Siskiyou Streamside Protections Review: Summary of Literature Review

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Main Findings

Stream temperature

- Relevant literature (12 studies) suggests implementation of current FPA rules will not ensure maintenance of Protecting Cold Water standard or the Human Use Allowance.
- Results from existing literature indicate that harvested sites infrequently exceeded the Biologically-based Numeric Criterion.
- A paucity of data, combined with complex spatial and temporal dynamics of heat transport, present many challenges in quantifying cumulative effects from multiple upstream timber harvests. The only component of these dynamics for which there were data showed no consistent trends in warming downstream of harvest units.

Shade

- Results from TMDL modeling and from existing literature (4 studies) suggest that shade increases with buffer width, and trees within ~50 and ~70 feet, respectively, of streams provide the most shade to streams.
- In the 50-70 feet range of buffer widths, additional trees appear to increase shade by a few percent, and not at all beyond approximately 80-100 feet range of buffer widths.

1. Background

1.1 Policy

In January 2012, the Oregon Board of Forestry (Board) found degradation of water quality for small and medium streams based on an Oregon Department of Forestry (ODF) study (Groom *et al.*, 2011a), which initiated the Riparian Rule Analysis. In 2017, the Board adopted additional riparian rules for small and medium streams with salmon, steelhead, and bull trout ("SSBT rules"). The Board voted to apply these rules in all of western Oregon except in the Siskiyou geographic region.

In March 2018, the Board directed ODF to assess the sufficiency of Forest Practices Act (FPA) rules to meet riparian goals along small and medium fish streams in the Siskiyou, and thereby commencing the Siskiyou Streamside Protections Review ("Siskiyou Project"). These goals were Desired Future Conditions (DFC) and Oregon Department of Environmental Quality (DEQ) water quality standards for stream temperature. In 2019, ODF staff completed a systematic review of literature to inform these Board sufficiency decisions (Cowan *et al.*, 2019). The geographic scope of this review was included studies from the Siskiyou and adjacent areas of northern California with similar forests.

Based on the results of this initial review, the Board found in June 2019 there was insufficient evidence to make a decision on the sufficiency of the Forest Practices Act (FPA) rules to protect stream temperature and DFC. The Board directed the department to formulate a range of approaches to study sufficiency of rules, including additional work with DEQ and further evaluation of Total Maximum Daily Load (TMDL) information. In September 2019, the Board directed ODF staff to draft an executive summary of relevant scientific literature with an expanded geographic scope to include forests similar to those of the rest of western Oregon (Appendix I, Figure I.1).

In February 2020, a group of environmental and forest industry stakeholders signed a Memorandum of Understanding (MOU) requesting the legislature revise the FPA and pass permanent rules for small and medium SSBT streams in the Siskiyou georegion. Although a bill in support of this MOU and legislation was drafted, the legislature did not vote on this bill. In order to support the work of this MOU, signatories of the MOU requested the Board: 1) pass a temporary rule extending the SSBT rules to the Siskiyou, and 2) pause the Siskiyou Project. The Board approved these recommendations on June 3, 2020, when the report was nearly completed. At their special session in late June 2020, the legislature passed Senate Bill 1602 which directed the Board to begin permanent rulemaking for SSBT streams in the Siskiyou Georegion.

1.2 Science: Stream Temperature and Shade

Since the 2013 systematic review on stream temperature and shade in forestry (Czarnomski *et al*., 2013), a number of publications have reported results on harvesting effects on stream temperature and shade throughout western Oregon including paired watershed studies (Bladon *et al*., 2016; Bladon *et al*., 2018; Reiter *et a*l., 2020), ODF's Riparian Function and Stream Temperature study ("RipStream"; Davis *et al*., 2016; Groom *et al*., 2017; Groom *et al*., 2018; Arismendi and Groom, 2019), the Density Management and Buffer Study (Anderson and Poage, 2014; Leach *et al*., 2017), and the work of Cowan et al. (2019). There were also similar experiments in other areas of the Pacific Northwest relevant to this summary, including northern

California (Jones *et al*. 2013), western Washington (McIntyre *et al.* 2018), and British Columbia (Guenther *et al*. 2014)[1].

A common theme among many of these studies is that riparian buffers provide shade to streams, which is important for preventing substantial increases in stream temperature associated with forest harvest. For example, the paired catchment studies observed greater increases in stream temperature following harvesting for headwater streams with no buffers as compared to buffered streams (Bladon *et al*., 2018; Reiter *et al*., 2020). RipStream papers addressed DEQ water quality standards, including the frequency of exceedances of the Biologically Based Numeric Criteria ("NC"; Groom *et al*., 2017), and buffer width requirements to maintain stream temperature from exceeding the protecting cold water (PCW) criterion (Groom *et al*., 2018). RipStream papers also evaluated harvesting effects on downstream temperature (Davis *et al*., 2016; Arismendi and Groom, 2019). A few studies (Gomi *et al*., 2006; McIntyre *et al*., 2018) outside of Oregon provide results that are used in this summary, even though these studies did not explicitly test DEQ standards.

This summary informs the Board's policy considerations regarding attainment of DEQ water quality standards for temperature for small and medium fish-bearing streams in the Siskiyou geographic region. The following sections address relevant findings to two DEQ water quality standards[2]: 1) Protecting Cold Water Criterion (PCW); and, 2) NC. We also include a third section that summarizes findings that address the cumulative effects of multiple timber harvest units throughout a watershed. Not all studies directly assessed whether FPA rules are effective in meeting DEQ water quality standards, which presents a challenge in addressing questions that were not specifically in the original analysis. We have included results from these studies as they provide insight into potential harvesting effects on stream temperature and shade, as well as effects of harvesting on downstream temperature.

Most studies included in this analysis measured stream temperature and shade adjacent to or downstream of clearcuts with a hard-edged, unthinned buffer, unless otherwise noted. This summary combines the information on stream temperature and shade described in Czarnomski *et al.* (2013), Cowan *et al*. (2019), and any publications completed since 2013 relevant to this summary. The similarity of forests, and their resultant shade and stream temperature dynamics, between the Siskiyou and the rest of western Oregon are not evaluated in this paper. This report is a summary, and therefore is not exhaustive.

2. Analysis

2.1 Protecting Cold Water and Human Use Allowance

The PCW prohibits human activities, including harvesting, from increasing stream temperatures by more than 0.3 °C. From the RipStream study, Groom *et al.* (2011a) found that clearcut harvesting and retaining buffers on privately owned lands showed a 40% probability of exceeding the PCW. For the aforementioned Riparian Rule Analysis, ODF had a systematic science review drafted (Czarnomski *et al*., 2013), along with additional technical evaluations.

Czarnomski *et al*. (2013) found that exceedances of the PCW occurred in other studies in the Interior geographic region in Oregon with riparian buffer widths that were consistent with FPA

[1] For a complete list of publications used in this report, see Appendix III.
[2] Oregon Administrative Rule (OAR) 340-041-0028

rules[3] for fish streams. Building on the results of Czarnomski *et al*. (2013), we show that, on average, studies within a number of regions in the Pacific Northwest (Fig. 1) observed harvest-associated changes in stream temperature (ΔT) that exceeded the PCW criterion. Data in Figure 1 include study sites with buffer widths ranging from 20' to 70', which reflects the minimum width (20') that would contain sufficient basal area to meet targets in the FPA, and the widest required possible buffer width (70') required by the FPA for medium streams with insufficient conifer basal area.

We make the distinction between two types of study designs (i.e., upstream/downstream and paired catchment designs) due to differences in how data were collected and locations of reference stream locations (Fig. 1). The upstream/downstream design typically involved stream temperature sensor placement above and below a treatment reach with additional sensors in a control reach further upstream. Paired catchment designs had stream temperature sensors located within and below treatment reaches, which had corresponding reference locations in a different stream catchment prior to and following harvest.

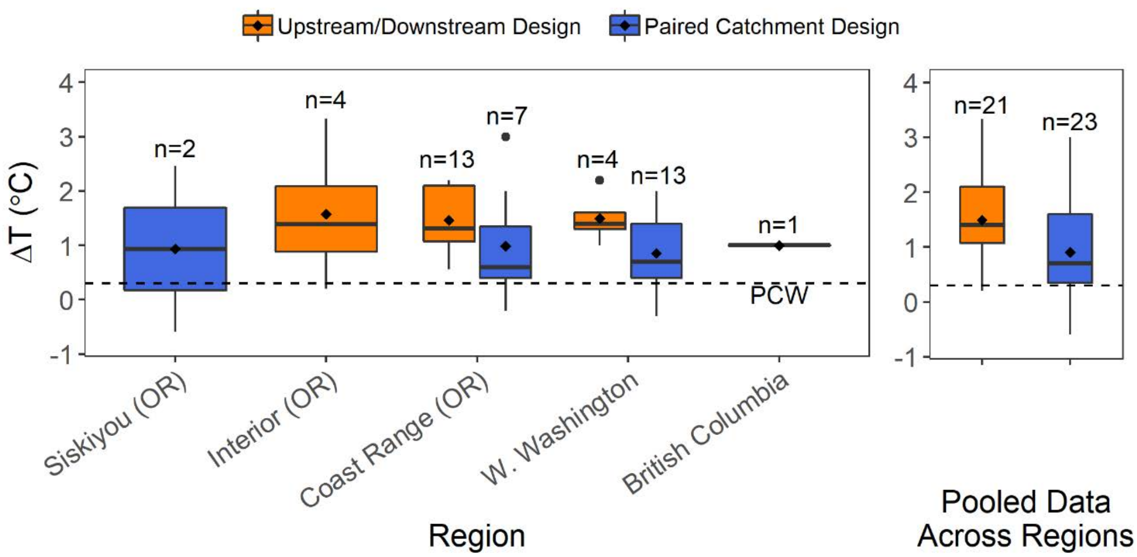

Figure 1. Boxplots of harvest-associated changes in stream temperature (ΔT, °C) by FPA geographic regions (e.g., Siskiyou, Interior, and Coast Range) and other regions of the Pacific Northwest (e.g., western Washington, British Columbia). The one site in British Columbia used a paired catchment design. Mean values by study design across regions are shown in the right panel. The dashed line corresponds with the Protecting Cold Water criterion of 0.3 °C. Each box shows the interquartile range from the 25th to 75th percentile represented by the bottom and top, respectively, of the box. The median is the horizontal line near the center of the boxes and the mean is the point within the box. The maximum and minimum are the ends of each vertical line, and outliers are points above or below the maximum and minimum. The number of sites (n) per region are provided above each boxplot.

[3] Note: Most studies available for this review looked at buffer widths as the controlling variable on stream temperature or shade. Those widths which do not correspond precisely with FPA fish stream rules, which have a 20 foot no cut buffer, plus requirements for basal area retention out to 50 feet and 70 feet for small and medium streams, respectively.

Given the Board's decision to expand the geographic scope of literature included in this summary for their consideration, a central question in consideration is the extent to which ΔT may differ between geographic regions. When viewing our findings within each study design, mean ΔT were fairly consistent across the regions. For example, ΔT ranged from 1.46 to 1.58 °C for upstream/downstream designs, whereas ΔT ranged from 0.85 to 1.00 °C for paired catchment designs.

Our analysis suggests study design influences ΔT measured in a study (Fig. 1). On average, paired catchment study designs found smaller ΔT. After pooling data across regions, we found mean ΔT was 1.5 and 0.9 °C for upstream/downstream and paired catchment designs (Fig. 1), respectively, despite the upstream/downstream designs having a greater mean buffer width (48 feet) than the paired catchment designs (40 feet).

Figure 2a shows site-specific relationships between ΔT and buffer width[4], from data across a broad geographic range in the Pacific Northwest (Fig. I.2.A, Appendix I), but with only a few points representing the Siskiyou region (Volpe, 2009). As buffer width increases, ΔT decreases, highlighting the importance of riparian buffers in moderating stream temperature. This trend is apparent despite the relatively large spread in the data, some of which may be an artifact of differing study designs and reported metrics. Similar to our analysis in Figure 1, study design appeared to influence the relationship between ΔT and buffer width. When fitting a curve (e.g., quadratic function) to the data in Figure 2, we found that the curve crossed the PCW threshold at a narrower buffer width for the paired catchment studies, as compared to studies that used an upstream/downstream design (data not shown).

Based on a Bayesian model using RipStream data, Groom *et al*. (2018) predicted riparian buffer widths of 90 feet to maintain ΔT below the PCW threshold of +0.3 °C (Fig. 2b). Because basal area was often maintained above the FPA requirements at RipStream sites, ODF staff estimated buffer widths under the scenario of landowners harvesting down to minimum FPA basal area requirements (Oregon Department of Forestry, 2015a, b). These widths averaged 23 and 41 feet for small and medium streams, respectively. These widths correspond with increases in ΔT of 1.9 and 1.4 °C, respectively (Fig. 2b). In contrast, significant increases in ΔT were not found along streams with riparian buffers (~50 feet) in Alsea Watershed Studies (Revisited) in western Oregon (Bladon *et al.*, 2016).

Basal area of riparian stands is another important factor in influencing shade, and therefore, stream temperature. Groom *et al.* (2011b) show that basal area and mean tree height were strong predictors of stream shade, and explain more variation in shade as compared with buffer width. Similar to the Bayesian modeling approach in Groom *et al.* (2018), ODF staff predicted a stand total basal area[5] (conifers and hardwoods) of 280 ft^2 per 1000 ft. to maintain ΔT below the PCW threshold of +0.3 °C (Fig. 2c). Note that this prediction only used data from no-cut buffers adjacent to clearcuts, and thus we cannot determine how appropriate the predictions are for thinned buffers or uplands.

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[4] Appendix III provides details on how these data were obtained and/or calculated.

[5] Note that the basal area standard targets for fish streams in the FPA (OAR 629-642-0100(6)) are based primarily on conifers, and only allow up to 10% of hardwood basal area to count towards these targets.

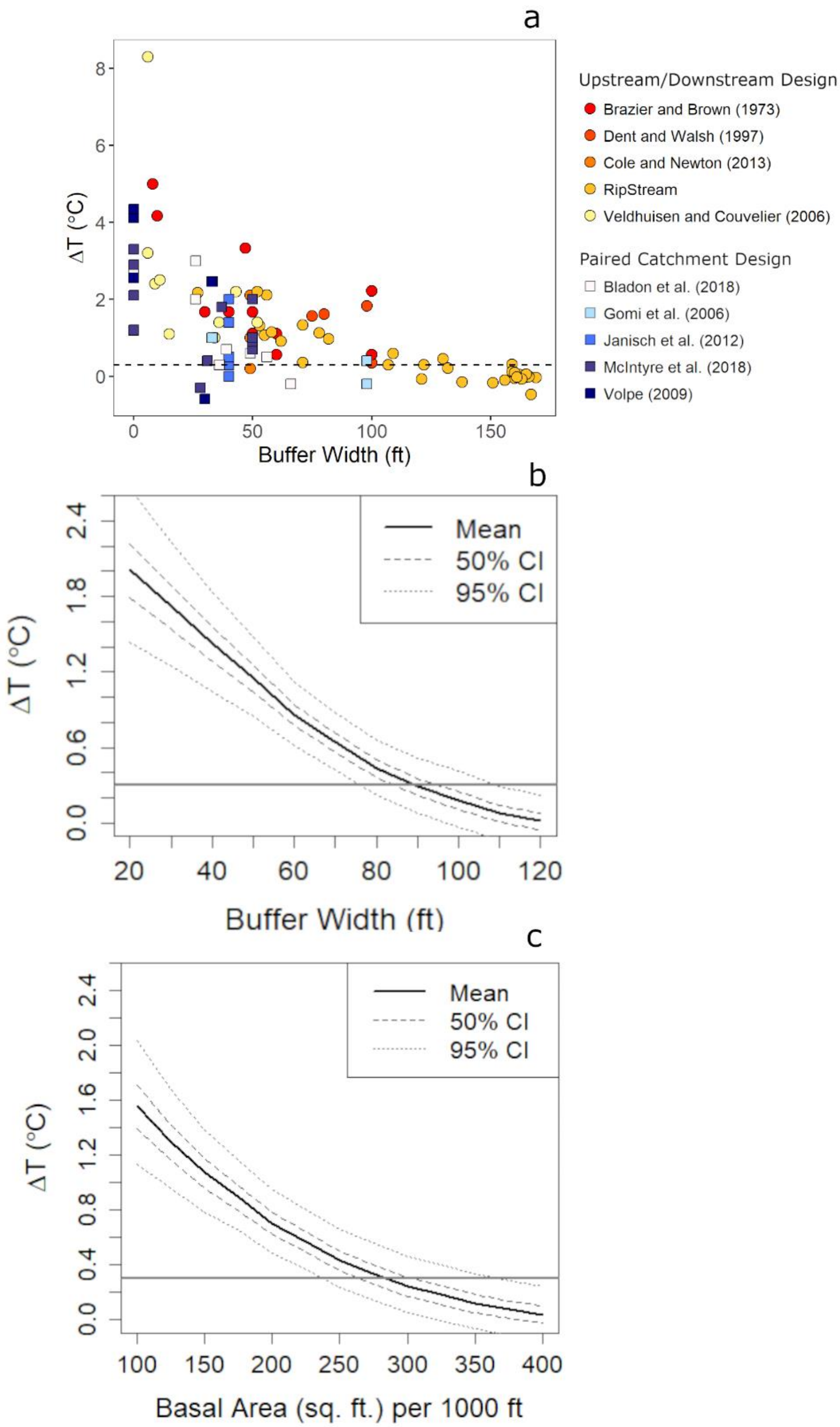

Figure 2. Post-harvest changes in stream temperature (ΔT, °C) as a function of: buffer width using literature (Panel a), buffer width as predicted by Groom *et al.* (2018)(Panel b), and basal area as predicted by Groom *et al.* (2018) (Panel c). Data points (Panel a) are color-coded by study that used an upstream/ downstream design (circles) and a paired catchment design (squares). The dashed line crosses the y-intercept at the PCW threshold (+0.3 °C). The dashed and dotted lines (Panel b and c) represent the 50% and 95% credible intervals (CI), respectively. A 95% credible interval indicates there is a 95% probability that the mean will fall within that interval.

Stream temperature TMDLs are implementation plans for how to achieve DEQ water quality standards (PCW and NC). These TMDLs prescribe the amount of heat that a water body can receive in order to attain the water quality standards. Private forest landowners must meet the requirements set by a human use allowance (HUA) if a temperature TMDL has been established in their watershed. Under current EPA approved plans, private forests landowners are expected to meet this requirement by following stream protection rules in the Forest Practices Act rules. In the Siskiyou geographic region, six temperature TMDLs have been established: the Rogue River Basin TMDL, Upper Sucker Creek Watershed TMDL, Lower Sucker Creek Watershed TMDL, Applegate Subbasin TMDL, Bear Creek Watershed TMDL, and the Upper Klamath and Lost River Subbasins TMDL. The HUA for all of these waterbodies is 0 °C, except for the Rogue Basin, which is 0.04 °C. Thus, for these watersheds, there are greater restrictions for stream temperature than that of the PCW. Where the PCW is not met, HUA is also not being met given its lower temperature threshold. For western Oregon, the modeling conducted by Groom *et al.* (2018) suggests that a buffer width of 120 feet or more would be required to prevent $\Delta T > 0$ °C (Fig. 2b).

Because shade is the major human-influenced control on stream temperature, and is the surrogate measure used in TMDLs to assess proper implementation, we examined shade data from the literature[6]. Based on studies that reported shade as a function of buffer width in the Coast Range geographic region (Allen and Dent, 2001; Reiter *et al.*, 2020), there is an increasing trend in shade with increasing buffer width (Fig. 3a). This trend is most apparent for the RipStream data, which covered a range of buffer widths from 27 to 168 feet. There is evidence that Reiter *et al.* (2020) and McIntyre *et al.* (2018) (77-80%) measured greater shade for a given buffer width (20-70 feet) than the other studies (69-71%). Reiter *et al.* (2020) and McIntyre *et al.* (2018) were conducted on non-fish-bearing streams that were likely narrower, and therefore have more canopy cover due to its overhanging streams more than the fish-bearing streams studied in Allen and Dent (2001) and in the RipStream study.

Comparing pre- and post-harvest shade also provides insight on harvest-associated changes in stream temperature. Three studies reported both pre-and post-harvest shade (RipStream; Reiter *et al.*, 2020; McIntyre *et al.*, 2018) with which to evaluate harvest-associated changes in shade (Fig. 3b). The change in percent shade ranged from -31% to +4 percent. The 18 sites with buffer widths greater than 120 feet, on average, experienced no net loss of shade, whereas the remaining thirteen sites (< 120 feet) experienced an average change in shade of -19%. Buffers in the Trask Watershed Study (Reiter *et al.*, 2020) showed a smaller decrease in shade for a given buffer width. This smaller decrease in shade may be a result of aforementioned narrower channel widths at the Trask Watershed study sites.

[6] Note that most studies assessed sites with forests less than 80 years old, and thus these sites were not at either the FPA's desired future condition, or DEQ's site potential vegetation.

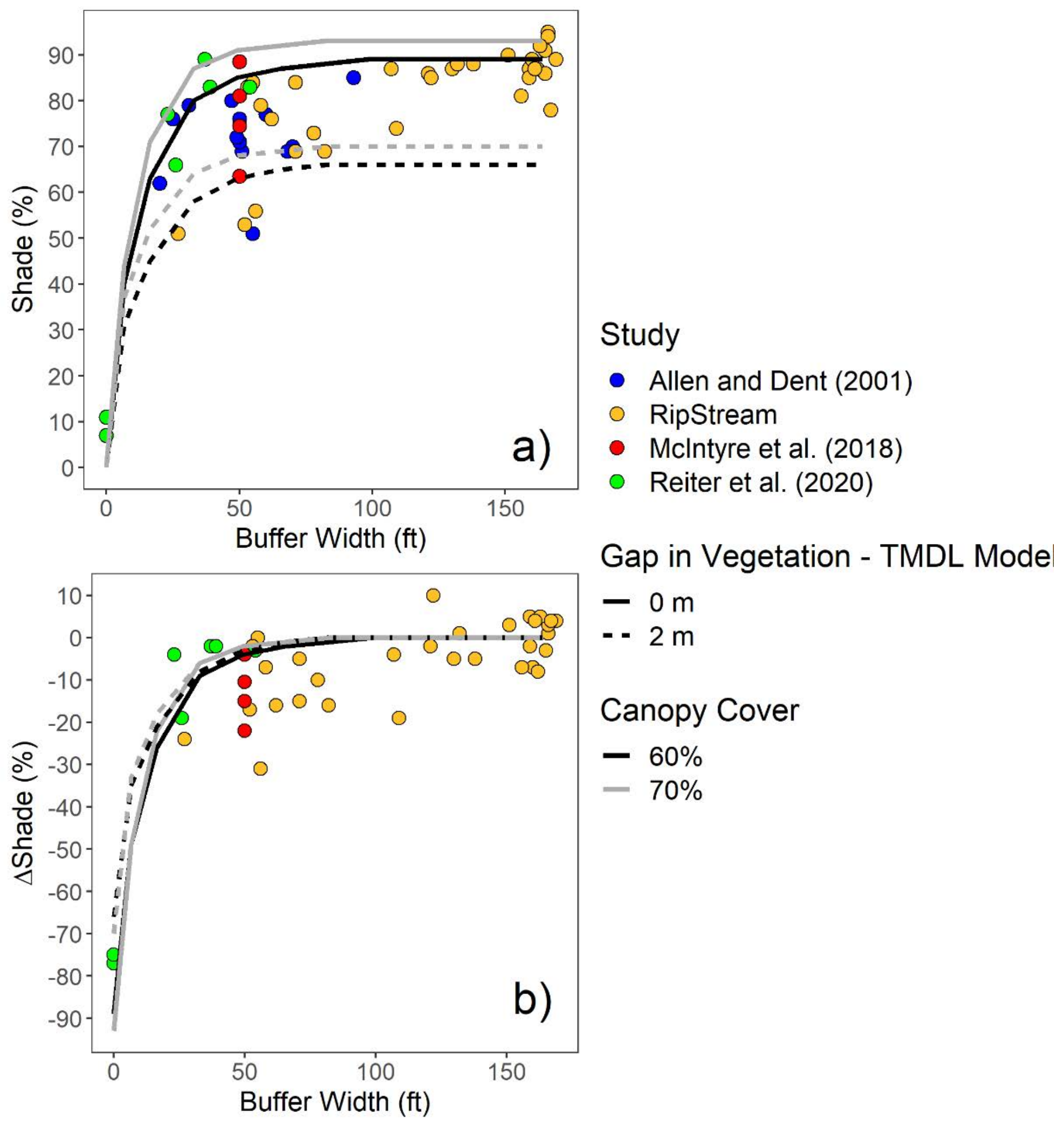

Figure 3. Shade (Panel a) and changes in shade (ΔShade; Panel b) as a function of buffer width from the literature and TMDL model shade data for riparian stands. The TMDL model used in this analysis was calibrated for mid-Coast, which is in proximity to most of the field data.

To gain a sense of what shade might be expected to be at these sites, we show predicted shade and change in shade (Δshade) values as a function of buffer width from the DEQ TMDL heat source model ("TMDL values") in Figures 3a and b, assuming a 0 and 2 m gap[7] in vegetation

[7] For comparison, Groom et al (2011b) reported an average wetted channel width of 2.1 meters (Range 1.0-3.7 m).

(i.e., directly above the stream)[8]. In Figure 3a, most field data fall within the range of the 0 and 2 m gap TMDL shade values, which appear to provide a reasonable approximation of shade values observed in western Oregon.

TMDL Δshade values show steep declines in the 0-40 foot buffer range, with small changes in the 50-80 foot buffer range (Fig. 3b). Field data approximately follow the TMDL values for change in shade (Fig. 3b), except they are more negative than the TMDL curves in the 50-80 foot range of buffer widths. Discrepancies between field data and TMDL values may be explained by a number of factors. First, the model assumes a uniform vertical and horizontal distribution of leaves (i.e., cover) within the canopy, which may not be the case for riparian stands in western Oregon. Second, RipStream stands might not be consistent with DEQ's recommended model input parameter of 60-70% canopy cover. Finally, canopy cover input values used in the TMDL shade modeling are based on measurements occurring in the riparian area (outside of stream), whereas our RipStream measured 90% canopy cover a directly above the streams.

DEQ policy on HUA in the Siskiyou watersheds states that there can be no increase in stream temperature from forestry activities, and thus any reduction in shade can cause a stream to not meet the HUA (R. Michie, personal communication). In Fig. 3b, a 0% change in shade (Δshade) for 3 of 4 modeled curves correspond with a buffer width of 80 feet, and the remaining curves reaches 0% Δshade at a buffer width of 100 feet. These TMDL values are presented without uncertainty that is inherent in the natural world, and thus we have also considered TMDL Δshade values that are from 0 to -5% to account for some degree of uncertainty around a 0% change in shade (i.e., the value required by the HUA). These Δshade values reach this -5% threshold at a buffer width of 50 feet for all curves.

2.2 Biologically Based Numeric Criterion (NC)

In the Rogue Basin, the NC prohibits human activities, including harvesting, from increasing the seven-day-average maximum stream temperature above 16 °C for streams that have core cold water habitat, and above 18 °C for streams that have salmon and trout rearing and migration use.

Cowan *et al.* (2019) reported results from one study (Volpe, 2009) that evaluated NC. The study's treatments were thinning of wildfire fuels in riparian areas, and thus their shade dynamics are significantly different than unthinned buffers adjacent to clearcuts (i.e., the treatments from the other studies assessed in this summary). Volpe (2009) reported the number of days that exceeded NC for: 1) untreated ("control") catchments; 2) catchments that experienced thinning and prescribed fire to the stream edge; and, 3) catchments that retained a no cut buffer with upland thinning and prescribed fire. Regarding the control watersheds, one site had zero days exceeding the NC both pre- and post-harvest, and the other site decreased by a few days from pre- to post-harvest years. Of the three thinned buffer sites, one increased from 36 to 56 days/summer, one had a small increase, and one went from zero to 49 days/summer. For the

[8] The TMDL shade values in Figure 3 are based on approximations of pre-harvest stand conditions in order to compare with similar field data. These data do represent stand conditions and not site potential vegetation as used by DEQ to estimate shade targets to achieve heat load allocations set by TMDLs. Figure 3 uses shade predictions from the Mid-Coast TMDL model, and not from TMDLs in the Siskiyou region, since most of the field data are from the Coast Range. DEQ said for these TMDL models, to use 25 m tall trees, and 65% canopy cover for the mid-Coast.

no cut buffer sites, one site remained at zero days/summer pre- and post-harvest, and the other increased from three to 70 days/summer.

In extending the geographic scope, we found two additional studies that specifically address harvesting effects on NC in western Oregon (Bladon *et al.*, 2016; Groom *et al*., 2017). Groom *et al*. (2017) showed that on private land, exceedances of the NC associated with harvesting occurred at 3 sites out of a total of 18. For these three sites, daily exceedances occurred during 6 to 16% of the time over the course of one post-harvest summer (e.g., year 1 post-harvest in July and August). Buffer widths for the 3 sites with NC exceedances ranged from 56 to 82 feet with an average buffer width of 67 feet. The remaining 15 sites had buffer widths that ranged from 27 to 159 ft. with an average buffer width of 78 feet. In contrast to sites on private land, 0 sites exceeded the NC following state forest prescriptions. Furthermore, exceedances were generally only observed within the first two years following harvesting. Groom *et al*. (2017) also found exceedances of NC pre-harvest, and thereby highlighted the challenge in identifying specific causes of NC exceedances.

In the Alsea watershed, the numeric criterion for core cold-water fish (16 °C), non-core juvenile rearing and migration (18 °C), and migrating salmon and trout (20 °C) were never exceeded along stream reaches within the harvested area with a riparian buffer and downstream (~1600-2000 feet) of the harvest unit (Bladon *et al.* 2016). Reiter *et al*. (2020) also evaluated duration of stream temperature above three thresholds (15, 16, and 18 °C), which represent the thermal niche for coastal giant salamanders (15 °C) and coastal tailed frogs (16 °C), as well as the threshold for mortality of coastal tailed frog eggs (18 °C). Streams with FPA buffers did not experience changes in the duration of temperature above either threshold as a result of harvesting, which indicates harvest did not cause exceedances of NC since these thresholds are at or below those of the NC.

2.3 Cumulative Effects

The PCW indicates that water flowing into salmon, steelhead or bull trout (SSBT) stream reaches require protection so that the receiving stream does not increase ΔT more than 0.3 °C at the point of maximum impact (POMI) [9]. Additionally, HUAs[10] in temperature TMDLs have the same restriction. This measure indicates that multiple harvest units, as well as management activities on other land uses such as agricultural or urban land, may exceed the PCW and HUA downstream if their combined heat loads resulted in a ΔT > 0.3 °C at the POMI due to cumulative effects. This exceedance might occur even if ΔT at each location (e.g., harvest unit or farm) was below the 0.3 °C threshold.

Rigorously quantifying cumulative ΔT at a POMI presents many challenges, such as:

1) identifying the specific location of the POMI for a given set of harvest units throughout a small watershed;
2) quantifying the heat load for each harvest unit; and,

[9] In OAR 340-041-0028 (11), the PCW "…applies to all sources taken together at the point of maximum impact where salmon, steelhead or bull trout [SSBT] are present".

[10] OAR 340-041-0028 (12); note that stream temperature TMDLs focus on heat load as the pollutant, but temperature is the metric for attainment.

3) quantifying heat dissipation downstream of harvest units intermixed with additional heat load from other sources, which requires knowing transit times of diurnal heat pulses.

Quantifying cumulative effects, and subsequent regulation of those effects, would also require predicting when and where timber harvests are occurring within a watershed, which is not within ODF's statutory authority. Overall, development of a model to rigorously analyze cumulative effects would require many assumptions, potentially leading to spurious model results. However, we can gain some insight into the downstream heat dissipation using existing literature that involved stream temperature measurements downstream of harvests.

In western Oregon, a few studies evaluated the effects of harvesting on stream temperature further downstream from individual harvest units (Cole and Newton, 2013; Davis *et al.,* 2016; Arismendi and Groom, 2019) and paired watershed studies (Bladon *et al.* 2018). An additional study assessed cumulative effects by implementing treatments with no buffers, partial buffers, and FPA buffers intermixed with non-treatment reaches (Newton and Cole, 2013). They observed temperature decreases approximately 260 feet downstream of all treatments. However, three of four streams experienced elevated downstream temperatures relative to that of pre-harvest.

Using RipStream data, Davis *et al.* (2016) modeled ΔT 1000 feet downstream of harvest, and found the range of downstream ΔT was 82 to 1% (56% on average) of that at the downstream end of the harvest reach. The primary factors that influenced the downstream temperature changes included stream width, depth, and gradient.

Arismendi and Groom (2019) further evaluated these same RipStream data. They observed mixed findings with regard to downstream ΔT. For example, 50% of the sites showed increases and the other 50% showed decreases in the difference between the downstream and harvest reaches first summer post-harvest. Across all post-harvest years, the downstream ΔT increased 0.2 °C on average. The greatest differences between the treatment and downstream reaches were observed during the first and second year post-harvest (Arismendi and Groom, 2019). By year 5 post-harvest, temperature patterns downstream were most similar to pre-harvest conditions, which may partially be explained by increasing understory vegetation near the channel in response to greater light availability following harvesting. Overall, their results suggests streams may warm or cool downstream prior to and after harvesting. As described above, there is evidence other factors (e.g., stream morphology) likely play an important role in determining temperature response of reaches downstream of harvesting.

From the paired catchment studies, Bladon *et al.* (2018) evaluated downstream ΔT for sites that ranged from 50 to 4659 feet from the downstream boundary of harvest units. There was strong evidence that downstream cooling did occur once streams exited the harvested unit and entered into unharvested areas, and no evidence for warming at downstream sites. Downstream transport of ΔT was primarily controlled by bedrock characteristics and percentage of harvested area within the catchment. In catchments with a less permeable bedrock, the thermal regime appeared to be more tightly coupled with the effective shade provided by vegetation (i.e., greater temperature increases in response to harvesting). Bladon *et al.* (2018) suggested geology played an important role in influencing downstream transport of heat due to the role of the underlying lithology in determining the relative proportions of surface flow, groundwater, and subsurface flow. In more permeable geology, streamflow is primarily dominated by groundwater, which tends to be cooler and thermally stable compared to surface water during the summer.

Data gaps

There were no analyses of:

- Heat transport downstream of harvests (only temperature down stream of harvests was analyzed)
- The effect of thinned buffers adjacent to clearcuts, on stream shade or temperature
- The impact on stream shade or temperature due to differences in:
    - stand density
    - stream flow for small vs. medium streams or
    - stream width

Limitations

Out of scope for this report were:

- Additional impacts of climate change on stream temperature and shade
- Assessment of the extent, if any, of different harvest-related impacts on stream temperature and shade from different forest types in the Siskiyou vs. those of the rest of western Oregon, or the resulting confidence in extrapolating results from western Oregon to the Siskiyou
- A rigorous analysis of variables that explain outcomes of studies

3. Conclusions

In extending the geographic scope of the Siskiyou Streamside Protections Review we reviewed recent literature in addition to literature that was reviewed in Czarnomski *et al.* (2013) and Cowan *et al.* (2019). Our review of relevant literature suggests implementation of current FPA rules likely do not meet the PCW ($\Delta T \leq 0.3$ °C) criterion of water quality standards. For example, studies with buffers similar to those of the FPA had ΔT in the 0.9-1.5 °C range. This conclusion is further supported by Groom *et al.* (2018), who show that buffer widths less than 90 feet are likely to result in exceedances of the PCW. Previous work by ODF staff also show implementation of minimum FPA requirements for vegetation retention would result in buffer widths of 23 and 41 feet along small and medium streams, respectively, in the Coast Range. These widths correspond to ΔT of 1.9 and 1.4 °C, respectively.

Furthermore, we show 88% of sites with buffers widths 20 to 70 feet and 73% sites of sites with buffers >70 feet appear to exceed the PCW (Table 1) for most relevant studies that involved implementation of FPA rules for vegetation retention along streams during logging operations. It is worth noting Groom *et al.* (2011a) applied a more rigorous approach to evaluating PCW for RipStream sites and found sites on private land had a 40% probability of exceeding the PCW. The discrepancy between Groom *et al.* (2011a) and our analysis may be due to a few reasons including the larger geographic used in this analysis and the use of multiple post-harvest years by Groom *et al.* (2011a).

There is evidence that clear-cut harvesting under FPA rules for fish streams resulted in a net loss of shade as a result of harvesting, which likely explains exceedances of the PCW ($\Delta T \leq 0.3$ °C), and therefore also the HUA ($\Delta T = 0$ °C).The DEQ TMDL modeling predicts 0% Δshade as a result of harvesting when buffer widths are ~80 feet or greater, and less than a 5% Δshade when buffer widths are ~50 feet or greater. Results from recent studies partially confirms the model projections from the TMDL model, although there are a few inconsistencies. For example, the RipStream study showed greater actual post-harvest decreases in Δshade than that of the TMDL model for buffer widths of 50 to 80 feet.

In contrast to the PCW, sites appeared to infrequently exceed the NC. We found that 17% of sites with buffer widths of 20-70 feet, and 9% of sites with buffer widths >70 feet, exceeded the NC. All exceedances were observed in the RipStream study, whereas the five sites in the Alsea and Trask Watershed studies did not appear to exceed the NC (Table 1). Considering shade, most of these field data are in the range of TMDL shade values, which likely explains why NC is met at most sites harvested following the FPA.

Table 1. Summary of data from relevant studies that identify whether the FPA is meeting water quality standards. This table includes studies that implemented current FPA prescriptive rules on vegetation retention along streams[11]. The number of sites that appeared to meet or not meet the PCW and NC, as well as total number of and percentage of sites, are provided.

Study	# of Sites	= FPA or > FPA	Buffer width (ft.) Mean (Range)	Appear to Meet PCW? (# of Sites)		Appear to Meet NC? (# of Sites)	
				Yes	No	Yes	No
Dent and Walsh (1997)	4	> FPA	88 (75 – 100)	0	4	-	-
Newton and Cole (2013)	3	= FPA	49	1	2	-	-
RipStream: Groom *et al.* (2011); Groom *et al.* (2017)	7	= FPA	52 (27 – 62)	0	7	5	2 [a]
	11	> FPA	107 (71 – 159)	4	7	10	1 [a]
Bladon *et al.* (2016)	2	= FPA	49	-	-	2	0 [b]
Bladon *et al.* (2018)	7	= FPA	43 (26 – 66)	1	6	-	-
Reiter *et al.* (2020)	3	= FPA	43 (37 – 54)	-	-	3	0 [c]
		= FPA	***Total:***	***2***	***15***	***10***	***2***
			Percentage:	***12%***	***88%***	***83%***	***17%***
		> FPA	***Total:***	***4***	***11***	***10***	***1***
			Percentage:	***27%***	***73%***	***91%***	***9%***

[a]Numeric criterion included a 16 °C criterion for sites with salmon and anadromous trout core cold-water habitat and an 18 °C criterion for sites used for non-core juvenile rearing and migration by salmon and trout.

[b]Stream temperature never exceeded the 16 °C criterion for salmon and anadromous trout core cold-water habitat, the 18 °C criterion for sites for rearing and migration by salmon and trout, or the 20 °C for migrating salmon and trout.

[c]Although the numeric criterion was not explicitly tested, Reiter *et al.* (2020) show that stream temperature of buffered streams never exceed 15, 16 or 18 °C, which corresponds with the upper thermal niche for coastal giant salamanders (15 °C) and coastal tailed frogs (16 °C), as well as the threshold for mortality of coastal tailed frog eggs (18 °C).

[11]Not including sites that implemented additional forest management plans (e.g., ODF State Forest Northwest Forest Management Plan)

In consideration of TMDL shade values, our results suggest that assuming a 0-meter gap in vegetation with DEQ's recommended 60-70% canopy cover for a 50 year-old Douglas fir stand sets a high shade target of 91% that are achieved by about thirty percent of pre-harvest sites (Table 2). In contrast, all pre-harvest stands were capable of achieving a shade value of 68%, which was the TMDL shade value for a 2-meter gap. Most of these stands continued to provide post-harvest shade equaling or exceeding 68% (Table 3). While maximizing shade and canopy cover for streams is an important goal, it is important to identify inherent limitations of riparian stands in providing shade to streams. In some cases, stream temperature decreased further downstream for some sites, but it also increased downstream for other sites. In the paired watershed Studies in western Oregon, there was strong evidence that downstream cooling of harvest units occurred[12].

Table 2. Pre-harvest comparison of treatment sites with DEQ effective shade lookup tables for 82 foot tall vegetation, at 65% riparian canopy density.

Study	**# of Sites**	**Buffer width (ft.) Mean (Range)**	**Meet 0-m gap TMDL curve max (91%)? (# of Sites)**		**Meet 2-m gap TMDL curve max (68%)? (# of Sites)**	
			Yes	No	Yes	No
McIntyre (2018)	4	NA	2	2	4	0
Reiter (2020)	5	NA	1	4	5	0
RipStream[a]	31	NA	9	22	31	0
	7[b]	NA				
		Total:	***12***	***28***	***40***	***0***
		Percentage[c]:	***30%***	***70%***	***100%***	***0%***

[a] Groom *et al.* (2011; 2017)
[b]Sites listed in Table 3 (subset of 31 listed in previous line).
[c]For sites listed in Table 3, 16/16 (100%) meet 68% shade criterion.

[12]Not including sites that implemented additional forest management plans (e.g., ODF State Forest Northwest Forest Management Plan)

Table 3. Post-harvest comparison of treatment sites with DEQ effective shade lookup tables for 82 foot tall vegetation, at 65% riparian canopy density.

Study	# of Sites	Buffer width (ft.) Mean (Range)	Meet 0-m gap TMDL curve max (91%)? (# of Sites)		Meet 2-m gap TMDL curve max (68%)? (# of Sites)	
			Yes	No	Yes	No
Allen and Dent (2001)	12	48 (20 – 70)	8	4	11	1
McIntyre (2018)	4	50	0	4	3	1
Reiter (2020)	5	36 (23 – 54)	0	5	4	1
RipStream: Groom *et al.* (2011) Groom *et al.* (2017)	7	52 (27-62)	0	7	4	3
		Total:	***8***	***20***	***22***	***6***
		Percentage:	***29%***	***71%***	***79%***	***21%***

*Of studies with pre-harvest data, 69% (11/16) of post-harvest treatments meet the TMDL value of shade for 2-m gap.

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Appendix I. Geographic Area Covered by Report

This appendix shows the geographic scope, per Board direction, for studies to be considered relevant for this report (Figure I.1), and sites from studies included in the report (Figure I.2).

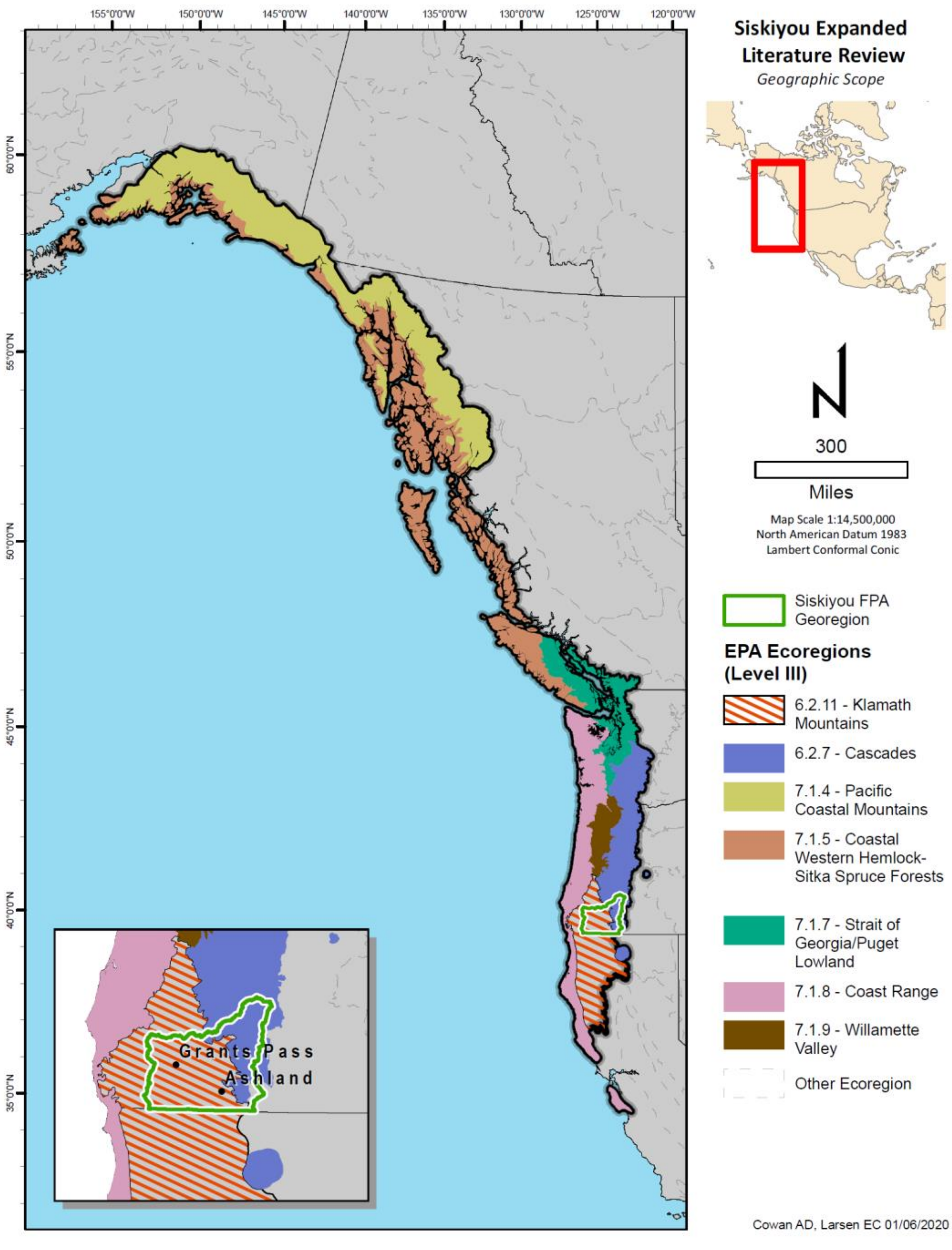
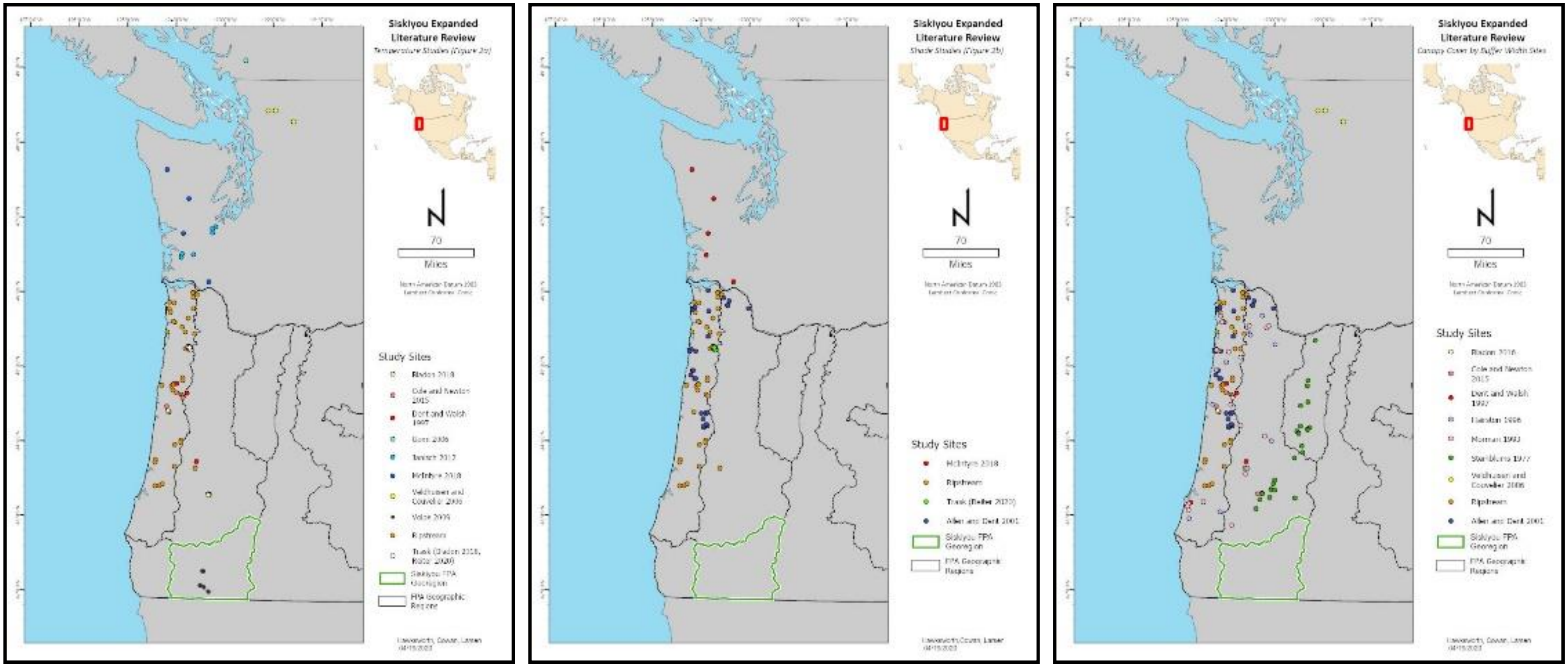


Figure I.1. Map of expanded geography, per Board direction, for studies to be considered in this summary. Map credits: Ariel D. Cowan and Erik C. Larsen.



A. B. C.

Figure I.2. Distribution of survey sites for studies in the literature review, relative to the Siskiyou FPA Geographic Region. A). Temperature studies listed in Report Figure 2a. B). Shade studies listed in Report Figure 3. C). Studies that reported both canopy cover and buffer width. Brazier and Brown (1973) was not included in panel A because of uncertainty in site locations.

Appendix II. Instream Canopy Cover

To understand the range of instream canopy covers experienced in the field, we analyzed data from the literature. This resulted in a median estimate of 79% (Range 37%-96%; Bateman *et al.* 2018, Bladon *et al.* 2016, Anderson *et al.* 2007), with most of the data from Oregon (mostly, Coast Range, some west Cascades). The largest single dataset came from RipStream (Figure II.1). Most of these stands exceeded 90% instream canopy cover, with few stands less than 80%. These estimates can assist with understanding the range of variability in natural riparian stands, and can be used for comparison with the Siskiyou Forest Practices Geographic Region.

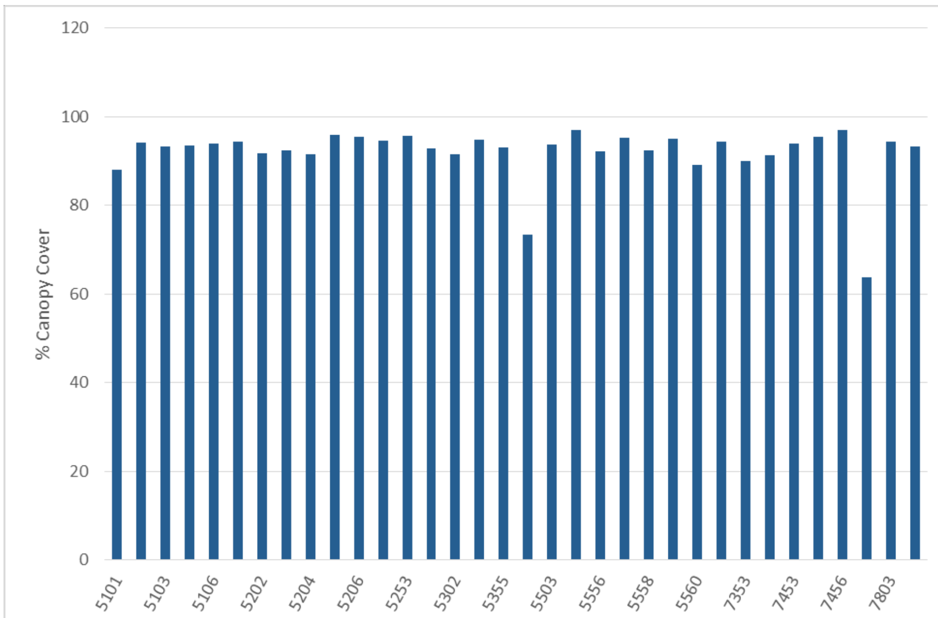


Figure II.1. Pretreatment mean instream canopy cover at RipStream sites. Mean 92%, Median 94%, Range 64-97%.

We further estimated instream canopy cover with age from a subset of eight studies representing 134 sites (Figure II.2). This estimation was considered important to determine how quickly baseline characteristics might be achieved, and whether there was a peak age for riparian canopy cover. Figure II.2 indicates that cover similar to baseline may be achieved by 20 years of age, although 30 may be a more conservative estimate. Once this age is achieved, there is little systematic variation in canopy cover.

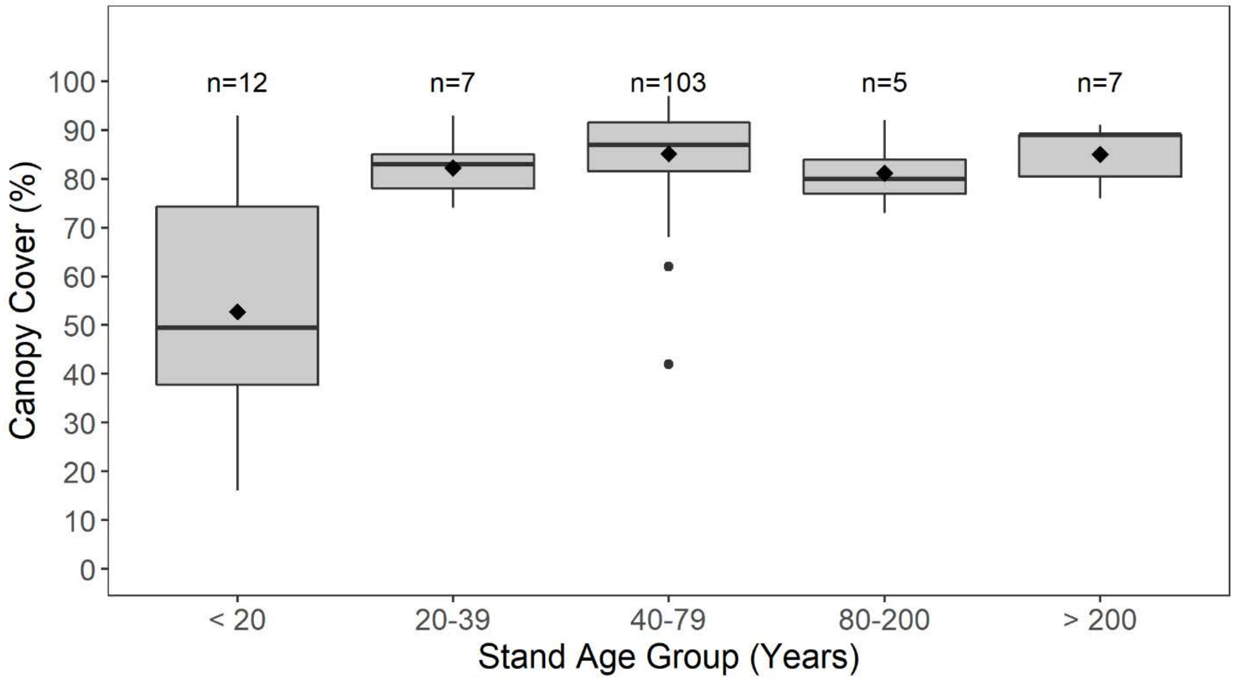


Figure II.2. Box plots of instream canopy cover as a function of stand age. "n" represents the number of sites within each age group; boxes represents the 25th to the 75th percentile of the data. The central line represents the median, while the central dot represents the mean; vertical lines represent the minimum and maximum ranges, except for dots beyond these lines that represent outliers. Stands in this figure exceeding 20 years of age had a median canopy cover[13] of 87%. Source: Allen and Dent, 2001; Bladon *et al.*, 2016; Brazier and Brown, 1973; Cole and Newton, 2015; Dent and Walsh, 1997; Hairston, 1996; Heimann, 1988; Kaylor and Warren, 2017; Kibler *et al.*, 2013; Morman, 1993; Newton and Cole, 2013; Piccolo and Wipfli, 2002; RipStream; Steinblums *et al.,* 1984; Veldhuisen and Couvelier, 2006; Warren *et al.*, 2013. In general, a number of studies have indicated a weak increasing trend of canopy cover with increasing buffer width. In our analysis, canopy cover was highly variable for buffer widths less than 75' across all data sets (data not shown). For example, instream canopy cover at a 50' buffer width ranged from 15%-95%, while buffers approximating 100' ranged from 60%-93%. Similar to shade, we found that decreases in canopy cover from pre- to post-harvest were greatest for smaller buffer widths (data not shown).

[13] Canopy cover is the percentage of visible sky blocked by vegetation (foliage, branches, stems) or topographic features, whereas effective shade is the percent reduction of potential daily solar radiation load delivered to the stream surface (DEQ 2008).

Appendix III. Methods

In the process of summarizing and extracting data from the literature, we also noted stream temperature and shade metrics used in the relevant papers, data sources within each paper, and how ODF staff or authors of the paper calculated changes in stream temperature (Tables III.1 and III.2). One challenge in analyzing and comparing results among different studies is in using multiple sources of data that have different metrics, as well as differences in study design.

The temperature metric most appropriate for evaluating PCW and NC is the 7-day moving average of daily maximum. In this analysis, we included results from studies that did not use this metric (Table III.1) because we felt that this information still provided valuable insight into the effects of harvesting on stream temperature. In summarizing exceedances of DEQ water quality standards in Table 1, most studies used the 7-day moving average of daily maximum, with two exceptions. Cole and Newton (2013) reported average daily maximum values, and Reiter *et al.* (2020) reported 30-minute stream temperature data. The Cole and Newton (2013) paper was used to assess PCW exceedances, whereas Reiter *et al.* (2020) was used to evaluate NC exceedances.

Regarding the use of daily maximum versus 7-day moving average of daily maximum, it is likely that both metrics will yield similar results, especially when these values are averaged over a period of a month or so, a common approach for studies used in the analysis. To test whether metrics would yield different results, we randomly generated stream temperature daily maximum values over a period of a month. We then compared a monthly average daily maximum values and a monthly average of 7-day moving average of daily maximum. Both approaches resulted in nearly identical values, which suggests that results from Cole and Newton (2013) are appropriate for testing exceedances of the PCW.

Regarding the use of 30-minute data vs. 7-day moving average of daily maximum stream temperature data to test the NC, Reiter *et al.* (2020) did not detect exceedances. A series of 30-minute stream temperature data over a period of a day or more includes daily maximums. Therefore, if no 30-minute stream temperature measurements exceed the NC, neither the daily maximum or 7-day moving average of daily maximum would have exceeded the NC.

Another caveat to the analysis in this report is that a few studies did not report pre-harvest stream temperature results (Brazier and Brown, 1973; Veldhuisen and Couvelier, 2006) or did not report pre-harvest data for sites that could be used in this analysis (Dent and Walsh, 1997). Pre-harvest measurements are used to account for inter-annual variability in stream temperature, which can potentially influence the change in stream temperature through a harvest unit. Note that Dent and Walsh (1997) was used in Table 1 due to geographic relevance and implementation of FPA buffers. Results from Brazier and Brown (1973) and Veldhuisen and Couvelier (2006) were only used in Figures 1 and 2.

In the shade analysis (Fig. 3a, b), we included predicted shade values from the Mid-Coast TMDL model, assuming 82-foot tall trees (mean tree height from RipStream; Groom *et al.*, 2011b) and riparian canopy cover of 60-70%. The 0-meter gap was chosen because that was the only assumption that matched DEQ system potential shade as quantified in shade curves in their

TMDLs (under system potential tree height and canopy density conditions, e.g., Rogue River TMDL (DEQ, 2008)) The 2-meter gap was also selected since Groom *et al.* (2011b) found that wetted width of streams studied in the RipStream study were 2 m on average, and DEQ uses wetted width as an approximation of vegetation gaps in the canopy above a stream.

Table III.1 Summary information for studies used in the stream temperature analysis of this report including stream temperature metrics, specific location of the data sources, and a brief description of how ΔT was calculated[14]e

Study	Geographic Region	Study Design	Water Quality Standard	Stream Temperature Metrics	Data Source	Calculation of ΔT
Bladon *et al.* (2016)	Coast Range, Oregon	Paired Catchment	NC	7-day moving average of daily maximum	Text of discussion, pg. 161	--
Bladon *et al.* (2018)	Coast Range, Oregon	Paired Catchment	PCW	7-day moving average of daily maximum	Figure 3* (data extracted)	1
Brazier and Brown (1973)	Coast Range and Interior, Oregon	Upstream/downstream	PCW	Average	Table 1 (Observed Temperature)	2
Cole and Newton (2013)	Coast Range and Interior, Oregon	Upstream/downstream	PCW	Daily maximum	Authors provided requested data to ODF	3
Dent and Walsh (1997)	Coast Range and Interior, Oregon	Upstream/downstream	PCW	7-day moving average of daily maximum	Table 3	2
Gomi et al. (2006)	Coastal British Columbia	Paired Catchment	PCW	Daily maximum	Table 3 (C, D, & H; Summer)	4
Janisch et al. (2012)	Western Washington	Paired Catchment	PCW	Daily maximum	Figure 3b (Continuous buffers)	4
McIntyre *et al.* (2018)	Western Washington	Paired Catchment	PCW	Daily maximum	Table 7-6 (OLYM, CASC, WIL1, WIL2); July and August	4, 5
Reiter *et al.* (2020)	Coast Range, Oregon	Paired Catchment	NC	30-min. stream temperature	Text of results and discussion	-
RipStream Groom *et al.* (2011, 2017, & 2018)	Coast Range and Interior, Oregon	Upstream/downstream	PCW, NC	7-day moving average of daily maximum	2014 Board of Forestry Workshop	3
Veldhuisen and Couvelier (2006)	Western Washington	Upstream/downstream	PCW	7-day moving average of daily maximum	Appendix 2, 3, 4b	2
Volpe (2009)	Siskiyou, Oregon	Paired Catchment	PCW, NC	7-day moving average of daily maximum	Table 2 (US2, F2, B1, LS2, F1)	1

[1]$\Delta T = (T_{Post.treatment} - T_{Pre.treatment}) - (T_{Post.reference} - T_{Pre.reference})$

[2]$\Delta T = T_{upstream} - T_{downstream}$

[3]$\Delta T = (T_{Post.downstream} - T_{Post.upstream}) - (T_{Pre.downstream} - T_{Pre.upstream})$

[4]$\Delta T = T_{Observed} - T_{Predicted}$; Regression analysis used to develop equations that described relationship between pre-harvest treatment vs. control. Equations were then used to predict post-harvest temperature ($T_{Predicted}$) at treatment reaches using control post-harvest. Observed values ($T_{Observed}$) included measured post-harvest stream temperature.

[5]Daily ΔT was averaged for each month to obtain a mean monthly temperature response.

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[14] Note: a publication came to our attention from the Siskiyou Advisory Committee's review for the first draft of this report, "An analysis of changes in stream temperature due to forest harvest practices using DHSVM-RBM" by Ridgeway (2019). Whereas it passed all the inclusion criteria, we decided not to include it since the analysis only included modeled stream temperature values that were not validated at the location of the harvest in California, and would have therefore required its own distinct section and discussion, and cannot be rigorously compared with field data.

Table III.2. Summary information for studies used in the shade and canopy cover analysis of this report including timing of measurement relative to harvesting, specific location of the data sources, and a brief description of methodology and measurements.

Study	Geographic Region	Study Design	Parameter	Measurement Timing	Data Source	Measurement Method
Allen and Dent (2001)	Coast Range, Oregon	Multiple Watershed	Shade, Canopy cover	Postharvest, with unharvested controls	Tables A-1 and B-1	Hemispherical Photos; Densiometer
McIntyre *et al.* (2018)	Western Washington	Paired Catchment	Shade, Canopy cover	Preharvest, Postharvest	Appx Table 7-B-1, 7-B-2, 7-B-5	Hemispherical Photos; Densiometer
Reiter *et al.* (2020)	Coast Range, Oregon	Paired Catchment	Shade	Preharvest, Postharvest	Table 1	Hemispherical Photos
RipStream	Coast Range and Interior, Oregon	Upstream/downstream	Shade, Canopy Cover	Preharvest, Postharvest	ODF Data	Hemispherical Photos; Densiometer
Bladon *et al.* (2016)	Coast Range, Oregon	Paired Catchment	Canopy Cover	Preharvest, postharvest	Text of discussion, pg. 154	Densiometer
Brazier and Brown (1973)	Coast Range and Interior, Oregon	Upstream/downstream	Canopy Cover	Postharvest	Table 1 (Angular Canopy Density)	Angular Can. Densiometer
Cole and Newton (2015)	Coast Range and Interior, Oregon	Upstream/downstream	Canopy Cover	Preharvest, Postharvest	Table A-1	Multiple, Densiometer numbers used.
Dent and Walsh (1997)	Coast Range and Interior, Oregon	Upstream/downstream	Canopy Cover	Postharvest with control reach, 1 site preharvest	Appendix A.	Densiometer, Fisheye lens camera
Hairston 1996	Western Oregon	Paired Catchment	Canopy Cover	Postharvest	Appendix A	Densiometer
Heimann (1988)	Coast Range, Oregon	Multiple Watershed	Canopy Cover	Postharvest	Table 7 (page 44)	Densiometer
Kaylor and Warren(2017)	HJ Andrews, WC, Oregon	Upstream/Downstream	Canopy Cover	Preharvest, Postharvest	Table 1 (page 5)	Densiometer
Kibler et al (2013)	Hinkle Cr, Interior, Oregon	Paired Catchment	Canopy Cover	Preharvest, Postharvest	Table 5 (p 688), and text on pages 686-687	Densiometer

Table III.2. *cont.*

Study	Geographic Region	Study Design	Parameter	Measurement Timing	Data Source	Measurement Method
Morman. (1993)	Western Oregon	Multiple Watershed	Canopy Cover	Preharvest, Postharvest	Section 3: pages 47-149	Densiometer
Newton and Cole (2013)	Coast Range, Interior, Oregon	Upstream/Downstream	Canopy Cover	Postharvest	Table 4	Densiometer
Piccolo and Wipfli (2002)	Prince of Wales Is., SE Alaska	Multiple Watershed, replicated	Canopy Cover	Postharvest	Table 1 (p 506)	Viewing Tube
Steinblums (1977)	Western Cascade and Interior, Oregon	Multiple Watershed	Canopy Cover	Postharvest	Table 2 (US2, F2, B1, LS2, F1)	Angular Can. Densiometer
Veldhuisen and Couvelier (2006)	Western Washington	Upstream/downstream	Canopy Cover	Postharvest	Appendix 4a	Densiometer
Warren et al (2013)	HJ Andrews, WC, Oregon	Upstream/Downstream	Canopy Cover	Postharvest, SG with OG reference	Table 2 (p 552)	Densiometer

Appendix IV. Stakeholder Feedback on Draft Report

Comments from all stakeholders are compiled into themes, along with their respective ODF responses.

Theme: How are Desired Future Conditions (DFC) being addressed in this report?

Response: In addition to temperature, this review covered information on the shade component of DFC. The other components of DFC will be addressed in a separate forthcoming report.

Theme: Please provide detailed comparisons between the design and location of the studies included in this report.

Response: Based on previous stakeholder feedback and limited time, the Monitoring unit elected to use a less intensive version of a systematic review. As a result, detailed information comparing each study was out of scope. However, the report discusses the relevance of each study to the Forest Practices Act (FPA) rules.

Theme: Be clearer about what conclusions are statistically-based and reword references to magnitude of evidence without statistical results.

Response: The discussion and conclusion sections were reworded to address this concern. The methods outlined before starting the literature review stated that no new analysis would be conducted with this review (only use statistical results provided in the included literature).

Theme: The point of maximum impact (POMI) and analysis of the Numeric Criterion (NC) exceedances needs further addressing.

Response: The ODF Monitoring unit is currently working with DEQ to discuss related topics, and we appropriately modified wording in the report related to NC and POMI.

Theme: Why is flow not included in this report?

Response: The current scope of this rule review does not consider flow. However, the Board of Forestry can request a review on impacts of rules regarding flow.

Theme: Why is climate change not mentioned in this report?

Response: Climate change is not addressed in the FPA and this review specifically assesses the rule's goals as they were written in the FPA. Per the Board's direction, the Monitoring Unit provided contextual information to the Board on climate change in the Siskiyou by inviting experts to present on the subject at the June 2020 Board of Forestry meeting.

Theme: Why are geology, stream size, width, basal area and other variables not part of the analysis?

Response: Stream characteristics like size and geology are considered important effects modifiers. However, extensive analysis of these characteristics was not one the objectives of the rule review, although we acknowledge it in the report as data gaps. The format of this review did not include any new analysis. A figure with additional discussion on basal area was added to the report.

Theme: "ODF states that 17% of sites with buffer widths of 20-70 feet and 9% of sites with buffer widths less than 70 feet exceeded the NC. We are concerned that evidence of exceedances of the NC (17% of sites with buffers 20-70 feet) has been characterized as "little evidence." Under the Clean Water Act, any exceedance of the water quality standard would be a violation."

Response: The report has been updated to address these concerns.

Theme: ODF should provide more context on limitations and assumptions for this report.

Response: The report has been updated to address these concerns.

Theme: ODF should more specifically address how RipStream field data shows the PCW is likely not met with buffer widths less than 90 feet (Groom *et al.* 2018) and buffer widths >50 feet are important for achieving the PCW.

Response: The report has been updated to address these concerns.

Theme: Do not conflate second-growth forest conditions with mature forest conditions in the results.

Response: Language was added to the report to address this concern.

Theme: Consider riparian stocking density within the reviewed datasets.

Response: We do not have studies published with this information. Riparian stocking densities, if found in the literature and relevant to the view, may be compared in the forthcoming report on DFC. Language was added to the temperature/shade report to clarify this.

Theme: Are the assumptions of the Human Use Allowance (HUA) appropriate/adequate?

Response: It is outside the scope of this review to question the assumptions of the HUA.

Theme: A 5-10% reduction in shade can cause a riparian area not to meet the HUA based on RipStream results and TMDL analysis.

Response: The report was modified to include this information.

Theme: Using a 90% canopy cover is too high in the model context. Use a canopy cover in the 60-70% range for the Siskiyou region.

Response: 90% canopy cover was measured at RipStream sites. However, per direction from DEQ on using their TMDL model information, we included shade curves from the look-up table using 60-70% canopy cover.

Theme: If the shade allocations are not attainable because the site does not support the type of vegetation that would provide that shade, then there should be no loss of shade from pre- to post- harvest for meeting the intent of the TMDL shade targets.

Response: The report was modified to address this information.

Theme: Most sites included in the Groom et al (2011a) study retained post-harvest basal area above ODF prescribed minimum targets, and therefore did not represent potential shade loss associated with FPA prescriptions. If FPA riparian basal area retention requirements allow for a buffer that is narrower than the buffer widths in the studies considered, then the change in temperature found in these studies is likely to be less than it would be under minimum retention requirements. Therefore, fixed buffer widths should not be used as an explanatory variable.

Response: The report specifies what the average buffer widths would be for small and medium streams if landowners removed all the basal area allowed per the FPA, and the associated temperature increases.

Theme: Include the temperature response and expected temperature increase associated with the application of FPA rule on private forest lands with small and medium fish streams.

Response: The report was modified to address this information.

Theme: The presented "Shade Curve" results are different than the Bayesian model, DEQ model, and field data, therefore the "Shade Curve" results are not correctly assessing the effect of buffer width reduction on stream shade conditions.

Response: The "Shade Curve" results are from the DEQ model, and are compared with field data in nearby forests to place the data in context.

Theme: Current management to meet FPA rules in the Siskiyou may not match the default FPA buffer widths. Monitoring (field data collection) is needed to identify whether water quality standards are being met in this region.

Response: New collection of field data is out of scope for the review at this time.

Theme: Include the study on Caspar Creek in Northern California.

Response: Addressed with a footnote in Table III.1.

Theme: Why are there different responses and what is the significance for interpretation of buffers meeting stream temperature criteria?

Response: This report was a summary of literature, and thus detailed analysis as to why the different responses was outside the scope of the work.

Theme: Are the studies included applicable to the rule review for the Siskiyou region?

Response: The geographic extent of the review was widened at the request of Board members. We acknowledge the risk of extrapolation in exchange for more information.

Theme: Canopy cover and shade is difficult to measure with significant possible variations between observers and equipment/methods.

Response: We assume that methods for collecting field data, within a given study, were consistently applied per their stated methods narratives. We acknowledge in the report that between-study variations in methods presents a challenge when comparing them.