Literature Review: Post-Disturbance Harvest

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Executive Summary

Senate Bill 1501 (2022) directed that the Oregon Board of Forestry ("Board") complete rulemaking related to post-disturbance harvest. The PFA Report offered recommendations to guide the rulemaking process, including that the Oregon Department of Forestry ("Department") review literature related to post-disturbance harvest to help inform the Board's decision making about next steps in the rulemaking process. The literature review method used was a rapid review, a rigorous, modified, systematic evidence review (SER) that can be performed in a shorter time period than a full SER. The purpose of this review is to determine whether the post-catastrophic event alternative vegetation retention prescriptions described in Oregon Administrative Rules (OAR) 629-643-0300(3) are effective in avoiding, minimizing, or mitigating effects on riparian areas and aquatic habitat.

Current rule is intended to ensure stream shade, large woody debris, bank stability, and quick establishment of a healthy stand in riparian areas where there is not sufficient vegetation to protect water quality and fish and wildlife habitat without intervention (OAR 629-643-0300 (3)). As different disturbance types result in different impacts on the landscape, they have varied impacts on riparian areas and streams. Appropriate management prescriptions may therefore be site dependent. Outcomes are dependent on pre-disturbance site conditions, the disturbance's effects on the landscape, and interactions between post-disturbance harvest and disturbance impacts.

Several key findings about stream shade emerged from the literature we reviewed. In the absence of live trees, dead trees provide more stream shade than no trees. Rapidly growing hardwoods, particularly red alder (*Alnus rubra*), provide better stream shade than slowly growing conifers in the time period immediately after a disturbance. Impacts on water temperature resulting from post-disturbance harvest depend on the percentage of live and dead trees present after a disturbance, the level of stream flow, and whether streams interact with groundwater.

With respect to large woody debris and bank stability, the location of large wood in a stream network determines how it interacts with the stream. Pre-disturbance conditions and the nature of the disturbance type affect whether it is appropriate to retain or remove large wood from riparian

areas. Several studies showed that post-disturbance harvest can deplete the large woody debris supply in ways that impair riparian and aquatic ecological function. When riparian buffers are applied, disturbance type appears to have a greater effect on bank stability than post-disturbance harvest. Both soil erosion and bank instability from disturbances and post-disturbance harvest were, in turn, found to have negative effects on water quality and aquatic habitat. Stands that were healthy before fire, however, were found to regenerate on their own and, through sprouting, could begin to stabilize banks within two to five years.

With respect to stand regeneration, we found that pre-disturbance conditions and the nature of the disturbance affect stand regeneration outcomes. 'No-cut' zones near streams mean that post-disturbance harvest and replanting are less likely to occur in those areas. Unmanaged riparian stands tend to be dominated by hardwoods rather than conifers.

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Introduction

Natural forest disturbances include events like fire, floods, debris flows, insect infestations, disease outbreaks, and seismic events like earthquakes and volcanic eruptions. These disturbances can change forest ecosystems' vegetation structure, species composition, and geomorphology. In the Pacific Northwest, notable historical disturbances have included the Tillamook Burns between 1933 and 1951, the eruption of Mount St. Helens in 1980, and the storms and subsequent landslides in 1996.

More recently, the 2020 Labor Day fires burned over one million acres of forestland, primarily in the western Cascades. Nearly half of the burned area was in private timberland. When a catastrophic disturbance like the Labor Day fires occurs, landowners, timber operators, and other members of the forest sector may salvage damaged timber to recover losses and promote reforestation. In the case of the 2020 fires, salvage logging and subsequent processing activities were projected to recover approximately $2.6 billion (Rasmussen et al. 2021). Timber quality of dead and damaged trees can deteriorate quickly due to physical changes and the activity of insects and decay fungi. These changes mean that profitability of salvage logging declines within about two years (Rasmussen et al. 2021). Salvage activities after catastrophic disturbance, however, can result in complex and context-dependent impacts on riparian ecosystem recovery and stand re-establishment (Reeves et al. 2006).

As part of the Private Forest Accord (PFA) Report (Private Forest Accord 2022) the PFA authors provided recommendations to the Oregon Department of Forestry ("Department") about post-disturbance harvest rulemaking. This report served as the foundation for significant changes to the Forest Practices Act (Chapter 33, Oregon Laws 2022). As part of these statutory changes, the Oregon Legislature mandated that the Department complete post-disturbance harvest rulemaking by no later than November 30, 2025 (Section 6, Chapter 33, Oregon Laws 2022).

Riparian area prescriptions after catastrophic events are currently provided in rule only for situations where there is not enough vegetation remaining after a disturbance for a streamside forest stand to protect fish and wildlife or water quality over time (OAR 629-643-0300(1)). These prescriptions are meant to provide stream shade, large wood, bank stability, and quick and healthy stand establishment in riparian areas after a catastrophic disturbance. Oregon

Administrative Rules (OAR) 629-643-0300(3), the alternative prescription applied after a catastrophic disturbance, "applies to streamside stands that have been damaged by wildfire or by catastrophic windthrow, or by insect or disease mortality" and "is intended to provide adequate stream shade, woody debris, and bank stability for the future while creating conditions in the streamside area that will result in quick establishment of a new and healthy stand."

Before the Department can make changes to existing rules, the Board of Forestry ("Board") is required to evaluate those rules to determine if they cause or have the potential to cause degradation on the landscape (ORS 527.714(5)(a)(A)). The PFA Report (2022) recommended that the Department assist the Board in making this determination by evaluating current rules' effectiveness in meeting PFA goals, particularly those of creating greater business, environmental, and regulatory certainty (Private Forest Accord 2022, 6). This review alone does not constitute the Oregon Revised Statutes (ORS) 527.714 procedure. Rather, this review specifically addresses subsection (5)(a)(A). That is to say, it provides information required for the Board to determine if there is "evidence that documents that degradation of resources maintained under ORS 527.710(2) … is likely" and provides the board with additional information necessary for the ORS 527.714 process (see ORS 527.714(5)(a)(A)).

The purpose of this review is to determine whether the post-catastrophic event alternative vegetation retention prescriptions described in OAR 629-643-0300(3) are effective in avoiding, minimizing, or mitigating effects on riparian areas and aquatic habitat.

Method

This literature review is a rapid review (Abou-Setta et al. 2016) , a rigorous, modified, systematic evidence review (SER) that can be performed in a shorter time period than a full SER. These modifications allowed us to meet the statutorily required timeline to engage in rulemaking and the timeline for inclusion in the Private Forest Accord Habit Conservation Plan. Our approach retained the key features and rigor of a systematic evidence review but excluded time-consuming procedures that could not be undertaken in the time available to complete this review, like searching for and translating any available studies published in languages other than English (Livoreil et al. 2017; Mengist, Soromessa, and Legese 2020; Pullin et al. 2022). With the intent to fully document our process and to ensure transparency and reproducibility (Xiao and Watson

2019), the team followed the Collaboration for Environmental Evidence (Pullin et al. 2022) guidance to develop a study protocol before starting the review. The protocol used a similar, previous review of the topic (Barrett and Reilly 2017) to identify search terms. Redundant terms were removed, relevant terms were added, and the list was formatted for use with academic and federal research databases. In addition to searching peer-reviewed journal articles and technical reports, ODF staff reached out to 56 external subject matter experts to discuss the project and request recommendations for other peer-reviewed articles and reports. We also received feedback from internal subject matter experts and engaged in a public input session.

ODF staff manually screened more than 2,200 articles and reports from all sources. All screeners used the same predetermined systematic selection criteria to determine whether an article met six criteria for inclusion in the review (Table 1). Each article was screened iteratively, in up to three phases. If it was clear from the article title that any one of the criteria were not met, the article was removed from consideration. If a reviewer could not determine whether all criteria were or were not met by reading the title, the same criteria were applied to the abstract. The procedure was then repeated for the remaining articles by reviewing the full article text.

Table 1. Article Selection Criteria

Category	Criterion
Location	Location must be ecologically similar to Eastern Oregon, Western Oregon, or both
Resource	Riparian area, stream or other flowing body of water, stream-adjacent wetland, aquatic habitat
Disturbance	Fire, weather event, natural disaster, insect infestation, disease outbreak
Treatment	Salvage with seeding/replanting, salvage without seeding/replanting, natural regeneration
Outcome	Stream shade, woody debris/large wood, bank stability

All articles and reports selected for this literature review were read and analyzed by multiple staff members as part of the selection process. Forty-seven articles met the selection criteria and were included in the analysis that follows.

Post-Disturbance Harvest Rules and Impacts on Natural Resources

OAR 629-643-0300(3) begins with a statement of intent: "This alternative prescription is intended to provide adequate stream shade, woody debris, and bank stability for the future while creating conditions in the streamside area that will result in quick establishment of a new and healthy stand." It should be noted that this rule only applies to situations where there is stand-level mortality from a natural disturbance and there is insufficient vegetation to meet the desired future condition (DFC) described in OAR 629-643-0000. In OAR 629-643-0000(3), the DFC is to grow and retain vegetation so that average conditions across the landscape become similar to conditions of mature streamside stands. Mature streamside stands are characterized as having a stand age of 80 to 200 years and are generally made up of multi-aged trees of appropriate and varied density.

As part of the basis for the Board's analysis under ORS 527.714(5)(a)(A), the Board must determine whether a current rule causes or has the potential to cause degradation on resources described in ORS 527.710(2). ORS 527.710(2) states that rules shall provide for the overall maintenance of soil productivity, air quality, water resources, and fish and wildlife. The sections in this review are organized by the four resources described in OAR 629-643-0300(3): stream shade, large woody debris, bank stability, and quick, healthy stand regeneration. In each section we describe the relevant post-disturbance harvest rules and their subsections, synthesize scientific literature addressing the impacts of post-disturbance harvest on the resource, and show how these synthesized findings relate to resources described in ORS 527.710(2).

While we performed an extensive search and reviewed over 2,000 documents to select the studies we included in this review, post-disturbance harvest in riparian areas has not been studied extensively because the contemporary use of riparian buffers means that post-disturbance harvest near streams does not occur as frequently as it did in the past (e.g., Goodman et al. 2022). Additionally, such studies can only take place if a catastrophic event has, in fact, occurred. The timing of this study meant that research related to the 2020 fires has, for the most part, not been published. Finally, only two of the selected studies related to post-disturbance harvest in this literature review evaluated post-disturbance harvest that was conducted under Oregon

Administrative Rules (Coble et al. 2023; Slesak, Schoenholtz, and Evans 2015). Coble et al. (2023) further cautioned that as salvage was ongoing while they conducted their study, so studies of impacts from salvage “may be better explored in subsequent years” (6).

Stream shade

Rule description

In OAR 629-643-0300(3), the vegetation retention goals in subparagraphs (b), (c), and (d) contain prescriptions intended to contribute to stream shade. This rule requires operators to retain live and dead trees within 20’ of the high-water level for large and medium streams and within 10’ of the high-water level for small streams. Tables 5 and 6 in OAR 629-643-0300(3) provide basal area retention minima by stream size and type. These tables are currently constructed so Table 5, which provides basal area retention recommendations for fish-bearing streams, does not encourage the retention of hardwoods next to those streams. Table 6, on the other hand, provides for hardwood retention targets in basal area calculations. This table applies to non-fish-bearing streams. The current long-term DFC is for streamside stands to resemble mature (80- to 200-year-old) stands over time (OAR 629-643-0000(3)). This rule also acknowledges, however, the diversity of Oregon tree species, as well as the faster rate at which hardwoods and some conifers grow.

Literature synthesis

In the Oregon Coast Range, Nierenberg and Hibbs (2000) found that, historically, over half of surveyed sites that had never been harvested had little to no shade along streams, indicating that variability on the landscape is a norm. Similarly, a modeling experiment in Eastern Oregon indicated that stream shade may not be naturally present in many historically unharvested riparian areas, and that riparian stand structure across the landscape varies based on specific site attributes, natural disturbance histories, and site capacity (Nierenberg and Hibbs 2000; Wondzell, Hemstrom, and Bisson 2007). This background variation in riparian forests influences post-disturbance levels of stream shade (Halofsky and Hibbs 2009).

In addition to the pre-disturbance conditions, two post-disturbance factors determined how much stream shade was present following disturbance in the studies we examined for this review. The first factor, shade retention, describes the amount of living or standing dead trees or shrubs retained after disturbance to provide stream shade. The second factor, shade recovery, describes resprouting and growth of trees that survived the disturbance as well as germination and growth of seedlings to provide increased stream shade over time. We found three studies that described the impacts or likely impacts of post-disturbance harvest on indicators of stream shade retention and recovery following a catastrophic disturbance. One study directly compared stream canopy cover percentage between sites with tree mortality only from mountain pine beetle infestation and sites that had been additionally salvaged (Rex et al. 2009). Two other studies measured shade provided by living and dead standing vegetation following mixed-severity wildfires to estimate the effects of post-disturbance harvest (Amaranthus, Jubas, and Arthur 1989; J. A. Leach and Moore 2010). The detailed results of these studies are described below.

In British Columbia, Rex et al. (2009) identified pairs of stream reaches in 18 watersheds affected by stand-level mortality from mountain pine beetle. One reach in each watershed had been salvaged within the last five years and one had not been harvested. The researchers measured two indicators of stream shade: percent canopy cover and light levels at the stream surface during the periods of highest solar radiation (10 AM to 2 PM in August). They found that salvaged areas had significantly less stream canopy cover (55%) than unharvested mountain pine beetle affected areas (65%). Similarly, stream reaches in salvaged areas received significantly more light than those in unharvested beetle-affected areas. The interactions between shade, light levels, and water temperature will be discussed in relation to water quality in a later section.

Amaranthus, Jubas, and Arthur (1989) found that one year after high-intensity wildfire in the Klamath Mountains, percent canopy cover of the stream provided by dead vegetation (17%) during the summer maximum temperature period was three times greater than cover from topography alone (5%) and two times greater than cover from live vegetation (7.4%). Four years after a mixed-severity wildfire on Fishtrap Creek in British Columbia, Leach and Moore (2010) estimated that standing dead trees reduced net solar radiation reaching the stream during mid-August by about one third (modeled daily peaks of 675 W/m^2 excluding shade provided by dead trees compared to 500 W/m^2 including dead trees). These three studies show that shade responses to disturbance and real or estimated post-disturbance harvest are variable. Together, they suggest that, particularly in areas of high disturbance severity where few live trees remain, retention of dead riparian vegetation can provide significant shade in the first five years following disturbance.

Different species of riparian vegetation provide different rates and levels of stream shade recovery in the first decade following disturbance. Specifically, shade from rapidly regenerating hardwood seedlings and sprouts recovers more quickly following riparian disturbance than shade from slowly regenerating conifers (Halofsky and Hibbs 2009; Martin, Wasserman, and Dale 1986). Red alder (*Alnus rubra*) appears particularly suited for rapidly restoring stream shade (D'Souza et al. 2011; Martin, Wasserman, and Dale 1986).

Relationship to ORS 527.710(2)

We found no literature linking disturbance and post-disturbance harvest's effects on stream shade with impacts to soil productivity and air quality. However, the other two resources listed in ORS 527.710(2), water resources and fish and wildlife, are strongly linked to disturbance's and post-disturbance harvest's effects on stream shade. Temperature is a key indicator of water quality and habitat suitability for many native fish. Several studies examining disturbance and/or post-disturbance harvest impacts described the complex relationship between light, shade, water temperature, stream flow, and groundwater interactions. Rex et al. (2009) found that post-disturbance harvest of mountain pine beetle killed trees in British Columbia resulted in decreased canopy cover, increased light penetration, and increased air temperature compared to non-salvaged areas. Streams with wetland or lake sources were significantly warmer downstream of salvaged areas compared to non-salvaged areas. No difference in downstream temperature was observed for salvaged and non-salvaged areas of headwater streams. Leach and Moore (2008; 2010) found a similar pattern of water temperature following wildfire (without post-disturbance harvest), where groundwater entry into streams mitigated the effects of shade loss.

Two studies (Amaranthus, Jubas, and Arthur 1989; J. A. Leach and Moore 2010) found that dead riparian vegetation was a dominant source of stream shade, with one finding that both lower streamflow and lower total shade were associated with increased stream temperature following wildfire (without post-disturbance harvest) (Amaranthus, Jubas, and Arthur 1989). Taken together, these results suggest that post-disturbance harvest has the greatest potential to degrade short term water quality when high-severity disturbance kills large proportions of total riparian trees, streams have relatively low flow, and streams have little interaction with groundwater.

Large woody debris

Rule description

OAR 629-643-0300(3) encourages the recruitment and delivery of large woody debris (LWD) to streams by requiring operators to retain fallen and windthrown logs, including logs that have fallen in the stream. The rule incentivizes retaining down wood and retaining dead and dying trees, which have the potential to deliver large wood as they die and fall, by allowing them to count double toward basal area retention after live conifers have been given priority.

Literature synthesis

The effects of post-disturbance harvest on LWD recruitment and delivery are variable, in part because the effects of disturbance on LWD are variable. When disturbance removes most of the LWD from riparian areas, as in the case of high-severity fire or scouring flood or mud flow, LWD recruitment can take decades to recover (Berg, Azuma, and Carlson 2002; Coble et al. 2023). When certain disturbances extend into upland forests (e.g. Mount St. Helens eruption, or mixed-severity fire) they can create a supply of riparian wood that may be delivered to streams over time (Lisle 1995; Flitcroft et al. 2016). By definition, post-disturbance harvest of riparian areas decreases the total volume of large woody debris and changes its distribution among standing dead trees and logs (Kennedy and Spies 2007). The impacts of this removal and structural change from post-disturbance harvest may depend on the status of the LWD supply following the disturbance and will be discussed below in the ORS 527.710(2) resources section.

Beyond describing changes to volume and structure of LWD, the riparian post-disturbance harvest literature highlighted contrasting roles of hardwoods and conifers. Riparian hardwoods, particularly red alder, may provide more and larger woody debris more quickly than conifers following both stand-replacing and lower-severity disturbance (Beechie et al. 2000; Coble et al. 2023; Martin, Wasserman, and Dale 1986).

Relationship to ORS 527.710(2)

We found no literature linking disturbance and post-disturbance harvest's effects on LWD with impacts to air quality. LWD can contribute to soil productivity by preserving bank stability, but effects of post-disturbance harvest on these processes are discussed in the bank stability section to follow. Post-disturbance harvest's effects on LWD can impact both water resources and fish and wildlife.

Both disturbance and salvage change the total amount and the dimensions of LWD. The size of channel-spanning wood and wood capable of resisting high flows and creating jams will be dependent on individual stream characteristics. Therefore, not all combinations of large wood and stream characteristics will result in the same in-stream structure or habitat creation (Beechie et al. 2000). However, several studies showed that post-disturbance harvest can deplete the LWD supply in ways that impair riparian and aquatic ecological function.

In British Columbia, Rex et al. (2009) examined the impacts of insect infestation and post-disturbance harvest on multiple riparian and aquatic ecosystem indicators, including qualitative assessments of in-stream wood and riparian large wood supply. Compared to unsalvaged areas, areas that had been salvaged met fewer criteria for riparian area health. While multiple riparian and aquatic indicators contributed to the overall health assessment, large woody debris supply was specifically mentioned as contributing to poor scores for salvaged areas. The authors tested buffer widths ranging from about 10 to 33’ (3 to 10 m) and found that 33’ (10 m) buffers were the minimum width at which riparian area health was consistent with unsalvaged riparian areas. The study recommended live tree retention in riparian areas as well as selective dead tree retention where necessary to preserve short- and middle-term large woody debris recruitment supporting aquatic ecosystem health.

A study within the blowdown/scorch zone around Mount St. Helens compared unharvested naturally regenerating areas with salvaged and planted areas. The exact nature of the salvage and planting with regard to riparian buffers is not detailed in the study. At the time of study, 27 years following the eruption, the unharvested areas were characterized by high levels of downed logs, snags, and regenerating vegetation. In contrast, the salvaged and planted areas were characterized by greater overstory canopy but little LWD, understory, or litter depth (Spear, Crisafulli, and Storfer 2012b). The study compared the genetics of populations of coastal tailed frogs between these two management areas and found genetic signs of restricted movement and/or reproduction in areas of post-disturbance harvest and replanting. The authors provide evidence that these frogs are especially reliant on riparian corridors in the salvaged areas and suggest that the landscape-level reduction in LWD and understory vegetation may have contributed to restricted movement and/or reproduction.

While most studies about LWD examined discrete sites, several studies advocated thinking at the level of the stream network when managing large wood (Czarnomski et al. 2008; Goodman et al. 2022; Flitcroft et al. 2016). The authors of these studies found that local large wood conditions are impacted both by local and upstream characteristics, and that fish and wildlife may depend on different parts of a stream network throughout their lifecycles.

Bank stability

Rule description

In OAR 629-643-0300(3), the vegetation retention goals in subparagraphs (b), (c), and (d) contain prescriptions intended to contribute to bank stability. This rule requires operators to retain live and dead trees within 20' of the high-water level for large and medium streams and within 10' of the high-water level for small streams. Tables 5 and 6 of OAR 629-643-0300(3) provide basal area retention minima by stream size and type.

Literature synthesis

Current forest practices rules require retention of streamside vegetation to protect from the additional soil destabilization and sediment delivery that would occur if trees were not adjacent to streams. Our literature search did not find articles that examined a direct relationship between post-disturbance harvest in riparian areas and bank stability, likely because most studies took place after the application of riparian buffers and streamside no-cut areas became common practice. Instead, the included studies examined indirect effects to bank stability from post-disturbance harvest that took place upslope. Several studies about post-disturbance harvest's effects on bank stability investigated multiple disturbances over long time periods. These studies examined disturbance impacts at the landscape scale (Goodman et al. 2022; Wondzell, Hemstrom, and Bisson 2007; Zhang and Wei 2014). In one study area, some salvage took place before applying riparian buffers was a common practice (Goodman et al. 2022). Another study was a modeling experiment that estimated salvage impacts on the landscape as part of a broader examination that included livestock grazing in modeled human impact estimates (Wondzell, Hemstrom, and Bisson 2007). In the synthesis that follows we note where the impacts of post-disturbance harvest cannot be separated from other forestry activities or the impacts of disturbance alone.

In a study conducted in the Western Oregon Cascades, Goodman et al. (2022) found that historical forest practices' interactions with regional geomorphic processes had direct impacts on watershed responses to disturbance. Reforested stand ages at the time of the study were 40 to 70 years old, and watershed conditions had stabilized, with debris movement on the study site returning to pre-disturbance levels over that time. It should be noted that the results of this study did not distinguish between impacts from salvage and impacts from forestry activities conducted under normal conditions. Wondzell et al. (2007) modeled post-colonization activity in the Blue Mountains of Eastern Oregon and found that current land management practices, including clearcuts, post-disturbance harvest, and grazing, could result in 60% of stream reaches lacking bank stability in 120 years. This study did not focus solely on the impacts of post-disturbance harvest, so it is unclear what or how much that specific activity contributed to the instability. In contrast to Goodman et al (2022), Wondzell et al. (2007) estimated that passive restoration of Grand Ronde River riparian areas would result in quick recovery of bank stability by some stream types and very slow recovery by others. Like the previous two studies, Zhang and Wei (2014) did not separate the effects of post-disturbance harvest from the impacts of the natural disturbances that preceded it. However, the authors noted that removal of trees from the landscape can lead to earlier and greater streamflows as a result of increased snowmelt, which in turn can reduce bank stability. These changes have direct and immediate negative impacts on fish that depend on these streams for spawning grounds (Zhang and Wei 2014; see also Forest Practices Board 2007). In this British Columbia watershed, salvage took place while the ground was frozen to reduce the impacts of heavy machinery on the landscape. The authors also noted that heavy equipment use when soils are not frozen can decrease soil stability.

Finally, in British Columbia, Rex et al. (2009) examined the impacts of insect infestation and post-disturbance harvest on multiple riparian area health indicators, including qualitative assessments of bank stability. Areas that had been salvaged met fewer criteria for riparian area health than unsalvaged areas, but the relative contribution of bank stability compared to other indicators in the decreased health scores was not reported. This research team tested buffer widths ranging from 10 to >130' (3 to >40 m) on each side of streams and found that 33' (10 m) buffers were the minimum width at which measures of riparian area health, including bank stability, were similar to the measures in unharvested riparian areas.

Relationship to ORS 527.710(2)

Sediment delivery to streams and turbidity are key water quality metrics the Board may evaluate under ORS 527.714(1)(c) and ORS 527.710(2). Unstable stream banks contribute sediment to streams, which in turn can interfere with both water quality and fish and wildlife habitat. Studies that took place after fire and floods found watershed changes, including bank erosion and channel migration (Owens et al. 2013; Polzin and Rood 2006).

Soils in riparian areas are vulnerable to high-severity wildfires. In late summer, low soil and fuel moisture can result in fire-affected riparian area soils that are similar to neighboring upland areas (Tollefson, Swanson, and Cissel 2004), which can increase both soil erosion and bank instability. Both soil erosion and bank instability from disturbances and post-disturbance harvest were, in turn, found to have negative effects on water quality and aquatic habitat (Jaeger, Anderson, and Dunn 2023; Wondzell, Hemstrom, and Bisson 2007). Fire damage to riparian area plants weakened root structures, which led to loss of bank stability for three to five years (Owens et al. 2013). Sprouting in riparian areas that were healthy before fire, however, were found to naturally reseed, thereby increasing bank stability within two years of mixed-severity fires (Halofsky and Hibbs 2009; see also Foster et al. 2020; Kobziar and McBride 2006).

After a series of floods, Rood et al. (2015) found that grassland-dominated riparian areas were subject to channel braiding and increased in-stream sediment levels. Riparian areas dominated by trees, however, showed more stable channel morphology and bank stability after a series of floods. Benda et al. (2005) suggested, however, that these flooding-related changes to channel morphology could be a long-term indicator of riverine health.

Studies that evaluated riparian forest regeneration’s contribution to post-disturbance bank stability recovery showed mixed support for active reforestation. While Halofsky and Hibbs (2009) suggested that healthy riparian areas will naturally regenerate and stabilize banks on their own after fire, Wondzell et al. (2007) suggested that the rate of passive riparian area recovery may be variable. It should be noted that these two studies took place in regions of Oregon that are ecologically different from each other, which may indicate that the need for active remediation may be site- and ecoregion dependent.

Stand regeneration

Rule description

In addition to providing stream shade, woody debris, and bank stability, OAR 629-643-0300(3) is intended to result in quick establishment of a new and healthy stand (see also OAR 629-643-0300(1)). The rule prescribes forest management practices (e.g., retaining live trees and down wood and logs) that generally promote seedling regeneration.

When considering OAR 629-643-0300(3) in this context, it is important to bear in mind that this rule only applies to situations where a riparian area had few remaining trees after a disturbance, meaning that how it contributes over time to the "average condition across the landscape" described in DFC may vary depending on pre- and post-disturbance site conditions. Natural variation across sites may result in areas that historically have supported few trees, or that were dominated by hardwoods rather than conifers (Mollot, Bilby, and Chapin 2008; Nierenberg and Hibbs 2000; Wimberly and Spies 2001; Wondzell, Hemstrom, and Bisson 2007). While OAR 629-643-0300(4) addresses hardwood dominated stands, OAR 629-643-0300(3) does not account for areas that were dominated by hardwoods before a disturbance. It only allows hardwoods to be counted toward basal area retention for non-fish-bearing streams (see OAR 629-643-0300(3)(c), (d)).

Literature synthesis

We found no studies in our review that directly investigated the impacts of post-disturbance harvest on stand regeneration in riparian areas. However, studies investigating natural regeneration of riparian areas following disturbance found them to be dominated by hardwood species and not conifers (see, e.g., Claeson et al. 2021; Gom and Rood 1999; Polzin and Rood 2006). A study conducted after a natural dam-break flood indicated that, over time, there could be variability within individual sites, with patches of hardwood-dominated areas, patches of mixed hardwoods and conifers, and patches that were conifer-dominated (Acker, Beechie, and Shafroth 2008), in keeping with Nierenberg and Hibbs's 2000 findings about succession and stand composition in the Oregon Coast Range. Wimberly and Spies (2001) found that while inland sites were hardwood-dominated, riparian areas less than 2 miles (< 5 km) from the Oregon coast were dominated by Sitka spruce (*Picea sitchensis*); they hypothesized that this may be related to moisture conditions nearer the Oregon coast. One study focusing on genetic structure of coastal tailed frogs 27 years following the eruption of Mt. Saint Helens did note that actively managed areas which had experienced salvage and replanting had “significant canopy overstory” (Spear, Crisafulli, and Storfer 2012, 857). The overstory of naturally regenerating areas was not described, but may be assumed to be less, given context of other portions of the study discussion (Spear, Crisafulli, and Storfer 2012).

The speed of natural stand regeneration following disturbance in any given riparian area is strongly influenced by the tree species that were present before a catastrophic disturbance and pre-disturbance stand health (Halofsky and Hibbs 2009; Nierenberg and Hibbs 2000; Wondzell, Hemstrom, and Bisson 2007). In the short term, quickly growing hardwoods like red alder provide important short-term ecological benefits like stream shade and bank stability. This allows slower growing trees time to establish and replace the shorter-lived hardwoods while still providing ecological benefits necessary to riparian area health (Beechie et al. 2000; Halofsky and Hibbs 2009).

Relationship to ORS 527.710(2)

Halofsky and Hibbs (2009) found that riparian areas that were healthy before fire successfully regenerated on their own. Fairfax and Whittle (2020) found that beaver dams reduced riparian area burn severity and increased refugia during fires of varying severity but made no difference in the rate of site recovery in the year after fire. A historical study in Western Oregon and a modeling experiment in Eastern Oregon both found considerable natural variability in stand composition across the landscape, and that riparian stand structure was variable depending on site-specific attributes like slope, aspect, microclimate, and elevation (Nierenberg and Hibbs 2000; Wondzell, Hemstrom, and Bisson 2007; see also Kay 1993; Mollot, Bilby, and Chapin 2008; Sarr 2004; Stolnack and Naiman 2010). Because natural variation on the landscape means that not every stand will develop in the same way, it is not clear whether overarching prescriptions could be successfully implemented across all sites (e.g., Everett et al. 2003; Wimberly and Spies 2001).

Discussion

The PFA Report (Private Forest Accord 2022) recommends evaluating “whether the current rules and practices related to post-disturbance harvest are sufficient to meet the goals of the PFA, and will consider post-fire ecology, post-fire forest regeneration, and worker safety” (9). ORS 527.710 grants the Board discretion to make rules about ecological issues on the landscape if there is no specific statutory directive about those issues. While the Board has been tasked with making rules about post-disturbance harvest, there are no specifics in either the PFA Report (2022) or Section 6, Chapter 33, Oregon Laws 2022 about what these rules might entail or contain. Before rulemaking goes forward, though, the Board must find that current rule causes or is likely to cause degradation on the landscape (ORS 527.714(5)(a)(A)). The studies selected for this review point to possible areas of insufficiency in OAR 629-643-0300(3).

Although this report focuses directly on OAR 629-643-0300(3), it is important to put this rule in context with the Desired Future Conditions (DFC) described in OAR 629-643-0000), as well as the goals described in OAR 629-643-0300(1). Key elements of DFC are expressed in the long term. Like most forestry objectives, the DFC for vegetation retention along streams is expressed over decades and centuries. OAR 629-643-0300(1) states that rules for catastrophic events are intended to promote DFC for riparian areas that have insufficient vegetation to “maintain fish, wildlife, and water quality resources over time.” OAR 629-643-0300(3) applies after a catastrophic event, but only for riparian stands that meet the criteria in OAR 629-643-0300(1). In combination, these two rules are intended to accelerate stand development and stream health, but only in riparian areas that have insufficient vegetation to promote stream health and habitat for aquatic species.

Rapid development of young riparian stand structures result in stream shade soon after a disturbance (Halofsky and Hibbs 2009; Martin, Wasserman, and Dale 1986). Promoting this development may mean encouraging rapidly growing hardwoods like red alder to provide stream shade faster than if the emphasis on live tree retention remains on conifers (D’Souza et al. 2011; Martin, Wasserman, and Dale 1986). Additionally, the first five years after high-severity fire tend to be the period when fire- and salvage-related impacts increase runoff and sediment delivery to streams (James 2014; Lewis, Rhodes, and Bradley 2019; Olsen, Wagenbrenner, and

Robichaud 2021). Multiple studies showed that after two to five years the amount of sediment delivered to streams from post-disturbance harvest after fire equalized with the amount of sediment delivered to streams due to soil damage from the fire itself (Cole et al. 2020; Prats, Malvar, and Wagenbrenner 2021; Slesak, Schoenholtz, and Evans 2015; Wagenbrenner, Robichaud, and Brown 2016).

After high-severity fires, soils can become water repellent, resulting in increased runoff and erosion (e.g., Robichaud et al. 2020; Wagenbrenner, Robichaud, and Brown 2016). These changes result in increased runoff and erosion that can deliver sediment to streams. Post-disturbance harvest can exacerbate this increased sediment delivery by compacting soil, largely due to use of heavy equipment in yarding corridors. Soil compaction from post-fire salvage further increases post-disturbance runoff (Cole et al. 2020; Olsen, Wagenbrenner, and Robichaud 2021; Wagenbrenner, Robichaud, and Brown 2016). In this review, several studies' findings indicated that increases in sediment delivery directly related to post-fire salvage equalized between two and five years after a salvage operation (Cole et al. 2020; Slesak, Schoenholtz, and Evans 2015). Several experimental studies found that applying ground cover (e.g., slash) helped reduce the amount of runoff directly related to post-disturbance harvest (Cole et al. 2020; Prats, Malvar, and Wagenbrenner 2021; Robichaud et al. 2020; Wagenbrenner, Robichaud, and Brown 2016).

Along with upslope mitigation, riparian buffers were found to reduce or prevent sediment delivery to streams during the five-year period before sedimentation from post-disturbance harvest decreased to similar levels as sedimentation from disturbance alone (Czarnomski et al. 2008; Rex et al. 2009; Robichaud et al. 2021). In a study east of the Cascades, measures of soil conditions, infiltration, and runoff were compared across levels of burn severity and over time following mixed-severity fire (Robichaud et al. 2021). This information was used to estimate riparian buffer widths that would be effective in completely preventing sediment delivery to the stream following fire and post-fire salvage. They recommend that for areas of high soil burn severity 400' (120 m) buffers be used for salvage occurring within the first year of fire. For salvage occurring within the second year following fire and in high soil burn severity areas, they recommend 200' (60 m) buffers, and in the third year, 100' (30 m) buffers. For low soil burn severity areas the recommendations are 200' (60 m) in the first year, 100' (30 m) in the second year, and the unburned harvest standard for Washington of 50’ (15 m) in the third year post fire or later. The authors note that “these recommendations are most applicable for volcanic ash-derived soils in mixed conifer ecosystems with good regrowth potential…” (Robichaud et al. 2021, 12). After catastrophic beetle kill followed by post-disturbance harvest, Rex et al. (2009) found that buffers ~33’ (10 m) or wider were sufficient to maintain riparian area health of small streams (< 6.5’, < 2 m width) where salvage took place upslope. Division 643 provides riparian buffer prescriptions that apply generally; OAR 629-643-0300(3)(b) requires operators to all retain live and dead trees 10’ to 20’ from streams, depending on stream size. This rule, however, applies in limited circumstances, as discussed above. Otherwise, the rules are silent about how or whether operators should approach salvage in disturbed riparian areas that do not meet the current rule criteria.

Three articles in this review examined the role of riparian buffers in reducing or preventing upslope sediment delivery to streams. These studies indicated that riparian buffer widths have positive effects on both stream and riparian area health after fire (Czarnomski et al. 2008; Rex et al. 2009; Robichaud et al. 2021). Robichaud et al. (2021) further found that temporarily increasing buffer widths after a fire may be necessary to mitigate or prevent sediment delivery to streams from fire and post-disturbance harvest. As there are only three articles about riparian buffers included in this study from which we can draw information, we caution against using these findings as a decision tool to determine appropriate short-term post fire buffer widths. We do suggest, however, that the findings in these articles show the importance of riparian buffers to protect streams from upslope runoff.

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