Evaluating the Ecological Trade-Offs of Riparian Thinning for Headwater Stream Ecosystems in Second-Growth Redwood Forests[1]

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After decades of intensive timber harvest and land use change that removed forests from the landscape, recent satellite data show that forest cover has increased in North America (Liu et al. 2015). However, these regenerating forests differ greatly in structure and composition than the forests that preceded them (McIntyre et al. 2015). This has been especially evident on the Pacific coast, where only 3 to 5 percent of old-growth coast redwood (*Sequoia sempervirens* (D. Don) Endl.) forest remains (Russell 2009). To address this, land managers are actively thinning second-growth forests to restore old-growth conditions (O'Hara et al. 2010, Teraoka and Keyes 2011). Whereas most thinning has taken place in upland forests, thinning also could accelerate recovery in second-growth riparian forests (Keyes and Teraoka 2014).

Riparian forests are highly connected to adjacent streams and rivers (Baxter et al. 2005, Gregory et al. 1991). For example, riparian forests shade stream channels, keeping temperatures cool for cold-water adapted species and contribute leaf litter and terrestrial insects that act as the primary sources of energy for aquatic macroinvertebrates, amphibians, and fish (Baxter et al. 2005, Vannote et al. 1980). Historical timber harvest practices which clearcut riparian forests disrupted these ecological processes, altering in-stream conditions with adverse effects on some sensitive species (Campbell and Doeg 1989). In response, contemporary forest management practices now require buffers to protect riparian forests (Marczak et al. 2010). Though such practices are intended to protect riparian forests, dense growth of young trees and early successional species can become dominant. In these cases, the question of actively managing these forests to more quickly restore late-successional forest structure and composition has been raised (Keyes and Teraoka 2014, Russell 2009).

It has been long understood that riparian forests provide inputs of organic matter that support aquatic species (Vannote et al. 1980); in addition, evidence shows that light is also an important driver of in-stream productivity (Kiffney et al. 2004). Previous studies have documented that increased light associated with opening riparian canopies catalyzed in-stream productivity at multiple trophic levels (Bilby and Bisson 1992, Wilzbach et al. 2005, Wootton 2012). However, this increase in aquatic productivity is often at the expense of increased stream temperature (Beschta and Taylor 1988). This ecological trade-off has caused some to hypothesize that a more subtle change in riparian forest cover, like those associated with thinning, could strike a balance by providing some increased light without substantially increasing stream temperature (Wilzbach et al. 2005).

As streams and the biota they support can be sensitive to terrestrial disturbances (Welsh and Ollivier 1998), it is essential that we understand how streams respond to changing riparian forest conditions (Warren et al. 2016). Therefore, before thinning treatments are applied to second-growth riparian forests it is essential that we understand the effects on headwater stream ecosystems. As a result, we are evaluating the effects of experimental riparian thinning treatments on: 1) canopy cover,

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light, and stream temperature; 2) stream-riparian food webs; and 3) growth and bioenergetics of stream amphibians and fishes. We also examine the extent to which site-level responses to riparian thinning are evident at larger spatial scales, including further downstream and across entire watersheds.

Our study is taking place in three headwater stream networks in second-growth redwood forests of coastal northern California. Two streams, the west and east forks of Tectah Creek, are located on private timber land owned by Green Diamond Resource Company and flow into the lower Klamath River. The third stream, the middle fork of Lost Man Creek, is located in Redwood National Park and flows into Redwood Creek. These streams drain two distinct land ownerships, but proposed riparian thinning treatments on both are motivated by many similar objectives and are conducted under a common set of regulatory requirements.

Riparian thinning treatments are occurring at seven locations distributed across these three watersheds. Riparian thinning treatments consist of a reduction to 50 percent canopy cover over the stream channel along a 100 to 200 m reach. To evaluate the effects of riparian thinning, data are collected following a Before-After-Control-Impact (BACI) study design. Data are collected immediately upstream and downstream of experimental treatment reaches to understand the potential responses in context to local conditions and if those responses extend further downstream. Data are also being collected seasonally to understand how thinning affects streams during different times of year.

In order to evaluate the effects of riparian thinning on streams, first we are measuring how changes in canopy cover and light affect stream temperature. Second, we are determining how the food webs in these streams are currently structured (riparian vs. freshwater pathways of productivity) and how that may change with thinning. To do this, we are collecting macroinvertebrates in the diets of coastal giant salamander and coastal cutthroat trout and using stable isotopes to discern if freshwater or riparian pathways support these food webs. Next we are examining how stream fish and amphibian communities respond to the thermal and trophic responses associated with the thinning treatments by measuring seasonal growth rates. We are also modeling bioenergetics for coastal cutthroat trout using the combined temperature and diet data. Finally, a food web systems dynamics model will assemble the composite abiotic and biotic data to provide a comprehensive perspective of how these streams are responding to riparian thinning.

As riparian forest conditions continue to change, it is likely that freshwater ecosystems will be affected (Warren et al. 2016). Our studies focus on the potential changes in thermal and trophic conditions that are most likely to interact in supporting important aquatic species that inhabit headwater stream ecosystems. By combining empirical data collection with contemporary approaches in spatial stream network, food web, and bioenergetics modeling, we hope to provide a more comprehensive understanding of how these stream ecosystems are responding to riparian thinning. We hope that data collected by this study will not only address existing knowledge gaps, providing crucial information for multiple stakeholders, but will also help inform future riparian forest management in redwood ecosystems.

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