Effectiveness Monitoring Committee - Completed Research Assessment for EMC-2018-006 – "Effectiveness of Class II Watercourse and Lake Protection Zone (WLPZ) Forest Practice Rules (FPRs) and Aquatic Habitat Conservation Plan (AHCP) Riparian Prescriptions at Maintaining or Restoring Canopy Closure, Stream Water Temperature, and Primary Productivity"

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Part 1. Does the study fulfill and address scientific questions posed in the proposed research?

Yes, the studies addressed the resources outlined in the proposals. The funded concept proposal identified 3 key questions the research would address. These were:

> "(a) How do the current FPRs and GDRCs AHCP Class II riparian requirements influence important controls on water quality and stream metabolism, including canopy closure, solar radiation, and near-stream air temperature during the summer low flow period?
>
> (b) What is the relative importance of the different drivers (objective a) in influencing the variability in stream temperature dynamics (e.g., maximum, minimum, diurnal variations), dissolved oxygen, and primary productivity during summer low flow across different Class II WLPZ prescriptions?
>
> (c) Integrate the data from objectives (a) and (b) to develop a model to improve understanding of the effectiveness of different Class II WLPZ prescriptions at mitigating undesirable changes in stream temperature and primary productivity following forest harvesting activities across a range of scenarios."

The research successfully addressed objectives (a) and (b) by pairing appropriate experimental controls with riparian thinning treatments in two disparate watersheds in coast redwood (*Sequoia sempervirens*) and Douglas fir (*Pseudtsuga menziesii*) riparian forests in Humboldt and Del Norte Counties. By collecting a suite of stream temperature and watershed-level variables before and after treatment, the study was able to compare the effects of thinning treatments and identify factors that were the strongest determinants of stream temperature and other key stream variables known to affect aquatic organisms. The authors were able to model stream temperature using methods that were applicable to the study sites (c).

In addition to the scientific goals described above, the study also interpreted results in terms of the applied silvicultural prescriptions in the final report. Using this applied lens to interpret scientific results highlights the value of the study to the work of the Board of Forestry.

Does the study inform a rule, numeric target, performance target, or resource objective?

Yes, the studies directly addressed the effects of riparian thinning on Class II-L stream habitat characteristics and some water quality metrics. The studies measured the effects of riparian thinning prescriptions on water temperature, streamflow, effective shade, canopy closure, nutrient concentration, and chlorophyll (a proxy for photosynthetic organisms such as algae).

The studies found that stream temperature is controlled by multiple factors including canopy cover (the variable regulated under the Forest Practice Rule's). In addition, the studies found that thinning as applied in this study had minimal effects on stream temperature in the Anadromous Salmonid Protection (ASP) treatments and Green Diamond Habitat Conservation Plan (HCP) treatments, and found that observable effects on stream habitat were generally reduced in the second year following thinning treatments.

Does the study inform the Forest Practice Rules?

Yes, the study directly addresses the Forest Practice Rules (FPRs), including the Watercourse and Lake Protection Rules (FPR 916.4, 916.5) and ASP rules (FPR 916.9). The FPRs currently prohibit timber operations with heavy equipment within 30 feet of Class II L streams without justification and limit the amount of harvesting that can occur within a buffer of 70 feet outside of this core zone (FPR 916.4 and 916.9). By comparing Watershed and Lake Protection Zone (WLPZ) treatments allowable under the current rules with pre-ASP WLPZ retention standards (canopy reduction within the inner and outer zones down to 50% overstory canopy) the study was able to identify whether current and historical practices are effective in maintaining stream temperature and habitat at these sites. It is important to note that the canopy was reduced to pre-ASP standards on only one side of the watercourse during the study.

The study design can also help determine the effectiveness of previous iterations of the watercourse protection rules. The study used three different WLPZ treatments that included the current ASP rules (2009), a functionally similar treatment allowed by Green Diamond Resource Company's HCP, and forest practice rules that were in effect prior to the adoption of the current ASP rules. By comparing each of these treatments with unharvested controls, the study was able to determine both the effectiveness of current WLPZ harvest rules and whether the current rules made a significant change in the effectiveness of the rules prior to the adoption of the ASP rule package in 2009.

Part 2. Is the study scientifically sound?

Was the study carried out pursuant to valid scientific protocols (i.e., study design, peer review)?

Yes. The studies used an appropriate research design to reduce confounding effects such as randomly assigning treatments to stream sections and including comparisons with an untreated control watershed in a paired watershed design. Measurements were carefully collected using appropriate techniques and process controls. Paired watershed approaches are still the best available empirical approach when testing the effects of treatments on hydrological processes. Results were analyzed using appropriate statistical methods. The modelling approaches applied by the PI's is an appropriate way to address the variability between watersheds. The studies also resulted in two peer-reviewed publications that were scrutinized by experts in the field during the peer-review process.

Part 3. Is the study scalable?

The studies' results can be reliably applied to the portions of the redwood belt. However, one of the findings of recent Effectiveness Monitoring Committee (EMC) funded studies by members of this research group is that stream temperature is affected by different factors in different regions (Wissler 2021, Wissler et al. 2022). In addition, the authors urge caution in interpreting the results broadly (Miralha et al. 2023). Even so, the lack of empirical research on modern forest practice in California make the group of studies discussed here an important and valuable case study moving forward. Hydrological process knowledge gleaned from this study can be conservatively applied to other areas where boundary conditions and controlling factors are similar.

Synthesis of Key Findings

A group of studies were conducted using the same set of treatments under this grant. The studies were related in scope but examined different aspects of stream conditions resulting from riparian thinning treatments. The major results of each study are listed below under the resulting thesis or publication.

Miralha, L., Wissler, A. D., Segura, C., & Bladon, K. D. (2023). Characterizing stream temperature hysteresis in forested headwater streams. *Hydrological Processes*, 37(1), e14795.

In this study, the authors used a combination of stream temperature gauges and air temperature monitors to evaluate seasonal and storm water input effects on hysteresis at two second growth Douglas fir – Coast Redwood dominant sites in Humboldt and Del Norte Counties. Stream measurements were collected at Green Diamond Resource Company managed forests in the Tectah Creek and McGarvey Creek watersheds. Data were analyzed for the wet portion of the 2020 water year, from Oct. 1st 2019 through June 15th, 2020.

The authors found that the direction of hysteresis, or lag between water temperature and air temperature change, differed by season. In Spring and Summer storm events, stream water temperatures were warmer as stream water rose followed by cooler water inputs from storm events as the storm events continued (clockwise hysteresis). In fall and winter, stream temperatures tended to be cooler earlier in the storm and stream temperatures tended to be warmer due to the input of stormwater (counterclockwise hysteresis). The effect of storm events on the pattern of warming in streams was affected by hydrologic connectivity between streams and groundwater, groundwater saturation, air temperature, and topography.

Pimont, C. (2022). Effects of Contemporary Forest Practices on Stream Nutrients, Temperature, and Periphyton in Small Headwater Streams. (Undergraduate Thesis). Oregon State University

Nicholas, J. (2022) Summer Low Flow Response to Timber Harvest and Riparian Treatments in Forested Headwater Streams of Coastal Northern California. (Master's Thesis). Oregon State University

Miralha, L., C. Segura, K. D. Bladon (2024). Stream temperature responses to forest harvesting with different riparian buffer prescriptions in northern California, USA, Forest Ecology and Management, Volume 552-121581

These studies compared the effects of three riparian thinning treatments on stream characteristics at Tectah, Tarup, Ah Pah and McGarvey Creeks in Humboldt and Del Norte Counties. Treatments were conducted on one side of each class II L designated stream and were implemented to match three silvicultural prescriptions. Prescriptions included the current **ASP** rules with a 30 foot core zone without harvest and a 70 foot inner zone retaining 80% of canopy cover, a treatment consistent with Green Diamond Resource Company's Habitat Conservation Plan (**HCP**) with a 30 foot core zone include 85% of canopy retention and a 70 foot outer zone with 70% canopy retention, and a **Pre-ASP** treatment meant to implement riparian thinning allowed prior to the adoption of the WLPZ rules with a 100 foot buffer from stream with 50% canopy retention required.

Riparian thinning prescriptions were operated by Licensed Timber Operators in 2020. The results only found evidence for a change in basal area during the post-harvest period in the Pre-ASP sites where the median basal area was reduced to 1.8 m2 ha. Both the Pre-ASP and HCP treatments removed a statically significant amount of canopy, but the ASP treatment did not result in a statistically significant reduction in canopy cover (Figure 1). In all treatments, thinning could have been more aggressive and still met the requirements of the Forest Practice Rules. Canopy and basal area measurements were collected within the 70 foot inner zones in all treatments.

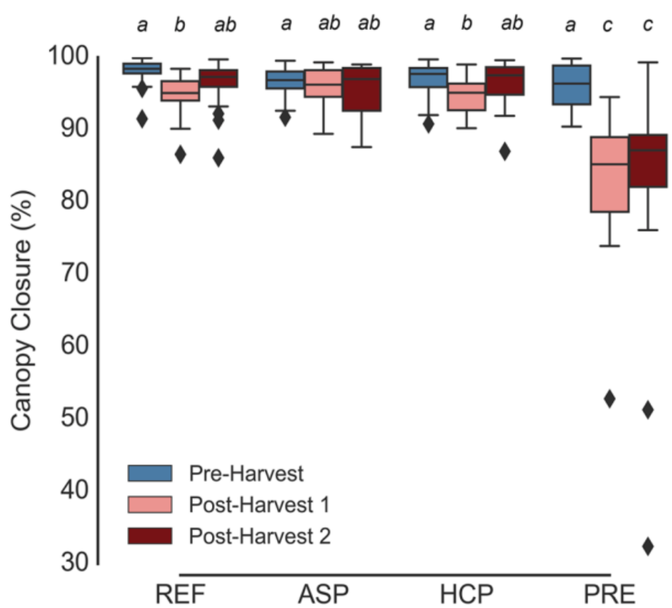

Figure 1 "Box plot of … canopy closure for each of the site types and study time periods. Site types: unharvested reference (REF), Anadromous Salmonid Protection (ASP – 20% of riparian area harvested) prescription, GDRC Habitat Conservation Prescription (HCP – 30% of riparian area harvested), and the pre-ASP prescription (PRE – 50% of riparian area harvested). Distinct letters represent the outcomes of Dunn's post-hoc analysis and indicate statistical differences among groups at a significance level of 0.05. Miralha et al. (2023).

The authors measured several key potential effects of thinning treatments including stream temperature, stream nutrient concentration, daily stream flow fluctuations, and potential evapotranspiration.

Both ASP treatments and HCP treatments effectively limited changes to solar radiation and stream temperature increases. Both warmer temperatures and reduced effective shade were observed in streams in the Pre-ASP treatment. Stream temperatures were more affected by season with the greatest effects of thinning observed during the summer and fall for all treatment types.

A modelling approach was used to compare reference areas and treated areas. Modelled stream temperature results suggested that ASP treatments were not significantly different from unharvested reference sites in the first year after harvest. In the first year after harvest, results indicated that maximum stream temperatures in the HCP treatments were greater than reference treatments in fall (+0.3 C), spring (+ 1.4 C), and summer (+0.5 C). Pre-ASP treatment maximum stream temperatures were greater than reference treatments in fall (+1.6 C), spring (+ 1.3 C), and summer (+0.6 C)(Figure 2). These differences were greatly reduced in the 2nd year post-harvest, and the PRE-ASP treatment in the fall was the only stream temperature that differed significantly from reference site temperature (Figure 2).

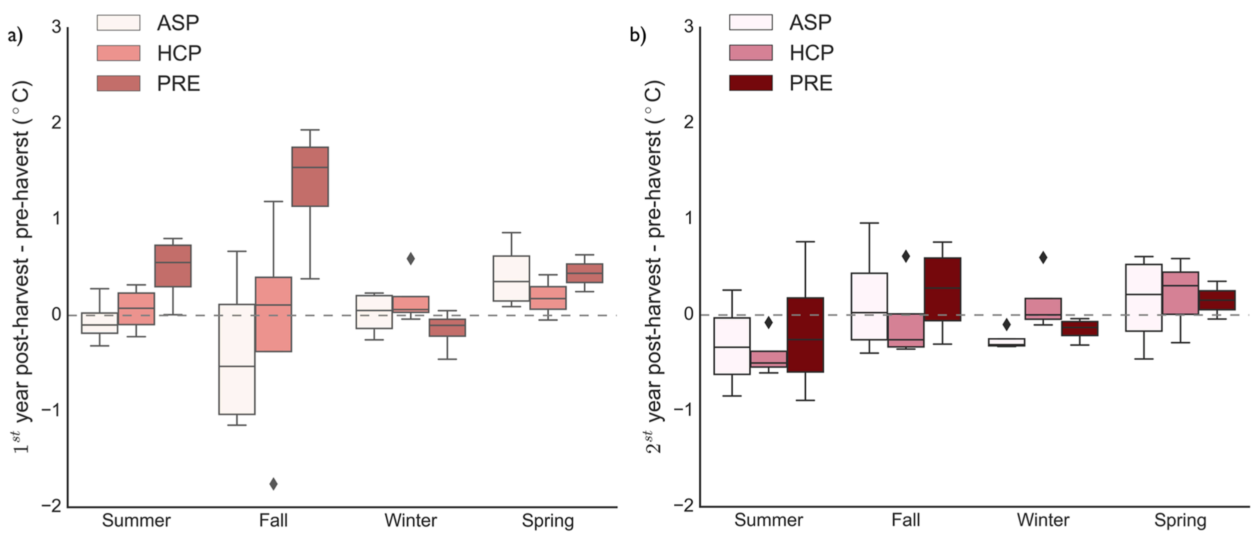

Figure 1. Box plots of (a) the difference in stream temperature (T7-day-max) between the first year after harvesting and the pre-harvest period in the harvested sites relative to the reference sites, and (b) the difference in T7-day-max between the second year after harvesting and the pre-harvest period. Site types: Anadromous Salmonid Protection (ASP – 20% of riparian area harvested) prescription, GDRC Habitat Conservation Prescription (HCP – 30% of riparian area harvested), and the pre-ASP prescription (PRE – 50% of riparian area harvested). Miralha et al. 2022

The authors compared the effects of multiple potential controls on maximum stream temperatures using a random forest analysis. The models were most sensitive to elevation, change in stream stage, and precipitation depending on the season. This analysis did not identify thinning treatment as one of the most important determinants of maximum stream temperature. While stream temperature was influenced by riparian thinning treatments, other factors including elevation had a greater effect on stream temperature in this study.

Thethinning treatments supported multiple student-led studies. In an undergraduate thesis, a student evaluated labile nitrogen and orthophosphate concentrations in water samples as a proxy for nutrient transport after harvest (Pimont 2022). The study did not examine trends due to specific harvest prescriptions, but found that in general, riparian thinning increased nitrate/nitrite concentrations in streams in the first year after harvest. No clear trend in orthophosphate concentrations after harvest were detected.

An additional study leading in part to an MS thesis (Nicholas 2022) tested whether riparian thinning prescriptions resulted in an increase in stream water availability and a change in daily fluctuations in streamflow. This study hypothesized that more intensive treatments would lead to increased streamflow and lower daily fluctuations in water availability as evapotranspiration decreased after harvest. The study found that all treated areas had increased streamflow. However, increases tended to be more correlated with the treatments in the entire catchment area (localized watershed) rather than the intensity of the riparian thinning prescription. Similarly, diel streamflow (the magnitude of daily fluctuations in streamflow due to evapotranspiration) was also strongly affected by the proportion of catchment area harvested. However, the intensity of riparian thinning treatment also affected diel streamflow, with the greatest decrease in diel streamflow in the Pre-ASP treatment and the smallest in the ASP treatment. See Nicholas (2022) for diagrams describing these phenomena.

Part 4. More research needed?

Yes, the current WLPZ rules serve to protect downstream resources from sedimentation and protect critical habitat for CA's aquatic species. These rules provide important habitat protections for federally and state listed anadromous fish and amphibians listed as species of special concern by CDFW. However, similar to upland forests in CA, woody fuels can accumulate in riparian areas and riparian forests also experience a much lower fire return interval today than in the past (Syphard et al 2007). The study provides a very useful template for additional work that tests the effects of light to moderate thinning in riparian forests. Additional funding is not being requested by the PI's to continue these experiments. However, additional work would be needed to determine the effects of thinning in other regions with different hydrologic and biotic conditions.

Additional modelling studies are one potential avenue to help identify key factors in maintaining stream function. Empirical studies at relevant scales, like this study, are expensive and have inherent logistical challenges. Modelling approaches could be used to isolate and vary key factors that are expected to control stream temperature across a broader range of stream and riparian forest conditions.

Challenges in interpreting the study's results for Forest Practice

As stated by the authors in one publication, caution should be applied in using the results of this study to create regulations (Miralha et al. 2024). While the work was rigorous, some challenges in applying the studies' results broadly include the small sample size, narrow geographical range of study, and limited harvesting relative to that currently allowed by the forest practice rules.

- Sample Size- the studies tested the effects of riparian thinning in four watersheds. While the work was well designed, the results determined that multiple aspects of the watershed's underlying hydrology and landscape level variables (such as the proportion of watershed harvested) were key determinants of stream temperature and other stream characteristics. These aspects of harvest prescription are not directly regulated by the WLPZ regulations.

- Geographical Extent – These studies were conducted within the coastal range. Replication at multiple sites and within each watershed gives great confidence in the results. However, the results of these studies have shown great variation in the controlling factors for stream temperature depending on watershed characteristics. It will be critical to evaluate how harvesting in the WLPZ affects stream temperature and chemistry in other forest types and hydrologic conditions. For example, riparian forest in the Sierras may have lower canopy cover and warmer summer and fall temperatures and streams may be more likely to experience increased radiation due to harvest in the WLPZ. At the same time, increased solar radiation may be offset by cooler groundwater inputs, as hypothesized in the Wissler (2022) study (see EMC-2015-001). Collectively, these studies identify important considerations for applying WLPZ thinning in different regions.

- Finally, interpretation of these studies in terms of the Forest Practice Rules may be challenging because the treatments were less intense than are currently allowed by the FPRs. The treatments intended to reduce canopy cover as specified in the rules. However, the final treatments removed much less timber and canopy cover than the rules prescribed. While the studies used the terms ASP, HCP, and pre-ASP, the actual canopy reduction measured post-harvest was 11-35%, and averaged less than what could have occurred under the current rules. In addition, harvest treatments occurred on only one side of each watercourse. For these reasons, the study should be interpreted in terms of the actual canopy reduction achieved, rather than as a blanket test of the effects of the current and past rule packages. Had harvesting treatments reduced more canopy, the resulting effects to the environment could have been greater.

  It is important to note that treatments reflect the judgement of the RPF and how difficult it can be to achieve canopy retention standards. Foresters often operate in a risk adverse space when flagging timber in WLPZ areas and rarely meet retention targets, possibly to avoid the potential for violations. In this study, the Forester's application of a (10-35%) reductions in canopy did not negatively impact the steam in this study. Additional work where one side of the stream is treated closer to Pre-ASP standards would help to determine if 50% canopy retention leads to negative impacts to the stream.

Part 5. Scientific Applications - What is the scientific basis that underlies the rule, numeric target, performance target, or resource objective that the study informs? How much of an incremental gain in understanding do the study results represent?

Even with the challenges in interpretation listed above, this study represents an incredibly valuable test of the Forest Practice Rules and the effects of thinning on riparian function. Prior to these studies, research on the effects of riparian thinning in California was limited and no studies had occurred that test the effects of harvesting since the current WLPZ rules were adopted in 2009. Studies have shown that intense harvesting in the WLPZ can have dramatic impacts on stream qualities such as increased stream temperature, but there has been wide variation in responses (Gravelle and Link 2007, Janisch et al. 2012, Richardson and Beraud 2014).

Even fewer studies have addressed the effects of riparian thinning on the Coast Ranges of Californias diverse Timberlands. Most of our understanding of the effects of riparian thinning come from experiments conducted in timberlands further north in Pacific Northwest. Observations from within the redwood belt have generally examined the effects of intensive riparian thinning, often greater than the 50% canopy retention applied prior to the adoption of the ASP rules. These studies have found that harvesting in riparian forests can increase temperature, subsurface flow, sedimentation, and stream nitrogen concentration (Lewis 1998, Lisle and Napolitano 1998, Hill and McCormick 2004).

The EMC funded studies presented here are a continuation of work in the Tectah watershed by research group's at Oregon State University and Green Diamond Resource Company. Previous work by these collaborators evaluated the effects of a treatment similar to the Pre-ASP treatment (50% canopy cover removal up to the waterline on both sides of a Class I watercourse). This study found that canopy thinning treatments of 50% canopy retention up to the waterline over 200m lengths significantly increased stream temperature and when harvest units were too closely spaced together, propagated downstream (Roon et al 2021 and Roon et al. 2021). Thinning also increased periphyton growth and benthic insect biomass but did not change prey biomass in diets of top fish predators (Roon et al. 2022). The Tectah watershed study also found that riparian thinning led to increased cutthroat trout biomass (+ 27-111%) and density (+8-31%) but did not translate to increased growth (Roon et al. 2022).

Additional EMC funded studies (EMC 2015-001) compared the factors affecting how closely stream temperatures tracked air temperatures while measuring forest conditions, watershed characteristics, and water source (groundwater or surface stormwater runoff) at a Redwood dominant riparian forest and Sierran mixed conifer dominant forest (Wissler 2021). The authors found that stream temperatures responses differ based on site conditions such as elevation and groundwater inputs (Wissler et al. 2022). These results highlight the need to consider site conditions in evaluating the potential effects of riparian thinning.

The results of these studies represent a significant gain in our understanding of the efficacy of the application of the Forest Practice Rules. Few studies have addressed riparian thinning in California and fewer have attempted to test the prescriptions taken directly from the Forest Practice Rules. The current discussion around riparian thinning treatments and the push to reduce fuels in California forests further increase the value of these results to the BOF's work.

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