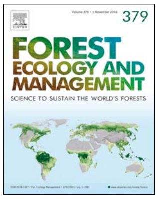
Forest Ecology and Management 411 (2018) 142–157

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco



Fish response to contemporary timber harvest practices in a second-growth forest from the central Coast Range of Oregon

D.S. Bateman[a,*], R.E. Gresswell[b], D. Warren[c], D.P. Hockman-Wert[d], D.W. Leer[a], J.T. Light[e], J.D. Stednick[a,f]

[a] Department of Forest Engineering, Resources and Management, College of Forestry, 210A Snell Hall, Oregon State University, Corvallis, OR 97331, USA
[b] U.S. Geological Survey, Northern Rocky Mountain Science Center, 2327 University Way, Suite 2, Bozeman, MT 59715, USA
[c] Department of Forest Ecosystems and Society, College of Forestry, 321 Richardson Hall, Oregon State University, Corvallis, OR 97331, USA
[d] U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, 3200 SW Jefferson Way, Corvallis, OR 97331, USA
[e] Plum Creek, Philomath, OR 97370, USA
[f] Watershed Science Program, Colorado State University, Fort Collins, CO 80523, USA

ARTICLE INFO

Keywords:
Logging
Coastal cutthroat trout
Oncorhynchus clarkii clarkii
Movement
Growth
Size
Stream habitat
Pit-tags
Coast Range
Paired-watershed
Abundance
Fish condition
Coho
Oncorhynchus kisutch
Water temperature
Nutrients
Shrub cover
Canopy cover
And low-flow discharge

ABSTRACT

We used a paired-watershed approach to investigate the effects of contemporary logging practices on headwater populations of coastal cutthroat trout (*Oncorhynchus clarkii clarkii*) and juvenile coho salmon (*Oncorhynchus kisutch*) in a second-growth Douglas-fir forested catchment in Oregon. Stream habitat and fish population characteristics, including biomass, abundance, growth, size, and movement, were assessed over a 9-year period (4 years pre- and 5 years postlogging). The logged catchment was located on private industrial forestland and had been previously logged in 1966. The reference catchment was covered by an unharvested, fire-regenerated forest approximately 150–160 years old, which was unroaded and managed as a Research Natural Area by the USDA Forest Service. A single clearcut harvest unit of the upper 40% of the treatment catchment was implemented following current forest practice regulations, including the retention of riparian buffer of standing trees adjacent to fish bearing channels. No statistically significant negative effects on coastal cutthroat trout or coho salmon occurred following logging, and in fact, both late-summer density and total biomass of age-1+ coastal cutthroat trout increased in the logged catchment following logging. Increases in age-1+ coastal cutthroat were greatest closest to the harvest area and declined downstream as distance from the logged area increased. In contrast to the previous timber harvest in the catchment when few logging regulations existed, current forest practice regulations and logging techniques appear to have reduced acute negative effects on coastal cutthroat trout.

1. Introduction

Response of aquatic systems to disturbance (e.g. fire, flood, and timber harvest) is context dependent (Resh et al., 1988; Detenbeck et al., 1992; Gresswell, 1999). Strong linkages between terrestrial and aquatic systems result in a complex pattern of effects related to the interaction among physical, chemical, and biological characteristics of these systems (Gregory et al., 1991), and effects are often propagated downstream (Hicks et al., 1991; Gomi et al., 2002; Richardson and Danehy, 2007). Prior conditions of the system interact with the type, timing, and intensity of the disturbance to alter the system at a variety of spatial scales, and biota respond to these changes (Hartman and Scrivener, 1990; Andrew and Wulder, 2011). For example, the effects of timber harvest are contingent on the bedrock geology and geomorphic characteristics of the system, the stand age, and the methods used to harvest the timber (Hartman et al., 1987; Mellina and Hinch, 2009; Valdal and Quinn, 2010).

Effects of timber harvest on previously unharvested forests have been studied for decades (Murphy and Hall, 1981; Duncan and Brusven, 1985; Bilby and Bisson, 1987). Although biotic responses vary, effects can have substantial negative consequences for aquatic habitat and vertebrates (Hartman et al., 1987; Reeves et al., 1993; Mellina and Hinch, 2009). In some cases, effects related to changes (both negative and positive) in light flux may be apparent at various points in time

---

[*] Corresponding author.
E-mail address: doug.bateman@oregonstate.edu (D.S. Bateman).

https://doi.org/10.1016/j.foreco.2018.01.030
Received 13 October 2017; Received in revised form 17 January 2018; Accepted 19 January 2018

(Kaylor and Warren, 2017; Connolly and Hall, 1999); however, persistent alterations are often related to the construction of roads and methods used to yard timber (Trombulak and Frissell, 2000; Valdal and Quinn, 2010; Richardson et al., 2012). Indeed, harvests that occurred in the first half of the 20th century included the use of small stream channels as roadbeds and movement corridors for yarding timber (Richardson et al., 2012).

Prior research played an important role in the development of forest management regulations that were intended to safeguard aquatic resources while facilitating timber harvest (Tschaplinski et al., 2004; Stednick, 2008a). Contemporary forest practices have advanced considerably in recent decades (Richardson et al., 2012). Currently timber harvest occurs primarily on private industrial timberlands and has shifted from harvesting old growth or naturally-regenerated mature timber, to logging previously-harvested stands on shorter stand rotation intervals, using pre-existing road networks (Bateman et al., 2016). All of these activities occur in concordance with forest practice regulations (e.g., Oregon Department of Forestry, 2006) developed in response to prior research (Ice et al., 2010; Richardson et al., 2012), and regulations generally require standing tree riparian buffers when timber harvest is adjacent to streams where fish are present (Lee et al., 2004).

Effects of harvest in second-growth forests on fish are not as well-documented (De Groot et al., 2007), but there is some evidence that many of the negative consequences reported with the harvest of previously unharvested forests have not occurred during subsequent logging activities (Mellina and Hinch, 2009). In fact, in some cases the removal of thick closed-canopy, young- to middle-aged forests can increase aquatic productivity by increasing light availability to the stream benthos (Ambrose et al., 2004), and if water temperatures do not exceed recognized optimums, growth and total biomass of stream-dwelling salmonids may increase (Murphy and Hall, 1981; Connolly and Hall, 1999; Wilzbach et al., 2005). Although conceptual models suggest changing trends in fish abundance and forest stand development through time (Warren et al., 2016), the long-term effects of second-growth timber harvests (with standing tree riparian buffers) on persistence of salmonid populations has not been investigated with empirical field studies.

Whether muted responses of aquatic systems to timber harvest of second-growth forests is the result of improved management practices or related to diminished system capacity or some combination of the two is not well understood. For example, the installation of infrastructure (e.g., roads and landings) associated with removal and transport of downed trees often caused press disturbances (Lake, 2000) that persisted long after the harvest of primeval forests (Sedell et al., 1991). Because additional roads and infrastructure development are frequently unnecessary during second-growth harvest, physical alterations of the watershed associated with erosion and subsequent streambed sedimentation may not occur, or may be substantially reduced during these secondary perturbations (Bateman et al., 2016). Furthermore, research focused on reducing the negative consequences of logging have resulted in substantial changes in forest-harvest practices, and contemporary forest practices are intended to reduce the negative effects of harvest. Alternatively, it has been argued that effects on physical and biotic components of some systems following old-growth timber harvest persist. Because these second-growth systems have never fully recovered, they no longer have the capacity to respond to disturbance associated with timber harvest (sensu Frissell et al., 1997).

Second-growth forests now being subjected to harvest (50–60 years of regrowth) provide the opportunity to investigate the effects of logging on fish populations in adjacent channels (De Groot et al., 2007) or in channels downstream of harvest (Bateman et al., 2016). These recent studies provided examples that stream adjacent logging could occur without negatively affecting fish abundance when bank and streambed disturbance was avoided and large wood was left in the channel; however; capacity of these systems prior to logging was unknown.

Plans to commercially harvest portions of the Alsea watershed in the Coast Range of western Oregon provided a unique opportunity to revisit an area where a paired-watershed study conducted in the 1950s–1960s documented the influence of the harvest of mature forests on headwater watersheds and the populations of coastal cutthroat trout and coho salmon in those systems (Stednick, 2008a). This seminal study was a primary impetus for changes in forest practices throughout the Pacific Northwest. We took advantage of this opportunity to revisit the Alsea Watershed Study during timber harvest of second-growth coniferous forest using contemporary forest practices, including standing tree buffers in the fish bearing portions of the logged catchment. Our goal was to document the effects of the harvest on stream physical habitat and stream salmonids using the paired-watershed approach and to compare these effects to those documented in the original Alsea Paired Watershed Study (Moring and Lantz, 1975, Hall and Stednick, 2008).

Examining the effects of contemporary forest harvest in paired catchments of the Alsea River watershed allows us to place current research in an important historical context because the Alsea Watershed Study, initiated in 1959, also used this approach and provides some indication of the pre-harvest capacity of Needle Branch. Given documented sensitivity to historic forest management, this system was ideal for evaluating the response of fish populations to harvest of second-growth forest under contemporary regulations. Although replication would be required to assess the influence the relative proportion of response related to diminished capacity or improved logging practices, Needle Branch provides a unique opportunity to observe the response of a previously harvested system to a subsequent harvest after water quality and fish abundance parameters have returned pre-logging conditions. Furthermore, an evaluation of fish response to upslope clearcut logging in the presence of a standing tree buffer has not been conducted in the Pacific Northwest since the Alsea Watershed Study, but recent studies evaluating effects of contemporary logging practices on fish under a range of logging treatments (De Groot et al., 2007; Olson et al., 2013; Bateman et al., 2016) have not documented negative effects on headwater fish populations. We hypothesized that in the presence of a standing tree buffer and contemporary upslope clearcut logging, effects in parameters commonly used to evaluate the status of fish populations and habitat quality would not be biologically significant.

2. Methods

2.1. Study location and background

Needle Branch and Flynn Creek are small headwater catchments (85 and 212 ha respectively) that flow into Drift Creek, approximately 16 km inland from the Pacific Ocean in the Alsea River watershed of the Oregon Coast Range (Fig. 1). Elevations range from 140 to 590 m (Hall and Stednick, 2008). The maritime climate is characterized by mild wet winters and dry summers. Most of the annual precipitation (mean = 250 cm) occurs as rain falling between October and March (Hall and Stednick, 2008). Bedrock is primarily sandstone of the Tyee formation (Corliss and Dyrness, 1965). Douglas-fir (*Pseudotsuga menziesii*) in plantation and fire-regenerated forests dominates Needle Branch and Flynn Creek, and red alder (*Alnus rubra*) is common in riparian areas (Moring and Lantz, 1975). Salmonberry (*Rubus spectabilis*), skunk cabbage (*Lysichitum americanum*), sword fern (*Polystichum munitum*), and vine maple (*Acer circinatum*) are common in the understory (Moring and Lantz, 1975). Coastal cutthroat trout, coho salmon, reticulate sculpin (*Cottus perplexus*), western brook lamprey (*Lampetra richardsoni*), and Pacific lamprey (*L. tridentata*) comprise the fish community (Hall and Stednick, 2008). Steelhead trout (*Oncorhynchus mykiss irideus)* are occasionally collected in the study catchments. Additional vertebrates found in the study catchments include the coastal giant salamander (*Dicamptodon tenebrosus*) and the coastal tailed frog (*Ascaphus truei*).