Report as of FY2007 for 2006MT92B: "Impacts of beaver on invasion ecology of brook trout (Salvelinus fontinalis)"

Publications

Project 2006MT92B has resulted in no reported publications as of FY2007.

Report Follows

Title: Impacts of beaver on invasion ecology of brook trout (*Salvelinus fontinalis*)

Water Resources Research Program – Interim Report

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Abstract:

As a keystone species, beaver promote the creation and maintenance of wetland areas, provide complex habitat for wildlife and fish, improve water quality, and augment late season flows. Beaver ponds create excellent juvenile rearing and overwintering fish habitat resulting in substantial benefits to native fish species. Promoting beaver through either natural population expansion or active transplantation for watershed restoration purposes is gaining favor with some landowners and managers, but is a very controversial strategy. Aside from direct human-beaver conflicts such as flooding of agricultural lands and damming of irrigation systems, there is also the possibility of negative effects on native fish such as, barrier creation and the potential of beaver ponds to facilitate invasion by exotic fish species. In Montanan streams, brook trout are an exotic species whose invasion often displaces native cutthroat trout through competitive interactions. Even though many of Montana's native species often benefit from beaver ponds, it has also been suggested that the more pool-adapted and temperature tolerant brook trout have a competitive edge in beaver ponds over more riffle-adapted colder water species. Use of these habitats as "source" populations may then enable their colonization of colder "sink" habitats, thus sustaining invasions across a larger range. Beaver ponds may therefore (i) be detrimental to natives through the creation of warmer, pool habitat that gives brook trout a competitive advantage, or (ii) act as a buffer, facilitating coexistence of both species by adding habitat size and complexity. Analyses of data collected in the summer and autumn of 2006 show that beaver do have observable effects on stream temperature regimes, and that distributions and growth rates of brook trout and westlope cutthroat could be tied to this habitat modification. Completion of fieldwork, scheduled for summer 2007, will allow definitive conclusions regarding the influence of beaver disturbance on brook trout invasions and the implications for westslope cutthroat trout.

Introduction

Beaver (*Castor canadensis*) play a keystone role on the landscape, driving a significant watershed disturbance regime through their feeding and damming behaviors. Their impoundments create lentic habitat in otherwise lotic systems, leading to fundamental changes in channel geomorphology, hydrology and nutrient cycling. Consequently, beaver have been shown to promote changes in succession dynamics, increase biotic productivity, and enhance diversity of floral and faunal assemblages[3-7]. Increases in water storage capacity through beaver impoundments improve riparian habitat, and potentially augment water supply and late season flows[8]. These aspects of beaver impoundments have resulted in the active transplantation of beaver as restoration tools into degraded wetlands of the Pacific northwest[9]. This restoration strategy is of increasing interest to landowners and managers in Montana, especially in light of prolonged drought conditions. For example the Big Hole Watershed Committee (BHWC), a group that acts as a liaison between land management agencies and the public, is currently evaluating proposals to remedy water shortage problems in the upper Big Hole River watershed of western Montana. This area, like much of the western U.S., is experiencing an extended drought period linked to gradual climatic change, exacerbated by a shift to more water intensive land-use practices. Transplantation of beaver into tributary streams of the Big Hole River was one considered by the BHWC as an alternative approach to increasing landscape water storage through human dam construction[10].

Promoting beaver on the landscape, either through natural population expansion or active transplantation of beaver, is a controversial strategy. Aside from direct human-beaver conflicts such as timber damage, flooding of agricultural, grazing, and developed lands, and damming of culverts and irrigation systems[3], there is also the possibility of negative effects on native fish species, such as barrier creation and warming of coldwater streams[11]. Relatively little is known about the effects of beaver impoundments on stream fish assemblages in North America. Fish community shifts have been demonstrated to be highly variable among and within regions, affected by beaver pond age, position in the watershed, and dependent on the original (pre-beaver) conditions and species present[3, 12]. The patterns and mechanisms behind how beaver may influence fish community structure, abundance and distribution is a contested issue in the western U.S. and in Montana in particular. The formation of pool habitat may increase water temperatures, prey availability to fish, and juvenile rearing habitat for species such as Atlantic salmon (*Salmo salar*) and brook trout (*Salvelinus fontinalis*)[13], as well as providing important winter habitat for many stream fishes including cutthroat trout (*Oncorhynchus clarki*) and bull trout (*Salvelinus confluentus*)[14].

In mountain streams of western North America brook trout are an exotic species, and their invasion of pristine ecosystems often results in displacement of native cutthroat trout through age-specific biotic interactions that reduce juvenile cutthroat trout survival[15]. Thus, understanding both what limits the spread of the distribution of brook trout within a system and what factors influence the outcome of cutthroat and brook trout species interactions is critical for the conservation and management of cutthroat trout in mountain ecosystems of the western U.S. Gradual upstream declines in growth rates associated with declining water temperatures may explain the upstream limit for brook trout in some mountain stream systems[16]. Any factors that affect demographic parameters such as growth rates, age-0 recruitment, and dispersal can influence the spread of an exotic species[17]. Furthermore, it has been posited that brook trout, which are more pool adapted and temperature tolerant, may have an advantage in beaver ponds, and can use these habitats as “source” populations, enabling them to colonize colder “sink” sections of the stream, thus sustaining invasions across a larger range[15]. In addition, beaver ponds may alter the outcome of species interactions between westslope cutthroat and brook trout. If beaver ponds provide habitat that preferentially increases abundances of brook trout in a stream, then their impact on westslope cutthroat may be larger. Also, elevation of stream temperature has been implicated in an increased ability of brook trout to outcompete westslope cutthroat trout, with research suggesting enhanced brook trout competitive ability between 13°C and 17°C[2]. Therefore, if beaver ponds increase overall stream temperatures, brook trout may have a greater competitive advantage over cutthroat trout.

The presence of beaver on the landscape is a controversial issue. Our discussions with various federal and state fisheries biologists in Montana reveal that different managers, often working in the same drainages often have polarized views on the subject. This sometimes culminates in some managers transplanting beaver into watersheds as restoration tools, whilst others remove them as a nuisance species. Management efforts to improve landscape water retention must work in synchrony with efforts to curtail brook trout spread and maintain native cutthroat trout populations. To be effective, such efforts should be based on a sound scientific understanding of the ecological mechanisms operating within the system. It is therefore imperative that we enhance our knowledge as to how beaver activity influences processes related to exotic species invasion in western Montana.

Objectives of the project

The objective of this research is to (1) evaluate potential causal mechanisms associated with beaver facilitation of brook trout invasions in pristine mountain ecosystems, and (2) assess potential consequences of this relationship on cutthroat trout populations. The three main themes of this research, and the predictions associated with each, are:

(i) *The influence of beaver activity on stream temperatures*: We predict that beaver impoundments will increase temperatures in the created pool as well as downstream of the impoundment, thus affecting a large portion of the watershed's thermal regime.

(ii) *The influence of beaver activity on exotic and native salmonid species distribution and abundance*: This theme includes multiple predictions (Table 1).

(iii) *The influence of beaver activity on exotic/native species interactions*: This theme includes multiple predictions (Table 2).

Table 1. *Predictions* associated with our ***hypotheses*** regarding how streams with beaver ponds may affect brook trout (BT) spread compared with non-beaver control streams.

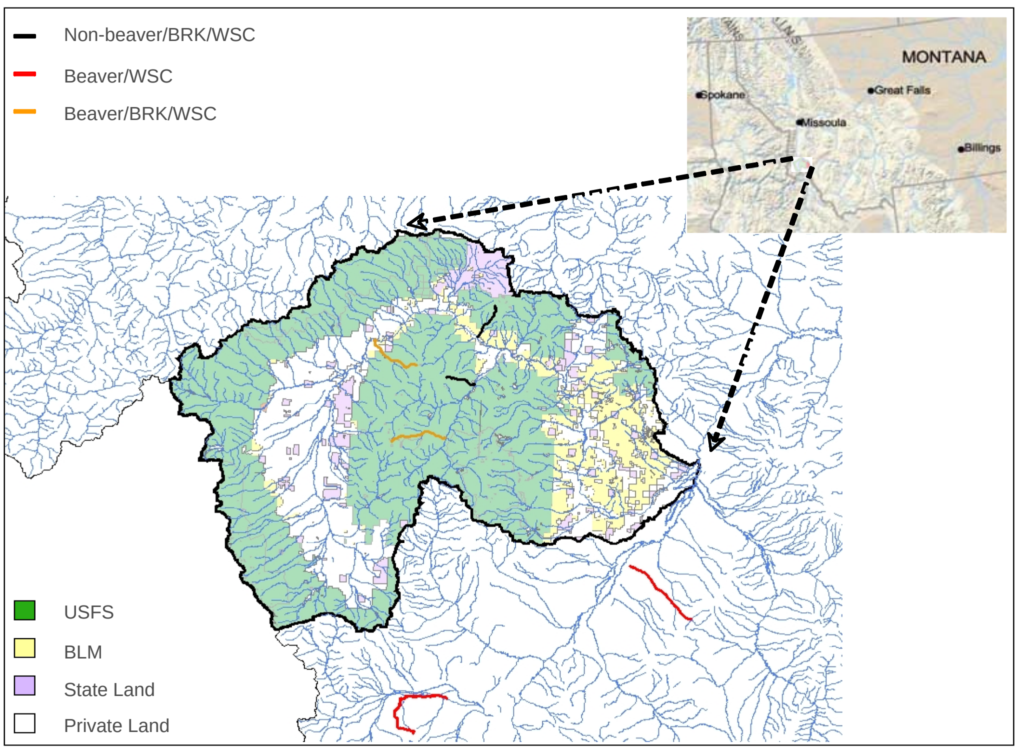
RESPONSE VARIABLES	***Streams with beaver ponds compared with non-beaver controls***		
	Facilitate brook trout spread	***Reduced brook trout spread***	***Have no effect on brook trout spread***
Distribution of BT	*↑BT distribution, especially at higher elevations above ponds*	*↓BT distribution with elevation*	*No difference in distribution*
Abundance	*↑BT in beaver streams*	*↓BT in beaver streams than control streams*	*No difference in BT abundance*

Table 2. *Predictions* associated with our ***hypotheses*** regarding how streams with beaver ponds may influence the outcome of species interactions between brook trout (BT) and westslope cutthroat trout (WSC) compared with non-beaver control streams.

RESPONSE VARIABLES	***Streams with beaver ponds compared with non-beaver controls***		
	Enhance negative interactions	***Buffer negative interactions***	***Have no effect***
Juvenile BT growth	*↑juvenile BT growth rates & survival in beaver streams*	*No difference or ↓juvenile BT growth rates and survival in beaver streams*	*No difference in BT growth rates and survival*
Juvenile WSC growth	*↓juvenile WSC growth rates & survival in beaver streams*	*↑WSC growth rates and survival in beaver streams*	*No difference in WSC growth rates and survival*
Composition (BT:WSC abundance)	*↑BT:WSC ratio in beaver streams*	*↓BT:WSC ratio in streams with beaver ponds than control streams*	*No difference in ratio of BT:WSC*

Study Sites

To investigate the influence of beaver on stream temperatures and brook trout and westslope cutthroat trout species interactions, we chose six study streams. These were located in the Beaverhead-Deerlodge National Forest and adjacent BLM and private lands in or near the Big Hole River drainage in southwest Montana (Map 1). Study sites incorporate three replicated treatment types: (i) beaver, westslope cutthroat, and brook trout (ii) beaver and westslope cutthroat (no brook trout), and (iii) westslope cutthroat and brook trout (no beaver).



Map 1: Map of study area showing the locations of treatment streams

Methods

Influence of beaver on stream temperatures:

To evaluate impacts of beaver on stream temperatures, temperature loggers were deployed longitudinally along each stream and set to record data every 30 minutes. Within beaver ponds, loggers were placed along a depth gradient to evaluate if there was summertime stratification and maintenance of deeper cool water. Temperature loggers were deployed in spring 2006, retrieved and data downloaded in autumn 2006, then reinstalled in the stream to collect data every 2 hours during the winter months. In summer 2007, these loggers will be collected and replaced for the duration of summer 2007, giving us over a year of relatively continuous temperature data for these streams.

Influence of beaver on brook trout/cutthroat trout distributions, abundances, and growth rates:

In early summer 2006, we block-netted and electrofished (using a Smith-Root model 15-D backpack electrofisher) six 200 m sections within mid- and high-elevations of each stream. All brook trout and cutthroat trout were identified, measured, and weighed. Additionally, trout greater than 55 mm were individually marked with a Passive Integrated Transponder (PIT) tag and scales were taken for aging and growth rate calculations. In late summer/early autumn 2006, we re-sampled each stream section. New fish were processed as above, whilst recaptures were measured, weighed and re-released.

Potential growth of cutthroat trout was calculated using average seasonal temperature data for each stream and a growth equation[1] that characterizes the potential growth at a given temperature. This equation was originally formulated for bull trout, but performs well when applied to cutthroat trout[1].

Results and continuing work

Influence of beaver on stream temperatures:

Temperature is considered an important factor in determining how westslope cutthroat trout and brook trout interact. Indeed, research has shown that brook trout are able to outcompete cutthroat at temperatures of between 13°C and 17°C[2]. Therefore, by examining detailed stream temperature profiles in beaver and non-beaver systems, it is possible to ascertain how beaver influence stream habitat characteristics, and determine how this may impact competitive interactions of our focal fish species. Examination of temperature profiles of Johnson Creek (a non-beaver stream) and Squaw Creek (a beaver stream) shows distinctive differences, with the non-beaver system showing a gradual increase in stream temperature with a reduction in elevation (Figure 1a). This is contrasted by Squaw Creek, which exhibits a much more dynamic temperature profile, with areas of rapid warming observed at known beaver pond locations (Figure 1b).

The vertical temperature profile of a beaver pond on Squaw Creek shows distinct temperature stratification with depth. Beaver ponds elevate surface temperatures at the site and a short distance downstream of the site. Some beaver ponds may provide cooler refuge habitat through the summer depending on their depth. Temperature profiles for a series of other beaver and non-beaver streams display a similar pattern and are shown in Appendix A.

Influence of beaver on brook trout/cutthroat trout distributions, abundances, and growth rates:

The observed increase in stream temperature in beaver systems suggests that beaver may play a role in brook trout invasion of a system and their interaction with westslope cutthroat trout. This is likely due to the temperature pattern observed in Squaw Creek, whereby the stream appears to be warmed to temperatures that favor brook trout in competitive interactions with westslope cutthroat[18].

In summer 2006, we completed a mark and subsequent recapture session (median recapture rate = 20%). A total of 909 brook trout were captured (498 PIT tagged) and 591 westslope cutthroat (524 PIT tagged). This allowed us to calculate species distributions, relative composition, and within-season growth rates.

Initial analysis of data from a Squaw Creek (beaver) and Johnson Creek (non-beaver) suggests that beaver may influence species distribution and composition. In the non-beaver stream there is an increase in the relative proportion of cutthroat relative to brook trout with increasing elevation (Figure 1a). The site at 2137 m represents the upper distributional limit for both species due to the presence of an impassable barrier immediately upstream. In Squaw Creek however, the pattern of fish species composition is subtly different from that observed in the non-beaver watershed (Figure 1b). There are gradual increases in the proportion of cutthroat upstream, but brook trout continue to dominate the community through the entire stream reach. This suggests that beaver may be influencing the ability of brook trout to invade into higher reaches of the watershed, relative to non-beaver streams. These differences exist across our focal streams, but are based only on one field season and as such, are speculative.

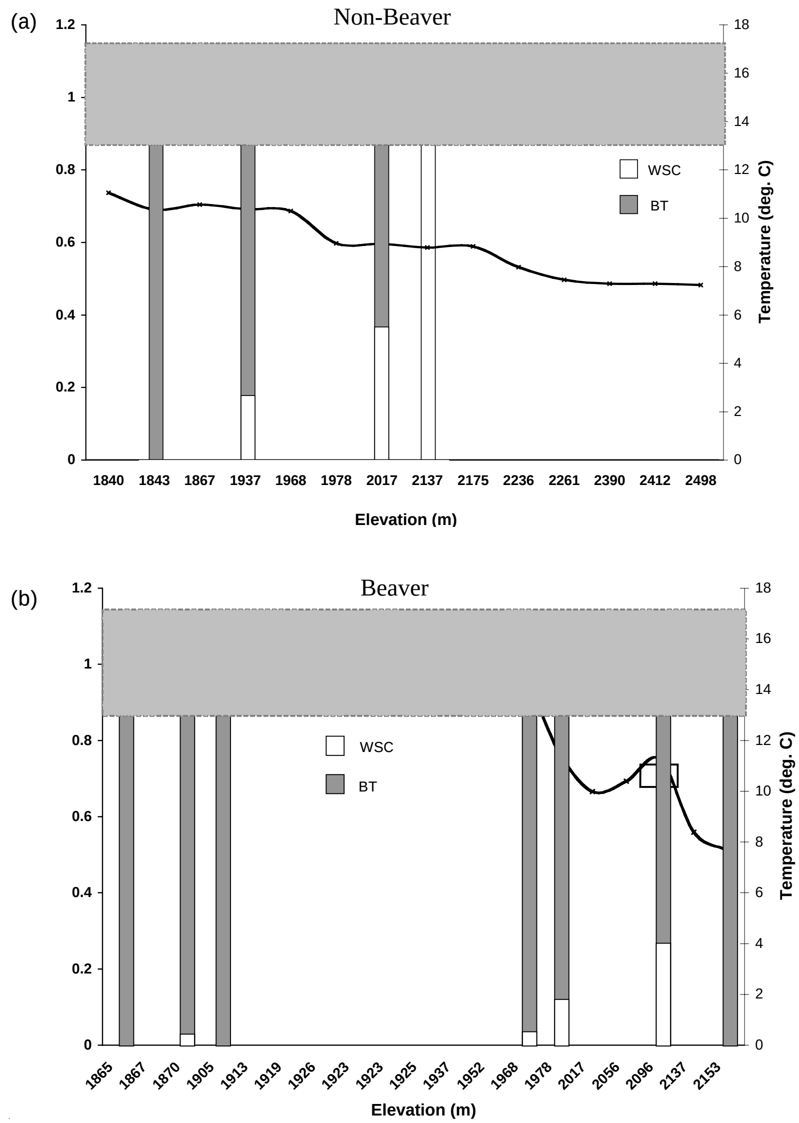


Figure 1: Average summer temperature profile and relative composition of westslope cutthroat (WSC) and brook trout (BT) in (a) Johnson Cr. (non-beaver), and (b) Squaw Cr. (Beaver). Rectangles on Squaw Cr. temperature profile denote areas on known beaver activity

During the 2006 mark-recapture sessions over 1000 fish were individually tagged. Recapture of known individuals provides an estimate of growth rates for brook and cutthroat trout in each treatment. Analysis of recapture data from these streams suggests that brook trout and cutthroat trout grow faster at higher temperatures (Figures 2a & 2b). The average potential growth rate of cutthroat trout based only on temperature[1] is considerably higher than realized values, and suggests that factors other than temperature (such as interspecific competition or prey availability) is influencing the growth rate of westslope cutthroat trout. In the beaver system, despite a consistently high potential growth rate for cutthroat, the average summer temperatures consistently lie within the temperature range defined by Thomas[2] as conferring competitive advantage to brook trout in interspecific interaction with cutthroat trout. This corresponds with the observation that few cutthroat trout are found at elevations within this temperature range (Figure 1a and 1b).

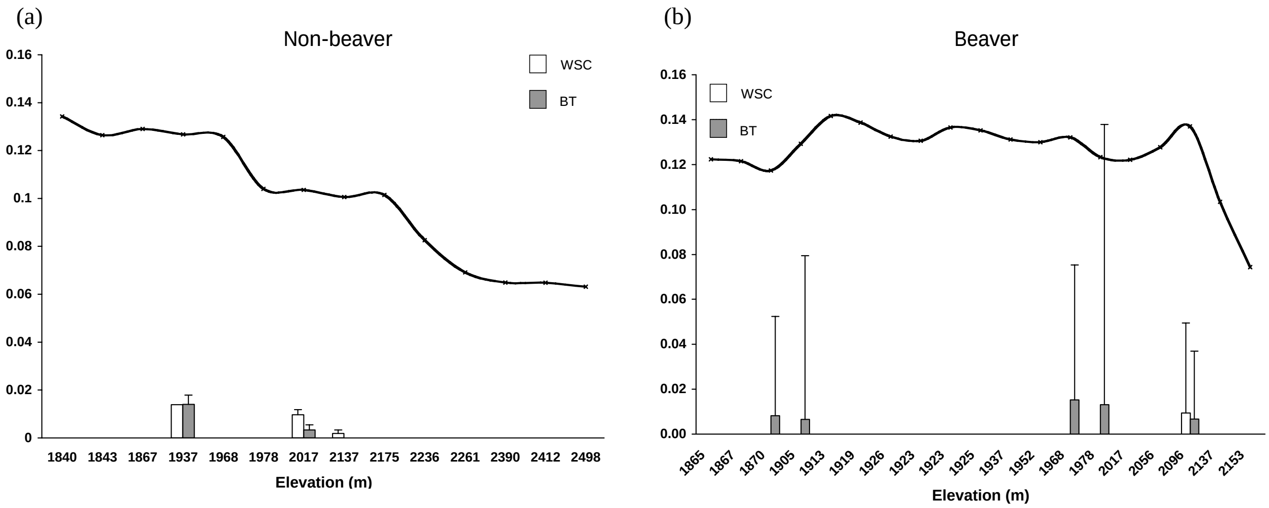


Figure 2: Average potential WSC growth based on temperature, and within-season growth rates (+/- 1 SE) for westslope cutthroat (WSC) and brook trout (BT) in (a) Johnson Cr. (non-beaver/WSC/BT), and (b) Squaw Cr. (Beaver/WSC/BT).

Since we expect negative competitive interactions between brook trout and westslope cutthroat to adversely affect juvenile cutthroat most[15], we have begun to examine how the distribution of fish in the size range 55-150 mm corresponds to available temperature within the stream. Distributions of juvenile fish caught during the first capture session were related to temperature data for three streams (Figure 3), representing each treatment type. Where brook trout are not present, westslope cutthroat juveniles select temperatures between 14 and 16°C. Where both brook trout and beaver are present there is a relatively high degree of overlap in brook and cutthroat distributions, and where beaver are absent there appears to be less overlap between the two species. Where brook trout occur with cutthroat, brook trout appear to dominate areas with higher temperatures. Calculation of potential growth rates[1] for cutthroat trout at the actual temperatures experienced by the juvenile cutthroat in each of these stream indicate that highest growth rates are expected in the absence of brook trout, while the lowest growth rates are most likely where brook trout are present and beaver are absent (Figure 3). Hence, the presence of beaver in a watershed may buffer the negative effects of brook trout competition on westslope cutthroat populations.

We are currently analyzing scales taken from both brook trout and cutthroat trout. This, in conjunction with recapture work in summer 2007 will allow us to estimate growth rates with more precision.

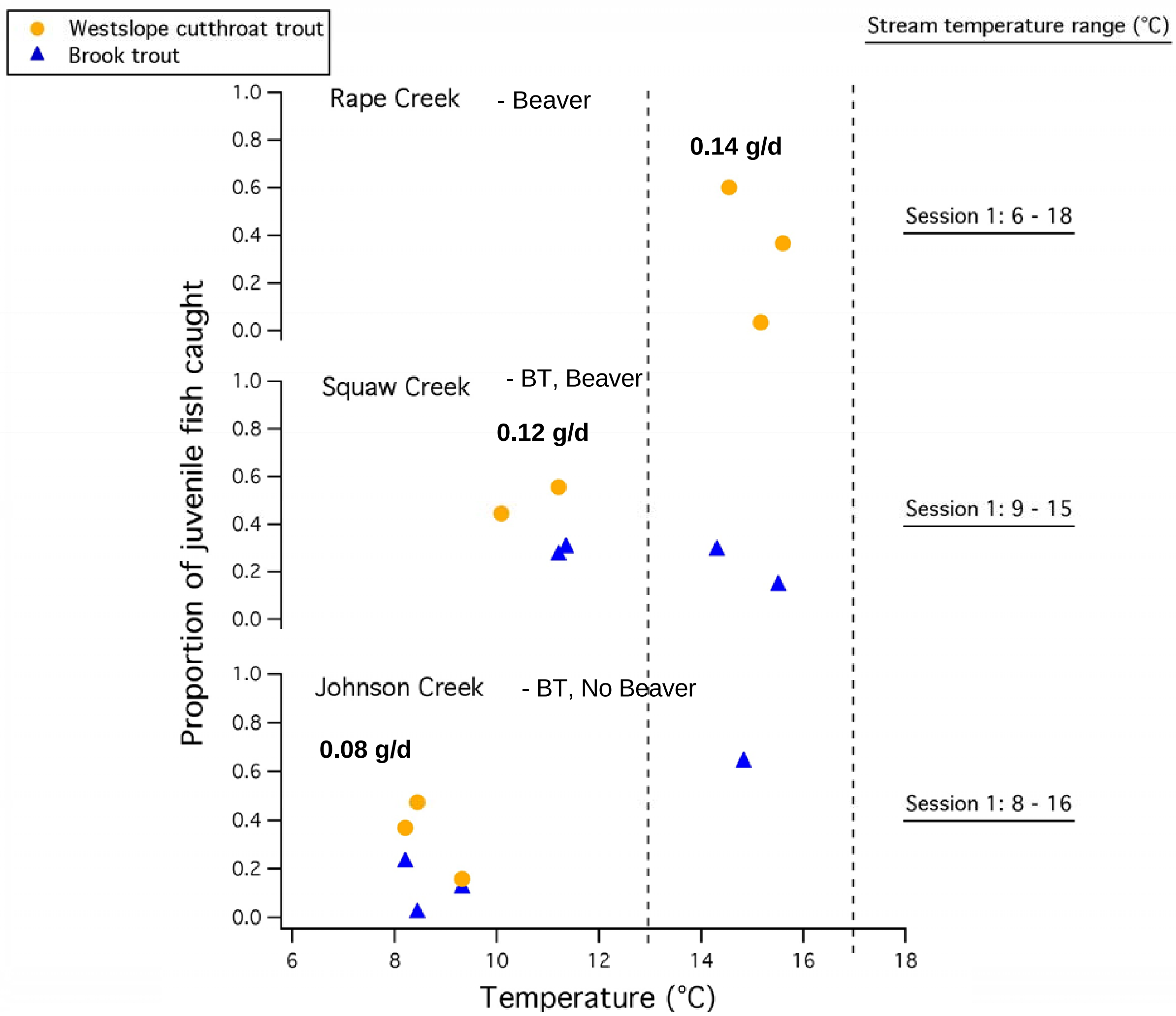


Figure 3: The distribution by temperature of brook trout (triangles), and westslope cutthroat trout (circles) in three treatment types. Potential growth rates of cutthroat in each stream are shown in bold, and were calculated with Sloat's[1] equation. The dashed lines indicate the temperature range in which brook trout are thought to outcompete cutthroat trout[2]

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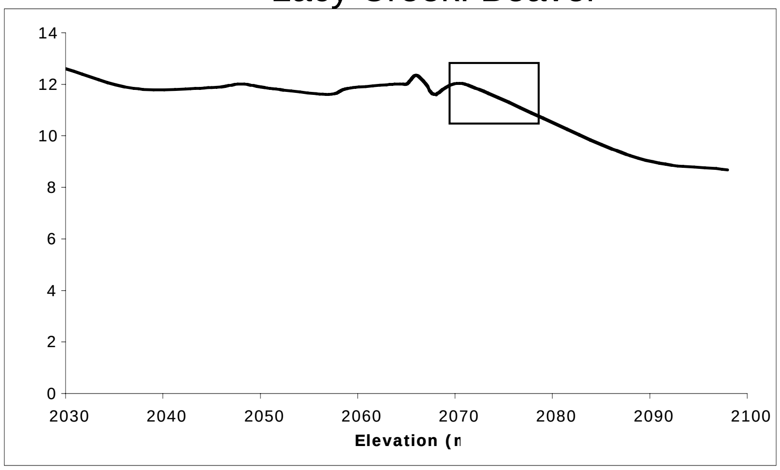
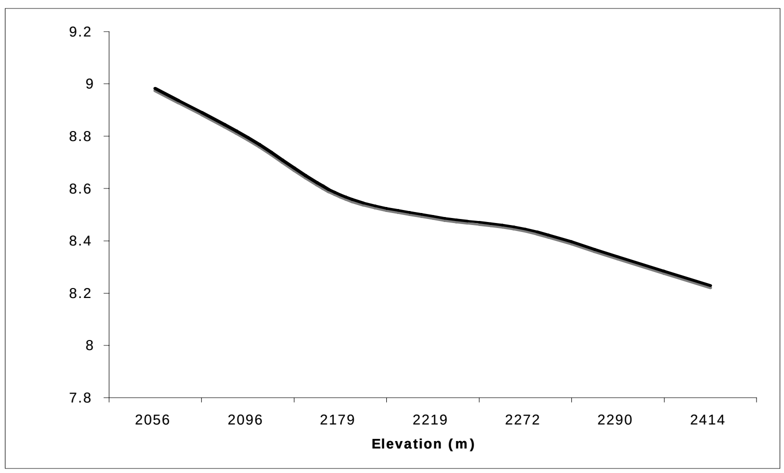
Appendix A

Lacy Creek: Beaver



Stine Creek: Non-beaver



Stone Creek: Beaver

Stream temperature profiles of beaver and non-beaver streams. Rectangles denote areas of known beaver impoundment.