pages of discussion are devoted to the impacts of this scenario in the Final EA.[20] For the Forest Service to comply with NEPA it must disclose: (1) the effects of the mortality event across the

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[15] *Southeast Alaska* at *26.
[16] *Id.* (emphasis added).
[17] Final EA at 28.
[18] *WildEarth Guardians*, 920 F.3d at 1255.
[19] Final EA at 32.
[20] *Id*. at 53.

area; (2) the effects of logging the lands subjected to the mortality event across the 30,000-acre area; and (3) the difference between doing nothing and logging within the dead or dying area. The Final EA does none of these things. It can't be a "worst case scenario" disclosure if the agency doesn't disclose the impacts at all.

The inclusion of this aspect of the project as a postscript after release of the Preliminary EA is not accompanied by requisite NEPA analysis. In essence, the agency is proposing to treat a *large acreage* of *changed forest condition* years down the line with an EA that analyzes treating *specific areas* based on *current forest conditions*. The two analysis scenarios do not match up, and the District of Alaska's decision demonstrates that the management proposed by the Forest Service has not complied with the law.

B. The Final EA Fails to Disclose the Taylor Park Project's Site-Specific Impacts

CEQ's regulations establish specific ways agencies must analyze project-level decisions, including a detailed discussion of direct, indirect, and cumulative impacts and their significance. The Taylor Park project is a project-level decision. As a result, any analysis must include the detailed information and examination that NEPA and the CEQ regulations require because there will be no further NEPA analysis beyond the Final EA. In sanctioning 29,095 acres of logging in CTAs and 3,153 acres of "fuel treatments to be determined", the Final EA fails NEPA's requirement that analysis disclose specific information about the when, where, and how of agency actions.

Under the agency's original proposed action (Alternative 1), 8,767 acres would be made available for potential treatment should there be a "Changed Condition/Mortality Event."[21] The Preliminary EA acknowledged that "[t]his assessment does not identify specific sites for salvage clearcut."[22] Nor is this identified in the Final EA. Having a placeholder for almost 30,000 acres of salvage clearcuts that "would remove all merchantable dead and associated live conifer, except those required to meet wildlife snag requirements",[23] without identifying specific sites and impacts, violates NEPA.

We are concerned with the removal of "associated live conifer". In the event of a mortality event caused by beetles, the probability is high that removing live, uninfected trees could actually increase total mortality above levels that occur from just the beetle outbreak alone.[24] Removing live trees while the outbreak is underway is likely to remove potential survivors that have genetic adaptations that confer resistance to beetles.[25] This could make future outbreaks more likely. A recent scientific study, apparently not reviewed by the Forest Service, found that "during outbreaks, beetle choice may result in strong selection for trees with greater resistance to attack. Our findings suggest that survivorship is

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[21] Final EA at 33.
[22] Preliminary EA at 21.
[23] Final EA at 214.
[24] Six, D. L., E. Biber, and E. Long. 2014. *Management for mountain pine beetle outbreak suppression: does relevant science support current policy?* Forests 5: 103-133. Exhibit 2.
[25] Six, D. L., C. Vergobbi, and M. Cutter. 2018. *Are survivors different? Genetic-based selection of trees by mountain pine beetle during a climate change-driven outbreak in a high-elevation pine forest*. Frontiers in Plant Science 9: 993. Exhibit 3.

genetically based and, thus, heritable. Therefore, retaining survivors after outbreaks to act as primary seed sources could act to promote adaptation."[26]

New evidence confirms there is a genetic basis for tree survival after beetle outbreaks.[27] Baker[28] reviewed evidence that retaining survivors and post-disturbance natural tree regeneration from seed will further genetic adaptation to the emerging hotter climate and its associated patterns of beetle outbreaks, droughts, and fires. Key to the success of this adaptation approach is to avoid logging survivors, since this would reduce selection and genetic adaptation to emerging climate change and associated disturbances.

1. The Final EA Fails to Disclose the Project Area's Baseline Conditions.

For the Forest Service to fulfill its obligation to take a "hard look" at the environmental effects of salvage logging 29,096 acres, the EA must focus its analysis on those areas and resources likely to be impacted by the proposed action.[29] As part of that hard look, agencies must "succinctly describe the environment of the area(s) to be affected or created by the alternative under consideration."[30] NEPA requires the agency to set an appropriate baseline detailing the nature and extent of the resources in the area. The concept of a baseline against which to compare predictions of the effects of the proposed action and reasonable alternatives is critical to the NEPA process. "Without establishing . . . baseline conditions . . . there is simply no way to determine what effect [an action] will have on the environment and, consequently, no way to comply with NEPA."[31]

Because the CTAs are large landscapes that may (or may not) be affected by various stressors in the future, the EA cannot provide baseline information about conditions that do not yet exist and may never exist. The location and type of treatments, and their impact on the forest, could be significantly influenced by changed forest conditions, as the Final EA admits.[32] The forest of 10-20 years from now may be very different from the forest of today. In addition, public uses in the increasingly-popular Taylor Park area may be very different from uses today. As such, the EA fails to disclose the *values* and *resources* anticipated in the future within the CTAs that are proposed for road construction, logging, and significant human intrusion. All the agency can do at this point is point to large areas on the landscape that *could be* logged, without disclosing information about the forest conditions that that will exist at the time of treatment operations in those areas. The agency's failure to disclose this information to the public violates NEPA's hard look mandate and the requirement that agencies disclose baseline conditions.

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[26] *Id*.
[27] *Id*.
[28] Baker, W. L. 2018b. *Transitioning western U.S. dry forests to limited committed warming with bet-hedging and natural disturbances.* Ecosphere 9: article 302288. Exhibit 4.
[29] *See* 40 C.F.R. § 1508.25(c); *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 350-51 (1989).
[30] 40 C.F.R. § 1502.15.
[31] *Half Moon Bay Fishermans' Mktg. Ass'n v. Carlucci*, 857 F.2d 505, 510 (9th Cir. 1988).
[32] Final EA at 28.

NEPA requires that the hard look assessment take place at the site-specific level if there are no additional NEPA processes yet to occur in the future to fully implement the project and the environmental impacts are reasonably foreseeable.[33] Future forest conditions, future specific treatment types and locations, and future dates of treatments within the CTAs are all unknown. Given these unknowns, it is impracticable, and illegal, for the NEPA analysis at hand to attempt to provide baseline assessments and analysis of these relationships.

2. The Final EA Fails to Disclose the Impacts of Treatments in Contingency Treatment Areas.

Without knowing, or disclosing, specifically where it will conduct timber treatments across an almost 30,000-acre landscape, and when and what kinds of specific treatments may occur, the agency is unable to analyze, disclose, or understand the effects of the proposed action or to craft and analyze alternatives to protect these values. The Final EA is essentially a programmatic document. But its programmatic nature does not obviate the agency's responsibility to analyze site-specific impacts. CEQ guidance states:

> A broad (e.g., regional or landscape) description may suffice for characterizing the affected environment in programmatic NEPA reviews, *so long as potentially impacted resources are meaningfully identified and evaluated*.[34]

The fact that the decision would allow future salvage logging on 29,095 acres is not even acknowledged in the project's DDN/FONSI. Rather, that document states: "Additionally, *in total*, Alternative 2 includes a stand-replacing prescribed fire component on 4,180 acres, increasing the project's anticipated actionable acres to 17,714."[35] Instead, Alternative 2, in total, increases the project's potential actionable acres to 29,095. The DDN/FONSI goes on to say that: "[Alternative 2] is more refined and detailed with its proposed actions while anticipating the need for potential treatments in the instance of a mass mortality event such as epidemic insect infestation, landscape-scale wildfire or windthrow."[36] We can find little in the Final EA reflecting this refinement and detail as it pertains to salvage logging in the instance of a potential future mass mortality event. Anticipating the need for treatments and fulfilling NEPA's mandate to analyze site-specific impacts of those potential treatments are not the same thing.

In describing Alternative 2, the DDN/FONSI states:

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[33] *See New Mexico ex rel. Richardson*, 565 F.3d at 718-19 (requiring site-specific NEPA analysis when no future NEPA process would occur); *Colo. Envtl. Coalition v. Ofc. of Legacy Mgmt.*, 819 F. Supp. 2d 1193, 1209-1210 (D. Colo. 2011) (requiring site-specific NEPA analysis even when future NEPA would occur because "environmental impacts were reasonably foreseeable"); *cf. Wyoming v. U.S. Dept. Agric.*, 661 F.3d 1209, 1256 (10th Cir. 2011) (not requiring site-specific NEPA analysis because decision was "a 'broad' nationwide rule" allowing Forest Service to evaluate effects "generically").

[34] Council on Environmental Quality, Memorandum for Heads of Federal Departments and Agencies, *Effective Use of Programmatic NEPA Reviews* (December 18, 2014), at 32 (emphasis added). Exhibit 5.

[35] Draft Decision Notice/FONSI at 4 (emphasis added).

[36] *Id*.

> The EA provides a matrix of potential treatments that could be applied once treatment-specific resource surveys have been completed. This flexibility allows the Forest Service to be more responsive to rapidly changing forest conditions if and when they occur.[37]

This appears to authorize almost any kind of treatment in the CTAs. Also, as part of the "Implementation Process", step 2 in the Adaptive Management Framework is "Define contingency treatment areas."[38] This clearly indicates the Forest Service intends to implement treatments in the CTAs.

The Forest Service's response to HCCA's previous comments regarding this concern states:

> Implementation of any salvage treatments would be determined though Appendix B and follow the implementation process of Appendix E, which includes public participation and Appendix A (surveys and design features). It would comply with project design features and Table 1 decision-making triggers found in the EA. Further, *Alternative 2 establishes and defines contingency treatment areas* where treatments could be applied for early beetle infestation above endemic levels or treatments should mortality events occur. *A salvage scenario was assumed for analysis to capture the extent of effects*.[39]

Establishing and defining areas for logging is not the same as analyzing direct, indirect, and cumulative impacts of that logging. It is unclear where the analysis of a full-blown salvage scenario across 30,000 acres is in the Final EA. The Final EA devotes approximately two pages in a section titled "Effects of Salvage Clearcutting/Overstory Removal in Alternative 2 Contingency Treatment Areas"[40] to this topic, but even that acknowledges the agency's inability to address this, with statements like: "The potential harvest volume from salvage logging of dead trees in the CTAs is not included in the numbers shown in Table 16 *due to the large uncertainty surrounding where, when, and how much tree mortality could occur*."[41] The best the agency can guarantee is: "Public notice and comment on an annual basis for the upcoming cycle of treatments."[42] Notifying the public post-hoc of a decision already made undermines NEPA's mandate that agencies "look before they leap," rendering public comment meaningless while removing accountability.

The fact that not all of the 29,095 acres would be salvage logged does not make this more palatable. The Final EA notes that it will design treatments to avoid certain areas:

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[37] *Id.* at 3.
[38] Final EA at 235.
[39] Taylor Park Public Comment/Comment Summary and Responses at 29 (emphasis added).
[40] Final EA at 53.
[41] *Id*. at 55. This is a far cry from the 'worst-case scenario' the FS prepared in the *WildEarth Guardians* case. This makes no assumptions at all about the greatest potential impacts to values. Instead, the Forest Service merely throws up its hands and claims an inability to predict impacts.
[42] *Id*. at 23.

> During implementation, should epidemic level insect infestations or mortality event conditions occur, and treatment be desired, specific treatment areas would be delineated within the CTAs. These specific treatment areas would be reduced in size due to constraints from economic feasibility, design feature restrictions (e.g., WQSP-5B(D)—Limits ground disturbing activities above 40 percent slopes, WQSP-5A—Limits detrimental soils disturbance to 15 percent for the activity area), and the yellow/red light decision triggers (e.g., thresholds for maximum allowable disturbance in Lynx habitat and subwatersheds).[43]

Avoiding some areas means concentrating logging in other areas. Because the Final EA fails to disclose *where* most of these values may exist that vegetation treatments are designed to protect or avoid, neither the public nor the decision-maker can understand the impact to the environment of these avoidance measures. None of these areas are identified on maps, though they clearly could be because the Forest Service identifies CTA locations. Nor is the extent of these areas described or quantified. This failure to disclose where logging *will not* take place, thus confining where logging *will* take place, violates NEPA, and deprives both the public and the decisionmaker of the information necessary to understand the action and its impacts and to conclude that the action will not have significant impacts.

3. The Final EA Fails to Disclose the Impacts of "Fuel Treatments to be Determined".

In addition to the 29,095 acres of CTAs, the project decision also includes a placeholder for 3,153 acres of "fuel treatments to be determined."[44] The Final EA does not delineate what specific types of treatments would constitute fuel treatments in specific locations. Rather: "any of the treatments described above could be implemented in the fuel treatment areas."[45] Treatments "described above" include commercial thinning, roadside hazard tree felling, dwarf mistletoe sanitation, pre-commercial thinning, shelterwood cutting, group selection, salvage overstory removal, salvage clearcut, overstory removal, non-commercial dwarf mistletoe edge treatment and hand treatment of edge strips in wet areas, clearcutting, clearcutting of products other than sawlogs, and dwarf mistletoe edge strip cuts.[46] The Forest Service is keeping on the table every possible treatment option across a 3,000-plus acre landscape for a project with a shelf life of 20 years – longer than the life of a Forest Plan.

The Final EA acknowledges that these areas contain a "diversity of vegetation types and stand conditions."[47] The Alternative 2 Map provided with the Final EA indicates potential fuel treatment sites scattered throughout the project area. Yet the Forest Service provides no analysis of impacts to these varied and diverse lands from the multitude of treatment options left available. For example, the impacts to wildlife of a clearcut in spruce-fir are very different from a thinning treatment in lodgepole. A

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[43] *Id*. at 28.
[44] *Id*. at 29.
[45] *Id.* at 48.
[46] *Id.* at 44-48.
[47] *Id.* at 48.

significant percentage of the project area is thus in an analysis black hole, removed from site-specific consideration of impacts that could accrue from a combination of over a dozen different treatment options.

In our joint May 13, 2019 comments Objectors wrote:

> The EA proposes 2,820 acres of fuel treatment, yet it lacks any site-specific planning or analysis for this project component. The Forest Service states: 'Fuel treatments would include variety of tactics ranging from thinning to clearcutting.'[] Especially given that many of the fuel treatments are close to human infrastructure and communities, it stands that affected members of the public would have a keen desire to know the specifics of these extensive treatments.[48]

The Forest Service response to HCCA's comments is:

> We work with local county governments to define Wildland-Urban interface areas in the context of adopted wildfire protection plans. WUI is defined in the Fire and Fuels Management section of the EA. Cohen's recommendations address structure protection and avoidance of individual structure ignition. The larger WUI used in this project aims at reducing fire risk and hazard to private property over a greater general area. Additionally, treating a larger area provides more opportunity to allow natural ignition to burn with minimal influence from fire suppression efforts. Also see Alternatives Considered but Eliminated from Detailed Study.[49]

This does not address our concern that the Final EA's analysis of the project's proposed fuel treatments "lack any site-specific planning or analysis for this project component." Supplanting NEPA analysis with *potential* coordination with local county government does not address this problem.

4. The Final EA's Reliance on Adaptive Management Violates NEPA.

The Final EA improperly relies on the adaptive management process to address environmental impacts. "The Taylor Park Project EA/DN specifies this adaptive implementation framework for defining treatment locations and design, determining monitoring questions, reviewing and evaluating the effects of treatments, and adjusting management towards desired conditions and away from undesirable conditions."[50]

To be effective and legal, adaptive management must disclose in this project's NEPA documents the impacts caused by that change in management.[51] Because the Final EA fails on this account, the Forest Service cannot rely on the adaptive management strategy as currently proposed.

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[48] At 8.
[49] Taylor Park Public Comment/Comment Summary and Responses at 13.
[50] Final EA at 232.
[51] 36 C.F.R. § 220.5(e)(2).

Forest Service's NEPA regulations state that:

> An adaptive management proposal or alternative must clearly identify the adjustment(s) that may be made when monitoring during project implementation indicates that the action is not having its intended effect, or is causing unintended and undesirable effects. The EIS *must disclose not only the effect of the proposed action or alternative but also the effect of the adjustment*. Such proposal or alternative must also describe the monitoring that would take place to inform the responsible official during implementation whether the action is having its intended effect.[52]

The preamble to the Forest Service's regulation that adopted the adaptive management definition states that the agency must identify the proposed changes, and their impacts, in the NEPA document. "When proposing an action the responsible official may identify possible adjustments that may be appropriate during project implementation. *Those possible adjustments must be described and their effects analyzed* in the EIS."[53] Here, the Forest Service fails to disclose the impacts of the adjustments, specifically salvage logging on up to nearly 30,000 acres, in violation of Forest Service regulations.

5. The Agency Must Complete an EIS.

NEPA requires federal agencies to prepare an EIS before undertaking "major Federal actions significantly affecting the quality of the human environment."[54] As the Tenth Circuit has explained, "[i]f the agency determines that its proposed action *may* 'significantly affect' the environment, the agency must prepare a detailed statement on the environmental impact of the proposed action in the form of an EIS."[55]

"Significance" under NEPA requires consideration of the action's context and intensity.[56] An agency must analyze the significance of the action in several contexts, including short- and long-term effects within the setting of the proposed action (including site-specific, local impacts).[57] Intensity refers to the severity of the impact and requires consideration of factors that may generally lead to a significance determination, including: "(5) The degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks; (6) The degree to which the action may establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration."[58]

Because the Taylor Park decision sanctions treatments years down the road in what would be a significantly changed forest, the possible effects on the environment are highly uncertain. Should the situation arrive in the future that compels the Forest Service to respond to changed forest conditions

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[52] *Id*. (emphasis added).
[53] 73 Fed. Reg. 43,084, 43,090 (July 24, 2008).
[54] 42 U.S.C. § 4332(C).
[55] *Airport Neighbors Alliance v. U.S.,* 90 F.3d 426, 429 (10th Cir. 1996) (citation omitted) (emphasis added).
[56] 40 C.F.R. § 1508.27.
[57] *Id.* § 1508.27(a).
[58] 40 CFR 1508.27(b)

that it determines warrant salvage logging, it would be best to do additional NEPA for the CTAs shortly before they are to be treated. But if the agency insists on approving a decision that includes these CTAs now, an EIS that fully discloses the likely impact of treating these areas must be prepared. Because the Forest Service has included an expanded acreage of CTAs in its Final EA without disclosing the impacts of treating these areas, the impacts of which are unknown but could be significant, the agency must complete an EIS.

SUGGESTED REMEDIES

1. The identification of CTAs, and treatments within those CTAs, should be removed from this decision. In the alternative, the Forest Service must prepare an EIS to disclose the site-specific location, and impact, of treatments within those 29,095 identified acres.

2. The Forest Service must prepare a supplemental NEPA document to disclose the site-specific impacts of treating 3,153 acres identified as "fuel treatments to be determined."

3. The Forest Service must prepare a supplemental NEPA document to include an adaptive management plan that meets Forest Service regulations by clearly identifying the adjustment(s) that may be made when monitoring shows triggers have been reached, and disclosing the impacts of implementing any and all of the adjustments, for treatments in CTAs.

4. If CTAs are retained in the project decision, the Forest Service must prepare an EIS that fully discloses the impacts of future treatments in the CTAs.

II. THE FINAL EA FAILS TO DISCLOSE FULLY THE PROJECT'S IMPACT ON LYNX.

Objectors addressed this issue on pp. 16-17 of our joint May 13, 2019 comments.

A. Lynx Habitat in the Project Area Is Likely Not Correctly Determined.

Table 5 in the Biological Assessment (BA) for the project describes the lynx analysis units (LAUs) that overlap the project area. Lynx habitat comprises 47-66 percent of the total acreage in each LAU, with almost all of it considered suitable.

We note that a sizable part of the project area is not in a lynx analysis unit. This is the area north and east of Taylor Reservoir; it is bisected by Forest Service Roads 762 and 209. This area is bordered by all but one of the other five LAUs within the project area.[59] Presumably, this area, not being in an LAU, is believed to have little or no lynx habitat. That seems unlikely, as the map of proposed treatment areas for Alternative 2 shows this area with some units proposed for overstory removal and group shelterwood, indicating there is some mid- to late-successional forest in this area which could be lynx habitat.

[59] *See* Taylor Park EA Planning Unit LAUs map at Exhibit 6.

The Canada Lynx Conservation Assessment and Strategy states: "Engelmann spruce, subalpine fir and lodgepole pine forest cover types occurring on cold, moist potential vegetation types provide habitat for lynx."[60]

Therefore, it seems that more land within each LAU should be lynx habitat.

Lodgepole pine and spruce-fir types comprise 65 percent of the project area.[61] Though it is not broken out by cover type, 74 percent of the area proposed for treatment in Alternative 2 is in structural stages 3B, 3C, 4B, or 4C, which are mid- and late-seral stages with 40 percent or more canopy closure.[62] The BA further states that "the project area's lodgepole pine stands are predominately in the late-mid or late seral stages."[63]

Thus much of the lodgepole pine, as well as the spruce-fir, in the Taylor Park project area should be lynx habitat. It may not be the highest quality habitat, as it may lack sufficient horizontal cover (but see below); however, it still allows lynx to travel between areas of higher quality habitat and to disperse. Note that "[h]abitat connectivity is defined as 'cover vegetation' in sufficient quantity and arrangement to allow for the movement of lynx."[64] Most of the project area's lodgepole pine stands should thus provide habitat that allows lynx to move between areas of higher quality habitat, within and between LAUs.

Much of the lodgepole pine in the project area is infected with the parasite dwarf mistletoe.[65] The witches' brooms produced by mistletoe are said to form fuel ladders that would help carry fire into the crowns of the trees having the brooms.[66] If mistletoe witches brooms form fire ladders, then they should also provide some dense horizontal cover for lynx and its favorite prey, snowshoe hare.

In conclusion, most of the project area's forests that have not been treated or recently burned should be lynx habitat. This should increase the total amount of lynx habitat in each LAU (and in the portion of the project area not in an LAU) over what is stated in the BA.

B. The Project Would Degrade or Destroy More Lynx Habitat Than What is Stated in the BA.

According to BA Table 12, about 3,052 acres of suitable lynx habitat would be treated. However, only 373 acres of suitable habitat would be converted to stand initiation structural stage (SISS).[67]

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[60] Interagency Lynx Biology Team. 2013. *Canada Lynx Conservation Assessment and Strategy*. 3rd edition. USDA Forest Service, USDI Fish and Wildlife Service, USDI Bureau of Land Management, and USDI National Park Service. Forest Service Publication R1-13-19, Missoula, MT. 128 pp., at 26.
[61] Final EA at 37.
[62] From Final EA Table 12 at 39.
[63] BA at 23; citation omitted.
[64] *Id*. at 22.
[65] See discussion at EA p. 40
[66] BA at 15; Worrall, Jim. *Lodgepole Pine Dwarf Mistletoe in Taylor Park, Colorado. Report of for the Taylor Park Environmental Assessment*. Gunnison Service Center, Rocky Mountain Region, at 6.
[67] BA at 29.

This seems very low, as the following treatment methods in Alternative 2 would convert all or most of the lynx habitat to SISS:[68]

- Prescribed fire (4,180 acres)[69]
- Clearcut/dwarf mistletoe edge clearcut (2,699) acres
- Clearcut/POL (135 acres)
- Overstory removal (445 acres)
- Non-commercial dwarf mistletoe treatment (137 acres)
- Hand dwarf mistletoe treatment (101 acres).

This totals 7,097 acres. All of these treatment types would convert at least some of any existing lynx habitat to unsuitable, as overstory trees would be cut, removed, or burned. Parts of understories, some containing dense horizontal cover, would be damaged or destroyed by logging operations, if not by the treatments themselves. Clearcutting would, by definition, remove all trees and would thus eliminate habitat for lynx. Burning would involve varying, but considerable amounts of overstory mortality, up to 100 percent.[70]

In addition, 1,257 acres of group selection treatments would convert some habitat to unsuitable. Pre-commercial thin/sanitation (3,222 acres) would reduce or eliminate hare habitat, and/or prevent or delay areas where this treatment is applied from becoming lynx habitat in the next 40 years or so.

C. The EA Fails to Analyze or Disclose the Effects on Lynx from Treatment in the "Contingency" Areas.

As described in the DDN, selected Alternative 2 "anticipat[es] the need for potential treatments in the instance of a mass mortality event such as epidemic insect infestation, landscape-scale wildfire or windthrow."[71]

For this alternative, the Forest Service identified "contingency treatment areas" which "cover a large acreage to provide for adaptability in the face of potential fast changing or changed forest conditions."[72] In the event of a mass mortality event(s), the treatment in the contingency areas would be salvage.[73] Salvage logging usually involves cutting and removing all the dead or dying trees. Treatments are not subject to the 40-acre opening size limitation imposed by the National Forest Management Act and the

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[68] BA Table 1, pp. 4-5; see also EA Table 4, p. 29.

[69] BA p. 29 states: "Prescribed fire would only be applied in timber harvest units…" However, a look at the map for Alternative 2 shows only a minor overlap between cut units and areas to be burned. Also, BA at p. 5 states that prescribed fire would be applied "[i]n lodgepole pine dominated forest where commercial timber harvest is not currently appropriate or practical due to poor access, rocky terrain, and steep slopes." The Draft Decision notice states that Alternative 2 "includes a <u>stand-replacing prescribed fire component</u> on 4,180 acres". Id. at 4; emphasis added. All of this indicates that areas to be prescribed burned are separate units, and that lynx habitat would be damaged or destroyed. The impacts on lynx habitat from burning must be accurately disclosed.

[70] *See* BA at 5.

[71] DDN at 4.

[72] Final EA at 28.

[73] *Id*.

Planning Rule on commercial logging.[74] Where applied, this treatment would likely convert all of the lynx habitat to unsuitable.

Objectors raised this issue in our joint January 15, 2020 comments on the supplemental EA. We specifically asked for the following:

> Given the new opportunity for tripling the acreage identified as Priority Treatment Areas in Alternative 2, please correctly calculate the amount of suitable [lynx] habitat that would be converted to stand initiation structural stage (SISS). Also calculate the acreage of habitat that would be reduced in quality – e.g., by death, during felling and skidding of trees – of understory trees that form dense horizontal cover. Then adjust the finding in the Biological Assessment of "not likely to adversely affect" as necessary.[75]

However, we do not find in either the EA or BA any analysis of possible impacts to lynx habitat from treatment of the CTAs. Final EA Figure 9 shows the areas that could be treated, but there is no discussion of the impacts to lynx habitat (or to any other resources). The cumulative impacts from treatments in the CTAs, along with those from Alternative 2 and SBEADMR, could be considerable.

This failure to disclose impacts is a violation of NEPA. See Section I above.

D. The Analysis Does Not Account for the Possible Impacts of Hazard Tree Removal.

We addressed this issue on p. 7 of our joint January 15, 2020 comments. Under Alternative 2, "Hazard trees within 200 feet of open public roads in the planning area would be removed during the life of the project."[76]

Cutting 200 feet on each side of open public roads is much more than is needed to eliminate hazard trees, as no tree in the project area is anywhere near 200 feet tall. Under this treatment, long, 400-feet-wide clearcuts could be implemented along every open pubic road. This would further fragment habitat for lynx and other wildlife species.

"Hazard Tree Removal" for 2,340 acres is listed in EA Table 5. However, the areas proposed for hazard tree treatment are not shown on the map for Alternative 2, nor are they depicted on the map showing the CTAs.[77] We find no indication in the BA that the possible impacts from hazard tree cuts on lynx have been analyzed.

<u>SUGGESTED REMEDIES</u>

1. Show how lynx habitat was determined in the project area. Justify the determination that any mid- to late-seral forests are not lynx habitat.

2. Delineate the portion of the project area not in existing LAUs to a new LAU or add it to existing LAUs, or justify why this area does not need to be in an LAU.

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[74] *See* 36 CFR 219.11(b)(4)(iii).
[75] HCCA January 15 comments at 8-9.
[76] Final EA at 28.
[77] Final EA Figures 8 and 9 at 31 and 32, respectively.

3. Include prescribed fire and other treatments listed in subsection B above as treatments that will convert suitable lynx habitat to SISS, which would be unsuitable habitat.

4. If the decision for the project will approve future treatment in contingency areas, then analyze and disclose the potential impacts to lynx habitat for this treatment. This must include analysis and disclosure of effects from hazard tree removal, if that treatment could occur.

5. Prepare a new biological assessment showing all of the above and a new determination of the project's likeliness to affect lynx.

CONCLUSION.

High Country Conservation Advocates, Center for Biological Diversity, and Rocky Smith hereby request a meeting to discuss potential resolution of issues raised in this objection, pursuant to 36 C.F.R. § 218.11(a).

We hope that the Forest Service will use the objection process and such a meeting as opportunities to engage with stakeholders, including us, to develop a project that is legally and ecologically sound.

Sincerely,

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No *Shepard's* Signal™
As of: March 16, 2020 3:10 PM Z

Se. Alaska Conservation Council v. United States Forest Serv.

United States District Court for the District of Alaska

March 11, 2020, Decided; March 11, 2020, Filed

Case No. 1:19-cv-00006-SLG

Reporter
2020 U.S. Dist. LEXIS 43499 *

SOUTHEAST ALASKA CONSERVATION COUNCIL, et al., Plaintiffs, v. UNITED STATES FOREST SERVICE, et al., Defendants.

Core Terms

Forest, cards, harvest, site-specific, impacts, timber harvest, subsistence, acres, environmental, map, project area, plans, effects, timber sale, decisions, briefing, national forest, habitat, maximum, Island, Vegetation, Wildlife, acreage, logging, lynx, road construction, agency's action, Plaintiffs', merits, resources

Counsel: **[*1]** For Southeast Alaska Conservation Council, Alaska Rainforest Defenders, Center for Biological Diversity, Sierra Club, Defenders of Wildlife, Alaska Wilderness League, National Audubon Society, Natural Resources Defense Council, Plaintiffs: Olivia Elisabeth Glasscock, Thomas S. Waldo, LEAD ATTORNEYS, EARTHJUSTICE (Juneau), Juneau, AK.

For United States Forest Service, United States Department of Agriculture, David Schmid, in his official capacity as United States Forest Service Region 10 Regional Forester, Earl Stewart, in his official capacity as Forest Supervisor for the Tongass National Forest, Defendants: Erika Danielle Norman, LEAD ATTORNEY, U.S. Department of Justice, Environmental & Natural Resources Division, Washington, DC.

For Alaska Forest Association, Amicus: Julie A. Weis, LEAD ATTORNEY, PRO HAC VICE, Haglund Kelley Horngren Jones & Wilder LLP, Portland, OR.

Judges: Sharon L. Gleason, UNITED STATES DISTRICT JUDGE.

Opinion by: Sharon L. Gleason

Opinion

DECISION AND ORDER

This is an action in which Plaintiffs Southeast Alaska Conservation Council, Alaska Rainforest Defenders, Center for Biological Diversity, Sierra Club, Defenders of Wildlife, Alaska Wilderness League, National Audubon Society, and Natural **[*2]** Resources Defense Council seek the invalidation of portions of the 2018 Environmental Impact Statement and 2019 Record of Decision for the Forest Service's Prince of Wales Landscape Level Analysis Project for the Tongass National Forest. Briefing on the merits concluded on August 23, 2019.[1] Oral argument was held on February

[1] Pursuant to the briefing schedule for administrative agency appeals, *see* L. R. Civ. P. 16.3(c), Plaintiffs' Opening Brief is at Docket 10, Defendants' Brief in Opposition is at Docket 12, and Plaintiffs' Reply Brief is at Docket 19. Plaintiffs subsequently filed a Notice of Errata and Corrected Opening Brief at Docket 22.

7, 2020.[2]

BACKGROUND

The factual background for this case was set out at some length in the Court's prior order granting Plaintiffs' motion for a preliminary injunction.[3] It is repeated here to a certain extent with some additions.

The Tongass National Forest ("Tongass") is a 16.7 million-acre forest in Southeast Alaska.[4] The nation's largest national forest,[5] the Tongass has seen timber harvesting of varying intensity over the past 100 years.[6] In the 1950s, the Forest Service awarded several 50-year timber sale contracts in the forest to "provide a sound economic base in Alaska through establishment of a permanent year-round pulp industry."[7] But logging in the Tongass began to slow in the 1980s and 1990s, when several of these long-term contracts were terminated due to market fluctuation, litigation, and other factors.[8]

Prince of Wales Island, a large island in the Alexander **[*3]** Archipelago, lies within the Tongass.[9] Two large pulp mills once operated on the island, where industrial scale logging occurred in the second half of the 20th century, but both mills closed in the 1990s.[10] There are 12 communities on the island with a total of approximately 4,300 residents, many of whom are Alaska Native.[11] Tourism and sport and commercial fishing are important to the local economy,[12] and many residents rely to some degree on subsistence hunting, fishing, and gathering.[13]

Pursuant to the *National Forest Management Act ("NFMA")* and its implementing regulations, the Forest Service has developed land and resource management plans, also called forest plans, to govern its management of the Tongass.[14] Forest plans "operate like zoning ordinances, defining broadly the uses allowed in various forest regions, setting goals and limits on various uses . . . , but do not directly compel specific actions, such as cutting of trees in a particular area or construction of a specific road."[15] Any activity occurring within a national forest must comply with the governing forest plan,[16] which the Forest Service is required to revise at least every 15 years.[17] The current forest plan for the **[*4]** Tongass was issued in 2016, following the completion of an environmental impact statement ("EIS").[18] The Forest Plan provides that "[t]imber harvest unit cards will document resource concerns and protection measures," and requires that these "unit cards, including a map with relevant resource features, . . . be provided electronically when Draft or Final NEPA documents and decisions are published."[19]

In late 2016, the Forest Service initiated environmental planning for a proposed project within the Tongass: the Prince of Wales Landscape Level Analysis Project ("Project").[20] The agency describes the Project as "a large landscape-scale NEPA analysis that will result in a decision whether or not to authorize integrated resource management activities on Prince of Wales Island over the next 15 years."[21] The Forest Service released a final EIS for the Project on October 19, 2018[22] and issued a Record of Decision ("ROD") selecting the preferred

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[2] Docket 37.

[3] Docket 27 at 2-7

[4] Administrative Record ("AR") 833_0404 at 063052, 063054.

[5] AR 833_0404 at 063407.

[6] AR 833_2077 at 069553-55.

[7] AR 833_2077 at 069553.

[8] AR 833_2077 at 069553-55.

[9] AR 833_0404 at 063054.

[10] AR 833_2167 at 01750.

[11] AR 833_2167 at 01753; *see also* AR 833_2167 at 01751, tbl. 70 (showing population change).

[12] AR 833_2167 at 001750

[13] *See* AR 833_2167 at 001753-57 (describing different communities on the island).

[14] *See* *16 U.S.C. § 1604*.

[15] *Citizens for Better Forestry v. United States Dep't of Agric., 341 F.3d 961, 966 (9th Cir. 2003)*.

[16] *16 U.S.C. § 1604(i)*.

[17] *36 C.F.R. § 219.7(a)*.

[18] AR 833_0404 at 063039-063554 (2016 Tongass Forest Plan); AR 833_2079 at 071034-072626 (EIS for Tongass Forest Plan).

[19] AR 833_0404 at 063265.

[20] AR 833_2167 at 001468.

[21] AR 833_2167 at 001459.

[22] AR 833_2167 at 001437-001863 (Final EIS).

alternative from the EIS on March 16, 2019.[23]

The Project encompasses all of the land within the national forest system on Prince of Wales Island, consisting of roughly 1.8 million acres.[24] It authorizes four categories of activities within this area: vegetation **[*5]** management, including timber harvesting; watershed improvement and restoration; sustainable recreation management; and "associated actions."[25] The EIS for the Project does not specify when and where individual activities will occur within the Project Area. Rather, the Project is designed to be a flexible planning framework intended to allow the Forest Service to tailor resource management to changing conditions on the ground over the course of the Project's 15-year term.

The Forest Service appended to the EIS what it terms an Activity Card for each of the 46 activities included in the four activity categories.[26] "The Activity Cards describe each potential activity and the related resource considerations," and include "[p]roject-specific design criteria and mitigation measures."[27] The Activity Cards were designed using "on-the-ground inventories, computer (GIS) data, and aerial photographs to assess project area conditions and resource-specific concerns."[28] The Activity Cards describe and govern activities at the project level, but they do not identify the specific geographic areas within the Project Area where each activity will occur.[29] Unlike prior sales, the Project EIS was not accompanied **[*6]** by timber harvest unit cards with maps detailing specific harvest configurations.[30]

In preparing the Project EIS, the Forest Service also developed a Logging System Transportation Analysis ("LSTA") to "identif[y] potential stands for timber harvest and the associated transportation network that would be needed."[31] The LSTA "was developed for National Forest System lands within the project area layer using information from the Forest GIS library, aerial photos, and the Forest Service Activity Tracking System database."[32] The LSTA identified 125,529 acres of potential timber harvest in the Project Area: 48,140 old-growth acres and 77,389 young-growth acres.[33] The LSTA also identified 643 miles of new roads, 505 of them temporary and 138 permanent.[34] The Forest Service represented this information in a Commercial Vegetation Management map,[35] which it appended to the ROD, and to which it provided a link in the EIS.[36]

The Project EIS addresses four alternatives in detail, including a no-action alternative.[37] Each activity under each alternative must be consistent with the applicable Activity Card and certain alternative-specific features,

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[23] AR 833_2427 at 000776-001118; *see also* *42 U.S.C. § 4332(2)(C)* (requiring agencies to prepare a "detailed statement" for actions with significant environmental impacts).

[24] AR 833_2167 at 001460-61; *see also* AR 833_2427 at 000781 (map showing distribution of national forest system land on Prince of Wales Island).

[25] AR 833_2167 at 001443.

[26] AR 833_2427 at 000848-001030.

[27] AR 833_2167 at 001492; *see, e.g.*, AR 833_2427 at 000848-52 (Activity Card 01).

[28] AR 833_2167 at 001492.

[29] *See, e.g.*, AR 833_2427 at 000848 (Activity Card 01 explaining that "rotational harvest of young growth using even-aged management" may occur "within the suitable land base based on legal and technical factors" and "within potential harvest units as shown in the [LSTA]"); AR 833_2167 at 001459 ("The Activity Cards are used to identify and analyze a suite of possible activities that could be implemented in the project area. With this approach, activities can vary in magnitude and intensity to respond to resource conditions.").

[30] *Cf*. AR 833_2084 at 061279-80 (card for timber harvest unit 101 in 2007 Kuiu Timber Sale EIS).

[31] AR 833_2167 at 001561.

[32] AR 833_2167 at 001561; *see also* AR 833_2167 at 1561-71 (describing Forest Service's methodology and integration of LSTA into Project EIS); AR 833_1369 at 074744 (providing path for GIS data .zip file for the draft EIS); AR 833_2115 at 074758 (providing path for GIS data .zip file for the final EIS); AR 833_2403 at 074762-074854 (Jan. 1, 2015 spreadsheet documenting raw GIS numbers for entire Tongass National Forest).

[33] AR 833_2167 at 001481. The Forest Service further subdivided the Project Area into 18 Timber Analysis Areas ("TAA") "[t]o allow for more site-specific analysis." *Id.* at 001562; *see also id.* at 001563 (map showing distribution of TAAs); *id.* at 001569-70 (tables showing distribution of old-and young-growth acreage across TAAs).

[34] AR 833_2167 at 001481.

[35] 833_2178. This map is attached as an appendix to this decision. *See* Docket 40-1.

[36] AR 833_2167 at 001480.

[37] AR 833_2167 at 001479-80.

and each activity must also **[*7]** occur within the areas identified for that activity in the LSTA.[38] Each action alternative establishes a maximum potential amount of timber harvest and road construction.[39] Focusing on timber harvest, Alternative 2, the preferred alternative, allows a maximum of 23,269 acres of old-growth harvest and 19,366 acres of young-growth harvest, or roughly 34 percent of the total potential acreage in the LSTA.[40] However, the EIS does not identify where the harvest authorized by each alternative would occur within the potential acreage identified in the LSTA.[41]

In order to capture the "maximum effects" of the Project, the Project EIS makes several assumptions in addressing each alternative.[42] First, in analyzing each alternative, the Forest Service indicates that it assumed that all acres of potential harvest in the LSTA would be harvested and all roads proposed by the alternative would be built.[43] Second, the Forest Service assumed that all acres would be harvested using clear-cut methods.[44] Third, the Forest Service assumed that each Wildlife Analysis Area—a land division used by the Alaska Department of Fish and Game—would be harvested to the maximum acreage available.[45]

As noted **[*8]** above, the alternatives do not provide the specific locations or configurations of harvest or roadbuilding within the LSTA. Instead, the Project EIS provides that "site-specific locations and methods" for activities such as timber harvest "will be determined during implementation" over the 15-year lifespan of the Project.[46] It explains that siting decisions and the parameters of actual timber sales will be determined pursuant to an Implementation Plan, in a way that is consistent with the alternative selected by the ROD and the Activity Cards developed for the EIS.[47] However, the EIS makes clear that these subsequent, site-specific decisions will not be subject to additional NEPA review.[48] The Forest Service terms this approach "condition-based analysis."[49]

The Implementation Plan published with the ROD sets out a nine-step process for making site-specific

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[38] *See* AR 833_2167 at 001480 (describing role of LSTA and Activity Cards in comparison of alternatives); *id.* at 001485-92 (describing features specific to the action alternatives).

[39] AR 833_2167 at 001480 ("The total acreage and maximum miles of road construction under any one alternative is expected to change based on the logging systems used and where harvest occurs on the landscape, but would not exceed the amount identified within that alternative.").

[40] AR 833_2167 at 001481. Alternative 3 allows a maximum of 13,014 acres of old-growth and 36,670 acres of young-growth harvest, or roughly 40 percent of the total potential acreage in the LSTA; and Alternative 5 allows a maximum of 6,365 acres of old-growth and 36,670 acres of young-growth harvest, or roughly 34 percent of the total potential acreage in the LSTA. *Id.*

[41] Instead, each alternative considers the Project Area as a whole and "describe[s] the conditions being targeted for treatments and what conditions cannot be exceeded in an area, or place[s] limits on the intensity of specific activities." AR 833_2167 at 001459.

[42] AR 833_2167 at 001639.

[43] *See, e.g.*, AR 833_2167 at 001629 ("[A]ssumptions include that all harvest stands from the LSTA would be harvested . . . ."); AR 833_2167 at 001789-90 (discussing road construction by alternative); *see also* Docket 12 at 31 (describing analytical approach). It is unclear from the record whether the Forest Service assumed that the maximum potential harvest in the LSTA would be harvested or the maximum acreage under each alternative would be harvested; it appears that the agency made different assumptions about harvest intensity depending on the impact under consideration. *See* Docket 39 at 13:23-16:3 (Tr. of Feb. 7, 2020 Oral Arg.) (discussing Forest Service's methodology).

[44] AR 833_2167 at 001450.

[45] *See* AR 833_2167 at 001500. There are 32 Wildlife Analysis Areas in the Project Area. *Id.* at 001514.

[46] AR 833_2167 at 001459.

[47] AR 833_2167 at 001459; *see also* 833_2169 at 002076-002126 (Implementation Plan attached to Project EIS).

[48] *See* AR 833_2169 at 002078. At oral argument, the Forest Service maintained that the Implementation Plan could require supplemental NEPA analysis if new information arose indicating that an "activity is no longer going to have an effect that was disclosed or analyzed" in the Project EIS. Docket 39 at 21:18-25. The Court has been unable to locate a specific provision in the Implementation Plan that mandates supplemental review, but the plan does require the Forest Service to "verify that the effects of the proposed activity [are] within the effects analyzed for the Selected Alternative" in the EIS. AR 833_2427 at 001039.

[49] AR 833_2167 at 001443; *see also* AR 833_2427 at 000802 ("The POWLLA FEIS uses a condition-based approach where specific harvest units and roads will be determined during implementation through a collaborative public process and interdisciplinary review.").

determinations.[50] This process includes checking the action against the relevant Activity Card, the final EIS, and the ROD, as well as engaging in "workshops and other public involvement techniques."[51] It is during this process, also, that site-specific unit cards will be developed that describe particular harvest configurations. **[*9]** [52] The ROD explains that the Implementation Plan "is integral to the analysis of effects in the [Project EIS] and the Selected Alternative in the [ROD]," and was "developed . . . to provide a linkage from the [Project EIS] to the project-specific work without the need for additional NEPA analysis."[53] That said, the ROD describes the Implementation Plan as a "living document" that "may need to be adjusted."[54]

The Forest Service began implementing the Project shortly after issuing the ROD. It held a public workshop on April 6, 2019[55] and published an "Out-Year Plan" for fiscal year 2019 that included a proposed timber sale of 1,156.34 acres, known as the Twin Mountain Timber Sale.[56] The Forest Service also published draft unit cards for the sale, which identify the specific locations and method of timber harvest in graphical and narrative form.[57]

Plaintiffs initiated this case on May 7, 2019.[58] The Complaint is brought pursuant to the *Administrative Procedure Act ("APA"), 5 U.S.C. §§ 702-06*, and alleges that the Project EIS violates three federal laws: (1) the *National Environmental Policy Act ("NEPA"), 42 U.S.C. § 4332*; (2) the *Alaska National Interest Lands Conservation Act ("ANILCA"), 16 U.S.C. § 3120*; and (3) the **[*10]** *National Forest Management Act ("NFMA"), 16 U.S.C. § 1604*.[59] The Complaint seeks declaratory judgment, vacatur of the ROD "or portions of it deemed not in compliance with law," and "preliminary and permanent injunctive relief as needed to prevent irreparable harm from implementation of the [Project]."[60] Plaintiffs refine their claim in their merits briefing, requesting vacatur of the "portions of the ROD authorizing vegetation management and road construction."[61]

On September 23, 2019, the Court entered a preliminary injunction, which prohibited the Forest Service from awarding a contract or authorizing ground-disturbing activities associated with the Twin Mountain Timber Sale during the pendency of this case.[62] In the preliminary injunction order, the Court found that Plaintiffs had raised serious questions going to the merits of their NEPA

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[50] *See* AR 833_2427 at 001037 (graphically describing Implementation Plan).

[51] AR 833_2427 at 001037. The ROD explains that a proposed activity "will take several months to a year to go through all steps of the implementation process." *Id.*

[52] AR 833_2427 at 000826.

[53] AR 833_2427 at 001034. The ROD expanded on the relationship between the Activity Cards and the Implementation Plan, stating that the "Activity Cards provide activity-specific design criteria, best management practices, and mitigation measures and the implementation plan includes site conditions, triggers, or other requirements for each type of activity to inform future data needs and field visits to develop treatment scenarios that are consistent with the NEPA analysis." *Id.*

[54] AR 833_2427 at 001034. The ROD explains that "[a]s activities are designed, the process will likely be smoother and new technology or expertise may be used." *Id.* At oral argument, the Forest Service maintained that the Implementation Plan was "not necessary for NEPA compliance." Docket 39 at 18:18-19; *cf.* Docket 12 at 19 ("Implementation is an integral part of the Project's design.").

[55] *See*, U.S. Forest Serv., Prince of Wales Landscape Level Analysis Project, Dear Planning and Implementation Participant Letter, https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd622020.pdf (last visited March 5, 2020).

[56] *See*, U.S. Forest Serv., Prince of Wales Landscape Level Analysis Project, Out-Year Plan, https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd622075.pdf (last visited March 5, 2020); *see also* Docket 21-1 at 2-3, ¶ 6 (providing size of sale).

[57] *See*, U.S. Forest Serv., Twin Mountain Sale Draft Unit Cards, https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd641767.pdf (last visited March 5, 2020). Plaintiffs have produced an area map of the proposed timber activities. *See* Docket 10-2 at 5 (Ex. A).

[58] Docket 1.

[59] Docket 1 at 15-19, ¶¶ 47, 51, 58.

[60] Docket 1 at 19, ¶¶ 1-5. Plaintiffs also seek "the costs of this action, including reasonable attorneys' fees pursuant to the *Equal Access to Justice Act, 28 U.S.C. § 2412*." *Id.* at 19, ¶ 6.

[61] Docket 22-1 at 43-44. In the alternative, Plaintiffs seek a permanent injunction of "the vegetation management activities and road construction in the ROD." *Id.* at 44-47.

[62] Docket 27 at 25.

claim.[63] The order also informed the parties that the Court intended to issue a final decision on the merits no later than March 31, 2020.[64]

JURISDICTION

The Court has subject matter jurisdiction pursuant to *28 U.S.C. § 1331*, which "confer[s] jurisdiction on federal courts to review agency action, regardless of whether the APA of its own force may serve as a jurisdictional predicate."[65]

LEGAL [*11] STANDARD

Plaintiffs' claims arise under the APA.[66] Under that statute, a reviewing court shall not set aside an agency's decision unless it is "arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law."[67] Agency action is arbitrary and capricious if it

> relie[s] on factors which Congress has not intended it to consider, entirely fail[s] to consider an important aspect of the problem, offer[s] an explanation for its decision that runs counter to the evidence before the agency, or is so implausible that it c[an]not be ascribed to a difference in view or the product of agency expertise.[68]

A court's review of whether an agency action is arbitrary and capricious should be "searching and careful," but "narrow," as a court may not substitute its judgment for that of the administrative agency.[69] Courts will generally "uphold agency decisions so long as the agencies have 'considered the relevant factors and articulated a rational connection between the factors found and the choices made.'"[70]

"Agency action is 'not in accordance with the law' when it is in conflict with the language of the statute relied upon by the agency."[71] "Whether agency action is 'not in accordance with law' **[*12]** is a question of statutory interpretation, rather than an assessment of reasonableness in the instant case."[72]

DISCUSSION

The Court will address Plaintiffs' NEPA, ANILCA, and NFMA claims in turn.

I. National Environmental Policy Act

Pursuant to NEPA, agencies must prepare an EIS before taking an action "significantly affecting the quality of the human environment."[73] Regulations issued by the Council on Environmental Quality require an EIS to include discussion of the direct and indirect effects of the action, as well as "[t]he environmental effects of alternatives."[74] After completing an EIS, "the agency must select a course of action within the range of alternatives analyzed and issue an ROD," which "explains why the agency chose a particular alternative, whether all practical means for avoiding or minimizing environmental harm have been adopted, and, if not, why not."[75]

"An EIS must 'reasonably set forth sufficient information to enable the decisionmaker to consider the

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[63] Docket 27 at 20.

[64] Docket 27 at 8.

[65] *Califano v. Sanders, 430 U.S. 99, 105, 97 S. Ct. 980, 51 L. Ed. 2d 192 (1977)*.

[66] Docket 1 at 15-19, ¶¶ 47, 51, 58.

[67] *5 U.S.C. § 706(2)(A)*.

[68] *Protect Our Cmtys. Found. v. Lacounte, 939 F.3d 1029, 1034 (9th Cir. 2019)* (alterations in original) (quoting *Motor Vehicle Mfrs. Ass'n v. State Farm Mut. Auto. Ins. Co., 463 U.S. 29, 43, 103 S. Ct. 2856, 77 L. Ed. 2d 443 (1983))*.

[69] *Marsh v. Oregon Natural Resources Council, 490 U.S. 360, 378, 109 S. Ct. 1851, 104 L. Ed. 2d 377 (1989)* (quoting *Citizens to Preserve Overton Park, Inc. v. Volpe, 401 U.S. 402, 416, 91 S. Ct. 814, 28 L. Ed. 2d 136 (1971))*.

[70] *Prot. Our Cmtys. Found., 939 F.3d at 1034* (quoting *City of Sausalito v. O'Neill, 386 F.3d 1186, 1206 (9th Cir. 1206))*.

[71] *City of Cleveland v. Ohio, 508 F.3d 827, 838 (9th Cir. 2007)*.

[72] *Singh v. Clinton, 618 F.3d 1085, 1088 (9th Cir. 2010)* (citing ***Northwest Envtl. Advocates v. EPA, 537 F.3d 1006, 1014 (9th Cir. 2008))***.

[73] *42 U.S.C. § 4332(2)(C)* (requiring a "detailed statement" analyzing "the environmental impact of the proposed action," among other things).

[74] *40 C.F.R. § 1502.16*.

[75] *Protect Our Cmtys. Found., 939 F.3d at 1035* (citing *40 C.F.R. §§ 1505.1*, *1505.2*).

environmental factors and make a reasoned decision.'"[76] The agency meets this obligation if its EIS "contains a reasonably thorough discussion of the significant aspects of the probable environmental consequences."[77] The NEPA process **[*13]** "serves two fundamental objectives": "First, it 'ensures that the agency, in reaching its decision, will have available, and will carefully consider, detailed information concerning significant environmental impacts," and "second, it requires 'that the relevant information will be made available to the larger audience that may also play a role in both the decisionmaking process and the implementation of that decision.'"[78]

"NEPA requires . . . procedural steps but does not require an agency to reach any particular result."[79] Indeed, agencies retain significant discretion over their "methodology and planning strategy" when engaging in environmental review, and "NEPA's 'requisite "hard look" does not require adherence to a particular analytic protocol.'"[80] The act "merely prohibits uninformed—rather **[*14]** than unwise—agency action."[81] To determine whether an agency has complied with NEPA's requirements, courts apply a rule of reason, which involves "a pragmatic judgment whether the EIS's form, content and preparation foster both informed decision-making and informed public participation."[82]

One method available for agencies engaging in long-term planning is to first prepare a programmatic EIS that considers the broad, program-level effects of a coordinated series of actions, and then conduct subsequent site-specific NEPA analysis for each action as it occurs, tiering back to the programmatic EIS.[83] Regarding this approach, the Ninth Circuit has explained that "[t]he detail that NEPA requires in an EIS depends on the nature and scope of the proposed action," and that "[t]he critical inquiry in considering the adequacy of an EIS prepared for a large scale, multi-step project is not whether the project's site-specific impact should be evaluated in detail, but when such detailed evaluation should occur."[84]

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[76] *Alaska Ctr. for the Env't v. Armbrister, 131 F.3d 1285, 1289 (9th Cir. 1997)* (quoting *Oregon Environmental Council v. Kunzman, 817 F.2d 484, 493 (9th Cir. 1987))*; *see also* *Tenakee Springs v. Block, 778 F.2d 1402, 1407 (9th Cir. 1985)* (explaining that EIS must be "sufficient 'to give to decision makers . . . removed from the initial decision sufficient data from which to draw their own conclusions.'" (omissions in original) (quoting *Coalition for Canyon Preservation v. Bowers, 632 F.2d 774, 782 (9th Cir. 1980)))*.

[77] *WildEarth Guardians v. Mont. Snowmobile Ass'n, 790 F.3d 920, 924 (9th Cir. 2015)* (quoting *City of Sausalito v. O'Neill, 386 F.3d 1186, 1206 (9th Cir. 2004))*.

[78] *Id.* (quoting *Robertson v. Methow Valley Citizens Council, 490 U.S. 332, 349, 109 S. Ct. 1835, 104 L. Ed. 2d 351 (1989)*. Put another way:

> The requirement of an EIS serves two ends. A properly prepared EIS ensures that federal agencies have sufficiently detailed information to decide whether to proceed with an action in light of potential environmental consequences, and it provides the public with information on the environmental impact of a proposed action and encourages public participation in the development of that information.

Or. Envtl. Council v. Kunzman, 817 F.2d at 492.

[79] *Protect Our Cmtys. Found., 939 F.3d at 1035*.

[80] ***Or. Natural Desert Ass'n v. BLM, 625 F.3d 1092, 1121 (9th Cir. 2010)*** (quoting *Ass'n of Pub. Agency Customers, Inc. v. Bonneville Power Admin., 126 F.3d 1158, 1188 (9th Cir. 1997))*.

[81] *Methow Valley Citizens Council, 490 U.S. at 351*.

[82] *Churchill Cty. v. Norton, 276 F.3d 1060, 1071 (9th Cir. 2001)* (quoting *California v. Block, 690 F.2d 753, 761 (9th Cir. 1982))*.

[83] *See, e.g.,* *W. Watersheds Proj. v. Abbey, 719 F.3d 1035, 1049 (9th Cir. 2013)* (noting that agencies can plan at programmatic or site-specific levels and that "[w]hen an agency develops an EIS for a programmatic plan . . . , the EIS 'must provide "sufficient detail to foster informed decision-making," but "site-specific impacts need not be fully evaluated until a critical decision has been made to act on site development"'" (quoting ***Friends of Yosemite Valley v. Norton, 348 F.3d 789, 800 (9th Cir. 2003)))***; *see also* *40 C.F.R. § 1502.20* (NEPA regulation encouraging tiering to "eliminate repetitive discussions of the same issues and to focus on the actual issues ripe for decision at each level of environmental review").

[84] *California v. Block, 690 F.2d at 761*. The Circuit added that "[w]hen a programmatic EIS has already been prepared, . . . site-specific impacts need not be fully evaluated until a 'critical decision' has been made to act on site development." *Id.* (quoting *Sierra Club v. Hathaway, 579 F.2d 1162, 1168 (9th Cir. 1978))*; *see also* *City of Tenakee Springs v. Block, 778 F.2d 1402, 1407 (9th Cir. 1985)* ("Where there are large scale plans for regional development, NEPA requires both a programmatic and a site-specific EIS." (citing *40 C.F.R. § 1508.28*, *1502.20*; *Kleppe v. Sierra Club, 427 U.S. 390, 409-14, 96 S. Ct. 2718, 49 L. Ed. 2d 576 (1976)))*; *cf.* *Prot. Our Cmtys. Found., 939 F.3d at 1039* (explaining that "a site-specific project demands site-specific analysis" and that "[a]gencies cannot rely on a general

The Forest Service chose not to take that approach here. Instead of preparing a programmatic EIS to be followed by site-specific NEPA analyses for individual **[*15]** timber sales as they occur, the agency compressed its NEPA review for the entire 15-year Project into a single document. The Forest Service maintains that its "landscape-scale NEPA analysis" enables informed decision-making about integrated resource management at the programmatic level and contains sufficient site-specific information and analysis to proceed with individual timber sales over the 15-year Project period without additional NEPA review.[85]

The Court will not here decide whether the nature of the Project required the Forest Service to complete a programmatic EIS to which later planning documents would tier.[86] Nor do Plaintiffs request such a decision.[87] Instead, the Court will evaluate the analytical method that the agency employed and determine whether the Project EIS, a landscape-level long-term planning document, adequately evaluated the site-specific impacts of as-yet undefined timber sales that could potentially occur on certain acreage on Prince of Wales Island over the Project's term.

Plaintiffs contend that the Project EIS does not provide sufficient site-specific information or analysis to comply with NEPA.[88] They argue that this case is governed by the Ninth **[*16]** Circuit's decision in *City of Tenakee Springs v. Block*.[89] In that case, the Circuit reversed a district court's decision not to enjoin "construction of an 11-mile road through the Kadashan watershed" in the Tongass.[90] The plaintiffs had challenged the adequacy of an EIS for a five-year operating plan that "specified no timber harvesting in the Kadashan Watershed in the years 1981 through 1986," but did authorize the construction of the road for future harvest activity.[91] The Circuit ordered the entry of a preliminary injunction, in part due to its conclusion that the plaintiffs had raised serious questions about the merits of their NEPA claim.[92] It explained that the challenged EIS did not "g[ive] any indication of its overall plan for timber harvesting" in the designated area and that "it [was] impossible to determine where and when harvesting will occur on the 750,000 acres of land."[93] The Circuit held that the EIS was inadequate, reasoning that the location and timing of logging would affect "the locating, routing, construction techniques, and other aspects of the road, or even the need for its construction."[94]

In *City of Tenakee Springs*, the Ninth **[*17]** Circuit separately rejected the trial court's conclusion that the Forest Service had discretion to determine the specificity of its environmental review.[95] Instead, it held that "[a]lthough the agency does have discretion to define the scope of its actions, such discretion does not allow the agency to determine the specificity required by NEPA."[96] The Circuit explained that "[w]here there are large-scale plans for regional development, NEPA requires both a programmatic and a site-specific EIS."[97]

Here, Plaintiffs argue that the Project EIS, with its condition-based analysis, is similarly deficient, and that the Forest Service impermissibly limited the specificity of

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discussion in a programmatic EIS or other document to satisfy [their] NEPA obligations for a site-specific action").

[85] Docket 12 at 24-35; *see also* AR 833_2167 at 001459 (describing purpose of EIS); AR 833_2169 at 002078 (stating that there is no "need for additional NEPA analysis" under the Forest Service's approach).

[86] *See* *Churchill Cty., 276 F.3d at 1074-79* (cataloguing cases regarding the necessity of programmatic EISs).

[87] Docket 22-1 at 22-36.

[88] Docket 22-1 at 22-36; *see also* Docket 1 at 16-17, ¶¶ 44-47 (Count I of Compl.). The Court has already considered this argument in its order granting Plaintiffs' request for a preliminary injunction, where it found that Plaintiffs had raised serious questions on the merits on their NEPA claim. *See* Docket 27 at 14-20. The Court will necessarily repeat that analysis to a certain degree here.

[89] *778 F.2d 1402 (9th Cir. 1985)*.

[90] *Id. at 1403*.

[91] *Id. at 1408*.

[92] *Id. at 1407-08*.

[93] *Id. at 1408*.

[94] *Id.* (quoting *Thomas v. Peterson, 753 F.2d 754, 760 (9th Cir. 1985)*, *abrogated on other grounds by* *Cottonwood Envtl. Law Ctr. v. U.S. Forest Serv., 789 F.3d 1075 (9th Cir. 2015))*.

[95] *Id. at 1407*.

[96] *Id.* (citing *California v. Block, 690 F.2d 753, 765 (9th Cir. 1982))*.

[97] *Id.*

its environmental review.[98] The Forest Service maintains that it has complied with NEPA by creating a project-level map that "provide[s] information on where timber harvest and road construction activities may take place."[99]

The Forest Service used the LSTA to identify "potential stands for timber harvest as well as the transportation network needed to access those stands" within the roughly 1.8-million-acre Project Area over a 15-year period.[100] Through this process, the agency identified 125,529 acres of timber for potential harvest: **[*18]** 48,140 acres of old growth and 77,389 acres of young growth.[101] The Project EIS links to a Commercial Vegetation Management map, which portrays this potential acreage graphically.[102] However, the EIS expressly leaves site-specific determinations about the actual location of timber harvest within this potential acreage for future determination.[103] For example, Alternative 2—the selected alternative—allows 23,269 acres of old-growth harvest, but does not specify where this harvest will be located within the 48,140 acres of old growth identified as suitable for harvest in the Project Area.[104] The Activity Cards likewise do not identify with specificity where harvesting will occur, although they do contain mitigation measures that could constrain future siting decisions.[105]

The Forest Service maintains that it properly exercised its discretion to determine the scope of the Project while at the same time providing the specificity required by NEPA.[106] The agency argues that through Project EIS, it "has provided information on where timber harvest and road construction may take place and is not 'attempt[ing] to justify' any lack of information, or to opt-out of any **[*19]** of NEPA's requirements."[107] However, similar to the EIS found inadequate by the Ninth Circuit in *City of Tenakee Springs*, the Project EIS does not include a determination—or even an estimate—of when and where the harvest activities or road construction authorized by each alternative will actually occur.[108] Rather, it reserves actual siting decisions for the future, as individual timber sales are offered.

The Forest Service contends that the phrase from *City of Tenakee Springs* on which Plaintiffs rely—that it "is impossible to determine where and when harvesting will occur on the 750,000 acres of land"—was factually inaccurate, citing the district court's decision on remand.[109] But regardless of that statement's factual accuracy, the Circuit's reasoning is still binding precedent: NEPA requires that environmental analysis be specific enough to ensure informed decision-making and

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[98] Docket 22-1 at 23-25.

[99] Docket 12 at 26-27, 28-30.

[100] AR 833_2167 at 001480.

[101] *See* AR 833_2167 at 001481 tbl. 2. The Forest Service also determined that a maximum of 505 miles of temporary roads and 138 miles of permanent roads would be necessary to access the potential timber harvest. *Id.*; *see also* AR 833_2178 (showing potential locations of temporary and permanent road construction).

[102] AR 833_2167 at 001480; *see also* AR 833_2178.

[103] AR 833_2167 at 1459 ("The site-specific locations and methods [of activities authorized by the EIS] will be determined during implementation based on defined conditions in the alternative selected in the [ROD] in conjunction with the Activity Cards . . . and Implementation Plan.").

[104] AR 833_2167 at 001481 tbl. 2. Similarly, the Project EIS does not specify where the 129 miles of temporary roads and 35 miles of permanent roads would be located. *See id.* The EIS explains that for each alternative, "[t]he total road miles needed will be determined by the specific harvest units offered and the needed transportation network." AR 833_2167 at 001789.

[105] *See, e.g.*, AR 833_2168 at 001935-36 (Activity Card for old-growth clearcutting requiring Forest Service to, among other things, "limit the size of even-age openings to 100 acres with certain exceptions" and "locate activities outside of required nest/den buffers" where feasible); *but see* Docket 12 at 29 (Forest Service asserting that the "Activity Cards are site-specific to the Project Area in that they reflect analyses by resource specialists who used on-the-ground inventories, GIS data, and aerial photographs to develop them").

[106] Docket 12 at 26-28 (distinguishing *City of Tenakee Springs v. Block, 778 F.2d 1402, 1407 (9th Cir. 1985)*).

[107] Docket 12 at 26-27 (alteration in original) (quoting Docket 22-1 at 24).

[108] *See, e.g.*, AR 833_2167 at 001789 ("The total road miles needed will be determined by the specific harvest units offered [for sale] and the needed transportation network.").

[109] Docket 12 at 27; *see City of Tenakee Springs v. Courtright*, No. J86-024 CIV., 1987 WL 90272, at *3 (D. Alaska June 26, 1987) ("The [Ninth Circuit] opinion also contains puzzling language suggesting that the EIS did not state where and when harvesting would take place in the APC contract area. This may be an improperly-drafted allusion to the fact that the final EIS did not reveal where and when logging would take place along the Kadashan Road . . . .").

meaningful public participation.[110] The Project EIS's omission of the actual location of proposed timber harvest and road construction within the Project Area falls short of that mandate.

The Forest Service maintains that Plaintiffs **[*20]** are demanding more detail than is required by NEPA. The agency relies on *Stein v. Barton*, which concerned a challenge to the EIS for a five-year operating plan for an area of the Tongass that was then being logged pursuant to a long-term contract held by the Ketchikan Pulp Company.[111] Among other issues, the plaintiffs in that case argued the "harvesting plans for each area" were not sufficiently site-specific, "object[ing] that they cannot determine from the FEIS 'where, when, and how logging and roading activities will occur on the 812,477 acres of land.'"[112] The district court rejected this argument, concluding that the EIS "contain[ed] comprehensive, detailed quantitative and qualitative descriptions of the logging and roading plans for each harvest unit."[113] The court noted that "the only details that the FEIS does not disclose are exact timetables and locations on the ground for planned harvesting activities in each harvest unit," but that this was not a fatal omission since "the Forest Service does not develop these details at the pre-implementation stage."[114]

The Forest Service contends that Plaintiffs' arguments are similar here and that NEPA does not require disclosure of the exact **[*21]** location of actual timber harvest in the Project Area.[115] But the EIS that survived review in *Stein* contained significantly greater site-specificity than the Project EIS at issue here. In *Stein*, the district court described a "nine-volume FEIS [that] employ[ed] a combination of annotated topographic maps, textual, and tabular data to describe the project alternatives and their impacts on cognizable values within the affected areas" and contained "comprehensive, detailed quantitative and qualitative descriptions of the logging and roading plans for each harvest unit."[116] Similarly, in *Alliance for the Wild Rockies v. Weber*, another case the Forest Service cites,[117] the district court upheld an environmental analysis for a timber sale that "identif[ied] the project boundaries down to the township and range level" and contained maps that would "allow the Plaintiffs to identify where those activities will take place in relation to bull trout critical habitat," a resource value the plaintiffs had claimed was inadequately addressed.[118]

The Project EIS at issue here does not approach this level of specificity; it does not delineate harvest units, let alone identify **[*22]** planned activities within them and describe their impacts on localized cognizable values. Nor does the Project EIS allow the public to identify where specific harvest activities will occur in relation to various cognizable values on Prince of Wales Island.[119] Far from "unwarranted 'fly-specking,'"[120] Plaintiffs' objections identify serious shortcomings in the sufficiency of the Project EIS's environmental analysis.

Moreover, the district court in *Stein* rejected the plaintiffs'

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[110] *Tenakee Springs v. Block, 778 F.2d 1402, 1407-08 (9th Cir. 1985)*; *see also* *Alaska Ctr. for the Env't v. Armbrister, 131 F.3d 1285, 1289 (9th Cir. 1997)* ("An EIS must 'reasonably set forth sufficient information to enable the decisionmaker to consider the environmental factors and make a reasoned decision.'" (quoting *Oregon Environmental Council v. Kunzman, 817 F.2d 484, 493 (9th Cir. 1987))*). Also, the Court notes that the district court in *City of Tenakee Springs v. Courtright* invalidated an EIS that did not provide sufficient site-specific detail for "information [to] . . . sufficiently correlat[e] with environmental factors, such as distribution of fish and wildlife populations, to facilitate public discussion of the [four alternative road and harvest] configurations." 1987 WL 90272, at *4.

[111] Docket 12 at 26 (citing *740 F. Supp. 743, 746 (D. Alaska 1990))*.

[112] *Stein, 740 F. Supp. at 749* (citing plaintiffs' briefing).

[113] *Id.*

[114] *Id.*

[115] Docket 12 at 26. Plaintiffs note in their reply that they "do not fault the [Project EIS] for lack of timetables." Docket 19 at 13.

[116] *Stein, 740 F. Supp. at 749*.

[117] Docket 12 at 25.

[118] *979 F. Supp. 2d 1118, 1125-28 (D. Mont. 2013)*. Moreover, the district court in *Alliance for the Wild Rockies* held that the Forest Service reasonably concluded that the sale at issue fell within a categorical exclusion, such that no NEPA analysis was required at all. *Id. at 1124-25*; *see also* *40 C.F.R. § 1508.4* (authorizing agencies to categorically exclude activities from NEPA's analysis requirements).

[119] As Plaintiffs maintained at oral argument: "The island complex is 130 miles long and 60 miles wide. So if you live in one of the 12 subsistence communities on this island, the timber sales that have been approved in this project might be right next door to you, or they might be a hundred miles away." Docket 39 at 8:24-9:3.

[120] *Stein, 740 F. Supp. at 749*.

site-specificity claims because they had not asserted or "show[n] why disclosure of more details regarding site-specific impacts [was] necessary in order to 'foster both informed decision-making and informed public participation.'"[121] Here, Plaintiffs maintain that more detailed information about the specific location of timber harvest under the Project is necessary to properly assess its ecological and subsistence impacts.[122]

The Forest Service contends, however, that the EIS satisfies NEPA because it analyzes the Project's maximum potential impacts.[123] In its briefing before this Court, the agency describes the Project EIS as assuming that "the entire . . . Project Area would be harvested by clear-cut methods and that every mile of road would be constructed up to the maximum number of harvest acres and miles of road authorized under each alternative."[124] The Forest Service maintains that as a result of this worst-case-scenario analysis, "whatever units [it] ultimately selects within the constraints outlined in the alternatives, Activity Cards, and Implementation Plan, the Project will produce environmental effects that fall within those already disclosed and analyzed in the EIS."[125]

It is not entirely clear from the record, but for at least some of the impacts analyzed, the Project EIS assumes that considerably more timber would be harvested than is actually authorized under each alternative. For example, **[*24]** to determine the effects of each alternative on wildlife and subsistence, the Project EIS focused on the 32 Wildlife Analysis Areas ("WAA")—"land divisions used by [the Alaska Department of Fish and Game] for wildlife analysis and regulating wildlife populations"—situated in the Project Area.[126] In its briefing, the Forest Service explained that "for each WAA, the Service assumed [timber] harvest would be concentrated in that WAA and would occur at the maximum level."[127] At oral argument, the agency confirmed that this approach could cause the EIS to assume that more harvest would occur under each alternative than actually allowed by that alternative.[128] And language in the Project EIS itself indicates that this approach assumed that *all* potential harvest stands identified in the LSTA were cut, regardless of the acreage authorized by the alternative in question.[129] The Project EIS makes these assumptions despite its recognition that "[t]he specific location and amount of harvest in each WAA would be determined during implementation and vary by alternative."[130]

The Forest Service cites *WildEarth Guardians v. Conner* to defend its approach.[131] There, the Tenth Circuit

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[121] *Id.* (quoting *Oregon Environmental Council v. Kunzman, 817 F.2d 484, 492 (9th Cir. 1987))*.

[122] *See* Docket 22-1 at 28-34. For example, Plaintiffs argue:

> [W]hile all of [the species occurring within the Project Area] depend to some degree on old growth, the extent of that dependence varies, and they have different needs respecting forest structure, elevation, proximity to beaches and streams, proximity to roads, prey availability, and fragmentation **[*23]** of their habitat. For all these reasons . . . the specific locations proposed for new logging and road construction matter a great deal for wildlife, for hunters, and for other people who use and enjoy the forest.

Docket 22-1 at 34.

[123] Docket 12 at 30-32.

[124] Docket 12 at 31 (citing AR 833_2167 at 001449, 001634).

[125] Docket 12 at 32 (citing *WildEarth Guardians v. Conner, 920 F.3d 1245, 1258 (10th Cir. 2019))*.

[126] AR 833_2167 at 001514.

[127] Docket 12 at 37.

[128] Docket 39 at 19:1-18.

[129] *See, e.g.*, AR 833_2167 at 001629 ("For purposes of analysis [of impacts to wildlife], assumptions include that all harvest stands from the LSTA would be harvested and the only harvest method would be clearcut."); *id.* at 001634 ("The effects of the POW LLA Project [on wildlife] are similar between all alternatives because all alternatives assume that all acres proposed for timber harvest will be harvested.").

[130] AR 833_2167 at 001639.

[131] Docket 12 at 17 n.5, 31, 32 (citing *920 F.3d 1245 (10th Cir. 2019))*. The Forest Service also cites *Protect Our Cmtys. Found. v. Jewell, No. 13CV575, 2014 U.S. Dist. LEXIS 50698, 2014 WL 1364453, at *9 (S.D. Cal. Mar. 25, 2014)*, *aff'd* *825 F.3d 571 (9th Cir. 2016)*, to support its assertion that its maximum-impacts analysis satisfied NEPA. Docket 12 at 31. However, the narrow holding in that case is inapplicable to the Project EIS. There, the Bureau of Land Management ("BLM") "adopted a cautious and conservative approach to measuring turbine noise" in completing the EIS for a proposed wind facility. *2014 U.S. Dist. LEXIS 50698, 2014 WL 1364453, at *9*. This analysis led BLM to conclude that the facility would result in adverse noise impacts and caused it to develop a "site-specific noise mitigation plan." *Id.* The district court rejected the plaintiffs' argument that BLM should have modelled turbine noise using larger turbines and that it had therefore "underestimate[ed] overall noise levels," citing the agency's

upheld an Environmental Assessment **[*25]** ("EA") for a tree-thinning project designed to address a beetle infestation in two national forests.[132] The EA "evaluat[ed] the Project's effects on lynx in a worst-case scenario in which all the mapped lynx habitat in the Project area is treated."[133] Due to the listing of the Canada lynx as a threatened species, the Forest Service had previously amended the forest plans for the two forests to prohibit the clearcutting of more than 15% of lynx habitat or precommercial thinning of more than 1% of lynx habitat in a given analysis area after analyzing the impact of these changes in an EIS.[134] In the subsequent EA for the tree-thinning project, the Forest Service took "the conservative approach of assuming that *all* lynx habitat in the Project area w[ould] be treated."[135] Using that approach, the Forest Service found that only 6% of lynx habitat would be subject to clearcutting, and no more than 0.2% subject to precommercial thinning—well below the percentages prohibited by the governing forest plans.[136] The Tenth Circuit held that because the project's impacts to lynx habitat were below the caps established in the amended forest plans, which had been adopted after a full analysis of the lynx-habitat **[*26]** impacts in the EIS, the Forest Service "could reasonably assess the maximum impact that the Project could have on the lynx and conclude it was unlikely to adversely affect them."[137]

Although in the instant case the Forest Service applied an analytical framework similar to the one it used in *WildEarth Guardians v. Conner*, the difference between an EA and an EIS renders that case inapplicable. An EA is meant to determine whether a proposed action will have a significant impact on the environment, such that an EIS is necessary.[138] In contrast, an EIS must compare the environmental impacts of different alternatives, not just determine whether environmental impacts will occur.[139] While an agency's analysis of a proposed action's maximum potential impacts may be appropriate for an EA, the Forest Service's analytical framework in this case is not sufficient to meet the requirements for an EIS.[140]

The Forest Service candidly acknowledges in the EIS

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scientific expertise. *Id.*; *see also* Native Ecosystems Council v. Weldon, 697 F.3d 1043, 1051 (9th Cir. 2012) ("A court generally must be 'at its most deferential' when reviewing scientific judgments and technical analyses within the agency's expertise under NEPA." (quoting N. Plains Res. Council, Inc. v. Surface Transp. Bd., 668 F.3d 1067, 1075 (9th Cir. 2011))). This issue was not raised on appeal, but the Ninth Circuit did address the BLM's consideration of inaudible noise impacts and similarly deferred to the agency's judgment. Protect Our Cmtys. Found. v. Jewell, 825 F.3d 571, 584 (9th Cir. 2016). The present case does not concern a discrete "evaluation of complex scientific data" such as the proper method to model noise impacts from a wind turbine, *id.*; rather, it presents a broad legal question about the general structure of the Project EIS. Moreover, as Plaintiffs note, BLM in *Protect our Communities Foundation* "was not substituting the worst-case analysis for site-specific decisions," but was instead using the analysis to assess the impact produced by a wind facility in a specific location. Docket 19 at 15.

[132] 920 F.3d at 1251.

[133] Id. at 1258.

[134] Id.at 1252-53, 1256. Precommercial thinning is "a process of thinning stands that were clear-cut 20-30 years earlier, so that growth can be concentrated on the more commercially valuable trees." Id. at 1255.

[135] Id. at 1255 (emphasis in original).

[136] Id. at 1255-56.

[137] Id. at 1257.

[138] *See* id. at 1251 (describing purpose of EA).

[139] *See id.*; *see also* 40 C.F.R. § 1502.16(d) (requiring discussion of "[t]he environmental effects of alternatives including the proposed action"); 40 C.F.R. § 1502.14(a) (requiring EIS to "[r]igorously explore and objectively evaluate all reasonable alternatives").

[140] Indeed, the Tenth Circuit explained in *WildEarth Guardians v. Conner* that it had earlier held an EIS inadequate that did not base its analysis of impacts to vegetation and wildlife on the actual location of the project, "reasoning that 'the location of development greatly influences the likelihood and extent of habitat preservation'" because "'[d]isturbances on the same total surface acreage may produce wildly different impacts on plants and wildlife depending on the amount of contiguous habitat between them.'" 920 F.3d at 1257-58 (quoting N.M. ex rel. Richardson v. BLM, 565 F.3d 683, 706-07 (10th Cir. 2009)); *see also* Docket 17 at 14 (Plaintiffs arguing that "[w]here . . . significant environmental impacts demand an EIS for a site-specific project, the agency must disclose with specificity where it intends to undertake the project, what the impacts will be, and what alternatives are available."). Yet the Tenth Circuit was careful to note that its holding in *Richardson* was not "that an agency's EA or EIS *always* must specify the precise locations within a project area that will be affected." WildEarth Guardians v. Conner, 920 F.3d at 1258 (emphasis added).

that its analytical framework overestimates the Project's impacts and is unlikely to reflect the actual extent and nature of activities **[*27]** under each of the proposed alternatives within the Project Area.[141] By focusing on the Project's maximum potential impacts for all alternatives rather than its actual or foreseeable impacts for each alternative, the EIS falls short of NEPA's directive to "contain[] a reasonably thorough discussion of the significant aspects of the *probable* environmental consequences" for each alternative.[142] This approach, coupled with the lack of site-specific information in the Project EIS, detracts from a decisionmaker's or public participant's ability to conduct a meaningful comparison of the probable environmental impacts among the various alternatives. For example, in the introduction to the section discussing the Project's impacts to wildlife habitat, the EIS states that "[t]he effects . . . are similar between all alternatives because all alternatives assume that all acres proposed for timber harvest will be harvested. The analysis also assumes that all acres will be harvested by even-aged harvest methods."[143] Due to these identical assumptions for each alternative, it appears that at least with respect to wildlife impacts, the Project EIS only meaningfully analyzed the different mitigation measures **[*28]** contained in each alternative, not the harvest limits.[144] And where the Project EIS does differentiate between alternatives, it does so in partly conditional terms due to its lack of site-specific information. For example, when discussing impacts to high productive old growth habitat, the EIS concludes that Alternative 2 "*may* result in two [Wildlife Analysis Areas] dropping below 50% habitat remaining."[145]

The Project EIS identified a total acreage of potential timber harvest, but not the distribution of the specific acreage authorized by each alternative within these areas. This omission is meaningful given the duration and scale of the project.[146] Despite "additional parameters that limit the ultimate selection of units and activities,"[147] such as mitigation measures contained in the Activity Cards,[148] the Project EIS's structure creates ambiguity about the actual location, concentration, and timing of timber harvest and road construction on Prince of Wales Island.[149] By doing so, the Project EIS fails to provide a meaningful comparison of alternatives.

By authorizing an integrated resource management plan but deferring siting decisions to the future with **[*29]** no additional NEPA review,[150] the Project EIS violates NEPA. The Forest Service has not yet taken the requisite

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[141] *See, e.g.*, AR 833_2167 at 1634 ("The total acres estimated to be needed to meet timber needs are likely over-estimated and therefore the effects are likely over-estimated as well."). The Forest Service's briefing admits this as well, stating that the Project EIS "analyz[es] the Project's maximum potential impacts, . . . even though in reality impacts would be less." Docket 12 at 31; *see also id.* at 31 n.10 (noting that "under Alternative 2, about fifty-seven percent of the old-growth acreage proposed for harvest would be harvested using uneven-aged harvest prescriptions," even though the EIS's analysis assumed that all acres would be clear-cut).

[142] *WildEarth Guardians v. Mont. Snowmobile Ass'n, 790 F.3d 920, 924 (9th Cir. 2015)* (emphasis added) (quoting *City of Sausalito v. O'Neill, 386 F.3d 1186, 1206 (9th Cir. 2004))*.

[143] AR 833_2167 at 001634; *see also supra* note 43 and accompanying text.

[144] *See*, AR 833_2167 at 001642-43 (differentiating impacts of alternatives to deep snow habitat purely in terms of mitigation measures).

[145] AR 833_2167 at 001500 (emphasis added).

[146] For example, Alternative 2 authorizes a maximum 42,635 acres of timber harvest—23,269 acres of old growth and 19,366 acres of young growth—which is roughly 34 percent of the 125,529 acres identified for potential old-and young-growth harvest in the Project Area. AR 833_2167 at 001481.

[147] Docket 12 at 29.

[148] *See, e.g.*, AR 833_2168 at 001935-39 (Activity Card for "Rotational Harvest of Old Growth Using Even-aged Management").

[149] *See* Docket 19 at 9 ("Even the maximum level of logging . . . and road-building . . . could be distributed in countless combinations around the 125,529 acres allowed in the Project.")

[150] The ROD states that the Implementation Plan is to "provide a linkage from the [Project EIS] to the project-specific work without the need for additional NEPA analysis." AR 833_2427 at 001034. As Plaintiffs note, the Forest Service's "approach might be permissible if the agency were going to prepare a subsequent EIS" for decisions at the site-specific level. Docket 22-1 at 26; *see also* *Tenakee Springs v. Block, 778 F.2d 1402, 1407 (9th Cir. 1985)* ("Where there are large-scale plans for regional development, NEPA requires both a programmatic and a site-specific EIS." (citing *40 C.F.R. §§ 1508.28*, *1502.20*)); *California v. Block, 690 F.2d 753, 761 (9th Cir. 1982)* ("The detail that NEPA requires in an EIS depends upon the nature and scope of the proposed action. . . . The critical inquiry in considering the adequacy of an EIS prepared for a large scale, multi-step project is not whether the project's site-specific impact should be evaluated in detail, but when such detailed evaluation should occur.").

hard look at the environmental impact of site-specific timber sales on Prince of Wales over the next 15 years. The Forest Service's plan for condition-based analysis may very well streamline management of the Tongass and decrease the amount of falldown acreage associated with each timber sale;[151] however, it does not comply with the procedural requirements of NEPA, which are binding on the agency.[152] "NEPA favors 'coherent and comprehensive up-front environmental analysis to ensure . . . that the agency will not act on incomplete information, only to regret its decision after it is too late to correct."[153] Plaintiffs have therefore established Count I of the Complaint; the Project EIS violates NEPA and is therefore not in accordance with law.[154]

II. Alaska National Interest Lands Conservation Act

Congress enacted ANILCA to "cause the least adverse impact possible on rural residents who depend upon subsistence uses of the resources of [the public lands in Alaska]."[155] To achieve this purpose, *§ 810 of ANILCA* imposes procedural requirements upon federal decisionmakers; pursuant to **[*30]** its terms, an agency proposing an action resulting in the "use, occupancy, or disposition of public lands" must evaluate that action's effects on "subsistence uses and needs," the availability of other lands for the same purpose, and "other alternatives" that would reduce the impacts to subsistence uses.[156] Upon determining that the action "would significantly restrict subsistence uses," the agency must provide notice to the affected communities, hold public hearings, and make three findings:

> [T]hat (A) such a significant restriction of subsistence uses is necessary, consistent with sound management principles for the utilization of the public lands, (B) the proposed activity will involve the minimal amount of public lands necessary to accomplish the purposes of such use, occupancy, or other disposition, and (C) reasonable steps will be taken to minimize adverse impacts upon subsistence uses and resources resulting from such actions.[157]

When the proposed action requires completion of an EIS, the agency "shall provide the notice and hearing and include the findings required by [*ANILCA § 810(a)*] as part of such [EIS]."[158]

The Project EIS contains a section discussing the impacts to subsistence activities. **[*31]** [159] This section recognizes that "[s]ubsistence hunting, fishing, trapping, and gathering activities are a major focus of life for many residents on Prince of Wales Island."[160] The EIS notes that commenters were particularly concerned about the Project's impacts to Sitka black-tailed deer, which the EIS "considered an 'indicator' for potential subsistence resource effects concerning the resources associated

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[151] Docket 12 at 10 (describing condition-based management as "superior method to analyze the environmental effects of multi-year, landscape level analyses such as this one"). At oral argument, the Forest Service explained that one motivation behind the decision to adopt condition-based analysis was to minimize downward reductions of harvest volume as sales are finalized, known as "falldown." Docket 39 at 19:20-20:8; *see also* AR 833_2167 at 001561 (describing falldown). The Court notes that while the EIS does discuss falldown, neither it nor the ROD identifies falldown as a motivating factor in the Project's design.

[152] *See* *Protect Our Cmtys. Found. v. Lacounte, 939 F.3d 1029, 1035 (9th Cir. 2019)* ("NEPA requires . . . procedural steps but does not require an agency to reach any particular result."). In its briefing, the Forest Service maintained that "resource concerns and mitigations measures [would be] further refined" through the Implementation Plan "after treatment units are identified." Docket 12 at 29-30. But the Implementation Plan is not a valid substitute for NEPA. For example, NEPA provides for a minimum 45-day comment period on draft EISs, *40 C.F.R. § 1506.10(c)*, while the Implementation Plan allows for only a 30-day comment period. AR 833_2427 at 001035. The ROD notes that the Implementation Plan may be altered by the Forest Service, *see* AR 833_2427 at 000811, and the agency maintained at oral argument that the Project would be NEPA-compliant even if no Implementation Plan existed. Docket 39 at 18:6-13.

[153] *Protect Our Cmtys. Found., 939 F.3d at 1035* (alterations in original) (quoting *Churchill County v. Norton, 276 F.3d 1060, 1072-73 (9th Cir. 2001)*).

[154] *See* *5 U.S.C. § 706(2)(A)*.

[155] *16 U.S.C. § 3112(1)*; *see also* *Amoco Prod. Co. v. Vill. of Gambell, 480 U.S. 531, 544, 107 S. Ct. 1396, 94 L. Ed. 2d 542 (1987)* ("The purpose of *ANILCA § 810* is to protect Alaskan subsistence resources from unnecessary destruction.").

[156] *16 U.S.C. § 3120(a)*.

[157] *16 U.S.C. § 3120(a)(1)-(3)*.

[158] *16 U.S.C. § 3120(b)*.

[159] AR 833_2167 at 001540-1559.

[160] AR 833_2167 at 001540.

with old-growth forest habitat."[161] Using the maximum-impact methodology described in the previous section of this order,[162] the Forest Service determined that the Project presents "a significant possibility of a significant restriction for the use of deer," largely "due to the loss of deep snow habitat in some WAAs [Wildlife Analysis Areas]."[163] The Project EIS identified "five WAAs of concern . . . [:] 1214, 1315, 1317, 1318, and 1420," which are "near the communities of Thorne Bay, Coffman Cove, Hollis and Klawock."[164]

In light of this determination, the Forest Service held seven subsistence hearings in Prince of Wales Island communities after issuing the draft EIS.[165] In response to concerns raised at two of these hearings, the agency decided "not to authorize commercial **[*32]** harvest of old-growth stands in the area 'North of the 20 Road, and in VCU 5280."[166] In the final Project EIS, the Forest Service made the three findings required by *ANILCA § 810(a)(3)*.[167]

Plaintiffs contend that "[t]he lack of site-specific information in the [Project EIS] violates not only NEPA, but also *section 810 of ANILCA*."[168] They maintain that "analysis of impacts on subsistence uses under *section 810* should be at least as site-specific as that for the environmental impacts under NEPA."[169] As such, Plaintiffs also argue that the Forest Service's *§ 810(a)(3)* findings were premature since they were made "before deciding the specific location or extent of logging or road construction over the next 15 years."[170]

The Forest Service argues that Plaintiffs have simply repackaged their NEPA claim.[171] However, due to the similarities between the procedural requirements of NEPA and ANILCA, courts have evaluated the two statutes under similar standards.[172] Although there is little case law on the issue, at least one court has looked to NEPA decisions to determine the site-specificity required by *ANILCA § 810*. In *City of Tenakee Springs v. Clough*, the district court rejected the plaintiffs' claims that supplemental EISs were "deficient because they discuss site-specific **[*33]** impacts of proposed harvesting on subsistence resources but do not correlate those impacts with the specific subsistence needs of each affected community."[173] The court cited *Stein v. Barton*'s description of NEPA site-specificity as the relevant standard, stating that "[p]roposed activities must be sufficiently correlated with environmental factors in each affected area to facilitate public discussion of the project."[174] But the court found that no additional site-specificity was necessary to comply with ANILCA

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[161] AR 833_2167 at 001540.

[162] *See supra* 26-27; *see also* Docket 12 at 37 ("In other words, for each WAA [Wildlife Analysis Area], the Service assumed [timber] harvest would be concentrated in that WAA and would occur at the maximum level.")

[163] AR 833_2167 at 1557. Regarding other subsistence resources, the Forest Service concluded that "[n]one of the project alternatives would present 'a significant possibility of a significant restriction' of subsistence uses for most subsistence resources (food plants, personal use timber, upland game birds and waterfowl, furbearers, and marine mammals)." AR 833_2167 001545; *see also* AR 833_2167 at 001548 (finding same for aquatic resources).

[164] AR 833_2167 at 001550. The Project EIS noted that "[t]he Forest Plan estimates that with full implementation of the Forest Plan, WAAs 1420 and 1421 in the project area may retain 50 percent or less of the estimated deer habitat capability." AR 833_2167 at 001554; *see also* AR 833_2167 at 1500-01 (showing impacts of various alternatives to different habitats).

[165] AR 833_2167 at 001470. The Forest Service held subsistence hearings in Whale Pass, Klawock (twice), Hydaburg, Point Baker, Kasaan, and Naukati. *Id.*

[166] AR 833_2427 at 000787. The "area North of 20 Road" is on the northern tip of Prince of Wales Island, to the East of the communities of Point Baker and Port Protection. *See* AR 833_2178.

[167] AR 833_2167 at 001558-59.

[168] Docket 22-1 at 36; *see also* Docket 1 at 17-18, ¶¶ 48-51 (Count II in Complaint).

[169] Docket 22-1 at 37.

[170] Docket 22-1 at 39.

[171] Docket 12 at 35.

[172] *See, e.g.,* *Alaska Wilderness Recreation & Tourism Ass'n v. Morrison, 67 F.3d 723, 731 (9th Cir. 1995)* (evaluating adequacy of EIS's consideration of alternatives under NEPA and ANILCA together); *Tenakee Springs v. Clough, 915 F.2d 1308, 1310-12 (9th Cir. 1990)* (same); ***Sierra Club v. Penfold, 664 F. Supp. 1299, 1307 (D. Alaska 1987)*** ("NEPA case law is helpful in interpreting *§ 810*.").

[173] *750 F. Supp. 1406, 1422 (D. Alaska 1990)*, *rev'd on other grounds*, *915 F.2d 1308 (9th Cir. 1990)*.

[174] *Id. at 1422* (quoting *Stein v. Barton, 740 F. Supp. 743, 749 (D. Alaska 1990))*.

because the "EIS's identify site-specific impacts on subsistence resources, incorporate maps identifying which sites are important for subsistence use generally, and catalog how and to what extent each community utilizes subsistence resources, including data on per capita consumption."[175]

The Court has already determined that the Project EIS does not contain the level of site-specificity required by NEPA. For the same reasons, the Court finds that despite the public hearings it held and the findings it made, the Forest Service has failed to comply with *ANILCA § 810*. The purpose of that section is to promote informed decision-making, such that the impacts of an **[*34]** action to subsistence activities are considered; those actions "which would significantly restrict subsistence uses can only be undertaken if they are necessary and if the adverse effects are minimized."[176] This purpose can only be fulfilled if specific information about the actual, not the potential, proposed action is available. This is made clear by the statute's command to consider site-specific aspects of a proposed action, such as its effect on local "subsistence uses and needs."[177]

The Forest Service contends that it has fulfilled its duty under ANILCA by "identifying where Project activities would occur, evaluating the maximum impacts of the Project on subsistence uses, and by taking actions to benefit subsistence uses and reduce the adverse effects of the project on . . . those uses."[178] However, as discussed above, the Commercial Vegetation Management map only identifies the potential, and not the actual, locations of timber harvest and road building within the 1.8-million acre Project Area. The Forest Service's evaluation of the Project's maximum impacts does not evaluate the Project's actual expected impacts.[179] By not developing actual site-specific information, the Forest **[*35]** Service limited its ability to make informed decisions regarding impacts to subsistence uses and presented local communities with vague, hypothetical, and over-inclusive representations of the Project's effects over a 15-year period.[180]

The Implementation Plan does envision additional information-gathering and public participation before site-specific decisions are made.[181] However, as Plaintiffs note, this process does not require the Forest Service to make additional findings under *ANILCA § 810(a)(3)* or provide the public with a right of appeal.[182] Moreover, the Implementation Plan is subject to change by the Forest Service, and there is no certainty that its public participation provisions will last for the Project's 15-year duration.[183] Without either an up-front discussion of actual site-specific impacts or future ANILCA analysis when siting decisions are made, the Project EIS and ROD are inconsistent with *ANILCA § 810*. Plaintiffs have therefore established Count II of the Complaint; the Project EIS violates ANILCA and is therefore not in accordance with law.[184]

III. National Forest Management Act

Pursuant to NFMA, the Forest Service must prepare a land and resource management plan, also called a "forest **[*36]** plan," for each forest it manages.[185] Projects occurring in a national forest must comply with that forest's management plan.[186] Standard and

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[175] *Id.*

[176] *Amoco Prod. Co. v. Vill. of Gambell, 480 U.S. 531, 544, 107 S. Ct. 1396, 94 L. Ed. 2d 542 (1987)*.

[177] *16 U.S.C. § 3120(a)*; *see also supra* note 119.

[178] Docket 12 at 35-36.

[179] *See supra* 30-32. As noted previously, *see supra* note 146, Alternative 2 authorized 42,635 acres of timber harvest, or 34 percent of the 125,529 acres identified for potential harvest by the LSTA, but gave no indication of where that harvest would occur within the total acreage. AR 833_2167 at 001481.

[180] As Plaintiffs note, "subsistence activities are inherently location-specific," and "[p]eople care about the places they use for subsistence and how the action will affect those places and nearby habitat." Docket 19 at 18.

[181] *See* AR 833_2427 at 001037 (describing implementation process).

[182] Docket 19 at 19.

[183] *See* AR 833_2427 at 000811 ("The plan is meant to be a 'living' document and may need to be adjusted . . . .").

[184] *See 5 U.S.C. § 706(2)(A)*.

[185] *See 16 U.S.C. § 1604(a)*.

[186] *16 U.S.C. § 1604(i)*; *see also Friends of Southeast's Future v. Morrison, 153 F.3d 1059, 1068 (9th Cir. 1998)* ("[P]ursuant to the NFMA, the Forest Service must demonstrate that a site-specific project would be consistent with the land resource management plan of the entire forest." (quoting ***Neighbors of Cuddy Mt. v. United States Forest Serv., 137 F.3d 1372, 1377 (9th Cir. 1998)))***.

Guideline TIM3.I.C in the 2016 Forest Plan that currently governs management of the Tongass provides:

> Timber harvest unit cards will document resource concerns and protection measures. The unit cards, including a map with relevant resource features, will be provided electronically when Draft or Final NEPA documents and decisions are published. (Consult Tongass National Forest Supplement 1909.15-2015-1.)[187]

Tongass National Forest Supplement 1909.15-2015-1, which "[e]stablishe[d] procedures for producing and distributing unit and road cards associated with NEPA documents,"[188] was rescinded by the Forest Service in October 2018.[189]

The Project EIS does not contain unit cards, and the ROD explains in the section describing Activity Cards that "[u]nit cards would be developed for any timber sales when site-specific locations are determined" through the Implementation Plan.[190] Plaintiffs contend that the "Forest Service violated the forest plan requirement to include unit cards with the draft or final EISs for the Prince of Wales Project."[191]

Responding to comments arguing that the Project EIS had failed to comply with the Tongass Forest Plan, the Forest Service explained that it understood the rescission of Tongass National Forest Supplement 1909.15-2015-1 to have rendered "the timing for when electronic unit cards are provided . . . no longer applicable."[192] The Forest Service added that the Implementation Plan's "opportunity for public comment on the maps, and unit and road cards meets the intent of Forest Plan TIM3.I.C."[193]

In its briefing to this Court, the Forest Service advances a different argument. It now contends that TIM3.I.C is ambiguous regarding "the contents and format of unit cards, *except* that the cards 'will document resource concerns and protection measures' and 'include[e] [sic] a map with relevant resource features.'"[194] The Forest Service maintains that the Activity Cards and Commercial Vegetation Management map provided with the Project EIS comply with this requirement.[195]

The Forest Service argues that its interpretation of TIM3.I.C is entitled to *Auer* deference, which accords "defer[ence] to agencies' reasonable readings of genuinely ambiguous regulations."[196] But *Auer* deference is not automatic; the Supreme **[*38]** Court has explained that "before concluding that a rule is genuinely ambiguous, a court must exhaust all the 'traditional tools' of construction," meaning it "must 'carefully consider[]' the text, structure, history, and purpose of a regulation."[197]

Addressing first the Forest Service's position in the administrative record, the Court finds no ambiguity in TIM3.I.C about when the agency is required to provide unit cards, notwithstanding the rescission of the supplement cited therein. The Standard and Guideline clearly states that "[t]he unit cards . . . will be provided electronically *when Draft or Final NEPA documents and decisions are published*."[198] Under the plain language of the Forest Plan, the Forest Service must provide unit cards when the relevant NEPA document is published.

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[187] AR 833_0404 at 63265. Forest plans for the Tongass have included a unit-card requirement since at least 1997. AR 833_2076 at 068765 (1997 Tongass Forest Plan).

[188] AR 833_2526 at 074726.

[189] AR 833_2525 at 074720-25.

[190] AR 833_2427 at 000826; *see also id.* at 000802 ("The Implementation Plan identifies that unit and road-specific cards will be developed when specific harvest units and road locations are determined as part of the Implementation Plan process.")

[191] Docket 22-1 at 39; *see also* ***[*37]*** Docket 1 at 18-20, ¶¶ 52-58 (Count III in Complaint).

[192] AR 833_2440 at 000020 (Responses to Comments on Draft ROD); *see also* AR 833_2427 at 000802 (ROD determining that publishing unit cards during Implementation Plan "is an alternative way to fully comply with Forest Plan Standard TIM3.I.C, which is no longer applicable in terms of timing when unit cards are provided").

[193] AR 833_2171 at 002149 (Responses to Comments on Draft EIS).

[194] Docket 12 at 42 (emphasis and alterations in original) (quoting AR 833_0404 at 063265).

[195] Docket 12 at 41-45.

[196] *Kisor v. Wilkie, U.S. , 139 S. Ct. 2400, 2408, 204 L. Ed. 2d 841 (2019)* (citing *Auer v. Robbins, 519 U.S. 452, 117 S. Ct. 905, 137 L. Ed. 2d 79 (1997))*.

[197] *Id.* at 2415 (2019) (second alteration in original) (first quoting *Chevron U.S.A. Inc. v. NRDC, 467 U.S. 837, 843 n.9, 104 S. Ct. 2778, 81 L. Ed. 2d 694 (1984)*, then quoting *Pauley v. BethEnergy Mines, 501 U.S. 680, 707, 111 S. Ct. 2524, 115 L. Ed. 2d 604 (1991)* (Scalia, J., dissenting))).

[198] AR 833_0404 at 63265 (emphasis added).

Regardless of the provision's intent,[199] the Forest Service departed from the unambiguous directive of TIM3.I.C. The agency's decision to delay the publication of unit cards until the Implementation Plan, after NEPA review was completed for the Project, is therefore inconsistent with the Forest Plan.

The Court finds the Forest Service's position in its briefing to be no more convincing. While TIM3.I.C does not **[*39]** fully explain what a unit card should contain, it is clear from the Standard and Guideline's language that each card must relate to a discrete geographic area, or "[t]imber harvest unit," within the Project Area.[200] The Commercial Vegetation Management map does not identify specific timber harvest units,[201] and the Activity Cards "document resource concerns and protection measures at the Project level."[202] They are not unit cards within the meaning of TIM3.I.C.[203]

Moreover, even if TIM3.I.C were ambiguous, the current interpretation advanced in the Forest Service's briefing would not be entitled to *Auer* deference. Throughout the administrative record, the Forest Service's position is consistent: provision of unit cards after the completion of NEPA review complies with TIM3.I.C due to the rescission of Tongass National Forest Supplement 1909.15-2015-1. It is only in its briefing to this Court that the agency asserts that the Activity Cards and the Commercial Vegetation Management map themselves constituted the unit cards required by TIM.3.I.C.[204] "[A] court should decline to defer to a merely 'convenient litigating position' or '*post hoc* rationalization[n] advanced' to 'defend past **[*40]** agency action against attack.'"[205] And the administrative record itself belies the Forest Service's litigation position; in the ROD, the agency differentiated between Activity Cards and unit cards and explained that the latter would be provided through the Implementation Plan in an effort to comply with TIM3.I.C.[206]

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[199] *See* AR 833_2171 at 002149 (stating that Implementation Plan's "opportunity for public comment on the maps, and unit and road cards meets the intent of the Forest Plan TIM3.I.C").

[200] AR 833_0404 at 63265.

[201] AR 833_2178.

[202] Docket 12 at 44; *see also* AR 833_2427 at 000826 (describing Activity Cards).

[203] *Friends of Southeast's Future v. Morrison, 153 F.3d 1059, 1069 (9th Cir. 1998)* ("However, an agency's interpretation does not control, where, as here, it is plainly inconsistent with the regulation at issue."). The Forest Service has previously used the term "activity cards" collectively to refer to cards "used to explain site-specific proposed activities," including "timber harvest units and proposed and existing roads." AR 833_2084 at 061267 (EIS for Kuiu Timber Sale). Unlike the Activity Cards in this case, the Kuiu Timber Sale unit cards described harvest activities in specific geographic locations, including both graphical and narrative information for each harvest unit. *See* AR 833_2084 at 061279-80 (card for unit 101); *see also id.* at 061268-76 (describing activity cards, as defined by that project, and locating individual harvest units and roads on map of Project Area). Although Forest Supplement 1909.15-2015-1 was still effective when the Kuiu Timber Sale EIS was prepared, the Court finds a comparison between the timber harvest unit cards in that case and the Activity Cards used here to be instructive.

[204] At oral argument, the Forest Service maintained that the agency had twice asserted in the administrative record that the Activity Cards and Commercial Vegetation Management map themselves complied with TIM3.I.C. Docket 39 at 24:24-26:19 (citing AR 833_2427 at 000802 and AR 833_2171 at 002149). Not so. As discussed above, the two pages of the record cited by the Forest Service concern the timing of unit card publication.

[205] *Kisor v. Wilkie, U.S. , 139 S. Ct. 2400, 2417, 204 L. Ed. 2d 841 (2019)* (alteration and emphasis in original) (quoting *Christopher v. SmithKline Beecham Corp., 567 U.S. 142, 155, 132 S. Ct. 2156, 183 L. Ed. 2d 153 (2012))*.

[206] The ROD lays out the difference between Activity Cards and unit cards, explaining that the former inform but do not replace the latter:

> The POWLLA FEIS uses a condition-based approach where specific harvest units and roads will be determined during implementation through a collaborative public process and interdisciplinary review. Activity Cards and maps were included with the FEIS and Draft ROD and will also be part of this Final ROD. The Activity Cards were designed to honor the public process developed at the community level during the POW LLA NEPA process, to be a resource for the public and Forest Service resource specialists, to assist in alternative development, and to accompany the EIS to provide clarity for environmental effects analysis and guide implementation . . . . The Implementation Plan identifies that unit and road-specific cards will be developed when specific harvest units and road locations are determined as part of the Implementation Plan process. This Implementation Plan allows for more collaboration **[*41]** during implementation, and responsiveness to dynamic on-the-ground conditions, new science information, and public input. This process provides for publishing unit and road cards online and providing an opportunity for public review and comment before final line officer decisions on specific project

Due to their failure to include timber harvest unit cards corresponding to discrete geographic locations, the Project EIS and ROD are inconsistent with the 2016 Tongass Forest Plan. Plaintiffs have therefore established Count III of the Complaint; by not complying with the applicable forest plan, the Project violated NFMA and is therefore not in accordance with law.[207]

Nevertheless, the Forest Service asserts that this error was not prejudicial.[208] "Relief is available under the APA only for 'prejudicial error.'"[209] Plaintiffs challenging agency action bear the burden of showing prejudice, but this is not **[*42]** "a particularly onerous requirement."[210] Plaintiffs have met their burden here. They argue that they "were prejudiced by the lack of unit cards that would have given them the opportunity to provide meaningful input on logging locations, impacts, and alternatives."[211] The Ninth Circuit has consistently held that an error that affects the public's ability to meaningfully participate in the NEPA review process is prejudicial.[212]

The Forest Service contends that Plaintiffs had the opportunity to comment on the Activity Cards and Commercial Vegetation Management map, which contain "proposed locations of timber harvest."[213] However, as discussed above, these documents do not contain the level of site-specificity required by TIM3.I.C—or by NEPA for that matter—and did not allow Plaintiffs to meaningfully comment on the specific harvest activities that would have been identified on timber harvest unit cards had they been published with the draft EIS.[214] The Court therefore finds that the NFMA violation was prejudicial and that relief is warranted under the APA.

IV. Proper Remedy

Having determined that Plaintiffs prevail on all three counts in their Complaint, the Court **[*43]** turns to the question of the proper remedy. Plaintiffs request a judgment declaring that the Project EIS "violates NEPA, *section 810 of ANILCA*, and NFMA," and "vacating those portions of the ROD authorizing vegetation management and new road construction."[215] The Forest Service contends that remand without vacatur may be appropriate, and requests the Court to allow supplemental briefing to address the proper remedy.[216]

Vacatur is the default remedy under the APA, which directs reviewing courts to "hold unlawful and set aside" unlawful agency action.[217] The Ninth Circuit has explained that a court should "order remand without vacatur only in 'limited circumstances,'" and "leave an

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activities are made. This has been clarified in the Implementation Plan, ROD Appendix 2, under step 4. I have determined this process is an alternative way to fully comply with Forest Plan Standard TIM3.1.C, which is no longer applicable in terms of the timing of when unit cards are provided.

AR 833_2427 at 000802.

[207] *See* *5 U.S.C. § 706(2)(A)*.

[208] Docket 12 at 45-47.

[209] ***Drakes Bay Oyster Co. v. Jewell, 747 F.3d 1073, 1090-91 (9th Cir. 2014)*** (quoting *5 U.S.C. § 706*).

[210] *Shinseki v. Sanders, 556 U.S. 396, 410, 129 S. Ct. 1696, 173 L. Ed. 2d 532 (2009)*.

[211] Docket 19 at 24; *see also supra* note 119.

[212] *See, e.g.,* ***Or. Natural Desert Ass'n v. Jewell, 840 F.3d 562, 571 (9th Cir. 2016)*** (holding error to be prejudicial where "the public was not able to tailor its comments to address concerns regarding the potential winter presence of sage grouse" because "baseline conditions [were] inadequately established"); *Friends of Southeast's Future v. Morrison, 153 F.3d 1059, 1068 (9th Cir. 1998)*; *cf.* *Cal. Wilderness Coalition v. United States DOE, 631 F.3d 1072, 1091-92 (9th Cir. 2011)* (reaffirming Circuit's "consistent case law holding that 'harmless error' requires a determination that the error 'had no bearing on the procedure used or the substance of [the] decision reached'" (alteration in original) (quoting *Paulsen v. Daniels, 413 F.3d 999, 1006 (9th Cir. 2005))*).

[213] Docket 12 at 46.

[214] Further, the ability to comment on draft unit cards produced pursuant to the Implementation Plan does not render the error harmless, *see* Docket 12 at 47, since the Implementation Plan is subject to change and does not provide for the same public participation and review process as NEPA. *See supra* note 152.

[215] Docket 22-1 at 43.

[216] Docket 12 at 47-49.

[217] *5 U.S.C. § 706(2)(A)*. Both partial and complete vacatur of the offending agency action are acceptable forms of relief under the APA. *See* *Monsanto Co. v. Geertson Seed Farms, 561 U.S. 139, 165-66, 130 S. Ct. 2743, 177 L. Ed. 2d 461 (2010)* ("If a less drastic remedy (such as partial or complete vacatur of APHIS's deregulation decision) was sufficient to redress respondents' injury, no recourse to the additional and extraordinary relief of an injunction was warranted.").

invalid rule in place only 'when equity demands.'"[218] To determine whether to remand an action without vacatur, a court is to "weigh the seriousness of the agency's errors against 'the disruptive consequences of an interim change that may itself be changed.'"[219]

The Forest Service maintains that "[b]oth considerations are informed by the Court's decision on the merits," and the agency "believes the consequences of vacatur would be extremely disruptive due to the recent low and uncertain supply of timber in Southeast Alaska, which threatens **[*44]** businesses in the region."[220] The Forest Service maintains that "[t]he economic need for Project timber and the harm that would be caused by delaying timber harvesting activities authorized by the Project cannot be adequately addressed within the page limits for [its] merits brief."[221] In response, Plaintiffs note that the Forest Service "made a strategic choice to devote more pages to the merits of the claims, with no basis to assume it was entitled to supplemental briefing on the remedy."[222] Since Plaintiffs did choose to devote a section of their briefing to the remedy issue, they maintain that allowing supplemental briefing would unfairly prejudice them.[223]

The Court finds that supplemental briefing on the appropriate remedy could be helpful. Any prejudice to Plaintiffs as a result of this delay will be eliminated because the Court will keep the preliminary injunction in effect until the appropriate remedy is determined.

CONCLUSION

In light of the foregoing, IT IS HEREBY ORDERED that:

Plaintiffs' request at Docket 10 for declaratory relief is GRANTED. The Project EIS violates NEPA, *42 U.S.C. § 4332(2)(C)*, ANILCA, *16 U.S.C. § 3120(a)*, and NFMA, *16 U.S.C. § 1604(i)*. It is therefore "arbitrary, capricious, an abuse of discretion, or otherwise not in accordance **[*45]** with law."[224]

Each party may file a supplemental brief addressing the proper remedy in this case **within 21 days of the date of this order; such brief shall not exceed 15 pages**. Each party will then have **an additional 14 days to file a response, not to exceed 8 pages**.

The preliminary injunction at Docket 27 shall remain in place until the Court enters a final judgment.

DATED this 11th day of March, 2020 at Anchorage, Alaska.

/s/ Sharon L. Gleason

UNITED STATES DISTRICT JUDGE

End of Document

[218] *Pollinator Stewardship Council v. United States EPA, 806 F.3d 520, 532 (9th Cir. 2015)* (first quoting *Cal. Cmtys. Against Toxics v. United States EPA, 688 F.3d 989, 994 (9th Cir. 2012)* then quoting *Idaho Farm Bureau Fed'n v. Babbitt, 58 F.3d 1392, 1405 (9th Cir. 1995))*.

[219] *Id.* (quoting *Cal. Cmtys. Against Toxics, 688 F.3d at 992*).

[220] Docket 12 at 48.

[221] Docket 12 at 49.

[222] Docket 19 at 26.

[223] Docket 19 at 26.

[224] *5 U.S.C. § 706(2)(A)*.

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Review

Management for Mountain Pine Beetle Outbreak Suppression: Does Relevant Science Support Current Policy?

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Abstract: While the use of timber harvests is generally accepted as an effective approach to controlling bark beetles during outbreaks, in reality there has been a dearth of monitoring to assess outcomes, and failures are often not reported. Additionally, few studies have focused on how these treatments affect forest structure and function over the long term, or our forests' ability to adapt to climate change. Despite this, there is a widespread belief in the policy arena that timber harvesting is an effective and necessary tool to address beetle infestations. That belief has led to numerous proposals for, and enactment of, significant changes in federal environmental laws to encourage more timber harvests for beetle control. In this review, we use mountain pine beetle as an exemplar to critically evaluate the state of science behind the use of timber harvest treatments for bark beetle suppression during outbreaks. It is our hope that this review will stimulate research to fill important gaps and to help guide the development of policy and management firmly based in science, and thus, more likely to aid in forest conservation, reduce financial waste, and bolster public trust in public agency decision-making and practice.

Keywords: bark beetle; clearcut; climate change; climate change adaptation; daylighting; *Dendroctonus ponderosae*; forest pest management; monitoring; sanitation; thinning

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1. Introduction

Insect outbreaks are increasing in size and severity on a global scale [1]. In North America alone, three massive insect outbreaks occurred within the last two decades, all involving native bark beetles in conifers [2]. Of these, the mountain pine beetle (*Dendroctonus ponderosae*) outbreak is an order of magnitude larger than any previously recorded. A variety of factors, natural and anthropogenic, converged to result in these dramatic events [2]. Each outbreak has not only had severe ecological effects, but each has also triggered human responses that, for better or for worse, have resulted in additional impacts along with massive expense [3]. Predictions are that outbreaks of bark beetles will become more frequent and severe in the future [4,5] indicating an imperative need to critically assess the efficacy and impacts of our approaches to their management.

Outbreaks of bark beetles are not new. They have been occurring for millennia and have played a major role in shaping coniferous forest ecosystems of the world. While considerable research has been conducted on controlling bark beetles, massive gaps in knowledge remain. In particular, there is a disturbing dearth of rigorous replicated empirical studies assessing the effects of various management strategies, particularly timber harvest treatments, for bark beetle outbreak suppression. Even fewer studies have focused on how such treatments meet explicit goals or affect forest structure, function and future outbreak dynamics [6]. Particularly pertinent at this time, there is a lack of information to address forest adaptation to climate change in light of increasingly "out of historic norm" behavior of bark beetles. Despite this, there is a widespread belief in the policy arena that timber harvesting is an effective and necessary tool to address beetle infestations. That belief has led to proposals for, and enactment of, significant changes in federal environmental laws to encourage more timber harvests. Our question is, does that belief have a sound grounding in current science?

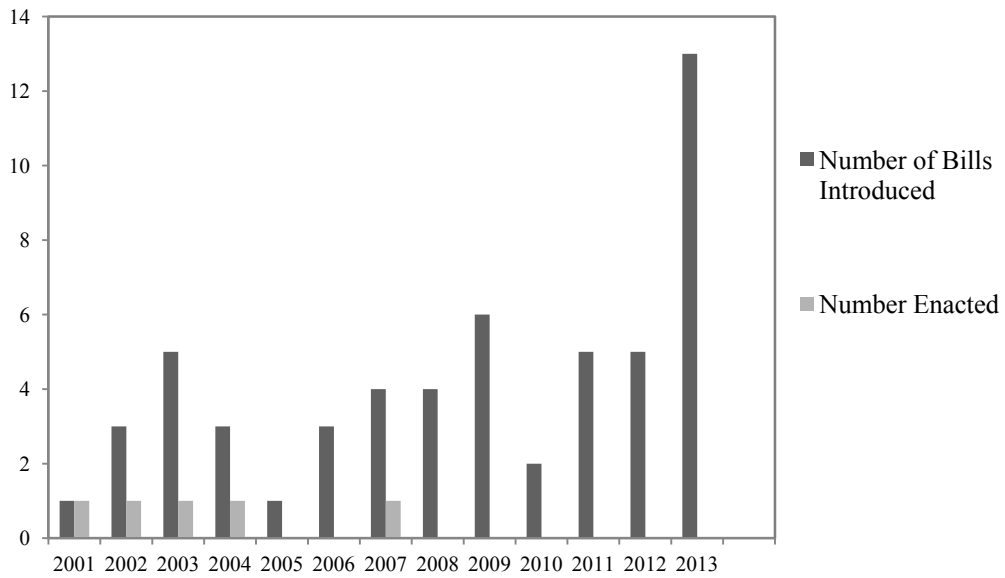
In this review, we focus on mountain pine beetle as an exemplar to critically evaluate the state of science behind the use of timber harvest treatments for bark beetle suppression during outbreaks. The mountain pine beetle was chosen because it is the most studied, most intensively managed, and most aggressive of the irruptive bark beetles. It has also responded strongly to climate change, resulting in a recent massive outbreak of unprecedented size that, in turn, has initiated numerous human responses, mostly involving implementation of timber harvests. It has also initiated many policy changes with many more currently in the pipeline.

We begin with an overview of the current policy situation. We then briefly review the biology of mountain pine beetle to form a foundation for understanding the factors that initiate and maintain outbreaks and how anthropogenic factors are contributing to current problems. We then describe the primary timber harvest treatments used to suppress bark beetle outbreaks and examine how well relevant science and ecological principles support their use. We conclude with a discussion on how well policy reflects the actual state of current science and identify where significant gaps between science and practice occur particularly in light of climate change. We also discuss the need to use advanced tools, including genetics and remote sensing, to adapt old practices to new situations-particularly in the realm of climate change adaptation. It is our hope that this review will stimulate research to fill important gaps and to help guide the development of policy and management firmly based in science, and thus, more likely to aid in forest conservation, reduce financial waste, and bolster public trust in public agency decision-making and practice.

2. The Current Policy Situation

There have been many recent proposals to streamline, reduce, or eliminate perceived legal obstacles to implementing timber harvests to address beetle epidemics on federal public lands (Figure 1). Between the 107th Congress (January 2001) and the 113th Congress (present), we found 55 bills that were introduced where at least one goal of the legislation was to increase timber harvests in order to respond to beetle infestations (Figure 1). Most of these proposals focused on the US Forest Service, which manages the majority of forests on federal public lands.

Figure 1. Number of bills involving timber sales that included bark beetle control that were introduced and/or enacted from 2001 to 10 July 2013.



Some of these proposals have been enacted. By far, the most important legal change has been the Healthy Forest Restoration Act of 2003 (HFRA). HFRA reduced the level of environmental analysis required for certain timber projects under the National Environmental Policy Act (NEPA), specifically by limiting the number of alternatives that the Forest Service was required to analyze. It also significantly restricted the ability of members of the public to challenge certain timber projects in court (by making participation in the agency's administrative process a precondition for filing suit). Further, it sought to streamline the Forest Service's internal administrative process for considering citizen challenges to certain timber projects. HFRA applies nationally to all National Forest System and Bureau of Land Management lands, and has resulted in forest treatment projects on an average of 220,000 acres of federal land per year since its enactment [7]

HFRA authorizes this streamlined process for timber projects on "Federal land on which…the existence of an epidemic of disease or insects, or the presence of such an epidemic on immediately adjacent land and the imminent risk it will spread, poses a significant threat to an ecosystem component, or forest or rangeland resource, on the Federal land or adjacent non-Federal land" [8,9].Moreover, while other types of HFRA projects in old growth forests are subject to limitations intended to protect

old growth structure and large trees, timber projects to address insect epidemics can occur in old growth forests without those limitations [10,11].

HFRA also sets up a special experimental management process to develop better management methods for beetle infestations. After a long list of findings by Congress about the risks of beetle infestations in US forests, Congress authorized up to 250,000 acres of "applied silvicultural assessment and research treatments" on National Forests that would be categorically excluded from NEPA; these treatments could include timber harvesting [12,13]. HFRA section 401(b)(3) [14] requires that these applied silvicultural assessments and treatments must be peer reviewed by non-agency scientists.

HFRA is not alone. Another enacted bill created exemptions from environmental laws to allow timber harvest projects in a geographically limited area. As part of a massive supplemental appropriations act to address recovery from the September 11, 2001 terrorist attacks, Congress exempted a series of timber harvest projects in the Black Hills of South Dakota from any and all environmental laws; the law specifically stated that the projects were intended to reduce both fire risk and beetle infestations [15].

Other recent enactments create additional incentives for timber harvests intended to address beetle infestations. Congress permitted state forestry agencies to perform beetle control timber harvest projects on federal lands in Colorado and Utah under what is called "Good Neighbor Authority" [16]. These state forestry agencies must also implement "similar and complementary" services on state land adjacent to federal land in order to use the authority. Additionally, in the 2008 Farm Bill, Congress expanded subsidies for the production of "renewable biomass" energy to include timber produced from projects intended to reduce or contain disease or insect infestation [17].

There have been many more recent proposals for additional changes. Congress has considered multiple bills to expand the scope of HFRA. One proposal would require the Forest Service to implement at least one insect and disease control pilot project in at least one subwatershed in every national forest in a state that is "subject" to an insect or disease epidemic [18–24].Congress has also considered many other changes to encourage timber harvesting to control beetle infestations besides expanding HFRA. Some proposals would expand the exemptions to the Forest Service's Roadless Rule (which prohibits commercial timber projects and road construction in unroaded areas of National Forests) in order to allow more timber projects that are intended to address beetle infestations; some of these projects would be exempt from judicial review [25–27].

Congress has considered giving additional benefits under the Clean Air Act for "renewable biomass" produced from timber projects on federal lands, including projects intended to control beetle infestations [28,29], giving grants and other subsidies for beetle control timber projects [30], extending the Good Neighbor Authority to more states [31–33], and reducing or eliminating the fee that private timber contractors pay for timber contracts in exchange for agreements to implement restoration work, such as culvert removals, road improvements, or invasive weed removal, if the project provides insect control and other forest management benefits [26]. Finally, two bills have proposed that designation of additional federal lands as protected wilderness be paired with exemptions of beetle-related timber projects from environmental laws [34,35].

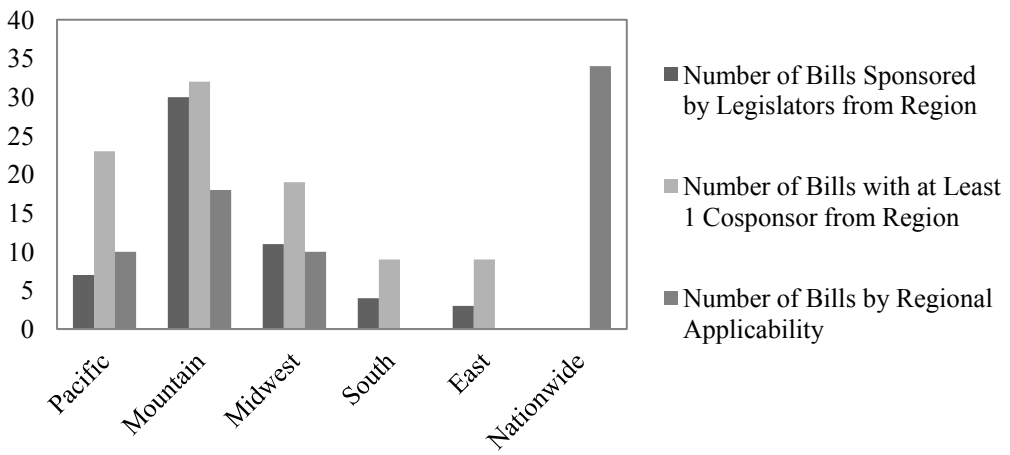
Throughout this policy debate, members of Congress and major stakeholders have regularly stated that timber harvest on federal lands is a necessary component of efforts to fight beetle infestations and

control outbreaks and that additional flexibility under environmental laws is necessary for agencies to pursue these timber harvest projects [36–41].

Likewise, the U.S. Forest Service and other U.S. federal land management agencies have prescribed timber harvests as a necessary component of beetle control. For example, the Forest Service's Western Bark Beetle Strategy calls for the agency to "reduce the number of trees per acre and create more diverse stand structures to minimize extensive epidemic bark beetle areas" by using thinning and other harvest treatments [42]. While the Forest Service has applauded HFRA as "very helpful" in addressing beetle outbreaks (U.S. Forest Service, Review of the Forest Service Response: The Bark Beetle Outbreak in Northern Colorado and Southern Wyoming, September 2011), available at [43], agency leaders do not look favorably upon all legislative proposals to weaken environmental laws to facilitate timber harvest for beetle control. For example, Tom Tidwell, Chief of the Forest Service, criticized recent bipartisan legislation [25] because it would "shortchange the environmental review process, cut out public engagement and collaboration…and override roadless protections." (Testimony from House Subcommittee on Public Lands and Environmental Regulation Legislative Hearing on H.R. __, H.R. 1294, H.R. 818, H.R. 1345, H.R. __, and H.R. 1442 available at [44].

Given the geographic concentration of federal public lands in the West, most of the bills have a specific focus on western states, and were introduced or supported by westerners (Figure 2). But that is not universally the case. Two of the proposals to expand the scope of HFRA were sponsored by Representative Markey, a Democrat from Massachusetts [19,23]. Moreover, support for these bills is bipartisan, showing that the belief that timber harvest can address beetle infestations crosses the political spectrum. Of the 55 total bills, 17 were sponsored by Democrats alone, 21 sponsored by Republicans alone, and 17 had bipartisan sponsors. Markey himself has received very high ratings from the League of Conservation Voters, with a 94% lifetime score from the group.

Figure 2. Bill sponsorship, co-sponsorship, and applicability by region. (Pacific = CA, OR, W, AK, HI; mountain states = MT, ID, NV, WY, UT, CO, AZ, NM; Midwest = ND, SD, NE, KS, MN, IA, MO, WI, IL, IN, MI, OH; SOUTH = TX, OK, AR, LA, KY, TN, MS, AL, GA, FL, SC, NC, VA, WV; east = ME, NH, VT, MA, NY, RI, CT, NJ, DE, MD, PA).



The 55 bills introduced since 2001 show that many legislators, particularly those from western states, believe that timber harvests are a necessary tool to address beetle infestations. This belief has

led to the enactment of laws that reduce compliance burdens under NEPA and other federal environmental laws. There are many more proposals for additional significant changes to federal environmental laws to encourage more timber harvests for beetle control. While "there is certainly a tremendous amount of social and political pressure to 'do something' about beetles," there is also growing concern by many that timber harvests for beetle control are expensive and ineffective and that long-term impacts on forests are unknown [42 citing Ann Merwin, director of policy and government affairs for the Wilderness Society]. The policy debate demonstrates the need to critically examine how well these treatments work and place policy in the context of the best available science.

3. A Mountain Pine Beetle Primer

The mountain pine beetle is native to pine forests in western North America [45]. During outbreaks, it can kill millions of trees across extensive areas. The ability to cause such widespread mortality has led it to be described as the most destructive forest pest on the continent [46]. Indeed, economic and aesthetic impacts of outbreaks can be severe. From a manager's perspective, outbreaks are often perceived as a symptom of poor "forest health", while ecologists more often view outbreaks as natural ecological processes integral to the maintenance and resilience of the forest. These differing human perceptions have led to conflicting and ambiguous management goals as well as scientific, social, and political conflict.

The mountain pine beetle is polyphagous on pines (*Pinus*) [45]. It attacks not only native pines but also exotic pines used in ornamental landscaping. Within the natural range of the beetle, only *P. jeffreyi* appears to be avoided, likely due to its unusual chemistry [45]. Pines are well defended and are not easy targets for the beetle. They produce constitutive defenses consisting of resin that can flush the tiny beetles from trees, often drowning them [47–49]. Pines also produce induced defenses in the phloem comprised of resin containing elevated concentrations of toxic monoterpenes [49,50]. Induced defenses develop in response to attack, and thus, involve a lag time of one or more days to develop and can last for a month or more even when trees are killed [51].

To contend with a defensive host, the mountain pine beetle has evolved a complex chemical communication system it uses to coordinate a mass attack on a tree [52]. A female beetle will land, begin to tunnel, and release an aggregation pheromone that attracts conspecifics of both sexes to the tree. Subsequent arrivals release additional pheromone increasing attraction to the tree [53]. If enough beetles respond, the tree can be overwhelmed in just a few days. As defenses are depleted, the beetles release an anti-aggregation pheromone which repels late arriving beetles and acts to reduce intra-specific competition among brood [53]. At this point, the tree has reached "a point of no return" [54]. It will not recover and will slowly die, although it may remain green for nine months or more due to translocation of water to needles by capillary action in the xylem.

The number of beetles needed to kill a tree varies and depends, in part, on the strength of its defenses [55]. In general, as the strength of defenses increase so does the number of beetles needed. Several factors influence the strength of tree defenses. Trees weakened by drought, disease or damage can be overwhelmed by only a few hundred beetles while very vigorous trees may require many hundreds or even thousands [56]. Genetics of the host tree also play an important role. Within a tree species,

different genotypes result in differing levels of resistance and susceptibility [57,58]. Genetic differences are even more pronounced when considering differences in defenses among *Pinus* species [59,60].

The ability of tree defenses to affect mountain pine beetle success varies by whether the beetle is in endemic (non-outbreak), incipient (building) and eruptive (outbreak) phases. During the endemic phase, when beetle populations are low, host tree defenses are the major constraint in the ability of beetles to kill trees. However, tree defenses become inconsequential once the threshold to the incipient stage has been surpassed [61]. When numbers are low, beetles attack smaller diameter trees with low defenses. However, once populations rise to the incipient stage, beetles choose larger, healthier, resource-rich trees, despite their superior defenses [61]. Because larger trees have thicker phloem resources to support larval development, they support greater beetle productivity which results in positive feedback that helps fuel the expansion of the outbreak. Thus, host tree traits (primarily host defenses and diameter class) that determine which trees are killed when populations are low, may be unimportant or even have an opposing effect on beetle success when populations are high [61].

It is often reported in the press that mountain pine beetle populations are cyclical. This is not the case. The population dynamics of insects that develop cyclical outbreaks are typically dominated by *delayed* negative density dependent feedback involving regulation by natural enemies and induced resistance mechanisms [62]. This type of feedback results in predictable intervals (cycles) between outbreaks although the amplitude of population peaks can vary due to spatiotemporal variation in abiotic conditions. Bark beetle dynamics, instead, are driven by alternations of negative density dependent and positive density dependent feedbacks resulting in sporadic unpredictable population eruptions primarily driven by threshold effects and typically triggered by abiotic factors, particularly climate [61–63]. It is critical to distinguish between cyclical and eruptive population dynamics as insects exhibiting these two types of dynamics demand different management and monitoring approaches. In particular, eruptive dynamics are triggered by abiotic factors typically outside the realm of human manipulation.

Mountain pine beetle can remain in non-outbreak phase for very long periods of time, even when forests are composed of suitable age classes of host trees and in a condition often considered to be highly susceptible and "unhealthy". Outbreaks occur *only* when multiple thresholds involving temperature, tree defenses, and brood productivity are surpassed that allow positive feedbacks to amplify across several scales [2,64]. While outbreak development is complex, the primary elements that must exist are an abundance of suitable hosts *and* a trigger [63]. Triggers for mountain pine beetle that allow population amplification and subsequent widespread outbreak initiation are warm temperatures and drought, conditions that often co-occur [65]. There can also be a substantial lag period, even several years, from the initiation of the abiotic factors that trigger an outbreak to when populations actually amplify [65,66]. However, once a threshold number of beetles is surpassed, the outbreak becomes self-perpetuating.

While forest conditions alone do not cause outbreaks, certain forest conditions can support larger and more severe outbreaks once they are initiated. Mountain pine beetle attacks only pines (except in rare instances where it "bleeds over" into spruce) [67], and typically only those larger than ca. 15 cm in diameter [68]. Therefore, forests comprised mainly of large diameter pine can be at higher risk of widespread mortality when a trigger occurs than are forests comprised of young, small diameter pine or composed of a mix of tree species including non-pines [68]. Processes that homogenize forest structure and composition such as abnormally widespread stand replacement events (e.g., fires of 1910,

Yellowstone 1988) or particular types of forest management (e.g., some timber harvest practices, fire suppression) that alter forest composition and structure over large areas, can contribute substantially to the extent and severity of an outbreak once it is initiated. Processes that result in heterogeneity, such as "normative" wildfires and bark beetle outbreaks, and some land management practices (e.g., restoration treatments focused on restoring a mosaic structure of forest stands of different age classes) tend to reduce outbreak severity and extent by reducing the amount of contiguous susceptible hosts [68].

Climate acts as a trigger for mountain pine beetle outbreaks for a very good reason. Like all insects, mountain pine beetle is poikilothermic-it cannot regulate its body temperature, and thus, all its metabolic rates and vital functions are dependent upon the temperature of its environment [69]. As temperatures rise, feeding, activity, development and reproductive rates increase. Importantly, this also means that the length of the mountain pine beetle life cycle is determined by temperature [69]. Under optimal thermal conditions, development is univoltine (one year). A univoltine cycle allows synchronized emergence of brood adults in mid-late summer, supporting not only mass attacks, but also attacks at a time that allows subsequent offspring to enter winter as cold-hardened larvae [70,71]. Cold hardening is a gradual process that occurs as temperatures fall in autumn. Once larvae are cold hardy it can take temperatures as low as −40 °C to kill significant numbers [72]. However, cold air incursions in fall when beetles are not yet cold hardened or in spring when larvae have lost cold hardening in preparation for transitioning to the adult stage can result in widespread mortality. This can halt an outbreak if subsequent conditions are no longer favorable for the beetle. However, if favorable conditions return, beetle populations rebuild. Importantly, outbreaks require a univoltine life cycle combined with moderate winter temperatures [73].

In areas where temperatures are too cool to support a univoltine life cycle, a semivoltine (longer than one year) life cycle occurs [73]. A semivoltine life cycle is maladaptive for the beetle in several ways. First, adaptive seasonality is disrupted, increasing the percentage of brood that enter winter in stages vulnerable to freezing (eggs, pupae and adults). Additionally, mortality increases when beetles must pass through two winters and feed on a food source increasingly depleted in moisture, nutrients, and symbiotic fungi [74]. Warm periods support not only greater brood production and survival in areas typically suitable for the beetle, but also allow a transition from a semivoltine to a univoltine life cycle in areas otherwise too cool. This increases the spatial extent of suitable habitat and tree mortality. Thus, abnormally warm periods can vastly increase the total area suitable for the beetle and play a major contribution to the synchronicity and coalescence of outbreaks across regions [2,65].

Drought can also play an important role in outbreak initiation. Host tree defense mechanisms are compromised during drought allowing beetles to more easily attack trees [2,75]. Tree defenses are major constraints when beetles are in non-outbreak phase. However, drought-weakened trees can support population amplification until a point where stand level densities surpass a critical threshold. Once this threshold is passed, tree defenses lose their importance in regulating beetle populations [61]. Very importantly, drought stresses large numbers of trees at a regional scale. This results in large numbers of trees that are easier for the beetles to kill, further supporting outbreak intensification [65,76].

Recent studies have found that drought occurring years or even decades before the outbreak can influence outbreak initiation. Furthermore, prolonged drought stress appears to pre-condition trees to be more susceptible, an effect that can continue for years after normal precipitation has

returned [58,65,77]. There also appears to be a genetic component to tree sensitivity to drought, and subsequently, susceptibility to beetles. In two studies, one conducted in whitebark pine and the other in ponderosa pine, differences in growth of surviving trees and trees killed by beetles over the last century suggest that adaptive differences to changes in climate exist. In the whitebark pine study, the trees studied were co-dominants and not significantly different in diameter age or mean growth over their lifetimes [58]. However, trees that were killed exhibited faster rates of growth in the first half of the century suggesting they were better adapted to the cooler wetter conditions of that period. The surviving trees had greater growth in the latter half of the century when conditions were warmer and drier. Millar *et al.* [58]) suggested that the beetle-caused tree mortality in the stands they studied resulted in a strong natural selection event that removed trees less fit under our current climate while leaving those more well-suited.

Likewise, Knapp *et al.* [77] found genotypes of ponderosa pine that were slow-growing in the two to three decades prior to the outbreak were much more vulnerable to beetle infestation than those that were fast-growing, again suggesting the beetle may act as a selective agent shifting genetic structures in stands over time to those most suited to prevailing climatic conditions. In lodgepole pine, trees of similar age and diameter growing intermixed in the same stand and under the same conditions exhibited different levels of sapwood moisture that were highly correlated with susceptibility to beetle attack [74] hinting at genetic differences in water efficiency. Those with lower sapwood moisture were attacked and killed by the beetle while those with higher sapwood moisture were not [74].

While mountain pine beetle has developed outbreaks for millennia, the current outbreak is far outside the historic norm [2,78]. The unprecedented size and severity of this outbreak is due to a combination of increasingly favorable climate for the beetle and forest conditions. Warming trends have supported the development of a univoltine cycle in many areas that previously were too cool and have resulted in greater beetle productivity and survival [79]. This has led to massive tree mortality, not only in areas previously favorable for the beetle, but also in areas previously suboptimal or unusable. Warmer temperatures and high population levels have also supported expansions of the beetle's range hundreds of kilometers further north in British Columbia and eastward across Alberta [80–82]. In these new locations, the beetle is infesting naïve hosts including (in the eastern expansion) a novel species, jack pine [80,82]. These naïve hosts exhibit lower defenses to beetle attack [83] as well as similar chemical compositions to natural hosts [84] promoting establishment. Predictions are that the beetle will continue to move across the continent through the boreal forest and finally into eastern pine forests [78].

Warming has also allowed the beetle to move higher in elevation where it is devastating whitebark pine, a tree that is foundational to the western North American subalpine ecosystem and that was previously protected from the beetle by cold [73,85]. Movement into the subalpine has been supported by overall warmer temperatures and milder winters allowing the beetle to switch from a semivoltine to a univoltine life cycle while simultaneously reducing winter mortality [85–87]. The resulting mortality to whitebark pine in many areas, particularly the greater Yellowstone Ecosystem, has been so severe the tree is now proposed for listing as an endangered species [88]. The tree is already listed as an endangered species in Canada due to the combined effects of mountain pine beetle and white pine blister rust [89].

4. Mountain Pine Beetle Outbreak Suppression

Treatments used to mitigate the effects of mountain pine beetle are grouped into three broad categories. Treatments that strive to reduce or eliminate beetle populations are termed direct controls [90]. Treatments aimed at increasing tree vigor and altering stand conditions to be less favorable for beetles are called indirect controls [90,91]. Prophylactic treatments aim to protect high value individual trees or stands of trees from infestation. Salvage, while often included in beetle management programs does not actually reduce or impact beetle populations-it is the removal of dead trees for economic or other reasons and often involves removal of trees that are already 'empty' of beetles and thus has no impact on beetle population size. Because our focus is on how well science supports the use of timber harvests (including tree felling and destruction of trees in place) to reduce or suppress bark beetle outbreaks, we will focus primarily on direct and indirect controls concentrating on these treatments.

Direct control includes sanitation treatments such as removing single trees or small patches of trees that are infested with the insect, clearcutting (also called block harvesting) and prescribed burning of infested trees, as well as fell and burn, trap trees, debarking, and application of insecticides or toxins such as MSMA (monosodium methanearsonate). Sanitation cuts attempt to remove most or all beetles in an area by removing infested trees before the beetles developing within them can emerge and disperse [90,92]. Prescribed burns, fell and burn, debarking, and toxin applications attempt to destroy beetles in infested trees on-site. Trap trees are trees that are baited with attractant pheromone baits in an attempt to draw beetles into specific areas where they are concentrated into the baited trees which are subsequently taken to the mill or destroyed. Each of these methods relies on killing as many beetles as possible in order to lower beetle population thresholds below which they can maintain outbreak dynamics.

Indirect controls are primarily silvicultural in nature. The main treatment used for mountain pine beetle is thinning. Thinning is thought to act by reducing inter-tree competition for water, nutrients, and light, enhancing greater tree vigor, and thus defenses against the beetle [93]. Thinning treatments are also thought to reduce successful beetle attacks by altering microsite conditions by increasing temperatures on bark surfaces on bark in summer and decreasing them in winter, as well as disrupting beetle communication by increasing wind flow [94,95]. A new treatment recommended for reducing bark beetle infestation is "daylighting" which involves removing trees and shrubs from around trees that are to be protected to increase light on the tree's stems to disrupt beetle colonization. Other silvicultural treatments include removal of beetle-suitable hosts (mature trees and old growth) and conversion of stands from species preferred by beetles (pines) to species that are not hosts or converting stands that are primarily pine to a mixed species composition [91,92]. Most of these approaches involve, completely or partially, the use of timber harvests.

4.1. Efficacy of Direct Controls

Direct control treatments are extremely expensive in time, effort and resources. They address only one aspect of an outbreak which is the amount of beetles present in a stand or area. Because they do not address the underlying conditions that support an outbreak (climate, tree condition/stress) their effects are considered a holding action until conditions shift to being less favorable for the beetle [92].

Direct control efforts must be maintained at a high level on an annual basis until the outbreak ceases [3,90,96]. It is highly controversial whether direct controls are effective in reducing tree mortality in the short-term, and if they can be effective in halting or suppressing outbreaks in the long-term.

One of the biggest problems in assessing the utility of direct controls is a general lack of monitoring or *post hoc* assessments of the outcomes of implementing these practices. Despite decades of direct control and large-scale implementation of these practices, few rigorous studies on its efficacy have been done and there remains no agreement among scientists or foresters regarding its ability to reduce beetle populations or losses of trees. Studies conducted prior to the current outbreak have variously concluded that direct treatments may merely act to delay infestation of susceptible stands [97], or that if used correctly, can be effective [98,99]. Many studies found that while some treatments slowed the rate of infestation, overall, they had little to no impact on mountain pine beetle populations [97,100–104].

The US and Canadian governments have spent hundreds of millions of dollars in direct control efforts to address the current outbreak. However, assessments of the efficacy of these efforts are nearly non-existent and only a few studies on assessments have been published. The few that have been published are reviewed here. Although much of our review addresses how well science supports US policy, we use primarily studies conducted in Canada as few studies have been published on direct control measures during the current outbreak in the US.

Nelson *et al.* [3] evaluated the efficacy of five direct control treatments in British Columbia roughly midpoint in the portion of the current outbreak as it progressed in that province. The assessment was extremely short-term and looked only at the response of beetles in the year immediately post-treatment. However, it provides one of the very few broadscale assessments ever conducted of the efficacy of direct controls during an outbreak. The treatments assessed were applications of MSMA, trap trees, fell and burn, and clearcutting. The study was split into three geographic regions to account for potential sources of variability due to location and different background levels of beetles. The northern-most region was at the margin of the beetles range (expansion zone) and possessed relatively low beetle populations, while the central and southern regions had higher beetle populations and were known to have supported high beetle populations historically. The study found that, overall, sites receiving MSMA treatments exhibited higher infestation intensities (a metric based on kernel density estimators) than randomly selected untreated sites with similar characteristics. This was particularly pronounced in the southern region. Results for trap tree treatments showed substantial variability within and among regions. A reduced infestation rate in response to treatment was observed more often than not in the northern area where beetle pressure was low. However, in the central and southern regions where beetle pressure was higher, the range of infestation intensities was similar for treated and untreated sites although a larger number of comparisons found higher infestation intensities in the treated sites. The overall conclusion was that MSMA and trap tree treatments may be effective, but not reliably, and only when beetle pressure is low and environmental conditions are not highly favorable for the beetle.

Results for fell and burn were also variable. In the northern region, intensities were lower overall in treated *vs.* untreated sites. However, in the central area, treated areas tended to have greater infestation intensities. In the southern area, no discernible effect of treatment was seen. Therefore, like with trap trees, fell and burn appeared to sometimes be effective, but only when populations of beetles were low,

and became increasingly unreliable as beetle pressure increased and the infestation moved into outbreak phase.

Removal of trees in patches was studied only in the central region. No significant effect of treatment was detected. Clearcuts were assessed in the central and southern areas and were found to lead to a significant reduction in infestation intensity. In almost all cases, infestation intensities were lower in treated *vs.* untreated areas. However, this was likely due to the removal of all living trees (potential subsequent hosts) that survived the beetle as well as the infested trees. The overall conclusion of the study was that mitigation treatments are effective when populations are low to moderate and if infested trees can be kept to 2.5 or fewer per hectare. Efficacy was also recognized to be contingent upon a high level of accuracy in detecting infested trees and wide-scale and continuous implementation of treatments. However, with only one year of data, the authors could not predict how long treatments would need to be sustained to remain effective, nor what effect beetle pressure from surrounding areas might have on the subsequent fate of treated stands. No follow up study has been published to report how these treatments fared as the outbreak progressed.

Fell and burn has been a stalwart component of the direct control efforts against mountain pine beetle in Canada during the current outbreak, particularly on the advancing front as the beetle expands its range eastward. Coggins *et al.* [105] examined the efficacy of fell and burn treatments to "stabilize" such infestations (*i.e.*, prevent expansion) using field plot data from sites at the expanding edge of the mountain pine beetle infestation in 2008 in eastern British Columbia and western Alberta. The authors used multiple modeling scenarios along with ground data to demonstrate how infestations may develop with and without mitigation, and to predict how long mitigation may need to be maintained to be effective given different levels of infestation and detection accuracy. They found non-mitigated plots experienced more tree mortality due to the beetle and that infestations in these plots expanded more rapidly. The higher the expansion factor (means rate of increase, e.g., 2 would indicate a doubling of the population each year) the greater the detection accuracy that was required to maintain a static population. When a beetle population had an expansion factor of 5.1 (high), an 80% detection rate was required, whereas with a population with an expansion factor of 1.1 (very low), the minimum detection rate could be as low as 10% and still be effective. The authors also modeled how long it would take to achieve population stability given different levels of infestation. On average, across their stands, with a 70% detection accuracy rate, mitigation would take 11 years, at 80% 6 years, and at 90% 3 years. The actual mean mitigation efficiency at their sites was found to be 43%, a level at which no control could occur. They concluded that the stabilization of mountain pine beetle populations is possible, but only with a much higher detection accuracy than commonly occurs coupled with an intense level of mitigation maintained potentially over a very long timeframe.

Wulder *et al.* [96] looked at the effectiveness of sustained mitigation on slowing the beetle's expansion in western Canada. The results were difficult to assess because of the unevenness of application of mitigation treatments (for example, in one year only 68% of sites slated for mitigation were treated) and differences in background beetle populations. However, such a situation is typical and thus may represent the reality of many on-the-ground direct control efforts. One site where little mitigation was conducted early on, did exhibit a strong increase in tree mortality due to the beetle that declined once extensive mitigation efforts were implemented. However, overall, the conclusion was

that mitigation must be extensive and continuous to work and may only be effective when populations are low to moderate.

Trzcinski and Reid [104] studied the trajectory of beetle populations in treated and untreated zones in Banff National Park from 1997–2004. The Park used a combination of pheromone-baited trees and fell and burn to remove as many beetles as possible from treatment zones—they also conducted prescribed burns to reduce beetle numbers and lodgepole pine hosts. The area colonized by the beetle increased rapidly over this time period in both the untreated and treated zones. After four years of treatment, control measures did not reduce the area affected by beetles and infestations continued to expand at a similar rate in both zones. The authors estimated that between 45% and 79% of infested trees had failed to be detected in the treated areas. This equated to *only* 0.7–3.7 infested trees remaining per thousand ha yet still was sufficient to support subsequent rapid beetle population growth.

A general consensus of these studies is that suppression of a beetle outbreak would require massive sustained efforts with extremely high detection rates to succeed. It has been estimated that 97.5% of beetles in an area must be killed to merely stabilize a mountain pine beetle population [90]. Even a small increase in survival above this value can allow a substantial increase in population size. For example, if mortality drops to 95%, this would allow a population to *double* in size annually. If the goal is not just to stabilize a population, but to reduce it, mortality of beetles would need to be higher than 97.5%, a goal that is highly unlikely given the vast areas that would need to be treated on a continual basis when conditions are favorable for outbreak development. Even if 100% removal of infested trees from an area was feasible, the migration of beetles into treated stands from surrounding areas allows reestablishment and subsequent tree mortality further decreasing the potential for effective direct control.

The on-the-ground reality is that direct control efforts typically fall far below the levels needed to stabilize, let alone control, mountain pine beetle populations. In the above cited studies, rates of detection in mitigated stands ranged from 45%–79%. These situations are not unusual. Direct control treatments are laborious, extremely costly and time consuming, and require high levels of training. Logistical difficulties, including proper seasonal timing, access, inclement weather, and lack of trained personnel, increase the odds that they will not be effective. The high financial cost of such efforts coupled with a volatile market for sawtimber, pulp and pellets further complicates the use of direct controls. Importantly, outbreak development is extremely swift and the amount of mitigation required can rapidly outstrip the ability of managers to respond.

During an outbreak the number of trees killed annually is often in the millions and infestations may cover hundreds of thousands of hectares [90]. Carroll *et al.* [90] presents an example of the degree of mitigation that would be required for an outbreak that covers 300,000 hectares with a rate of increase of 2 (the population doubles in one year-a conservative rate for an outbreak). In this case, 150,000 ha of infested trees would need to be removed each year just to maintain a *static* beetle population–this would still allow tree mortality to occur for many years, potentially until most or all mature trees were killed. In reality, such a high level of detection and mitigation is impossible. Given that the goal of direct management is to reduce populations and protect trees, the effort that would be needed to actually reduce such a high beetle population would require an even more unlikely effort.

Studies in other bark beetle systems also have found that a high degree of detection accuracy and intensity of mitigation is required to reduce beetle numbers. Fahse and Heurich [106] found that control of *Ips typographus*, a less aggressive European bark beetle, requires a detection and removal level of around 80% to be effective. They concluded that direct control efforts are useless and should be dropped if survival probabilities of the beetle after treatment are above 20%–30%. This estimate is in line with those developed in studies on mountain pine beetle in North America and highlights the challenge the high reproductive capacity of bark beetles poses when conditions are favorable for outbreak development.

It is not just the difficulty of dealing with the extreme spatial extent of outbreaks and the challenge of detection and treatment that makes the efficacy of direct control measures unlikely, but also the time frame over which direct controls must be maintained. Carroll *et al.* [90] estimated that to control a population involving 10,000 infested trees with expansion factor of 2 (conservative) and with a detection and removal rate of 80% (difficult), it would take at least 10 years of annual treatment to reduce the population to a single tree. If the population was tripling or quadrupling, a more likely scenario during an outbreak, it would take 18 or 41 years, respectively. A costly, intensive detection and treatment program lasting that long, assuming sufficient trees even remained to be infested, would be unlikely [90].

Carroll *et al.* [90] emphasized three requirements for direct controls to be effective in treating *individual* infestations: infestations must be detected early, efforts must be applied quickly and intensively, and control programs must be maintained continuously until the desired population level is achieved. Because of the cost and intensity of treating individual infestations, the US Forest Service recommends that direct control measures only be applied to higher value stands [92]. However, treating individual infestations or stands during outbreaks can fail because of the regional nature of outbreaks. Outbreaks are driven by abiotic factors that affect entire regions (warm temperatures and drought). Thus, they consist of many infestations that occur synchronously across a very large area. These infestations often coalesce to form vast expanses where beetle populations are extremely high. These characteristics mean that many stand level efforts are prone to failure due to high beetle pressure and migration into treated areas by beetles from surrounding areas. Given that treating entire regions is impossible, and that many treatments are not in line with other land use objectives, direct control efforts may in some cases, not be worth their costs. The consensus of studies and retrospectives over the course of several outbreaks is that even after millions of dollars and massive efforts, suppression using direct controls has never been effectively achieved, and at best, the rate of mortality to trees was reduced only marginally [90,101,102,105]

4.2. Efficacy of Indirect Controls

Thinning is the primary indirect control measure used to manage the mountain pine beetle. It is generally considered a preemptive measure to be implemented prior to the initiation of a mountain pine beetle outbreak, although it is increasingly employed to reduce damage by the insect during outbreaks. It is often touted as a global panacea for problems with pest bark beetles. One type of thinning is even termed “beetle-proofing” [107], further reinforcing the view among managers, the public, and policy makers, that this approach is failsafe. While overall, evidence suggests that thinning can reduce

mortality of trees due to mountain pine beetle, the outcome is frequently more variable than is often recognized or reported. This is particularly true when outbreak populations are involved.

So how exactly does thinning work, and how well does thinning hold up under outbreak conditions? Surprisingly, the mechanism(s) by which thinning affects beetle activity in forest stands is still not well understood. Two, non-mutually exclusive, lines of thought exist. One hypothesis is that thinning increases tree vigor, and thus tree defenses, by reducing competition among trees for light, nutrients and water [93,108]. Intuitively, this makes sense, and indeed, immediate impacts of thinning on reducing water stress have been seen [109]. Likewise, increases in growth and photosynthetic rates also have been observed post-thinning, albeit after a lag period of one or more years [107,109,110]. Increases in growth and vigor are predicted to increase the amount of energy that trees allocate to defense, leading to greater resistance to beetle attack through increased resin and monoterpene production. In fact, the initial impetus for the use of thinning to manage mountain pine beetle came from an early study that found that ponderosa pines in thinned stands produced more defensive resin [93]. However, subsequent studies have reported a variety of responses in resin production as well as growth in response to thinning. For example, Zausen *et al.* [111] found that ponderosa pines in the thinned stands exhibited lower water stress but also produced less resin. This, along with the thicker phloem (greater food resources) found in trees in thinned stands, indicates they might be not only more susceptible to attack but also a more productive resource for beetles. In contrast, McDowell *et al.* [112] found greater resin flow in thinned stands. Both studies were conducted in southwestern US ponderosa pine forests indicating that the variable responses observed were not due to major regional differences in hosts. Six and Skov [113], in a study conducted in ponderosa pine in the northern Rocky Mountains looking at effects of thinning and burning treatments, found that resin flow was highest in trees in burn treatments, intermediate in controls, and lowest in thinned treatments. Raffa and Berryman [114] tracked the fate of trees over time during an outbreak and found no significant difference between resin flow for lodgepole pines that survived attack vs those killed by the beetle.

A number of studies have noted a reduction in beetle caused-mortality of trees immediately after thinning treatments were applied and before trees had time to respond physiologically to lower stocking densities. This timing suggests that the effects of thinning may have more to do with microsite conditions than to changes in tree vigor or defense. These observations led to the second line of reasoning that thinning affects beetle activity through changes in microsite conditions.

Thinning alters temperature, light intensity and wind speed within a forest stand; factors that can have major effects on insect behavior and success. A number of studies have tried to describe how shifts in microsite conditions due to thinning may influence mountain pine beetle activity. Bartos and Amman [94] investigated how incident solar radiation, wind speed, wind direction and temperature were altered by thinning and whether changes affected beetle responses to stands. They did not conduct statistical analyses on their data; however, there was a trend for south sides of trees in thinned stands to be warmer, and ambient temperatures in thinned stands to be overall warmer during parts of the day. Incident solar radiation was higher in the thinned stand. It is not known if bark temperature affects beetle attack behavior, although higher temperatures on south sides of trees in thinned stands have been suggested to be deleterious to beetle development [94]. However, this speculation does not account for differences in local environmental conditions. For example, at cool sites, increased

temperatures and insolation could ostensibly support better beetle development by increasing thermal units sufficiently to support a univoltine life cycle.

Light intensity affects the flight behavior of mountain pine beetles [115]. However, if and how different levels of light in treated and untreated stands affect beetle attack behavior is unclear. It has been hypothesized that a reduced propensity for flight in darker stands might concentrate beetles for mass attack, while beetles may be more likely to disperse in open stands [116].

The hypothesis that light has a strong effect on mountain pine beetle behavior, particularly in reducing attacks, has led to a new treatment called daylighting. This approach is currently being implemented on a broad scale by federal and western state agencies. Daylighting involves removing trees and vegetation from around trees that are targeted for retention and is believed to work by repelling beetles from the boles of trees by increasing light and solar radiation [117]. While widely recommended, the efficacy of this treatment is unknown; there are no published studies on its effects on bark beetles.

Changes in wind speed and direction due to thinning have also been suggested to alter beetle behavior by disrupting beetle communication via disruption of pheromone communication. Schmid *et al.* [118] found no statistically significant differences in horizontal and vertical wind patterns in thinned and unthinned stands. However, disruption of pheromone plumes by greater wind speeds may affect communication and thus the potential for successful attacks [95]. Ultimately, we need to look at actual population dynamics of beetles in treated and untreated stands to understand if microsite effects hold under epidemic conditions. MacQuarrie and Cooke [119] found that, under outbreak conditions, mountain pine beetle populations exhibited density-dependent dynamics and that thinning did not change the epidemic equilibrium. In this study, population growth curves did not exhibit responses that would be expected if microsite conditions played a role in beetle behavior. It is evident that more research is needed to understand how these effects ultimately influence tree mortality due to beetle attack.

While we may not have a complete understanding of how thinning works, it is clear that this practice can have a significant effect on mountain pine beetle infestations. Several studies have reported striking differences in mortality to trees caused by beetles in thinned *vs.* un-thinned forests (reviewed in [120,121]). In contrast, only a small number of studies have reported failures. However, the disparity in numbers of successes and failures must be placed within a broader context. Many studies assessing the efficacy of thinning have been conducted under non-outbreak conditions. Their results do not reflect how stands perform during an outbreak. Additionally, failures are often not reported, dismissed as a result of poor management 'next door' or targeted for management without evaluation. This is unfortunate because thinned stands that fail may have particular characteristics that could inform a better understanding and application of this approach.

Studies conducted during outbreaks indicate that thinning can fail to protect stands. In Colorado, thinning treatments in lodgepole pine implemented in response to the outbreak that began in the 90s often only slowed the spread. Klenner and Arsenault [122] reported high levels of mortality due to the mountain pine beetle across a wide range of stands densities in lodgepole pine in British Columbia during the same outbreak. They noted that silvicultural treatments were largely ineffective in reducing damage to the beetle. Preisler and Mitchell [123] found that once beetles invaded a thinned stand the probability of trees being killed there can be greater than in unthinned stands and that larger spacings

between trees in thinned stands did not reduce the likelihood of more trees being attacked. Whitehead and Russo [107] reported on the performance of 'beetle-proofed' (stands thinned to an even spacing of about 4–5 m between mature trees) and un-thinned stands in five areas in western Canada during approximately the same time period. These treatments were successful in protecting stands when they were combined with intensive direct control measures (removal of infested trees) in the areas surrounding the thinned units, but failed if units were exposed to beetle pressure from the neighboring area—a situation most thinned stands experience during an outbreak.

Unfortunately, long-term replicated studies monitoring beetle responses to thinned forests from non-outbreak to outbreak to post-outbreak phase are virtually non-existent. One large fully-replicated long-term study was initiated in 1999 under non-outbreak conditions and continues to track beetle activity [113]. In this study, mountain pine beetle was low in all treatments in the period leading up to the outbreak, but increased in some controls and burn treatment replicates as the outbreak developed. Although more trees were killed overall in control units during the outbreak, all controls still retained a greater number of residual mature trees than did thinned stands as they entered the post-outbreak phase [124].

Two factors contribute substantially to our inability to assess how well thinning performs under outbreak conditions. One, very few thinning treatments are monitored after implementation over either the short- or the long-term. Thus, for the vast majority of stands that have been treated, we have no data on how well they perform once an outbreak of the insect initiates (or for that matter, even under non-outbreak conditions). Second, stands that become infested, thinned or otherwise, are often targeted for intensive suppressive management and are cut without assessment or data collection. This even includes studies and sites that are intended to inform management. For example, at the sites studied by Whitehead and Russo [107], infested trees were being removed from the study sites even before data collection for their study could be completed. The long-term study discussed previously [113,124] is under continual pressure to be logged to remove beetle kill even though the site lies within an experimental forest designated specifically for studies assessing the outcomes of forest management.

5. What are the Goals?

When we manage forests, we do so in an attempt to achieve one or more outcomes, preferably with minimal negative effects on non-target resources. To be effective, management must have explicit and appropriate goals as well as clear metrics for success. Ideally, management is monitored to assess how well it meets its goals, where it falls short, and whether and how it can be improved. This approach is called adaptive management and implies an iterative process through time whereby we learn from the outcomes of our actions and base future actions on improving performance [125].

Not only outcomes, but the costs of management must be factored into decision making. These include direct financial costs as well as the less tangible (at least in dollar values) effects on ecosystem services and functions. By considering the full cost of management along with benefits as verified through monitoring and evaluation, we lessen the risk of failure, financial waste, and unnecessary negative environmental impacts.

In assessing how well we meet goals when managing for mountain pine beetle, we must ask several questions. Do our management practices actually control the beetle during outbreaks? Do the outcomes

justify the financial and ecological costs? And, what long-term impacts do these treatments have on forests and their ability to adapt to climate change? These questions are difficult to answer. Only limited data are available on the short-term efficacy of direct and indirect controls, and information on long-term effects is virtually nonexistent. The results of short-term assessments can be difficult to interpret. For example, often only the proportion or numbers of trees killed by beetles post-treatment are reported. This does not allow a complete evaluation of outcomes. A study may report that 75% of trees in controls are killed by the beetle, whereas only 10% are killed in thinned stands. At first glance, this appears to be a resounding success in saving trees. However, if we approach this situation from a pretreatment perspective, our interpretation of success may change. In this example, 400 mature trees existed in each plot prior to treatment. After treatment, 100 mature trees remain in the thinned plots (300 trees have been removed by thinning). Doing the math, we find that once the beetles have run their course, more residual living trees (100) actually remain in the control plot than in the thinned plot (90) and, in fact, humans have contributed more to tree mortality than have the beetles. In the case of silvicultural intervention, humans typically must expend considerable effort and expense. They also choose the trees that remain, and thus the structure and composition of the remaining forest. This may result in very different trajectories for residual forests as discussed below.

When we include pre-treatment conditions as well as post-treatment responses we can assess the management efficacy from a more informed position. For instance, in a retrospective study investigating the effects of management on spruce beetle, researchers found that post-infestation, untreated stands had more live spruce trees and greater basal areas. When comparing only residual large spruce, final densities in both stand types were similar [126]. Six [124] found higher numbers of mature living trees remained in control stands of ponderosa pine than in thinned stands post-mountain pine beetle outbreak. In a study in Canada focusing on stocking density of living lodgepole pine post-outbreak, the authors found that, even in hard hit stands, stocking density in post-outbreak unmanaged stands was sufficient to maintain desired levels of productivity [127]. Klutsch *et al.* [128] in a study conducted in lodgepole pine forests in Colorado, found greater mortality of trees due to the beetle in more densely stocked stands. However, while the density and basal area of lodgepole pine in infested plots declined 62% and 71%, respectively, the number of trees that remained and their size distribution post-outbreak indicated that lodgepole pine would remain the dominant overstory tree. In another study in Colorado, the beetle killed 60%–92% of overstory lodgepole pine. However, these stands retained residual overstory trees as well as advance regeneration. Furthermore, untreated stands were predicted to return to pre-outbreak stocking levels approximately 25 years sooner than treated stands [129]. Other studies have found similar results for both lodgepole and ponderosa pine [130–134]. These studies highlight a seldom considered impact of mountain pine beetle- that it can act as a natural thinning agent and seldom removes all mature trees during outbreaks. These effects are an important part of the ecological role that the beetle plays in western pine forests [135].

It is also important to recognize there can be significant differences in long-term forest trajectories for stands thinned by beetles *vs.* those thinned by humans. When humans thin, they select for particular size classes, often favoring the retention of larger, older trees, selecting toward one desired tree species, and often 'thinning from below' which removes advanced regeneration (small trees) [123,136]. Thinning prescriptions also typically call for relatively even spacing between residual trees [92,107,121]. Mountain pine beetle, on the other hand, often selects the largest trees during

outbreaks (with exceptions; [121,123,131]) which can lower the mean diameter of the stand [128]. However, beetles often leave sufficient numbers of large diameter trees to maintain a dominant overstory of pine. Beetles also leave substantial amounts of advanced regeneration to replace the mature trees that arekilled [121,129]. Spacing among trees after an outbreak is uneven, resulting in a clumpy network of living trees [129]. Patches where all trees are killed are seldom extensive and add to a mosaic structure as forests recover post-outbreak. Heterogeneous stand and mosaic forest structures are more typical of natural conditions and can support greater biodiversity and resilience against fire and subsequent beetle outbreaks [137–139]. In contrast, intensive thinning treatments by humans typically favors the retention of mature pines. Over time, these pine-dominated stands grow, they are predicted to have increased susceptibility and potential for tree mortality from future mountain pine beetle outbreaks [123,136].

Very importantly, the beetle exercises selectivity in the trees it kills. While extremely high numbers may override this selectivity, evidence is accumulating that, even under outbreak conditions, beetles choose trees that have particular qualities. Beetles commonly select trees for attack that exhibit lower growth rates, defenses, and higher water stress [58,74,77]. While these factors can be influenced both locally and regionally by site conditions and climate, much of the variation in these properties within individual stands that affect bark beetle choice likely has a genetic basis. Outbreaks can result in strong natural selection against trees with phenotypes (and likely genotypes) favorable for the beetle and for those that possess unfavorable qualities [58,77]. However, when humans thin forests, trees are removed according to size, species, and density, without consideration of genetics. Thus, trees best adapted to surviving beetle outbreaks are as likely to be removed as those that are not.

When humans thin forests, they typically manage for resistance and resilience, rather than adaptation which involves genetic change. It is very important to distinguish between resistance, resilience, and adaptation, as each have different goals and operate on different temporal scales [140]. Resistance is a short-term holding action where we try to maintain an existing state. 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]. In contrast, practices that promote resilience attempt to allow forests the ability to adjust to gradual changes related to climate change and to recover after disturbance. However, like resistance, resilience is not a long-term solution. In the long term, forests must be able to adapt to change. Adaptation involves genetic change driven by natural selection. Currently, much of forest management, including bark beetle management, focuses on resistance and resilience, mainly through direct and indirect management, respectively. However, neither approach allows for true adaptation. For long term continuity of our forests, it will be imperative to begin to incorporate this aspect of management into our approaches.

We also need to reassess the ecological role of bark beetles, including the mountain pine beetle, in our forest ecosystems. As has been well demonstrated by a century of fire suppression, the dampening or suppression of natural disturbance can alter forest trajectories in undesirable ways, many of which can be irreversible. Although beetle outbreaks, like fire, can have negative impacts on timber values and aesthetics, their natural role in many forest ecosystems is seldom considered and beetle suppression is often perceived as something that must be conducted at all costs. However, as with fire, suppression of beetles over the long term may alter forests in ways that are not desirable or sustainable. While

intensive management for bark beetle suppression is called for in some situations such as in the wildland urban interface, it may not be appropriate in many other areas where natural processes including natural selection are needed to maintain a dynamic and functional forest.

6. What are the Needs in Research and Monitoring?

There is clearly a need to better understand how well management programs aimed at reducing mountain pine beetle work, particularly under outbreak conditions, and what impacts these treatments have on forests in both the short and long term.

Perhaps the biggest area of need is in monitoring. Monitoring is essential to understanding whether mountain pine beetle treatments work, and in which contexts, but as noted above there has been all too little long-term monitoring of the effectiveness of various treatment efforts. This is a failing among both agencies and researchers. Agencies often do not have strong incentives to conduct long-term monitoring: Monitoring is costly; external and internal political pressures focus on short time frames; and monitoring may produce information that conflicts with agency goals or missions. It is also difficult to get strong public pressure to force agencies to conduct the necessary monitoring, particularly when the public has been led to believe that outbreaks are strictly the result of a lack of management. Even for scientists, long-term monitoring projects are not encouraged by short-term funding time frames and professional incentives or norms; monitoring is often not viewed as "real" science, and the long-time frames required for monitoring to result in significant gains in information are often longer than the time frames used for professional advancement (e.g., completion of a dissertation, tenure review) [141].

Addressing the shortage of monitoring for beetle treatments may, therefore, require far more than simply trying to provide additional funds (even assuming additional funding is politically feasible). Scientists can help by encouraging and rewarding projects that involve long-term monitoring. Agencies might try to establish units that are focused specifically on monitoring forest health, insulating monitoring projects from adverse political or bureaucratic pressure [141]. Finally, tools that might reduce the cost of monitoring significantly, such as retrospective studies and remote sensing, should be used to complement traditional monitoring and decrease its costs.

Monitoring is all the more essential if forest health management in general, and beetle treatments in particular, are truly to be guided by adaptive management. The high levels of uncertainty and dynamism associated with beetle infestations and the effectiveness of beetle treatments make adaptive management a very appealing tool to reduce uncertainty and allow us to respond to changes in global climate and forest ecosystems. But adaptive management requires monitoring to be successful [141], monitoring that is currently not occurring even as agencies conduct massive beetle treatments and propose to pursue even more.

There is also a real need to increase research on management efficacy and, in particular, how our approaches affect forest adaptation including genetic responses of trees to climate and the role in bark beetle selectivity and fitness. With a changing climate we will need to develop new approaches rather than trying to force old methods of questionable efficacy onto new conditions.

Unfortunately, most funding for research on bark beetles is very short-term, sometimes even as short as on an annual cycle, and thus cannot hope to address the complexities of beetle responses to

treatments. Funding cuts to research personnel, particularly in agencies like the US Forest Service, have exacerbated this problem exactly at the time when the need for rigorous research is increasing at a rapid pace. The US Forest Service has recognized that long-term planning must include explicit goals to increase forest resilience and adaptation to disturbance, including outbreaks of the mountain pine beetle. However, with extreme cuts to budgets and personnel, they are highly constrained to meet these needs at this time. Likewise, cuts in federal funding to agencies such as United States Department of Agriculture and the National Science Foundation concurrently reduce the ability of academic researchers to address these problems.

7. Aligning Policy to Science

Our survey of the relevant literature finds that there is significant uncertainty about whether the most commonly used beetle timber harvest treatments are, indeed, effective. Yet there has been little discussion of this uncertainty in the relevant policy debates. Politicians have instead latched on to beetle timber treatments as a cure-all for beetle infestations and have pushed to weaken or eliminate environmental laws that are perceived to be obstructing these treatments. Agencies such as the US Forest Service, to their credit, have been more nuanced in their support for bills that package beetle timber harvest treatments with weakened environmental laws; they have opposed several proposals to alter environmental laws to allow more treatments, but on the other hand, the agencies have at times also aggressively pushed for the implementation of treatments.

It seems clear that the policy debates–both in the agencies and in Congress–need to be better informed by science. Researchers should be more proactive in communicating their understandings of the current science to policymakers. This does not mean that researchers need to take a position pro or con vis-à-vis beetle treatments, or even vis-à-vis specific legal proposals. In the face of uncertainty, aggressive beetle timber harvest treatments may be warranted in some instances. However, policymakers should be aware of uncertainty when they are making the relevant decisions and should also be more willing to include the voices of scientists in the development of policy.

Given the uncertainty about the effectiveness of many beetle timber harvest treatments, the high financial costs of those treatments, the impacts on other environmental resources and values, and the possibility that in the long-run those treatments may interfere with the ability of North American forests to adapt to climate change, our position is that weakening or eliminating environmental laws to allow more beetle timber harvest treatments is the wrong choice for advancing forest health in the United States. Indeed, given the uncertainty, the costs, and the possibilities of both short-term harm to other resources and long-term ineffectiveness, we believe that the current structure of thoughtful, detailed environmental review for these projects is, in general, appropriate. If agencies believe that they need to be able to react quickly to specific infestations with treatments, and that this quick reaction is incompatible with existing legal procedures, we encourage the agencies to adopt overall programmatic environmental reviews based on the principles of adaptive management. Agencies should be able to build (or tier) on these programmatic reviews to respond quickly to individual events as needed. However, the programmatic reviews should allow the agency to build in the monitoring, replication, and variance of treatments that are essential for successful adaptive management [142].

8. Conclusions

The manner in which policy makers have accepted beetle timber harvest treatments as a panacea for responding to bark beetle outbreaks in North American forests raises a number of red flags. As ecosystems and places that have economic, social, and cultural value to human communities are altered by climate change, there is a risk that people will overreact because of a need to "do something" to respond to change, and to give themselves some sense of control over broader forces that appear to be out of control. That pressure, to "do something", might also interact with the uncertainty about which choices are effective and appropriate (as with beetle timber harvest treatments) to create an opportunity for political pressures to force the adoption of particular choices that benefit specific interest groups [143]. It is perhaps no accident that the beetle treatments that have been most aggressively pushed for in the political landscape allow for logging activities that might provide revenue and jobs for the commercial timber industry. The result is that the push to "do something," uncertainty, and political pressures might lead us to act to respond to climate change before we understand the consequences of what we are doing, in the end producing more harm than good.

Our argument here is not to forgo management, but rather that management should be led by science and informed by monitoring. Both direct and indirect management for bark beetles have their place. However, to manage our forests in a way that best ensures their long-term function while wisely using limited financial resources, policy makers and the public need a clearer understanding of current science and gaps.

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Conflicts of Interest

The authors declare no conflict of interest.

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Are Survivors Different? Genetic-Based Selection of Trees by Mountain Pine Beetle During a Climate Change-Driven Outbreak in a High-Elevation Pine Forest

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Increased mortality of forest trees, driven directly or indirectly by climate change, is occurring around the world. In western North America, whitebark pine, a high elevation keystone species, and lodgepole pine, a widespread ecologically and economically important tree, have experienced extensive mortality in recent climate-driven outbreaks of the mountain pine beetle. However, even in stands experiencing high levels of mortality, some mature trees have survived. We hypothesized that the outbreak acted as a natural selection event, removing trees most susceptible to the beetle and least adapted to warmer drier conditions. If this was the case, genetic change would be expected at loci underlying beetle resistance. Given we did not know the basis for resistance, we used inter-simple sequence repeats to compare the genetic profiles of two sets of trees, survivors (mature, living trees) and general population (trees just under the diameter preferred by the beetles and expected to approximate the genetic structure of each tree species at the site without beetle selection). This method detects high levels of polymorphism and has often been able to detect patterns associated with phenotypic traits. For both whitebark and lodgepole pine, survivors and general population trees mostly segregated independently indicating a genetic basis for survivorship. Exceptions were a few general population trees that segregated with survivors in proportions roughly reflecting the proportion of survivors versus beetle-killed trees. Our results indicate that during outbreaks, beetle choice may result in strong selection for trees with greater resistance to attack. Our findings suggest that survivorship is genetically based and, thus, heritable. Therefore, retaining survivors after outbreaks to act as primary seed sources could act to promote adaptation. Further research will be needed to characterize the actual mechanism(s) of resistance.

Keywords: ***Pinus albicaulis***, ***Pinus contorta***, ***Dendroctonus ponderosae***, **whitebark pine, climate adaptation, climate change, natural selection**

INTRODUCTION

The capacity of forests to adapt to rapid climate change is not known. Their ability to adapt will vary greatly depending upon tree species, amount and type of genetic variation existing within and among populations, type and degree of change required, strength and type of selection pressure, heritability of desirable traits, and the timeframe over which selection is able to act. Many long-lived sessile organisms, including trees, are unlikely to be able to track shifting conditions through migration (Kremer et al., 2012). This is especially true for those restricted to montane ecosystems where movement higher in elevation ends at the top of the mountain and poleward migration is blocked by competitors, valleys, and development (Jump and Penuelas, 2005; Aitken et al., 2008; Dullinger et al., 2012). For many tree species and forests, adaptation will need to occur in place if they are to persist into the future (Aitken et al., 2008).

Bioclimatic envelope models used to predict range expansions and contractions of forest trees treat species as clones, with all individuals exhibiting identical responses (Mimura and Aitken, 2007). While these models are useful to provide estimates of shifts in habitat suitability, they can mask the high genetic diversity and geographic differentiation of most tree species (Mimura and Aitken, 2007; Thuiller et al., 2008; Reed et al., 2011). Likewise, most management focuses primarily on increasing forest resilience through manipulating stand structure and composition while ignoring genetic diversity, natural selection, and the potential for adaptation (Churchill et al., 2013; O'Hara and Ramage, 2013; DeRose and Long, 2014).

Except for highly fragmented or relictual populations, forest trees possess moderate to high levels of standing genetic variation and often exhibit considerable local adaptation and within and among population diversity (Austerlitz et al., 2000; Hamrick, 2004; Savolainen et al., 2007; Alberto et al., 2013). Adaptation of forests to climate change will depend upon the outcome of interactions between existing genetic diversity, phenotypic plasticity, and selection pressure over a relatively short period of time. However, adaptation in trees can be slow due to long generation times and low mortality of older, well-established, but increasingly maladapted trees that continue to contribute to the gene pool (Savolainen et al., 2007; Kuparinen et al., 2010). Long generation times can result in considerable genetic load with long lags between mean optimal genotype and existing climate (Kuparinen et al., 2010). Additionally, while phenotypic plasticity may allow some genotypes to maintain high fitness over a broad range of environmental conditions and aid in resilience to climate change in the short-term, it may slow down or hinder adaptation and persistence in the longer-term (Valladeres et al., 2014).

Adaptation in trees may be accelerated when new conditions or agents lead to high levels of mortality and directional selection in favor of heritable traits associated higher fitness and survival. For example, Kuparinen et al. (2010) used computer simulations to investigate rates of adaptation to longer thermal growing seasons and found that mortality of established trees was the key factor regulating the speed of adaptation with dispersal ability and maturation age having substantially lesser effects. Disturbances caused by agents that use selective behaviors in choosing individual trees, such as herbivorous insects that respond positively to tree stress, can elicit rapid microevolution even in slow-growing tree species (Petit and Hampe, 2006). Such agents may benefit forests in the long-term by increasing mortality of poorly adapted trees, enhancing the reproductive potential of surviving better-adapted trees, and reducing genetic lag loads in affected populations (Kuparinen et al., 2010; Pedlar and McKenney, 2017).

The mountain pine beetle (MPB) (*Dendroctonus ponderosae*) is a highly selective insect that chooses hosts based on a complex array of chemical cues whose production by the tree is influenced by both tree condition and genotype (Emerick et al., 2008; Blomquist et al., 2010). Secondary metabolic chemicals produced by the tree are used by MPBs to distinguish among tree species as well as to assess the relative strength of defenses of individuals (Blomquist et al., 2010; Raffa et al., 2017). Such chemicals also likely signal adequacy of nutritional content for brood production given that beetles avoid hosts of very poor quality (Taylor et al., 2006; Dooley et al., 2015). Using such cues, a MPB will decide whether or not to enter a particular tree and initiate a mass attack. Once in the tree, the insect converts some terpenes to pheromones important in initiating and sustaining the mass attack required to kill the tree (Blomquist et al., 2010). When MPB populations are low to moderate in size, weakened trees with poor defenses that require fewer beetles to overcome defenses are most often attacked (Boone et al., 2011). However, during outbreaks, MPBs may switch to attacking healthier trees that, although better defended, possess thicker phloem and higher nutritional contents for brood development (Boone et al., 2011). Interestingly, some trees escape attack even when MPB populations are present in high numbers and suitable hosts become increasingly scarce.

In this study, we investigated whether trees that survive MPB outbreaks are genetically different than those that are selected for colonization and killed. Our overarching hypothesis was that surviving trees do not escape by chance, but rather possess genetically based characteristics that confer resistance. The basis for resistance, whether it is the ability to tolerate warmer drier conditions without a reduction in defenses, a chemical profile that negatively affects MPB host location or selection, or some other phenotypic trait, is likely to be under genetic control (González-Martínez et al., 2006; Keeling and Bohlmann, 2006).

MPB outbreaks are triggered by extended periods of warm weather and drought (Meddens et al., 2012). The recent MPB outbreak in western North America was a magnitude larger than any recorded in the past and affected millions of hectares of pine forest (Meddens et al., 2012). The outbreak was primarily driven by climate although its severity was intensified in some areas by past logging practices and fire suppression (Taylor et al., 2006; Creeden et al., 2014; Buotte et al., 2017). Climate change also supported movement of MPB further north in British Columbia and eastward across Alberta into naïve forests (those with no prior history of MPB) of lodgepole pine and jack pine (*P. banksiana*, a novel species for MPB) (Burke et al., 2017). While the size and extent of the recent outbreak was far outside the historic norm, outbreaks of MPB are not unusual and have likely

occurred for millennia. Selection by MPB during outbreaks, as well as persistent low-level activity during non-outbreak periods, are believed to have been a major force shaping constitutive and induced defenses in host pines (Raffa and Berryman, 1987; Franceschi et al., 2005). MPB activity in naïve forests can be expected to exert especially rapid and strong selection for host resistance because of high levels of susceptibility. Indeed, naïve lodgepole and jack pine forests exhibit lower defenses to MPB attack than those with a co-evolutionary history with the beetle (Clark et al., 2010; Cudmore et al., 2010; Raffa et al., 2013, 2017; Burke et al., 2017).

We focused on two tree species that have suffered high mortality by MPB in the recent outbreak. One is a relatively naïve host, whitebark pine (*Pinus albicaulis*), and the other is a highly co-evolved host, lodgepole pine (*P. contorta*). Whitebark pine is a high elevation tree that is considered a keystone in western subalpine ecosystems of the United States and Canada (Tomback et al., 2016). Historically, outbreaks in whitebark pine appear to have been rare and limited in size (Logan et al., 2010). During warm periods, beetles sometimes moved upslope from lower elevation outbreaks (Bartos and Gibson, 1990) where they killed some whitebark pine, but either did not reproduce successfully due to winter mortality, or completed only one or a few generations before the return of cold conditions once again limited them to lower elevations (Logan et al., 2010). The recent outbreak in whitebark pine has been extensive and has been driven by chronic warm temperatures that allowed the beetle to move into the subalpine and to persist there for an extended period (Buotte et al., 2016, 2017). With climate change, the presence of MPB in high elevation whitebark pine forests is expected to be persistent rather than occasional (Buotte et al., 2016, 2017). Whitebark pine exhibits many of the characteristics of a naïve host, including lower levels of defense chemicals and resin (Raffa et al., 2013, 2017). Reduced snow packs may also result in greater drought stress that may increase susceptibility (Larson and Kipfmueller, 2012). Outbreaks in this tree have been devastating in some areas, including the Greater Yellowstone Area, contributing to the recommendation that it be listed as an endangered species (United States Fish, and Wildlife Service [USFWS], 2011).

The second species studied was lodgepole pine, a co-evolved host that has experienced repeated extensive outbreaks in much of its range, likely over a long evolutionary period. Vigorous lodgepole pine typically exhibits strong constitutive and inducible defensive responses to beetle attack (Burke et al., 2017; Raffa et al., 2017). Outbreaks of MPB in lodgepole pine are considered natural disturbances that, much like fire, help maintain lodgepole pine forests by periodically regenerating new stands free of many diseases, initiating nutrient cycling, and stimulating regeneration, understory productivity, and supporting biodiversity (Dordel et al., 2008; Diskin et al., 2011; Pec et al., 2015).

Our objective in this study was to investigate whether whitebark and lodgepole pine growing in a mixed high elevation stand that survived the outbreak are genetically distinct. If so, this may indicate an increased potential for these pines to persist in the face of the more frequent and extensive outbreaks predicted due to a changing climate. We would expect genetic change at loci underlying beetle resistance but not at a genome-wide scale. Without knowing the basis for resistance in survivors, we chose to use inter-simple sequence repeats (ISSRs) to develop genetic profiles for whitebark and lodgepole pine. ISSRs target highly variable sequences within microsatellite regions (Parasharami and Thengane, 2012). Because ISSR markers can be used to detect high levels of polymorphism and are highly reproducible, they provide a powerful approach for comparing genetic diversity between individuals as well as within and among populations of plants including pines (Mehes et al., 2007; Parasharami and Thengane, 2012; Lucas-Borja et al., 2016). In many studies, ISSR profiles have been useful in marker assisted selection when particular markers were associated with particular traits (REFS). In our screens, we looked for patterns that indicted differences between survivors and susceptible trees.

MATERIALS AND METHODS

Site Description

This study was conducted at Vipond Park, a high-elevation plateau supporting a patchwork of grassland and open forest stands located on the Beaverhead National Forest, Montana, United States (2,501 m elevation, 45.6974°N, 112.9106°W). The site is relatively xeric with an understory of sagebrush and a diverse mixture of annual and perennial forbs. Vipond Park was chosen to take advantage of the high mortality to pines that occurred there during a recent high elevation outbreak of MPB (2009–2013) when approximately 93 and 75% of mature *P. albicaulis* and *P. contorta*, respectively, were killed. The relatively flat topography of the plateau combined with its location at the transition zone between lodgepole and whitebark pine-dominated forests allowed us to study the effects of MPB selection on more than one pine species growing under the same conditions and experiencing the same level of beetle pressure. Although *P. contorta* existed at lower numbers than *P. albicaulis* at the site, they were abundant enough to allow sufficient sampling to make comparisons with whitebark pine. Additionally, white pine blister rust infection incidence and severity were very low reducing the potential for the presence of the disease to influence the choice of individual host trees by the beetle (Six and Adams, 2007).

Transects

Transects were established in 2015 (*P. albicaulis*) and 2016 (*P. contorta*). These were variable length belt transects 2 m in width that started on the edge of a stand and then followed a randomly chosen bearing until another edge was reached at which point a new bearing was adopted to establish a new transect in the same or an adjacent stand. This process was continued until the desired number of trees per species per treatment were measured. When trees occurred in clumps (resulting from seed caching by Clark's Nutcrackers), we restricted measurements and samples to one tree per clump to avoiding sampling trees potentially originating from the same cone/parent.

Determination of the Diameter Distribution of Mountain Pine Beetle-Killed Pines

In initial transects, the diameter at breast height (DBH, 1.4 m above the soil line) of 100 *P. albicaulis* and 45 *P. contorta* killed by MPB were measured to estimate the diameter distribution of MPB-killed trees for each species. This distribution was used to inform our sampling of "survivors" (mature trees that survived the outbreak) so that a similar distribution was achieved, and to determine the diameter below which trees were not attacked.

Collection of Samples for Genetic Analysis

In 2015, transects were established as previously described. Thirty survivor *P. albicaulis* with diameters representative of the diameter distribution of MPB-killed *P. albicaulis* were located on the transects. For each tree, DBH was measured and each was rated for white pine blister rust infection severity using the method of Six and Newcomb (2005). Then, approximately 30 current-year needles were collected and placed in a small plastic bag that was sealed and placed on ice in a cooler. In the lab, needles were placed into silica gel for drying and preservation. In 2016, this procedure was repeated for *P. contorta* ($n = 20$) (except for rust rating) in the same stands sampled the previous year.

The smallest diameters of *P. albicaulis* and *P. contorta* killed by MPB were 12 and 18 cm, respectively. Because beetle-killed trees did not yield DNA, we used this information to choose a second set of living trees for sampling of each species we designated as the "general population." These trees were expected to approximate the genetic structure of the population of each tree species at the site without beetle selection and so should contain a mix of survivor and "susceptible" genotypes. If our hypothesis was correct that survivors were genetically distinct from beetle-susceptible trees, then we expected only a few general population trees would have genotypes matching those of survivors (roughly reflecting the proportion of mature survivors to mature MPB-killed trees at the site). To sample general population trees, we established similar transects as before, but collected needles from trees between 9–11 and 14–17 cm DBH for *P. albicaulis* ($n = 36$) and *P. contorta* ($n = 20$), respectively.

DNA Extraction and Amplification

Needles (3–5) from each sample were ground to a fine powder in liquid nitrogen using a mortar and pestle. DNA was then isolated from each sample using a Qiagen DNeasy Plant Kit (Qiagen, Valencia, CA, United States) following the protocol provided by the manufacturer.

Five ISSR primers were chosen for use (**Table 1**). Not all primers worked equally well for both species of trees. Therefore, we chose three primers for use with *P. albicaulis* and four for *P. contorta*. Two primers overlapped in use for both trees (**Table 1**).

For amplification we used a 25 μl reaction mixture consisting of 12.5 μl Promega Master Mix (Promega, Madison, WI, United States), 2.5 μl RNA-free water, 8 μl of 0.5 M primer and 2 μl of DNA template. Reactions were run individually with one of the five ISSR primers. PCR was conducted with one cycle denaturation at 95°C for 5 min, followed by 42 cycles of denaturation at 95°C for 1.3 min, annealing at 47°C for 2 min, and extension at 72°C for 1 min. A final cycle was conducted at 72°C for 1 min and final products were held at 6°C (Parasharami and Thengane, 2012).

PCR products were visualized in a 1% agarose gel prepared using 1× tris borate buffer (TBE) to which 2 μl ethidium bromide per 100 ml gel was added. A 100 bp ladder (Promega, Valencia, CA, United States) was placed in the first lane of each gel to provide a reference for scoring bands. Amplified DNA was loaded into the remaining lanes with bromophenol blue as a running dye. Each gel was run with 1× TBE as a running buffer at 70 mA until the dye moved ¾ of the length of the gel. Gel images were captured using a UV table. Any sample that gave ambiguous results (no, faint, or smeared bands) was repeated. Approximately 20% of samples were rerun and compared to check for consistency in results. Only samples exhibiting clear bands were included in the final analysis. Bands were scored manually.

Data Analysis

Diameter Distributions

A two-sample *t*-test was used to compare mean diameters among groups (survivor, general population, and beetle-killed) using Statistix 7 (Analytical Software, Tallahassee, FL, United States).

Genetic Analysis

Bands were scored as present (1) or absent (0) to develop a binary matrix combining data for all primers by tree species. The matrices were analyzed in Popgene v. 1.32 (Yeh et al., 1997) (assuming each group was in Hardy-Weinberg equilibrium) to calculate percent polymorphism, the Shannon information index (I), Nei's gene diversity index (h), total genetic diversity (H_T), genetic diversity within groups (survivor, general population) (H_S), and evidence for deviations from neutrality (selection) with an overall Ewens–Watterson test for neutrality. Population genetic structure was investigated using STRUCTURE v. 2.3 (Pritchard et al., 2000). The *admixture* model was used with a 10,000 burn-in period and 10,000 Markov Chain Monte Carlo replications. Twenty runs were performed with each value from 1 to 10 to estimate the optimal number of clusters (K) using the ΔK statistic (Evanno et al., 2005).

For each tree species, we examined genetic variation between groups using analysis of molecular variation (AMOVA) in GenAlEx 6.5 (Peakall and Smouse, 2006). We then conducted

TABLE 1 | Primers used for ISSR amplification.

Primer ID	Sequence	Tree species
HB12	CAC CAC CAC GC	*Pinus albicaulis*
17899A	GTG TGT GTG TGT CA	*P. albicaulis, P. contorta*
17901	CAC ACA CAC ACA AG	*P. contorta*
UBC 807	AGA GAG AGA GAG AGA GT	*P. albicaulis, P. contorta*
UBC 811	GAG AGA GAG AGA GAG AC	*P. contorta*

a principle coordinates analysis (PCoA) in GenAlEx based on genetic distances between individual trees in the two groups for each species of tree. Genetic distance matrices were developed for each tree species in the *Restml* program and then imported into *Neighbor* in PHYLIP 3.67 (Felsenstein, 2005) to produce an unweighted neighbor-joining tree. The tree was visualized using TreeView 1.6.6 (Page, 1996).

RESULTS

Diameter Distributions and Blister Rust Infection Severity

The mean, median, and range of diameters of beetle-killed and survivor *P. albicaulis* were similar (**Table 2**). The mean diameter was not significantly different between survivor and beetle-killed trees, while the diameter of general population trees, as expected, differed significantly from both groups (**Table 2**). The same was true for *P. contorta* (**Table 2**). Similarly, mean diameters of MPB-killed and survivor *P. albicaulis* and *P. contorta* did not differ from one another. However, the minimum size of tree attacked by the beetle differed by tree species resulting in the choice of different diameter distributions for sampling general population trees (**Table 2**). Blister rust infection severity was overall very low at the site, but significantly lower in survivors (mean = 1.3, $SD = 1.8$) than in general population trees (mean = 1.7, $SD = 2.4$; $F = 1.63$, $df = 65$, $P = 0.013$; potential range 0–18).

Genetic Analyses

Pinus albicaulis

Three primers (17899A, HB12, and UBC807) resolved well for *P. albicaulis* and were used for ISSR analysis. A total of 28 loci (bands) were resolved using the three primers (**Table 3**). Mean percent band polymorphism (BP) for all primers for all trees (general population and survivors) combined was 96.4% and this value was similar to the BP for each group individually. The Shannon information index and Nei's gene diversity was lower in general population trees compared with survivors (**Table 2**). Nei's unbiased measure of genetic identity between the survivor and general population trees was 95% while genetic distance was a corresponding 5%.

H_T, the total genetic diversity between the two study groups, was 0.26, and the diversity within groups, H_S, was 0.24. Seven of 28 loci (25%) exhibited significant differences between observed and expected frequencies of bands between the two groups (data not shown). However, no bands were unique to either group. The Ewens–Watterson test for neutrality detected only one marginally non-neutral locus. AMOVA indicated 87% of the variation exhibited existed within groups and 13% existed between groups.

The neighbor-joining tree resolved most general population trees together in the basal clades while one major terminal clade contained all survivor trees as well as eleven general population trees that were distributed throughout the clade (**Figure 1**). The results of Bayesian clustering using STRUCTURE indicated that the optimal K-value was 3 with the general population dominated by one cluster (red, **Figure 2**) and survivors dominated by the other two (blue and green, **Figure 2**). The eleven general population trees that clustered with survivor trees in the neighbor-joining tree exhibited predominantly blue and green profiles in the STRUCTURE bar graph (shown with asterisks) indicating similarity to survivors (**Figure 2**). In the PCoA, the first two principle coordinates explained a total of 33% of the variation associated with the two groups. Adding the third, 43.55% was explained. In general, the eleven general population trees that clustered with survivors in the neighbor-joining tree resolved separate from other general population trees and with survivors in the PCoA (**Figure 3**).

Pinus contorta

Four primers resolved well for this species (17899A, UBC807, UBC901, and UBC811). Using these primers, we were able to resolve a total of 85 bands. The mean percent BP across all primers and groups was 98.82. This was considerably higher than BP for the general population (89.4%) and survivor (88.2%) trees (**Table 2**). The mean number of effective alleles was slightly lower than the mean number of observed alleles. Shannon's information index was similar within and across groups while Nei's gene diversity was lowest in survivors and highest for both groups combined (**Table 2**). Nei's unbiased genetic identity and diversity between the two groups was 93 and 7%, respectively.

H_T was 0.26 and H_S was 0.25, similar to values for whitebark pine. Allele frequencies were significantly different between survivors and general population trees at 12 of 85 loci (14%) (**Table 3**). No bands were unique to either group. The Ewan–Watterson test for neutrality indicated that six loci in the general population and nine loci in the survivors were outside the 95% CI indicating non-neutrality. All had positive F-values greater than the upper bound indicating a potential for directional selection. AMOVA indicated that 89% of variation occurred within groups while 11% occurred between groups.

The neighbor-joining tree partitioned general population and survivor trees into several clades (**Figure 4**). Most (55%) general population trees resolved in one clade. The remainder resolved into two clades interspersed with survivors (**Figure 4**). The general population trees that resolved with survivors in the neighbor-joining tree shared clusters with survivor trees in the STRUCTURE analysis (**Figure 2**) and also partitioned with survivor trees in the PCoA (**Figure 3**). The first two principle coordinates in the PCoA explained 21.5% of the

TABLE 2 | Summary statistics for diameter breast height (cm) of *Pinus albicaulis* and *P. contorta* by group.

Tree	Group	N	Mean (*SD*)	Median	Minimum	Maximum
P. albicaulis	Beetle-killed	75	24.5 (5.3)[a]	24.2	12.0	37.3
	Survivor	30	25.0 (5.2)[a]	24.1	17.0	37.3
	General	36	10.0 (0.6)[b]	10.0	9.0	11.0
P. contorta	Beetle-killed	45	26.7 (5.0)[a]	26.4	17.5	36.8
	Survivor	20	27.5 (5.4)[a]	29.9	18	37.2
	General	20	15.3 (0.9)[c]	15.2	13.9	16.8

Different letters following means denote statistically significant differences, $\alpha = 0.05$.

TABLE 3 | Percent band polymorphism (BP), number of observed (N_a) and effective (N_e) alleles, Shannon's Information Index (*I*), Nei's gene diversity (*h*), and diversity between (H_T) and within groups (H_S), presented by tree species and group.

Tree species	Group	N	%BP	N_a	N_e	*I*	*h*	H_T	H_S
P. albicaulis	Survivor	30	96.58	1.97 (0.19)	1.39 (0.25)	0.40 (0.19	0.22 (0.14)		
	General	36	96.55	1.97 (0.19)	1.32 (0.27)	0.36 (0.14)	0.25 (0.14)		
	Combined	66	96.43	1.96 (0.19)	1.41 (0.19)	0.42 (0.18)	0.26 (0.14)	0.26 (0.10)	0.24 (0.01)
P. contorta	Survivor	20	88.24	1.88 (0.32)	1.40 (0.33)	0.25 (0.17)	0.39 (0.23)		
	General	20	89.41	1.89 (0.31)	1.40 (0.31)	0.26 (0.16)	0.40 (0.22)		
	Combined	40	98.82	1.90 (0.11)	1.41 (0.29)	0.27 (0.14)	0.42 (0.18)	0.27 (0.02)	0.25 (0.02)

Means are accompanied by standard deviations in parentheses.

variation between the two groups. Adding the third component explained 31%.

DISCUSSION

Knowledge of the effects of bark beetle outbreaks on host tree population genetic structure and resistance to attack will be increasingly valuable as climate change drives more frequent outbreaks and facilitates the movement of beetle species into naïve forests. Outbreaks of MPB seldom kill all mature trees despite high beetle numbers during population peaks. Our results suggest that surviving trees possess a wealth of information that can be used to inform our understanding of the genetic and phenotypic bases for resistance and to develop management approaches that support forest adaptation.

We found that surviving mature trees in a high elevation forest of whitebark and lodgepole pine were genetically distinct from "general population" trees that were assumed to represent the genetic structure of the population pre-outbreak and without selection by the beetle. In line with our hypothesis, a low percentage (<10%) of "survivor" genotypes were identified within the general population. The proportion of these survivors roughly mirrored the proportion of mature trees that survived the outbreak at Vipond Park. The neighbor-joining tree, the PCoA and the STRUCTURE analyses each indicated strong differentiation between survivors and "susceptible" individuals and identified the same trees as survivors within the general population. In the STRUCTURE analysis for both whitebark and lodgepole pine, susceptible trees belonged to one cluster while survivor trees belonged to two other clusters. This separation can also be seen in the PCoA. Further research will be needed to

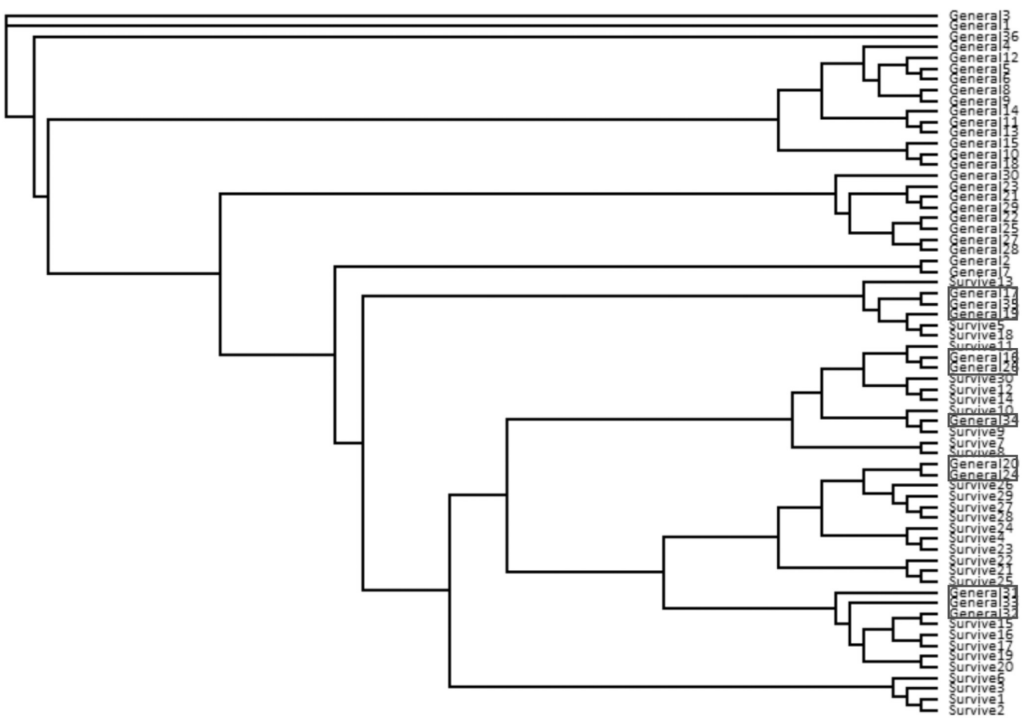

FIGURE 1 | Neighbor-joining tree from ISSR data for *Pinus albicaulis*. General = general population trees (with no *Dendroctonus ponderosae* selection). Survive = mature trees surviving *D. ponderosae* outbreak. Trees in boxes correspond to trees with arrows in **Figure 2** and in ellipses in **Figure 3**.

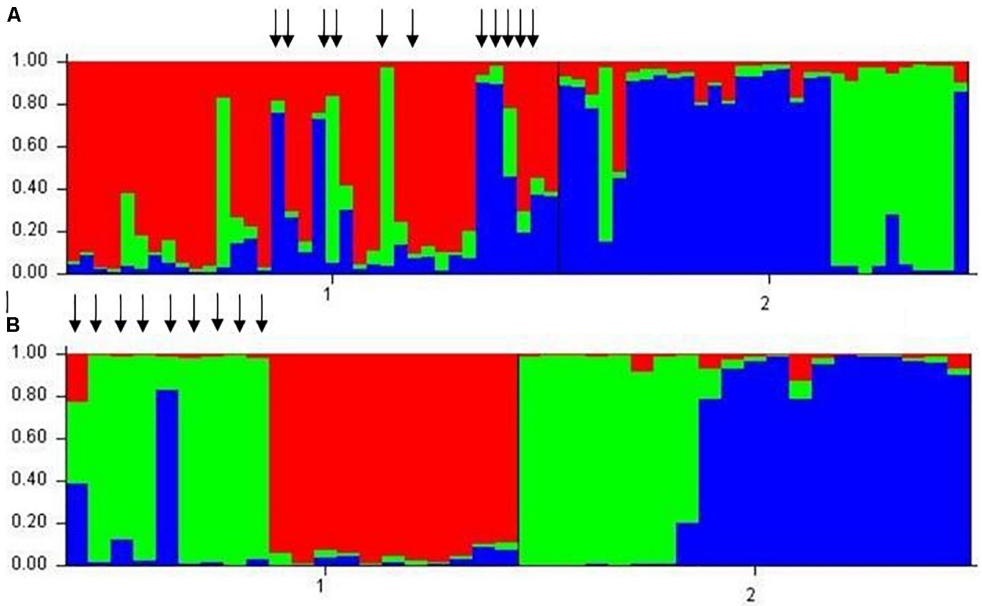

FIGURE 2 | Results of Bayesian clustering using STRUCTURE. Individual trees are represented by vertical bars. Colored segments represent the tree's estimated proportion similarity to each of the three clusters (red, blue, and green) optimally defined by STRUCTURE. **(A)** *Pinus albicaulis*. Arrows denote general population trees that resolved with survivors in neighbor-joining tree in **Figure 1**. **(B)**. *Pinus contorta*. 1 = general population trees. 2 = survivor trees.

determine whether the patterns we detected are indeed indicative of resistance, and if so, whether there are multiple or overlapping factors that account for survivorship.

We found surprisingly high levels of differentiation between survivor and general population trees in both species of pine. For whitebark pine, Nei's genetic distance between survivor and general population whitebark pines was 5%, a value that would indicate moderate differentiation if these comparisons had been made between tree populations. Likewise, AMOVA indicated 13% of the genetic variation present existed between groups. Considering that the trees in this analysis were not from different populations, but rather grew intermixed at the same site, these values seem strikingly high. Likewise, for lodgepole pine, Nei's genetic distance was 7%, and AMOVA indicated 11% of variation occurred between the groups.

These results indicate the presence of genetically based resistance in both pine species and that trees with resistant genotypes are not selected for attack. It has been thought that once MPB achieve high population levels during outbreaks, the selection of individual trees based on tree-produced compounds and condition becomes swamped by high levels of aggregation pheromone production and competition for increasingly rare hosts (Safranyik and Carroll, 2006). However, our results suggest that beetles remain selective even as outbreaks peak and collapse.

We chose ISSR profiling as a first step to determine whether survivors were different than trees chosen by MPB for colonization. This PCR-based method detects high levels of polymorphism, is highly reproducible, and allows the screening of a large number of trees relatively rapidly and economically. Unfortunately, this method cannot tell us why survivors are different, only that they are. Further study will be needed to further investigate whether survivors are indeed highly resistant and, if so, to determine the actual basis behind resistance. Ongoing studies are investigating correlations among genetic profiles of survivor and "susceptible" trees with phenotypic traits including defensive chemistry and growth rates in relation to climate. Genomic approaches will also be extremely useful to elucidate the basis of resistance.

This study corroborated the findings of other studies that found that MPB colonizes smaller diameter whitebark pine than lodgepole pine during outbreaks (Dooley et al., 2015). The mortality of younger whitebark pine trees indicates a more severe impact of MPB outbreaks on whitebark pine forests, at least in the short term, because advanced regeneration is killed along with large trees. However, the loss of large and mid-diameter trees may serve to open areas for nutcracker caching of seeds from the remaining resistant trees, potentially increasing the frequency of those genotypes and phenotypes at the site and within the larger population.

In a previous study, Six and Adams (2007) found that as infection severity increased so did the likelihood of attack by the beetle. However, while we found that white pine blister rust infection severity was significantly higher in general population trees than survivors, the mean level of infection severity at the site was very low and the size effect between means for survivors and general population trees was very small. Therefore, we feel it is unlikely blister rust played a significant role influencing beetle dynamics at the study site.

A caution is in order in interpreting our results. We were unable to amplify DNA from MPB-killed trees which forced us to use smaller diameter "general population" trees as a substitution

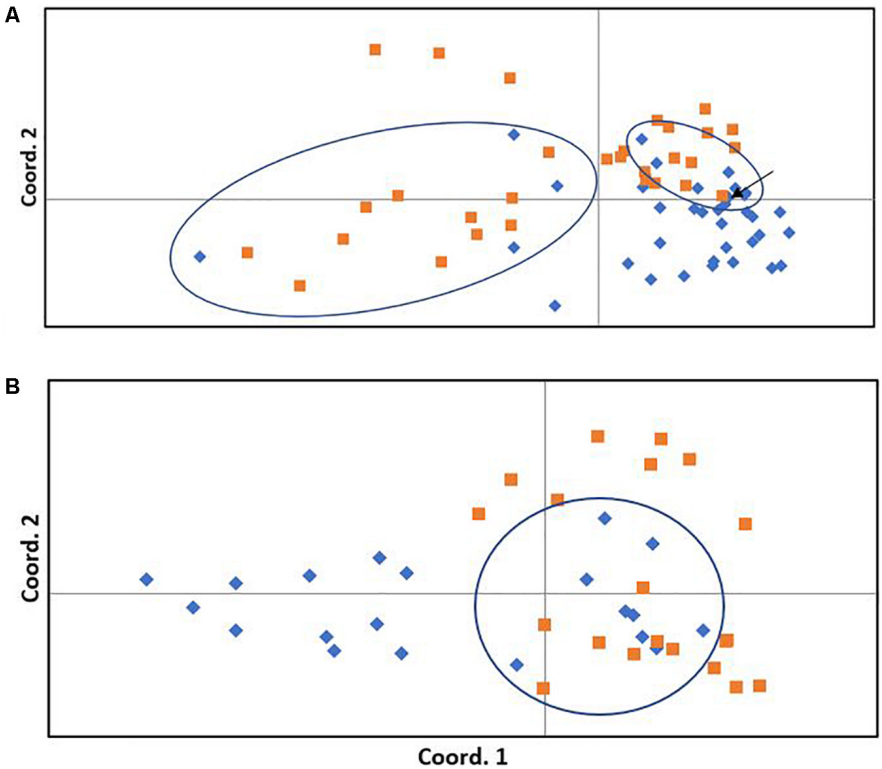

FIGURE 3 | Principle coordinates analysis of general (blue diamonds) and survivor (orange squares) trees. **(A)** *Pinus albicaulis.* The first and second coordinates explain 19.29 and 13.67% of the variation among trees, respectively (total 33%). **(B)** *Pinus contorta*. The first and second coordinates explain 10.98 and 10.55% of the variation among trees, respectively (total 21.5%). Ellipses surround general population trees that clustered with survivors in the neighbor-joining tree (**Figure 1** for *P. albicaulis*, **Figure 4** for *P. contorta*) and correspond to trees marked with an arrow in the STRUCTURE analysis (in this figure). Arrow indicates one general population tree within the ellipse that did not cluster with survivors in the neighbor-joining tree.

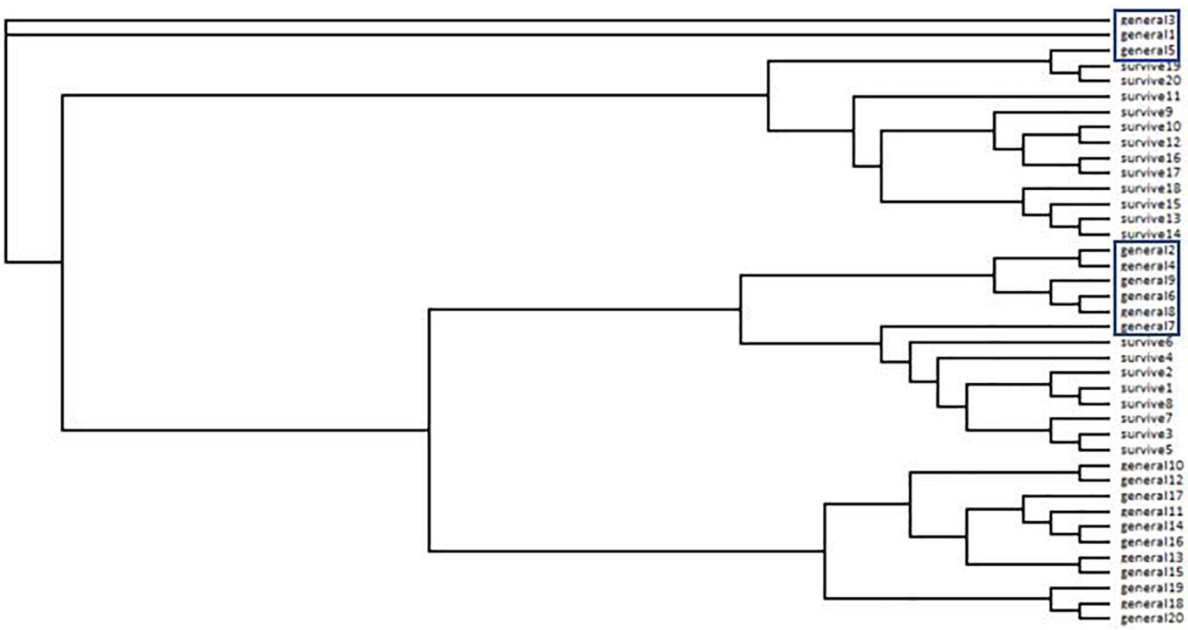

FIGURE 4 | Neighbor-joining tree from ISSR data for *Pinus contorta*. General = general population trees (with no *Dendroctonus ponderosae* selection). Survive = mature trees surviving *D. ponderosae* outbreak. Trees in boxes correspond to trees with arrows in **Figure 2** and in ellipses in **Figure 3**.

for "susceptible" trees. These trees were mature reproductive trees and only slightly smaller than trees selected by the beetle for colonization; however, some or all may constitute a cohort that regenerated under different environmental conditions resulting in a genetic structure unrepresentative of the larger trees that were available for selection by the beetle. However, the proportional distribution of survivor and "susceptible" trees in the neighbor-joining trees, PCoAs and STRUCTURE analyses indicate that the general population samples were likely appropriate proxies.

With climate change supporting the invasion of aggressive bark beetles into naïve forests, and predictions of more frequent and severe outbreaks, it is increasingly important to understand the capacity of trees to adapt and persist (Millar et al., 2007; Ramsfield et al., 2016). While the massive mortality of pines in western North America in recent years is cause for concern, we should also look at these hard-hit forests as opportunities to learn. In almost all cases, affected forests are not completely dead–they retain many living large diameter trees. If these trees are genetically different than those selected and killed by the beetles as our study suggests, these trees may aid in *in situ* adaptation and persistence. They may also be key to developing management and trajectories that allow for forest adaptation. For example, retaining surviving trees as a primary seed source, rather than removing them during salvage operations could support *in situ* adaptation. In contrast, the effects of natural selection in these stands could be instantly negated by clearcutting or replanting with general seed stock.

Supporting forest adaptation is critical in this time of rapid change (Millar et al., 2007). Given the great expanses of forest that are being affected by climate change and the fact that most will need to adapt *in situ*, it is imperative we begin to move past structural approaches to consider the genetic capacity of forest trees to adapt. The high degree of standing genetic variation found in most forest trees indicates many will have considerable ability to adapt. We need to be cognizant of adaptation that is occurring so that our management approaches act to support rather than hinder natural selection for traits needed under future conditions.

AUTHOR CONTRIBUTIONS

DS conceived of the project, participated in field work, conducted data analysis, and wrote the manuscript. CV conducted lab work on whitebark pine and participated in field work and data analysis. MC conducted field and lab work on lodgepole pine and contributed to data analysis.

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SYNTHESIS & INTEGRATION

Transitioning western U.S. dry forests to limited committed warming with bet-hedging and natural disturbances

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Abstract. Historical evidence suggests natural disturbances could allow more forest persistence, than expected from models, over 40 yr of transition to the net-zero emissions needed to limit warming to <2.0°C (e.g., Paris Agreement). Forests must ultimately equilibrate with committed warming from accumulated emissions. Historical dry-forest landscapes were heterogeneous from large, infrequent disturbances (LIDs) that reduced tree density and basal area, followed by slow, variable tree regeneration and recovery for 1–3 centuries. These together effectively provided bet-hedging through stand- and landscape-level heterogeneity that enhanced resistance and resilience to a diversity of unpredictable subsequent disturbances. Recent disturbances have not yet exceeded historical variability in rates and patterns, but could cause mortality of ~26–51% of dry-forest area in the transition. This also means 1/2 to 3/4 of dry-forest area could escape most mortality and the mortality area could also have substantial forest persistence. Projections are unavailable for droughts or beetle outbreaks, but they recently caused about 3–4 times as much tree mortality as did moderate- to high-severity fires. Mortality could reduce forest area if new trees do not regenerate, but 24 studies showed recent regeneration after high-severity fires was slow, but indistinct from historical variability. Survival of smaller trees provided regeneration after beetle outbreaks and droughts. Regeneration in general was projected by 2060 to decline by ~10% in one study and increase by 50% in another. If openings from disturbances increased, some grasslands and shrublands could be restored, increasing landscape heterogeneity and resistance to disturbance spread. Given these trends and our limited ability to prevent LIDs, I suggest (1) refocusing restoration to increase bet-hedging resilience to droughts and beetle outbreaks by retaining small trees and diverse tree species, (2) expanding development of fire-safe landscapes to protect people and infrastructure from unavoidable increased fire, (3) enabling more managed fire to restore and enhance stand- and landscape-scale bet-hedging, and (4) accepting that LIDs will revise resistance, resilience, and adaptation, which enhance forest persistence, particularly if post-disturbance survivors are not logged and trees are not planted. Natural disturbance and slow recovery, if bet-hedged to increase resistance and resilience, could enable substantial forest persistence.

Key words: adaptation; beetle outbreaks; bet-hedging; climate change; disturbances; droughts; dry forests; fire; natural recovery; resilience; succession.

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Introduction

Since the 2015 Paris Agreement, the world plans to reduce emissions to limit warming to much less than 2.0°C, possibly 1.5°C, and it is worthwhile to focus on how major ecosystems may transition to this more limited level of warming that is now a global commitment. Extensive disappearing climates and ecosystem changes and the need for widespread assisted migration by the mid- to late 21st century under continuing moderate- to high emissions (e.g., Rehfeldt et al. 2014) are less likely. Understanding is now needed of impacts of more limited warming for specific ecosystems. Here, I review how bet-hedging and natural-disturbance processes (Baker and Williams 2015) could help transition current dry-forest landscapes in the western United States to limited committed warming. Bet-hedging uses small trees, large trees, and diverse trees to hedge against diverse disturbances. Committed warming occurs because once emissions are reduced so they are at net zero (emissions balanced by fixation), the long persistence of emitted CO_2 in the atmosphere and high oceanic heat capacity cause global temperatures to remain elevated for centuries near where they are at net zero (Collins et al. 2013, Mauritsen and Pincus 2017).

Dry forests are major montane ecosystems (Fig. 1), covering ~25.5 million ha of the western United States (Baker 2015). Dry forests include (1) dry pine forests most often dominated by ponderosa pine (*Pinus ponderosa*) or similar pines with relatively few associated trees, and (2) dry mixed-conifer forests with pines plus several other trees (e.g., *Abies concolor*, *Abies grandis, Populus tremuloides, Pseudotsuga menziesii*). Dry-forest landscapes historically also included grasslands and shrublands, as well as younger forests (Fig. 2), some of which were seral stages after high-severity fires in dry forests, although others were more persistent (Baker 2017*a*).

To keep committed warming below 2.0°C across dry forests of the western United States, emissions may need to be net zero by A.D. 2050 when 80% of projections show 2.0°C of warming would be reached with current emissions (Karmalkar and Bradley 2017). However, globally committed warming of well below 2.0°C that might allow 2.0°C of committed warming across dry forests of the western United States could also be achieved if net-zero emissions are reached by A.D. 2060 after rapid near-term reductions (Sanderson et al. 2016). The 2.6 representative concentration pathway (RCP), the lowest scenario of the Fifth Assessment Report (AR5) from the Intergovernmental Panel on Climate Change, was thought to feasibly constrain warming to <2.0°C (IPCC 2015), but this now appears unlikely (Sanderson et al. 2016). The next IPCC report (AR6), with newer scenarios congruent with 1.5–2.0°C of committed warming, is not due until 2022. However, Shared Socio-Economic Pathways (SSPs) that are being developed suggest a 1.9 RCP could feasibly constrain warming to 1.5°C (Rogelj et al. 2018). Updated global carbon-emissions accounting and pathways make 1.5°C feasible (Tokarska and Gillett 2018, Van Vuuren et al. 2018). Thus, net-zero emissions by 2060 are needed and feasible to avoid rising above 1.5–2.0°C (Tanaka and O'Neill 2018). Therefore, I consider A.D. 2060, ~40 yr, as the main period for transitioning dry forests, after which further, slower adjustment to committed warming continues.

No projections yet exist for extent of climate loss (current climate moves elsewhere or is changed) or its effects on tree populations in dry forests for pathways leading to net-zero emissions by 2060, but perspective is still possible now. Projections of climate loss in dry forests, primarily from bioclimate models, were mostly for A.D. 2060–2100 and/or RCPs of medium to high emissions (Table 1). Loss of climate would likely be lower than in RCP 2.6 (Table 1), but specific projections are lacking. Nonetheless, by 2015, total human-induced global warming was 0.93°C (Millar et al. 2017), about 1/2 to 2/3 of the way to 1.5–2.0°C, suggesting that effects that will occur are well underway. Here, I synthesize what might ensue in dry forests based on recent trends in natural disturbances, tree mortality, and tree regeneration, aided by projections and scenarios to 2060 for low or modest emissions, where available. Further refinement will be needed, but substantial evidence is available now that can provide useful perspective.

Also, bioclimate models do not reveal ecological effects, since they usually lack demography, dispersal, or natural disturbance, and mostly

Fig. 1. Dry forests covered about 25.5 million ha of the western United States, including about 12.6 million ha of dry pine forests and 12.9 million ha of dry mixed-conifer forests. Data are Landfire biophysical settings, which predict historical vegetation (http://www.landfire.gov).

only show how the climate of an ecosystem may change, not effects (Campbell and Shinneman 2017). Climate loss is expected to move upward from lower-elevation and northward from southerly trailing edges of dry-forest ranges, and tree mortality may follow, but unpredictably. Adult ponderosa may be most vulnerable in interior populations (var. *scopulorum*) and less in Pacific populations (var. *ponderosa*) of ponderosa pine, but vulnerability in dry forests may be heterogeneous in general (McCullough et al. 2017). These models are generally only for

Fig. 2. Historical dry-forest landscapes included forests as well as openings with grasslands and shrublands, as shown here in this Whitman Cross photograph from 1897 looking south at Mesa Verde (on the skyline), southwestern Colorado, across a ponderosa pine landscape with Gambel oak (*Quercus gambelii*) shrublands and montane grasslands. Reproduced from a scanned print of the original photograph (Cross 297) at the U.S. Geological Survey Denver Library, Photographic Collection, Denver, Colorado.

adult trees, but tree regeneration may ultimately control tree persistence and expansion (Bell et al. 2014, Dobrowski et al. 2015, Petrie et al. 2017). Natural disturbances (droughts, beetle outbreaks, wildfires, and diseases) will likely cause the tree mortality as climate is lost. Forest resilience could be exceeded and a tipping point (Reyer et al. 2015) crossed. However, inertia from long tree life spans, changing disturbances, and tree survival and regeneration might allow more forest persistence (Campbell and Shinneman 2017).

Here, I first review the historical roles of large, infrequent disturbances (LIDs), post-disturbance legacies, and slow natural recovery in dry forests. Then, I review recent natural disturbances, tree regeneration, and how persistence of tree populations in dry forests to warming could be aided by bet-hedging. Emergence of climates at higher elevations may offset losses in current ranges, if dispersal succeeds (Campbell and Shinneman 2017), but is not addressed here.

Historical Variability in Natural Disturbance and Recovery in Dry-Forest Landscapes

Large, infrequent disturbances historically accomplished most renewal in dry-forest landscapes

Historical dry-forest landscapes included open, low-density stands with large, old trees and a history of low-severity fires, but probabilistic landscape-scale studies found these open forests over only about 34%, on average, of dry-forest area (Baker 2017*a*). The other 66% historically had more diverse stand structures (examples in Table 2, reviews in Odion et al. 2014, Hanson et al. 2015). Historical forests were often younger, denser, and had been burned in fires varying in intensity and severity, as described explicitly in Hessburg et al. (2007:19): "Instead, area was dominated by forest structures that were intermediate between new and old forests, i.e., by pole to medium sized, rather than large trees. . . . This observation suggested that before any extensive management had occurred, the influence of fire in the dry forest was

Table 1. Projected losses of current dry-forest climates for individual species that occur in current dry forests of the western United States, based on bioclimate and process-based (only Mathys et al. 2017) models.

Emissions level/location	Species	Change (%)†	Date	Emissions scenario or RCP‡	Author(s)
Low					
Arizona–New Mexico Plateau	*Pinus ponderosa*	−58.0	2075–2100	2.6	Mathys et al. (2017)
North America	*Pseudotsuga menziesii*	−22.0	2075–2100	2.6	Mathys et al. (2017)
Idaho Batholith	*Pseudotsuga menziesii*	−19.0	2075–2100	2.6	Mathys et al. (2017)
Wyoming Basin	*Pseudotsuga menziesii*	−1.0	2075–2100	2.6	Mathys et al. (2017)
Medium–high					
North America	*Abies concolor*	−13.4§	2071–2100	A2/B2 mean	McKenney et al. (2007)
North America	*Abies grandis*	−49.6§	2071–2100	A2/B2 mean	McKenney et al. (2007)
North America	*Picea pungens*	−51.2§	2071–2100	A2/B2 mean	McKenney et al. (2007)
North America	*Pinus jeffreyi*	−68.6§	2071–2100	A2/B2 mean	McKenney et al. (2007)
North America	*Pinus ponderosa*	−40.4§	2071–2100	A2/B2 mean	McKenney et al. (2007)
North America	*Pinus ponderosa* var. *ponderosa*	−45.0	2060	6.0	Rehfeldt et al. (2014)
North America	*Pinus ponderosa* var. *scopulorum*	−77.0	2060	6.0	Rehfeldt et al. (2014)
North America	*Populus tremuloides*	−24.7§	2071–2100	A2/B2 mean	McKenney et al. (2007)
North America	*Pseudotsuga menziesii*	−31.5§	2071–2100	A2/B2 mean	McKenney et al. (2007)
North America	*Pseudotsuga menziesii* var. *glauca*	−35.0	2060	6.0	Rehfeldt et al. (2014)
North America	*Pseudotsuga menziesii* var. *menziesii*	−18.0	2060	6.0	Rehfeldt et al. (2014)
High					
Southwestern USA	*Picea pungens*	−81.0	2070–2099	A2	Notaro et al. (2012)
Southwestern USA	*Pinus ponderosa*	−47.0	2070–2099	A2	Notaro et al. (2012)
Southwestern Colorado	*Populus tremuloides*	−52.0	2060	6.0/8.5 mean	Rehfeldt et al. (2015)
Southwestern USA	*Pseudotsuga menziesii*	−50.0	2070–2099	A2	Notaro et al. (2012)
North America	*Pseudotsuga menziesii*	−59.0	2075–2100	8.5	Mathys et al. (2017)
Southwestern USA	All needleleaf evergreen trees	−100.0	2099	A2	Jiang et al. (2013)

Note: Area outside current climates may also emerge with some new area of suitable dry-forest climates, not shown here.

† The change (%) is relative to the present.

‡ Emissions scenarios are A2 (High emissions), B1 (Low), and B2 (Low–Medium); RCP = representative concentration pathway, which is the change in radiative forcing (W/m^2) in 2100 relative to pre-industrial conditions, as defined for emissions scenarios by the Intergovernmental Panel on Climate Change (IPCC). RCP 2.6 is Low, 4.5 is Medium, 6.0 is Medium–High, and 8.5 is High emissions.

§ This is the "no dispersal" projection result.

of a frequency and severity that intermittently regenerated rather than maintained large areas of old, fire tolerant forest." The intermittent regeneration likely followed LIDs which varied in intensity, but were at least partly intense enough to kill substantial woody plants. Large, infrequent disturbances included fires, insect outbreaks, diseases, droughts, and blowdowns (Foster et al. 1998).

Many historical LIDs in dry-forest landscapes occurred in periodic climatic episodes. Large fires were often during droughts, as in 1848 when 41 of 63 fire-history sites across southwestern dry forests recorded this fire year (Swetnam and Baisan 1996), and in 1910 when 1.2 million ha burned in the northern Rocky Mountains (Odion et al. 2014). About 10 bark beetles had large outbreaks in dry forests (Bentz et al. 2010) when tree defenses were weakened by drought or other events, weather favored beetle reproduction, and mass attack could overcome tree resistance (Bentz et al. 2010, Negrón and Fettig 2014). An example is the 200,000- to 300,000-ha 1895–1909 mountain pine beetle (MPB; *Dendroctonus ponderosae*) outbreak in the Black Hills, South Dakota (Graham et al. 2016). Historical droughts, such as the A.D. 1574–1594 drought in the Southwest, also likely led to extensive tree mortality in dry forests (Swetnam and Betancourt 1998, Williams et al. 2013).

Large disturbances were likely infrequent in historical fire regimes and in other disturbance regimes. Modern fire regimes globally nearly all have log-normal fire-size distributions in which large fires are exponentially less frequent than small fires (Hantson et al. 2016). Historical fire-

Table 2. Examples of probabilistic studies and ancillary supporting sources that showed evidence of historical mixed-severity fire regimes, with substantial area of high-severity fire, that fostered heterogeneous historical dry-forest landscapes in the western United States.

Data source	Author(s)	Location(s)
Probabilistic		
Early aerial photographs	Hessburg et al. (2007)	WA, OR
Forest Inventory and Analysis data	Odion et al. (2014)	W USA
Early forest-reserve reports	Baker et al. (2007), Baker (2012, 2014), Williams and Baker (2014)	AZ, CA, OR, Rocky Mountains
Reconstructions–General Land Office surveys	Williams and Baker (2012*a*, *b*)	AZ, CO, OR
Reconstructions–Tree-rings at landscape scale	Sherriff et al. (2014)	CO
Ancillary supporting sources		
Early historical accounts	Baker (2012, 2014)	CA, OR
Early photographs	Baker (2009)	Rocky Mountains
Reconstructions–Paleo-charcoal	Compilation in Baker (2015)	W USA

Note: AZ, Arizona; CA, California; CO, Colorado; OR, Oregon; WA, Washington; W USA, western USA.

size and patch-size distributions in dry forests also had inverse-J shapes suggesting log-normal distributions (Williams and Baker 2012*a*, Baker 2017*a*). While rare, LIDs could be concentrated in episodes across large land areas, as were severe fires in the late 1800s in the southern Rocky Mountains (Veblen et al. 2000, Schoennagel et al. 2011, Baker 2017*b*), and large MPB outbreaks across the western United States and Canada (Jarvis and Kulakowski 2015).

The severely disturbed extent of LIDs had historical rotations (the expected time to affect the area of a landscape once) of one or more centuries. High-severity fires that killed >70% of basal area in dry forests historically had rotations of about 2–8 centuries (Baker 2015); moderate- to high-severity fires that killed 20% or more of basal area had rotations of 235–319 yr (Odion et al. 2014). Tree age distributions and early observations suggest large insect outbreaks and droughts were also infrequent events in dry forests (Blackman 1931, Swetnam and Betancourt 1998). The historical rotation for outbreaks of MPB, the main outbreak beetle in the western United States (Meddens et al. 2012), might be somewhat longer in ponderosa pine than lodgepole pine (*Pinus contorta*) forests, since ponderosa pine forests are more heterogeneous (Chapman et al. 2012). Jarvis and Kulakowski (2015) reconstructed MPB outbreaks in lodgepole pine at 10 sites in 200,000 ha of western Colorado and found four episodes from 1742 to 1910 that affected 0.5, 0.7, 0.5, and 0.4 of the 10 sites, a rotation of about 80 yr (168 yr/2.1). The rotation for drought-caused mortality in dry forests is unknown as there are no historical reconstructions. Pan-continental droughts that affected several U.S. regions occurred historically in $\sim$12% of the last 1000 yr, but megadroughts of a decade or more, mainly in the Southwest and Central Plains, were rare in the last 500 yr (Cook et al. 2014). The 1574–1594 event, mentioned earlier, is the only historical one known to have caused extensive mortality in dry forests.

In the case of fires, the few percent that are large typically account for most of the total burned area (Strauss et al. 1989) and are often more intense (Swetnam and Baisan 1996). This importance of only a few percent of fires, the largest fires, to total burned area is evident in modern dry forests (Farris et al. 2010) and other forests (Baker 2009). Larger fires often have a mix of intensities and higher intensity, since fires become large because of rapid spread, driven by wind and drier fuels that allow more fuel consumption, increasing fire intensity (Alexander 1982). Large beetle outbreaks and lengthy droughts also appear to cause most tree mortality (Allen et al. 2010, Baker and Williams 2015, Graham et al. 2016), likely because resistance thresholds in trees are difficult to cross with smaller, less severe events (Romme et al. 1998).

Large, infrequent disturbances updated resistance, resilience, and legacies that facilitated recovery and bet-hedging

Large, infrequent disturbances with varying severities historically provided episodic adjustment across dry-forest landscapes, reducing area,

density, and basal area of less disturbance-resistant trees, while increasing more disturbance-resistant trees, although current trees simply regenerate at times. Competition was lessened and the canopy was opened (Fig. 3a, b), often reducing vulnerability to subsequent disturbances for decades or longer (Parks et al. 2016).

Large, infrequent disturbances episodically tested and updated resistance, resilience, and bet-hedging across changing landscapes. Large, infrequent disturbances fostered diverse surviving tree species, sizes, and regeneration strategies that provided resistance and resilience to subsequent diverse disturbances (Table 3). This diverse stand and landscape structure and composition after LIDs could effectively provide stand- and landscape-level bet-hedging against an uncertain array of subsequent disturbances (Baker and Williams 2015). At the stand scale, bet-hedging was provided by combinations of large, old trees with thick bark that resisted mortality in fires and some beetle outbreaks (Graham et al. 2016, Welch et al. 2016), abundant small trees that resisted mortality in beetle outbreaks and droughts (Baker and Williams 2015), and diverse tree species so that some trees were not vulnerable to particular insects or diseases. At the landscape scale, areas of large trees, other fire-resistant trees, and low tree density provided landscape resistance to severe fires. Low-to-moderate fuel continuity allowed fires to spread, but with patchiness. Openings reduced ignitions, slowed disturbance spread, and reduced severity, while natural breaks could slow or terminate fires. Low–moderate contiguity of large trees and diverse patches may have reduced beetle spread and limited the size of patches of tree mortality (Graham et al. 2016). Young, recovering forests had high tree survival in beetle outbreaks (Graham et al. 2016) and droughts (Allen et al. 2010).

Natural recovery exemplifies resilience: "…the capacity of a system to absorb disturbance and reorganize while undergoing change so as to retain essentially the same function, structure, identity and feedbacks" (Walker et al. 2004:2). Large, infrequent disturbances in dry forests left behind complex effects from variable disturbance types and severities (Fig. 3), and these legacies (Foster et al.

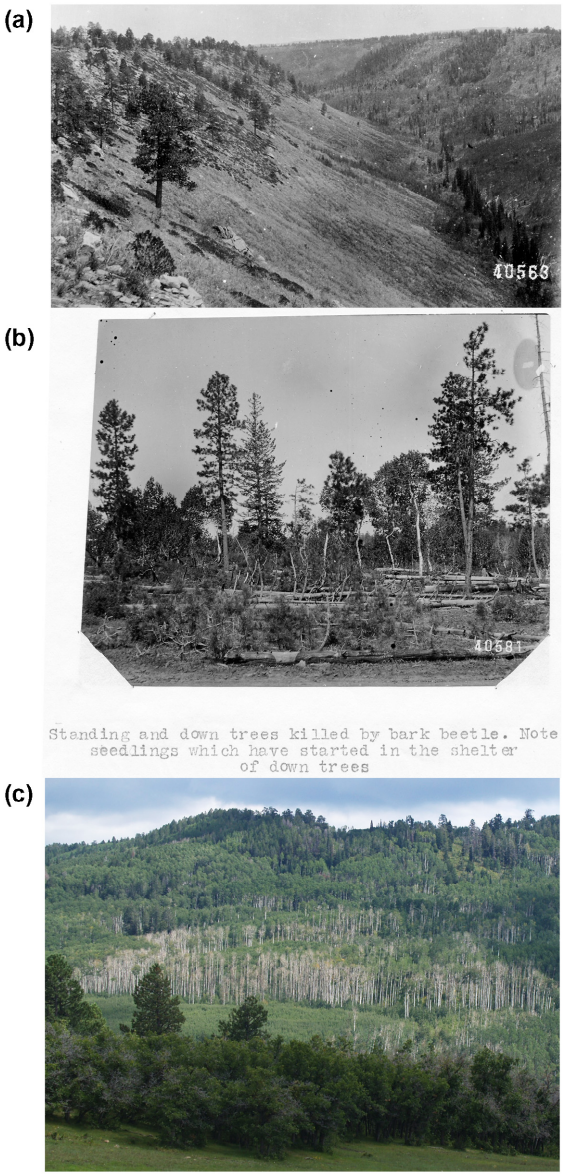

Fig. 3. Legacies after large, infrequent disturbances in dry forests: (a) a historical moderate- to high-severity fire in dry forests on the Uncompahgre Plateau, western Colorado, photograph in 1903 from Riley (1904); (b) a historical beetle outbreak in dry forests on the Uncompahgre Plateau, western Colorado, photograph in 1903 from Riley (1904); and (c) sudden aspen decline (SAD), a recent drought-linked disturbance, in southwestern Colorado, photograph by W. L. Baker, in 2006.

Table 3. Some historical structures (table entries), created by LIDs and environmental heterogeneity, that provided resistance and resilience at the stand and landscape scales to the three main types of LIDs in dry forests.

Property	Moderate- to high-severity fires	Beetle outbreaks	Droughts
Resistance–stand scale	Abundant large trees, some small trees	Abundant small trees, some large trees	Abundant small trees
	Fire-resistant trees	Diverse tree species	Diverse tree species
	Moderate fuel continuity (e.g., patches of rocks, low fuels)	Contiguous patches of small trees	Diverse topo-edaphic settings, some with more moisture
	Lower tree density/fuels, where this occurred, reducing fire severity	Lower tree density, where this occurred	Lower tree density, where this occurred
	Higher tree density/cover leading to shaded, moister fuels, where this occurred		
Resistance–landscape scale	Areas of large trees	Low–moderate contiguity of areas of large trees	Low–moderate contiguity of areas of large trees
	Areas of fire-resistant trees	Diverse patches dominated by different tree species	Diverse patches dominated by different tree species
	Areas of low tree density/fuels, where they occurred	Areas of low tree density, where they occurred	Areas of low tree density, where they occurred
	Limited areas of young, recovering forests	Large areas of young, recovering forests	Large areas of young, recovering forests
	Moderate fuel continuity	Discontinuous suitable host trees	
	Areas of higher tree density/ cover leading to shaded fuels		
	Openings that slowed fire spread (e.g., grasslands, wetlands)	Openings that broke up contiguous suitable host trees	
	Natural fire breaks (e.g., rock outcrops, streams, moist stands)	Natural openings with few or no host trees	
Resilience–stand scale	Resprouting trees and shrubs	Resprouting trees and shrubs	Resprouting trees and shrubs
	Surviving large seed trees, some patches of surviving small trees	Abundant small trees, some large surviving trees for seed	Abundant small trees, some large surviving trees for seed
		As much diversity in tree species as possible	As much diversity in tree species as possible
Resilience–landscape scale	Large seed trees, likely to survive, every 50–100 m, limited patches of small trees	Large areas with abundant small trees likely to survive, some patches of large trees	Large areas with abundant small trees likely to survive, some patches of large trees
	Diverse tree densities, basal areas, and tree species composition	Diverse tree densities, basal areas, and tree species composition	Diverse tree densities, basal areas, and tree species composition
	Most severely burned area within 100–200 m of an unburned edge	Patches with a diversity of dominant tree species	Patches with a diversity of dominant tree species

Note: LIDs, large, infrequent disturbances.

1998) or ecological memory (Johnstone et al. 2016) facilitated natural recovery. Resilience was enhanced by resprouting trees and shrubs, large old trees that provided post-disturbance seed, and variable tree densities and basal areas that provided diverse post-disturbance recovery (Table 3).

Highly variable historical tree regeneration, particularly in the Southwest

Successful ponderosa pine regeneration was limited by a required coincidence of favorable processes from seed formation to seedling survival (Pearson 1923, Feddema et al. 2013, Savage et al. 2013). However, land-survey records from 22,206 km of transects across 1.7 million ha of dry forests in the late 1800s showed that seedlings and/or saplings were present over 35–57% and dense over 20–30% of dry-forest area in Oregon, California, and part of northern Arizona (Baker and Williams 2015). Pulses of regeneration seen in some age structures were favored by canopy-reducing disturbances, particularly fire

that created mineral seedbeds and reduced competition by grass, followed by fire-free periods or pluvials, that sustained regeneration (Dugan and Baker 2015). Moderate- to high-severity fires led to more regeneration than did low-severity fires (Wu 1999, Ehle and Baker 2003, Schoennagel et al. 2011, Baker and Williams 2015).

About 14% of dry-forest area, mostly in the Southwest, had sufficiently frequent low-severity fire (Baker 2017*a*) and drier climate to potentially limit regeneration to exceptional pluvials and fire-free periods (Covington and Moore 1994, Savage et al. 1996, 2013). Land-survey records document that seedlings and/or saplings were present over only 4–13% of two large landscapes in Arizona and one in Colorado (Baker and Williams 2015). However, forest age structure in two cases showed more continuous regeneration not limited to wet or fire-free periods, with broad peaks evident in one case (Mast et al. 1999). Broad episodes bring into question whether regeneration was rare and confined to unusual climatic episodes (Savage and Mast 2005).

Contrasting regeneration findings in the Southwest are also documented in early forest-reserve reports. Leiberg et al. (1904:28) said of the 329,000-ha San Francisco Peaks forest-reserve area on the western part of the Mogollon Plateau in northern Arizona:

> Reproduction of the yellow pine is, generally, extremely deficient as regards seedling and young sapling growth, except in an area lying east of Stoneman Lake and south of Morman Lake. Apparently there has been an almost complete cessation of reproduction over very large areas during the past twenty or twenty-five years, and there is no evidence that previous to that time it was at any period very exuberant.

What happened to favor regeneration near the lakes is unexplained, but a nearby landscape also had abundant regeneration. Stabler (1906:7) said of the eastern extension of the Mogollon Plateau onto Black Mesa and into the White Mountains:

> The reproduction of the yellow pine portion of the commercial forest type is wonderfully good. This in spite of the fact that the pine bunchgrass is as a rule very thick and vigorous and but little of it kept down by grazing. The fact that the grass is not grazed makes the numerous ground fires more serious than they otherwise would have been, but in spite of these fires. . .the reproduction is good and occurs in all ages.

A compelling explanation is lacking for contrasts in historical regeneration over large land areas.

Historically slow and incomplete natural recovery after LIDs in dry forests

Severely disturbed dry forests historically regenerated variably, but often slowly, and could remain unforested or sparsely forested for ≥100 yr (Table 4). Post-fire regeneration was at times very dense over extensive area in the Southwest (Fig. 4a, b). High-severity fires could be followed by extended tree regeneration lasting 20–60 yr, which could also be lagged by 15–20 yr and even have >50-yr lags with little or no tree regeneration (Table 4). Openings (grasslands, shrublands) created or maintained by high-severity fires could persist for 130–150 yr or more (Tables 4, 5) and be quite large. For example, in the Sierra, Show (1924:83) reported:

> Perhaps the most striking characteristic of the timber region of northern California. . .is the very large area occupied by brushfields. The brushfields, for the most part, are the results of fires which have destroyed the timber and allowed the brush to occupy the ground; in round numbers 1,500,000 acres [607,000 ha] are now in this condition. Of this million and a half acres probably 75% is restocking naturally, scattered individuals and groups of trees having survived the fires of the past, and can be depended on to take care of themselves. . ..

Forests often, but not always, recovered after intense fires, particularly if surviving seed trees were nearby; if so, trees regenerated and tree density and basal area increased, and forests often became denser (Fig. 4c). Probabilistic studies found dense middle-aged forests and created or maintained grasslands and shrublands in all dry-forest landscapes (Table 2). However, many pathways of forest recovery likely occurred (Kashian et al. 2007). In dry forests, open forest patches and some dense forest patches may have simply persisted and grown older, and some dense forest patches may have been thinned by competition or disturbances (Oliver 1995, Zhang et al. 2013) until a mature forest re-established (Moir and Dieterich 1988).

Including the lag before tree regeneration, recovery of a mature forest after high-severity fire historically required >100 yr (Table 6). Old growth could be reached within 150–200 yr (Mehl 1992, Hamilton 1993), but 150–300 yr for

Table 4. Historical lags in tree regeneration and the length of successful episodes of natural tree regeneration after high-severity fires in dry forests, based on tree-ring reconstructions and early observations.

Topic/Author(s)	Location	Observation
Huckaby et al. (2001)	Front Range, Colorado	Tree regeneration delayed on average by 18 yr after high-severity fires, ranging from 0 to 33 yr for 16 fires from A.D. 1531–1880
Boerker (1915:15)	Western Sierra, California	"Unlike the chaparral regions of southern California, this brush is only a temporary type and is, in most cases, the result of fire having destroyed the forest cover. . .In most cases, in from 5 to 10 years after the fire has consumed the timber, the brush takes possession of the land. . .after the brush has established itself, if seed trees are nearby, seedlings will get started and fight their way through the brush. It takes from 15 to 30 years for a seedling to get large enough to overtop the brush. . ."
Wu (1999)	San Juan Mts., Colorado	Tree regeneration concentrated within 20 yr after higher-severity fires
Baker (2017*b*)	Uncompahgre, Colorado	Tree regeneration sparse or lacking in a stand 24 yr after high-severity fire
Ehle and Baker (2003)	Front Range, Colorado	Tree regeneration concentrated within 20–25 yr after high-severity fires
Nagel and Taylor (2005:448)	Lake Tahoe Basin, California	"Tree regeneration into the chaparral stands was highest during the first two or three decades after the fire [6 fires in 1861–1882], but tree establishment continued for at least five decades after the last fire in all of the stands"
Lauvaux et al. (2016:82)	Southern Cascades, California	"Tree populations were multi-aged. Initial establishment [after 6 fires in 1864–1918] was slow and typically peaked five or more decades after the fire"
Duthie (1914:14)	Front Range, Colorado	Tree regeneration sparse or lacking for first 50 yr: "A careful reconnaissance of the region made in 1911 showed that there are over 10,000 acres of land from which all forest cover was consumed by these fires half a century ago, and upon which there has been practically no natural restocking"
Sherriff (2004)	Front Range, Colorado	Tree regeneration concentrated within 19–60 yr after high-severity fires
Huckaby et al. (2001:25)	Front Range, Colorado	". . .openings were created by a fire in 1851, and remained unforested 149 years later. . .the northern part of the area may have burned again in 1880, slowing tree regeneration"
Kaufmann et al. (2003:239)	Front Range, Colorado	". . .historical mixed severity fires and delays of regeneration into openings created by fire contributed to a very open, spatially complex and temporally dynamic landscape structure"
Pearson (1914:249)	Arizona and New Mexico	"A characteristic feature of the timbered mountains in Arizona and New Mexico at altitudes above 8000 feet is the occurrence of extensive burns. The original forests below 9500 feet were composed mainly of western yellow pine (*Pinus ponderosa*), Douglas fir. . ., limber pine. . ., Mexican white pine. . ., and white fir. . .The greater portions of the burns have grown up to quaking aspen. . ., but extensive areas are practically bare. Scattering trees of the original forest usually remain, and where this condition exists or where the burn is comparatively small conifers are generally restocking the land. . ."

conifers to regain dominance over aspen in mixed-conifer forests (Table 6). Historical high-severity fire rotations of 2–8 centuries (Baker 2015) would have often allowed full recovery to old growth before the next high-severity fire.

Fluctuating historical dry-forest landscapes of recovery had heterogeneous structure

Overall, historical dry-forest landscapes in the western United States fluctuated from infrequent large natural disturbances that included substantial severe fires, beetle outbreaks, and droughts that killed many trees, leaving a diversity of legacies, followed by 100–300 yr of natural recovery. Where tree density and basal area were reduced, vulnerability to droughts and beetle outbreaks often declined; where old trees persisted, vulnerability to severe fires was reduced. Slow, variable post-disturbance tree regeneration and growth made natural recovery after LIDs a dominant

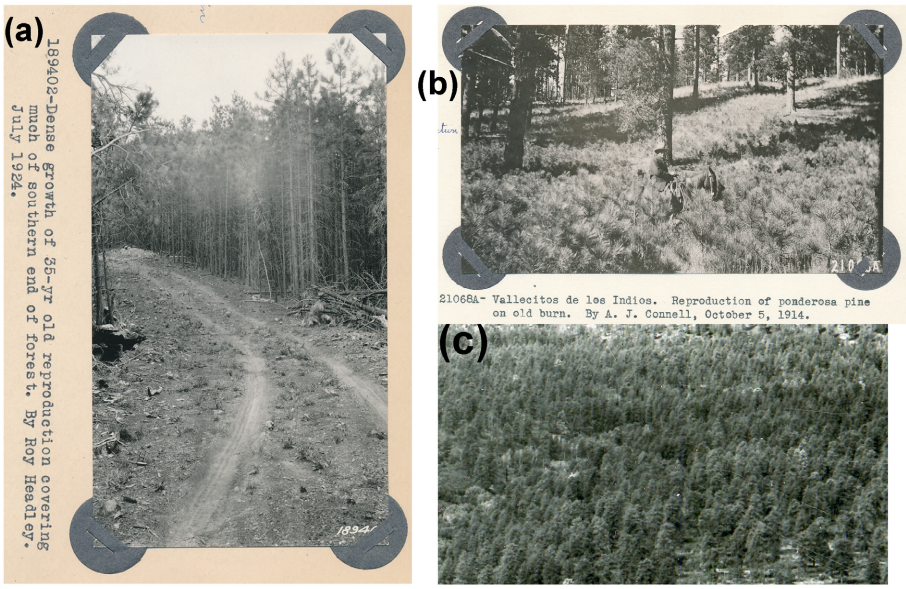

Fig. 4. Dense historical ponderosa pine regeneration after fire in the Southwest: (a) after likely large high-severity fire in the late 1800s in ponderosa pine forests, southern Coconino National Forest, Mogollon Plateau, Arizona, photograph taken in 1924 by Roy Headley, Historical Photo Collection, Region 3, U.S. Forest Service, Albuquerque, New Mexico; (b) after fire in the Jemez Mountains, New Mexico, photograph taken in 1914 by A. J. Connell, Historical Photo Collection, Region 3, U.S. Forest Service, Albuquerque, New Mexico; and (c) an example of a dense middle-aged historical forest, reproduced from a zoom of the right center of Fig. 2, an 1897 photograph by Whitman Cross.

ongoing process in most historical dry-forest landscapes. Episodes of LIDs across large areas meant that large land areas may have been synchronously recovering from natural disturbances. Infrequent disturbances and slow, variable natural recovery explain why historical dry-forest landscapes were spatially heterogeneous with a mix of old forests, middle-aged forests, recently disturbed forests, large and small openings with incipient or nearly completed regeneration, and more persistent openings, as documented by probabilistic landscape-scale studies (Table 2). This stand and landscape diversity conferred resistance, resilience, bet-hedging, and adaptation to diverse, unpredictable future disturbances, but substantial fluctuation still occurred.

Emerging Patterns of Transition to Committed Warming

Tree-mortality agents in dry forests over the last few decades

Increased tree mortality and regeneration decline or failure are expected during the transition. Increasing tree mortality is evident around the world (Allen et al. 2010). In dry forests, mortality is occurring from fires, beetle outbreaks, and directly from drought and temperature stress (Anderegg et al. 2013). Background rates of tree mortality (non-catastrophic, including all agents) increased significantly (3.3% per year, a doubling time of 22 yr), likely from warming, in the 15 old-forest plots most likely in dry forests, since they had short mean fire intervals (Van Mantgem et al. 2009: Table 1). In all plots censused from 1955 to 2007 across the western United States, 19% of trees died over the roughly 50-yr period (Van Mantgem et al. 2009), which is a 263-yr rotation (50/0.19). That would not lead to lasting loss of old forests, as 263 yr is ample time to regrow old trees, but if mortality doubled further, then it could become very limiting, and drought and heat stress could become the main cause of tree mortality (Allen et al. 2010).

Even with more severe (non-background) mortality from beetle outbreaks, droughts, and fires, there are survivors that play key stand-level roles

Table 5. Longer-term studies and observations of post-fire creation or maintenance of grasslands and shrublands after historical high-severity fires in dry-forest landscapes of the western United States.

Author(s)	Location	Years after fire	Observation
Guiterman (2016)	Jemez Mts., New Mexico	>115	Most of the area of 5 large patches (totaling 1142 ha) of mixed montane shrubland, dominated by Gambel oak (*Quercus gambelii*) that originated primarily in 1894–1900 remained largely unforested. Originating fires were likely mixed- to high-severity
Baker (2014)	Sierra Nevada, California	109–118	About 22% of montane chaparral, likely burned in high-severity fires in the late 1800s, did not become forested, and instead remained as montane chaparral, over periods of 109–118 yr
Nagel and Taylor (2005)	Northern Sierra, California	~120–140	About 38% of montane chaparral patches that originated after high-severity fires in 1861–1882 had not become forested by the 2000s
Lauvaux et al. (2016)	Southern Cascade Mts., California	~100–150	About 35% of montane chaparral patches that originated after high-severity fires in 1864–1918 had not become forested by the 2010s
Huckaby et al. (2001), Baker (2009:249)	Front Range, Colorado	~120–150	By about A.D. 2000 [120–50 yr after fires], some forests burned in high-severity fires in 1851 or 1880 had recovered to dense, middle-aged forests, but some openings were still unforested grasslands that were slowly reforesting
Baker (2017*b*)	Uncompahgre Plateau, Colorado	~130–150	About 40% of a large ponderosa pine and mixed-conifer landscape with evidence of high-severity fire in the late 1800s was nonforested (e.g., shrubs, small trees, grasslands); about half the nonforested area that was a mixture of grasslands, shrublands, recent burns, and areas with small trees was not forested by 2010, likely indicating at least century-scale stability after high-severity fires

in forest resilience (Table 3). In beetle outbreaks, most smaller trees survive as do some percentage of larger trees. A 1965–1978 MPB outbreak in the Colorado Front Range killed 25% of ponderosa pines of all sizes, especially 20–36 cm dbh, and reduced basal area by 38% (McCambridge et al. 1982). In British Columbia, a more severe 2005–2008 MPB outbreak, also with western pine beetle (*Dendroctonus brevicomis*), killed ~80% of trees, including 23–42% <15 cm dbh, 81% 15–30 cm, and 94% >30 cm over >175,000 ha, with little variation across a wide range of tree densities (Klenner and Arsenault 2009). In the Black Hills of South Dakota and Wyoming, an MPB outbreak over ~157,000 ha in 2004–2014 mostly killed ponderosas 23–43 cm dbh (Graham et al. 2016). Stands with <21 m^2/ha of basal area were little affected, but mortality increased up to 28–34 m^2/ha, where 74% of trees were killed, but 60% for >34 m^2/ha (Graham et al. 2016). Many trees survived, with means of 141 trees/ha of tree density and 11.7 m^2/ha of basal area. After beetle outbreaks, there were surviving trees of all sizes, especially small trees, as well as patches of surviving trees (Six et al. 2014). Dry forests were substantially renewed, and yet able to persist.

Mortality from droughts in dry forests has not been isolated, as beetles often ultimately kill many drought-affected trees. However, similar mortality patterns were evident with trees of all sizes killed and the highest percent mortality in larger trees (Ganey and Vojta 2011). Droughts put tall, old conifers especially at risk of replacement by shorter trees and shrubs (Bennett et al. 2015, McDowell and Allen 2015, McDowell et al. 2015), because taller trees are more physically vulnerable to failure to conduct water. A surprising 70% of a global sample of trees, in both dry and wet environments, operates with low physiological safety margins for escaping mortality from drought (Choat et al. 2012). Mortality consistent with these drought vulnerabilities is already occurring (Bennett et al. 2015). In contrast, larger trees generally better survive fires, because of thicker bark, elevated branches, and other adaptations (Baker 2009).

Table 6. Longer-term studies and observations of post-fire recovery to forest after historical high-severity fires in dry-forest landscapes of the western United States.

Author(s)	Location	Years after fire	Observations of post-fire succession in dry forests
MacKenzie et al. (2004)	Western Montana	60–100	Tree density/basal area approached pre-fire level within about 60–100 yr, basal- area increase slowed ~100 yr after high-severity fire
Baker (2014)	Sierra Nevada, California	109–118	About 78% of chaparral, likely burned in high-severity fires in the late 1800s, became forested over periods of 109–118 yr
Smith and Smith (2005), Baker (2017*b*)	Uncompahgre Plateau, Colorado	100–137	Conifers can begin to overtop aspen within about 100 yr, with mixed conifer–aspen stands at about 137 yr after high-severity fires
Nagel and Taylor (2005)	Northern Sierra, California	~120–140	About 62% of montane chaparral patches that originated after high-severity fires in 1861–1882 had become forested by the 2000s
Lauvaux et al. (2016)	Southern Cascade Mts., California	~100–150	About 65% of montane chaparral patches that originated after high-severity fires in 1864–1918 had become forested by the 2010s
Huckaby et al. (2001), Baker (2009:249)	Front Range, Colorado	~120–150	By about A.D. 2000 [120–150 yr after fires], some forests burned in high-severity fires in 1851 or 1880 had recovered to dense, middle-aged forests, but some openings were still reforesting
Baker (2017*b*)	Uncompahgre Plateau, Colorado	~130–150	About 40% of a large ponderosa pine and mixed-conifer landscape was nonforested (e.g., shrubs, small trees, grasslands) in the late 1800s; about half that area had become forested by 2010, likely indicating natural recovery after high-severity fires
Leiberg (1902:74)	Western Sierra, California	150	"The yellow pine on these tracts is mostly old growth; that is, the greater percentage of suitable size for mill timber is over 150 years of age"
Wu (1999:134)	San Juan Mts., Colorado	~150–200	"Even-aged stands still maintain their structure, such as a prominent post-fire cohort of aspen or ponderosa pine, 150 years after their last lethal fires, which occurred in the period from 1850 to 1880. . .therefore, this study estimates that all-age structure requires at least two hundred years to develop"
Kercher and Axelrod (1984)	Western Sierra, California	~250	Simulation suggested that about 250 yr would be required for Sierran mixed-conifer forests to recover and stabilize after severe disturbance
Baker (1925:89)	Central Rocky Mountains	≥250	"On the assumption that conifers found in the aspen zone will bear seed at 80 years, most areas ought to be well seeded in with reproduction in three tree generations or about 250 years in the Douglas fir-white fir zone. . .certain areas in the lower zones may require more than 250 years. . ."
Duthie (1914:14)	Front Range, Colorado	200–300	"It is estimated that two or three centuries would elapse before these burns would again be fully reforested if natural regeneration were depended upon to produce a satisfactory forest cover" (describing recovery after high-severity fires that occurred a half century earlier)
Zier and Baker (2006:261)	San Juan Mts., Colorado	Long periods	Over about a century, 40% of mixed-conifer forests visible in 25 scenes in early photographs showed increased conifers, while in 60%, there was no change in proportions of aspen and conifers, suggesting that ". . .long periods of time may be needed for conversion from aspen to conifers, if it occurs at all"

Given these vulnerabilities and documented mortality effects, what were recent sources of mortality; were severe fires, beetle outbreaks, or droughts the largest cause of non-background tree mortality over the last few decades? Details of analysis are in Appendix S1. Most important from this analysis is that insects-disease, on average, overall led to 2.1 times as much mortality

area as did moderate- to high-severity fires, 1.7 times in ponderosa, and 2.6 times in dry mixed conifer (Table 7). Estimated rotations were 565 yr for moderate- to high-severity fires and 221 yr for insects-disease in dry mixed-conifer forests (Table 7). Rotations were 408 yr for moderate- to high-severity fires and 247 yr for insects-disease in ponderosa pine. These are similar to 2003–2012 mortality rotations of 500 yr for fire and 286 yr for beetles across all forests of the western United States from the inverse of annual mortality of 0.20% for fire and 0.35% for beetles, and the ratio of insects-disease to moderate- to high-severity fire of 1.75 is also similar (Berner et al. 2017). Under a hypothetical California-type drought scenario moving across dry forests (Appendix S2), an affected area of 5.5 million ha every six years would have a mortality area of 1.3 million ha (24%); if half from direct drought mortality, this would be a drought mortality rotation of 191 yr (6 yr/(0.65 million ha/20.7 million ha)). If so, droughts and insects-disease would likely account for about 3–4 times as much mortality area as severe fires.

Recent sizes and rates of beetle outbreaks, droughts, and moderate- to high-severity fire in dry forests are probably not yet outside the historical range of variability (Table 8), although evidence about historical variability is limited and some individual events have been exceptional locally (e.g., 2012–2016 California drought). Large beetle outbreaks have individually affected up to about 175,000 ha in dry forests, approaching the same scale as the 200,000- to 300,000-ha outbreak in the Black Hills in 1895–1909. The estimated recent beetle mortality rotation of 241 yr would not preclude full recovery of old-growth forests during or after the transition. The historical beetle-outbreak mortality rotation is too poorly known to be certain that this recent rate is or is not similar. Available evidence is insufficient to be able to assess historical vs. recent drought impacts on dry forests, but drought rates themselves are in general not outside historical variability in the western United States (Wuebbles et al. 2017; Appendix S3). However, if the frequency distribution of droughts does not change, $\sim$1°C elevated temperature alone will cause an increase in drought events sufficient to kill ponderosa pine seedlings by about 1.8 events by A.D. 2100 under RCP 2.6 (Adams et al. 2017). Larger recent moderate- to high-severity fires have individually affected about 30,000–60,000 ha, except for the 128,000-ha Rodeo–Chediski fire in Arizona (Table 8). Historical fire-size evidence is limited, in general, but the area burned at moderate to high severity on the Uncompahgre Plateau, Colorado, likely in 1879, was at the scale of about

Table 7. Affected area and estimated mortality area in dry forests across the western United States from 1999 to 2012 (n = 14 yr) from moderate- to high-severity fire and insects-disease.

Area and measure	Ponderosa pine	Dry mixed conifer	Total
Affected area			
Fire area (ha)	518,580	415,971	934,551
Insects-disease area (ha)	2,319,651	2,874,101	5,193,752
Fire rotation (yr)	265	367	311
Insect rotation (yr)	59	53	56
Ratio: insects-disease/fire area	4.5	6.9	5.6
Mortality area from multiplying affected fire area by 0.65 and affected insects-disease area by 0.24			
Fire area (ha)	337,077	270,381	607,458
Insects-disease area (ha)	556,716	689,784	1,246,500
Fire rotation (yr)	408	565	478
Insect rotation (yr)	247	221	233
Ratio: insects-disease/fire area	1.7	2.6	2.1
Fire area in 40 yr (% of total), if no change	9.8	7.1	8.4
Insects-disease area in 40 yr (% of total), if no change	16.2	18.1	17.2
Fire area in 40 yr (% of total), if projected	15.4	10.5	12.8
Total analysis area (ha)	9,825,679	10,910,705	20,736,384

Notes: Data on affected areas and total analysis areas are from Baker and Williams (2015). See Appendix S1 for an explanation of estimation of mortality area.

Table 8. Comparative sizes, durations, and rotations of recent large infrequent disturbances in dry forests and the expected mortality area during the 40-yr transition.

Attribute	Insects-diseases	Droughts	Moderate- to high-severity fires
Example events among the largest (ha) events since 1984 in dry forests†	~ 157,000 ha SD/WY‡ >175,000 ha BC§	~5, 500,000 ha CA¶ ~700,000 ha U.S.#	30,146-ha 2012 Whitewater Baldy, NM 34,432-ha 2002 Hayman, CO 36,611-ha 2012 Ash Creek, MT 50,287-ha 2013 Rim, CA 56,174-ha 2011 Wallow, AZ 127,667-ha 2002 Rodeo–Chediski, AZ‖
Duration of these example events (yr)	4–14	5	1
Estimated recent mortality rotation (yr) across total dry-forest area††	233	191	478
Estimated historical mortality rotation (yr) across total dry-forest area for reference	>333‡‡	Unknown	362–491§§
Expected mortality area (% of total dry-forest area) in transition if no change in rotation¶¶	17.2	20.9	8.4
Projected mortality area (% of total area) in transition if climate change shortens rotation¶¶	Not available	Not available	12.8

Note: Province and state abbreviations: AZ, Arizona; BC, British Columbia; CA, California; CO, Colorado; NM, New Mexico; SD, South Dakota; WY, Wyoming.

† These are affected areas, in ha, not mortality areas.

‡ Graham et al. (2016).

§ Klenner and Arsenault (2009).

¶ From Tree Mortality Task Force (2017) and Potter (2017).

From Worrall et al. (2013) for roughly the area of aspen decline affecting dry mixed-conifer forests.

‖ From MTBS data (www.mtbs.gov); the area is the sum of the moderate- and high-severity classes in the MTBS pdf map of each fire.

†† From the text, in the case of drought, and from Table 7, in the case of fire and insects-diseases; rotation is the time, in years, it is expected to take for these disturbances to affect land area equal to whole landscapes.

‡‡ The original rotation estimate of >80 yr for affected area is given in the text. The rotation for mortality area can be estimated by dividing by 0.24, which is the estimate from Hicke et al. (2016) used in Table 7.

§§ The original rotation estimate from Odion et al. (2014) was 235–319 yr for affected area, and the rotation for mortality area can be estimated by dividing by 0.65, as explained in the text and used in Table 7. After division, the original 235–319 yr range becomes 362–491 yr.

¶¶ From Table 7.

75,000–90,000 ha (Baker 2017*b*), thus similar to larger recent fires. The geometric mean higher-severity patch size was 47% lower in the recent than the historical period across 624,156 ha of dry forests in the Colorado Front Range (Williams and Baker 2012*a*). Moderate- to high-severity fire in dry forests was not operating from 1984 to 2012 at rates that exceeded historical rates, and the fraction of fires that burned at high severity had not increased (Baker 2015). The recent fire-mortality rotation for moderate- to high-severity fires of 478 yr is within, but toward the long end of the estimated historical rotation of 362–491 yr (Table 8).

Assuming no increase, in ponderosa pine, a resulting fire-mortality rotation of 408 yr would lead to expected mortality area of 9.8% over the 40-yr transition (Table 7). In dry mixed conifer, a fire-mortality rotation of 565 yr would lead to mortality area of 7.1%. In ponderosa pine, an insects-disease mortality rotation of 247 yr would lead to mortality area of 16.2% over the 40-yr transition (Table 7). Similarly, in dry mixed conifer, an insects-disease mortality rotation of 221 yr would lead to mortality area of 18.1% (Table 7). Under a California-type drought scenario, a 191-yr mortality rotation would lead to a mortality area of 20.9%. Overall, if no change in rates over the 40-yr transition, actual mortality area from fire and insects-disease would total ~26% of dry-forest area, 1/3 from moderate- to high-severity fires and 2/3 from insects-disease, a mortality rotation of 154 yr, which could still leave substantial area of old forests by the end of the transition. However, if a California-drought scenario ensued, an added 21% in 40 yr could

lead to a total mortality area of ~47%, a rotation of ~85 yr, which could leave much less old forest, since it is particularly vulnerable to droughts and beetles.

Projecting possible increases in these disturbances during the 40-yr transition period is only roughly possible, and only for fire (Table 7; Appendix S3). There are no specific projections for only 1.5–2.0°C of warming on drought, fire, and insects. The U.S. Global Change Research Program reported low-to-medium confidence in a current anthropogenic climate-change effect on fire in the western United States (Wuebbles et al. 2017). Nonetheless, to estimate an upper bound on possible increases in moderate- to high-severity fire in dry forests, I used the midpoint of the low range of projected increases in area burned by A.D. 2046–2065 across 23 analysis areas under moderate emissions (RCP 4.5), which is 1.57 in ponderosa pine and 1.48 in dry mixed conifer (Baker 2015). These were the most recent area-burned projections, which are needed to estimate future mortality area. Using these, the percentage of mortality area from fire would increase from 9.8% to 15.4% in ponderosa pine and from 7.1% to 10.5% in dry mixed-conifer forests (Table 7). If combined with the hypothetical California-drought scenario, the total could reach about 51%.

Recent and projected tree regeneration in dry forests

Is there evidence of tree-regeneration decline in dry forests that could make the forest loss from tree mortality more permanent? Current rates and patterns of tree regeneration in all dry forests are relevant, but the only systematic monitoring is by the Forest Inventory and Analysis Program (FIA). Since 1995, FIA data are remeasured at 5- to 10-yr intervals on plots each representing about 2429 ha (Bechtold and Patterson 2005). Forest Inventory and Analysis data were used to analyze recent recruitment of juvenile vs. adult trees relative to climate in the western United States (Bell et al. 2014, Dobrowski et al. 2015). Ponderosa pine and Douglas-fir seedlings were much less likely to be present than were adults (28,177 plots), particularly along the warmer western and southern range margins of ponderosa pine (Bell et al. 2014). Similarly, for most conifers (13 species in 33,665 plots) in dry forests, juveniles occupied moister sites than did adults (Dobrowski et al. 2015). A caveat is that historical variability in tree regeneration was naturally high, as reviewed earlier, leaving in question whether these short periods of observation represent lasting trends.

These studies provide context, but tree regeneration after severe disturbances in dry forests is most relevant to the transition, since disturbances leave forests most dependent on regeneration. A focus has been on regeneration after high-severity fires; 24 studies, all I found, showed tree regeneration after these fires was almost universally heterogeneous (Table 9). Within the first 30 yr, substantial area lacked any conifer regeneration, while other area had adequate or dense regeneration (Table 9). Where studied, regeneration density was nearly always lowest in high-severity areas, relative to low- or moderate-severity areas. Ponderosa regeneration was commonly highest adjacent to the unburned margin of the fire and declined into the fire to low levels within 100–200 m, often attributed to seed-dispersal limitations, the hotter environment of open areas, or competition with shrubs or deciduous trees. Studies that analyzed topographic effects found regeneration especially deficient at low elevations and on south-facing slopes. Regeneration after high-severity fires in Colorado was concentrated in only three years with unusually high growing season precipitation over a 24-yr period, based on precisely dated seedlings (Rother and Veblen 2017). Less concentrated years of regeneration were evident in young adult trees, less precisely datable, after older New Mexico fires (Savage et al. 2013). Although regeneration was still sparse and favored near unburned margins at 28 and 45 yr post-fire, it was extrapolated to extend within ~50 yr across the 28-yr-old high-severity burn (Haire and McGarigal 2010). Substantial declines in post-fire tree regeneration occurred from warmer and drier conditions since 2000, suggesting possible declines with warming (Stevens-Rumann et al. 2018).

Tree regeneration after recent high-severity fires was often considered unnatural or deficient, but historical evidence now does not support this. Dense regeneration was earlier considered hyperdense and outside the natural range of variability (Savage and Mast 2005). Since then, we have found (1) dense regeneration occurred

Table 9. Studies of tree regeneration up to 64 yr after high-severity fires in dry forests of the western United States arranged by the number of years since fire.

Author(s)	Location	Years after fire	Post-fire seedling/sapling density (trees/ha)
Bonnet et al. (2005)	South Dakota Black Hills	2	>700 ha^{-1} in burn (19 transects in 1 fire) within 12 m of unburned edge, declining inward, still some at 120 m, 180 m; positive effect, scorched needles on burned mineral soil; negative, high understory cover
Keyser et al. (2008)	South Dakota Black Hills	2–5	By year 5 (36 sites in 1 fire), >1000 ha^{-1} in unburned, low and moderate severity; little in high severity
Meigs et al. (2009)	Oregon Eastern Cascades	4–5	Range 0–62,134 conifers/ha (64 plots in 4 fires); no difference among unburned, low, and moderate severity. In ponderosa forests, no ponderosa regeneration in high-severity fires and in mixed conifer limited conifer regeneration in high-severity fires
Ouzts et al. (2015)	Northern Arizona–New Mexico	7–10	Range 0–1433 conifers/ha (46 plots in 8 fires); 2 fires had 0 conifers/ha 7–10 yr after fire, 5 fires had <50 conifers/ha, 1 fire had 1500 conifers/ha; litter cover positively associated with seedlings
Crotteau et al. (2013)	California Southern Cascades	9–10	Mean 2235 conifers/ha in unburned (60 units in 1 fire), 2252 conifers/ha in low-severity, 7868 conifers/ha in moderate-severity, and 733 conifers/ha in high-severity fire; *Abies concolor* dominated regeneration over pines in more severe fire areas
Dodson and Root (2013)	Oregon Eastern Cascades	10	Mean 362 conifers/ha (18 plots in 1 fire); Range 0–1807 with 0 in 5 of the 7 plots <1000 m elevation
Collins and Roller (2013:1807)	Northern California Sierra	2–11	Omitting plots with post-fire management (leaving 21 patches in 5 fires), "there was no pine regeneration in over 90% of sampled patches". No significant effect from distance to unburned forest. Negative effect from shrubs, low seed production or soil moisture
Welch et al. (2016: Fig. 5)	California Sierra, Klamath, Southern Cascades	5–11	Mean about 500 trees/ha in yellow pine (246 plots in 12 fires), about 2000 trees/ha in dry mixed conifer (489 plots in 10 fires), interpolated from a bar graph. Overall across all vegetation types, not just yellow pine and dry mixed conifer, 54% of plots had 0–1 conifers, in interiors of severe burns, in dry areas, where more shrubs
Hanson (2018)	California Sierra Nevada/San Bernardino Mts.	1–12	Mean 3803 conifers/ha at ≤50 m into fire (20 plots in 7 fires), 1850 ha^{-1} at 51–150 m into fire (15 plots in 7 fires), 798 ha^{-1} at 151–300 m into fire (22 plots in 7 fires), and 336 ha^{-1} at >300 m into fire (25 plots in 7 fires). More within 50 m, but no significant difference among other distances. Percent shrub cover not correlated with density of conifer regeneration
Kemp et al. (2016)	Idaho–Montana Northern Rocky Mountains	5–13	Mean 7047–8153 conifers/ha (182 sites in 21 fires); Range 0–127,500 conifers/ha, but 5% of 182 sites had 0 conifers within 500 m; seedling presence probable if within 95 m of live seed source, especially if high basal area; fire severity little effect as most burn area was within 95 m of live trees
Owen et al. (2017)	Northern Arizona	12–13	Mean 84.1 conifers/ha in edge plots (6 plots in 2 fires), 41.4 conifers/ha in interior plots having no surviving trees within 200 m (6 plots in 2 fires); Range 13.0–153.8 conifers/ha in edge plots, 12.0–124.0 conifers/ha in interior plots. Regeneration significantly lower in interiors. Some long-distance dispersal (>300 m) found
Rother and Veblen (2016)	Colorado Front Range	8–15	Mean 37–1424 conifers/ha (302 plots in 6 fires), nearly all lower than pre-fire density, and 59% of plots had 0 conifers in 100 m^2 plot, with 83% of plots having <370 conifers/ha. Few seedlings in hot, dry lower elevations or on south-facing slopes, more seedlings within 50 m of live seed source, also in more southerly locations with summer rainfall
Ziegler et al. (2017)	South Dakota, Northern Colorado	11–15	Mean 43.0 trees/ha (18 plots in 3 fires)
Foxx (1996)	Northern New Mexico	0–16	Two sites in 1 fire had no seedlings in year 1, 0 and 210 trees/ha in year 8, and 218 and 318 trees/ha in year 16
Haffey (2014)	Arizona–New Mexico	6–16?	Only 24% of plots (179 plots in 9 fires) had ponderosa pine regeneration; within 150 m of a seed source, 38% of plots had tree regeneration; no regeneration beyond 250 m from a seed source. Nearly half of ponderosa pine seedlings were near a nurse structure, most often a log or large branch
Roccaforte et al. (2012)	Arizona	1–18	Range 0–11,234 conifers/ha (399 plots at 14 sites in 11 fires); 8 sites had 0 conifers/ha 1–12 yr after fire, 3 sites had 37–74 conifers/ha, 2 sites had 297–336 conifers/ha, and 1 site had 11,234 conifers/ha. Deciduous regeneration was dominant at all but 2 sites

(Table 9. *Continued*)

Author(s)	Location	Years after fire	Post-fire seedling/sapling density (trees/ha)
Chambers et al. (2016)	Colorado Front Range	11–18	Mean 225 trees/ha (305 plots in 5 fires) across unburned, low, and moderate severity. Mean tree density lowest in high severity (118 trees/ha) and in only 25% of plots, whereas 60% of low- to moderate-severity plots had regeneration. Regeneration greatest at high elevations and adjacent to unburned, declining to 10 conifers/ha at 200 m
Shatford et al. (2007)	Southern Oregon–Northern California	9–19	Mean 1694 trees/ha (24 plots in 8 fires); Range 83–8188 trees/ha. Plots showed a wide range from immediate and rapid regeneration to slow and constant to chronically limited. No significant effect of distance from seed source on seedling density; up to 84–1100 trees/ha >300 m from a seed source. Positive effect of shrub and hardwood cover
Guiterman et al. (2015)	Northern New Mexico	20	Mean 11 conifers/ha (10 plots in 1 fire); conifers present in 4 of 10 plots; maximum distance from a ponderosa seedling to unburned edge was 77 m
Rother and Veblen (2017)	Colorado Front Range	8–23	Ponderosa pine and Douglas-fir regeneration was concentrated in years with especially high growing season precipitation (413 dated seedlings at 10 sites in 5 fires); for all sites combined, three years (1995, 1998, and 2009) in twenty-four (1988–2011) accounted for most of the post-fire regeneration. Regeneration lags after the 5 fires were 0–4 yr
Passovoy and Fulé (2006)	Northern Arizona	3–27	Range 0–1052 conifers/ha (210 plots in 7 fires). Four of seven fires in years 4–8 had <50 conifers/ha and one had 26 conifers/ha at year 27, the other two fires had 170 conifers/ha and 1052 conifers/ha in years 4 and 9, respectively
Haire and McGarigal (2010)	Northern Arizona–New Mexico	28, 45	Little within years 1–8 (68 plots in 1 fire) or 1–15 (79 plots in 1 fire); ~8000, 2000 trees/ha near low-severity edge; most within 200 m of low-severity edge, but some to 304 m, 410 m; could reach all of fire area within ~50 yr
Savage and Mast (2005)	Northern Arizona–New Mexico	25–54	Regeneration began within 1–2 yr at 7 sites, within 6–10 yr at 3 sites (300 plots in 10 fires); 5 sites <200 trees/ha, 5 sites >400 trees/ha
Savage et al. (2013)	New Mexico	47–64	Regeneration did not begin for 3–20 yr (5 fires); Range (from 150 plots in 5 fires) per fire: 96–443 adult conifers/ha (≥1.4 m height and >6 cm dbh), 94–1629 seedlings and sapling conifers/ha for a total of 201–2112 trees/ha

Note: ? indicates that the Years after fire entry is uncertain.

historically over 20–30% of dry-forest areas in Oregon, California, and part of northern Arizona (Baker and Williams 2015); (2) dense younger established forests were historically common in nearly all dry-forest landscapes, suggesting past regeneration had been successful and dense (Williams and Baker 2012*b*); and (3) very dense post-fire trees are shown here to have covered large area on the southern Mogollon Plateau in northern Arizona (Fig. 4a) and occurred in the understory of burned forest in the Jemez Mountains, New Mexico (Fig. 4b). Dense and even very dense regeneration, in general and after high-severity fires, was within the historical range of variability in dry forests.

Some also considered poor regeneration after high-severity fires to indicate potentially unnatural type conversion of forests to shrublands or grasslands (Savage and Mast 2005, Haffey 2014), possible indicators of emerging tipping points (Reyer et al. 2015). However, of 24 studies, 21 (88%) covered only up to 27 yr after high-severity fires (Table 9). In general, 27 yr is insufficient, as historical tree regeneration after high-severity fires in dry forests could extend over periods of up to 60 yr (Table 4). Some large areas could even lack regeneration for ≥50 yr (Table 4) in part because of few climatically favorable periods for tree regeneration (Savage et al. 1996, Rother and Veblen 2017). A way to offset insufficient post-fire records is to extrapolate spatially (Haire and McGarigal 2010), but this has not generally been done (Table 9). Evidence is insufficient to conclude that post-fire tree regeneration is outside historical variation.

Historical tree regeneration after high-severity fires in dry forests failed or was slow at times, creating forest openings (Tables 4, 5), but recent studies often did not show modern failure was outside historical variability (Lauvaux et al. 2016). Opening creation by high-severity fire is likely operating at or below historical levels, since

high-severity fires are at or below historical rates in dry forests (Baker 2015). Some openings have declined (Coop and Givnish 2007); thus, creation of new openings by high-severity fires is likely restorative (Baker 2017*b*, Boisramé et al. 2017). Openings also enhance resistance to fire spread (Boisramé et al. 2017, Owen et al. 2017) and increase the heterogeneity of landscape structure (Kaufmann et al. 2003), enhancing resistance and resilience (Table 3); thus, added openings in the transition are generally beneficial.

In contrast, tree regeneration after beetle outbreaks and droughts is not currently thought to be declining, because advance regeneration continues. In the multi-decadal period that background tree mortality increased in dry forests as temperatures rose, tree recruitment was unchanged (Van Mantgem et al. 2009). In beetle outbreaks, (1) 75% of trees <20 cm dbh survived (McCambridge et al. 1982), (2) 77% of trees <7.5 cm dbh and 58% of trees 7.5–15 cm dbh survived a severe outbreak (Klenner and Arsenault 2009), and (3) >95% of trees survived in stands with <18 m^2/ha of basal area, about 170 trees/ha in trees up to 37 cm dbh (Graham et al. 2016).

Future regeneration of dry-forest trees in general, not just after disturbances, was projected. Dobrowski et al. (2015) modeled the recruitment niche of 10 dry-forest trees relative to minimum temperature, evapotranspiration, and climatic water deficit. They then projected recruitment prevalence across the West through A.D. 2100 under RCP 8.5 (high emissions) and found recruitment declines of only about 10% or less (estimated from graphs) by A.D. 2060, at the end of the transition. Petrie et al. (2017) modeled climatic effects on stages in ponderosa regeneration (Feddema et al. 2013, Savage et al. 2013) and then projected future conditions with a water-balance model under RCP 4.5 and 8.5. Regeneration potential would be increased by +50% ± 106%, at 47 sites across the West by A.D. 2020–2059, from more flowering, seed production, and germination, especially in Arizona, Colorado, and New Mexico. After A.D. 2060, at the end of the transition, tree regeneration would decline, due to lower seedling production and survival, especially in the Pacific Northwest (−67%), but less so in the Intermountain region (−29%).

In summary, background rates of tree mortality are increasing in dry forests, and major recent droughts and beetle outbreaks have killed many trees. Recent droughts and beetle outbreaks together account for perhaps 3–4 times as much tree mortality as do moderate- to high-severity fires. Together, natural disturbances could cause tree mortality over 26–51% of dry forests in the transition. Tree regeneration is not apparently outside historical variability and is projected to only slightly decline or even increase. Some opening creation from tree mortality followed by tree-regeneration failure could actually restore grasslands and other openings. Current dry-forest area is not all at risk, as 1/2 to 3/4 could escape substantial mortality under committed warming, and the remainder could have more resistant and resilient forests that persist more than expected.

Transitioning Dry-Forest Landscapes

Large, infrequent disturbances that will enact tree mortality during the transition are capable of rapidly affecting millions of hectares and are generally beyond control. The spatial extent (25.5 million ha) of dry-forest landscapes and associated human communities and infrastructure provides large inertia for preparations. Our ability to control LIDs by manipulating forest structure is limited, and structurally ideal or restored landscapes may help, but a broader tie-in strategy, with a refocus on bet-hedging to enhance resilience to natural-process management may be more feasible and effective.

Limited ability to directly prevent LIDs or reduce their impacts on dry forests in the transition

Our ability to directly prevent LIDs or reduce their impacts is limited. Graham et al. (2016) reviewed the long history of failed attempts at controlling bark beetles through direct suppression or indirect manipulation of forest structure. At best, evidence suggests thinning, the most common manipulation, might modify the extent and pattern of tree mortality over limited area. Fettig et al. (2014) found thinning treatments to reduce tree mortality from MPB were costly and did not work during outbreaks without added direct control; thinning worked in some cases in ponderosa pine forests but had no significant effect in others. Six et al. (2014) also found thinning could possibly work at times, but failures

occurred during outbreaks, and unthinned stands may actually have more survivors. Droughts are not directly controllable. Some drought treatments aim to protect particular trees by reducing competition (McDowell and Allen 2015), but this will likely ultimately fail under hotter droughts (Bennett et al. 2015). Fuel treatments to reduce fire spread and severity have also not been very effective: "Mechanical fuels treatments on U.S. federal lands over the last 15 yr (2001–2015) totaled almost 7 million ha. . .but the annual area burned has continued to set records" (Schoennagel et al. 2017:4586). Schoennagel et al. (2017) explained that treatments can reduce fire severity and increase low-severity fire in some dry forests, but the probability of having an effect is low, as only about 1% of treatments actually experience wildfire each year. Thinning treatments have been ineffective for LIDs in dry forests, in general, and are best as short-term, small-area holding actions (Six et al. 2014).

Can ideal or restored landscapes discourage LIDs from crossing tipping points?

Evidence that ideal or restored landscapes can discourage tipping points is also limited. To maintain MPBs in an endemic condition, discouraging an outbreak, Graham et al. (2016:157) suggested, based on high tree survival in an outbreak: ". . .heterogeneous landscapes composed of stands with heterogeneous structures and containing densities in the neighborhood of 80 feet^2 [18.3 m^2/ha] of basal area are resistant to MPB infestations. . ." However, they said forests in the late 1800s were dominantly in that condition when the largest known MPB outbreak in ponderosa pine forests occurred, the 200,000- to 300,000-ha 1895–1909 outbreak in the Black Hills. Thus, ideal landscapes might only be resistant to some beetle outbreaks. Lundquist and Reich (2014:472) said: "Existing models show that diverse composition and configuration is the best and possibly only long-term, large-scale approach to bark beetle management. . ." For droughts, ideal stands and landscapes have not emerged, and there is little historical evidence. For wildfires, low-density stands with large, old ponderosa pines and few understory trees and shrubs are most resistant and resilient to subsequent wildfires (Allen et al. 2002). However, probabilistic studies (Table 2) have shown this structure was a significant, but not dominant component of most historical dry-forest landscapes, which had more heterogeneous stands across heterogeneous landscapes (Table 2). Thus, historical and ideal landscapes appear congruent, and achievable through restoration, for droughts and beetle outbreaks, and at least partly for fires.

Idealized and historical stand and landscape structures are unlikely to prevent LIDs from causing substantial tree mortality, some tree-regeneration failures, and some opening creation, as these were natural components of historical processes of disturbance and recovery in dry forests. Large, infrequent disturbances occurred in historical dry-forest landscapes and led to substantial landscape change and large fluctuations. Dry-forest landscapes appear to have been capable of general recovery after LIDs (Table 6), but some nonforest, created by disturbance, persisted for 100–150 yr or more (Table 5). Whether tipping points were crossed or this simply represents slow natural recovery is uncertain, but in either case dry-forest landscapes were dynamic and subject to large fluctuations that created and renewed resistance and resilience features that fostered bet-hedging (Table 3).

Natural fluctuation means that restoration and management in dry forests are less a matter of restoring and managing forest structures (Table 3) and more a matter of restoring and managing natural disturbance and recovery processes. Most structures are inherently ephemeral, persisting for only years or decades, and are quickly recreated by disturbances, and thus do not warrant intentional restoration. Widespread micro-management of fuel loads and forest structures after LIDs, based on fears of hypothetical mass fires (Stephens et al. 2018), is likely a waste of resources, because extensive structure management to reduce severe fires has been ineffective (Schoennagel et al. 2017). However, old trees and their associated stand- and landscape structures could persist for centuries, are not recreated by disturbances, and have been lost to excessive logging. Structure restoration and management make sense for these long-persisting structures not created quickly by disturbances, but process management, and associated facilitative structures (e.g., bet-hedging) now make sense for most landscape restoration and management.

A tie-in strategy using bet-hedging and process management of disturbances in the transition

Given substantial uncertainty and limited ability to control LIDs, a broad tie-in strategy, using actions beneficial for people and nature no matter what occurs, could likely facilitate more forest persistence in the transition. Suggested actions include (1) refocusing intentional ecological restoration on bet-hedging using historically congruent structures that provide resistance and resilience to diverse future disturbances (Baker and Williams 2015), (2) expanding development of fire-safe landscapes for people and infrastructure (Schoennagel et al. 2017), (3) expanding managed fire, and (4) accepting that LIDs will beneficially revise resistance, resilience, and genetic adaptation (Six et al. 2014). Restoring forest structure is costly, and resistance structures may fail, favoring structures that facilitate more process-based restoration (Millar et al. 2007).

Droughts and beetle outbreaks are likely to be 3–4 times as important as fires during the transition, which means that abundant small trees and high tree species diversity are now the more important resistance and resilience structures for transitioning dry forests (Table 3). Most large restoration programs (Reynolds et al. 2013, Addington et al. 2018) are likely to be ineffective, as they are focused on structures resistant to fire, when it is more likely that drought and beetles will determine the structures that persist in the transition. These programs to thin forests to resist damage by moderate- to high-severity fires have unfortunately reduced the small trees and diverse tree species that most provide resilience to droughts and beetle outbreaks. These programs could be quickly modified to instead retain small and diverse trees. In forests already deficient in small and diverse trees, if only one prescribed fire occurs before managed wildfire for resource benefit ensues, that last fire will likely stimulate some tree regeneration to repopulate small trees. If low-severity fires are generally managed to mimic historical spatial and temporal variability, opportunities will likely occur for diverse trees to repopulate (Baker 2017*a*).

The unpredictability of future disturbances suggests hedging bets (Millar et al. 2007, Baker and Williams 2015) in stand-level restoration by maintaining large and small trees and available tree species diversity. After restoration, most stands, even open low-density stands, can have numerical dominance by small trees of all available species, but also sufficient replacement larger trees of all available species. Early land surveys across 1.7 million ha of dry forests showed small trees (typically <40 cm dbh) were, on average, 62% of total trees (Baker and Williams 2015). Given loss of large trees to logging, retaining all large trees, and mid-sized trees that are their future replacements, is sensible. After disturbances, successful tree regeneration is favored by large surviving trees that provide seed within about 100–200 m (Table 9). Larger trees may later be lost to hotter droughts and beetle outbreaks. However, if there were 20–50 larger (>40 cm dbh) trees per ha, and >5% survived, that could provide needed surviving large trees. Bet-hedging in restoration leaves abundant trees of all species and sizes with small trees dominant.

At the landscape scale, diverse historical forest structures could reduce the spread and effects of natural disturbances (Table 3) and bet-hedging at this key scale of LIDs is very important now. For fires, areas of large fire-resistant trees, openings, and naturally moist areas or shaded fuels provide resistance and favor survivors that aid post-fire resilience. For beetle outbreaks and droughts, diverse tree species and smaller trees provide the most important resistance and resilience. Recovering younger to middle-aged forests were common historically, based on studies in Table 2, and naturally conferred resistance and resilience to beetles and droughts. Kautz et al. (2017:534) found that "…more than 60% of global forests are in various stages of recovery from a past disturbance at any given time." Protecting young, naturally recovering forests is thus feasible, congruent with historical forests, and a key landscape part of a process-restoration approach (Baker 2017*b*). Young forests can survive beetle outbreaks and possibly droughts at much higher rates than older forests (Graham et al. 2016). To maximize bet-hedging, mixtures of diverse resistance and resilience structures across landscapes, with much more focus on beetle outbreaks and droughts, in addition to fire, are now more congruent with expected LIDs.

It would benefit both people and nature to rapidly increase protection of infrastructure, homes, and communities from increased wildfires, and this would also enable more managed use of natural disturbances. With ~7 million ha of fuel-reduction treatments, but fires still

burning homes (Schoennagel et al. 2017), we need to prevent the expansion of developments into fire-prone settings and finish full fire protection around all homes, infrastructure, and communities. Effective ways to reduce vulnerability and live with wildfire have been articulated (Cohen 2000, Baker 2009, Calkin et al. 2014, Moritz et al. 2014, Smith et al. 2016, Schoennagel et al. 2017). Tools include fire-safe construction, zoning, building codes, incentives, easements, growth boundaries, insurance policies, and other means (Kennedy 2006, Baker 2009, Schoennagel et al. 2017). Homeowners can use fire-safe construction focused on the home-ignition zone (Cohen 2000). Possibly most effective is for communities and developments to designate growth boundaries that enclose a wide margin of open, fire-resistant land uses that can serve as an effective fire break (e.g., ball fields, wetlands, irrigated agricultural fields), whether they are already in place or require construction. This alone would definitively stop expansion into fire-prone vegetation, protect key concentrations of people and infrastructure from fire, and make it more feasible to manage wildfires for resource benefit on adjoining public lands (Baker 2009).

Among LIDs, using more managed fire for resource benefit would be effective wherever it is safe and feasible, especially in the early part of the transition. Moderate- to high-severity wildfire has the longest recent rotation (Table 8) and is the only LID that can be directed. Prescribed fires are typically not sufficiently intense for effective restoration (Van Wagtendonk and Lutz 2007, Baker 2014), but prescribed burning once across landscapes and near homes and infrastructure is best before initiating managed fire (Baker 2017*a*). Managed wildfires can accomplish more renewal and enhancement of resistance and resilience, and also help prepare communities for future LIDs (Schoennagel et al. 2017). Expanding managed fire is scientifically supported (North et al. 2015, Schoennagel et al. 2017), and solutions to institutional barriers are identified (Stephens et al. 2016). Managed fires early in the transition are especially important to reduce tree density and basal area, which can lower vulnerability to droughts and beetle outbreaks more likely with higher temperatures later in the transition. Early managed fires could also stimulate tree regeneration, when it is favored (Petrie et al. 2017). Recovering small trees and entire stands recovering after fires provide resilience to droughts and beetles and foster asynchrony in tree populations that can slow disturbance spread (Millar et al. 2007, Seidl et al. 2016). If openings or low-density patches are created by early disturbances, those could also reduce later vulnerability. Openings are less likely to ignite (Baker 2009), may slow fire, and could hinder beetle spread.

Acceptance of the benefits of LIDs and protection of the post-LID environment are sensible, since we cannot prevent LIDs in the transition. For example, bark-beetle outbreaks may naturally thin and diversify forest structures (Oliver 1995, Graham et al. 2016), updating resistance and resilience, while increasing biodiversity and furthering genetic adaptation to emerging climates and LIDs (Six et al. 2014, Beudert et al. 2015). Large, infrequent disturbances also provide selection against individual trees not resistant to the LID or post-LID environment (Six et al. 2014). Survivors and post-disturbance regeneration can revise tree adaptations to both emerging climate and patterns of LIDs. Rapid evolutionary response to extreme climatic events is possible, even in long-lived trees (Grant et al. 2017). For example, MPB outbreaks favor survival of slower-growing ponderosa pines, even though faster-growing trees may outcompete them at other times (De la Mata et al. 2017). Also, since post-LID tree regeneration is favored within 100–200 m of surviving trees (Table 9), and LIDs can leave isolated patches of surviving trees that, by chance, have different gene frequencies, the opportunity for locally adapted genetic change is high. As Howe (1976:263) said: "Prevention of major conflagrations… would eliminate the ingredients for drift, i.e., the replacement of large, continuous populations by tiny islands of isolated interbreeders from which most ensuing regeneration would emanate…" To preserve genetic adaptation of trees to emerging climate and LIDs, it is important to not prevent LIDS, not plant trees, and not log post-disturbance survivors (Lindenmayer et al. 2008). Genetic adaptation to committed warming could enhance possibilities for more dry-forest persistence in the transition and during the extended period of adjustment after the initial transition to committed warming.

Conclusions

Limiting warming, as with the Paris Agreement, should enable more persistence of current dry forests in the transition to committed warming than projected by models. Here, I reviewed evidence that (1) LIDs historically produced diverse forest stands and landscapes that naturally provided resistance and resilience to subsequent disturbances; (2) LIDs cannot be generally prevented through direct control or indirect manipulation of forest structure; (3) fires, droughts, and beetle outbreaks are not yet having effects in dry-forest landscapes that appear outside historical variability; (4) in the last few decades, droughts and beetle outbreaks have caused roughly 3–4 times as much tree mortality as fires; (5) primary opportunities to enhance forest persistence are from expanded bet-hedging at stand and landscape scales focused on resistance and resilience to droughts and beetle outbreaks, and facilitating adaptation as disturbances occur; and (6) 1/2 to 3/4 of dry-forest area could possibly escape most mortality during the transition.

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Supporting Information

Additional Supporting Information may be found online at: http://onlinelibrary.wiley.com/doi/10.1002/ecs2.2288/full

EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL ON ENVIRONMENTAL QUALITY
WASHINGTON, D.C. 20503

December 18, 2014

MEMORANDUM FOR HEADS OF FEDERAL DEPARTMENTS AND AGENCIES

FROM: MICHAEL BOOTS
COUNCIL ON ENVIRONMENTAL QUALITY

SUBJECT: Effective Use of Programmatic NEPA Reviews

The Council on Environmental Quality (CEQ) is issuing this guidance for Federal departments and agencies on effective use of programmatic National Environmental Policy Act (NEPA) reviews. This guidance is issued in accordance with NEPA, 42 U.S.C. § 4321 et seq., and the CEQ Regulations for Implementing the Procedural Provisions of NEPA (CEQ Regulations), 40 CFR Parts 1500-1508. The guidance explains the requirements of NEPA and the CEQ Regulations when agencies prepare programmatic NEPA reviews.

The text of the final guidance follows.

Effective Use of Programmatic NEPA Reviews

I. Introduction

A. Purpose of this Guidance

B. The Nature of Programmatic NEPA Reviews

II. Programmatic NEPA Reviews in the Council on Environmental Quality Regulations

III. When to Use a Programmatic and Tiered NEPA Review

IV. Practical Considerations for Programmatic Reviews and Documents

A. Determining the Utility and Scope of the Programmatic NEPA Review

1. Purpose and Need

2. Scope of Analysis

3. The Proposed Action

4. The Alternatives

5. The Impacts

B. Collaboration, Public Engagement, and Coordination with Other Environmental Reviews

1. The Importance of Collaboration and Cooperation

2. Public Involvement

3. Coordination with Other Environmental Reviews

B. Preparing the Documents

1. Programmatic Environmental Assessment or Programmatic Environmental Impact Statement?

2. Level of Detail in Programmatic NEPA Documents

3. Depth of Impact Analysis in Programmatic NEPA Documents

C. Mitigation and Monitoring

D. Handling New Proposals While Preparing a Programmatic NEPA Review

E. The Decision Document

V. Subsequent Proposal-Specific NEPA Reviews

A. Deferred Issues

B. Tiering NEPA Reviews

C. New Information and Supplementing Documents

VI. The Lifespan of a Programmatic NEPA Document

VII. Conclusions

APPENDICES

A: Table of Key Distinctions between Programmatic and Tiered Analyses

B: Sample Programmatic Analyses

I. INTRODUCTION

In this guidance, the Council on Environmental Quality (CEQ) provides clarification on when and how Federal agencies should use programmatic NEPA reviews[1] in accordance with the National Environmental Policy Act (NEPA), 42 U.S.C. § 4332, and the CEQ Regulations for Implementing the Procedural Provisions of NEPA, 40 C.F.R. parts 1500-1508 (CEQ Regulations). This guidance provides an overview of opportunities for departments and agencies to use programmatic analyses to provide for greater efficiency in their work to comply with NEPA requirements for preparing NEPA reviews that help agencies make better informed decisions.[2] This guidance also reflects the need to integrate environmental reviews into the decisionmaking process, coordinate multi-agency or multi-governmental reviews and approvals, and ensure meaningful public engagement in the decisionmaking process.[3] The

[1] The term "NEPA review(s)" is used to encompass the process, analyses, and documents developed under NEPA to inform a Federal agency's decision.

[2] This guidance provides CEQ's interpretation of existing regulations promulgated under NEPA, and does not change agency obligations with regard to NEPA and the CEQ Regulations. This guidance is not a rule or regulation, and the recommendations it contains may not apply to a particular situation based upon the individual facts and circumstances. This guidance does not change or substitute for any law, regulation, or any other legally binding requirement and is not legally enforceable. The use of non-mandatory language such as "recommend," "may," "should," and "can," is intended to describe CEQ policies and recommendations. The use of mandatory terminology such as "must" and "required" is intended to describe controlling requirements under the terms of NEPA and the CEQ Regulations, but this document does not establish legally binding requirements in and of itself.

[3] Programmatic NEPA guidance was first recommended by the interagency 2003 NEPA Task Force Report to the Council on Environmental Quality: Modernizing NEPA Implementation. The need for guidance was reiterated in 2012 in comments received on CEQ's Implementing the Procedural Requirements of the National Environmental Policy Act. In addition, recent trends in legislation (e.g., MAP-21 Section 1305, Water Resources Reform and Development Act of 2014 § 1040) encourage agencies to apply programmatic approaches in their NEPA reviews. The goal of this guidance is to encourage a more consistent approach to programmatic NEPA analyses and documentation that will allow comprehensive programmatic reviews.

goal of this guidance is to encourage a more consistent approach to programmatic NEPA reviews.

NEPA requires Federal agencies to consider the effects of a proposed action and any reasonable alternatives on the human environment. Those effects include, among others, impacts on social, cultural, economic, and natural resources.[4] To implement NEPA, agencies undertake an assessment of the environmental effects of their proposed actions prior to making decisions. The NEPA review process is an integral and valuable tool for public engagement and thoughtful decisionmaking, a process that often produces more sound analysis and information that the federal government might otherwise overlook. The NEPA process:

- Leads to a better outcome;[5]
- Includes meaningful public engagement;
- Provides transparent, accountable, and informed government decisionmaking;
- Allows for the consideration of reasonable alternatives that may not otherwise be identified;

[4] 40 CFR *§ 1508.8*

[5] For example, Russell Train, former Administrator of the Environmental Protection Agency and the first Chairman of the Council on Environmental Quality, found that NEPA's "[c]onsideration of the impacts of proposed government actions on the quality of the human environment is essential to responsible government decision-making. Government projects and programs have effects on the environment with important consequences for every American, and those impacts should be carefully weighed by public officials before taking action. Environmental impact analysis is thus not an impediment to responsible government action; it is a prerequisite for it." September 19, 2005 Letter to the Honorable Cathy McMorris, Chair of the Task Force on Improving the National Environmental Policy Act. In August 2010, the Environmental Law Institute published *NEPA Success Stories: Celebrating 40 Years of Transparency and Open Government*. This publication provides numerous case studies that illustrate how NEPA works for better decisions and better outcomes for federal agencies and all stakeholders.

- Identifies mitigation alternatives and measures; and
- Encourages collaboration with interested parties.

Each Federal agency has its own agency NEPA implementing procedures which adapt the framework established by the CEQ Regulations to address agency specific missions and decisionmaking authority. The NEPA process begins when an agency has a proposal.[6] Once the proposal is conceptualized and any reasonable alternatives have been developed, the agency must determine if the proposed action or any reasonable alternatives have the potential to affect the quality of the human environment. Agencies fulfill their NEPA responsibilities by:

- Applying a Categorical Exclusion established in the agency's NEPA implementing procedures;
- Preparing an Environmental Assessment; or
- Preparing an Environmental Impact Statement.

NEPA reviews may be on a site- or project-specific level or on broader – programmatic – level. Programmatic analyses have value by setting out the broad view of environmental impacts and benefits for a proposed decision. That programmatic NEPA review can then be relied upon when agencies make decisions based on the Programmatic Environmental Assessment (PEA) or Programmatic Environmental Impact Statement (PEIS)[7] such as a rulemaking or establishing a

[6] 40 CFR § 1508.23.

[7] The terms PEA and PEIS are also know by some agencies as "generic" or "tier 1 NEPA review".

policy, program, or plan, as well as when decisions are based on a subsequent – tiered[8] – NEPA review. Programmatic NEPA reviews should result in clearer and more transparent decision-making, as well as provide a better defined and more expeditious path toward decisions on proposed actions. Agencies are encouraged to revise or amend their NEPA implementing procedures, if necessary, to allow for analyses at a programmatic level.

A. Purpose of This Guidance

This guidance was prepared to assist Federal agencies to improve and modernize their use of programmatic NEPA reviews. The term "programmatic" describes any broad or high-level NEPA review; it is not limited to a NEPA review for a particular program.[9] Programmatic NEPA reviews assess the environmental impacts of proposed policies, plans, programs, or projects for which subsequent actions will be implemented either based on the PEA or PEIS, or based on subsequent NEPA reviews tiered to the programmatic review (e.g., a site- or project-specific document). Programmatic NEPA reviews are governed by the same regulations and guidance that apply to non-programmatic NEPA reviews. This guidance addresses both programmatic NEPA reviews that make decisions applicable to subsequent tiered NEPA reviews and programmatic NEPA reviews without a subsequent, tiered, review.

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[8] "Tiering" refers to an approach where federal agencies first consider the broad, general impacts of proposed program, plan, policy, or large scope project – or at the early stage of a phased proposal – and then conduct subsequent, narrower, decision focused reviews. See 40 CFR §§ 1502.20 and 1508.28.

[9] For example, programmatic NEPA reviews are used when agencies revise forest or land and resource management plans, establish programs to eradicate or control invasive species, or develop similar infrastructure (e.g., similar recovery projects following a major disaster) in multiple jurisdictions.

Programmatic NEPA reviews have not been fully used for their intended purpose and when used, have often not fulfilled agency or stakeholder expectations.[10] On March 6, 2012, CEQ published guidance highlighting the efficiencies provided for in the CEQ Regulations[11] and received feedback from several external stakeholders and Federal agencies that additional guidance on programmatic and tiered NEPA reviews would provide a valuable addition to agency practices and procedures for providing more timely and efficient NEPA reviews.

This guidance is designed to assist in the preparation and proper use of programmatic NEPA reviews, and help agencies inform and meet public expectations for programmatic reviews that will enhance the focus and utility of public review and comment. It builds on guidance issued in 1983 that explains the use of tiering and its place in the NEPA process.[12]

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[10] The NEPA Task Force, Report to the Council on Environmental Quality, "Modernizing NEPA Implementation," September 2003 (finding that reliance on programmatic NEPA documents has resulted in public and regulatory agency concern that programmatic NEPA documents often result in a "shell game" of when and where deferred issues will be addressed, undermining agency credibility and public trust. The report found that the public may fail to understand: (1) the significance of the broad decisions being analyzed; and (2) that the specific details will be provided in subsequent site-specific documents. On the other hand, when programmatic NEPA documents are focused, some respondents fear that some issues and analyses will be deferred and ultimately never addressed. The NEPA Task Force found that agencies that provide the greatest specificity in programmatic documents have the greatest difficulty in maintaining the viability and durability of these documents. This difficulty associated with maintaining document relevancy has led some agencies as well as members of the public to conclude that preparing programmatic NEPA documents is not cost effective. The recommendation of the Task Force was that CEQ develop advice to agencies on the analytical requirements associated with the different uses of programmatic NEPA reviews, to foster agreement and consistency between agency decisions and public expectations).

[11] Council on Environmental Quality, "Memorandum for Heads of Federal Departments and Agencies: Improving the Process for Preparing Efficient and Timely Environmental Reviews under the National Environmental Policy Act," March 6, 2012.

[12] Council on Environmental Quality, "Guidance Regarding NEPA Regulations," Memorandum for Heads of Federal Agencies, July 28, 1983.

This new guidance focuses specifically on programmatic NEPA reviews and not on other types of programmatic analyses such as data collection, assessments, and research. CEQ recognizes that analyses conducted outside the context of NEPA can also play an important role, for example, in assessing existing conditions. Although these types of analyses may be used – either by incorporation by reference or as a starting point for developing the NEPA review – an analysis prepared by an agency is not a NEPA programmatic review unless that agency is making decisions on a proposed Federal action. This important distinction was explained in previous NEPA guidance which referred to a non-NEPA programmatic review as a joint inventory or planning study:

> In geographic settings where several Federal actions are likely to have effects on the same environmental resources it may be advisable for the lead Federal agencies to provide historical or other baseline information relating to the resources. This can be done either through a programmatic NEPA analysis or can be done separately, such as through a joint inventory or planning study. The results can then be incorporated by reference into NEPA documents prepared for specific Federal actions so long as the programmatic analysis or study is reasonably available to the interested public.[13]

B. The Nature of Programmatic NEPA Reviews

Programmatic NEPA reviews address the general environmental issues relating to broad decisions, such as those establishing policies, plans, programs, or suite of projects, and can

[13] Council on Environmental Quality, "Guidance on the Consideration of Past Actions in Cumulative Effects Analysis," June 24, 2005.

effectively frame the scope of subsequent site- and project-specific Federal actions. A well-crafted programmatic NEPA review provides the basis for decisions to approve such broad or high-level decisions such as identifying geographically bounded areas within which future proposed activities can be taken or identifying broad mitigation and conservation measures that can be applied to subsequent tiered reviews.[14] Effective programmatic NEPA should present document reviewers with the agency's anticipated timing and sequence of decisions, which decisions are supported by the programmatic NEPA document and which decisions are deferred for some later time, and the time-frame or triggers for a tiered NEPA review.

One advantage of preparing a programmatic NEPA review for repetitive agency activities is that the programmatic NEPA review can provide a starting point for analyzing direct, indirect, and cumulative impacts. Using programmatic NEPA reviews allows an agency to subsequently tier to this analysis, and analyze narrower, site- or proposal-specific issues. This avoids repetitive broad level analyses in subsequent tiered NEPA reviews and provides a more comprehensive picture of the consequences of multiple proposed actions. An agency relying on a programmatic NEPA review must consider whether the depth of analysis needed for a tiered decision requires adding to, or building on, the analysis provided in the programmatic NEPA review. A programmatic NEPA review can also be an effective means to narrow the consideration of alternatives and impact discussions in a subsequent tiered NEPA review. For example, a land management plan PEIS for "zoning" certain uses can narrow future alternatives to specific uses.

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[14] See Council on Environmental Quality, "Appropriate Use of Mitigation and Monitoring and Clarifying the Appropriate Use of Mitigated Findings of No Significant Impact," January 14, 2011. See also *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 350 (1989).

Decisionmakers may also call for a programmatic NEPA review for other reasons. For example, programmatic NEPA reviews may serve to influence the nature of subsequent decisions, thereby providing for an integrated and sustainable policy, planning framework, or program. Programmatic NEPA reviews may also support policy- and planning-level decisions when there are limitations in available information and uncertainty regarding the timing, location, and environmental impacts of subsequent implementing action(s). For example, in the absence of certainty regarding the environmental consequences of future proposed actions, agencies may be able to make broad program decisions and establish parameters for subsequent analyses based on a programmatic review that adequately examines the reasonably foreseeable consequences of a proposed program, policy, plan, or suite of projects.

II. PROGRAMMATIC NEPA REVIEWS IN COUNCIL ON ENVIRONMENTAL QUALITY REGULATIONS

The concept of "programmatic" NEPA reviews is imbedded in the CEQ Regulations that address analyses of "broad actions" and the tiering process.

The CEQ Regulations at 40 CFR §§ 1502.4(b)-(c) state:

> (b) Environmental impact statements may be prepared, and are sometimes required, for broad Federal actions such as the adoption of new agency programs or regulations (§ 1508.18). Agencies shall prepare statements on broad actions so that they are relevant to policy and are timed to coincide with meaningful points in agency planning and decision-making.

(c) When preparing statements on broad actions (including proposals by more than one agency), agencies may find it useful to evaluate the proposal(s) in one of the following ways:

(1) Geographically, including actions occurring in the same general location, such as body of water, region, or metropolitan area.

(2) Generically, including actions that have relevant similarities, such as common timing, impacts, alternatives, methods of implementation, media, or subject matter.

(3) By stage of technological development, including Federal or Federally assisted research, development or demonstration programs for new technologies which, if implemented, could significantly affect the quality of the human environment….

CEQ interprets its regulations as allowing for the use of a programmatic approach in developing an EA as well as in an EIS.

In cases where a policy, plan, program, or broad project analysis identifies but does not provide sufficiently in-depth analysis for potential future actions, then subsequent analyses are appropriate and are referred to as "tiered" analyses. Tiering is one way "to relate broad and narrow actions and to avoid duplication and delay."[15] Appendix A provides a table of key distinctions between programmatic and the subsequent tiered NEPA reviews, Appendix B contains examples of programmatic NEPA reviews.

[15] 40 CFR § 1502.4(d). Tiering is described at 40 CFR § 1502.20 and further defined at 40 CFR § 1508.28.

III. WHEN TO USE A PROGRAMMATIC AND TIERED NEPA REVIEW

Programmatic NEPA reviews add value and efficiency to the decision-making process when they inform the scope of decisions and subsequent tiered NEPA reviews. Programmatic NEPA reviews can facilitate decisions on agency actions that precede site- or project-specific decisions and actions, such as mitigation alternatives or commitments for subsequent actions, or narrowing of future alternatives. They also provide information and analyses that can be incorporated by reference in future NEPA reviews.[16] Programmatic NEPA review may help an agency look at a large or multi-faceted action without becoming immersed in all the details of future site- or project-specific proposals. Although a programmatic EIS may often be inadequate relative to an individual action, there is no reason to require a site-specific statement to duplicate the analysis in the PEIS. Using programmatic and subsequent tiered NEPA reviews effectively will allow for a focused review at the proper level.

A programmatic NEPA review may be appropriate when the action being considered is subject to NEPA requirements and falls into one of the four major categories of actions to which NEPA can apply (40 CFR § 1508.18(b)):

- Adopting Official Policy. Decision to adopt in a formal document an official policy that would result in or substantially alter agency programs. The programmatic analysis for such a decision should include a road map for future agency actions with defined objectives, priorities, rules, or mechanisms to implement objectives. Programmatic examples include:
    - Rulemaking at the national- or regional-level;

[16] The NEPA review and the decisionmaking is compromised when a programmatic NEPA review narrows or limits alternatives based on only a superficial or general review of potential impacts.

- Adoption of an agency-wide policy; or
- Redesign of an existing program.

- Adopting Formal Plans. Decision to adopt formal plans, such as documents that guide or constrain alternative uses of Federal resources, upon which future agency actions will be based. For example, setting priorities, options, and measures for future resource allocation according to resource suitability and availability. Specific programmatic examples include:
    - Strategic planning linked to agency resource allocation; or
    - Adoption of an agency plan for a group of related projects.
- Adopting Agency Programs. Decision to proceed with a group of concerted actions to implement a specific policy or plan; e.g., an organized agenda with defined objectives to be achieved during implementation of specified activities. Programmatic examples include:
    - A new agency mission or initiative; or
    - Proposals to substantially redesign existing programs.
- Approving Multiple Actions. Decision to proceed with multiple projects that are temporally or spatially connected and that will have a series of associated concurrent or subsequent decisions. Programmatic examples include:
    - Several similar actions or projects in a region or nationwide (e.g., a large scale utility corridor project); or
    - A suite of ongoing, proposed or reasonably foreseeable actions that share a common geography or timing, such as multiple activities within a defined boundary (i.e., Federal land or facility).

Agencies should exercise judgment and discretion when determining whether to prepare a PEA or PEIS.[17] CEQ recommends agencies give particular consideration to preparing a PEA or PEIS when: (1) initiating or revising a national or regional rulemaking, policy, plan, or program; (2) adopting a plan for managing a range of resources; or (3) making decisions on common elements or aspects of a series or suite of closely related projects.

Agencies may prepare a single NEPA document to support both programmatic and project-specific proposals. Such an approach may be appropriate when an agency plans to make a broad program decision, as well as timely decisions to implement one or more specific projects under the program. Such a programmatic NEPA review should address both the broad impacts of the proposed broad Federal action and provide sufficiently detailed environmental analyses for specific decisions, such as determining the locations and designs of one or more proposals to implement the broad Federal action. If subsequent actions remain to be analyzed and decided upon, that would be explained in the programmatic document and left to a subsequent tiered NEPA review. Agencies should clearly communicate the purpose and need for the programmatic and subsequent decisions, clearly state the decisions the agency proposes to make based directly on the PEA or PEIS, and distinguish the analysis of impacts and alternatives of the broad programmatic proposals from project- or site-specific proposals.

A programmatic NEPA review may not be a cost effective effort for an agency if the effort required to perform the review is substantially greater than the time and effort saved in analyzing subsequent proposals or if the lifespan of the programmatic NEPA document is limited. Agencies usually benefit by asking two questions when determining whether to prepare a programmatic NEPA review: (1) Could the PEA or PEIS be sufficiently forward looking to

[17] *National Wildlife Federation v. Appalachian Regional Commission*, 677 F.2d 883, 888 (D.C. Cir. 1981).

contribute to the agency's basic planning of an overall program?; and (2) Does the PEA or PEIS provide the agency the opportunity to avoid ‘segmenting’ the overall program from subsequent individual actions and thereby avoid unreasonably constricting the scope of environmental review?[18]

IV. PRACTICAL CONSIDERATIONS FOR PROGRAMMATIC REVIEWS AND DOCUMENTS

This section provides practical guidance to help agencies implement a successful programmatic approach for informed decision-making. The following points will be addressed:

- Answering the fundamental question of what decision(s) the agency needs to make;
- Answering the question of what actions would the agency subsequently want to take based on the programmatic NEPA review;
- Determining the purpose and need of the programmatic proposal to be analyzed and decided on and its relationship to subsequent tiered level proposals and decisions;
- Defining a practical temporal and spatial scope for the programmatic review that is appropriate to the broad action being analyzed;
- Gathering and analyzing environmental resource data for broadly scoped actions that potentially affect large geographic areas;
- Coordinating among the multiple overlapping jurisdictions and agencies that may have a role in assessing or determining whether and how a subsequent action may proceed;

[18] *Piedmont Environmental Council v. F.E.R.C.*, 558 F.3d 304, 316 (4th Cir. 2009) (quoting *Nat'l Wildlife Fed'n v. Appalachian Reg'l Comm'n*, 677 F.2d 883, 888-89 (D.C. Cir. 1981) (agency can do all individual EISs but not if that is an attempt to segment the program and thereby limit regulation. If so, a programmatic should have been done)).

- Communicating the scope, content, and purpose of a programmatic NEPA analysis in a way the parties involved in the process and the public can understand;
- Communicating the opportunities for public engagement in the development of the tiered NEPA reviews; and
- Maintaining the relevancy of programmatic NEPA documents for subsequent tiered analyses.

A. Determining the Utility and Scope of the Programmatic NEPA Review

Agencies should carefully consider, as early as practicable, the benefits of making the initial broad decisions and the amount of effort required to perform a programmatic NEPA review to ensure that it facilitates decision-making and merits the investment of time and effort. To determine the utility of the PEA or PEIS, and the scope of analysis, an agency may find it helpful to consider:

- What Federal decisions need to be made now and in the future regarding the broad Federal action being proposed?
- What are the meaningful decision points[19] from proposal through implementation, and where are the most effective points in that continuum to address the potential for effects?
- What are the appropriate geographic (spatial) and time frame (temporal) limits for this programmatic review?
- Is it necessary to analyze the particular effects of a proposed action at a broader scale to facilitate analysis and/or decision-making at a more refined (i.e., tiered) level, and is a

[19] 40 CFR § 1502.4(b) ("Agencies shall prepare statements on broad actions so that they are relevant to policy and are timed to coincide with meaningful points in agency planning and decision-making.").

programmatic NEPA review the best way to do this? For example, a programmatic NEPA review may serve as an efficient mechanism to describe Federal agency efforts to adopt sustainable practices for energy efficiency, reduce or avoid greenhouse gas emissions, reduce petroleum product use, and increase the use of renewable energy including bioenergy, as well as other sustainability practices. Likewise, it may be more efficient to conduct and maintain an ongoing cumulative effects analysis versus a programmatic NEPA document. The definition of "proposal" for the purposes of NEPA review should be considered when answering this question.[20]

- How long will the programmatic review continue to provide a relevant framework for tiering subsequent actions and what factors may result in the need to supplement or refresh the review?
- Are there any other federal agencies that may provide meaningful input during the development of the programmatic or tiered NEPA reviews?

1. Purpose and Need

The purpose and need statement is key to developing the NEPA review, as it establishes the scope of the analyses, range of reasonable alternatives, and frames the decision to be made. The purpose and need for a programmatic review will differ from the purpose and need for a project- or site-specific EA or EIS.[21] The purpose and need for a PEA or a PEIS should be

[20] 40 CFR § 1508.23 ("'Proposal' exists at that stage in the development of an action when an agency subject to the Act has a goal and is actively preparing to make a decision on one or more alternative means of accomplishing that goal and the effects can be meaningfully evaluated... A proposal may exist in fact as well as by agency declaration that one exists.").

[21] Council on Environmental Quality, "Guidance Regarding NEPA Regulations," 1983 ("If tiering is utilized, the site-specific EIS contains a summary of the issues discussed in the first

written to avoid eliminating reasonable alternatives and focused enough for the agency to conduct a rational analysis of the impacts and allow for the public to provide meaningful comment on the programmatic proposal. The purpose and need sets the tone for the scoping process and the course for conducting the NEPA review.

2. Scope of Analysis

The scope consists of the range of actions, the alternatives, and the associated impacts to be considered in a NEPA review.[22] A programmatic NEPA review, like project- or site-specific NEPA reviews, must address the potentially significant environmental impacts of a proposed Federal action. Consequently, the nature of the pending decision drives the scope of the environmental analyses and documentation. A programmatic document should not narrow or otherwise restrict decision(s) that will be addressed in subsequent NEPA review(s).

The planning process for the proposed action and the development of a programmatic NEPA review should start as early as practicable. By starting the planning process early, there should be sufficient time for establishing the reasonable scope of actions, alternatives, and impacts in the programmatic review, and identifying the decisions the programmatic review will support so that the level of analysis is clear from the start.

3. The Proposed Action

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statement and the agency will incorporate by reference discussions from the first statement. Thus, the second, or site-specific statement, would focus primarily on the issues relevant to the specific proposal, and would not duplicate material found in the first EIS.”).

[22] 40 CFR § 1508.25.

In addition to unconnected single actions, there are three types of actions set out in 40 CFR § 1508.25(a) that may be analyzed in NEPA reviews, including those that are programmatic: connected actions, cumulative actions, and similar actions.

Connected actions are closely related and therefore should be discussed in the same impact statement. Actions are connected if they automatically trigger other actions; or cannot or will not proceed unless a previous or simultaneous action is taken; or are interdependent parts of a larger action and depend on the larger action for justification.[23]

- Example: A proposed pesticide aerial application program EIS would analyze the proposal along with connected program actions such as standards for pesticide transport, handling, and storage.

Cumulative actions, which when viewed with other proposed actions have cumulatively significant impacts, should be discussed in the same NEPA review.[24] An analysis of the cumulative impacts for each resource would be provided in each level of review, either by relying upon the analysis in the programmatic NEPA review or adding to that analysis in the tiered NEPA review, either approach facilitated by incorporating by reference the cumulative impact analysis provided in the programmatic NEPA review.

- Example: A proposed aerial pesticide spray program with significant effects on an endangered butterfly should be analyzed in the same programmatic EIS with a proposed ground-spraying program as cumulative actions because they both have the potential to significantly affect the endangered species. Note that cumulative

[23] 40 CFR §§ 1508.25(a)(1) and 1508.25(a)(1)(iii)

[24] 40 CFR § 1508.25(a)(2).

effects would have to be considered when conducting the NEPA reviews for each of the proposals, whether in separate or combined NEPA reviews.

Similar actions are those which, when viewed with other reasonably foreseeable or proposed agency actions provide a basis for evaluating their environmental consequences together, such as common as timing, location, impacts, alternatives, or methods of implementation.[25]

- Example: Several energy development programs proposed in the same region of the country are proposals of similar actions if they have similar proposed methods of implementation and similar best practice and mitigation measures that can be analyzed in the same document.

Broad Federal actions may be implemented over large geographic areas and/or a long time frame. Programmatic NEPA documents must include connected and cumulative actions, and the responsible official should consider whether it is helpful to include a series or suite of similar actions.[26]

4. The Alternatives

Alternatives in a programmatic NEPA review are expected to reflect the level of the Federal action being proposed[27] and the standard NEPA requirements for alternatives apply.[28] In

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[25] 40 CFR § 1508.25(a)(3).

[26] 40 CFR § 1508.25(a).

[27] Council on Environmental Quality, "Forty Most Asked Questions Concerning CEQ's NEPA Regulations," Question and Answer 1, March 16, 1981. Reasonable alternatives depend on the nature of the proposal and the facts of the case. Factors may include the cost of the proposed alternative, the actual need or desire for the alternative in the affected community, and the state of the technologies involved in developing the alternative.

situations where there is an existing program, plan, or policy, CEQ expects that the no-action alternative in an EIS would typically be the continuation of the present course of action until a new program, plan, or policy is developed and decided upon.[29]

When preparing the programmatic NEPA review for a policy, plan, program, or project, alternatives, including non-agency alternatives, can be considered at the programmatic level to support focusing future decisions and eliminating certain alternatives from detailed study in subsequent NEPA reviews. Stating the nature of subsequent tiered decisions allows agencies to craft the alternatives for a programmatic review and focus the scope and development of alternatives for the subsequent tiered NEPA reviews. By articulating the reasoned choice between alternatives, with a discussion of why considered alternatives were not chosen, the range of alternatives in tiered NEPA reviews can be appropriately narrowed. The PEA or PEIS should include a brief written discussion of the reasons alternatives were eliminated[30] to provide the rationale for narrowing the range of reasonable alternatives to be considered in those tiered NEPA documents.

5. The Impacts

All NEPA reviews are concerned with three types of reasonably foreseeable impacts: direct, indirect, and cumulative.[31] The contrast between a programmatic and a project- or site-

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[28] 40 CFR §§ 1508.25(b) and 1508.9(3)(b).

[29] Council on Environmental Quality, "Forty Most Asked Questions Concerning CEQ's NEPA Regulations," Question and Answer 3, March 16, 1981.

[30] 40 CFR § 1502.14(a).

[31] 40 CFR §§ 1508.7 and 1508.8.

specific NEPA review is most strongly reflected in how these environmental impacts are analyzed. Because impacts in a programmatic NEPA review typically concern environmental effects over a large geographic and/or time horizon, the depth and detail in programmatic analyses will reflect the major broad and general impacts that might result from making broad programmatic decisions. Programmatic NEPA reviews address the broad environmental consequences relevant at the programmatic level (see Level of Detail in Programmatic Documents section). Agencies should be clear about the context of the decision to be made and how it relates to the context and intensity of any potential impacts.

As noted previously, agencies may propose standard mitigation protocols and/or operating procedures in a programmatic NEPA review and thereby provide a framework and scope for the subsequent tiered analysis of environmental impacts. For example, proposals for long range energy or transportation infrastructure programs are potentially good candidates for PEAs and PEISs that include an assessment of how the programs will contribute to or reduce water quantity and quality. Discussions of water quantity and quality could then be incorporated by reference in tiered NEPA reviews. By identifying potential program impacts early, particularly cumulative and indirect impacts, programmatic NEPA reviews provide opportunities to modify program components in order to avoid or mitigate adverse impacts when developing subsequent proposals.

B. Collaboration, Public Engagement, and Coordination with Other Environmental Reviews

1. Importance of Collaboration and Cooperation

The types of actions that agencies analyze in programmatic reviews may feature some jurisdictional complexity. Impacts on state, tribal and private lands, and potentially overlapping authorities between agencies and governments with different missions and authorities should be considered in programmatic reviews that address resources or actions across jurisdictional boundaries. Early collaboration and cooperation among Federal agencies, tribes, and state and local governments is particularly useful for successful completion of meaningful programmatic NEPA reviews.[32] Scoping early in the process provides agency decisionmakers with access to other agencies' and governments' expertise and can help agencies identify broad scale issues, develop alternatives for analysis, identify the appropriate temporal and spatial parameters, and determine the appropriate depth of analysis or level of detail for the programmatic NEPA review.

2. Public Involvement

Engaging the public is particularly important when developing programmatic NEPA reviews in order to ensure agency objectives are understood and to clarify how a programmatic review influences subsequent tiered reviews. Effective public engagement will also help manage expectations with regard to the purpose and need, the scope of the broad environmental analyses, and the purpose, need and scope of subsequent site- and project-specific environmental analyses. Outreach to potentially interested stakeholders should begin as early as possible – even in advance of formal scoping periods – to afford the public a meaningful opportunity to comment on and shape the programmatic NEPA review and/or develop alternatives to be considered.

[32] Council on Environmental Quality, "Memorandum on Environmental Collaboration and Conflict Resolution," September 7, 2012; Council on Environmental Quality, "Cooperating Agencies in Implementing the Procedural Requirements of the National Environmental Policy Act," January 30, 2002.

Proactive and robust public participation is encouraged and, if necessary, comment periods can be extended to ensure meaningful involvement.

When the public has a chance to see the big picture early[33] it can provide fresh perspectives and new ideas before determinations are made that will shape the programmatic review and how those determinations affect future tiered proposals and NEPA reviews. Early outreach also provides an opportunity to develop trust and good working relationships that may extend throughout the programmatic and subsequent NEPA reviews and continue during the implementation of the proposed action.[34] An agency can encourage early public participation by clearly explaining to the public not only what the proposed programmatic evaluation is meant to accomplish, but also how it relates to future actions, and why the public should get involved at the programmatic stage and not wait for any tiered reviews. The agency should clearly state which concerns are addressed at that level of NEPA review and with concerns will be tiered to a subsequent NEPA review. Clarity of approach is essential to avoid the impression that a programmatic NEPA review creates a situation whereby the public is too early to raise issues in the broader programmatic analysis and then too late to raise them in any subsequent tiered analyses.

Stakeholders for a programmatic review may span multiple states and large areas. Consequently, public engagement should be well thought through to include all the potentially

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[33] Members of the public are less likely to participate or engage in the commenting process if they do not fully understand how a particular project affects them. It is critical that agencies provide context and as much information as possible in the beginning of the public involvement process.

[34] 40 CFR § 1501.7; see also Council on Environmental Quality, "Collaboration in NEPA – A Handbook for NEPA Practitioners," October 2007.

interested Federal and state agencies, tribes, local governments, private organizations, and individual citizens.[35]

3. Coordination with Other Environmental Reviews

The purpose and need statement and the proposed action for the programmatic NEPA review are critical for determining the compliance requirements under other applicable laws and regulations, such as the Endangered Species Act (ESA), National Historic Preservation Act (NHPA), and Clean Water Act. For example, programmatic NEPA review can provide the fora for considering programmatic agreements under the ESA and NHPA. They are also critical for determining when these other reviews must be completed and for developing a strategy to address all environmental review and consultation requirements in a coordinated manner. Coordinating compliance with other environmental reviews supports a broad discussion, facilitates a comprehensive project management schedule, provides opportunities to meet data, public engagement, and documentation requirements more efficiently, and generally promotes greater transparency in Federal decision-making. For example, an agency may coordinate with ESA regulatory agencies to develop ESA section 7(a)(1) consultations for the first programmatic

[35] Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," February 11, 1994, provides that "each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations." See Council on Environmental Quality, "Environmental Justice: Guidance Under the National Environmental Policy Act," December 10, 1997. For example, a good way to reach out to such a large and diverse public is through non-governmental organizations, citizen's groups, labor organizations, and trade associations. These organizations frequently know what their constituents care about and they may have effective means for communicating with those constituents. Agencies are also encouraged to use conference calls, web meetings and teleconferences to facilitate easy participation by the interested public.

review document and a separate consultation for any subsequent tiered programmatic NEPA review.

Programmatic NEPA analysis and subsequent tiered NEPA analysis support a phased decision-making process that allows certain statutory and regulatory compliance to be achieved at the programmatic level. The nature of the decision at each phase and the extent to which it may constrain the subsequent consideration of alternatives will help determine an agency's overall environmental compliance requirements. NEPA requires a full evaluation of all specific impacts when the agency proposes to make an irreversible and irretrievable commitment of the availability of resources which usually occurs following a tiered site- or project-specific NEPA review.[36]

Provided programmatic NEPA review has sufficient specific data and information, it may satisfy other relevant legal requirements for site-specific future actions, even when there is no irreversible or irretrievable commitment of resources at the programmatic level. The determination of whether a particular decision in a phased or incremental decision-making process represents this level of commitment begins with a well formulated description of the proposed action.[37] Agencies should be aware that preparing a programmatic NEPA review is not a substitute for compliance with other environmental laws.

For example, approval of land use plans that establish future management goals and objectives for resource management, and the measures to achieve those goals and objectives, may not necessarily require completion of the Section 106 process under the NHPA. In some cases, an agreement with stakeholders, such as a programmatic agreement pursuant to Section 106 of the NHPA, demonstrates an agency's compliance requirements for phased decisions

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[36] *N. Alaska Envtl. Ctr. V. Lujan*, 961 F.2d 886 (9th Cir. 1992).

[37] *Friends of Yosemite Valley v. Norton*, 348 F. 3d, 789, 801 (9th Cir. 2003).

being analyzed through a programmatic NEPA review. For instance, where a Federal agency's broad decision will narrow the opportunities for adverse effects in future specific proposals, then the agency may initiate the Section 106 process as part of the programmatic review. This will allow the agency to complete that process by establishing steps for meeting its responsibility as it implements the broad decision and prior to subsequent project- and site-specific proposals.

Agencies should clearly and concisely articulate their intentions to defer particular environmental review and consultation requirements for consideration until a subsequent project- or site-specific proposal is developed. It may be helpful for the agency to set a timing reference or triggering event that initiates the next tier of analysis. When deferring these requirements, agencies may still need to analyze and address related statutory requirements to some extent in the programmatic document. To avoid confusion with respect to subsequent timing and sequencing of Federally required consultation activities, the extent to which consultations are being undertaken in connection with the programmatic NEPA analysis should be clearly defined when scoping the programmatic NEPA document. An example is the subsequent action such as bridge construction tiered to a programmatic transportation NEPA review that will require authorization under Section 404 of the Clean Water Act (CWA) prior to construction of the bridge. When addressing the CWA 404 requirements, agencies should include, after consultation with the U.S. Army Corps of Engineers, a discussion of the range of alternatives necessary to demonstrate compliance with the Section 404(b)(1) Guidelines, and whether there are any practicable alternatives that have less adverse impact on the aquatic ecosystem – and do not have other significant environmental effects – can then be made at the project-specific or site-specific level.

C. Preparing the Documents

1. Programmatic Environmental Assessment or Programmatic Environmental Impact Statement?

Programmatic approaches are usually associated with EISs and tiered documents with proposal-specific EAs. Tiering an EA or applying a CE from a PEIS is appropriate when there are no new significant effects or considerations, and the programmatic NEPA review addresses those measures that tiered proposals can rely on to address and reduce the significance of the site- or project-specific impacts.

An agency may prepare a PEA to determine whether an EIS is required at the programmatic level or when considering a proposal that does not have significant impacts at the programmatic level. A PEA may lead to a programmatic level finding of no significant impact (FONSI) or to a determination that a PEIS is required. Following a PEA that results in a FONSI, an agency may tier to a subsequent PEA that results in a finding of no significant impact,[38] or may tier to a PEIS when a subsequent site- or project- specific proposal has the potential for a significant impact on the environment.

- Example: A PEA may be used to articulate standard mitigation for a suite of similar projects, such as capturing vented methane. This PEA may result in a FONSI but any project-level construction that goes beyond the mitigation in the PEA will require a PEIS.
- Example: A PEA may result in a FONSI and a subsequent proposal presents a unique or unexpected circumstance that raises the potential for significant impacts. In such a circumstance, a tiered EIS would not undermine or invalidate the PEA and FONSI.

[38] *N. Plains Resource Council v. Lujan*, 874 F.2d 661, 665-66 (9th Cir. 1989).

Whether the agency prepares a PEA or a PEIS, that programmatic review should explain how the agency intends to use it to complete future proposal-specific NEPA reviews.

Reasonably available information that should be provided both during scoping and in the PEA or PEIS includes the expected timing of the tiered review(s) as well as the issues, and depth of analysis, it is expected to consider. At the project- or site-specific level, it is necessary to consider the potential impacts that have not been analyzed and considered in the previous programmatic review to which it tiers.

2. Level of Detail in Programmatic NEPA Documents

A PEA or PEIS addresses the broad environmental consequences relevant at the programmatic level. A subsequent tiered EA or EIS will address more particularized considerations, but can benefit from the programmatic by summarizing and incorporating by reference parts of it.[39] For example, the PEIS for the USDA National Gypsy Moth Management Program, supplemented in 2012, includes human health and ecological risk assessments for treatments approved for use in the Gypsy Moth Eradication Program thereby eliminating the need to do such analysis in the NEPA review for each individual treatment project. The PEIS analyzed and disclosed these risks, and deferred to site or project level analyses the specific application of these risk data to how the insecticides would be used in a given project (e.g., dose

[39] See *Nevada v. Dep't of Energy*, 372 U.S. App. D.C. 432 (D.C. Cir. 2006). 40 CFR § 1502.21 also requires that information incorporated by reference be "reasonably available" to the public for consideration during review and comment periods. It may be helpful to: post PEAs and PEISs online so that the public does not face challenges locating prior documents (note that a PEIS will be posted on EPA's Environmental Impact Statement Database); post PEAs on the agency website(s); have copies available at a reasonably accessible location (e.g., keep documents in reading rooms or regional and local libraries); and make documents available by mailing CD or DVD copies to interested stakeholders.

rates, number of applications, presence of "sensitive populations") and other specific issues and concerns raised during scoping.

The PEA or PEIS must provide sufficient detail to foster informed decision-making that reflects broad environmental consequences from a wide-ranging federal program.[40] Site- or project-specific impacts need not be fully evaluated at the programmatic level when the decision to act on a site development or its equivalent is yet to be made.[41] Alternatives need not consider every specific aspect of a proposal but rather should be detailed enough to make a reasoned choice between programmatic directions. For example, a programmatic analysis of a plan would not require consideration of detailed alternatives with respect to each implementation action proposed under the plan – otherwise a programmatic analysis would be practically impossible to prepare, requiring a compilation of a vast series of site specific analyses.[42]

The following considerations may be helpful to determine the scale and scope of impacts to be addressed in a programmatic NEPA review:

- First, what is the decision to be made?
- Second, what are the appropriate scales of the affected environment to be analyzed (e.g., watershed, basin, etc.)?
- Third, what environmental impacts are of concern at this scale?

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[40] *Found. On Econ. Trends. v. Heckler*, 756 F.2d 143, 159 (D.C. Cir. 1985).

[41] *Citizens for Better Forestry v. U. S. Dep't of Agriculture*, 481 F. Supp. 2d 1059, 1086 (D. Cal. 2007).

[42] *Greenpeace v. National Marine Fisheries Service*, 55 F. Supp. 2d 1248, 1276 (D. Wash. 1999).

- Fourth, what information can be garnered about environmental impact criteria (thresholds) to assist in describing when those impacts are best addressed in detail?

Determining the level of detail appropriate to a programmatic analysis requires weighing several factors, including the extent of the interrelationship among proposed actions, the scale and scope of any subsequent decisions, as well as practical considerations of feasibility. Resolving these issues will require the expertise of the agencies responsible for the proposed action informed by the agencies responsible for the potentially impacted resources.[43]

3. Depth of Impact Analysis in Programmatic NEPA Documents

The agency is obligated to conduct a meaningful impact analysis in accordance with NEPA, and that analysis should be commensurate with the nature and extent of potential impacts of the decision being made. A programmatic NEPA review should contain sufficient discussion of the relevant issues and opposing viewpoints to enable the decisionmaker to take a "hard look" at the environmental effects and make a reasoned choice among alternatives.[44] There should be enough detail to enable those who did not have a part in its compilation to understand and meaningfully consider the factors involved.[45]

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[43] *Texas Committee on Natural Resources v. Bergland*, 573 F. 2d 201 (5th Cir. 1978).

[44] Neither Congress nor the courts have indicated precisely how much detail an EIS must contain. However, courts consistently have held that, at a minimum, NEPA imposes a duty on Federal agencies to take a "hard look at environmental consequences." *Natural Resources Defense Council v. Morton*, 458 F.2d 827, 838 (D.C. Cir. 1972). If the EIS provides good faith analysis and sufficient information to allow a firm basis for weighing the risks and benefits of a proposed action, the court will find the EIS to be sufficient. *County of Suffolk v. Secretary of the Interior*, 562 F.2d 1368 (2nd Cir. 1977), *cert. denied*, 434 U.S. 1064 (1978).

[45] *Baltimore Gas and Electric Co v. NRDC*, 462 U.S. 87 (1983).

A broad (e.g., regional or landscape) description may suffice for characterizing the affected environment in programmatic NEPA reviews, so long as potentially impacted resources are meaningfully identified and evaluated. Impacts can often be discussed in a broad geographic and temporal context with particular emphasis on cumulative impacts. Those impacts can often be shown in a meaningful way by displaying a range of potential effects. The scope and range of impacts may also be more qualitative in nature than those found in project- or site-specific NEPA reviews.

It may be more difficult for an agency to analyze the environmental impacts in depth when there is no clear indication – no site- or project-specific proposal pending – for the level of activity that may follow a programmatic decision.[46] A programmatic NEPA review should carefully consider the scope of both the programmatic and the subsequent tiered NEPA review. CEQ's 1981 scoping guidance addressed this issue and the need to be clear about the type of programmatic NEPA review:

> [I]f a proposed program is under review, it is possible that site specific actions are not yet proposed. In such a case, these actions are not addressed in the EIS on the program, but are reserved for a later tier of analysis.[47]

Thus, the deferred analysis should be identified and the intended use of tiering made clear at the outset of scoping, and articulated in the programmatic review. Informing participants and the public of the expected timing of the tiered review(s), as well as the issues and depth of analysis, allows them to concentrate on the issues at hand, rather than on those that will be

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[46] 40 CFR § 1508.23.

[47] Council on Environmental Quality, "Memorandum for General Counsels, NEPA Liaisons, and Participants in Scoping," April 30, 1981.

addressed later. Courts have affirmed NEPA's requirement that Federal agencies document the environmental impacts of proposed broad actions, such as programs, but recognize the difficulty in predicting the level of activity that will occur and that it may not be possible to thoroughly analyze the environmental effects of, and the resource commitments involved in, such a broad proposed activity.[48]

For example, in the PEIS for the Container Terminal Development Plan prepared by the Port of Seattle Marine Planning & Development Department, the port determined that it was impossible to know the precise demand for container service in the future, and therefore it was impossible to predict the precise location, type and timing of specific facilities and their environmental impacts. Recognizing the uncertainties involved, the PEIS evaluated potential environmental impacts and opportunities comprehensively by focusing on a bounded range of potential activities and their impacts. The port's Container Plan projected a low and high range for container service demand and a range of new or improved facilities. The EIS evaluated strategies for meeting low and high range demand and the preferred alternative based on the plan, providing a flexible market-driven approach in recognition of the dynamic nature of the shipping industry and supply of regional container facilities.[49]

D. Mitigation and Monitoring

Programmatic NEPA reviews provide an opportunity for agencies to incorporate comprehensive mitigation planning, best management practices, and standard operating

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[48] *Kleppe v. Sierra Club*, 427 U.S. 390 (1976).

[49] Final Environmental Impact Statement, Container Terminal Development Plan, Port of Seattle Marine Planning & Development Department, 1-17 (October 1991) (on file with the Council on Environmental Quality).

procedures, as well as monitoring strategies into the Federal policymaking process at a broad or strategic level. These analyses can promote sustainability and allow Federal agencies to advance the nation's environmental policy as articulated in Section 101 of NEPA.[50]

By identifying potential adverse impacts early during the broad programmatic planning, programmatic NEPA reviews provide a unique opportunity to modify aspects of the proposal and subsequent tiered proposals to avoid or otherwise mitigate those impacts. A thoughtful and broad-based approach to planning for future development can include best management practices, standard operating procedures, adaptive management practices, and comprehensive mitigation measures that address impacts on a broad programmatic scale (e.g., program-, region-, or nation-wide). These can expedite the preparation of subsequent project- or site-specific proposals by establishing siting, design, operational, or other relevant implementation criteria, requirements, and protocols. The subsequent tiered NEPA review would then include those measures to address potentially significant impacts and focus on the impacts and mitigation alternatives available at the project- or site-specific level that were not considered in the PEA or PEIS.

For example, a Forest Service and Bureau of Land Management PEIS for coal bed methane development on Federal lands in San Juan National Forest established siting and engineering techniques and best management practices to reduce the effects of coal bed methane development on surface water quality, quantity, and use; established a suite of mitigation measures for when pipelines, roads, or power lines crossed a stream, wetland, or riparian area; established the development of site-specific mitigation plans; and required monitoring plans for

[50] 42 U.S.C. § 4331. See also Executive Order 13423, "Strengthening Federal, Energy, and Transportation Management."

individual wells that would disturb wetlands or riparian areas.[51] These types of programmatic decisions provide valuable information for project proponents (e.g., applicants for Federal licenses or rights-of-way) as they design proposals and implementation activities and give the public insight into the kinds of protections that would be afforded in designing and permitting such facilities.

Programmatic NEPA reviews also afford agencies the opportunity to develop monitoring programs to address impacts on a broad scale. This provides agencies the opportunity to ensure that mitigation commitments on the programmatic level are actually being implemented. Further, it allows agencies to determine whether the mitigation measures achieved the environmental outcomes they were designed to accomplish.[52]

Finally, monitoring is critical when agencies establish adaptive management strategies in a programmatic NEPA review to increase their flexibility in managing a program without further NEPA review or in developing and analyzing subsequent proposals for tiered NEPA review. Identifying when a need for changing the course of implementation and the associated effects arises, and analyzing those impacts at the programmatic level, can allow the agency to change the course of implementation without the need for developing supplemental NEPA reviews and

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[51] *San Juan Citizens Alliance v. Stiles*, 654 F.3d 1038 (10th Cir. 2011).

[52] Council on Environmental Quality, "Appropriate Use of Mitigation and Monitoring and Clarifying the Appropriate Use of Mitigated Findings of No Significant Impact," Memorandum for Heads of Federal Departments and Agencies, January 14, 2011. Agencies are encouraged to consider opportunities to integrate the results of a NEPA review into an Environmental Management System as a way to further the environmental sustainability and enhancement policies contained in Section 101 of NEPA; and to use adaptive management to address unintended impacts of a program that might occur over time by using a "predict, mitigate, implement, monitor and adapt" approach (see Council on Environmental Quality, "Aligning National Environmental Policy Act Process with Environmental Management Systems (EMS)," April 2007.

the associated documentation. Ranges of results inform the public and the decisionmaker about which parameters are acceptable for continued management under the proposed adaptive management regime. Monitoring can provide assurance that the environmental impacts have been adequately considered in the programmatic review.

E. Handling New Proposals While Preparing a Programmatic NEPA Review

Agencies are sometimes reluctant to conduct programmatic NEPA reviews because of the risk of delaying ongoing and newly proposed actions. The CEQ Regulations enable interim actions to proceed provided certain criteria are met.[53] Typically, proposed actions of relatively limited scope or scale that would have local utility may be taken as an interim action before completing the programmatic analysis.

The CEQ Regulations address interim action criteria for site- or project-specific EAs or EISs when required PEAs and PEISs are not yet completed.[54] Although the CEQ Regulations address criteria for interim actions specifically in the context of PEISs, in those cases where part of a proposed action needs to proceed while a PEA is being prepared, agencies should use the criteria in the CEQ Regulations. The CEQ Regulations recognize and provide for situations where the programmatic review is not available when the program is at an investment stage or there is a commitment to implementation that will limit future alternatives.[55]

The CEQ Regulations, at 40 CFR § 1506.1(c), state:

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[53] 40 CFR § 1506.1.

[54] 40 CFR § 1506.1 (a) and (c).

[55] 40 CFR § 1502.4(c)(3).

> While work on a required program environmental impact statement is in progress and the action is not covered by an existing program statement, agencies shall not undertake in the interim any major Federal action covered by the program which may significantly affect the quality of the human environment unless such action:
>
> (1) Is justified independently of the program;
>
> (2) Is itself accompanied by an adequate environmental impact statement; and
>
> (3) Will not prejudice the ultimate decision on the program. Interim action prejudices the ultimate decision on the program when it tends to determine subsequent development or limit alternatives.

Under the first criterion regarding independent justification, agencies may take an interim action that the agency determines could be undertaken irrespective of whether or how the program goes forward, assuming the other two criteria are met. For example, in cases where an agency is obligated by law to carry out a proposed interim action, the agency should be able to demonstrate that the action has independent utility.

The second criterion makes it clear that an EIS must be prepared for a proposed interim action that has the potential for significant environmental impacts. Although completion of a PEIS first may be more efficient than preparing an adequate EIS for a proposed interim action, the agency could complete an adequate EIS for the interim action. In cases that do not involve significant impacts, an EA would be sufficient to provide adequate NEPA support to meet this second criterion.

Under the third criterion, agencies may take an interim action when they determine that the proposed interim action would not jeopardize the objective consideration of reasonable

alternatives. Agencies should take care to distinguish interim actions from ongoing actions. An agency does not need to suspend all operations because it has elected to prepare a programmatic NEPA document. For example, in the case of an area-wide or site-wide PEIS considering a new proposed operations plan, ongoing operations within the area or site may continue and such ongoing operations would be considered under the no action alternative in the PEIS.

F. The Decision Document

The decision is documented in a Record of Decision (ROD) following preparation of a PEIS or a decision may be based on a FONSI following preparation of a PEA. The decision document should clearly explain the decision and indicate whether tiered analyses will follow. For example, the agency should articulate its intentions with regard to future decisions, describe how the agency will use the programmatic NEPA document as a basis for tiering future NEPA reviews, and indicate when any deferred issues will be addressed.

The programmatic decision document following a PEA or a PEIS should provide the information required in a ROD. It should include a description of the alternatives considered, the environmentally preferable alternative, economic and technical considerations, agency statutory missions, essential considerations of national policy, and all practicable means to avoid or minimize environmental harm from the alternative selected that were adopted or, if not, why not. A monitoring and enforcement program should also be adopted and summarized for any mitigation where that is applicable.[56]

V. SUBSEQUENT PROPOSAL-SPECIFIC NEPA REVIEWS

[56] 40 CFR § 1505.2(c).

A. Deferred Issues

Certain issues may not be addressed in a PEA or PEIS, but rather are discussed fully in subsequent tiered NEPA analysis. These deferred issues can include issues that will be addressed in additional tribal consultations or further National Historic Preservation Act Section 106 consultation, Endangered Species Act Section 7 consultation, or other determinations and consultations. To provide clarity to the public and the decisionmaker, programmatic NEPA reviews should make clear when the analysis of potential environmental impacts will be deferred and, if possible, any timeframes or criteria for determining when analysis in a subsequent NEPA review is appropriate. When preparing a PEA, it is acceptable for an agency to limit its analysis to those foreseeable effects resulting from the programmatic decision at hand. The programmatic document should clearly explain that while there may be other effects, those other effects do not affect the programmatic decision and full review of those other effects is being deferred. In this case agencies should logically explain why there is no effect on the programmatic decision, and also include sufficient information to explain where and when deferred issues raised by the public and/or regulatory agencies will be addressed.

The scoping process and subsequent public involvement provide an opportunity to clarify why and when subsequent reviews and opportunities for review and comment will take place.[57] The programmatic document should also, whenever practicable, explain when the interested parties will be notified of any subsequent reviews.

B. Tiering NEPA Reviews

[57] See 40 CFR §§1501.7 (scoping), 1501.4 (public involvement in EAs), 1506.6 (public involvement).

One advantage of a programmatic NEPA review is the ability to tier subsequent reviews, such as site- or proposal-specific reviews.[58] Tiering has the advantage of not repeating information that has already been considered at the programmatic level so as to focus and expedite the preparation of the tiered NEPA review(s). When a PEA or PEIS has been prepared and an action is one anticipated in, consistent with, and sufficiently explored within the programmatic NEPA review, the agency need only summarize the issues discussed in the broader statement and incorporate discussion from the broader statement by reference and concentrate on the issues specific to the subsequent tiered proposal.[59]

There are times when an analysis at one level is sufficient. For example, one level of analysis may be appropriate when an agency undergoes rulemaking, adopts an agency-wide policy, adopts a formal plan, or redesigns an existing program. When the programmatic review has taken the required "hard look" at the potential environmental impacts, an agency can rely upon the analysis provided in the PEA or PEIS.[60] On the other hand, an agency may determine that detailed analysis should be deferred to the tiered analysis. The programmatic review must be clear when issues are being deferred, and any subsequent tiered documents will need to review briefly what level of analysis has been considered and whether it is still contemporary.

While CEQ Regulations specifically authorize an agency to tier other NEPA reviews to an EIS, there is no barrier to tiering an EIS to an EA prepared in accordance with NEPA, the CEQ Regulations, and agency NEPA implementing procedures, so long as a sufficient

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[58] 40 CFR § 1502.20. This would not be applicable to all programmatic NEPA reviews; for example, a programmatic NEPA review to establish a land or resource management plan could be sufficient to decide to establish the plan, leaving subsequent project- or site-specific reviews for actions proposed to implement or execute the plan.

[59] 40 CFR § 1502.20.

[60] *Natural Resources Defense Council v. Morton*, 458 F.2d 827, 838 (D.C. Cir. 1972).

explanation for such an approach is proffered. A programmatic NEPA review may defer some decisions, and make use of tiering and incorporation by reference, and still be considered a "hard look." Some of the cases that address "improper tiering" involve situations where an agency attempts to tier a NEPA review to a non-NEPA document and that is not appropriate.[61]

Confusion over what level of NEPA analysis is required for tiered proposals may occur when a programmatic EIS is complete and the site-specific project will have a significant impact as indicated in the programmatic document. When this occurs, the appropriate question is not if there is a significant impact from the proposed action, but if there is a *new* significant impact that was not already considered and addressed in the programmatic review. If there are no new significant impacts, an EA may be appropriate instead of an EIS so long as the aspects of the proposed action that involve significant effects have not changed since the PEIS, and the agency presents its reasons for determining that the effects and potential mitigation measures were adequately considered in the PEIS. Consequently, as an agency determines the appropriate scope for a PEIS, it should consider the potential for significant site- or project-specific impacts and the cost/benefit of addressing them programmatically.

C. New Information and Supplementing Documents

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[61] *Kern v. BLM*, 284 F.3d 1062, 1073 (9th Cir. 2002), the Court found that, "tiering to a document that has not itself been subject to NEPA review is not permitted, for it circumvents the purpose of NEPA." In *Northcoast Environmental Center v. Glickman*, the Court found that, "[a]lthough CEQ procedures allow agencies to incorporate by reference certain materials to cut down on the bulk of an EIS, they cannot 'tier' their site-specific EISs to the broader POC program where the program itself has not been subject to NEPA procedures." Courts have also held that agencies can't properly tier when agencies tier to an outdated PEIS (*League of Wilderness Defenders v. Marquis-Brong*, 259 F. Supp. 2d 115, 1122-23 (D. Or 2003), or an inadequate or flawed PEIS (*Muckleshoot Indian Tribe v. U.S. Forest Serv*., 177 F.3d 800, 811 (9th Cir. 1999)).

The CEQ Regulations provide a procedural framework for keeping environmental analyses current. They require agencies to prepare supplements upon determining there is significant new information of relevance to the proposed action or its impacts.[62] The possibility of new information arising after an EA or EIS is completed exists regardless of whether a NEPA review is programmatic.

When new information reaches an agency, it should be initially screened with respect to the following considerations:

- Does the new information pertain to a programmatic NEPA review that was prepared for a now-completed decision-making process?
- Are there any more decisions to be made by the agency that would use the original NEPA review to meet all or a portion of the agency's NEPA compliance responsibilities for any upcoming decision?
- If there are no further decisions to be made, revising the original programmatic NEPA review serves no purpose and is not required.
- If the new information is relevant to a future decision for which the agency intends to rely upon the original programmatic NEPA review to meet all or a portion of its NEPA compliance responsibilities, then the new information may be

[62] See 40 CFR §§1505.3 (monitoring), 1502.9 (supplementation). See also *Seattle Audubon Society v. Moseley*, 798 F. Supp. 1473, 1482 (D. Wash. 1992) ("A federal agency has a continuing duty to gather and evaluate new information relevant to the environmental impact of its actions, even after release of an environmental impact statement."). However, once a decision has been made on certain proposed actions, such as a decision to establish a plan rather than a decision to implement an action that advances or meets the plan, there is no more "proposed action" for which there is a duty to supplement the NEPA analysis (*Norton v. Southern Utah Wilderness Alliance*, 542 U.S. 55, 73 (2004)).

reviewed in order to determine if it has any potential effect on the content of the original programmatic review, either in terms of: (a) the accuracy of the previously analyzed impacts (direct, indirect or cumulative); or (b) the feasibility of the alternatives presented or their comparative analysis.

- If supplementation is not required, agencies should consider documenting that determination. For example, an agency could include a memorandum to the administrative record for the programmatic NEPA review.

The agency is responsible for making a reasoned determination whether new information raises significant new circumstances or information regarding environmental impacts or involves substantial changes in the actions.[63] When a PEA was used, the determination must consider whether the PEA and FONSI are sufficient or whether an EIS is now necessary. If there is a need to supplement, a supplemental PEA can address the new information and result in a FONSI when such a finding is appropriate.[64]

When an agency determines there is a need to supplement a NEPA review, programmatic NEPA reviews provide alternative ways to complete that supplementation. The traditional approach would be to supplement the base document, the original PEA or PEIS. Alternatively, if a new tiered NEPA review can include consideration of the programmatic issues, then the tiered review can also serve as the vehicle for supplementing the PEA or PEIS. When the new information's effects are limited to potential impacts or alternatives associated with the next stage, or project- or site-specific decision, then the tiered analysis can address the new information without having to supplement the PEA or PEIS.

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[63] 40 CFR § 1502.9.

[64] 40 CFR § 1508.27.

VI. THE LIFESPAN OF A PROGRAMMATIC NEPA DOCUMENT

Agencies must consider and make reasonable efforts to anticipate the length of time the programmatic decision and its supporting NEPA review will be maintained and used for subsequent tiered reviews. Programmatic documents may become outdated and require supplementation or a new analysis, depending on the specificity and analyses included in the PEA or PEIS. There is no fixed timeline or expiration date for a PEA or PEIS. Agencies should determine the factors that may result in the need to supplement or refresh the analysis,[65] establish criteria for evaluating the programmatic document for its use as a basis for subsequent proposal-specific NEPA, and communicate this to stakeholders. When a programmatic review is projected to be used for subsequent decision-making and have a long life span, then the agency should pay close attention to the possible effects of new information.

VII. CONCLUSIONS

This guidance is intended to assist agencies in preparing PEISs and PEAs that address broad, strategic, programmatic level analyses. Agencies should consider using PEAs and PEISs whenever appropriate. Programmatic NEPA reviews provide an opportunity for considering environmental consequences at a broader level and enhance the integration of environmental concerns and mitigations into an agency's planning procedures. In addition, agencies that are

[65] 40 CFR § 1502.9(c).; Refer to question 32 in CEQ's Forty Most Asked Questions ("As a rule of thumb, if the proposal has not yet been implemented, or if the EIS concerns an ongoing program, EISs that are no more than 5 years old should be carefully reexamined to determine if the criteria in Section 1502.9 compel preparation of an EIS supplement.").

able to clearly explain how specific, outstanding, or future actions will be addressed in subsequent tiered documents, and how the analyses will be vetted publicly, will ensure that the public is informed and can improve the quality of participation and analysis agencies receive from the public, thereby enhancing decision-making. This guidance also is intended to assist NEPA practitioners in realizing the benefits of programmatic NEPA reviews. It should be used in conjunction with the regulations and guidance previously issued by CEQ and any applicable agency NEPA procedures established in accordance with 40 CFR § 1507.3.

# # #

Appendix A: Programmatic and Tiered Analyses

Programmatic and tiered analyses differ in their focus and scope. The following table indicates the general differences between programmatic and subsequent tiered analyses.

	Programmatic Level (e.g., Tier 1)	**Subsequent (e.g., Project- or Site-Specific or Tier 2) Tiered Level**
Nature of Action	Strategic, conceptual	Construction, operations, site-specific actions
Level of Decision	Policy, program, planning, suite of similar projects	Individual project(s)
Alternatives	Broad, general, research, technologies, fiscal measures, socioeconomic, land use allocations	Specific alternative locations, design, construction, operation, permits, site-specific
Scale of Impacts	Macroscopic, for example, at a national, regional, or landscape level	Project level, mainly local
Scope of Impacts	Broad in scale and magnitude	Localized and specific
Time Scale	Long- to medium-term (e.g., Regulatory)	Medium- to short-term (e.g., Permit)
Key Data Sources	Existing national or regional statistical and trend data, policy and planning instruments	Field work, sample analysis, statistical data, local monitoring data
Impacts	Qualitative and maybe quantitative to the degree possible	Generally quantifiable (though not always)
Decision	Broad, strategic program, policy, or plan	Detailed, project- or site-specific, action-oriented
Mitigation	General, broad suite of potential measures that could be applied after site-specific analysis	Specific, precise refinement of measures identified at the programmatic level

Table based on "Strategic Environmental Assessment (SEA) - current practices, future demands and capacity-building needs", a course manual by Maria Rosário Partidário, International Association for Impact Assessment Training, 2003. mp@fct.unl.pt

Appendix B: Sample Programmatic Analyses:

Example of Broad or Programmatic Analysis	Why Analysis Was Used	Tiered Actions for Further Analysis or Action	How Stakeholders Become Aware of Further Analysis or Actions
Geographic or regional action *Ex: DOT "Transportation Corridor" Tier I EIS*	*The EIS examines broad issues such as general location, mode choice, air quality, and land use implications of major alternatives*	*As site-specific projects are identified, each project will have a separate Tier II EA/EIS. Tier I EIS specifies decisions which must be resolved in Tier II documents.*	*Each site-specific Tier II project will have its own public involvement process, as specified in the Tier I EIS and ROD.*
Agency policymaking *Ex: USDA Fruit Fly Cooperative Control Program Final Environmental Impact Statement (EIS)—2001*	*Introduction of Invasive Fruit Fly species can occur at multiple potential sites throughout the United States. The EIS evaluates broad issues such as potential locations, control strategies, mitigation measures, and cumulative impacts avoids segmentation of analyses and provides basic information to foster efficiency by focusing the scope on critical issues that will be analyzed for site-specific assessments.*	*The detection of a non-native, invasive fruit fly species introduction at levels determined to be sufficient for establishment is the trigger for agency action and the preparation of a site-specific EA tiered to the EIS.*	*Each site-specific EA has its own public involvement process with associated public comment period.*

Range of activities and operations within a facility *Ex: Department of Energy (DOE) Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs (DOE/EIS-0203, April 1995).* *http://energy.gov/node/368803*	*The EIS supports two sets of decisions: (1) DOE-wide programmatic decisions on spent nuclear fuel (SNF) management (Volume 1), and (2) site-wide decisions on the future direction of environmental and waste management programs at the Idaho National Engineering Laboratory (now called the Idaho National Laboratory (INL) (Volume 2). This document has a "hybrid" character in that it served to (a) inform the broad DOE-wide and INL site-wide decisions and (b) to enable implementing decisions for a defined set of project-specific actions at INL.*	*In the analysis of broad DOE-wide SNF program alternatives, the PEIS considered the individual and collective environmental impacts of ongoing activities at INL and also reasonably foreseeable future projects. In addition to informing implementation decisions for a defined set of specific proposed projects at INL, other foreseeable projects also were analyzed to ensure adequate cumulative impacts analysis. The "trigger" for further analysis would be a DOE proposal to implement one of the other specific projects.*	*If DOE proposes to implement a specific project, additional NEPA review (e.g., an EA or EIS) would be conducted, with appropriate further public participation. DOE has completed several such tiered EISs under this PEIS (for example, DOE issued an EIS for the Advanced Mixed Waste Treatment Facility in Idaho, DOE/EIS-0290, January 1999: http://energy.gov/node/573151).* *In addition, DOE prepared five Supplement Analyses per DOE NEPA procedures (10 CFR 1021.314(c)). Based on these analyses, the most recent of which was issued in 2012, DOE determined that a supplemental or new PEIS was not required.*

U.S. Army's Programmatic Environmental Assessment: Army Net Zero Installations. http://aec.army.mil/Portals/3/nepa/Net_Zero_PEA.pdf	*The PEA evaluates various behaviors, processes, and technologies that can be used to achieve Net Zero and the associated environmental impacts and mitigation. The PEA supports the decision whether to implement Net Zero Army-wide, to strategically implement Net Zero based on mission needs and return on investment, or to not implement Net Zero; and it provides analysis that installations can draw on as they explore measures and processes that can be used in their site-specific analyses.*	*The PEA provides an analysis of the environmental, social, and economic issues at a programmatic level. After evaluation of mission needs, consumption and existing resource constraints at installations, potential Net Zero projects representing a broad spectrum of possible energy, water and waste related projects may be implemented.*	*All installation-specific actions to implement Net Zero will require an appropriate level of supplemental NEPA analysis and documentation, with appropriate level of public involvement.*

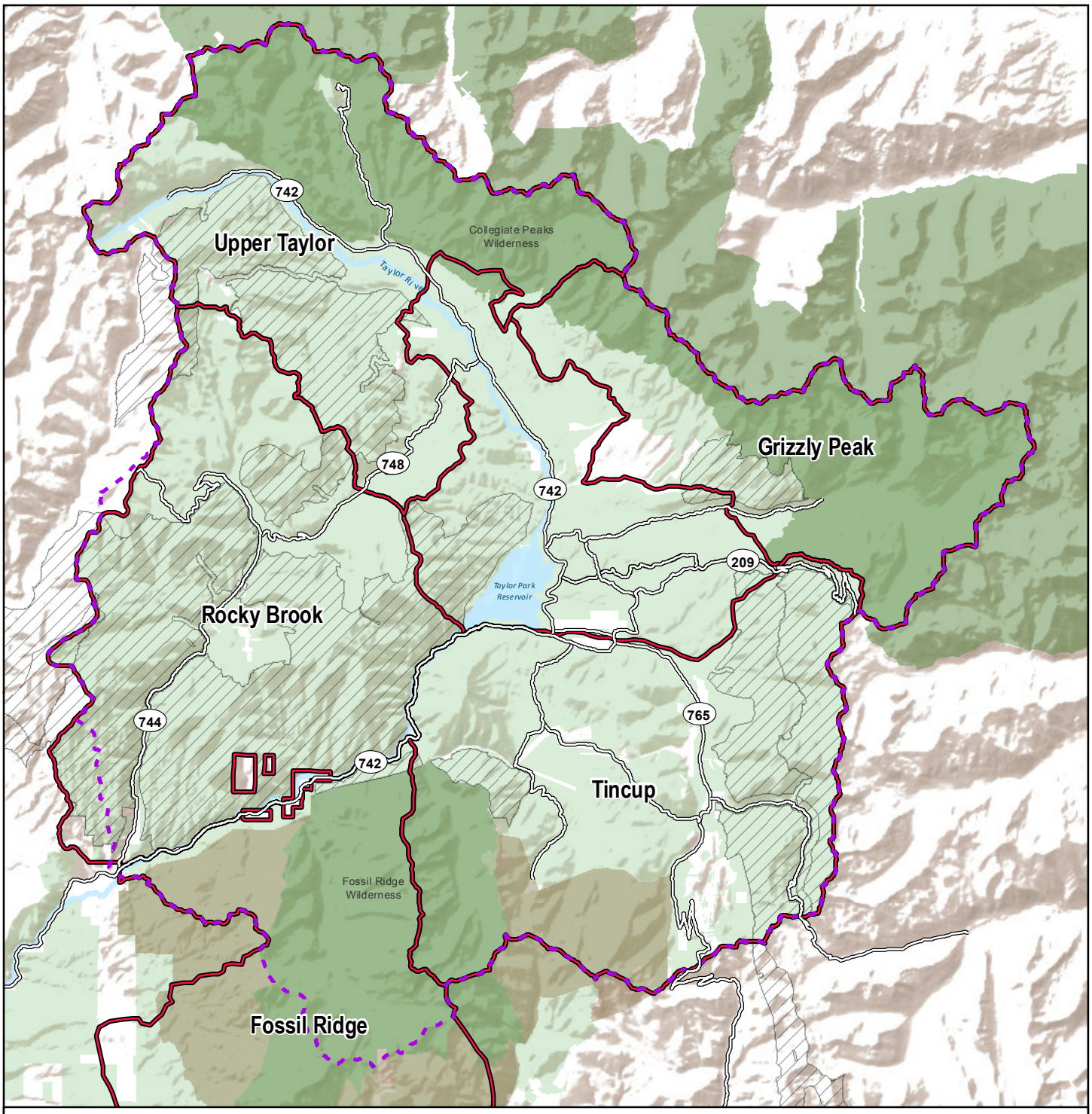
"Technical Program" with a combination of known elements or conditions *Ex: NASA's environmental assessment for routine payloads on expendable launch vehicles.* http://www.nasa.gov/pdf/603832main_FINAL%20NASA%20Routine%20Payload%20EA%20Resized.pdf	*Analyzed common launch vehicles, two common launch sites, and broad classes of payload risk. Allowed short-turnaround of projects within known risks.*	*Each new project completes a checklist to identify launch vehicle, launch site, and payload. Any of these parameters outside of those listed in the EA would result in a supplemental analysis (e.g. project EA).*	*Supplemental analyses (where required) are publicly announced in a manner similar to the original Programmatic EA (regional newspapers, local public meetings, etc.)*
National Science Foundation's Final Programmatic Environmental Impact Statement/Overseas Environmental Impact Statement for Marine Seismic Research funded by the National Science Foundation or Conducted by the U.S. Geological Survey. http://www.nsf.gov/geo/oce/envcomp/usgs-nsf-marine-seismic-research/nsf-usgs-final-eis-oeis_3june2011.pdf	*The PEIS examines the potential impacts that may result from marine geophysical seismic surveys conducted from research vessels in support of scientific research. The programmatic NEPA approach provides a format for a comprehensive cumulative impacts analysis by taking a view of marine geophysical research and survey activities as a whole.*	*Cruise-specific EAs would be prepared when a proposed seismic research activity is not covered by the PEIS, such as a proposed survey that uses a new technology or survey location not analyzed in sufficient detail.*	*Subsequent cruise-specific NEPA documents or other appropriate environmental documents would use the framework of the programmatic document and include appropriate public involvement.*

USDA National Gypsy Moth Management Program Programmatic Supplemental EIS *http://www.na.fs.fed.us/pubs/detail.cfm?id=5251*	*Analyzed the human health and ecological risk assessments for each pesticide approved for use in the Gypsy Moth Eradication Program thereby eliminating the need for such analysis when individual spraying projects are proposed. The PEIS analyzed and disclosed these risks, and deferred to site or project level analyses the specific application of these risk data to how the insecticides would be used in a given project (e.g., dose rates, number of applications, presence of "sensitive populations") and other specific issues and concerns raised during scoping.*	*As site-specific projects are identified, each project will have a separate Tier II project analysis and documentation. Tier I EIS specifies decisions which must be resolved in Tier II documents. All required consultations (both federal and state) are implemented at the project level.*	*Each site-specific Tier II project will have its own public involvement process, as specified in the Tier I EIS and ROD. Proposals on Federal lands will be on the Forest Service list of proposed projects on the "schedule of proposed actions" available online--http://www.fs.fed.us/sopa. Proposals on other lands will notify interested and affected parties according to their requirements (usually State, county, and local).*

US Forest Service land management plans	*The EIS examines the effects of approving a land management plan or amendment. Plans consist of plan components (goals, desired conditions, objectives, suitability of lands, standards, and guideline). The plan indicates where the plan components apply (entire plan area or part of the plan area). Because subsequent project proposals must be consistent with the plan components, the Plan EIS describes in general terms the expected effects of management during the plan period.*	*All project proposals for the National Forest System lands covered by the plan.*	*The public may become aware through NEPA "scoping" and the Forest Service list of proposed projects on a "schedule of proposed actions" available online--http://www.fs.fed.us/sopa*

US Forest Service regional invasive plant program analysis and subsequent decision adding management direction to all national forests in Oregon and Washington.	*Invasive Plant FEIS examined a range of options for integrated invasive plant management including prevention, treatment, restoration, and monitoring. Provided updated herbicide risk assessment information. Contains interagency agreement on monitoring framework. Amended all national forest plans in Oregon and Washington based on best available science and most recent agency policies.*	*Having the regional programmatic FEIS allows the Forest Service to focus site-specific effective prevention measures applied to various land use decisions and tier to the 2005 FEIS for invasive plant treatment. This allows the Forest Service to narrow the scope because alternatives such as using herbicides as a last resort have been addressed in the programmatic analysis.*	*Site-specific projects are on the Forest Service list of proposed projects on the "schedule of proposed actions" available online--http://www.fs.fed.us/sopa. The regional 2005 Invasive Plant Mgt ROD is clear that subsequent NEPA applies to projects on the ground. Public involvement is requested for each site-specific project based on local and some regional outreach with follow up depending on interest.*

Taylor Park EA Planning Area LAUs



Lynx Analysis Unit

Planning Area

Roadless

Wilderness

Fossil Ridge RMA

National Forest System Land

Main Roads

0 2.5 5 Miles

N W E S

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