Forestry-Fish Interactions:

A Literature Review to Guide Better Management of Westslope Cutthroat Trout in British Columbia

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Introduction

This report summarizes literature relating to forestry-fish interactions and provides insight into meaningful management options for the continued success of native Westlope Cutthroat Trout (WCT) in British Columbia. Forestry is the most important economic sector in British Columbia, accounting for close to 60,000 jobs province wide, and close 20 billion in revenue (NRC, 2018). Forestry activities can impact trout habitat by disrupting the balance of sediment input and removal (Sullivan et al, 1986), altering stream temperatures (Beschta et al, 1986), and increasing the amount of erosion into stream channels (Gregory et al, 1987). The landscapes and communities of terrestrial and aquatic ecosystems are intricately linked, and forestry practices alter those links (Gregory et al, 1987); however, the physical changes that occur as a result of logging activity are highly variable and show a high degree of spatial and temporal complexity (Hartman et al, 1987). Understanding the “big picture” of ecological relationships as well as the specific habitats and life strategies of trout is important to direct meaningful restoration of streams effected by forestry (Hunter, 1991).

In general, trout require cool, well oxygenated water, a clean gravel substrate, and abundant cover and shade (Toews and Brownee, 1981). They have specific requirements for spawning, rearing, and for migration, while also requiring an abundance of terrestrial and aquatic invertebrates for food (Toews and Brownee, 1981). Despite being able to withstand severe and variable environmental conditions, these specific requirements make salmonids very sensitive to the environmental changes associated with timber harvesting (Toews and Brownee, 1981). However, there is research to suggest that while overall impacts of forestry are resoundingly negative for salmonids, some populations, species, and age classes may benefit from timber harvest and increased temperatures (Gregory et al, 1987; Hartman et all 1987: MacDonald et al, 2014).

Our current foundation for understanding forestry-fish interactions came from several studies undertaken from 1960 through the 1980’s. Studies from Carnation Creek (Hartman et al, 1987), the Clearwater River (Cederholm and Reid, 1987), and the Alsea river (Hall et al, 1987) were some of the first long-term studies and were critical in helping quantify the effects of forestry activities; these case studies will be referenced throughout the report. Because these sources do not focus directly on WCT, their results are intended to highlight the processes in which forestry activity affects streams to compliment the results from more recent, regionally relevant studies specific to WCT.

One such study that will be discussed was undertaken in 2010 on tributaries of the upper Kootenay River by Valdal and Quinn. They found road density, in particular roads built within 100 m of streams, had the most significant relationship to trout abundance, offering insight into the cumulative effects of small-scale habitat degradation (Valdal et al, 2010). These results are consistent with those found in early studies (Hall et al, 1987; Cederholm and Reid, 1987; Huntington, 1998).

The frequency of pools is considered a limiting factor for WCT, due to their important role in providing overwintering habitat (COSEWIC, 2005; MacDonald et al, 2014), and their importance for growth and bio-energetic efficiency (Rosenfield and Boss, 2001). Studies have shown that coarse woody debris plays a critical role in pool formation, and that pool density decreases with logging activity (Huntington, 1998). The results of a study by V.A Poulin in 1991 provides evidence that restoration measure s to promote pool formation by placing LWD within the streambed can be very effective. In the study, they found an increase in pools in all reaches treated with LWD, proving restoration of compromised stream reaches is viable (Poulin, 1991).

Taken together, the sources analyzed in this report should provide readers with an understanding of how critical habitat parameters of WCT are impacted by forestry, and what measures are available regionally to ensure environmental and economic prosperity for both WCT and the forest industry well into the future.

Impacts of forestry: Early Studies

A. Sedimentation

James Hall studied logging related changes on the Alsea River from 1958-1973 and found that suspended sediment increased fivefold over expected values in a clearcut watershed, before returning to near normal values in the fourth year (1987). He found the effects in a patch-cut area to be small, and road failure was the primary cause of increased sediment (Hall et al, 1987). This supports the claim made by Fred Everest in his discussion of sedimentation, where he concluded that the impact of sedimentation due to harvesting is far more variable than and not nearly as significant as the impacts of sedimentation from roads; in both cases, impacts appear to be mostly limited to the short term, while roads are in use by logging trucks (1987).

The relationship between sediment transport and subsequent deposition is summarized nicely by Everest, where he stated “there seems to be a broad middle ground between too much and too little sediment in salmonid habitats” (1987). Sediment is required and increases productivity of streams (Everest et al, 1987); too much fine sediment, however, was shown to reduce the survival rate of eggs and emergent fry in salmonid species in Cederholm and Reid’s study on the Clearwater from 1972-1987.

Other results of Cederholm and Reid's study concluded that sediments cause stress to juveniles during summer, and that aggradation of coarse sediments causes loss of rearing habitats (1987). Despite evidence of negative effects from too much sediment, Everest concludes that sediment is not likely a limiting factor for trout other than in extreme cases, as trout have several ways to reduce the effects on their reproductive success (1987), and the results from Hall's study suggests impacts of sedimentation from harvest are temporary (1987). In particular, species with long or permanent freshwater residence times (like WCT) are less likely to be limited by reduced spawning success, but are more vulnerable to processes that cause changes to channel morphology and rearing habitat (Everest et al, 1987).

B. Increased Stream temperatures

In G. Hartman's study on Carnation Creek that took place between 1971 and 1984, results found that average summer temperatures increased from the average pre-logging temperatures by 29.3 % (Hartman et al, 1987). Winter temperatures increased by 39.3 % of the prelogging average (Hartman et al, 1987). The Alsea watershed study observed large changes in stream temperature on the clearcut watershed, while no changes were observed in the patch-cut watershed (Hall et al, 1987). The temperature regime on the clearcut watershed returned to near pre-logging values seven years following logging (Hall et al, 1987).

Surprisingly, Cutthroat Trout seemed to benefit from these changes in the Carnation Creek Study, as Cutthroat trout lengths were found to increase from 1972-85, likely due to earlier emergence of fry caused by warmer spring temperatures (Hartman et al, 1987). Moreover, smolt counts in Cutthroat showed no clear pattern of change during or after the period of forest harvest (Hartman et al, 1987). Recently, more evidence to suggest that Cutthroat Trout may benefit from warming thermal regimes was provided in a study by R. MacDonald in 2014. He concluded that altered thermal regimes due to climate change benefit WCT because of earlier fry emergence and thus increased survivorship (MacDonald et al, 2014). However, contrary to the results on Carnation Creek, this study found climate warming was only found to be significant in the summer, whereas winter, fall, and spring temperatures declined due to earlier onset of spring freshet (MacDonald et al, 2014). If the observed trend of cooling winter temperatures continues, MacDonald concludes it may limit the amount of overwinter habitat (pools) available to WCT, and thus limit the carrying capacity of the population (2014).

C. Increased Erosion and Changes to Stream Morphology

Surface erosion and physical changes to habitat following forestry was most extensively studied by Cederholm and Reid in their study of the Clearwater River published in 1987. They found the most significant sediment sources are road-related landslides and road-surface erosion (Cederholm and Reid, 1987). They found that 84 % of road-surface sediment was produced from 6 % of the road length, and that it was most strongly dependent on the intensity of road use (Cederholm and Reid, 1987). They also found that 95 % of landslides occurred on the steepest 10% of roads (35 degrees or more), and the likelihood of a landslide was 10 times greater two years after road construction than it was 10 years later (Cederholm and Reid, 1987). The aggradation of these road materials can result in a decrease in habitat, due to infilling of pools (Cederholm and Reid, 1987).

This was quantified in a study by C.W Huntington in Idaho where he compared pool frequency on roaded and unroaded reaches of streams; he found higher pools frequencies on unroaded reaches in all stream classes; the results were most significant on moderately steep (1.5-4% slope) and steep (4-10% slope) stream classes (1998). Other studies that support the loss of pool habitat due to increased erosion are eluded to by P. Anderson in his report from the Forest-Fish conference in 1996; he references studies that show a decrease in pool depth and frequency (Klein, 1984), and a decrease in fish holding capacity due to forestry related erosion (Bjornn et al, 1977).

Forestry Related Disturbance on Westslope Cutthroat Trout in the Kootenays

While the impacts discussed in the previous section provides the general mechanisms in which forestry impacts trout habitat, more regionally relevant and species-specific studies can help guide better management options specific to our own populations of WCT.

A study done in 2010 by Valdal and Quinn took place on 5 tributaries of the upper Kootenay River that have been influenced by logging. They measured trout abundance and compared that data to 12 variables, some environmental and some related to forestry, to see what variables statistically correlated to decreased trout abundance (Valdal and Quinn, 2010). Their results confirm the hypotheses formed from earlier studies; the impacts from road construction are far more significant than the impacts from actual harvesting of timber (Valdal and Quinn, 2010). They found significant ($p < 0.05$) correlative relationships for six variables (Valdal and Quinn, 2010). From strongest to weakest, those variables were: 1) amount of roads on erodible soils within 100 m of stream, 2) roads within 100 m of stream, 3) amount of logging on fish bearing streams since 1960, 4) road density, 5) recent logging on fish bearing streams, 6) roads on erodible soils (Valdal et al, 2010).

The results of this study offer a unique perspective due to its blocked design that treated each watershed as a discreet unit (Valdal et al, 2010) This isolated variables that correlated across all of the watersheds despite them all having different characteristics (geomorphology, elevation, gradient, logging history), that could effect local WCT populations (Valdal and Quinn, 2010).

Perhaps as interesting as the correlative variables are the variables that showed no correlation. This included equivalent clear-cut area, and total disturbance from both logging and wildfire (Valdal and Quinn, 2010). This supports the belief of many that the impacts to fish habitats were more closely related to variation in surficial geology and soils than to measures of industrial activity (Valdal and Quinn, 2010), and provides evidence that cutthroat are quite resilient to disturbance, whether from harvest or wildfire, so long as their habitat for spawning, rearing, and overwintering remain intact (Valdal and Quinn, 2010; Hall et al, 1987;Gregory et al, 1987).

The study was able to produce a regression model for trout abundance based on two of the variables; roads within 100 m of stream, and recently logged streams (Valdal and Quinn, 2010). This model accurately predicted trout abundance across all five watersheds (Valdal and Quinn, 2010), and application of this model to other watershed could be useful to limit further impact of these factors and identify compromised stream reaches.

Key conclusions from Valdal and Quinn's work are that road systems, as well as the spatial arrangement of road systems (roads within 100 m of streams) significantly effect the assemblages of WCT (2010). The significance of logging on all streams (including non-fish bearing stream) versus the non-significance of logging on fish bearing streams provides evidence that logging of non-fish bearing streams contributes to the degradation of trout habitat over time (Valdal and Quinn, 2010).

Meaningful Restoration

Throughout the report, the importance of pool habitat for WCT (MacDonald et al, 2014; Huntington, 1998; Valdal and Quinn, 2010) has been eluded to. It's significance as a limiting factor means that WCT populations within a watershed can only be as abundant as the pools that they rely on to survive winter are (COSEWIC, 2005).

Pools are substantially important for overwintering, however, they also play an important role in growth of juveniles and adults (Rosenfield and Boss, 2001). A study by Rosenfield and Boss on Hudson Creek in BC analyzed the bioenergetic efficiency of pool and riffle habitats for YOY (young-of-year) and one to two year old cutthroat trout; they found that cutthroat trout, on average, consistently gained weight in pools, but consistently lost weight in riffles, indicating that they are a habitat requirement for larger trout (2001). YOY trout preferred pool habitat, but due to their small size and energetic needs are able to exploit riffle habitats not available to larger fish (Rosenberg and Ross, 2001). Fish must grow to be able to reproduce; larger fish produce more eggs, increasing reproductive rates; they can travel further to find suitable habitat or to spawn; and can pass barriers that smaller fish are unable to pass (Toews and Brownee, 1981; Hunter 1991). These findings further support the need of pool habitat not only for overwintering but for growth and reproductive success (Rosenberg and Ross, 2001).

Pool formation is critically linked to the amount of large woody debris in the stream course, and, through logging of timber on non-fish bearing streams, salvage logging, erosion, removal of LWD during peak flows, and other mechanisms, the balance of inputs and outputs of LWD have been altered (Mellina and Hinch, 2009). The removal of LWD (which creates pools), along with the infilling of pools by sediment (Cederholm and Reid, 1987) has likely led to dramatic decreases in pool habitat for WCT, thus, limiting their abundance.

Restoration activities that encourage pool formation by adding LWD have proven to be successful (Poulin, 1991), and offer an opportunity to make meaningful habitat upgrades. V.A Poulin's land management report for the BC ministry in 1991 provided a compelling argument for these sorts of treatments. Treatments made to sites included placement of single and multiple log structures and creation of off-channel pools; average costs of LWD structures were $341 (Poulin, 1991). In Poulin's study, they found that trout habitat increased substantially in all sites treated with LWD through increases in pool area, the number of pools, average pool depth and stream cover. Almost every other parameter of trout habitat improved as well; more well-defined pool-riffle sequences, more depth variability, and more gravel storage sites, and more sediment variability due to sorting at LWD structures (Poulin, 1991). Juvenile trout response to LWD was also positive, with significant density increases compared to the control site at three of four creeks, while one of the creeks showed variable results (Poulin, 1991).

Conclusion

The effects of forestry includes changes to sedimentation, stream temperatures, and changes to stream morphology including loss of pool habitat (Everest et al, 1987; Hall et al, 1987; Mellina and Hinch, 2009); however, in all literature reviewed, it was determined that roads associated with forestry are the primary source of habitat degradation and not forest removal (Hall et al, 1987; Cederholm and Reid, 1987; Valdal and Quinn, 2010). Valdal and Quinn's study of the upper Kootenay identified two variables that can be used to model WCT abundance: roads within 100 m of stream, and recent logging (2010). Application of this model can help guide better regulatory for stream protection by enforcing measures to better manage their cumulative effects. Better management of road systems and road design should be complimented by restoration efforts in compromised streams that include placement of LWD into the stream channel; this treatment is a proven method to improve trout abundance (Poulin, 1991), and could offer immediate benefit to WCT as the province works towards implementation of better road building practices. The summary of sources provides evidence that WCT can prosper in areas of heavy forestry activity, so long as their habitat remains intact (Mellina and Hinch, 2009; Everest et al, 1987; Toews and Brownee, 1981).

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