Siskiyou Streamside Protections Review:

A Systematic Review on Stream Temperature, Shade, and Desired Future Condition

REPORT

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Abbreviations, acronyms, and terms

Board – Oregon Board of Forestry

BLM – Bureau of Land Management

CA – California

cfs – cubic feet per second (a unit of streamflow)

DBH – Diameter at breast height (4.5 feet from ground)

DEQ – Oregon Department of Environmental Quality

DFC – desired future condition (refers to streamside forest goals as referenced by OAR 629-642-0000(2)

FPA – Oregon Forest Practices Act (private lands)

Geographic regions – Forest Practices Act administrative areas (or regions) as described in OAR 629-635-0220

OAR – Oregon Administrative Rules

ODF – Oregon Department of Forestry

ODFW – Oregon Department of Fish & Wildlife

OR – Oregon

ORS – Oregon Revised Statutes

NC – Biologically-based numeric criterion

PCW – Protecting Cold Water criterion

RipStream – Riparian Function and Stream Temperature Study

RMA – Riparian Management Area

Rx – Prescribed or prescription (e.g., Rx fire, Rx buffer treatment)

Streamside – used interchangeably with riparian

SR – Systematic Review

USFS – United States Forest Service

Executive Summary

ES1. Introduction

ES 1.1 Background

At the November 2016 meeting, the Oregon Board of Forestry (Board) finalized the Private Forest Division's Monitoring Strategy. In conversing about the Strategy, the Board discussed the need to address streamside issues in the Siskiyou and Eastern Oregon geographic regions[1]. The Board directed the department to:

- Develop potential monitoring questions regarding streamside protections in the Siskiyou and eastern Oregon regions;
- Estimate the timeline and resources to address questions for various methods of study; and,
- Work with stakeholders to inform the department and the Board.

At the March 2018 meeting, the department presented information based on the aforementioned direction. The Board then directed the department to:

> *Conduct a study to assess the effectiveness of Forest Practices Act (FPA) streamside protection rules in the Siskiyou on medium and small Type F stream types to meet the purpose and goal for healthy streamside forests (desired future condition) and water protection relating to stream temperature and shade. Utilize research and monitoring data from peer-reviewed scientific articles, unpublished "gray" or "white" literature, TMDL analyses by ODEQ, watershed council data or analyses, status and trend data on fish populations, streamside and fish habitat data, and voluntary measures on non-federal lands to inform the monitoring study. Begin with a review of this literature.*

Additionally, the Board direction said:

- *New analysis of raw data sets is out of scope;*
- *This option also addresses key stakeholder concerns about water quality (stream temperature) and healthy forests (i.e., achieving DFC with active management), and contains the context relative to potential impacts to fish. Regarding this last point, implicit in the assumptions of the FPA is that by meeting the goals of water quality, aquatic habitat, and the riparian vegetation desired future condition, fish use will be adequately addressed. We therefore will not directly address the impact of forest practices on fish use. However, we propose to collaborate with appropriate partner agencies (e.g., ODFW) to characterize fish status and trend in the Siskiyou geographic region, and thereby provide the context of fish use.*

The expected outcome of this review will be a decision by the Board in spring 2019 on the sufficiency of riparian rules, to decide if:

- FPA or rules meet the stated objectives
- FPA or rules do not meet the stated objectives
- Not enough information for sufficiency decision: Additional study prioritized
- Not enough information for sufficiency decision: Other pending work prioritized at this time

[1] Geographic regions, or regions, are used interchangeably and refer to the Forest Practices Act geographic regions defined in OAR 629-635-0220.

If the Board found the rules did not meet stated objectives and that a resource is being degraded, they could consider changing the rules through a rule analysis, which could result in regulatory or voluntary measures. According to statute, effects to fish, wildlife, and water quality, and economic impacts to forest landowners and the timber industry must be considered in such decisions (ORS 527.714 and 527.765).

ES 1.2 Review objectives

1.2.1 Stream Temperature

One primary purpose of this systematic review is to provide scientific evidence to the Board on the effectiveness of the FPA rules in protecting stream temperature for small- and medium-sized fish-bearing streams in the Siskiyou region (water protection rules, OAR 629-635-0100; sufficiency per ORS 527.710 (2b) and ORS 527.765(1)).

The review seeks to answer the following policy question:

> ***Stream Temperature:***
> **For small and medium fish-bearing streams in the Siskiyou region, what is the effectiveness of FPA buffers to meet DEQ water quality standards for temperature[2]?**

The associated objective for this question is:
Objective 1. Assess if stream temperatures within or adjacent to forest management meet DEQ water quality temperature standards in the Siskiyou region's small and medium fish streams.

ES 1.2.2 Desired Future Condition (DFC)

The other primary purpose of this systematic review is to provide scientific evidence to the Board on the effectiveness of the FPA rules in achieving DFC of streamside forests along small- and medium-sized fish-bearing streams in the Siskiyou region (sufficiency per ORS 527.710 (2)).

Regarding DFC, the rule[3] states:

> *The desired future condition for streamside areas along fish use streams is to grow and retain vegetation so that, over time, average conditions across the landscape become similar to those of mature streamside stands. Oregon has a tremendous diversity of forest tree species growing along waters of the state and the age of mature streamside stands varies by species. Mature streamside stands are often dominated by conifer[4] trees. For many conifer stands, mature stands occur between 80 and 200 years of stand age. Hardwood stands and some conifer stands may become mature at an earlier age...*

For more on DFC, the reader is directed to this review's protocol (Appendix D).

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[2]"DEQ water quality temperature standards" refer to OAR 340-041-0028 (4) & (11).
[3]OAR 629-642-0000(2)
[4]Rule language states mature riparian stands as "often dominated" by conifers, however the Siskiyou region may be an exception due to high prevalence of hardwoods in the riparian management area (RMA). The FPA describes basal area targets geared towards conifer stands (including within the RMA; OAR 629-642-0100(6)). However, there are no RMA basal area targets for hardwoods. For this review, literature with data on streamside stands dominated by hardwoods will be within scope in order to capture what information may exist.

In order to address this primary purpose, a portion of the review will seek information on the range of characteristics that define DFC of streamside forests along these streams in the Siskiyou region. Additionally, the Board specifically directed ODF to address the shade outcome from streamside protections, which directly influences stream temperature, both immediately post-harvest, and at DFC. The review seeks to answer the following policy question:

> ***Desired Future Condition:***
>
> **For small and medium fish-bearing streams in the Siskiyou region, what is the effectiveness of FPA buffers in achieving the desired future conditions of streamside forests?**

The associated objectives for this question are:
Objective 2. Assess the range of the streamside stand conditions of mature forests in the Siskiyou region.
Objective 3. Assess the effectiveness of near-stream forest management on achieving FPA desired future conditions of streamside forests in the Siskiyou region.

This objective contains two parts:

> **Objective 3a.** Analyze the degree to which managed forests have, or if not then likely will have[5], understory and overstory characteristics similar[6] to those of mature streamside stands.
> **Objective 3b.** Analyze the degree to which managed forests have, or will have[2], streamside seedling/sapling species composition and age structure similar to those of mature streamside stands.

ES 2. Methods

A protocol for this systematic review was developed following guidance on conducting systematic reviews in the natural resource sciences. This method was selected because it provides for rigor and transparency concerning how studies are searched for, which ones are included in the review, and how they are analyzed. This protocol provided a road map for how to conduct the review of scientific literature relevant to the aforementioned policy questions.

The review seeks to answer this question with evidence, as opposed to the authors' interpretation of such evidence, from existing studies. Studies are rigorously screened for quality and relevance to this question. Finally, the entire process of conducting the review allows for greater inclusion of review partners (e.g., stakeholders and tribes), as all steps of the review are fully documented for transparency. ODF requested and received input from these partners, thereby strengthening the quality of this systematic review.

[5]Dependent on multiple sources of data to assess stand structure trajectory of unmanaged and managed riparian forests.

[6]For identifying and making comparisons, data from included studies will be categorized by Stand Age Range in this document using the following categories: being from "*mature*," "*pre-mature*," or "*post-mature*" streamside stands. The following pieces of information will be used to determine "stand age range": Stand Age: studies with conifer and/or hardwood stand ages near or between 80 to 200 years (+/- 10 years) will be identified as "*mature*," younger stands will be identified as "*pre-mature*" and older stands will be identified as "*post-mature*;" Stand Succession: studies with conifer and/or hardwood stands identified by study authors as being at a stand succession stage (e.g. early seral = "*pre-mature*;" old growth = "*post-mature*," etc.); Studies that can be logically construed as meeting the criteria of #1 or #2 by other methods (ex: time since stand establishment, etc.).

ES 3. Results and Synthesis

ES 3.1 Stream Temperature

This review assessed 3 papers with relevant stream temperature data. These papers presented data from a total of five streamside prescriptions, from 11 sites, that were used to assess the temperature water quality standard set by the Oregon Department of Environmental Quality (DEQ). The two particular water quality temperature criteria addressed are 1) the biologically-based numeric criteria[7] ("NC"; which is either 16 or 18 °C for a given stream reach in this review's paper); and, 2) the Protecting Cold Water criterion[8] ("PCW"; which allows for no more than 0.3 °C increase in stream temperature due to human activity).

Note that whereas none of the sites had the same prescription (no-cut buffer widths or basal area retention) as that required the FPA, they provide insight on the likelihood of the FPA meeting the applicable water quality criterion, based on the following reasoning:

- Sites with prescriptions that exceed FPA requirements but do not meet the applicable water quality standard suggest that the FPA does not meet it either. A total of three sites fit this category.
- Sites with prescriptions that are less than FPA requirements but do meet the applicable water quality standard suggest that the FPA does meet it too. A total of one site fits this category.
- Sites with prescriptions that exceed those of the FPA that meet applicable water quality standards, and sites with prescriptions less than those of the FPA that do not meet applicable water quality standards provide little insight on the FPA to meet applicable water quality standards. A total of seven sites fit this category.

An important caveat is that without knowing the retention of basal area compared with that of the FPA makes the above assertions weaker. For example, for sites with narrower no-cut buffers than those of the FPA, that met the applicable water quality standard might have retained more basal area, and hence potentially more shading, than the FPA.

See section 3.2 for more detail on stream temperature papers assessed in this review.

ES 3.2 Desired Future Condition

Nine studies (13 papers) addressed one or more of the metrics on streamside stand conditions. For basal area and canopy cover, only one site from one study described streamside stands with FPA prescriptions. No data were found for tree species composition and regeneration of streamside stands with FPA prescriptions. Additionally, no data were found for tree species composition and regeneration of mature streamside stands aside from one site in one study reporting a tree species richness of 12. Therefore, we caution readers to keep this in mind when interpreting the following comparisons.

The ranges of results on canopy cover and shade from mature streamside stands (both managed and unmanaged) were broad (62-81% streamside canopy cover, 53-89% in-stream shade). Percent in-stream canopy cover from stands managed per the FPA was above the percent canopy cover range of mature streamside stands, however, the canopy cover range of mature streamside stands was not measured in-stream (it was measured streamside from various plot widths). There was no measurement for in-stream

[7]OAR **340-041-0028(4)**
[8]OAR **340-041-0028(11)**

shade from stands managed per the FPA that could be compared with the range from mature streamside stands reported in the studies.

The range of results on basal area from studies with mature streamside stands (both managed and unmanaged) was broad, as well (332-784 ft^2/acre). All studies with basal area data, managed and unmanaged, had values below the range of basal area from studies with mature streamside stands, including those managed per the FPA 1-year post-harvest. Streamside stands managed per the FPA have the expectation that basal area immediately following harvest will be less than that of mature streamside stands and will have conditions under which it will grow to become similar to mature streamside stands (*Section 1.2.2*; Lorensen, 1994), therefore basal area comparisons with FPA streamside stands 1-year post-harvest are not effective for answering Policy question 2.

See section 3.3 for more details on papers with data related to DFC.

ES 3.3 Data gaps and limitations

Following are the data gaps and limitations of this review:

- No papers assessed the NC in the context of commercial harvest (thinning or clearcut), just thinning from below and prescribed fire, and thus *at best* are like a pre-commercial thin rather than timber harvest.
- The impact of streamflow on temperature was not directly addressed in any studies; this variable plays in both during drought years, and when flow may increase following harvest.
- Very few sites assess streamside buffers that are similar to those required by the FPA. Thus, Information from studies that did not explicitly measure stands managed per the FPA should be considered with caution when trying to assess the effectiveness of the FPA.
- Studies had few replicates that were relevant to this review.
- Data on stand age are missing from many papers, thus it is hard to determine whether stands are pre-, at, or post-mature.
- Data on management history were vague or not available.
- Stream sizes were estimated from some studies based on basin size per Lorensen *et al.* (1994) or stream order. Some streams were at threshold between medium and large classification, and yet are included in this review because of this ambiguity (though given lower relevance confidence score).
- Methods for sampling and study design varied greatly making it difficult to accurately compare results.
- We applied our own attempts at estimating the stand age for sites in the Fuels Reduction Treatments Study. We used site index curves from King, 1966 and Means & Helm, 1985. These estimates are coarse at best.
- Not all streamside stand information was available across all papers. Metrics reported were inconsistent from paper to paper.
- Data found to describe mature streamside stands were limited in sample size, therefore, we are unable to detect if any of the data included in this review are outliers.
- Some papers reported only one of the following: ranges of values, confidence intervals, standard deviation or standard errors. The inconsistency in reporting of descriptive statistics made it difficult to compare and present them in figures.
- Some values were identified from figures in literature and therefore are not exact values.
- There were no reported data to accurately assess if managed riparian stands are on a trajectory to achieve conditions similar to those of mature stands.

1. Introduction

1.1 Background

At the November 2016 meeting, the Oregon Board of Forestry (Board) finalized the Private Forest Division's Monitoring Strategy. In conversing about the Strategy, the Board discussed the need to address streamside issues in the Siskiyou (Figure 1) and Eastern Oregon regions. The Board directed the department to:

- Develop potential monitoring questions regarding streamside protections in the Siskiyou and eastern Oregon regions;
- Estimate the timeline and resources to address questions for various methods of study; and,
- Work with stakeholders to inform the department and the Board.

At the March 2018 meeting, the department presented information based on the aforementioned direction. The Board then directed the department to:

> *Conduct a study to assess the effectiveness of FPA streamside protection rules in the Siskiyou on medium and small Type F stream types to meet the purpose and goal for healthy streamside forests (desired future condition) and water protection relating to stream temperature and shade. Utilize research and monitoring data from peer-reviewed scientific articles, unpublished "gray" or "white" literature, TMDL analyses by ODEQ, watershed council data or analyses, status and trend data on fish populations, streamside and fish habitat data, and voluntary measures on non-federal lands to inform the monitoring study. Begin with a review of this literature.*

Additionally, the Board direction said:

- *New analysis of raw data sets is out of scope;*
- *This option also addresses key stakeholder concerns about water quality (stream temperature) and healthy forests (i.e., achieving DFC with active management), and contains the context relative to potential impacts to fish. Regarding this last point, implicit in the assumptions of the FPA is that by meeting the goals of water quality, aquatic habitat, and the riparian vegetation desired future condition, fish use will be adequately addressed. We therefore will not directly address the impact of forest practices on fish use. However, we propose to collaborate with appropriate partner agencies (e.g., ODFW) to characterize fish status and trend in the Siskiyou geographic region, and thereby provide the context of fish use.*

The expected outcome of this review will be a decision by the Board in spring 2019 on the sufficiency of riparian rules, to decide if:

- The FPA or rules are working as designed
- FPA or rules may not meet stated objectives
  - Not enough information for sufficiency decision: Additional study prioritized

For more information:

All forest practice rules, are available from the Secretary of State website:
http://sos.oregon.gov/archives/Pages/oregon_administrative_rules.aspx.

Statutes may be found at the Oregon State Legislature website:
https://www.oregonlegislature.gov/bills_laws/Pages/ORS.aspx.

The rules and statutes are also available on the Oregon Department of Forestry's website:
http://www.oregon.gov/ODF/Pages/LawsRules.aspx.

FPA Water Protection Rules:
https://digital.osl.state.or.us/islandora/object/osl:85361

Other ODF documents:
https://digital.osl.state.or.us/islandora/object/osl%3Adocs_f

- Not enough information for sufficiency decision: Other pending work prioritized at this time

If the Board found the rules did not meet stated objectives and that a resource is being degraded, they could consider changing the rules through a rule analysis, which could result in regulatory or voluntary measures. According to statute, effects to fish, wildlife, and water quality, and economic impacts to forest landowners and the timber industry must be considered in such decisions (ORS 527.714 and 527.765).

This report contains the aforementioned systematic review and associated elements (e.g., input from interested parties). Note that contextual information on fish status and trend from ODFW, and water quality evaluations from DEQ were presented to the Board in January 2019.

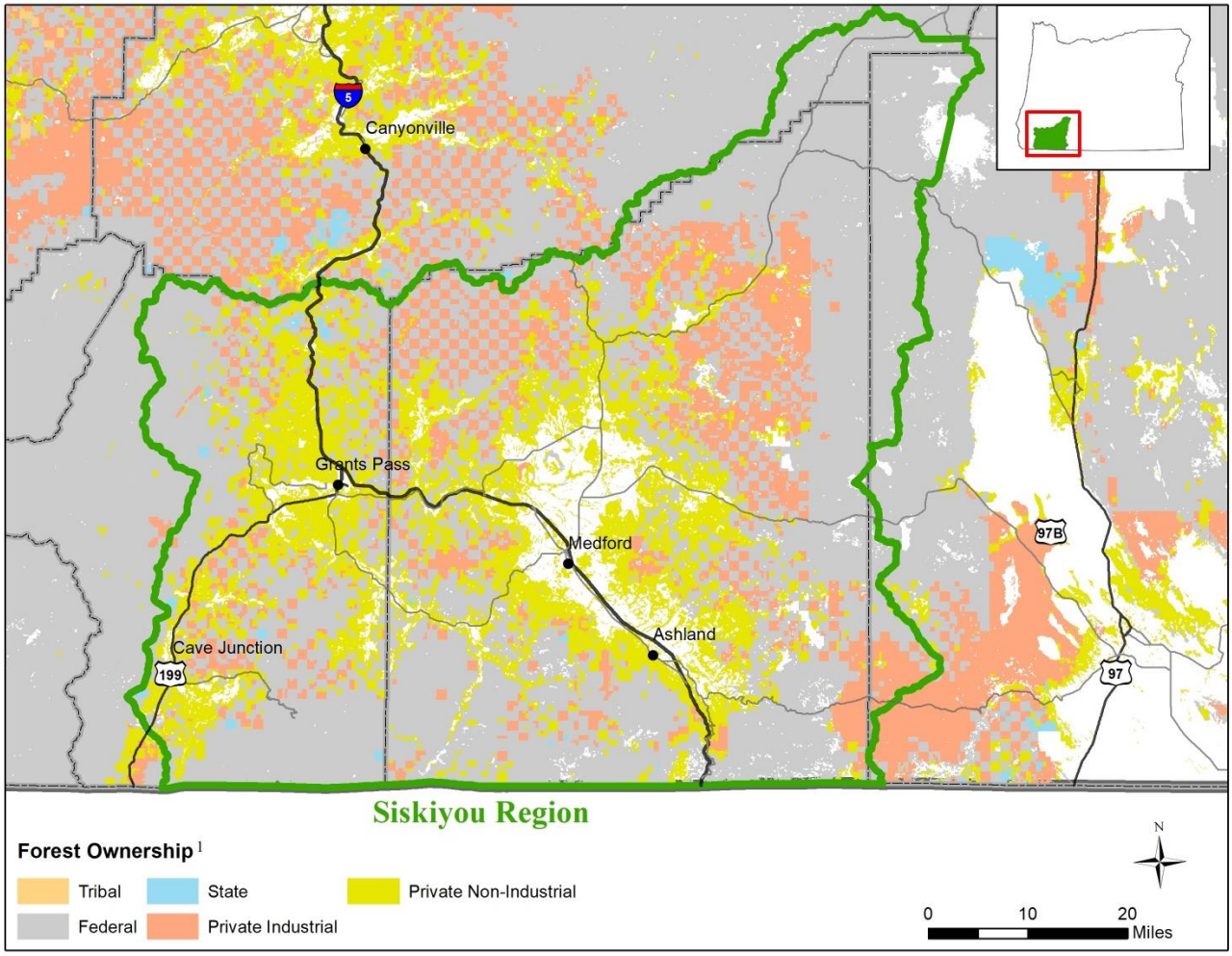

Figure 1. Forest ownership in the Siskiyou geographic region based on 2017 data.

1.2 Review purpose

1.2.1 Stream Temperature

One primary purpose of this systematic review is to provide scientific evidence to the Board on the effectiveness of the FPA rules in protecting stream temperature for small- and medium-sized fish-bearing streams in the Siskiyou region (water protection rules, OAR 629-635-0100; sufficiency per ORS 527.710 (2b) and ORS 527.765(1)).

The review seeks to answer the following policy question:

> ***Stream Temperature:***
> **For small and medium fish-bearing streams in the Siskiyou region, what is the effectiveness of Oregon FPA buffers to meet DEQ water quality standards for temperature?**

The associated objective for this question is:
Objective 1. Assess if stream temperatures within or adjacent to forest management meet DEQ water quality temperature standards in the Siskiyou region's small and medium fish streams.

The two particular water quality temperature criteria addressed are 1) the biologically-based numeric criteria[9] ("NC") and 2) the Protecting Cold Water criterion[10] ("PCW").

1.2.2 Desired Future Condition (DFC)

The other primary purpose of this systematic review is to provide scientific evidence to the Board on the effectiveness of the FPA rules in achieving DFC of streamside forests along small- and medium-sized fish-bearing streams in the Siskiyou region (sufficiency per ORS 527.710 (2)).

Regarding DFC, the rule[11] states:

> *The desired future condition for streamside areas along fish use streams is to grow and retain vegetation so that, over time, average conditions across the landscape become similar to those of mature streamside stands. Oregon has a tremendous diversity of forest tree species growing along waters of the state and the age of mature streamside stands varies by species. Mature streamside stands are often dominated by conifer[12] trees. For many conifer stands, mature stands occur between 80 and 200 years of stand age. Hardwood stands and some conifer stands may become mature at an earlier age...*

For more on DFC, the reader is directed to this review's protocol.

In order to address this primary purpose, a portion of the review will seek information on the range of characteristics that define DFC of streamside forests along these streams in the Siskiyou region. Additionally, the Board specifically directed ODF to address the shade outcome from streamside protections, which directly influences stream temperature, both immediately post-harvest, and at DFC.

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[9]OAR **340-041-0028(4)**
[10]OAR **340-041-0028(11)**
[11]OAR 629-642-0000(2)
[12]Rule language states mature riparian stands as "often dominated" by conifers, however the Siskiyou region may be an exception due to high prevalence of hardwoods in the riparian management area (RMA). The FPA describes basal area targets geared towards conifer stands (including within the RMA; OAR 629-642-0100(6)). However, there are no RMA basal area targets for hardwoods. For this review, literature with data on streamside stands dominated by hardwoods will be within scope in order to capture what information may exist.

The review seeks to answer the following policy question:

Desired Future Condition:

For small and medium fish-bearing streams in the Siskiyou region, what is the effectiveness of FPA buffers in achieving the desired future conditions of streamside forests?

The associated objectives for this question are:
Objective 2. Assess the range of the streamside stand conditions of mature forests in the Siskiyou region.
Objective 3. Assess the effectiveness of near-stream forest management on achieving FPA desired future conditions of streamside forests in the Siskiyou region.

This objective contains two parts:

Objective 3a. Analyze the degree to which managed forests have, or if not then likely will have[13], understory and overstory characteristics similar[14] to those of mature streamside stands.
Objective 3b. Analyze the degree to which managed forests have, or will have[2], streamside seedling/sapling species composition and age structure similar to those of mature streamside stands.

1.3 Overview of review approach

The department prefers to use systematic reviews (SR) for doing policy-related literature reviews (e.g., Czarnomski et al., 2013) because it provides for rigor and transparency concerning: search criteria, inclusion criteria, data extraction, and synthesis methods. All steps of the review process are documented for transparency. This documentation enables input from stakeholders and tribes at various stages in the review (discussed below under "Next Steps"). Note that for this report, we distinguish "study" (an observational or experimental investigation including its design and location) and "paper" (a written document for a given study, and studies may have more than one paper).

The first step in conducting a SR is the development of a protocol that provides a road map for the review of scientific literature relevant to a focused question. Staff developed this SR protocol following guidance on conducting SRs in the natural resource sciences (CEE, 2018). The protocol for the Siskiyou SR identifies key questions linked to policy goals within FPA rules, and describes the criteria for literature search and inclusion. It also lays out the framework for synthesizing the information extracted from the papers included in the SR. Elements incorporated in a systematic review are outlined in Table 1.

[13]Dependent on multiple sources of data to assess stand structure trajectory of unmanaged and managed riparian forests.

[14]For identifying and making comparisons, data from included studies will be categorized by Stand Age Range in this document using the following categories: being from "*mature*," "*pre-mature*," or "*post-mature*" streamside stands. The following pieces of information will be used to determine "stand age range": Stand Age: studies with conifer and/or hardwood stand ages near or between 80 to 200 years (+/- 10 years) will be identified as "*mature*," younger stands will be identified as "*pre-mature*" and older stands will be identified as "*post-mature*;" Stand Succession: studies with conifer and/or hardwood stands identified by study authors as being at a stand succession stage (e.g. early seral = "*pre-mature*;" old growth = "*post-mature*," etc.); Studies that can be logically construed as meeting the criteria of #1 or #2 by other methods (ex: time since stand establishment, etc.).

Table 1. Elements described in a protocol for conducting a systematic review.

Elements	Brief explanation
Question(s), Objective(s)	Focused, scientifically answerable question and objective that guides search strategy and inclusion criteria, and analysis
Search strategy	Methods (e.g., search terms and databases) to find papers pertinent to question
Inclusion criteria	Filters used to determine inclusion of papers to answer the question
Paper quality and relevance assessment	Criteria used to determine strength of paper methodology, and the relevance of paper findings to the review question
Data extraction	Tables used for consistently recording data from papers and reviewers' associated notes
Data synthesis	Methods (quantitative, qualitative) used for synthesizing data with respect to the review question

2. Methods

This section summarizes the protocol for conducting the systematic review (for details of the methods, refer to the final protocol, Appendix D), and other elements for completing the review (e.g., working with stakeholders). Note that for this report, we distinguish "study" (an observational or experimental investigation including its design and location) and "paper" (a written document for a given study, and studies may have more than one paper).

2.1 Review partners

A central element of how the Monitoring Unit works is extensive conversation and inclusion of stakeholders and tribes. This section describes this work with both internal and external stakeholders, and tribes.

Steps for inclusion of partners

All partners had the opportunity to provide input on:

- The protocol and question for this review;
- A draft list of papers to consider for inclusion in the review to assess if any papers were not found, and the opportunity to provide additional papers to consider for inclusion;
- A draft list of included papers to assess whether or not the inclusion criteria were appropriately applied;
- A draft of the SR report.

2.2 Search strategy

An important aspect of the SR is the use of a search strategy that specifies, *a priori*, how a comprehensive and unbiased sample of papers will be searched. We decided to search as widely as possible, then use rigorous inclusion criteria to determine which papers to include. All papers identified

in the search were saved in a database, except for internet searches from which the first 100 results were reviewed for relevant papers (this restriction follows CEBC (2018) guidance). Results with indeterminate information (e.g., incomplete citation) or duplicates were excluded. For every search, the following information is documented (see Table A.1, Appendix A):

- Date when search was conducted
- Database, search engine, website, library, or professional contact that was queried
- Exact search strings used

2.3 Paper inclusion criteria

Paper inclusion criteria are predefined to ensure a transparent and consistent selection of the relevant literature. For this review, the papers must directly inform at least one of the review questions. Only primary papers (i.e., papers that collected data, not reviews or meta-analyses) were included because ODF wants to base the review on primary results found in papers, not authors' interpretation of study results. While peer-reviewed articles are the gold standard in science, we decided to include "gray literature" (i.e., papers that might have less rigor in either peer-review or research methods / analysis, e.g., government reports, graduate theses) and manuscripts in review because some of these papers are most relevant to the review questions. This relevancy stems from a common requirement that agencies (e.g., ODF) assess the effectiveness of their respective rules via papers. The final inclusion criteria are:

- Papers must have descriptive, modeled, or observational data on at least one of the streamside stand metrics outlined in the protocol (Tables D.2; note: we are not examining raw data);
- Papers must have been located within the Siskiyou-Klamath Mountain region of southwest Oregon or northern California (EPA Level III Ecoregion 78, US EPA, 2013; Griffith et al., 2016; Pater et al., 1998);
- Papers must have been conducted in sites with similar stream sizes as ODF's classification of small and medium streams (<10 cfs, Oregon Department of Forestry, 1994);

Additionally, inclusion criteria must meet ***one of*** the following:

- For Objective 2, papers must meet the criteria of the desired future condition (mature streamside stands, 80-200 years, etc. (See 1.2.2 *Desired Future Condition* for definition and description of Stand Age Range)) or contain pre- or post-mature conditions which the department will use to place bounds on mature conditions;
- Papers must have proper controls with which to measure the effects of buffer treatments (Temperature- Objective 1; DFC- Objectives 3a, 3b);

Inclusion criteria are further detailed in the protocol (Table D.5).

With these criteria in mind, inclusion was determined initially on viewing the titles of articles. When titles provided insufficient information to ascertain consistency with inclusion criteria, we read abstracts to determine inclusion. Finally, where there was still insufficient information to make a decision, an article's inclusion was determined by reading the full text. Papers that meet all inclusion criteria are in this report. There were a few instances where the paper might meet all inclusion criteria if we have a little more information from the authors. For example, when authors use data (e.g., basal area) in a statistical model, but do not list those data in the paper. In these instances, we contacted the authors to try to get this information. For transparency, the fate (i.e., inclusion or exclusion), and basis for this decision, of each paper found in the search were documented (Table A.1, Appendix A).

2.4 Potential effects modifiers

Although papers may have very similar methods, they may show differences in the measured outcomes. These differences may be due to circumstances ("effects modifiers") that alter the outcomes and were not explicitly part of the SR policy questions or objectives. For example, two papers may have identical buffer widths, yet if they have different buffer lengths, they might exhibit different changes in stream temperatures. Thus, these effects modifiers are important to consider when synthesizing the information extracted from papers. The role effects modifiers played in paper outcomes is discussed in the protocol (Appendix A1).

2.5 Data extraction strategy

When conducting a systematic review, it is important to extract both information about the papers included and their respective results. This information focuses the review on evidence found in paper results instead of authors' discussion of the evidence. Data extraction tables allow for consistent, and transparent extraction of this data. In addition, these tables help to highlight gaps in our understanding. Each included paper's data were compiled using Table D.6, Appendix D. This table was developed by modifying those of Bowler et al. (2008) and Burnett et al. (2008), testing data extraction with several papers, and with input from stakeholders and tribes. We also assessed various components (e.g., bias, effects modifiers) that provide a more complete understanding of the context, relevance, and relative strength of papers (Table D.6).

2.6 Paper quality assessment and relevance

When synthesizing data from the papers, it is important to consider both the quality of each paper and its relevance to the review question and associated policy issue. For example, a paper might have directly addressed the review questions, yet was poorly conducted so as to provide little confidence in the paper's results. Conversely, a paper may have been conducted very well, yet has only weak relevance to the review questions.

We completed tables that enable quick and transparent comparisons of papers. Table D.7 addresses the quality of papers by determining e.g., the rigor of their controls and number of replicates. A summary metric, the Quality Confidence Score, combines the various aspects that make for a high quality paper. This metric is designed to help assess the quality of the information in regards to paper design, methods, and statistics (e.g., Figures D.1-12, Appendix D). This table also identifies paper relevance to the review question (the Relevance Confidence Score) by displaying our assessment of how well the paper matches the search criteria (e.g., papers on small and medium streams; within Siskiyou-Klamath ecoregion of Oregon or California; paper objectives align with the objectives of this review; comparison to FPA buffer prescriptions; paper contains data on mature streamside stands). Notes additionally provided by reviewers using Table D.7 further illuminate paper quality and reference (e.g., robustness of paper measures, sources of bias, consideration of effects modifiers).

2.7 Data synthesis

To make sense of the information extracted and analyzed from the papers, a narrative synthesizes the information collected in Tables D.6-7 (Appendix D). This synthesis assesses the differences and commonalities between streamside management scenarios used in papers and their respective outcomes. The synthesis discusses:

- Number of papers that directly or indirectly address the topic;
- Results;

- Role of effects modifiers in the stream temperature, DFC and [in-stream and streamside] shade outcomes that were measured; and
- Significant gaps in data available and gaps in our understanding of important mechanisms.

The synthesis also examines the magnitude of influence the effects modifiers had on results. It should be noted the synthesis does not include statistical analysis of results.

3. Results and Synthesis

3.1 Literature search and filter

In the literature search, 925 papers were initially identified. Based on paper inclusion criteria, 13 papers representing 9 studies are included in this review (i.e., they meet all inclusion criteria; see Table D.5, Appendix D), while 912 papers were excluded. Of included papers, three papers address Objective 1 (Temperature), eight papers address Objective 2 (Mature streamside stands), and nine papers address Objective 3 (Managed streamside stands; Table 2). Note that some of the papers cover more than one objective. Of the papers excluded from the review, approximately 80% were rejected based on the title, ~10-15% were rejected based on the abstract, and the remainder required reading a portion of the complete text. A summary of information from included papers is reported in Table 3 and stream morphology information from each study is reported in Table 4.

Papers included in this report were assessed for quality and relevance using standardized Quality Confidence and Relevance Confidence Scores (Table A.3, Appendix A). Most papers scored higher than 50% for quality (Figure 2). Messier et al., 2012 had the highest quality confidence score (93%). Most papers scored between 40% and 67% relevance with the exception of Dent, 2001 and papers from the Riparian Fuels Treatments Study (80% relevance, Figure 2).

Note that the papers actually included in this review have changed since we sought input from stakeholders and tribes on the list of included papers. Some papers were excluded upon much closer examination, in part because we realized that the exclusion criteria needed more specification than we had identified at the outset[15]. Additionally, we came across a few extra papers that met all the inclusion criteria.

Table 2. Number of papers and studies by objective1. "Study" refers to an observational or experimental investigation including its design and location. A "paper" refers to a written document for a given study, and studies may have more than one paper.

Objective[1]	Papers	Studies
Objective 1 (Temperature)	3	3
Objective 2 (Mature DFC)[2]	8	6
Objective 3 (Managed DFC)[2]	9	6
Total	13	9

[1] Some papers address more than one objective.

[15]Note: all changes to the protocol since the version sent to stakeholders and tribes have been documented and are available upon request.

[2] Note: some papers lacked information on stand ages, seral stages, and management history. These papers are included in this review because they inform one of the two objectives and demonstrate the range of different metrics (e.g., papers without information on stand age range were used to address Objective 3 but not used to address Objective 2).

Table 3. Summary information on papers in this review.

	Paper	Location	Management[1]	Stream Size(s)	Plot width (feet from stream)	Streamside Prescription	Upland Prescription[4]	Obj.[5]	Streamside Age Range[6]
	Cover et al., 2010	CA Klamath mountains	USFS	Small/ Medium[2]	16.4	Unmanaged	None	2	Mature, Pre-mature
	Dent, 2001	OR Siskiyou	OR FPA	Small	20, 50	FPA: 20' no-cut, 50' RMA[3] basal area target reached in first 20', buffer: 83'	N/A	3	N/A
	Farber & Whitaker, 2010a (McKinney)	CA Klamath mountains	CA FPA	Small/ Medium[2]	0, 50, 150	50' no-cut (0-50'); 50% cover (50-150')	Thin, clearcut	1,2, 3	Pre-mature
	Farber & Whitaker, 2010b (Etna Cr.)	CA Klamath mountains	CA FPA	Small/ Medium[2]	0, 25, 100 0, 75, 150	50' no-cut (0-75'); 50% cover (75-150');	Thin, clearcut	1,2, 3	Mature
	Halofsky & Hibbs, 2008	OR Siskiyou	USFS	Small/ Medium[2]	16.4	N/A	N/A	3	N/A[9]
	Messier et al., 2012	OR Siskiyou	USFS/BLM	Small[2]	30	Unmanaged	None	2	Post-mature
	USGS, 2012	CA Klamath mountains	NPS	Medium	0	Unmanaged	None	2	Mature[7]
Sarr Dissertation	*Sarr & Hibbs, 2007a* *Sarr & Hibbs, 2007b* *Sarr et al., 2011*	OR Applegate	USFS/BLM	Small[2]	27, 82 82 82	N/A	N/A	3	N/A[9]
Riparian Fuels Treatments Study	*DeJulio, 2009* *Stephens & Alexander, 2011* *Volpe, 2009*	OR Rogue/ Applegate	BLM	Small[2]	20	50' no-cut; thinned	Thin, Rx fire	2, 3 2, 3 1, 2, 3	Pre-mature, Mature, N/A[8]

[1]Management refers to applicable rules at the time of study that are followed for harvesting and stream buffer prescriptions based on land ownership and regulatory jurisdiction. OR FPA: Oregon Forest Practices Act (private land ownership); CA FPA: California Forest Practices Act (private land ownership); USFS: United States Forest Service; BLM: Bureau of Land Management; NPS: National Park Service.
[2]Stream size estimated based on basin size per Lorensen et al. 1994 (Table 1, Appendix B-10) or stream order. Some streams are at threshold between medium and large, and yet are included in this review because of this ambiguity. However, they are given a lower relevance.
[3]Streamside prescription; see Appendix E for specification of FPA requirements.
[4]Upland prescription: None=no removal of trees; N/A= Not available; Thin= selective removal of trees; Clearcut= most or all trees in an area are uniformly cut down.
[5]Objective 1 (stream temperature); Objective 2 (Mature DFC); Objective 3 (Managed DFC).
[6]Stand Age Range categories: Mature=80-200 year old stand; Pre-mature < 80 year old stands; Post-mature > 200 year old stands, or Unknown (which includes unreported, unable to determine, and mixed age ranges).
[7]Based on Ponderosa and Douglas-fir age estimates from Vernon et al. 2018.
[8]Based on Ponderosa and Douglas-fir age estimates using site index curves (King, 1966; Means & Helm, 1985). Note that these may be inaccurate estimates of stand age in oak or other hardwood-dominated stands because of our inability to estimate age of oaks and other hardwoods.
[9]Seral stage or stand ages not reported in papers; N/A= Not available.

Table 4. Stream morphology information from included studies. Information not found is denoted as N/A.

Paper	Bankfull width	Valley width	Hillslope/ Streambank slope %	Stream slope %	Basin area	Depth
Cover et al., 2010	5.4-5.5 m	32-37 m	N/A	5.4-5.8	12-14.2 km^2	N/A
Dent, 2001	N/A	N/A	N/A	N/A	N/A	N/A
Farber & Whitaker, 2010a	N/A	N/A	N/A	N/A	N/A	N/A
Farber & Whitaker, 2010b	N/A	N/A	N/A	N/A	7,000 ac	N/A
Halofsky & Hibbs, 2008	0.6-13.0 m	5.4-110 m	16-138	0-64	16,000 ha	N/A
Messier et al., 2012	N/A	N/A	N/A	N/A	N/A	N/A

Paper	Bankfull width	Valley width	Hillslope/ Streambank slope %	Stream slope %	Basin area	Depth
Sarr dissertation	N/A	N/A	N/A	N/A	630km2 (1sd: 590-680)	N/A
Riparian Fuel Treatments Study USGS, 2012	N/A	N/A	0-32	11-26	No-cut: 97-559 acre; Thin: 82-661 acre	N/A
	N/A	N/A	N/A	9.33	N/A	0.21 m mean, 0.82 m max

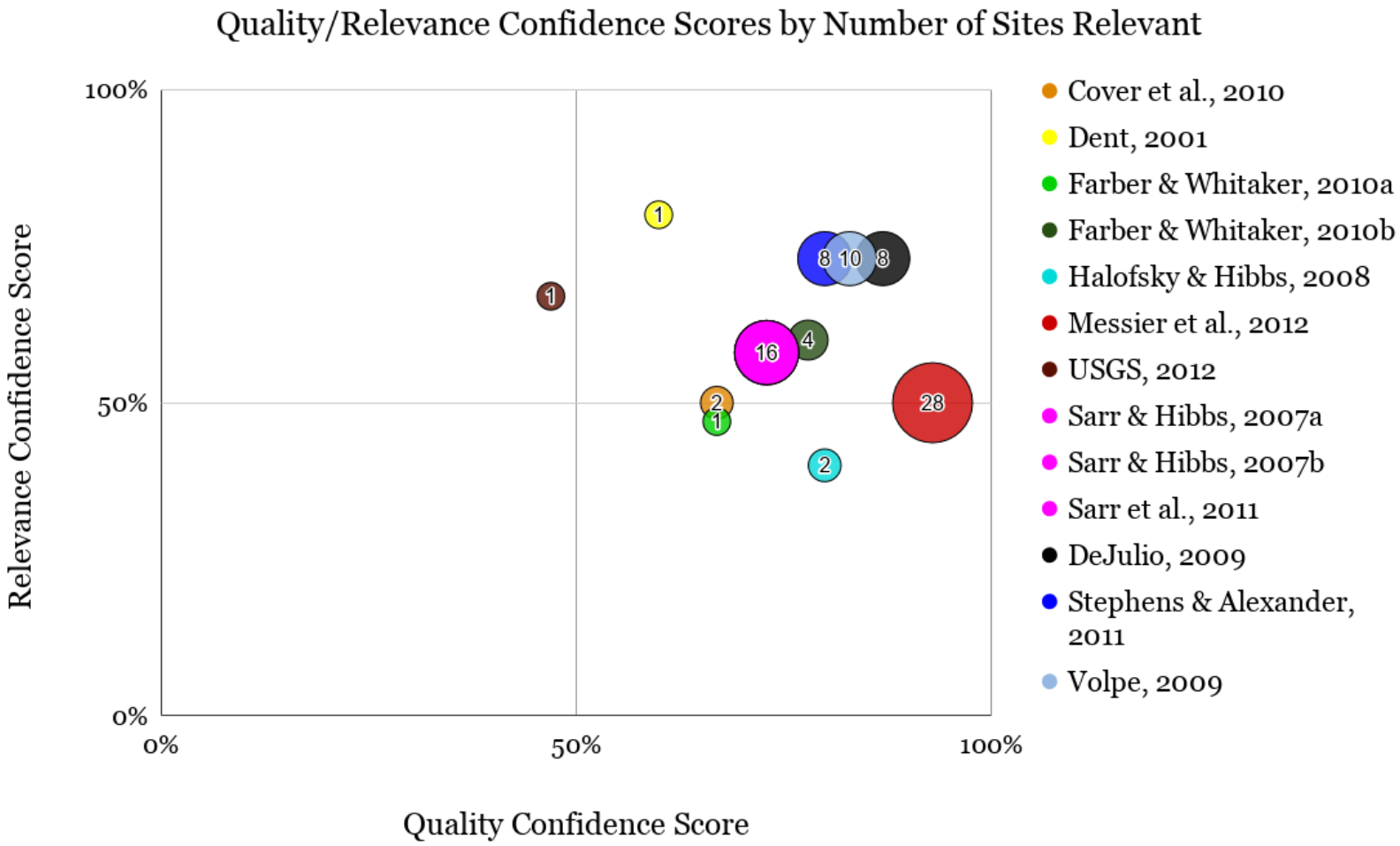


Figure 2. Quality Confidence Scores and Relevance Confidence Scores by number of sites[16] in paper found to be relevant to the Siskiyou Streamside Protections Systematic Review. Size of circle and number within circle refers to number of sites. See Table A.3, Appendix A for more information on confidence scoring. No relationship is implied between quality and relevance confidence scores.

[16]Note that for Volpe (2009), post-harvest was a drought year, thus stream temperature only had 5 sites, whereas other metrics had 10 sites and 8 sites had streamside stand data.

3.2 Stream Temperature

Papers Reviewed

Three of the papers included in this review had stream temperature data (Volpe, 2009; Farber and Whitaker, 2010a, b). In summary, these papers presented data from a total of five streamside prescriptions, from 11 sites, that were used to assess the temperature water quality standards set by the Oregon Department of Environmental Quality (DEQ). The two particular water quality temperature criteria addressed are 1) the biologically-based numeric criteria[17] ("NC"; which is either 16 or 18 °C for a given stream reach in Volpe, 2009); and, 2) the Protecting Cold Water criterion[18] ("PCW"; which allows for no more than 0.3 °C increase in stream temperature due to human activity), estimated from Farber and Whitaker (2010a, b). Shade is considered in the wider context of DFC, and is discussed below under subsection *3.3 Canopy Cover and Shade*.

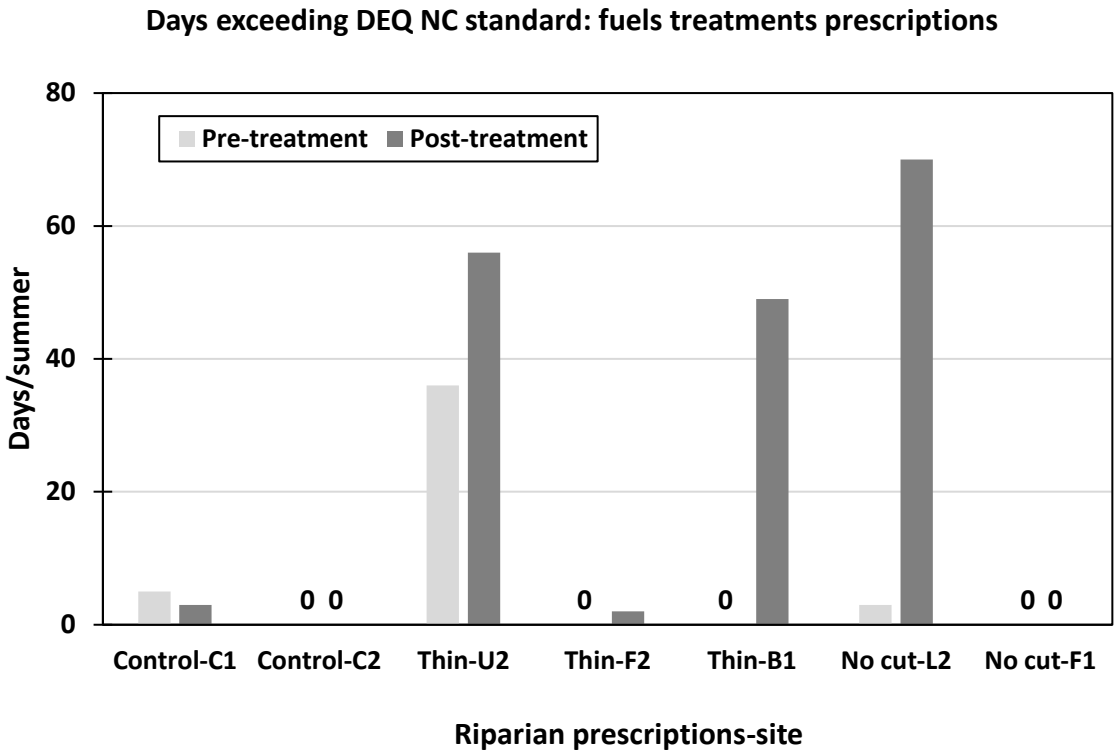
DEQ Biologically-based Numeric criterion (NC)

Volpe (2009) was part of a larger study ("Riparian Fuels Treatments Study," Table 3) assessing a variety of outcomes from treatments of wildfire fuels in streamside areas that used management prescriptions different from FPA rules (referred to as *Non-FPA Thin* and *Non-FPA No-cut*). This paper's Quality and Relevance Confidence Scores were 83% and 73%, respectively. Relevant data from this paper focused on only the NC. All streams were small.

The upland fuels treatments were a combination of thinning from below (i.e., removing ladder fuels, and maintaining overstory trees) and prescribed fire. The first of two streamside prescriptions, "Non-FPA Thin[19]" (3 sites), continued the upland prescription to the stream edge; data are lacking for assessing retention of basal area with respect to the FPA, and the no-cut area was less than that of the FPA. The second streamside prescription, "Non-FPA No cut" (2 sites), left a 50 foot no-entry buffer on perennial reaches of the streams, and a 25 foot no-entry buffer on intermittent reaches of the streams. This prescription has a wider no cut buffer than the FPA, but its basal area retention is unknown. Control sites had no thinning or prescribed fire in either the upland or streamside areas.

Volpe (2009) reported the number of days per summer that streams exceeded the basin-specific NC both pre- and post-harvest. Regarding the untreated watersheds ("control"), one site had zero days exceeding the NC both pre- and post-harvest, and the other decreased by a few days pre- to post-harvest years (Figure 3). Of the three "Non-FPA Thin" 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 "Non-FPA No cut" sites, one remained at zero days/summer pre- and post-harvest, and the other increased from three to 70 days/summer.

[17]OAR **340-041-0028(4)**
[18]OAR **340-041-0028(11)**
[19]In Volpe (2009), the "Thin" were called "unbuffered", and "No cut" were called "buffered."



Treatment	Streamside prescription	No-cut portion compared with FPA
Control	Untouched upland and streamside stands	Not applicable
Thin (Non-FPA Thin)	Thin from below + prescribed fire	<FPA
No cut (Non-FPA No cut)	No-entry (0-50 feet [perennial reaches] and 0-25 feet [intermittent reaches])	>FPA

Figure 3. Number of days per summer that sites exceeded DEQ's NC temperature standard (Volpe, 2009). On the X-axis, the type of prescription is separated by the site identifier with a dash. Stand stages for sites F2 and B1 are pre-mature, all others are unknown. Upland treatments for the non-control sites were thin from below followed by prescribed fire. The NC for F1 and F2 is 18 °C, and 16 °C for all other sites.

DEQ Protecting Cold Water criterion (PCW)

The two Farber and Whitaker (2010a, b) papers looked at streamside buffer prescriptions that were alternatives to California's riparian rules for timber harvest on private land. The quality scores were 67% and 78% for Farber and Whitaker (2010a and b, respectively), and the relevance scores were 47% and 60% for Farber and Whitaker (2010a and b, respectively).

The streamside prescriptions were:

- Rx[20]1 (Farber and Whitaker, 2010a; 1 site, medium stream size near transition to small): no cut buffer (0-50 feet), with an outer zone with retention at 50% cover (50-150 feet). The upland

[20] "Rx" is short for "prescription"

prescription consisted of 3 adjacent harvest units, the outer two of which were clearcuts, the center one was a thin. The basal area retention was larger than that required by the FPA

- Rx2 (Farber and Whitaker, 2010b; 1 site with medium stream): no cut buffer (0-75 feet), with an outer zone with retention at 50% cover (75-150 feet). The upland prescription was a clearcut.
- Rx3 (Farber and Whitaker, 2010b; 4 sites on small streams): cover was maintained at 70% in the inner zone of 0-25 feet, and at 50% in an outer zone of 25-100 feet. Uplands of three sites were commercially thinned, and one was a clearcut.

Note that basal area retention was not reported for Rx2 and Rx3.

The papers assessed pre- and post-harvest changes in maximum weekly maximum temperature (MMAT) for streams[21]. This is the same metric used for assessing attainment of the PCW and NC. The sites with medium streams used an upstream temperature station as control, whereas the small streams used nearby, unharvested small streams as controls. The two papers from this study report only the hottest MMAT for each year for each site (1 year pre-harvest and 2-3 years post-harvest).

In an attempt to assess whether or not sites might have met the PCW, we calculated the per year change in MMAT for a given site *k* due to harvest, $\Delta T_{harvest,i,k}$, as:

$$\Delta T_{harvest,i,k} = [(T_{downstream,i,k} - T_{control,i,k})_{post} - (T_{downstream,j,k} - T_{control,j,k})_{pre}]$$

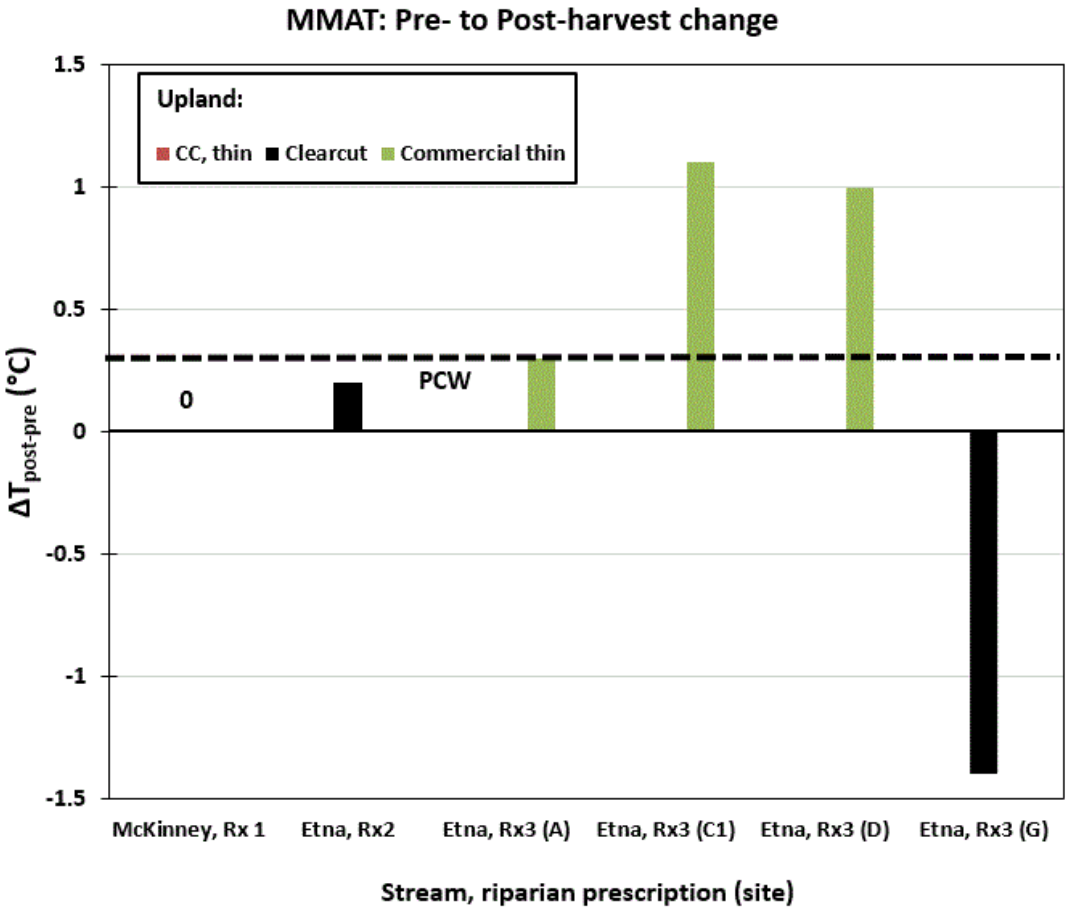
Where $T_{downstream,i}$ is the MMAT at the downstream end of harvest in year i (post-harvest) or j (pre-harvest); $T_{control,i}$ is the MMAT at the control in year i (post-harvest) or j (pre-harvest). The average change in MMAT for all post-harvest years for a given site *k* due to harvest, $\Delta T_{harvest,k}$, is:

$$\Delta T_{harvest,k} = [[\text{average}(T_{downstream,i,k} - T_{control,i,k})_{post}] - (T_{downstream,j,k} - T_{control,j,k})_{pre}]$$

This temperature change metric is reported in Figure 4.

Both of the medium-sized streams (Rx1 and Rx2) had harvest-related temperature responses below the PCW threshold (Figure 4). For the small streams (Rx3), there was a mixture of temperature responses: one was below this threshold, two were above it, and one was right at the threshold.

[21] Note that the authors only reported the highest MMAT for each season.



	Inner zone	Outer zone – retain 50% cover	No-cut portion compared with FPA	Stage	Stream size
Rx1	0-50 feet no entry	50-150 feet	>FPA	Pre-mature	Medium
Rx2	0-75 feet no entry	75-150 feet	>FPA	Mature	Medium
Rx3	0-25 feet retain 70% cover	25-100 feet	<FPA	Mature	Small

Figure 4. Change in maximum weekly maximum temperature (MMAT) pre- vs. post-harvest (McKinney Creek: Farber and Whitaker, 2010a; Etna Creek: Farber and Whitaker, 2010b). The legend refers to the upland prescription (note: combination of clearcut and thinned units for McKinney Creek only). The dashed line represents the threshold for the PCW

3.3 Desired Future Condition

Papers Reviewed

Literature searches revealed nine studies (13 papers) with data on unmanaged or managed streamside stands that address the topic of Desired Future Condition. All studies varied by data collection methods, plot size, and distance from stream (Table 3). Four papers with up to eight sites contained information on mature streamside stands, including basal area, shade, canopy cover, and tree species richness (Table

5). Only one paper with one site contained information on basal area and canopy cover of streamside stands managed per the FPA in the Siskiyou region (Table 6; Dent, 2001).

Three studies (Farber, et al. 2010a; Farber et al. 2010b; Riparian Fuels Treatments Study – Volpe, 2009; Stephens & Alexander, 2011; and, DeJulio, 2009) contained pre- and post-treatment data on streamside stands that used management prescriptions different from FPA rules (referred to as *Non-FPA Thin* and *Non-FPA No-cut*). The two Farber and Whitaker (2010a, b) papers looked at streamside buffer prescriptions that were alternatives to California's riparian rules on timber harvest on private land (referred to in figures and tables as *Non-FPA Rx1*, *Non-FPA Rx2*, and *Non-FPA Rx3*). The treatments employed in the Riparian Fuels Treatments Study and the two Farber and Whitaker (2010a, b) papers are outlined in Table 3 and *Section 3.2*. Alternatively, three papers (Cover et al., 2010; Messier, et al. 2012; USGS, 2012) with up to 30 sites contained information on various metrics to describe unmanaged streamside stands or stands that had not experienced direct human interference (mining, logging, etc.) in over 60 years (Table 3). These stands were of mature or post-mature stand age range.

The final two studies (Halofsky & Hibbs, 2008; Sarr dissertation— Sarr & Hibbs, 2007a & b; Sarr et al., 2011) recorded tree data from managed streamside stands of unknown age and unknown management or buffer prescription. The results from these last two studies are still reported in this review for context on managed streamside stands in the region (Objective 3).

Table 5. Number of studies/number of sites for each metric of DFC by stand age range. Mature stand age range is defined as roughly 80-200 year old stands.

Metrics	Pre-Mature	Mature	Post-Mature	Unknown
Basal area	1/1	2/2		2/3
Shade	1/3	2/2		1/4
Canopy cover	2/2	2/3		3/21
Tree density			1/28	
Tree species richness	1/1	1/1	1/28	2/6
DBH			1/28	
Tree seedling composition				1/4

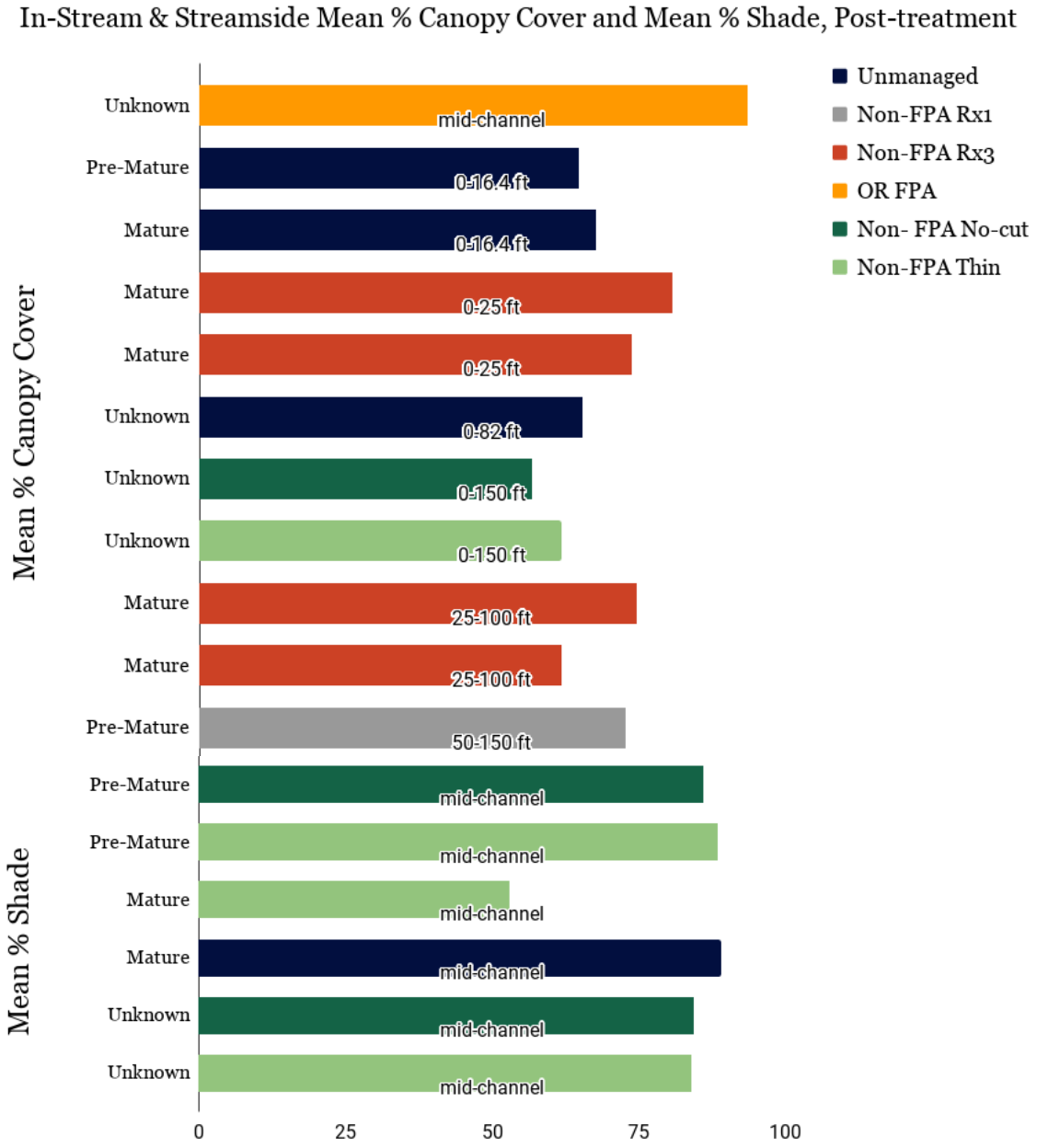
Table 6. Number of studies/number of sites for each metric of DFC by management. Management refers to harvesting and stream buffer prescriptions based on land ownership and state.

Metrics	Unmanaged	OR FPA	Non-FPA	Unknown
Basal area	1/2	1/1		1/2
Shade	1/1		1/8	
Canopy cover	1/2	1/1	3/12	1/4
Tree density	1/28			1/2
Tree species richness	2/30			2/6
DBH	1/28			
Tree seedling composition				1/4

Canopy Cover & Shade

As defined in the FPA, "ample" shade is one of goals for Desired Future Conditions of streamside stands. Riparian shade can influence stream temperature and other abiotic and biotic functions of stream ecosystems. Shade is difficult to measure directly because, for any given location, it changes both throughout the day and seasonally depending on the position of the sun. Researchers use various methods to quantify shade in ways that account for daily and seasonal changes. An assessment of canopy cover is sometimes used as a rudimentary evaluation of light interception without accounting for changes in sun position. This metric is considered different but related to shade. For the purpose of this review, we report shade and canopy cover results from both in-stream and streamside stands side by side (Figure 5). However, we caution about making direct comparisons among these metrics and methods.

Measurement precision and resolution for both canopy cover and shade was inconsistent across papers. Six of the included studies contained data on percent total canopy cover while only two studies contained data on percent total shade. Three studies measured canopy cover or shade within the stream (mid-channel), three studies measured canopy cover or shade in streamside stands, and one study measured canopy cover in both streamside stands and within stream channels. Most studies reporting canopy cover used a spherical densiometer (Dent, 2001; Farber et al. 2010a, b) while a couple of studies used digital photography (Cover et al. 2010) or eyesight to select a categorical range of percent cover (Sarr & Hibbs 2007a; Stephens & Alexander 2011). Studies reporting on shade either used digital photography with a Solar Pathfinder tool (Volpe 2009) or canopy angles from midpoint of the channel width (USGS 2012). Volpe 2009 collected shade measurements at multiple times throughout a summer season. Total canopy cover was calculated from the sum of "Overstory Cover" (trees) and "Shrub Cover" in both Sarr & Hibbs 2007a and Stephens & Alexander 2011. Farber et al. 2010a; Farber et al. 2010b; and USGS, 2012 studies took measurements from midpoint of stream channel (Table 3). Farber et al. 2010b contained canopy cover from outside the stream channel, at multiple distances from the stream (Table 3).



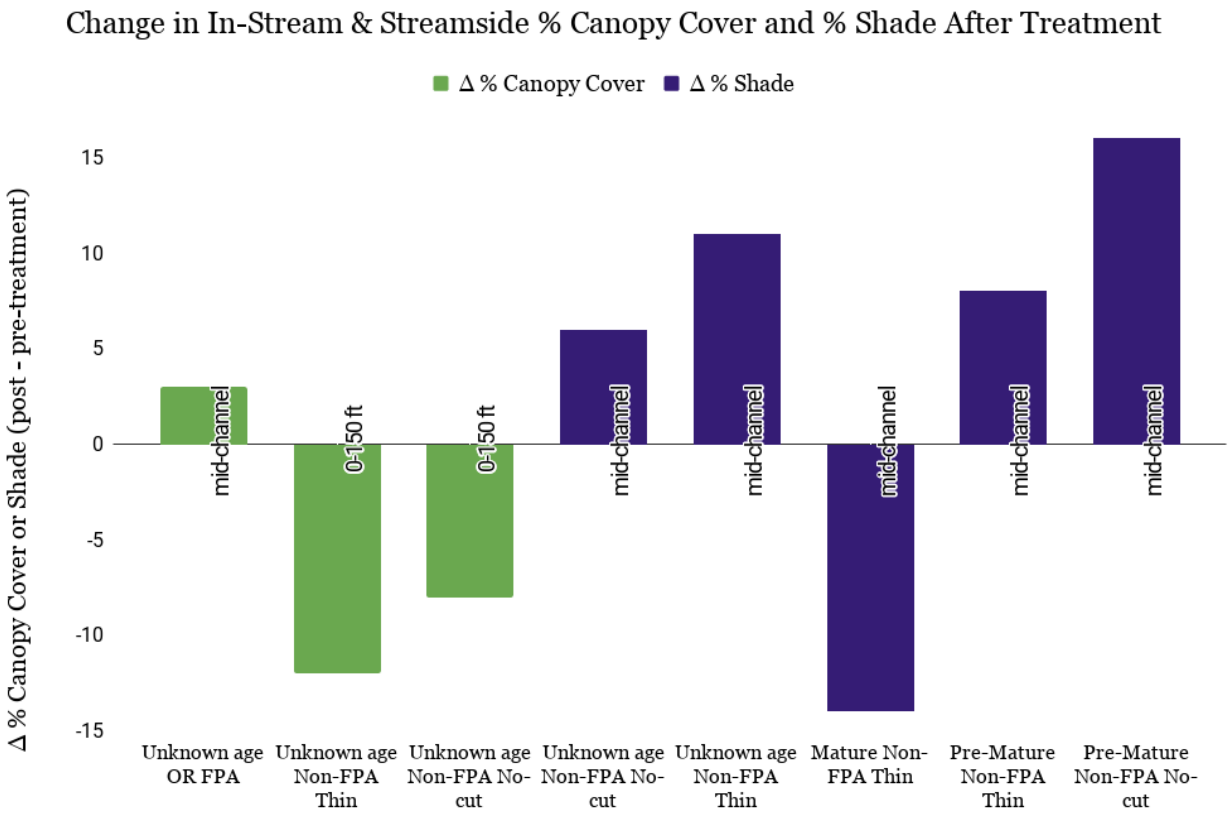
Treatment	Inner zone	Outer zone – retain 50% cover	No-cut portion compared with FPA
Rx1	0-50 feet no entry	50-150 feet	>FPA
Rx3	0-25 feet retain 70% cover	25-100 feet	<FPA
Treatment	**Streamside prescription**		
Thin	Thin from below + prescribed fire		<FPA
No cut	No-entry (0-50 feet [perennial reaches] and 0-25 feet [intermittent reaches])		>FPA
Treatment	**Streamside prescription (Small stream, Upland Harvest Type 2 or 3)**		

OR FPA	20’ No-cut; Riparian Management Area (RMA)=0-50 feet; Basal Area Target reached within 20 feet (40 ft.^{2}/1,000 feet); 83 foot buffer width	FPA

Figure 5. Mean percent canopy cover and mean percent shade by management type and streamside stand age range, post-treatment. Mature stand age range is defined as roughly 80-200 year old stands. Labels at center refer to distance (in feet) from stream edge (width of streamside stand measured); “mid-channel” refers to measurements taken in-stream. Management type OR FPA refers to streamside management defined by Oregon Forest Practices Act standards (Appendix E). Management type Non-FPA refers to buffer prescriptions above the FPA standards (more conservative, e.g. wider buffer and/or more basal area). See Table 3 for buffer prescription from Riparian Fuels Treatments Study and Farber et al. 2010a, b (*Section 3.2*).

Results from included studies showed a wide variety of post-treatment percent canopy cover or shade values (Figure 5). FPA-managed stands had higher in-stream percent canopy cover than other managed stands, however, the percent canopy cover of other managed stands was recorded from within streamside stands (not in-stream).

Pre- and post-treatment data on shade or canopy cover were available from Dent, 2001; Stephens & Alexander, 2011; and Volpe, 2009 (Figure 6). Stephens & Alexander, 2011 reported a 12% decrease in streamside percent canopy cover at sites where thinning from below occurred adjacent to the stream (“Thin” treatment). An 8% decrease at no-cut streamside sites were reported from the same study (“No-cut” treatment). However, Stephens & Alexander, 2011 collected data on streamside canopy cover from 0-150 ft. from the stream edge (recording data from both inside and outside the RMA), unlike other studies with canopy cover and shade measurements that report data from within the stream channel. Studies reporting in-stream measurements detected some increases (3-16%) in shade or canopy cover (Figure 6). All post-treatment measurements were recorded 1-3 years after treatment.



Treatment	Streamside prescription
Thin	Thin from below + prescribed fire
No cut	No-entry (0-50 feet [perennial reaches] and 0-25 feet [intermittent reaches])
Treatment	**Streamside prescription (Small stream, Upland Harvest Type 2 or 3)**
OR FPA	20' No-cut; Riparian Management Area (RMA)=0-50 feet; Basal Area Target reached within 20 feet (40 ft.^{2}/1,000 feet); 83 foot buffer width

Figure 6. Change in % canopy cover and % shade of streamside stands due to harvest by management type, 1-3 years post-treatment, and streamside stand age. Labels at center refer to distance (in feet) from stream edge (width of streamside stand measured); "mid-channel" refers to measurements taken in-stream. Mature stand age range is defined as roughly 80-200 year old stands; Unknown refers to age not reported in paper. Management type FPA refers to streamside management defined by Oregon Forest Practices Act standards (Appendix E). Management type Non-FPA refers to buffer prescriptions above the FPA standards (more conservative, e.g. wider buffer and/or more basal area). See Table 3 for prescription from Riparian Fuels Treatments Study.

Basal Area

Basal area describes the average cross-sectional area (at breast height) occupied by tree stems in a given stand and is typically expressed per unit area or per unit stream-length in streamside stands. Basal area values reported in m^2/ha or ft^2/1000ft were converted to ft^2/acre for this report. Included studies measured basal area with a wedge prism or calculated by multiplying average diameter at breast height (DBH) values by the number of tree stems for a given area.

Across seven papers, unmanaged mature streamside stands contained the highest mean basal area (784 ft^2/acre, Figure 7). Non-FPA stands reported mean total basal area ranging from 244-317 ft^2/acre. The mean basal area from an unmanaged pre-mature (streamside stand younger than 80 years old) was 217.8 ft^2/acre (Cover et al., 2010). The FPA-managed streamside stand (Dent, 2001) reported the lowest basal area (30 ft^2/acre at 0-20 ft from stream, 90 ft^2/acre at 0-50 ft from stream) though were above FPA standard targets (Figure 7, Appendix E) and were taken 1 year post-harvest.

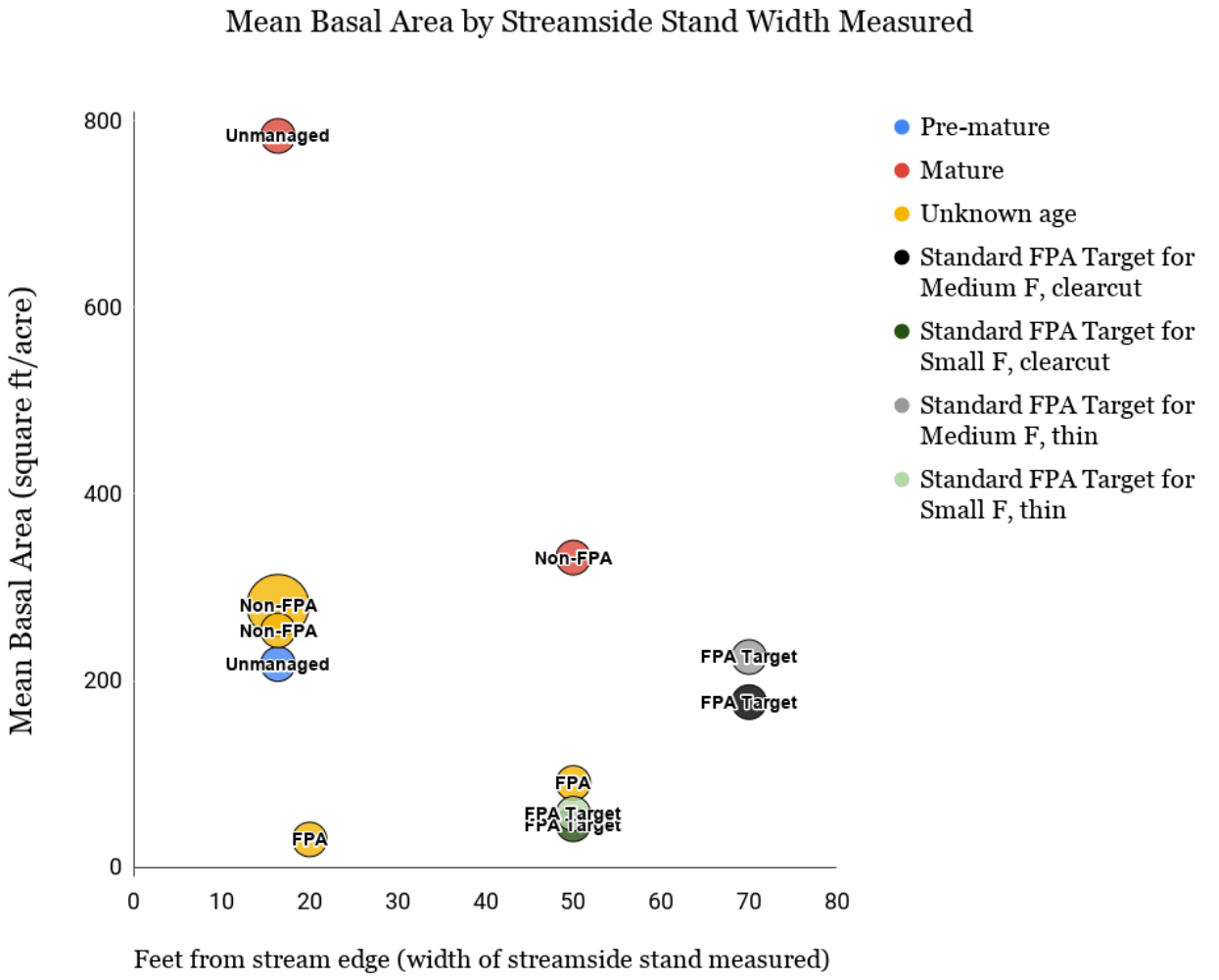


Figure 7. Mean total basal area in ft^2/acre by distance from stream edge (width of streamside stand measured), management type (post-harvest), and streamside stand age range. Small circles indicate 1 site; large circles indicate 2 sites. Management type FPA refers data 1 year post-harvest from Dent, 2001 (streamside stands managed per the Oregon Forest Practices Act). Management type Non-FPA refers to buffer prescriptions different from the FPA standards (e.g. wider buffer and/or different basal area targets). Mature stand age range is defined as roughly 80-200 year old stands. Non-FPA:Mature refers to data 2 years post-harvest from Farber et al. 2010a. For FPA basal area targets, see Appendix E. Note that FPA basal area targets are not expected to immediately achieve DFC but are expected to likely achieve DFC in the future.

Species Composition

Only Messier et al., 2012, a paper on unmanaged post-mature streamside stands, contained detailed data on species composition. Species composition data included diameter at breast height (DBH) by tree species, and density of each species by percent total stems. Sugar pine and ponderosa pine were the largest trees in both the "mixed conifer" and "Siskiyou valley" (forest types measured) post-mature streamside stands (Figure 8). Table 7 provides Latin names of common tree names identified in Figures 8, 9, 10, and 12 as well as environmental tolerance thresholds. A look at species composition by percent total stems revealed evidence of conifer dominance in these streamside stands in both mixed conifer and Siskiyou valley stands (Figures 9, 10).

Lastly, tree species richness (number of tree species) was reported in four studies (Figure 11). Richness increased with increasing stand age range. Tree species richness reported from streamside stands of unknown stand age range were similar to that of mature streamside stands, including stands identified as *Unknown* management from national forest land (Halofsky & Hibbs, 2008).

Table 7. Tree species identified by common name used in this report along with tolerance thresholds as reported in Sarr et al. 2011.

Scientific name	Common name	Shade tolerance	Flood tolerance	Heat tolerance	Drought tolerance
Abies concolor (Gord. & Glend.) Lindl. ex Hildebr.	White fir*	>5	≤5	>5	>5
Abies grandis (Dougl.) Forbes	Grand fir	8	6	7	6
Acer macrophyllum Pursh.	Bigleaf maple	7	5	6	6
Alnus rhombifolia Nutt.	White alder	2	9	2	1
Alnus rubra Bong.	Red alder	2	9	2	2
Arbutus menziesii Pursh.	Madrone	1	1	9	9
Calocedrus decurrens (Torr.) Florin.	Incense cedar	5	5	7	9
Castanopsis chrysophylla (Dougl.) DC	Chinquapin	5	4	7	8
Chamaecyparis lawsoniana (A. Murr.)Parl.	Port Orford cedar	7	8	7	4
Cornus nuttallii Aud.	Pacific dogwood	7	6	5	5
Fraxinus latifolia Benth.	Oregon ash	6	10	2	5
Pinus lambertiana Dougl.	Sugar pine	3	6	8	7
Pinus ponderosa Dougl.	Ponderosa pine	1	6	10	9
Pseudotsuga menziesii (Mirbel) Franco	Douglas-fir	5	2	8	8

Scientific name	Common name	Shade tolerance	Flood tolerance	Heat tolerance	Drought tolerance
Quercus chrysolepis Liebm.	Canyon live oak	4	1	9	9
Quercus garryana Dougl.	Oregon white oak	1	10	9.5	10
Quercus kelloggii Newberry	California black oak	1	1	10	10
Taxus brevifolia Nutt.	Pacific yew	10	6	2	5

*White fir tolerance values estimated from Natural Resource Conservation Service (https://plants.usda.gov/core/profile?symbol=ABCO).

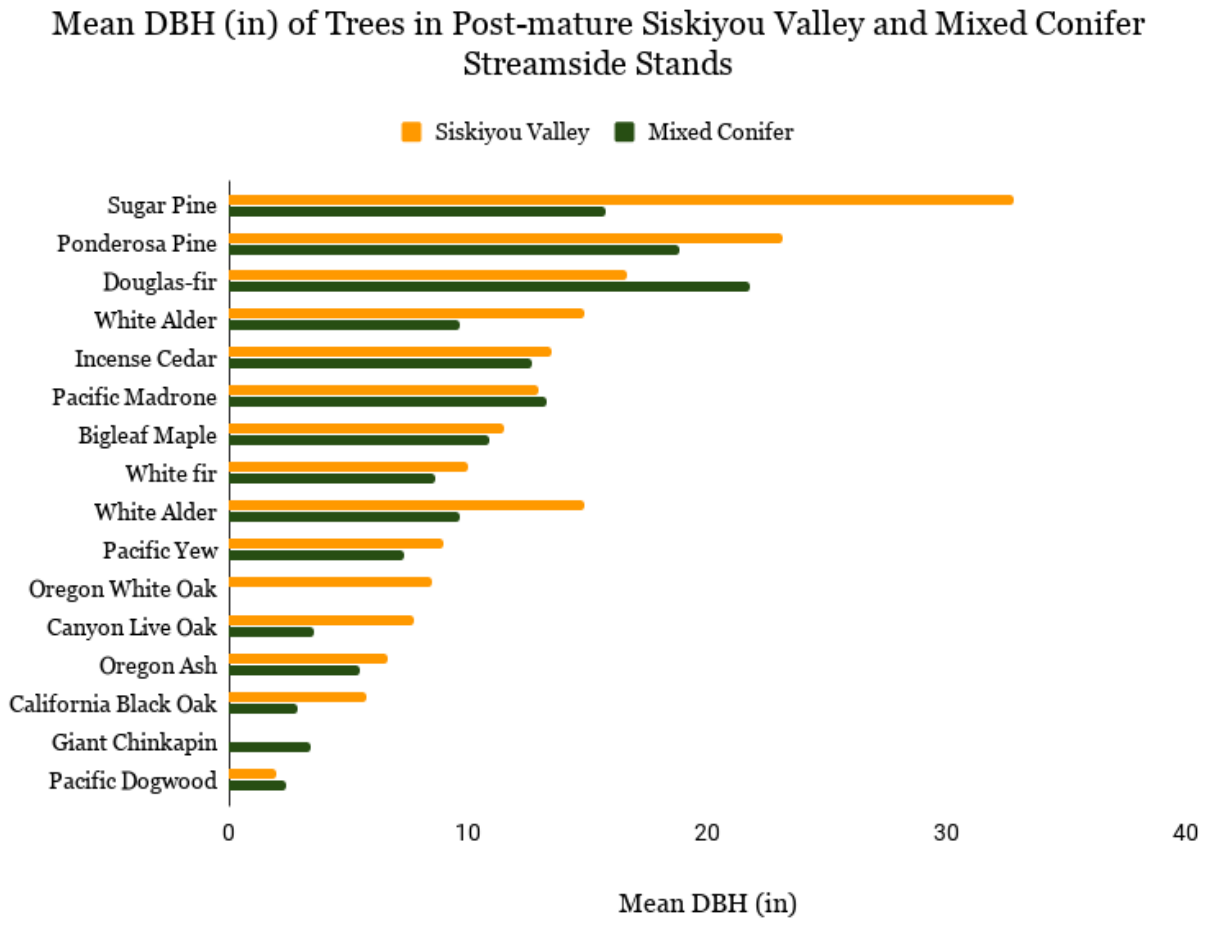


Figure 8. Mean Diameter at Breast Height (DBH) in inches by tree species in post-mature Siskiyou valley and Siskiyou mixed conifer streamside stands (two forest types measured). Post-mature stand age range is defined as older than 200 year old stands. Data from Messier et al. 2012. Common tree names identified by Latin name in Table 7.

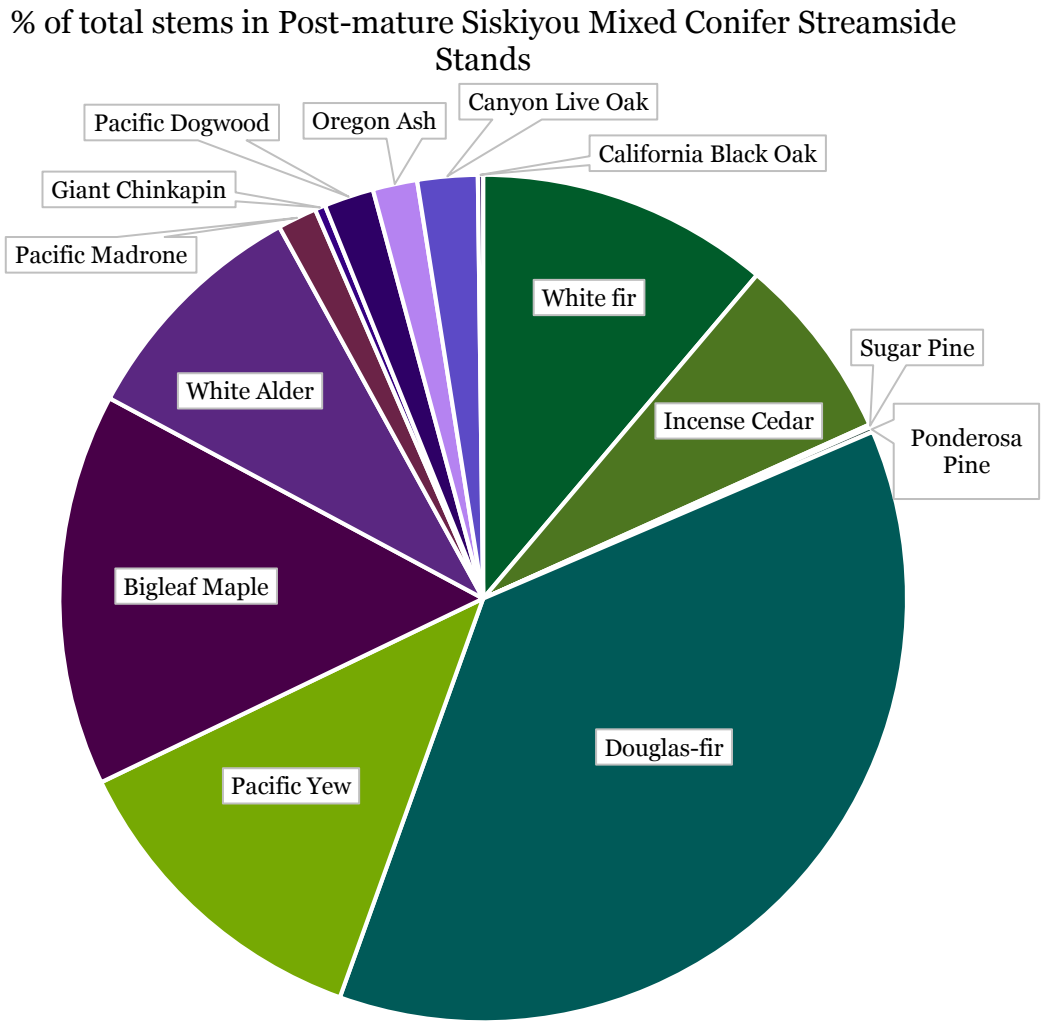


Figure 9. Percent total stems (tree boles) in post-mature Siskiyou mixed conifer streamside stands. Hardwoods in purple colors; conifers in green colors. Post-mature stand age range is defined as older than 200 year old stands. Data from Messier et al. 2012. Common tree names identified by Latin name in Table 7.

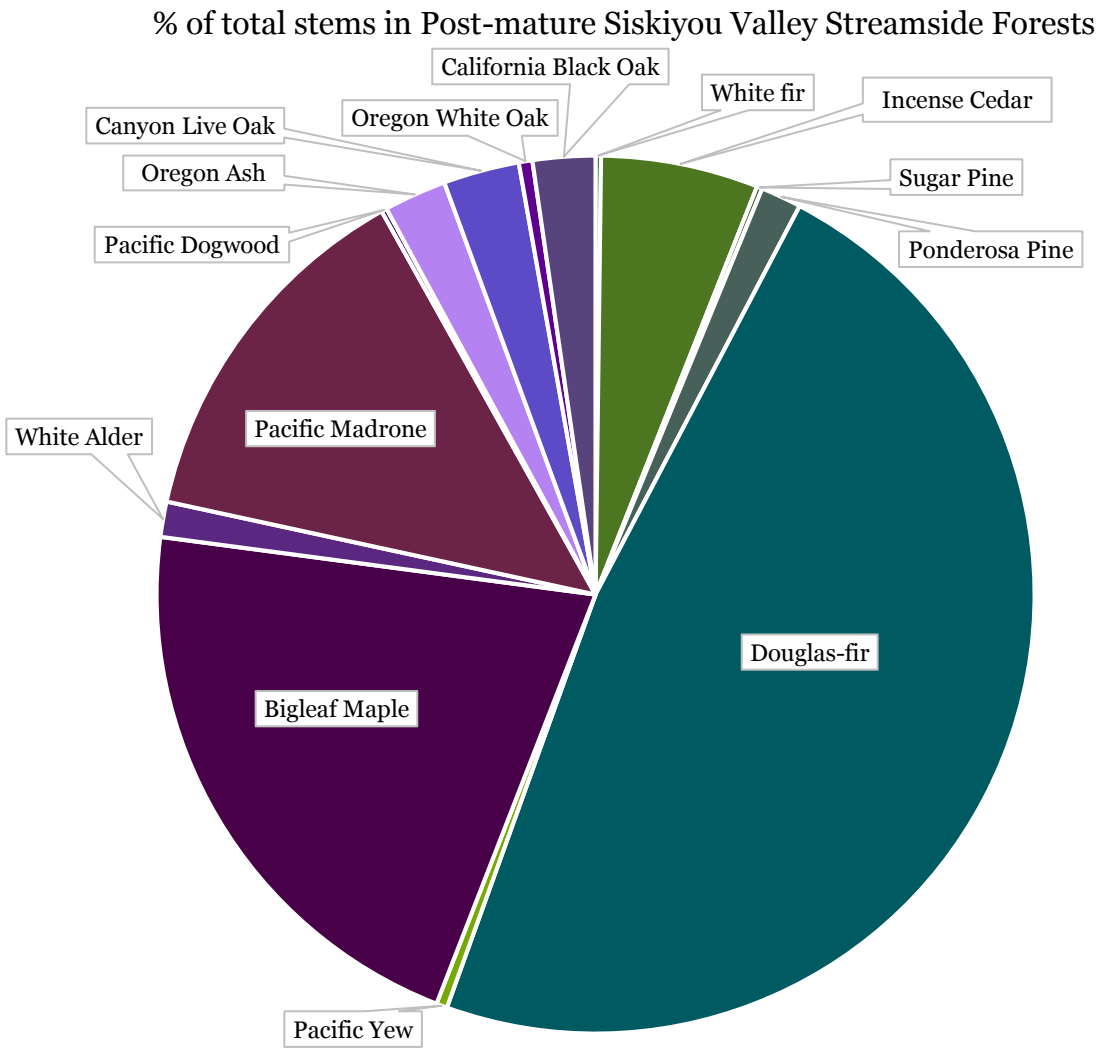


Figure 10. Percent total stems (tree boles) in post-mature Siskiyou valley streamside stands. Hardwoods in purple colors; conifers in green colors. Post-mature stand age range is defined as older than 200 year old stands. Data from Messier et al. 2012. Common tree names identified by Latin name in Table 7.

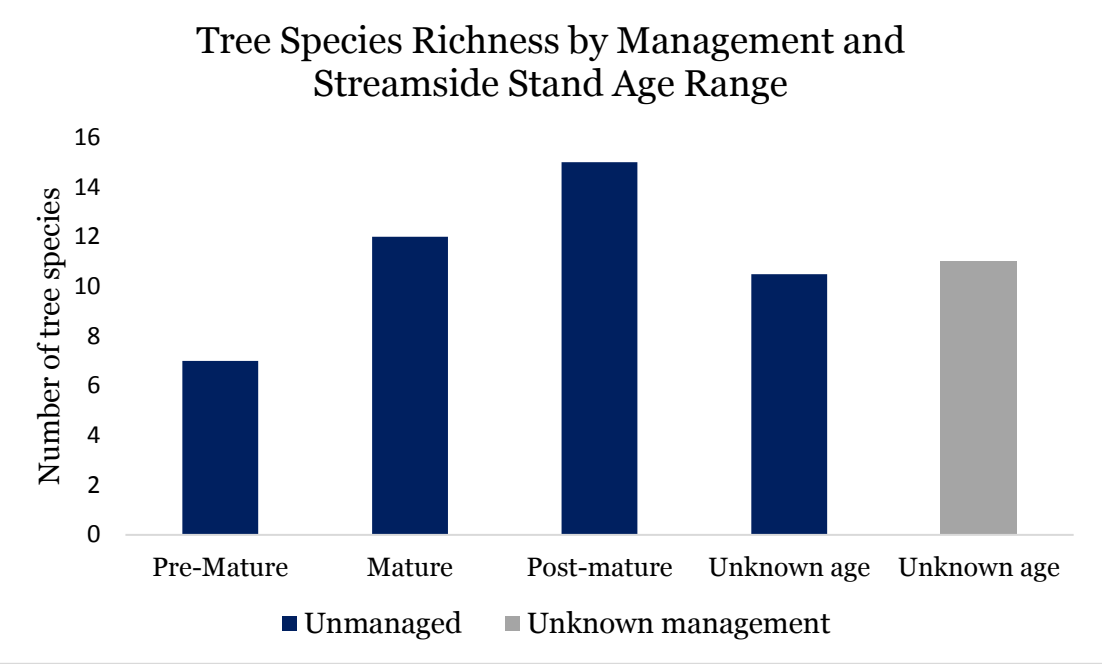


Figure 11. Streamside stand tree species richness by streamside stand age range and management type. Pre-mature stand age range is defined as younger than 80 year old stands, mature is around 80 to 200 year old stands, and post-mature is defined as older than 200 year old stands. Management type Unknown refers to streamside management prescription not reported in paper, however, stands are located on national forest land (Halofsky & Hibbs, 2008).

Tree regeneration

Sarr et al., 2011 was the only paper to report on seedlings in streamside stands. Mean seedlings per acre were greatest for hardwoods such as Bigleaf maple and Canyon live oak. Douglas-fir was the only conifer with mean seedlings per acre greater than 200 (Fig 12).

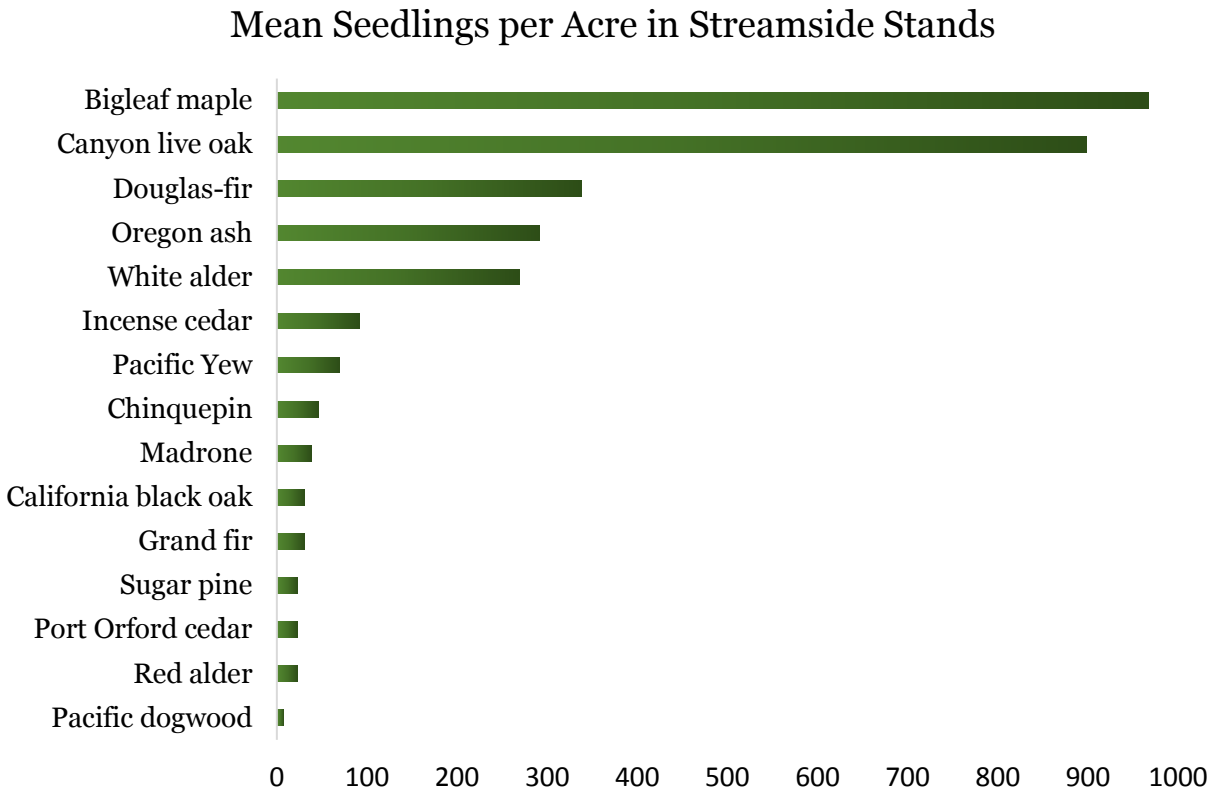


Figure 12. Mean seedlings per acre in streamside stands by tree species. Data from Sarr et al. 2011. Management and stand age unknown. Common tree names identified by Latin name in Table 7.

3.4 Effects modifiers

Aside from the various methods and study designs reported by the papers included in this review, uncontrollable conditions may have also affected their findings. In Table 8, we list these conditions and variables (though not limited), referred to as effect modifiers, that were identified in the papers or by reviewers of these papers. These effects modifiers can be important when considering the results reported in Sections 3.2 and 3.3 but this is outside the scope of this report.

Table 8. Effects modifiers reported from each paper.

Reference	Effects Modifiers
Cover et al., 2010	Debris flows, channel morphology, elevation, slope, historic road-building/timber harvest, historic weather events, geomorphic features
Dent, 2001	Hardwoods, slope, previous harvest
Farber & Whitaker, 2010a	Previous harvest, channel width, aspect, groundwater influence
Farber & Whitaker, 2010b	Previous harvest, channel width, aspect, groundwater influence
Halofsky & Hibbs, 2008	Fire, elevation, previous management

Reference	Effects Modifiers
Messier et al., 2012	Elevation
USGS, 2012	Harvesting and mining in the 1960's
Sarr & Hibbs, 2007a *Sarr & Hibbs, 2007b* *Sarr et al., 2011*	No management or fire history (other than no management in last 30 years)
DeJulio, 2009 *Stephens & Alexander, 2011* *Volpe, 2009*	Prescribed fire, invasive plants, elevation, thinning from below (prescription not based on basal area), drought year during study, hardwood dominated sites, Previous harvest, channel width, aspect, groundwater influence

4. Summary: addressing policy questions

This section summarizes information presented in the previous section, in order to provide condensed responses to the policy questions stated in section 1.2:

1. ***Stream Temperature:***
   For small and medium fish-bearing streams in the Siskiyou region, what is the effectiveness of FPA buffers to meet DEQ water quality standards for temperature[22]?
2. ***Desired Future Condition:***
   For small and medium fish-bearing streams in the Siskiyou region, what is the effectiveness of FPA buffers in achieving the desired future conditions of streamside forests?

4.1 Stream temperature (Policy Question 1)

For ease and clarity in addressing this objective, the information is summarized by DEQ water quality criterion. Note that whereas none of the sites had the same prescription (no-cut buffer widths or basal area retention) as that required under the FPA, they nonetheless provide insight on the likelihood of the FPA meeting the applicable water quality criterion, based on the following reasoning:

- Sites with prescriptions that are less than FPA requirements but do meet the water quality standard suggest that the FPA meets it too. A total of three sites fit this category.
- Sites with prescriptions that are greater than FPA requirements but do not meet the water quality standard suggest that the FPA does not meet it either. A total of one site fits this category.
- Sites with prescriptions that exceed those of the FPA that meet water quality standards, and sites with prescriptions less than those of the FPA that do not meet water quality standards provide little insight on the FPA to meet water quality standards. A total of seven sites fit this category.

An important caveat is that without knowing the retention of basal area compared with that of the FPA makes the above assertions weaker. For example, for sites with narrower no-cut buffers than those of the

[22] "DEQ water quality temperature standards" refer to OAR 340-041-0028 (4) & (11).

FPA, that met the applicable water quality standard might have retained more basal area, and hence potentially more shading, than the FPA.

4.1.1 Numeric Criterion (NC)[23]

One paper addressed this criterion (Volpe, 2009; Table 9), with quality and relevance scores of 83% and 73%, respectively. No sites explicitly followed FPA buffers. Two sites (*Non-FPA No-cut*) exceeded FPA no cut buffer widths but uncertain basal area retention, with one appearing to meet the NC, the other appearing to exceed it. Three sites had thinned buffers that couldn't be assessed with respect to FPA basal area retention, but had smaller no-cut buffer widths than the FPA. Of those sites, one appeared to meet the NC, and two appeared to exceed it. All sites were in the unknown or pre-mature stand stage.

Another way to look at those same data: Control sites exceeded the NC zero to five days/summer; pre-harvest sites exceeded the NC from zero to 36 days/summer, post-harvest sites exceeded the NC from zero to 70 days/summer.

4.1.2 Protecting Cold Water Criterion (PCW)

Two papers addressed this criterion (Farber and Whitaker, 2010a, b; Table 9). The quality scores were 67% and 78% for Farber and Whitaker (2010a and b, respectively), and the relevance scores were 47% and 60% for Farber and Whitaker (2010a and b, respectively). Two streamside prescriptions had larger no-cut zones than that of the FPA, four sites did not have no-cut zones and were thus less than that of the FPA. Basal area retention was greater than that required by the FPA at one of the sites with no-cut zones, and the other five sites did not have basal area retention reported. Four sites had pre- to post-harvest temperature changes at or below the PCW threshold, whereas for two sites this change was above the PCW threshold (Figure 4).

[23]See section 3.2 for summaries of water quality criteria.

Table 9. Summary info on meeting water quality standards from papers included in review (Volpe, 2009; Farber and Whitaker, 2010a, b).

Paper	Info Strength: Qual./Rel.[1]	# sites (<, =, > FPA no-cut buffer width)[2]	# sites (<, =, > FPA buffer basal area)[23]	Upland prescription	Streamside prescription	Stand age range	Likely meet WQ std.?[4,5]
Numeric Criterion							
Volpe, 2009	83%/73%	2 (>FPA)	2 (unknown)	Thin from below, Rx fire	50' no-cut/25' no-cut	N/A	Y=1, N=1
Volpe, 2009	83%/73%	3 (<FPA)	3 (unknown)	Thin from below, Rx fire	Thin from below, Rx fire	Pre-mature (2), N/A (1)	Y=1, N=2
Protecting Coldwater Criterion							
Farber & Whitaker, 2010a, b	67-78%/47-60%	2 (>FPA)	1 (>FPA) 1 (unknown)	Mostly clearcut, some thinning	No cut: 0-50', 0-75' 50% cover: to 150'	Pre-mature, Mature	Y=2
Farber & Whitaker, 2010b	78%/60%	4 (<FPA)	4 (unknown)	3 commercial thins, 1 clearcut	70% cover: 0-25' 50% cover: 25-100'	Mature	Y=2, N=2

[1]Quality and relevance scores listed in Table A.3, Appendix A.

[2] Number of sites used to address Policy Question 1 with information in parentheses referring to the no-cut buffer width as compared with FPA standard targets; N/A= Not available; Unmanaged=No upland or streamside harvest; Unknown=No upland or streamside harvest prescriptions reported.

[3]Number of sites used to address Policy Question 1 with information in parentheses referring to the amount of basal area retained in the streamside area as compared with FPA standard targets; N/A= Not available; Unmanaged=No upland or streamside harvest; Unknown=No upland or streamside harvest prescriptions reported.

[4] The number of sites that appear likely ("Y") and unlikely ("N") to meet DEQ's water quality standard.

[5] One site (Thin-F2, Figure 3) was borderline for likely to meet NC; one site (Etna, Rx3(A), Figure 4) was borderline for likely to meet PCW. Both of these sites judged as "Y" for likely to meet respective water quality standards.

4.2 Desired Future Condition (Policy Question 2)

Nine studies (13 papers) addressed one or more of the metrics on streamside stand conditions (Table 10). For basal area and canopy cover, only one site from one study described streamside stands with FPA prescriptions. No data were found for tree species composition and regeneration of streamside stands with FPA prescriptions. Additionally, no data were found for tree species composition and regeneration of mature streamside stands aside from one site in one study reporting a tree species richness of 12 (Figure 11). Therefore, we caution readers to keep this in mind when interpreting the following comparisons.

The ranges of results on canopy cover and shade from mature streamside stands (both managed and unmanaged) were broad (62-81% streamside canopy cover, 53-89% in-stream shade). Percent in-stream canopy cover from stands managed per the FPA was above the percent canopy cover range of mature streamside stands (Figure 5, Table 10), however, the canopy cover range of mature streamside stands was not measured in-stream (was measured streamside from various plot widths). There was no measurement for in-stream shade from stands managed per the FPA that could be compared with the range from mature streamside stands reported in the studies.

The range of results on basal area from studies with mature streamside stands (both managed and unmanaged) was broad, as well (332-784 ft^2/acre). All studies with basal area data, managed and unmanaged, had values below the range of basal area from studies with mature streamside stands, including those managed per the FPA 1-year post-harvest (Figure 7, Table 10). Streamside stands managed per the FPA have the expectation that basal area immediately following harvest will be less than that of mature streamside stands and will have conditions under which it will grow to become similar to mature streamside stands (*Section 1.2.2;* Lorensen, 1994), therefore basal area comparisons with FPA streamside stands 1-year post-harvest are not effective for answering Policy question 2.

Table 10. Summary info on achieving Desired Future Condition from papers included in review.

Paper	Info Strength: Qual./Rel.[1]	# sites (<, =, > FPA no-cut buffer width)[2]	# sites (<, =, > FPA buffer basal area)[3]	Upland prescription[4]	Streamside prescription[5]	Stand age range	Achieves DFC?[6]	Likely will achieve DFC?[7]
<u>Streamside</u> Canopy Cover, *Mature range: 62-81%*; <u>In-Stream</u> Shade, *Mature range: 53-89%*								
Cover et al., 2010	67%/50%	2 (unmanaged)	2 (unmanaged)	None-unmanaged	None-unmanaged	Mature (1)	-	-
						Pre-mature (1)	Yes (Streamside canopy cover ≈Mature)	N/A
Dent, 2001	60%/80%	1 (unknown)[7]	1 (>FPA)[7]	Unknown	<u>FPA: 20' no-cut, 50' RMA[3] basal area target reached in first 20', buffer: 83'</u>	Unknown (1)	**N/A (no mature *in-stream* canopy cover range to compare with)**	**N/A**
Farber & Whitaker, 2010a	67%/47%	1 (>FPA)	1 (>FPA)	Mostly clearcut, some thinning	<u>No cut</u>: 0-50' <u>50% cover</u>: 50-150'	Pre-mature (1)	Yes (Streamside canopy cover ≈Mature)	N/A
Farber & Whitaker 2010b	78%/60%	4 (<FPA)	4 (unknown)	3 commercial thins, 1 clearcut	<u>70% cover</u>: 0-25' <u>50% cover</u>: 25-100'	Mature (4)	-	-
Stephens & Alexander 2011	80%/73%	4 (>FPA)	4 (unknown)	Thin from below, Rx fire	<u>No cut:</u> 0-50'	Unknown (4)	No (streamside canopy cover <Mature)	N/A
		4 (<FPA)	4 (unknown)	Thin from below, Rx fire	Thin from below, Rx fire	Unknown (4)	Yes (streamside canopy cover ≈Mature)	N/A
Volpe, 2009	83%/73%	4 (>FPA)	4 (unknown)	Thin from below, Rx fire	<u>No cut:</u> 0-50'	Pre-mature (1)	Yes (In-stream shade ≈Mature)	N/A
						Unknown (3)	Yes (In-stream shade ≈Mature)	N/A
		4 (<FPA)	4 (unknown)			Mature (1)	-	-

Paper	Info Strength: Qual./Rel.[1]	# sites (<, =, > FPA no-cut buffer width)[2]	# sites (<, =, > FPA buffer basal area)[3]	Upland prescription[4]	Streamside prescription[5]	Stand age range	Achieves DFC?[6]	Likely will achieve DFC?[7]
				Thin from below, Rx fire	Thin from below, Rx fire	Pre-mature (2)	Yes (In-stream shade ≈Mature)	N/A
						Unknown (1)	Yes (In-stream shade ≈Mature)	N/A
USGS, 2012	47%/67%	1 (unmanaged)	1 (unmanaged)	None-unmanaged	None-unmanaged	Mature (1)	-	-
Basal Area, *Mature range: 332-784 ft²/acre*								
Cover et al., 2010	67%/50%	2 (unmanaged)	2 (unmanaged)	None-unmanaged	None-unmanaged	Mature (1)	-	-
						Pre-mature (1)	No (<Mature)	N/A
Dent, 2001	60%/80%	1 (unknown)[7]	1 (>FPA)[7]	Unknown	No cut: 0-20' BA target[4]: 20-50'	Unknown (1)	**No (<Mature)[8]**	**N/A**
Farber & Whitaker, 2010a	67%/47%	1 (>FPA)	1 (>FPA)	Mostly clearcut, some thinning	No cut: 0-50' 50% cover: 50-150'	Mature (1)	-	-
Halofsky & Hibbs, 2008	80%/40%	2 (N/A)	2 (>FPA)	Unknown	Unknown	Unknown (2)	No (<Mature)	N/A
Species Composition, *Mature (species richness): 12 tree species[9]*								
Messier et al., 2012	93%/50%	28 (unmanaged)	28 (unmanaged)	None-unmanaged	None-unmanaged	Post-mature (28)	N/A[9]	N/A
Cover et al., 2010	67%/50%	2 (unmanaged)	2 (unmanaged)	None-unmanaged	None-unmanaged	Pre-mature (1)	N/A[9]	N/A
						Mature (1)	N/A[9]	N/A
Halofsky & Hibbs, 2008	80%/40%	2 (N/A)	2 (>FPA)	Unknown	Unknown	Unknown (2)	N/A[9]	N/A

Paper	Info Strength: Qual./Rel.[1]	# sites (<, =, > FPA no-cut buffer width)[2]	# sites (<, =, > FPA buffer basal area)[3]	Upland prescription[4]	Streamside prescription[5]	Stand age range	Achieves DFC?[6]	Likely will achieve DFC?[7]
Sarr, 2007b	73%/58%	16 (N/A)	16 (N/A)	Unknown	Unknown	Unknown (16)	N/A[9]	N/A
Tree Regeneration								
Sarr et al. 2011	73%/58%	16 (N/A)	16 (N/A)	Unknown	Unknown	Unknown (16)	N/A	N/A

[1]Quality and relevance confidence scores listed in Table A.3, Appendix A.

[2] Number of sites used to address Policy Question 2 with information in parentheses referring to the no-cut buffer width as compared with FPA standard targets; N/A= Not available; Unmanaged=No upland or streamside harvest; Unknown=No upland or streamside harvest prescriptions reported.

[3]Number of sites used to address Policy Question 2 with information in parentheses referring to the amount of trees retained in the streamside area as compared with FPA standard targets; N/A= Not available; Unmanaged=No upland or streamside harvest; Unknown=No upland or streamside harvest prescriptions reported.

[4]Upland prescription: None=no removal of trees; N/A= Not available; Thin= selective removal of trees; Clearcut= most or all trees in an area are uniformly cut down.

[5]See FPA streamside prescriptions, Table E.1, Appendix E.

[6]The number of sites that are within range (≈), less than (<), or greater than (>) the range of values from mature streamside stands as found reported in included papers. N/A= Range or comparison not available. See *Section 1.2.2* for definition of mature streamside stands, the conditions of which are defined in the FPA as a goal for achieving Desired Future Condition (DFC). Text in bold refers to streamside stands managed per FPA streamside prescriptions. N/A = no information or not enough information available to compare to a range of mature streamside stand values. **Readers are cautioned to keep the number of sites and studies in mind when interpreting these comparisons. See Data Gaps and Limitations below.**

[7]"Likely will achieve DFC" refers to likelihood that metric is on a trajectory to meet DFC, which requires enough information to plot a trend.

[8]Dent, 2001 followed FPA streamside regulations, but left more basal area than was required and did not specify if no-cut buffer extended beyond 20 ft. Data was from 1 year post-treatment. FPA streamside rules were based on the expectation that basal area after harvest is less than that of mature streamside stands but maintains conditions under which it will grow to become similar to mature streamside stands (*Section 1.2.2*; Lorensen, 1994).

[9]Species richness of mature streamside stands based on one site from one study (Cover et al., 2010), therefore unable to identify range of values from mature streamside stands from which to compare with other studies.

5. Data Gaps and Limitations

Following are the data gaps and limitations of this review:

- No papers assessed the NC in the context of commercial harvest (thinning or clearcut), just thinning from below and prescribed fire, and thus *at best* are like a pre-commercial thin rather than timber harvest.
- The impact of streamflow on temperature was not directly addressed in any studies; this variable plays in both during drought years, and when flow may increase following harvest.
- Very few sites assess streamside buffers that are similar to those required by the FPA. Thus, information from studies that did not explicitly measure stands managed per the FPA should be considered with caution when trying to assess the effectiveness of the FPA.
- Studies had few replicates that were relevant to this review.
- Data on stand age are missing from many papers, thus it is hard to determine whether stands are pre-, at, or post-mature.
- Data on management history were vague or not available.
- Stream sizes were estimated from some studies based on basin size per Lorensen *et al.* (1994) or stream order. Some streams were at threshold between medium and large classification, and yet are included in this review because of this ambiguity (though given lower relevance confidence score).
- Methods for sampling and study design varied greatly making it difficult to accurately compare results.
- We applied our own attempts at estimating the stand age for sites in the Fuels Reduction Treatments Study. We used site index curves from King, 1966 and Means & Helm, 1985. These estimates are coarse at best.
- Not all streamside stand information was available across all papers. Metrics reported were inconsistent from paper to paper.
- Data found to describe mature streamside stands were limited in sample size, therefore, we are unable to detect if any of the data included in this review are outliers.
- Some papers reported only one of the following: ranges of values, confidence intervals, standard deviation or standard errors. The inconsistency in reporting of descriptive statistics made it difficult to compare and present them in figures.
- Some values were identified from figures in literature and therefore are not exact values.
- There were no reported data to accurately assess if managed riparian stands are on a trajectory to achieve conditions similar to those of mature stands

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Vernon, M.J., Sherriff, R.L., van Mantgem, P., Kane, J.M., 2018. Thinning, tree-growth, and resistance to multi-year drought in a mixed-conifer forest of northern California. Forest Ecology and Management 422, 190–198. https://doi.org/10.1016/j.foreco.2018.03.043

Wulff, M.L., May, J.T., and Brown, L.R., 2012, Upper Clear Creek watershed aquatic chemistry and biota surveys, 2004–5, Whiskeytown National Recreation Area, Shasta County, California: U.S. Geological Survey Open-File Report 2012–1173.

Appendix A. Information about papers

Table A.1. Determination of inclusion/exclusion of papers.
Available upon request.

Table A.2. Data Extraction tables.

Paper	Catastrophic disturbances in headwater streams: The long-term ecological effects of debris flows and debris floods in the Klamath Mountains, northern California
Author	Cover, M.R.; de la Fuente, J.A.; Resh, V.H.
Year	2010
Objective 1	N
Objective 2	Y
Objective 3	N
Study duration (# of years) and time since harvest	Substituting time for space, 2 yrs collecting but data spans about 150 yrs since debris flow
Study location (watersheds, region/state, country), settings where riparian buffers were applied	CA Klamath mtns near Klamath-Scott river confluence
Site history (if available)	harvest & roads, most intense between '60s-'80s
Stand age or succession stage (to determine if *mature*, *pre-mature*, or *post-mature*)	For Objective 2 ~ 150 yrs (DFC) and
Ecosystem type; plant association group; type of forest	
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	Basins <21 km2, mostly medium
Research question(s), hypotheses, objectives	What are the long-term effects of debris flows on stream ecosystem structure (including shade, basal area) and food web dynamics?
Study design	5x5m plots on both sides of stream @ start/middle/end of 200 m reach
Pretreatment/reference/control data (Y/N)	N
Managed or Unmanaged	Not recently managed… Mature
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams; FPA or other)	N/A
Metrics and their robustness (see protocol Table 7)	Tree species richness, Tree BA, % canopy cover, low sample size for "mature" stands but otherwise robust methods
Sample sizes and results with estimates of variation	2, SE reported for taxa metrics, etc.
Notes concerning study quality with evidence or reasoning behind the notes	Quality seems good but low sample size and concerned with how much 150 yrs post-debris flow is like a "mature stand" also stats not in great detail.
Potential sources of bias or error	None explicitly mentioned. Assumptions that these debris flows were result of historical logging.

Paper	Catastrophic disturbances in headwater streams: The long-term ecological effects of debris flows and debris floods in the Klamath Mountains, northern California
Effects modifiers	National Forest land; channel slope 5-10%; basin areas reported; reaches were at elevation 1500-6000ft
Method references	canopy cover: Engelbrecht and Herz 2001
similar FPA standards (y/n)	N
Notes	Can stand age be ~ for yrs since debris flow?
Paper	Harvest Effects on Riparian Function And Structure Under Current Oregon Forest Practices Rules
Author	Dent, L.
Year	2001
Objective 1	N
Objective 2	N
Objective 3	Y
Study duration (# of years) and time since harvest	about 1 yr; 1 yr post-harvest
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Jamison Creek, SW Oregon
Site history (if available)	Unknown
Stand age or succession stage (to determine if *mature*, *pre-mature*, or *post-mature*)	?
Ecosystem type; plant association group; type of forest	Siskiyou ecosystem, no other details
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	<2 annual cfs = small
Research question(s), hypotheses, objectives	1) Do hardwoods dominate the near-stream area on all stream sizes? 3) How does the available basal area in riparian management areas compare to standard targets?
Study design	500x100ft plots; 20ft zone full cruise; 20-100ft zone ITS method (20% stand sampled, systematic distribution)
Pretreatment/reference/control data (Y/N)	No control or reference, 1yr
Managed or Unmanaged	Managed and Unmanaged
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams; FPA or other)	100% of standard target BA within 20ft (40); RMA 50ft, 83 ft buffer width
Metrics and their robustness (see protocol Table 7)	BA for hardwoods/conifers, Canopy cover (densiometer), distance from the stream, species
Sample sizes and results with estimates of variation	n=1, no estimates of variation
Notes concerning study quality with evidence or reasoning behind the notes	Low quality due to sample size and not all metrics reported for this region
Potential sources of bias or error	Volunteered site, one site, ITS method (only 20% of stand assessed 20-100ft in RMA)
Effects modifiers	Unknown aspect; percent slope says recorded but I do not see it
Method references	Says see protocol. Must look for in ODF documents… ITS method?
similar FPA standards (y/n)	y

Paper	Catastrophic disturbances in headwater streams: The long-term ecological effects of debris flows and debris floods in the Klamath Mountains, northern California
Notes	Measured cover, for just Siskiyou; n=1 for Siskiyou; Why is post-harvest BA greater than pre-harvest??
Mature stand results	hardwoods dominate up till 20ft from stream (45 BA), 70 BA up to 50ft from stream; conifers 20 BA @ 20ft, 127 BA @ 50ft; 100% SBA target present in first 20ft; BA ~125 within 50ft from stream (RMA); 91% cover
Post-harvest results	BA ~170 within 50ft (RMA); 94 % cover; 83 ft buffer width
Paper	Short-term effects of Fuel Treatments on vegetation in headwater riparian corridors of the Middle Rogue River basin in Southwest Oregon
Author	DeJulio
Year	2009
Objective 1	N
Objective 2	Y
Objective 3	Y
Study duration (# of years) and time since harvest	2 yrs data collecting
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Siskiyou, Rogue/Applegate valley, BLM land
Site history (if available)	commercial timber harvest, mechanical mastication, road bed, placer mining, water withdrawals and wildland fire
Stand age or succession stage (to determine if *mature*, *pre-mature*, or *post-mature*)	?
Ecosystem type; plant association group; type of forest	Mixed conifer/hardwood forest with some oak woodland
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	small
Research question(s), hypotheses, objectives	What are the short-term effects of fuels treatments on riparian vegetative characteristics? (1) Can perennial and intermittent streams be treated without compromising riparian function? (2) Will biological diversity of riparian areas be maintained, lessened, or improved through fuels treatment?
Study design	BACI, paired watershed design, 4 plots per site (4 sites for each treatment) with 2 point intercept transects in each plot 60 ft length, random placement within 20 ft of stream bank on both sides
Pretreatment/reference/control data (Y/N)	Y
Managed or Unmanaged	Managed?
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams; FPA or other)	50 ft buffer on perennial streams, 25 ft on intermittent, thinning upland to reduce fuels *Thinned to what level? Thinned from below
Metrics and their robustness (see protocol Table 7)	Understory species richness
Sample sizes and results with estimates of variation	n=4
Notes concerning study quality with evidence or reasoning behind the notes	Unknown details on thinning amount
Potential sources of bias or error	
Effects modifiers	fire, elevation 1400-4400 ft

Paper	Catastrophic disturbances in headwater streams: The long-term ecological effects of debris flows and debris floods in the Klamath Mountains, northern California
Method references	McCune and Grace 2002; Dytham 2003; SPSS 2004; Smith 2002; Whitaker 1972
similar FPA standards (y/n)	
Notes	Same data as Volpe some shown differently, *Not FPA*; might not be able to use results from post burn?
Paper	Monitoring Results of Alternative Watercourse and Lake Protection Zones in the McKinney Creek Watershed in interior, Northern California
Author	Farber, Stuart and Jenny Whitaker
Year	2010
Objective 1	Y
Objective 2	Y
Objective 3	Y
Study duration (# of years) and time since harvest	4 (2 pre-, 2 post-harvest)
Study location (watersheds, region/state, country), settings where riparian buffers were applied	McKinney Creek flows north directly into Klamath R.
Site history (if available)	Unknown
Stand age or succession stage (to determine if *mature*, *pre-mature*, or *post-mature*)	60 yrs (40 years earlier, uneven age management)
Ecosystem type; plant association group; type of forest	mixed conifer, site class III
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	M
Research question(s), hypotheses, objectives	-Assess actual canopy closure reduction '-Assess stream temperature impacts from harvest '-Assess sediment transport through WLPZ from harvest
Study design	Before-after (but they do have upstream control); no replicates
Pretreatment/reference/control data (Y/N)	Y (2 years pre-harvest & upstream control)
Managed or Unmanaged	Managed, harvest of second growth
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams; FPA or other)	50' no harvest, 50'-150' maintain 50% cover and equipment limitation zone
Metrics and their robustness (see protocol Table 7)	-cover is well-measured '-stream temperature measured well, but not analyzed well
Sample sizes and results with estimates of variation	n=1, no estimates of variation
Notes concerning study quality with evidence or reasoning behind the notes	They did not assess stream temperatures with respect to water quality standards (I imagine CA has something similar to both NC and PCW)
Potential sources of bias or error	
Effects modifiers	-there was recent harvest in watershed, unclear if it was upstream

Paper	Catastrophic disturbances in headwater streams: The long-term ecological effects of debris flows and debris floods in the Klamath Mountains, northern California
Method references	Lewis et al., 2000; FFC, 1996; USGS, 1978; TreeData: Berbach et al. 1999, Zwienicki and Newton 1999
similar FPA standards (y/n)	n
Notes	
Paper	Monitoring Results of Alternative Watercourse and Lake Protection Zones in the Etna Creek Watershed in interior, Northern California
Author	Farber, Stuart and Jenny Whitaker
Year	2010
Objective 1	Y
Objective 2	Y
Objective 3	Y
Study duration (# of years) and time since harvest	4 (1 pre-, 3 post-harvest
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Etna Creek flows into Scott River, trib. To Klamath R.
Site history (if available)	Unknown
Stand age or succession stage (to determine if *mature*, *pre-mature*, or *post-mature*)	80+ years
Ecosystem type; plant association group; type of forest	mixed conifer, site class II
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	S, M, maybe L
Research question(s), hypotheses, objectives	-Assess actual canopy closure reduction '-Assess stream temperature impacts from harvest '-Assess sediment transport and microclimate impacts from harvest
Study design	; Class I prescriptions have no replicates; Class II prescription has 4 replicates, Before-after for class I streams, BACI for class II streams
Pretreatment/reference/control data (Y/N)	-Class I streams: 1 year pre-harvest, upstream control -Class II streams: 1 year pre-harvest, nearby watershed for control
Managed or Unmanaged	Managed, harvest of second growth
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams; FPA or other)	-downstream Class I stream: thinning unit; 50' no-cut, 50-150' maintain 50% canopy cover '-Upstream Class I stream: clearcut unit; 75' no-cut, 75'-150' maintain 50% canopy cover '-4 Class II streams: unclear re: harvest Rx outside of WLPZ; 0-25'=maintain 70% canopy; 25'-100' maintain 50% canopy cover
Metrics and their robustness (see protocol Table 7)	-cover is well-measured '-stream temperature measured well, but not analyzed well
Sample sizes and results with estimates of variation	n=1 (class I stream), n=4 (class II stream)
Notes concerning study quality with evidence or reasoning behind the notes	
Potential sources of bias or error	

Paper	Catastrophic disturbances in headwater streams: The long-term ecological effects of debris flows and debris floods in the Klamath Mountains, northern California
Effects modifiers	-there was recent, previous harvest upstream, so unclear how good the upstream "control" is (might still be recovering from those previous harvests - unclear how near they were)
Method references	Lewis et al., 2000; FFC, 1996; USGS, 1978; TreeData: Berbach et al. 1999, Zwienicki and Newton 2000
similar FPA standards (y/n)	n
Notes	
Paper	Determinants of riparian fire severity in two Oregon fires, USA
Author	Halofsky, J.E.; Hibbs, D.E.
Year	2008
Objective 1	N
Objective 2	N
Objective 3	Y
Study duration (# of years) and time since harvest	2 yrs post-fire, 1 season of collecting
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Biscuit Fire in Klamath-Siskiyou
Site history (if available)	Logging, mining. Fire suppression, cattle grazing and road-building, mostly NF land. No fire or logging in the last 15 yrs
Stand age or succession stage (to determine if *mature*, *pre-mature*, or *post-mature*)	Unknown, 15 yrs since last fire/management
Ecosystem type; plant association group; type of forest	Doug-fir, tanoak, mixed dry. Siskiyou, more precip for west watershed than east watershed
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	stream classes 1, 2, 3 (focusing on 2 & 3 for medium & small)
Research question(s), hypotheses, objectives	What are the factors influencing riparian fire severity?
Study design	47 plots from two watersheds, each plot started at stream edge and goes 5m from both sides of stream x 25 m parallel
Pretreatment/reference/control data (Y/N)	Y, prefire data
Managed or Unmanaged	Managed (last management 15 yrs ago)
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams; FPA or other)	N/A
Metrics and their robustness (see protocol Table 7)	% cover of live shrubs, pre-fire BA of trees, species, DBH, tree size class from GIS, hardwood BA, stems/ha
Sample sizes and results with estimates of variation	2 watershed, 47 points, range of data reported, SE bars on graphs, CI
Notes concerning study quality with evidence or reasoning behind the notes	High quality in terms of statistical reporting, measures of variance although no stand age and only 2 watersheds; No control or reference but somehow have prefire data; Used stratified random sampling; difference in stream classification from FPA may lead to mistranslation
Potential sources of bias or error	Scope limited to Biscuit fire; assumptions about prefire basal area (did not know which tree were already dead vs died from fire); unknown on specific to past management

Paper	Catastrophic disturbances in headwater streams: The long-term ecological effects of debris flows and debris floods in the Klamath Mountains, northern California
Effects modifiers	fire disturbance (burn severity reported), stream gradient, slope to upland plots, bankfull width, valley floor width, elevation range ~1200 to 3600ft
Method references	Atzet et al. 1996 for GIS layer plant association; Burnham and Anderson 2002 for model selection
similar FPA standards (y/n)	N
Notes	Does not describe buffers. Not sure where they got the prefire data? (Appendix)
Paper	Fire exclusion effects on riparian forest dynamics in southwestern Oregon
Author	Messier, M.S.; Shatford, J.P.A.; Hibbs, D.E.
Year	2012
Objective 1	N
Objective 2	Y
Objective 3	N
Study duration (# of years) and time since harvest	2 yrs
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Siskiyou, USFS and BLM land
Site history (if available)	fire and lack of fire
Stand age or succession stage (to determine if *mature*, *pre-mature*, or *post-mature*)	200+
Ecosystem type; plant association group; type of forest	Mixed Conifer
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	First and second order headwater streams = small type F
Research question(s), hypotheses, objectives	In riparian forests, how has tree density, species composition, age structure and temporal recruitment patterns changed since Euro-American settlement?
Study design	Nested design, 5 30x60ft plots within 900-1500ft long plots, within 30ft distance from stream
Pretreatment/reference/control data (Y/N)	N
Managed or Unmanaged	Unmanaged
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams; FPA or other)	N/A
Metrics and their robustness (see protocol Table 7)	BAI, DBH, age difference by distance, *density* total and large tree
Sample sizes and results with estimates of variation	28 sites (15 mixed conifer and 13 interior valley)
Notes concerning study quality with evidence or reasoning behind the notes	Observational, not experiment so no controls, high quality stats with details
Potential sources of bias or error	non-random site selection
Effects modifiers	1500-3000ft elevation
Method references	
similar FPA standards (y/n)	N
Notes	Note: snags and downed logs data

Paper	Catastrophic disturbances in headwater streams: The long-term ecological effects of debris flows and debris floods in the Klamath Mountains, northern California
Paper	Woody riparian plant distributions in western Oregon, USA: Comparing landscape and local scale factors
Author	Sarr, D.A.; Hibbs, D.E.
Year	2007
Objective 1	N
Objective 2	N
Objective 3	Y
Study duration (# of years) and time since harvest	1 year (different sampling seasons for gap (2000) vs. riparian inventory(1999)); 30+ years since harvest
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Applegate
Site history (if available)	only that at least 30 years since harvest, on BLM or USFS
Stand age or succession stage (to determine if *mature*, *pre-mature*, or *post-mature*)	Unknown
Ecosystem type; plant association group; type of forest	Mixed conifer oak woodland
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	avg. =110 ac. +/-11 ac. (small streams)
Research question(s), hypotheses, objectives	1) Is there a discernable and interpretable large-scale pattern to riparian species distribution in western Oregon? 2) How do landscape scale and local scale environmental factors singly or interactively influence observed patterns of riparian species distributions?
Study design	Inventory, 16 sites/watershed (each side was 1 ha (25 m x 200 m each side of stream); 18 (40 m2) sampling plots/site
Pretreatment/reference/control data (Y/N)	N
Managed or Unmanaged	Managed (?)
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams; FPA or other)	NA
Metrics and their robustness (see protocol Table 7)	-Cover (overstory, total, conifer) - mean and std. deviation *Note - this is measured on land, not in the stream '-species constancy/richness (% of sampling plots (n=288)/watershed with that species)
Sample sizes and results with estimates of variation	4 watersheds
Notes concerning study quality with evidence or reasoning behind the notes	Doesn't describe management history - if some of the 16 sites in a watershed are old growth, and others are 40-year old plantations - would expect very different stand characteristics
Potential sources of bias or error	1) Total cover has high heterogeneity, unclear how exact locations for these readings were determined to minimize bias
Effects modifiers	No management or fire history (other than nothing in last 30 years)
Method references	NA
similar FPA standards (y/n)	Unknown - probably not
Notes	Fig. 3 shows how different Applegate is to others

Paper	Catastrophic disturbances in headwater streams: The long-term ecological effects of debris flows and debris floods in the Klamath Mountains, northern California
Paper	Multiscale controls on woody plant diversity in western Oregon riparian forests
Author	Sarr, D.A.; Hibbs, D.E.
Year	2007
Objective 1	N
Objective 2	N
Objective 3	Y
Study duration (# of years) and time since harvest	1 year (different sampling seasons for gap (2000) vs. riparian inventory(1999)); 30+ years since harvest
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Applegate
Site history (if available)	only that at least 30 years since harvest, on BLM or USFS
Stand age or succession stage (to determine if *mature*, *pre-mature*, or *post-mature*)	Unknown
Ecosystem type; plant association group; type of forest	Mixed conifer oak woodland
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	avg. =110 ac. +/-11 ac. (small streams)
Research question(s), hypotheses, objectives	How strongly broad scale controls on plant distribution, such as climate, interact with or regulate local structures and processes. Are landscape scale controls primary or secondary influences? Do they influence species directly by physiological mechanisms? Or do they act indirectly, by controlling local conditions (e.g., competitive dynamics and gradient structure) within the riparian ecosystem?
Study design	Inventory, 16 sites/watershed (each side was 1 ha (25 m x 200 m each side of stream); 18 (40 m2) sampling plots/site
Pretreatment/reference/control data (Y/N)	only that at least 30 years since harvest, on BLM or USFS
Managed or Unmanaged	only that at least 30 years since harvest, on BLM or USFS
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams; FPA or other)	only that at least 30 years since harvest, on BLM or USFS
Metrics and their robustness (see protocol Table 7)	-Cover (overstory, conifer, clonal shrub) by binned distance from stream-Fig.5 '-understory light index by binned distance from stream Fig. 5 '-species richness (shrubs, trees, all woody species - Fig. 7, 8) by sampling plot, reach, and all 60 gaps (Table 6)
Sample sizes and results with estimates of variation	4 watersheds
Notes concerning study quality with evidence or reasoning behind the notes	
Potential sources of bias or error	
Effects modifiers	No management or fire history (other than nothing in last 30 years)
Method references	NA
similar FPA standards (y/n)	Unknown - probably not
Notes	Same data as Sarr 2007 shown differently
Mature stand results	NA
Post-harvest results	NA

Paper	Catastrophic disturbances in headwater streams: The long-term ecological effects of debris flows and debris floods in the Klamath Mountains, northern California
Paper	Influences of life history, environmental gradients, and disturbance on riparian tree regeneration in Western Oregon
Author	Sarr, D.A.; Hibbs, D.E.; Shatford, J.P.A.; Momsen, R.
Year	2011
Objective 1	N
Objective 2	N
Objective 3	Y
Study duration (# of years) and time since harvest	1 year (different sampling seasons for gap (2000) vs. riparian inventory(1999)); 30+ years since harvest
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Applegate
Site history (if available)	only that at least 30 years since harvest, on BLM or USFS
Stand age or succession stage (to determine if *mature*, *pre-mature*, or *post-mature*)	Unknown
Ecosystem type; plant association group; type of forest	Mixed conifer oak woodland
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	avg. =110 ac. +/-11 ac. (small streams)
Research question(s), hypotheses, objectives	"We explored relationships between environmental conditions and regeneration patterns for nearly two dozen native tree species that occur in mountain riparian forests across western Oregon. Our objectives were to: (1) analyze the regeneration behavior of a broad suite of native riparian trees and (2) report how regeneration behavior of native species responds to natural variation in the regeneration environment."
Study design	Inventory, 16 sites/watershed (each side was 1 ha (25 m x 200 m each side of stream); 18 (40 m2) sampling plots/site
Pretreatment/reference/control data (Y/N)	only that at least 30 years since harvest, on BLM or USFS
Managed or Unmanaged	only that at least 30 years since harvest, on BLM or USFS
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams; FPA or other)	only that at least 30 years since harvest, on BLM or USFS
Metrics and their robustness (see protocol Table 7)	-ordination of tree species with respect drought and shade tolerances (Fig. 2) '-% of sampling plots with tree regeneration by functional species group (Fig. 3) '-Seedlings/ha (all sampling plots by topographic position -Table 3; gap vs. interior forest - Table 4)
Sample sizes and results with estimates of variation	4 watersheds
Notes concerning study quality with evidence or reasoning behind the notes	
Potential sources of bias or error	
Effects modifiers	No management or fire history (other than nothing in last 30 years)
Method references	NA
similar FPA standards (y/n)	Unknown - probably not
Notes	

Paper	Catastrophic disturbances in headwater streams: The long-term ecological effects of debris flows and debris floods in the Klamath Mountains, northern California
Paper	Effects of fuel reduction on bird density and reproductive success in riparian areas of mixed-conifer forest in southwest Oregon
Author	Stephens, J.L.; Alexander, J.D.
Year	2011
Objective 1	N
Objective 2	Y
Objective 3	Y
Study duration (# of years) and time since harvest	3 yrs total (1st pretreat, 2nd post-thin, 3rd post-burn) a.k.a. post-burn data 2 yrs post-treatment
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Jackson county Siskiyou-Klamath
Site history (if available)	commercial timber harvest, mechanical mastication, road bed, placer mining, water withdrawals and wildland fire
Stand age or succession stage (to determine if *mature*, *pre-mature*, or *post-mature*)	?
Ecosystem type; plant association group; type of forest	Mixed conifer/hardwood forest
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	small
Research question(s), hypotheses, objectives	How do fuel reduction (thin or thin and burn) affect bird habitat within 1-2 yrs of treatment?
Study design	paired stream, BACI, design for veg: 150 ft radius plots
Pretreatment/reference/control data (Y/N)	Y
Managed or Unmanaged	Managed?
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams; FPA or other)	50 ft buffer on perennial streams, 25 ft on intermittent, thinning upland to reduce fuels *Thinned to what level? Thinned from below: "Thin" (3 sites), continued the upland prescription to the stream edge; data are lacking for assessing retention of basal area with respect to the FPA. The second riparian prescription, "No cut" (2 sites), left a 50 foot no-entry buffer on perennial reaches of the streams, and a 25 foot no-entry buffer on intermittent reaches of the streams (pers. comm., Jena Volpe 2019).
Metrics and their robustness (see protocol Table 7)	overstory, understory, upper-ground, and ground cover; not robust (estimated by sight)
Sample sizes and results with estimates of variation	n=4, SE reported
Notes concerning study quality with evidence or reasoning behind the notes	Statistical analysis sound but conversion of categorical cover to percent cover a little dubious (based on sight, not densiometer, etc.), non-random selection
Potential sources of bias or error	
Effects modifiers	fire, elevation 1400-4400 ft
Method references	Ralph et al. 1993 for radius plot design
similar FPA standards (y/n)	N, BLM
Notes	Same location as DeJulio/Volpe but different veg sampling design ** veg plots with 150 ft of stream

Paper	Catastrophic disturbances in headwater streams: The long-term ecological effects of debris flows and debris floods in the Klamath Mountains, northern California
Paper	Effects of Prescribed Riparian Fire in Small Headwater Streams in the Rogue River Basin, Southwest Oregon. (name on website is Hydrological Responses to Prescribed Fire in Riparian Areas)
Author	Volpe
Year	2009
Objective 1	Y
Objective 2	Y
Objective 3	Y
Study duration (# of years) and time since harvest	2 (1 each pre- and post-treatment)
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Little Applegate & Rogue basins
Site history (if available)	Some timber harvest and placer mining (not parsed out by watershed)
Stand age or succession stage (to determine if *mature*, *pre-mature*, or *post-mature*)	NA (see other pubs. From same study)
Ecosystem type; plant association group; type of forest	Mixed Conifer/hardwood
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	Small only
Research question(s), hypotheses, objectives	Assess effects of fuels treatments on riparian areas (both treated and untreated riparian areas, with surrounding uplands treated) - flow, WQ, Stream Temp., shade
Study design	Before-After (shade), Before-After-Control-Impact (temp.), 1 pair controls, 4 replicates of each of 2 treatments (however, temp. only had 1 pair of post-treatment because 3 streams dried up in drought)
Pretreatment/reference/control data (Y/N)	Y, 1 pre/post, plus control watershed
Managed or Unmanaged	Managed
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams; FPA or other)	25' and 50' no-cut buffers, and thinned buffers (all next to fuels treatments - cut, handpile, underburn brushy species and (some?) trees<8"dia)
Metrics and their robustness (see protocol Table 7)	-Mean Summer Effective Shade (veg.-shade): 20 points along perennial reaches (but not for controls); measured with Solar Pathfinder, in June, July, August '-Stream Temp. measured with HOBO Water Temp. Pro (v.1), 30 min. intervals (one each at bottom of basin outlet, other at top of perennial reach)
Sample sizes and results with estimates of variation	-Shade: 20 measurements/reach, 3 times/year '-Temp. continuous data: 30 minute intervals (pre: late May-Oct.1; post: before underburning (spring)-Oct.1)
Notes concerning study quality with evidence or reasoning behind the notes	
Potential sources of bias or error	-Shade not measured in controls '-Some reaches had significant tribs entering (some tribs treated, some not)
Effects modifiers	-uneven burning of understory
Method references	
similar FPA standards (y/n)	-unknown (Treated streams: 50' no-cut buffers; continuous thinning to stream edge)

Paper	Catastrophic disturbances in headwater streams: The long-term ecological effects of debris flows and debris floods in the Klamath Mountains, northern California
Notes	*Not FPA* Need to think carefully about Rx fire; how close were DS temp. loggers to treated reach? '-DeJulio has more data on sites; note: controls only used/reported in Volpe and not Stephens or DeJulio papers
Paper	Upper Clear Creek Watershed Aquatic Chemistry and Biota Surveys, 2004–5, Whiskeytown National Recreation Area, Shasta County, California
Author	USGS
Year	2012
Objective 1	N
Objective 2	Y
Objective 3	N
Study duration (# of years) and time since harvest	2 seasons 2004, 2005
Study location (watersheds, region/state, country), settings where riparian buffers were applied	CA Klamath mts (Whiskeytown National Rec Area) on NPS land
Site history (if available)	harvesting and mining before made national rec area in 1960's
Stand age or succession stage (to determine if *mature*, *pre-mature*, or *post-mature*)	60-90 yr old PIPO and PSME (See Vernon et al. 2018, unit treat F)
Ecosystem type; plant association group; type of forest	Mixed conifer oak
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	Medium (converted discharge to cfs and comm with author of Vernon et al. 2018)
Research question(s), hypotheses, objectives	Biotic and abiotic survey of Whiskeytown watershed
Study design	1 sample
Pretreatment/reference/control data (Y/N)	N
Managed or Unmanaged	Unmanaged (at time of data collection)
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams; FPA or other)	No recently managed at time of shade data collection…. Vernon et al. 2018 has basal area and DBH data on post-treat for fuel reduction and Rx burn but cannot use due to width of plots going upslope more than 300 ft.
Metrics and their robustness (see protocol Table 7)	% shade, not very robust because calculated from canopy angles at midpoint in stream. Also reported but did not use: Degree open canopy
Sample sizes and results with estimates of variation	1 (Only use BRAN2 - Brandy Creek near Sheep Camp because only site with info on stand age from Vernon et al. 2018)
Notes concerning study quality with evidence or reasoning behind the notes	small sample size
Potential sources of bias or error	from method for calculating shade
Effects modifiers	
Method references	Fitzgerald et al. 1998
similar FPA standards (y/n)	N
Notes	

Table A.3. Confidence scoring for included papers.

	Criteria specific to Temp objective	Criteria specific to DFC objectives		Quality						Quality: Normalized Confidence Score[12]	Relevance					Relevance: Normalized Confidence Score[12]
Citation	**Objective 1**	**Objective 2**	**Objective 3**	**Study design[1]**	**N_{sites}[2]**	**$N_{control}$[3]**	**$N_{replicate}$[4]**	**Methodologically robust[5]**	**Statistically robust[6]**		**Stream size[7]**	**Geography[8]**	**Objective[9]**	**Management[10]**	**Pre-Mature, Post-Mature, or Mature[11]**	
Cover et al., 2010	N	Y	N	M	M	-	M	M	M	67%	L	L	L	-	H	50%
Dent, 2001	N	N	Y	H	L	-	L	M	M	60%	H	H	H	H	?	80%
DeJulio, 2009	N	Y	Y	H	H	-	H	M	M	87%	H	H	L	L	H	73%
Farber & Whitaker, 2010a	Y	Y	Y	H	L	M	L	H	M	67%	L	L	H	L	L	47%
Farber & Whitaker, 2010b	Y	Y	Y	H	M	M	M	H	M	78%	L	L	H	L	H	60%
Halofsky & Hibbs, 2008	N	N	Y	M	M	-	H	M	H	80%	L	H	L	L	?	40%
Messier et al., 2012	N	Y	N	M	H	-	H	H	H	93%	L	H	L	-	L	50%
Sarr & Hibbs, 2007a	N	N	Y	M	H	-	H	L	M	73%	H	H	L	-	?	58%
Sarr & Hibbs, 2007b	N	N	Y	M	H	-	H	L	M	73%	H	H	L	-	?	58%
Sarr & Hibbs, 2011	N	N	Y	M	H	-	H	L	M	73%	H	H	L	-	?	58%
Stephens & Alexander, 2011	N	Y	Y	H	H	-	M	M	M	80%	H	H	L	L	H	73%
Volpe, 2009	Y	Y	Y	H	H	M	H	M	M	83%	H	H	L	L	H	73%
USGS, 2012	N	Y	N	L	L	-	L	M	M	47%	H	L	L	-	H	67%

[1] H=high=Experimental design with controls and/or sampling before and after treatment; M=medium=Observational design with replication; L=low=Case study (unreplicated, uncontrolled, single observation)(modified from (Salisbury and Fazey, 2002)). If mixture (e.g., some sites with and some sites without replicates), give mixed rating (e.g., L/M).

[2] Number of sites used in this review. H=high= >3; M=medium= 2-3; L=low= 1 site. This scoring rubric was chosen based on number of sites found in each of the studies combined with best professional judgement.

[3] Number of control replicates. Only applies to studies addressing Objective 1. H=high= >3; M=medium= 2-3; L=low= 1 replicate. Note that this category will only be applied to studies being used for Objective 1 (temperature) and Objective 3 (managed streamside stands) in order to assess quality of data capturing changes to stream temperature or changes to streamside stand conditions post-harvest.

[4] Number of replicates or treatments with the same prescription (e.g., buffer width) within sites. H=high= >3; M=medium= 2-3; L=low= 1 replicate within each site. This scoring rubric was chosen based on number of replicates found in each of the studies combined with best professional judgement.

[5] This category considers whether 1) methods used to collect data on metrics were robust and appropriate and 2) whether age or seral stage was reported/factored into site selection. H=high= yes to both questions; M=medium= yes to one question; L=low= no to both questions. This scoring was based on the Data Extraction Table (Table A.2, Appendix A), rows: Metrics and their robustness (see protocol Table 7); Stand age or succession stage; Method references.

[6] This category considers two questions: 1) Were the statistical analyses conducted appropriate for the data collected? And, 2) Did study authors adequately explore data (via analyses) to address study questions and objectives? H=high= yes to both questions; M=medium= yes to one question; L=low= no to both questions. Note that this category does not consider study design. This scoring was based on the Data Extraction Table (Table A.2, Appendix A), rows: Research question(s), hypotheses, objectives; Study design; Pretreatment/reference/control data (Y/N); Sample sizes and results with estimates of variation; Notes concerning study quality with evidence or reasoning behind the notes; Potential sources of bias or error; Method references.

[7] H=high=small or medium streams as defined by average annual flow less than 10 cfs average annual flow; L=low= ambiguous stream size or streams larger than 10 cfs average annual flow.

[8] H=high= EPA Ecoregions 78a-e; L=low= EPA Ecoregions 78f-r (78a-e are the EPA ecoregions that coincide with the FPA Siskiyou region and therefore have vegetation/geology more specific to the FPA region under review; EPA Level III Ecoregion 78, US EPA, 2013; Griffith et al., 2016; Pater et al., 1998).

[9] H=high=study objectives or questions directly relate to review question/objectives; L=low= study has relevant data even though study objectives or questions are not directly related to review question.

[10] H=high=managed stands from at least one of the treatments used current FPA buffers; L=low=managed stands from all treatments used other buffers (non-FPA) or unknown buffers.

[11] Studies will be identified by the time range the data captures: pre-mature, post-mature, or mature (within the defined goal for DFC, 80-200 year old streamside stand, as described in 1.2.2 Desired Future Condition). See 1.5.1 Objective 2 considerations. H=high=at least 1 site with unmanaged or managed stands within DFC age class ("mature"); L=low=unmanaged or managed stands are outside of DFC goals (“pre-mature” or “post-mature”); ?=unknown=age or seral stage mixed or not reported and we are unable to estimate seral stage with the reported data (no DBH or height for use in age models). Unknown will be scored as 0.

[12] Sum of points were divided by maximum points available for that study (See footnote 3 for whether study assessed controls if used to address objectives 1 or 3).

Appendix B. List of Stakeholders and Tribes contacted

List available upon request.

Appendix C. Feedback from partners

Input on literature for systematic review (SR)

In the fall of 2018, department staff completed an extensive search for papers to include in the literature review titled "Siskiyou Streamside Protections Review: A Systematic Review on Stream Temperature, Shade, and Desired Future Condition." We then assessed whether or not each paper should be included in this review, based on criteria outlined in the review's protocol[24]. Every inclusion/exclusion assessment for each paper was documented in a spreadsheet.

In the fall of 2018, the department solicited input from stakeholders and tribes on this spreadsheet. We asked them to address these two questions:

- Did we correctly apply the criteria for including and excluding papers from the systematic review?
- Do you have papers that we have not yet considered for the systematic review?

The department also contacted authors of potentially-relevant studies to request their sending papers from these studies.

The department received 16 responses from forest industry, conservation groups, academia, Oregon Department of Environmental Quality (DEQ), Oregon Department of Fish and Wildlife (ODFW), Bureau of Land Management (BLM), watershed councils, Oregon Department of Forestry (ODF) stewardship foresters, local landowners, and the general public.

They suggested considering 41 papers, all of which were considered for inclusion in the review. Five of these papers passed all inclusion criteria and were thus included in the review. None of the responses found that we misapplied the inclusion criteria.

The comments focused on several themes, many of which appeared in the same response. Ten respondents suggested to consider particular papers in the review. Three responses proffered opinions on what the policy outcome should be for the larger review process (all three wanted more restrictive streamside protections). Five respondents wanted the scope of the SR to be different (e.g., include large wood, larger geographic provenance for papers). Finally, five responses said ODF staff did a good job with the search and inclusion process.

Input on SR report

We received 12 sets of comments on the SR report from forest industry, conservation groups, tribal representative, academia, DEQ, ODFW, Environmental Protection Agency (EPA), and the general public.

Some responses were a paragraph or two in an email, some edited the document, and some used a spreadsheet to provide comments on particular sections of the report. Major comment themes from interested parties, along with the associated responses from staff, are provided below.

[24] See Table D.5 of the protocol (Appendix D).

Themes of input on both literature inclusion list, and SR report

This section categorizes input from stakeholders and tribes on both the inclusion of literature in the SR, and the SR report. The number of responses related to each theme are listed, followed by the associated ODF response to that input.

The reader is cautioned that these "number of responses" values are not necessarily representative of opinions of the greater public, stakeholders, or tribes. The values reflect only the number of responses we received from the larger group of interested parties that were contacted. Note that when a party provided similar feedback on both the inclusion list and the SR report, it is only counted once. From a request for input on the SR report sent to over 100 potentially-interested parties, we received 13 responses.

Theme: This review includes too few studies. It requires additional data analysis, field studies (with Forest Practices Act (FPA) prescriptions), long-term monitoring, or change of review scope.

Number of responses: 7

Oregon Department of Forestry (ODF) Response: Staff conducted the SR based on direction from the Board, which considered time and staff capacity tradeoffs presented at the March 2018 BOF meeting. The scope of this SR is also based on a previous Board decision to not extrapolate RipStream (and hence studies from similar landscapes) to the Siskiyou (November 2015). The Board has the discretion to direct the department to do additional work. This additional work may be data analysis, field studies, long-term monitoring, or change in scope for the next phase of the review. The Private Forests Division will set the direction for the Monitoring Unit's work, prioritizing projects as time and resources allow. If additional work products are chosen, the staff capacity guide discussed in the 2016 Monitoring Strategy will be used to evaluate what workload can be accommodated. The 2016 Monitoring Strategy is available upon request.

Theme: Explain how effects modifiers were considered in results (e.g., previous harvesting).

Number of responses: 6

ODF Response: Effects modifiers were documented for each study included in the review, however, the protocol stated that a rigorous analysis of these modifiers is beyond the scope of the SR.

Theme: Bankfull width, depth of stream should be reported.

Number of responses: 3

ODF Response: Not all papers reported on metrics of stream channel geometry. Additionally, while these effects modifiers play a role in the impact of changes in shade on stream temperature, the FPA does not have rules for different stream channel geometries. ODF staff have added a table (Table 4, Attachment 5) to the SR report on what information can be found in the included papers.

Theme: Provide implications of results and direct conclusions.

Number of responses: 3

ODF Response: ODF staff conclusions and recommendations can be found in Attachment 1 of the Board materials for the June 5th 2019 meeting.

Theme: Geographic scope should be expanded.

Number of responses: 3

ODF Response: Multiple comments from the draft Protocol review phase requested that the SR be expanded to a larger geographic scope. However, the Board made a policy decision in November 2015 to not extend the SSBT rule change and the associated monitoring in the rest of western Oregon to the Siskiyou. The Siskiyou geographic region (or region, OAR 629-635-0220) was not included in the SSBT rule change because of concerns about extrapolating results of the ODF Riparian Function and Stream Temperature (RipStream) study, which had no sites in the Siskiyou region. ODF staff aligned with this decision when outlining the scope of the SR for the Siskiyou Streamside Protections Review. The Board may request a new scope or other forms of study for the next phase of the review.

Theme: Climate change should be a central facet of this review.

Number of responses: 3

ODF Response: Climate change has been identified as an emerging issue for the Board to review under the "Role of Forests in Carbon Policy and Adaptation Strategies for Climate Change" work plan item. However, it is out of scope of this review. This topic was discussed at the April 2019 Board meeting and will be discussed further at the July 2019 Board meeting. The outcome of this discussion may inform future FPA effectiveness reviews.

Theme: Analyze shade and temperature together. Analyze the decreases in shade/canopy cover from pre- to post-harvest instead of comparing post-harvest shade/canopy cover with range from mature streamside stands.

Number of responses: 2

ODF Response: Shade and canopy cover are components of DFC. In order to determine effectiveness of rules, ODF staff refer back to the language in the FPA goals for DFC ("*to grow and retain vegetation so that, over time, average conditions across the landscape become similar to those of mature streamside stands*…"). As outlined in the SR protocol, the objectives for determining effectiveness, to reflect the FPA language, are to 1) assess the range of the streamside stand conditions of mature forests in the Siskiyou region; 2a) analyze the degree to which managed forests have, and if not now then likely will have, characteristics similar to those of mature streamside stands; and 2b) analyze the degree to which managed forests have, and will have, streamside seedlings/saplings species composition and age structure similar to those of mature streamside stands. Therefore, comparisons between pre- and post-harvest shade and canopy cover is not enough to determine effectiveness of DFC.

Theme: The systematic review construct is overly narrow and rigid.

Number of responses: 2

ODF Response: The systematic review format allows for detailed documentation of methods and extraction of data for transparency and rigor in order to avoid reviewer bias in literature inclusion and interpretation. This documentation and transparency facilitates stakeholder feedback at defined points along the process. In contrast, conventional literature reviews do not provide a rigorous method for what papers to include or how to address them, and thereby allow for much professional interpretation (which, in turn, allows for opaque author bias to influence the literature review outcomes).

Theme: In the SR report on page 35, the following statement is included in the Data Gaps and Limitations section: "No papers assessed the Numeric Criterion (NC) in the context of commercial harvest (thinning or clearcut), just thinning from below and prescribed fire, and thus at best are like a pre-commercial thin rather than timber harvest." This indicates that there is likely more shade loss and temperature increase under the FPA.

Number of responses: 2

ODF Response: The Thin treatment from the Riparian Fuels Treatment Study being referred to in the above statement may be categorized as less restrictive than FPA standards because thinning was allowed to occur directly adjacent to the stream without a no-cut buffer. There is not enough information to assume that more or less shade loss and temperature increase would occur under the FPA. There may be more shade under the FPA due to its no-cut buffer. On the other hand, there may be less shade under the FPA in situations of a clearcut with a hard-edged buffer if that edge is close enough to the stream.

Theme: The Board should make a finding of degradation of resources for water quality, and increase stream buffer widths.

Number of responses: 2

ODF Response: The Siskiyou Streamside Protections Review, as directed by the Board, is a review of the effectiveness of FPA rules specifically regarding stream temperature and desired future condition (DFC) of streamside stands, not a broad review of water quality. The Board will evaluate the findings of the SR report with the contextual information provided from GIS data, DEQ and ODFW information. After the Board determines whether or not the rules are sufficient, or more information is needed for each topic of stream temperature and desired future condition, they may subsequently direct the department to do additional work.

Theme: Some land managers and states have wider stream buffers than required by the FPA, and those were undoubtedly based on science.

Number of responses: 1

ODF Response: ODF conducted a rigorous search for, and screening of, scientific papers to review. This included searching electronic databases, web pages of relevant associations and organizations, and a public input phase requesting recommended literature. It is possible that unpublished reports exist that we did not find using these search methods. We agree that science plays a critical role in most natural resource decision making processes. Decision making processes are also influenced by the differing management objectives, policy frameworks, and decision making criteria across land managers and states. In combination, it is not surprising to see variation in stream buffer decision outcomes across the landscape.

Theme: Peer review should be a requirement of papers included in the review.

Number of responses: 1

ODF Response: ODF chose not to impose this particular limitation for inclusion. There are many papers (e.g., government monitoring studies) that provide valuable, highly relevant information for this review that are not formally peer-reviewed as commonly connoted for a peer-reviewed journal article.

Theme: Provide geology and soil information for each study. "Accounting for geologic and soils settings of the studied stream reaches are also important, as soils and streams associated with ultramafic rock units tend to have very low hardwood density and height compared to other rock types; thus streams in ultramafics tend to be much more highly dependent on conifers of all sizes… for steam shade."

Number of responses: 1

ODF Response: We do not have detailed information on geology and soils for all studies in the Siskiyou and Klamath Mountain regions. However, the scope was limited to the EPA level III ecoregion (78) that encompasses both of these regions. EPA ecoregions are "areas of similarity in the mosaic of biotic, abiotic, terrestrial, and aquatic ecosystem components… include geology, landforms, soils, vegetation, climate, land use, wildlife, and hydrology" (https://www.epa.gov/eco-research/ecoregions; accessed 4/8/2019).

ODF staff agree with the reviewer that the Siskiyou region's presence of ultramafic rock may result in different riparian vegetation and shade than other regions and therefore may require further study.

Theme: Port-Orford cedar root rot may explain the low numbers of Port-Orford cedar in figures showing tree density and seedlings abundance and the absence of Port-Orford in post-mature stand data.

Number of responses: 1

ODF Response: Port-Orford root disease (*Phytophthora lateralis*) is a tree disease of concern in the western portion of the Siskiyou region. Port-Orford species distributions generally extend from the coast to part way into the western half of the Siskiyou region. It is possible that some of the studies included in the SR were outside the range of this tree species or, as the reviewer commented, may have been detrimentally effected by Port-Orford root disease. The objectives of the SR were not to determine effects of this disease on current day presence of Port-Orford cedars in streamside stands of the Siskiyou region. The Board may request further information on this topic if they deem it important for determining whether the FPA rules are sufficient in achieving DFC in the region.

Theme: Explain how tree species richness is relevant to achieving DFC.

Number of responses: 1

ODF Response: The FPA, when referring to goals for DFC, the rule states "Oregon has high diversity of tree species growing along waters of the state…[25]". Tree species richness is one of the metrics found

[25] OAR 629-642-0000(2)

in the literature to describe mature streamside stands and the goal of DFC is to achieve conditions similar to that of mature streamside stands. Therefore, assessing tree species richness, as one of many measures of diversity, among streamside stands measured in the studies included in the SR report is one of the ways we may ascertain whether or not streamside stands managed per the FPA are similar to mature streamside stands.

Theme: Hinds Walnut is a rare riparian species in this region and was not identified in any of the studies. Please increase awareness and encourage conservation of this species.

Number of responses: 1

ODF Response: Hinds Walnut (*Juglans hindsii*) may not have been reported in the studies included in the SR because it is an uncommon tree species. We appreciate the reviewer bringing this culturally significant tree species to our attention and have forwarded the comments to Siskiyou region OSU extension staff and ODF staff.

Theme: There are no data on hardwood stands and their age that can be incorporated in the range of mature streamside stand conditions.

Number of responses: 1

ODF Response: The riparian rules acknowledge that some stands may be hardwood dominated and may become mature at an earlier age. The FPA does not describe what constitutes the DFC for a hardwood riparian stand other than to say it is a mature condition and that it may occur at a younger age than a conifer stand.

Theme: For the purposes of Siskiyou Streamside Protections Review, the Natural Conditions Criteria are a necessary and relevant factor for streamside temperature.

Number of responses: 1

ODF Response: "On Aug. 8, 2013, EPA disapproved a key provision of Oregon's temperature standard, the "natural conditions criterion." EPA's action was ordered by the Oregon Federal District Court on April 10, 2013 based on an earlier ruling in February 2012. Oregon DEQ can no longer use the natural conditions criterion to account for warmer temperatures in Oregon's rivers, lakes and streams."[26] The Oregon Department of Environmental Quality (DEQ) is in the process of addressing this issue.

Theme: There is no guidance on how to incorporate Quality and Relevance scores into findings and conclusions.

Number of responses: 1

[26] Oregon Department of Environmental Quality. Water Quality Standards Division. August 8, 2013. *Temperature Standards: Natural Conditions Criterion.* Retrieved from https://www.oregon.gov/deq/FilterDocs/TempStandardNatCond.pdf.

ODF Response: ODF staff conclusions and recommendations can be found in Attachment 1 of the Board materials for the June 5th 2019 meeting, including a connection between Quality and Relevance Confidence Scores and the Decision Framework.

Theme: Explain how you would expect canopy cover and shade to differ from mid-channel to within the riparian stand.

Number of responses: 1

ODF Response: Canopy cover and shade were not meant to be compared between mid-channel and streamside stands (within riparian management area). ODF staff sought to identify the range of mid-channel shade/canopy cover from mature streamside stands and compare them with mid-channel shade/canopy cover in or adjacent to FPA-managed stands. Likewise, comparisons were sought between mature streamside stand shade/canopy cover and streamside shade/canopy cover of FPA-managed stands. Figure 5 of the SR report (In-stream and streamside mean % canopy cover and mean % shade, post-treatment) has been changed to better reflect these coarse comparisons. ODF staff make no inferences about differences between mid-channel shade/canopy cover and streamside shade/canopy cover as this was not the objective of the review.

Theme: There is no reporting on other functional outputs (large wood, etc.), TMDLs, fish status & trend, that are needed for deciding on sufficiency of rules.

Number of responses: 2

ODF Response: We agree that large wood is very important for streams. Large wood was one of the topics considered by the Board in March 2018 when they directed ODF to conduct the Siskiyou Streamside Protections Review. However, they explicitly excluded large wood in their direction to ODF so that ODF would have staff resources to work on other projects simultaneously. We may revisit the topic of large wood in the Siskiyou at a later date depending on Board direction.

The Board stated they would not make a determination on the effectiveness of forest practices to achieve goals for fish. They did not direct ODF to revisit the assumption that meeting FPA goals for water quality and the riparian desired future condition would result in outcomes beneficial to fish, so this theme is considered out of scope. Fish status and trend information was presented directly to the Board by Oregon Department of Fish and Wildlife at the March 2019 meeting and is part of the record for their decision making process.

TMDL information was presented directly to the Board by DEQ at the March 2019 meeting. ODF staff incorporated the TMDL process and its findings into this rule review process by including a summary of DEQ's presentation on this topic in the Board materials for the June 2019 meeting. The Board will review these materials to inform their decision at that meeting.

Theme: The contradictory/unintuitive data reported in Figure 3 could indicate the NC criteria do not properly reflect real background biological conditions. Minor and/or temporary exceedances of NC criteria do not indicate water quality has been compromised.

Number of responses: 1

ODF Response: Objective 1 of the SR was to assess whether stream temperatures within or adjacent to forest management met DEQ water quality temperature standards. An assessment on the accuracy or effectiveness of the NC criteria to meet its beneficial use (fish) is not within scope of this review.

Theme: It is inappropriate for decisions on FPA rule effectiveness to be based on studies that did not explicitly measure Oregon FPA rules.

Number of responses: 1

ODF Response: ODF staff will report to the Board on a summary of the findings from all included studies along with the number of sites and the quality/relevance confidence scores associated with the studies the findings comes from. This summary can be found in the decision support document (Attachment 1) which points out the weaknesses of the information available in the SR report. It is important to note that riparian stands managed with either greater or lesser retention or no-cut distance than that of the FPA provide insight on the effectiveness of the FPA by placing bounds on its likely performance.

Theme: A simple assessment of stands in a given unit is inappropriate for determining achievement of DFC if rule effectiveness should reflect the FPA language "…achieve DFC… over time…. across the landscape…"

Number of responses: 1

ODF Response: The decision support document (Attachment 1) points out the weaknesses of the information available from the SR report. There is no information to identify a trajectory of streamside stands for any metric and therefore staff cannot complete the SR Objectives 3a and 3b on whether streamside stands "likely will achieve" DFC.

Appendix D. Siskiyou Systematic Review Protocol

D. Abbreviations and acronyms

Board – Oregon Board of Forestry

cfs – cubic feet per second (a unit of streamflow)

DEQ – Oregon Department of Environmental Quality

DFC – desired future condition (refers to streamside forest goals as referenced by OAR 629-642-0000(2)

FPA – Oregon Forest Practices Act (private lands)

OAR – Oregon Administrative Rules

ODF – Oregon Department of Forestry

ODFW – Oregon Department of Fish & Wildlife

ORS – Oregon Revised Statutes

PCW – Protecting Cold Water criterion

RipStream – Riparian Function and Stream Temperature Study

RMA – Riparian Management Area

SR – Systematic Review

D.1. Introduction

D.1.1 Background

In January 2012, the Oregon Board of Forestry (Board) found a degradation of resources by Oregon Forest Practices Act (FPA) rules regarding protection of small- and medium-sized fish-bearing streams. This specific finding was that the FPA did not meet an Oregon Department of Environmental Quality (DEQ) water quality standard for stream temperature (the Protecting Cold Water criterion [PCW][27]). The Board's finding was based on the scientific outcomes of the Oregon Department of Forestry (ODF) Riparian and Stream Function (RipStream) study (Groom et al., 2011). The findings inititated a riparian rule analysis in which the Board used evidence from RipStream, a systematic review of scientific literature, and additional analyses to decide on changes to streamside protection rules.

For more information:

All forest practice rules, are available from the Secretary of State website:
http://sos.oregon.gov/archives/Pages/oregon_administrative_rules.aspx.

Statutes may be found at the Oregon State Legislature website:
https://www.oregonlegislature.gov/bills_laws/Pages/ORS.aspx.

The rules and statutes are also available on the Oregon Department of Forestry's website:
http://www.oregon.gov/ODF/Pages/LawsRules.aspx.

FPA Water Protection Rules:
https://digital.osl.state.or.us/islandora/object/osl:85361

Other ODF documents:
https://digital.osl.state.or.us/islandora/object/osl%3Adocs_f

The geographic scope of the revised rules is limited to small and medium Fish streams in the Coast Range, South Coast, Interior and Western Cascade geographic regions of Oregon[28]. The rules do not apply to the Siskiyou and eastern Oregon regions. This geographic limitation was a policy decision by the Board.

At the March 2018 Board meeting, the Board directed ODF to initiate the Siskiyou Streamside Protections Review, which includes:

- A systematic literature review (SR) of the effectiveness of FPA riparian protections for desired future conditions (DFC), stream temperature and shade of small- and medium-sized fish-bearing streams in the Siskiyou geographic region (Fig. 1).
- Work with partner agencies (e.g., DEQ, Oregon Department of Fish and Wildlife (ODFW)) to provide contextual information on water quality and fish status and trends. This contextual information is not part of this systematic review. Rather, the information will be delivered directly to the Board by these agencies, to add context for the Board's decision in response to findings of the review.

This document details the protocols with which ODF will conduct a systematic review regarding a) stream temperature and shade, and b) DFC.

[27] Protecting Cold Water (PCW) criterion (OAR 340-041-0028(11)) prohibits human activities, including timber harvest, from increasing stream temperatures by more than 0.3 ºC at locations critical to salmon, steelhead or bull trout

[28] Stream size and Fish classification are defined in OAR 629-635-0200, and geographic regions are defined in OAR 629-635-0220.

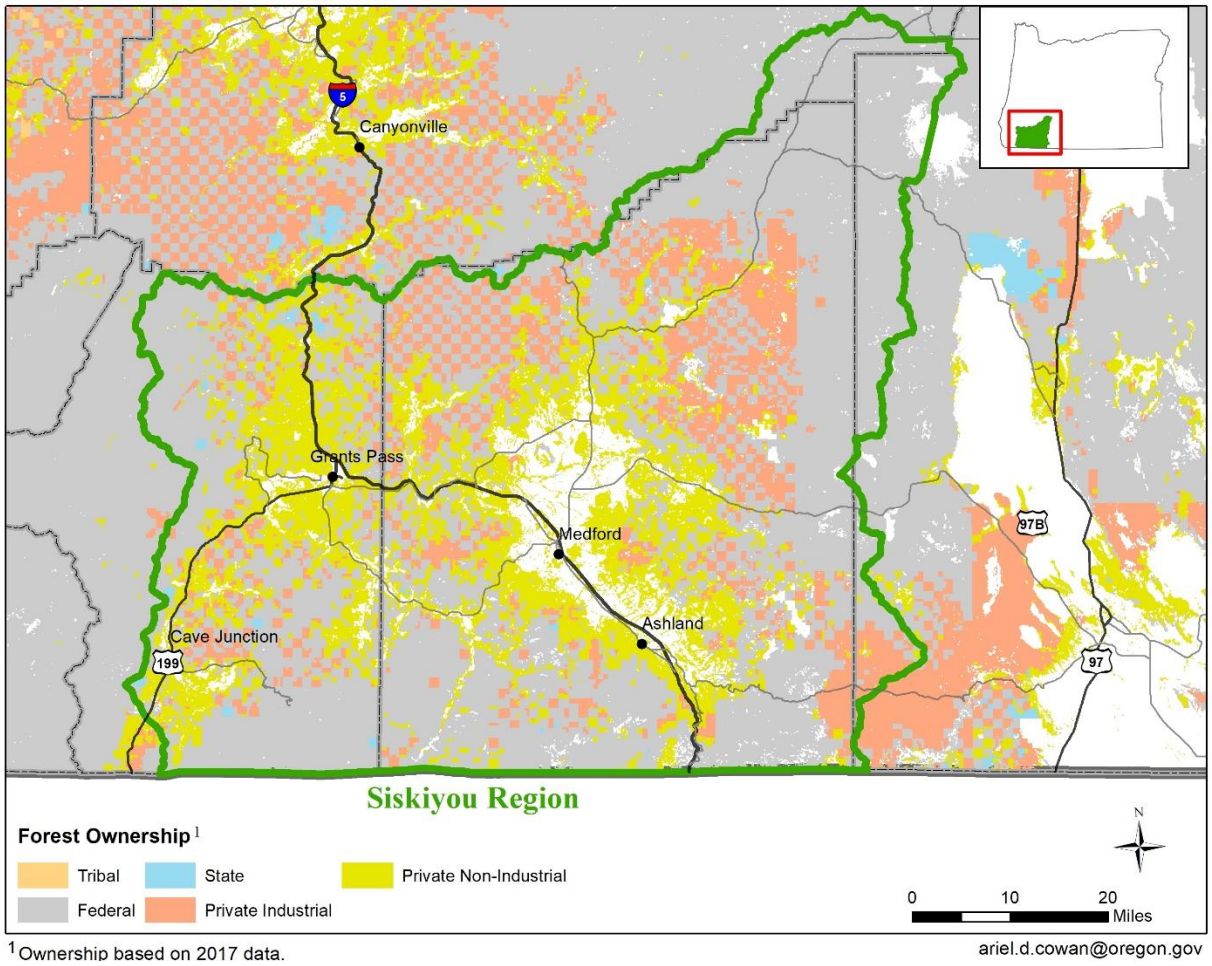

Figure D.1. Forest ownership in the Siskiyou geographic region based on 2017 data.

D.1.2 Review purpose

D.1.2.1 Stream Temperature

One primary purpose of this systematic review is to provide scientific evidence to the Board on the effectiveness of the FPA rules in protecting stream temperature for small- and medium-sized fish-bearing streams in the Siskiyou region (water protection rules, OAR 629-635-0100; sufficiency per ORS 527.710 (2b) and ORS 527.765(1)).

D.1.2.2 Desired Future Condition

The other primary purpose of this systematic review is to provide scientific evidence to the Board on the effectiveness of the FPA rules in achieving DFC of riparian forests along small- and medium-sized fish-bearing streams in the Siskiyou region (sufficiency per ORS 527.710 (2)). In order to address this primary purpose, a portion of the review will seek information on the range of characteristics that define DFC of riparian forests along these streams in the Siskiyou region. Additionally, the Board specifically directed ODF to address the shade outcome from streamside protections, which directly influences stream temperature, both immediately post-harvest, and at DFC.

D.1.2.3 Review scope

The scope of this review is bounded by both what the Board directed us to do, and by the policy to be assessed. Scope limitations were set by the Board for the purpose of assuring success in completing multiple projects on which the Monitoring Unit is simultaneously working. Regarding the DFC, the rule[29] states:

> *The desired future condition for streamside areas along fish use streams is to grow and retain vegetation so that, over time, average conditions across the landscape become similar to those of mature streamside stands. Oregon has a tremendous diversity of forest tree species growing alongwaters of the state and the age of mature streamside stands varies by species. Mature streamside stands are often dominated by conifer[30] trees. For many conifer stands, mature stands occur between 80 and 200 years of stand age. Hardwood stands and some conifer stands may become mature at an earlier age...*

The Board directed the department to focus on "healthy streamside forests", i.e., the effectiveness of achieving the primary characteristics, or functional "inputs," for achieving a mature riparian stand: overstory and understory structure, and stand regeneration. Large woody debris, root masses, snags, and litter fall are considered functional "outputs" from achieving DFC (resulting from structure provided by primary characteristics), and the Board did not direct us to assess these outputs. The exception to this scope limitation is the output of shade, which the Board directed ODF to include in the review.

The actual benefits to fish and wildlife (i.e., the functional outputs) from meeting vegetation goals is assumed and is beyond the scope of this review. Note that the department is working with partner agencies to provide some contextual information to the Board on both fish status and trend, and on water quality evaluations. Fish use, status, and trends are not within scope for the literature review. However, ODFW will present their information (including analysis, results, reviews and citations) on fish status and trends in the Siskiyou region at a Board of Forestry meeting.

Similarly, we are interested in trajectories of stands into the future. However, assessing potential impacts of climate change and disturbance factors (e.g., fire, floods), beyond considering them as effects modifiers, are out of scope for this review. Note that climate change is not currently part of the FPA, and there is no other Board policy regarding it. Climate change was identified as an emerging issue for the Board to review under the "Role of Forests in Carbon Policy and Adaptation Strategies for Climate Change" workplan item at their October 2018 meeting. The outcome of this discussion may inform future FPA effectiveness reviews. Regarding fire, floods or other disturbances and the FPA in riparian stands, this review is focused on the effectiveness of the General Vegetation Retention Prescription (OAR 629-642-0100). The Alternative Vegetation Retention Prescriptions that address management in RMAs for disturbance events is considered out of scope (OAR 629-642-0600). The Board may choose to change the scope of this analysis at any point as they see fit.

In November 2015, the Board made a policy decision to limit the scope of their rule change process to the rest of western Oregon and excluding the Siskiyou region. For this reason, the geographic extent of studies considered within scope for this review is limited to parts of the Siskiyou and Klamath

[29] OAR 629-642-0000(2)

[30] Rule language states mature riparian stands as "often dominated" by conifers, however the Siskiyou region may be an exception due to high prevalence of hardwoods in the riparian management area (RMA). The FPA describes basal area targets geared towards conifer stands (including within the RMA; OAR 629-642-0100(6)). However, there are no RMA basal area targets for hardwoods . For this review, literature with data on streamside stands dominated by hardwoods will be within scope in order to capture what information may exist.

Mountains in northern California similar to this region in e.g., climate, vetegetion, and geology (EPA Level III Ecoregion 78, US EPA, 2013).

In ODF's monitoring efforts, testing the effectiveness of rules means determining whether or not the rules meet the objectives stated in those rules. However, this testing should not be confused with assumptions testing. For example, the rules define "For many conifer stands, mature stands occur between 80 and 200 years of stand age." Thus the effectiveness monitoring tests to see if we are producing stands similar to those mature stands (Fig. 2). Assumption testing would be whether or not 80-200 year old stands are an accurate definition of "mature" or if this is an appropriate or ideal policy for the Board to adhere to.

In scope

- Mature forests (unmanaged)
- Any land ownership in region
- Studies with metrics on streamside forests
- Modeled stand conditions

Not in scope (per Board direction)

- Large woody debris, root masses, snags, and litter fall
- Potential impacts of climate change,fire, and other disturbances
- Fish impacts from forest practices

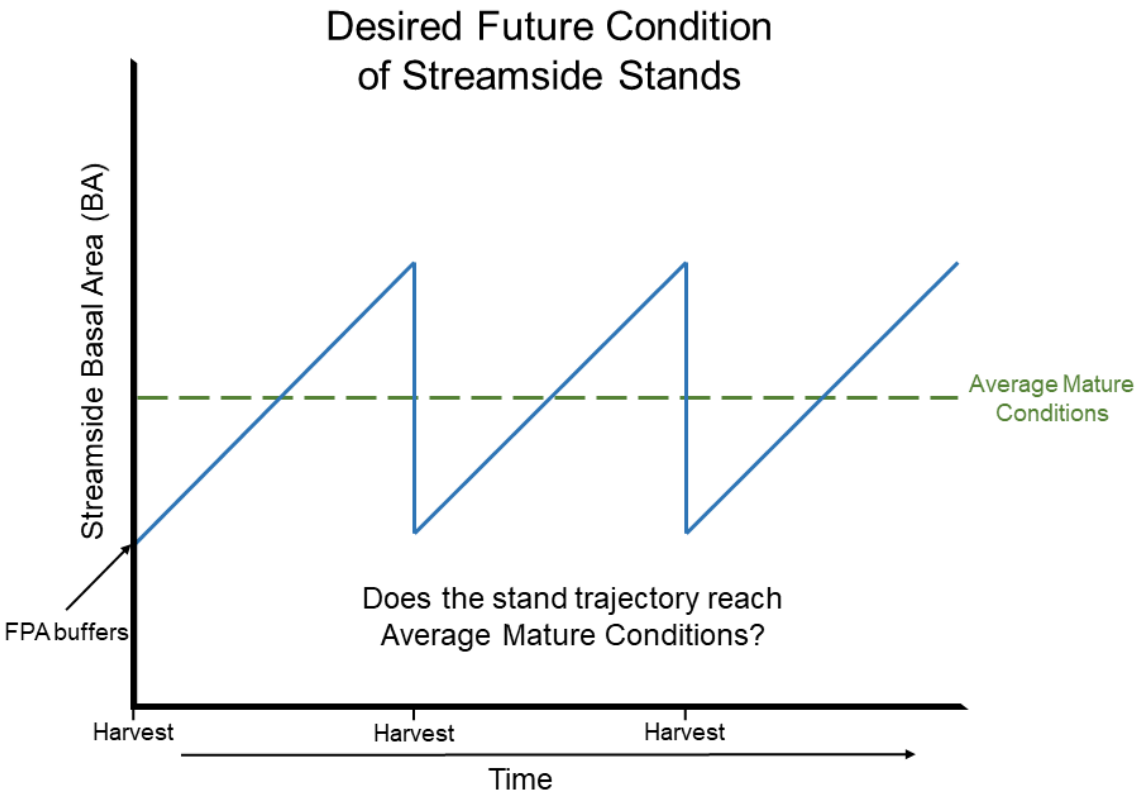

Figure D.2. Average condition of streamside stands in mature forests. Adapted from: Lorensen et al. 1994.

Excerpts from the Forest Practices Act

Oregon Revised Statutes (ORS) 527.710 Duties and powers of board; rules; inventory for resource protection; consultation with other agencies required.

(1) In carrying out the purposes of ORS 527.610 to 527.770, 527.990 (1) and 527.992, the State Board of Forestry shall adopt, in accordance with applicable provisions of ORS chapter 183, rules to be administered by the State Forester establishing standards for forest practices in each region or subregion.

(2) The rules shall ensure the continuous growing and harvesting of forest tree species. Consistent with ORS 527.630, the rules shall provide for the overall maintenance of the following resources:

(a) Air quality;

(b) Water resources, including but not limited to sources of domestic drinking water;

(c) Soil productivity; and

(d) Fish and wildlife.

ORS 527.765 Best management practices to maintain water quality; rules.

(1) The State Board of Forestry shall establish best management practices and other rules applying to forest practices as necessary to insure that to the maximum extent practicable nonpoint source discharges of pollutants resulting from forest operations on forestlands do not impair the achievement and maintenance of water quality standards established by the Environmental Quality Commission for the waters of the state. Such best management practices shall consist of forest practices rules adopted to prevent or reduce pollution of waters of the state. Factors to be considered by the board in establishing best management practices shall include, where applicable, but not be limited to:

(a) Beneficial uses of waters potentially impacted;

(b) The effects of past forest practices on beneficial uses of water;

(c) Appropriate practices employed by other forest managers;

(d) Technical, economic and institutional feasibility; and

(e) Natural variations in geomorphology and hydrology

D.1.2.4 Review Outcome

The expected outcome of this review will be a Board decision on the sufficiency of these rules. The Board will use the results of the review to decide if:

- The FPA or rules are working as designed
- FPA or rules may not meet stated objectives
- Additional study is warranted
- No action is needed

If the Board found the rules did not meet stated objectives, they could consider changing the rules through a rule analysis, which could result in regulatory or voluntary measures. According to statute, effects to fish, wildlife, water quality, and economic impacts to forest landowners and the timber industry must be considered in such decisions (ORS 527.714 and ORS 527.765).

D.1.3 Protocol elements

The first step in the review process is the development of a protocol. The protocol identifies key questions linked to policy goals within FPA rules and describes the criteria for literature selection. Developed following guidance on conducting systematic reviews in the natural resource sciences (CEE, 2018), the method for this protocol was selected for its rigor and transparency concerning how studies are searched for, which ones are included in the review, and how they are analyzed. It will provide a road map for how to conduct the review of scientific literature relevant to the policy questions.

Where ODF, with input from stakeholders and Tribes, finds ways to improve the protocol, it will be modified. Methods for nearly all studies in natural resources are adjusted between the study plan and their implementation, while remaining consistent with the study's objectives. As such, to improve meeting the review objectives ODF may also modify the protocol as we learn from the included studies. However, ODF will not change the purpose, scope, or questions of the protocol unless directed by the Board. Finally, all modifications will be documented for transparency and rigor.

Elements incorporated in a systematic review are outlined in Table 1. All steps of the review process are documented for transparency.

Table D.1. Elements described in a protocol for conducting a systematic review.

Elements	Brief explanation
Question(s), Objective(s)	Focused, scientifically answerable question and objective that guides search strategy and inclusion criteria
Search strategy	Methods (e.g., search terms and databases) to find studies pertinent to question
Inclusion criteria	Filters used to determine inclusion of studies to answer the question
Study quality and relevance assessment	Criteria used to determine strength of study methodology, and the relevance of study findings to the review question
Data extraction	Tables used for consistently recording data from studies and reviewer's associated notes
Data synthesis	Methods (quantitative, qualitative) used for synthesizing data with respect to the review question

D.1.4 Policy questions

The review seeks to answer policy questions with evidence from existing studies, as opposed to the authors' interpretation of such evidence. Studies are rigorously screened for direct relevance to answering these policy questions.

> ***Stream Temperature:***
> **For small and medium fish-bearing streams in the Siskiyou region, what is the effectiveness of Oregon FPA buffers to meet DEQ water quality standards for temperature[31]?**

[31] "DEQ water quality temperature standards" refer to OAR 340-041-0028 (4) & (11).

DFC:

For small and medium fish-bearing streams in the Siskiyou region, what is the effectiveness of Oregon FPA buffers in achieving the desired future conditions of streamside forests?

D.1.5 Review objectives

Within the policy **questions** stated above, there are multiple objectives focusing on each element to address. Here we outline each objective along with the associated policy goals and linkages. Scenarios to address, and metrics by which to measure each objective are displayed in Tables 2 and 3.

Note that whereas the goal of this review is to assess the effectiveness of FPA rules, additional riparian prescriptions are examined in this effort. These prescriptions are examined because operators often leave more trees than required (e.g., over half of Private forest sites in the RipStream study exceeded basal area requirements by more than 25%), and there are likely few, if any, sites in studies that exactly meet the FPA. Additionally, data from sites with prescriptions that lie on either side of FPA requirements help draw a more complete picture of the response to and put bounds on those prescriptions (Fig. 3).

Table D.2. Objective components for reviewing Siskiyou stream temperature.

Objective 1. Assess if stream temperatures within or adjacent to forest management meet DEQ water quality temperature standards in the Siskiyou region's small and medium fish streams. Policy linkages: ORS 527.710(2) and 527.765; and OAR 629-635-0100(7)(a)	
Scenarios in literature	**Extracted data (metrics)**
-DFC (Unmanaged mature riparian forests) -Pre-harvest -Post-harvest -Conifer- or hardwood-dominated	• Absolute temperature • Change in temperature (Pre- vs Post-harvest)

Table D.3. Objective components for reviewing Siskiyou desired future conditions (DFC).

Objective 2. Assess the range of the streamside stand conditions of mature forests in the Siskiyou region. Policy goals: Assess the metrics that characterize DFC for the Siskiyou region. Policy linkages: OAR 629-635-0100(7)(a, b, c), 629-642-0000(2); and ORS 527.710	
Scenarios in literature	**Extracted data (metrics)**
-DFC (Unmanaged mature riparian forests) -Pre-harvest -Conifer- or hardwood-dominated	• Basal Area/acre • Tree heights • Shade, % cover • PAR (Photosynthetically Active Radiation) • DBH • # of trees/acre • Tree species (e.g., relative abundance, dominant species) • Live crown ratio • Distribution with distance from stream

	• Understory vegetation (cover, species, distribution, etc.) • Seedlings/saplings • Patchiness of vegetation

Objective 3. Assess the effectiveness of near-stream forest management on achieving FPA desired future conditions of riparian forests in the Siskiyou region.
This objective contains two parts:

Objective 3a. Analyze the degree to which managed forests have, or likely will have[32], understory and overstory characteristics similar[33] to those of mature streamside stands.
Policy goals: Assessing primary characteristics, or functional "inputs," for achieving fish and wildlife habitat associated with mature riparian stands (e.g., hardwood-conifer distribution as a function of distance from stream, basal area). Note: this excludes assessing functional "outputs" of riparian stands (except shade), e.g., nutrient cycling, channel-influencing root masses, downed wood, snags.
Policy Linkage: OAR 629-642-0000(2), 629-635-0100 (7)(a, b, c), and FPA Water Protection Rules

Scenarios in literature	Extracted data (metrics)
-Managed, conifer-dominated streamside stands ≤200 years in age versus Objective 3 -Pre-harvest -Post-harvest (as-harvested) -Conifer- or hardwood-dominated	• Basal Area - Scenarios as compared to FPA standard targets • Tree heights • Shade, % cover • PAR (Photosynthetically Active Radiation) • DBH • # of trees/acre (conifers & hardwood) • Tree species (e.g., relative abundance, dominant species) • Live crown ratio • Distribution with distance from stream • Understory vegetation (cover, species, distribution, etc.)Patchiness of vegetation

Objective 3b. Analyze the degree to which managed forests have, or will have[6], streamside seedling/sapling species composition and age structure similar to those of mature streamside stands.
Policy goals: Assess the structure of streamside stands regeneration.
Policy linkage: OAR 629-642-0000(2)

Scenarios in literature	Extracted data (metrics)
-Pre-harvest -Post-harvest (as-harvested)	• Seedling/Sapling - Densities by species - Distance from stream

[32] Dependent on multiple sources of data to assess stand structure trajectory of unmanaged and managed riparian forests.
[33] See 1.5.1 Objective 2 considerations.

-DFC Mature forests (unmanaged, Objective 3) -Conifer- or hardwood-dominated	• Relative abundance

Narrative FPA goals for DFC do not have clear thresholds upon which to assess rule sufficiency, and thus the purpose for Objective 2 is to try to characterize these thresholds.

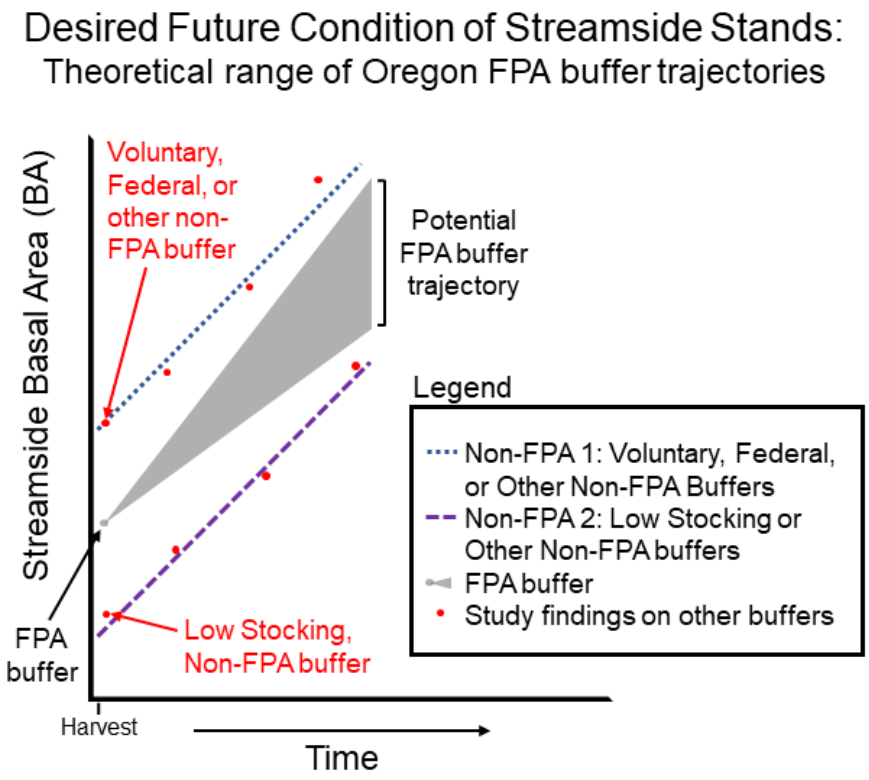

Figure D.3. Conceptual diagram on theoretical range of streamside stand condition trajectories with FPA buffers. Due to gaps in knowledge and limited available studies, ODF seeks to use examples of riparian forest management outside of FPA buffers in order to describe the range of potential DFC trajectories. This includes studies of buffers with either more or less basal area than FPA buffers in the Siskiyou region.

D.1.5.1 Objective 2 considerations

An important aspect of Objective 2 is the range of outcomes that are considered "similar" to those of mature streamside stands. Recall that mature stands are loosely defined in the FPA as occurring (for conifer stands) between 80 and 200 years of stand age and providing "ample" stream channel shade and other characteristics. Rule standards were developed by estimating the conifer basal area for average unmanaged mature streamside stands at age 120 then adjusting the basal area for assumed effects of riparian influences. Hardwood and some conifer stands are acknowledged as potentially being considered mature at an earlier age. Based on this information, included studies will be clearly identified as having stands that qualify as being "*mature*," "*pre-mature*" or "*post-mature*" stands using one of the following criteria:

1. Stand Age: studies with conifer and/or hardwood stand ages near or between 80 to 200 years (+/- 10 years) will be identified as "*mature*," younger stands will be identified as "*pre-mature*" and older stands will be identified as "*post-mature*;"

2. Stand Succession: studies with conifer and/or hardwood stands identified by study authors as being at a stand succession stage (e.g. early seral = "*pre*-mature;" old growth = "*post-mature*," etc.);
3. Studies that can be logically construed as meeting the criteria of #1 or #2 by other methods (ex: time since stand establishment, etc.).

Studies will also be clearly identified as having managed or unmanaged stands. The range of metrics identified in Table 3 for unmanaged "*mature*" stands will be compared with that of managed "*mature*" stands. If gaps exist in the information available, unmanaged "*pre-mature*" and unmanaged "*post-mature*" stands may be used to detect trends for the purpose of describing the potential range of unmanaged "*mature*" stands.

Department staff cannot dictate a priori how we will assess the similarity of mature riparian stands managed under the FPA with unmanaged mature riparian stands. The challenge is there are too many unknowns: there is a wide suite of potential metrics to assess, and it is hard to know whether or not there will be sufficient information to do quantitative analyses rather than descriptive ones. However, staff will transparently conduct this analysis using our best professional judgment, and all stakeholders will have a chance to comment on it.

D.1.5.2 Effects modifiers

This review will examine differences between studies that might explain variations among study outcomes. These differences may be due to effects modifiers (i.e., uncontrolled environmental factors). This additional question explicitly addresses the causes of these differences to the extent that relevant information is available in reviewed studies:

> **For small and medium fish-bearing streams in the Siskiyou region, how do effects modifiers (e.g., soils, mining, floods), in combination with near-stream forest management, effect stream temperature, shade, and desired future conditions of riparian stands?**

More details on effects modifiers can be found in Appendix D.A. Based on previous experience, rigorous analysis of these modifiers is both not possible based on the available data, and beyond the scope of this review. We will therefore likely have a brief, qualitative discussion of these modifiers.

D.1.6 Review partners

The entire process of conducting the review allows for greater inclusion of review partners. ODF will request and receive input from review partners, thereby strengthening the quality of the systematic review. These partners include university, federal, forest industry, and state scientists; staff from the Oregon Departments of Forestry, partner agencies (Departments of Environmental Quality, and Fish & Wildlife); landowners and operators; Tribes of Oregon; and non-governmental organizations (e.g., Rogue Riverkeepers, Wild Salmon Center, etc.). All partners will have the opportunity to provide input on:

- The protocol, questions, and objectives for this review;
- A draft list of publications to consider for inclusion in the review to assess if any studies were not found;
- A draft list of included publications to assess whether or not the inclusion criteria were appropriately applied;
- A draft of the completed review.

Table 4 provides an approximate timeline of the review development and opportunities for input by interested parties.

Table D.4. Tentative timeline for development of Siskiyou Board materials with opportunities for input from stakeholders and Tribes in bold.

Task	Date	Milestone / Deliverable
Phase 1 - Protocol		
Kickoff outreach with stakeholders and Tribes	Spring 2018	Completed list of contacts for stakeholders and Tribes
Collaborate with partner agencies for contextual information	Spring through Fall 2018	Reports on Fish status & trends, water quality evaluations for final Board materials
Develop literature review protocols	Summer 2018	Protocols for literature review
Present Monitoring Unit update to Board	Sept. 2018	Presentation on progress of review
Stakeholder and Tribal input on review protocols & studies to consider	Fall 2018	Record of stakeholder and Tribal feedback on review protocols, and literature to include in review
Determine inclusion of literature in review	Fall 2018	Literature selected for inclusion based on criteria
Stakeholder and Tribal input on inclusion-exclusion of literature to review	Fall 2018	Stakeholder and Tribal feedback on literature to include in review
Phase 2 – Review and Board decision		
Progress update for Board, contextual information from partner agencies	Jan. 2019	Subset of completed work for the Board
Data extraction, analysis, and writing of literature review	Winter 2019	Draft reports of literature review
Stakeholder and Tribal input on draft review	Spring 2019	Stakeholder and Tribal input on draft review
Address stakeholder & Tribal input on review	Spring 2019	Final drafts of literature review
Present completed work to Board for their determination of sufficiency of streamside protections	June 5, 2019	Project complete

D.2. Methods

D.2.1 Search strategy

The systematic review will use a search strategy that specifies, *a priori*, how a comprehensive and unbiased sample of literature will be searched. We will conduct a search as wide as possible, then use rigorous criteria to narrow down which studies to include. Citations of all publications found through various searched sources will be saved in a database. Results with indeterminate information (e.g., incomplete citation) or duplicates will be discarded. New searches will be conducted to capture literature produced since the previous search for the EOA/Siskiyou information tally (2016 to present) and added

to the pool of previously-found literature. For every search, the following information will be documented:

- Date when search was conducted
- Database, search engine, website, library, or professional contact that was queried
- Exact string of keywords/terms used in search

Search terms are divided into sets that represent an element of the review objectives. Terms within each set will be combined via Boolean operators (e.g., AND, OR) with those of each term within the other sets. Search terms (* indicates wildcard search term, "" indicates exact phrase).

Temperature & Shade:

Set 1. Management activity

(*Forest* or wood* or tree*) AND (thin* or harvest* or clear* or cut* or remov* or regenerat*)

Set 2. Treatment/intervention

(Riparian or streamside or "stream-adjacent" or "near stream") AND (buffer* or reserve* or manag* or zone or leave* or veg* or strip* or area or canopy)

Set. 3 Outcome

("stream temperature" or "water temperature" or shade or cover or light)

DFC:

Set 1. Management activity

(*Forest* or wood* or tree*) AND ((thin* or harvest* or clear* or cut* or remov* or regenerat* or treat* or post* or manage* or model*) OR (unmanaged or old growth or mature or reference or late succesional))

Set 2. Treatment/intervention

(*Riparian* or streamside* or "stream-adjacent" or "near stream" or stream or channel) AND (buffer* or reserve* or manage* or zone* or leave* or veg* or strip * or area* or canopy* or wood*)

Set 3. Outcome

("basal area" or age* or shade* or cover* or seedling* or sapling* or "leaf area" or composition* or "live crown" or distribution or specie* or regen* or understory or distance or frequency)

D.2.2 Search sources

The following electronic databases will be searched:

- Scopus
- Google Scholar

For searches performed using Google Scholar, internet cache and cookies will be cleared from the browser before each search to avoid browsing history influence in search repeatability.

All publications found in the afore-mentioned searches will be included in a table that clearly documents the fate of inclusion or exclusion from this systematic review. This documentation allows for us to be rigorous in recording our decisions, and allows for feedback from interested parties. In contrast, for the

searches discussed below, only the publications more carefully considered for inclusion (via e.g., reading the abstract) will be included in that table. This decision to not document EVERY article considered is because it would be a huge expenditure of our time to manually enter each publication from e.g., a review article, whereas the database searches can be easily exported to a spreadsheet table.

Because disciplines related to streamside forests have little consensus on key terms, the systematic search will be augmented with an *ad hoc* search to avoid overlooking useful publications. In the ad hoc search, bibliographies and citation searches of included studies and any traditional reviews will be examined for relevant references. Additionally, email or phone queries concerning obscure studies will be sent to scientists and interested parties (e.g., participating environmental NGOs) in the region who study, or work with people who study, riparian buffers, streamside forests, or shading of streams.

Searches will also be carried out within the web pages of relevant associations and organizations including, but not limited to:

- Tree Search: USDA Forest Service Research
- The US Environmental Protection Agency;
- National Council for Air and Stream Improvement;
- California Dept. of Forestry and Fire Protection;

Finally, to capture theses and dissertations that are electronically archived (i.e., not located in regular library catalogs), the search will include catalogues of graduate theses from research universities in the Pacific Northwest:

- Oregon State University;
- University of Oregon;
- Portland State University;
- Southern Oregon University;
- University of California system;
- California State University system

D.2.3 Study inclusion criteria

Study inclusion criteria are predefined to ensure an impartial selection of the relevant literature. For this review, the studies must directly inform at least one of the two main objectives. Only primary studies (i.e., studies with original data (field and/or modeling), not reviews, or meta-analyses) will be included since ODF wants to use evidence, not authors' interpretation of evidence. The inclusion of "gray literature" (i.e., articles that might have less rigor in either peer-review or research methods / analysis, e.g., government reports, graduate theses) and manuscripts in review allow for consideration of data that may be most relevant to the review objectives. The final inclusion criteria are:

- Studies must have descriptive, modeled, or observational data on at least one of the riparian stand metrics outlined in Tables 2 and 3 (note: we are not examining raw data);
- Studies must have been located within the Siskiyou-Klamath Mountain region of southwest Oregon or northern California (EPA Level III Ecoregion 78, US EPA, 2013; Griffith et al., 2016; Pater et al., 1998);
- Studies must have been conducted in sites with similar stream sizes as ODF's classification of small and medium streams (<10 cfs, Oregon Department of Forestry, 1994);

Additionally, inclusion criteria must meet <u>*one of*</u> the following:

- For Objective 2, studies must meet the criteria of the desired future condition (mature riparian stands, 80-200 years, etc. (See 1.2.2 *Desired Future Condition*)) or contain pre- or post-mature conditions which the department will use to place bounds on within-mature conditions;
- Studies must have proper controls with which to measure the effects of buffer treatments (Temperature- Objective 1; DFC- Objectives 3a, 3b);

Table 5 provides more details on these criteria.

Table D.5. Example table of inclusion criteria for filtering studies found in search for potentially relevant literature.

Study	Inclusion criteria				Criteria specific to Temp objective[6]	Criteria specific to DFC objectives	
	Relevant Data[1]	Setting[2]	Study type[3]	Geographic extent[4]	Objective 1	Objective 2[5]	Objective 3[6]
Brosofske 1997	Y	Y	Y	N	N	N	N

Studies must meet all inclusion criteria, plus at least one of the criteria for either DFC or temperature objectives..
[1] Reported (via at least one figure, table, or in the narrative) primary measurements or modeled data of riparian forest characteristics listed in Tables 2 and 3. For Objective 1, need to have appropropriate controls to assesss impact of harvest.
[2] Forest stands with streams comparable to small and medium streams (FPA definition: medium have 2-10 cfs average annual flow) within or adjacent to forest stands. Note that some studies may not state cfs rates in which case stream size will be inferred from other descriptors or what is known of study location.
[3] Peer-reviewed papers, NGO reports, government reports, manuscripts in review, and graduate theses, all of which must be primary studies that describe methods and results, and contain primary data.
[4]A portion of the study must have been conducted in any of the following locations: the Siskyous of Oregon, the Siskiyous of northern California, or the Klamath Mountains of northern California.
[5] Mature, pre-DFC, or post-DFC streamside stands. Managed or unmanaged, or applicable reference stands (See 1.5.1 Objective 2 considerations);
[6] Near-stream area managed with some type of buffer (e.g., hard-edged no cut, variable retention, thin). Buffer management prescription is clearly quantified (e.g., buffer width, basal area retention).

With these criteria in mind, inclusion will be initially determined by article titles. When titles provide insufficient information to determine meeting all inclusion criteria, abstracts will be read to determine inclusion. Where there is still insufficient information to make a decision, an article's inclusion will be determined by reading the full text. For transparency, the inclusion or exclusion of studies, and the basis for this decision, will be documented.

D.2.4 Data extraction strategy

A systematic review evaluates both information about included studies (e.g., strength of study design) and their respective primary or modeled data. This information focuses the review on: 1) evidence instead of authors' interpretation of the evidence; and, 2) the strength of that evidence. Data extraction tables allow for objective, consistent, and transparent extraction of these data from studies selected for inclusion. In addition, these tables help to highlight gaps in our understanding. Table 6 demonstrates a data extraction table for use in this review. Note that this review is not a meta-analysis.

Table D.6. Data to be extracted from each publication.

Publication title and author(s)
Study duration (# of years) and time since harvest (if applicable)
Study location (watersheds, region/state, country), settings where riparian buffers were applied
Site history (if available)
Stand age or succession stage (to determine if *mature*, *pre-mature*, or *post-mature*)
Ecosystem type; plant association group; type of forest
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)
Research question(s), hypotheses, objectives
Study design[1]
Pretreatment/reference/control data (Y/N), # of years of data (if used for temperature objective 1 or DFC Objective 3)
Managed or Unmanaged
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams; FPA or other)
Metrics and their robustness[2]
Sample sizes and results with estimates of variation[3]
Notes concerning study quality with evidence or reasoning behind the notes[4]
Potential sources of bias or error
Effects modifiers[5]
Method references[6]
Similar FPA standards (y/n)
Notes[7]

[1] Brief description of study design, e.g., # of sites, types of controls (pre-treatment, reference, upstream), site layout; and classification of study method, e.g., Before-After-Control-Intervention.
[2] Examples of outcome measures: basal area, species composition (See Tables 2 and 3). Robustness refers to how well outcomes were measured (e.g., accuracy of measurements, frequency, sound method for measuring, categorical, binned, estimated, or continuous data).
[3] For sample size, list with respect to particular results if appropriate (e.g., "basal area (n=4)"); list specific results that are most pertinent to answering the question and help inform the review objective, referencing a figure or table where appropriate; include confidence limits, ranges, or standard deviations.
[4] Address study quality questions such as: Did authors adequately address fundamental processes? How well did they conduct their statistical analyses? Were biases addressed?
[5] Which effects modifiers were considered (see list of effects modifiers in Appendix D.A), and how they were addressed.
[6] Refers to references that are essential to understanding methods of an article.
[7] Notes allows for additional insight reviewer may provide on study quality.

D.2.5 Quality and relevance

To help the Board consider the results from the various studies, we assess both the quality of each study selected for inclusion, and its relevance to this review's objectives. For example, a study might have directly addressed the review objectives, yet was poorly conducted and so provided little confidence in the study's results. Conversely, a study may have been conducted very well, yet has only weak relevance to the review objectives. Table 7 demonstrates how study quality and relevance will be evaluated.

Table D.7. Summary of information from each study for evaluation of quality and relevance to the review objectives.

Quality						Quality: Normalized Confidence Score[12]	Relevance					Relevance: Normalized Confidence Score[12]
Study design[1]	N_{sites}[2]	$N_{control}$[3]	$N_{replicate}$[4]	Methodologically robust[5]	Statistically robust[6]		Stream size[7]	Geography[8]	Objective[9]	Management[10]	Pre-Mature, Post-Mature, or Mature[11]	

[1] H=high=Experimental design with controls and/or sampling before and after treatment; M=medium=Observational design with replication; L=low=Case study (unreplicated, uncontrolled, single observation)(modified from (Salisbury and Fazey, 2002)). If mixture (e.g., some sites with and some sites without replicates), give mixed rating (e.g., L/M).

[2] Number of sites used in this review. H=high= >3; M=medium= 2-3; L=low= 1 site. This scoring rubric was chosen based on best professional judgement.

[3] Number of control replicates. Only applies to studies addressing Objective 1. H=high= >3; M=medium= 2-3; L=low= 1 replicate. Note that this category will only be applied to studies being used for Objective 1 (temperature) and Objective 3 (managed streamside stands) in order to assess quality of data capturing changes to stream temperature or changes to streamside stand conditions post-harvest.

[4] Number of replicates or treatments with the same prescription (e.g., buffer width) within sites. H=high= >3; M=medium= 2-3; L=low= 1 replicate within each site. This scoring rubric was chosen based on best professional judgement.

[5] This category considers whether 1) methods used to collect data on metrics were robust and appropriate and 2) whether age or seral stage was reported/factored into site selection. H=high= yes to both questions; M=medium= yes to one question; L=low= no to both questions. This scoring will be based on the Data Extraction Table (Table 2), rows: Metrics and their robustness (see protocol Table 7); Stand age or succession stage; Method references.

[6] This category considers two questions: 1) Were the statistical analyses conducted appropriate for the data collected? And, 2) Did study authors adequately explore data (via analyses) to address study questions and objectives? H=high= yes to both questions; M=medium= yes to one question; L=low= no to both questions. Note that this category does not consider study design. This scoring will be based on the Data Extraction Table (Table 2), rows: Research question(s), hypotheses, objectives; Study design; Pretreatment/reference/control data (Y/N); Sample sizes and results with estimates of variation; Notes concerning study quality with evidence or reasoning behind the notes; Potential sources of bias or error; Method references.

[7] H=high=small or medium streams as defined by average annual flow less than 10 cfs average annual flow; L=low= ambiguous stream size or streams larger than 10 cfs average annual flow.

[8] H=high= EPA Ecoregions 78a-e; L=low= EPA Ecoregions 78f-r (78a-e are the EPA ecoregions that coincide with the FPA Siskiyou region; EPA Level III Ecoregion 78, US EPA, 2013; Griffith et al., 2016; Pater et al., 1998).

[9] H=high=study objectives or questions directly relate to review question/objectives; L=low= study has relevant data even though study objectives or questions are not directly related to review question.

10 H=high=managed stands from at least one of the treatments used current FPA buffers; L=low=managed stands from all treatments used other buffers (non-FPA) or unknown buffers.

[11] Studies will be identified by the time range the data captures: pre-mature, post-mature, or mature (within the defined goal for DFC, 80-200 year old riparian stand, as described in 1.2.2 Desired Future Condition). See 1.5.1 Objective 2 considerations. H=high=at least 1 site with unmanaged or managed stands within DFC age class ("mature"); L=low=unmanaged or managed stands are outside of DFC goals (“pre-mature” or “post-mature”);

?=unknown=age or seral stage mixed or not reported and we are unable to estimate seral stage with the reported data (no DBH or height for use in age models). Unknown will be scored as 0.

[12] Sum of points were divided by maximum points available for that study (See footnote 3 for whether study assessed controls if used to address objectives 1 or 3).

D.2.6 Data synthesis

To make sense of the information extracted from the studies, the data must be analyzed and synthesized. Here we provide examples of the types of figures we might use to synthesize information from included studies. However, we acknowledge that our precise approach to synthesis depends on the types of data available, and thus cannot be precisely prescribed a priori.

Figure D.4. Mean change in temperature in relation to no-cut buffer width. Threshold for PCW criterion shown as dotted red line. Source: Terry Frueh. *Purpose:* Objective 1.

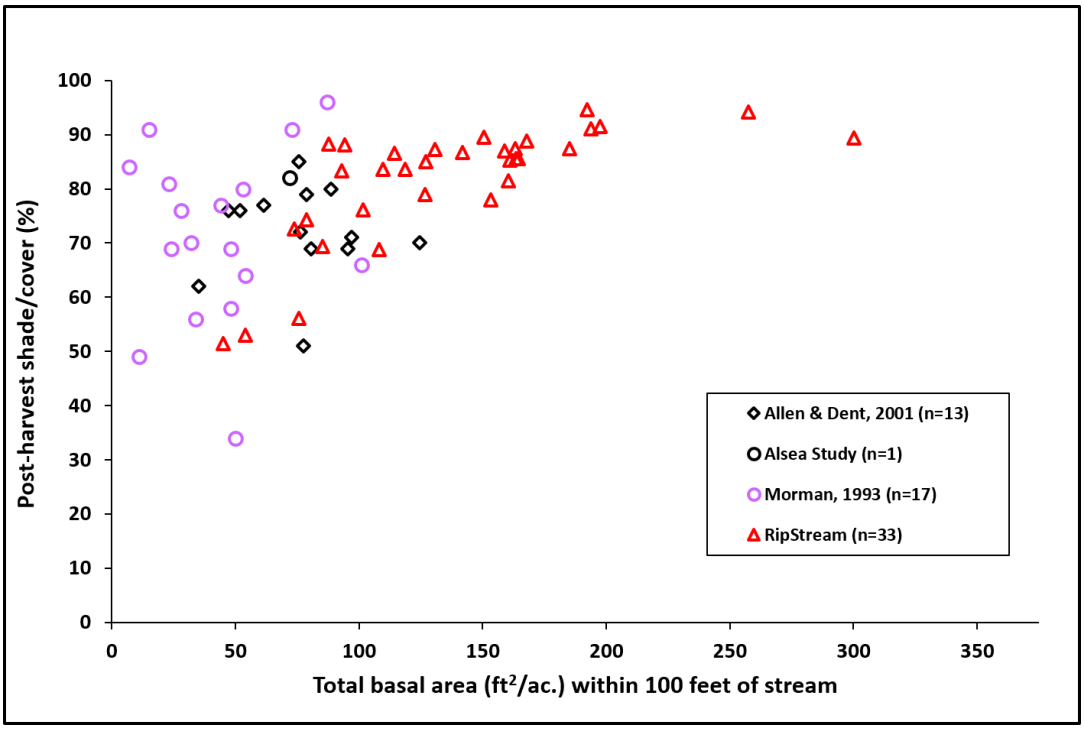

Figure D.5. Post-harvest shade/cover percentages in relation to total basal area within 100 ft of stream. Note: Comparisons will also be made with mature riparian forest shade. Source: Terry Frueh.

Purpose: **Objective 2, 3a.**

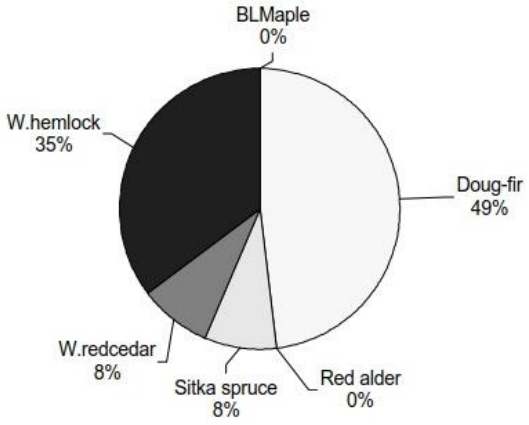

Figure D.6. Proportion of species found in the RMA. Same figure would be made to describe species composition in mature Siskiyou riparian stands. Source: Dent, 2001.

Purpose: **Objectives 2 and 3.**

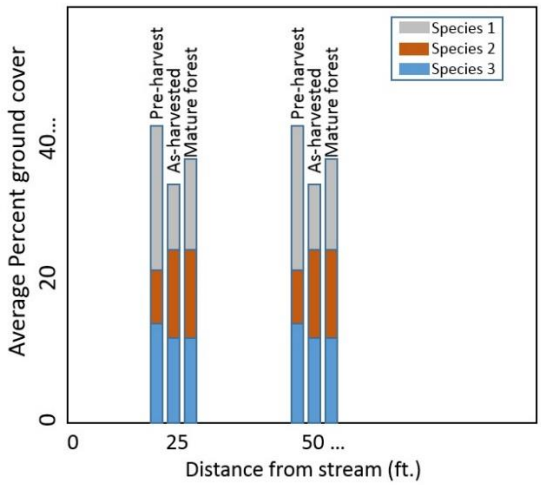

Figure D.7. Conceptual figure created by T. Frueh. Percent ground cover by three most common species vs. distance from stream for stands at DFC and managed stands (pre- and post-harvest).

Purpose: Objectives 2 and 3a.

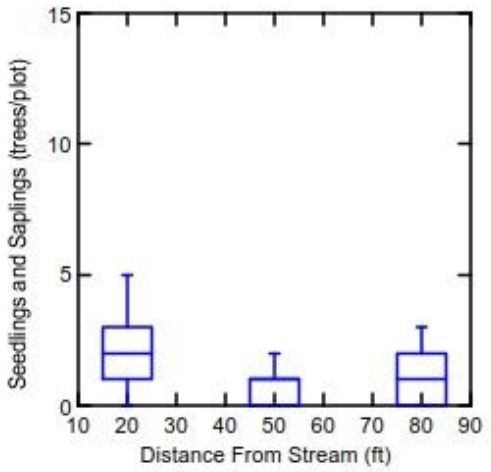

Figure D.8. Mean density of conifer seedling/saplings vs. distance from stream for stands at DFC and managed stands (pre- and post-harvest).

Source: Dent 2001. *Purpose:* Objective 2 and3b.

D.3. Next steps

Please send us studies to consider for inclusion. Your comments will be saved as public record. Emails can be sent to one of the following ODF contacts:

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U.S. Environmental Protection Agency, 2013, Level III ecoregions of the continental United States: Corvallis, Oregon, U.S. EPA – National Health and Environmental Effects Research Laboratory, map scale 1:7,500,000, https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-continental-united-states.

D.5. Appendix A1. Potential effect modifiers

While studies may have very similar methods, they may show differences in the measured outcomes. These differences may be due to circumstances ("effects modifiers") that alter the outcomes. For example, two studies may have identical buffer widths, yet if their forest types are very different (e.g., hardwood vs. conifer), they may exhibit very different stand characteristics. Thus, these effects modifiers are important to consider when synthesizing the extracted data.

The following lists of effects modifiers were determined by: 1) modifying a list of effects modifiers in a systematic review similar to this review (Bowler et al., 2008); 2) examining a subset of studies to see what are considered important effects modifiers; and, 3) incorporating input from stakeholders, tribes and technical experts.

Factors of, or affecting, the riparian zone and stream temperature:

- Dominant species, mix of species
- Tree harvest in part or all of the riparian reserve
- Type of trees e.g. deciduous or non-deciduous
- Tree height, age, distance from edge
- Crown height
- Tree density
- Residual stand composition
- Tree/basal area retention amount
- Other riparian vegetation: presence, % cover
- Animal impacts (e.g., browsing, trampling)
- Historical disturbances (fire, flooding)
- Aspect
- Method of vegetation or tree removal
- Clearcut vs. thin (outside of riparian reserve)
- Harvest on both sides or single side of riparian reserve
- Time since harvest
- Windthrow
- Other land use
- Substrate
- Gradient (stream and riparian areas)
- Channel conditions (e.g., incision, bank erosion)
- Elevation
- Geology and soils
- Changes in flow (e.g., due to harvest)
- Invasive species and noxious weeds
- Climate Change

Appendix E. FPA requirements for riparian management areas (RMAs)

Table E.1 Standard targets for small and medium Type F (fish) streams in the Siskiyou geographic region (OAR 629-642-0100(6)).

	Standard targets for basal area ($ft.^2$/1,000 feet)	
Upland harvest	**Small streams (RMA=50 feet)**	**Medium streams (RMA=70 feet)**
Type 2 and 3[1]	40	110
Type 1	50	140

[1] Includes clearcut harvests; see OAR 629-0600-0100 for more specification of harvest types.