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Seasonal and spatial variation in lipid and triacylglycerol levels in juvenile chinook salmon (*Oncorhynchus tshawytscha*) from the Bridge River, British Columbia

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ABSTRACT

Triacylglycerols (TAGs) are the primary form of energy storage in fish, but little work has been done on the dynamics of TAG storage and use in relation to environmental conditions. We sampled age-0 chinook salmon (*Oncorhynchus tshawytscha*) in two reaches of a regulated river in British Columbia, Canada that had different discharge regimes. During the summer, fish from the reach with high freshet flows grew more slowly and had lower TAG levels than those from the reach with lower and more stable flows. In addition, smaller individuals had lower TAG levels than larger ones. We suggest that in the reach with higher flows fish were unable to obtain sufficient surplus energy for somatic growth and lipid storage. In the fall, when flows were lower, TAG storage increased and the proportion of total lipids that were TAGs were similar for both small and large fish. The allocation of energy to TAG stores was likely a strategy to ensure individuals had sufficient energy for overwintering. Our results suggest that individual-based variation in TAG levels may be sensitive to environmental factors and can be used as a measure of fish condition and performance, but more work is needed to fully understand lipid dynamics in seasonally and spatially variable rearing environments.

Introduction

Freshwater fish living in temperate or polar environments balance the acquisition of energy during the growing season with the risk of predation associated with foraging (Post and Parkinson 2001; Biro et al. 2006). Energy that is acquired but is surplus to metabolic and activity needs can then be allocated to either somatic growth or to stored reserves needed for overwintering (Finstad et al. 2010). Variation in rates of energy acquisition and storage may be useful indicators of conditions that individuals experience (Driedger et al. 2010). For example, Post and Parkinson (2001) found in small lakes where young rainbow trout (*Oncorhynchus mykiss*) grew slowly, energy was directed to somatic growth during the summer at the expense of lipid storage, whereas in lakes that allowed for faster growth rates fish were “energy storage maximizers” and allocated more surplus energy to storage.

Most ecological studies use total body lipids as a measure of energy availability, however, the main form of stored energy in fish are triacylglycerols (TAGs; Henderson and Tocher 1987). Other forms of lipids such as cholesterol and phospholipids serve primarily a structural role in cell membranes, and are only metabolized during prolonged periods of starvation after TAGs have been depleted. Thus TAGs have the potential to be a more sensitive indicator of fish condition than total lipids, caloric content or body shape (Fraser 1989; Adams 1999; Næsje et al. 2006).

For stream-dwelling fishes the dynamics of TAG accumulation and depletion have not been well-studied. Næsje et al. (2006) showed that much of the seasonal variation in total lipid levels in juvenile Atlantic salmon (*Salmo salar*) could be attributed to variations in TAG levels, with the levels of the structural lipids remaining relatively constant throughout the year. Finstad et al. (2004) found that juvenile salmon with low energy content were less likely to survive winter, and these fish were also likely to have exhausted their TAG reserves. Habitat-specific differences in TAG accumulation in juvenile Atlantic salmon along a longitudinal gradient in a French river were reported by Descroix et al. (2009), but no pattern was found in 2 Canadian rivers by Johnston and Bergeron (2010).

Here we describe the seasonal dynamics of TAGs in juvenile chinook salmon (*O. tshawytscha*) in the Bridge River, a regulated river in southwestern British Columbia, Canada. The Bridge River is

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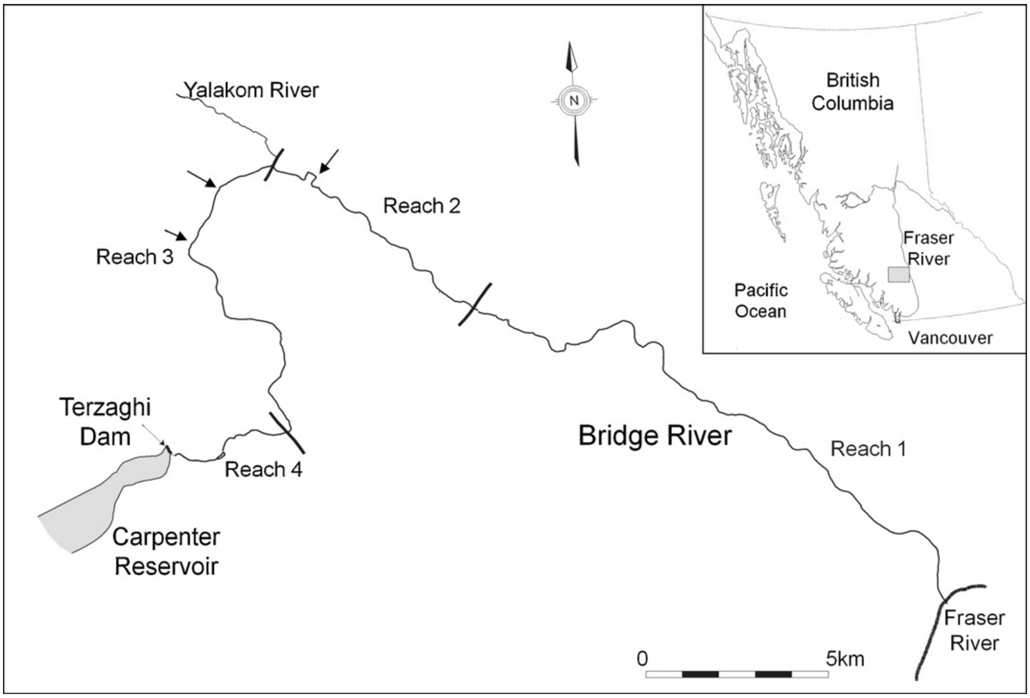

Fig. 1. Map of the study area. Arrows indicate approximate locations of the fish collection sites in Reaches 2 and 3.

the site of an adaptive management experiment designed to evaluate the effects of stream flow on salmonid production (Bradford et al. 2011). We were interested in understanding changes in TAG levels at both population and individual levels, particularly in relation to environmental conditions. To do this we contrasted seasonal changes in lipid levels in fish from two reaches of the river that have different flow regimes. Our ultimate goal is to determine whether TAG can be used as an additional indicator of fish performance in our evaluation of the effects of flow on salmonid production.

Materials and methods

Study area

The Bridge River is located in southwestern British Columbia, Canada (50°45′ latitude, 121°56′ longitude). It flows southeast from the snowfields of the Coast Mountains and drains into the Fraser River near the town of Lillooet. The Terzaghi Dam, located 41 km upstream from the Fraser River impounds the Bridge River and >95% of inflows are diverted to an adjacent watershed for electrical generation. The Bridge River downstream of the dam is a significant salmonid producing river and provides spawning and rearing habitat for juvenile chinook, coho (*O. kisutch*), pink (*O. gorbuscha*) and sockeye salmon (*O. nerka*), as well as steelhead and resident rainbow trout, bull trout (*Salvelinus confluentus*) and a number of other freshwater species (Higgins and Bradford 1996; Bradford and Higgins 2001).

We sampled two reaches on the Bridge River (Fig. 1). Channel gradient (0.7–3%) and substrate (consisting largely of boulders and large cobbles) is consistent throughout the study area (Higgins and Bradford 1996). However, each reach has a unique discharge regime (Fig. 2a) resulting in considerable differences in hydraulic conditions, especially during the summer months. During our study, flow in Reach 3 was largely from scheduled flow releases from Terzaghi Dam augmented by minor inflows from small tributaries and groundwater springs. Downstream in Reach 2 discharge is a combination of dam releases and inflow from the Yalakom River, a significant unregulated tributary. Flows in Reach 3 were low and relatively stable with discharge ranging from 1.8 to 5.1 $m^3\,s^{-1}$, whereas flows in the Reach 2 were higher and much more variable (range 3.0–38.5 $m^3\,s^{-1}$). Water temperatures were similar in the two reaches (Fig. 2b).

Juvenile salmon densities in the study reaches are estimated annually in September using depletion electrofishing at 18–20 shoreline sites in each reach (Bradford et al. 2011). During our study age-0 chinook salmon densities were lower in Reach 3 (2002: 0.07 m^{-2}, 2003: 0.10 m^{-2}) than in Reach 2 (2002: 0.32 m^{-2}, 2003: 0.32 m^{-2}). However total juvenile salmon densities (age-0 chinook and coho salmon, *O. kisutch*, and age-0 and age-1 rainbow trout, *O. mykiss*) were similar among reaches (Reach 2, 2002: 0.97 m^{-2}, 2003: 0.86 m^{-2}; Reach 3, 2002: 0.94 m^{-2}, 2003: 1.04 m^{-2}).

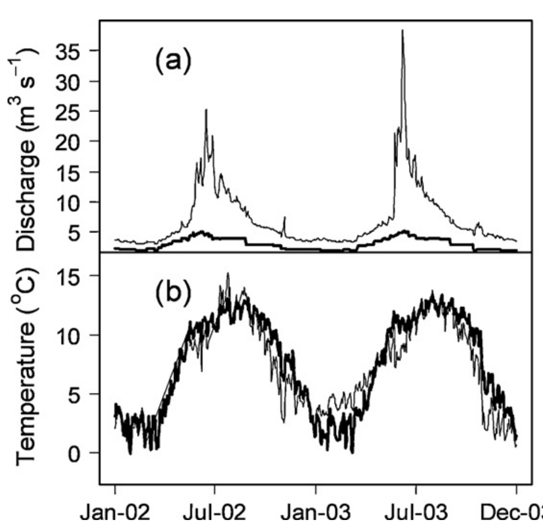

Fig. 2. Daily discharge (a) and mean water temperature (b) for Reach 2 (thin line) and Reach 3 (thick line), 2002–2003.