THESIS

ILLEGAL WALLEYE INTRODUCTION MAY DESTABILIZE A WILD LAKE TROUT—CUTTHROAT TROUT FISHERY IN A WYOMING RESERVOIR

Submitted by

Clark F. Johnson

Department of Fish, Wildlife and Conservation Biology

In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Spring 2016

Master's Committee:

Advisor: Brett M. Johnson

Julia Klein
Christopher Myrick

ABSTRACT

ILLEGAL WALLEYE INTRODUCTION MAY DESTABILIZE A WILD LAKE TROUT—CUTTHROAT TROUT FISHERY IN A WYOMING RESERVOIR

Introduced Lake Trout *Salvelinus namaycush* coexisted for decades with wild, native Yellowstone Cutthroat Trout *Oncorhynchus clarkii bouvieri* and Rainbow Trout *O. mykiss* in Buffalo Bill Reservoir, Wyoming. Recently, managers became concerned when illegally introduced Walleye *Sander vitreus* were discovered. The goals of this study were to examine potential habitat constraints on predator-prey interactions, and determine how arrival of a coolwater predator may affect the *Oncorhynchus* population. We measured limnological variables and used gill nets, electrofishing and trap nets to sample fish populations monthly during April–October in 2012 and 2013 to determine fish habitat use and collect samples for growth and diet analyses. Prior to thermal stratification Lake Trout, *Oncorhynchus* spp., and Walleye co-occurred at depths <18 m, but during summer Walleye and *Oncorhynchus* spp. remained in shallow water and Lake Trout retreated to the hypolimnion. Only large (≥ 600 mm TL) Lake Trout consumed *Oncorhynchus* spp. and only during the unstratified period, but 64% of diet of all Walleye sampled was *Oncorhynchus* spp. regardless of stratification. Low Secchi depth (mean = 1.6 m) and warm (19°C) epilimnetic temperatures appear to have inhibited Lake Trout predation on *Oncorhynchus* spp. in summer and made conditions more favorable for Walleye. Abundance estimation showed that Lake Trout abundance (17,894 fish > 210 mm TL, 68% CI = 13,765–22,531) was lower than *Oncorhynchus* spp. (43,872 fish, 90% CI = 33,627–54,118). Walleye appeared to still be rare and could not be enumerated with confidence.

Bioenergetics modeling showed that lifetime per capita consumption of *Oncorhynchus* spp. by Lake Trout (18.29 kg) was similar to that by Walleye (14.71 kg), despite the longer lifespan of Lake Trout. A growing Walleye population may adversely affect both Lake Trout and *Oncorhynchus* populations in this system.

ACKNOWLEDGEMENTS

I would like to thank my advisor Dr. Brett Johnson for his support and guidance throughout this project. His help and ideas during the course of this project helped to make it a much better final project. Brett has helped me greatly to complete this step and prepare me for the next in my career path. I am grateful to Brett, as well as Dr. Julia Klein, Dr. Christopher Myrick, and Mark Smith for participating on my graduate committee and critically reviewing me and my work.

I am grateful for Travis Neebling for his undying eagerness and interest in this project, along with a truly immense amount of field work and lab work that he has contributed. Travis is one of the hardest working biologists I know and has gone above and beyond. Thanks to Jason Burckhardt for his help with fieldwork on Buffalo Bill Reservoir and the hospitality of he and his wife by inviting me to their home for dinner or a place to stay on many occasions. I also thank Jeff Arnold and Pat Bigelow of the National Park Service for providing insight and data from Yellowstone Lake.

I received generous scholarships from the West Denver and Cutthroat chapters of Trout Unlimited, as well as the late Dr. Robert Behnke and the Rocky Mountain Fly Casters. I cannot extend enough thanks for their generous donations.

I cannot thank the Wyoming Game and Fish Department enough for their funding and support throughout the duration of this project. Numerous biologists and technicians provided a ton of help with field work.

I'd also like to thank the students and staff in the Fisheries Ecology Laboratory. Devin Olsen, Brian Wolff, and Bill Pate were great lab mates and provided tips and support. Without the following students, I would never have processed all the samples that led to this thesis: Will Radigan, Timothy D’Amico, Brian Metzger, Marshall Wolf, Katie Rohwer, Ann Bishop, Megan Weber, Jacob Hayungs, Andrew Oringer, and Jake Ruthven.

Most importantly, I would like to thank Danielle Bamberg and our families for all of their support and encouragement during this project.

TABLE OF CONTENTS

INTRODUCTION

Lake Trout *Salvelinus namaycush* were introduced to lakes and reservoirs across the western U.S. (Fuller and Neilson 2015) including numerous lakes and reservoirs in Wyoming beginning in 1890 (Baxter and Stone 1995). Lake Trout are large-bodied, lacustrine specialists and their native range extends from New York through the Upper Midwest to Alaska (Behnke 2002). Lake Trout prefer colder water than most North American salmonids and they are usually confined to the hypolimnion of stratified lakes during summer (Behnke 2002). In their native range, adult Lake Trout are known to feed primarily on salmonids in their native range (Scott and Crossman 1973; Behnke 2002). Predation by introduced Lake Trout has been harmful to wild and stocked salmonid fisheries across the western United States (Ruzycki et al. 2003; Quist and Hubert 2004; Martinez et al. 2009). Lake Trout predation is a major factor contributing to the decline of native lacustrine Cutthroat Trout *Oncorhynchus clarkii* (14 subspecies), most notably at Yellowstone Lake, Wyoming (Ruzycki et al. 2003). Cutthroat Trout historically had the widest distribution of any trout in North America, but their distribution is now <5% of the historical area prior to settlement by Europeans (Behnke 2002). Restoration of lacustrine and adfluvial Cutthroat Trout stocks has been hampered by resident Lake Trout populations (Al-Chokhachy et al. 2009; Kaeding 2012; Muhlfeld et al. 2012). The apparent long-term coexistence of Lake Trout and Yellowstone Cutthroat Trout *O. clarkii bouvieri* (and Rainbow Trout *O. mykiss*) at Buffalo Bill Reservoir in northwest Wyoming is in contrast to most other systems where Lake Trout and *O. clarkii* subspecies are sympatric. However, at the onset of the present study little was known about the nature of Lake Trout-Cutthroat Trout interactions in the reservoir.

Buffalo Bill Reservoir is unique in Wyoming because of its entirely wild, self-sustaining trout fishery. Wyoming Game and Fish Department (WGFD) manages 23 reservoirs >500 ha in size, but Buffalo Bill Reservoir is the only one that is managed as a wild trout (*Oncorhynchus* spp.) fishery (Jason Burckhardt, Wyoming Game and Fish Department, personal communication). Rainbow Trout and Lake Trout have not been stocked since 1949 and 1955, respectively. Yellowstone Cutthroat Trout, a species of greatest conservation need in Wyoming (WGFD 2010), have not been stocked since 1995 and Buffalo Bill Reservoir hosts one of the largest lentic stocks outside of Yellowstone Lake. Because they hybridize with Rainbow Trout, Buffalo Bill Reservoir's Cutthroat Trout are not considered a conservation population but the large (>500 mm), fast growing fish are highly prized by anglers. Buffalo Bill Reservoir is also home to smaller populations of Brown Trout *Salmo trutta*, Yellow Perch *Perca flavescens*, and Mountain Whitefish *Prosopium williamsoni*, as well as Longnose sucker *Catostomus catostomus* and White sucker *C. commersonii*. In 2008 Walleye *Sander vitreus* were discovered and microchemical analysis of otoliths determined that founder fish were introduced as early as 2002 (Carleton et al. in prep). Subsequent sampling indicated that Walleye were reproducing in the reservoir, raising managers' concern for the sustainability of the wild *Oncorhynchus* spp. population and fishery.

Walleye are a mid-sized freshwater piscivore that are native to central North America (Scott and Crossman 1973). Their natural distribution overlaps with that of Lake Trout throughout much of Canada, though the species are rarely found in sympatry (Johnson et al. 1977; Bertolo and Magnan 2006). Walleye are a popular and sought after sportfish, and they have been introduced extensively throughout North America (Billington and Sloss 2011). They are considered a coolwater species (Kitchell et al. 1977a; Christie and Regier 1988; Hasnain et al. 2010). Walleye are found in a large range of environments and can adapt to both lotic and lentic environments (Bozek et al. 2011). Walleye can be piscivorous throughout life and are able to forage effectively in low-light environments, either after dark or in systems with high turbidity (Bozek et al. 2011). Unlike in their native range where walleye generally don't overlap with salmonids, in the western U.S. Walleye prey heavily on salmonids, particularly *Oncorhynchus* spp. (McMahon and Bennett 1996; Yule et al. 2000; Baldwin et al. 2003), affirming managers' concern about possible impacts at Buffalo Bill Reservoir.

We believe ours is the first study to investigate the rather unusual stable coexistence of Lake Trout and wild Cutthroat and Rainbow trout populations in a large lacustrine system. As such, our work may provide insights into factors that affect Lake Trout predator-prey relations where the species is threatening or hindering recovery of wild *Oncorhynchus* populations. Further, it is one of the first to study co-occurrence of wild Walleye, Lake Trout, and Cutthroat Trout. Specific objectives for this study were to: 1) determine the current status of Lake Trout, *Oncorhynchus* spp., and Walleye populations in Buffalo Bill Reservoir, 2) describe environmental conditions and potential habitat constraints on predator-prey interactions, and 3) anticipate how the arrival of a shallow water predator may affect the persistence of the *Oncorhynchus* population in the future.

METHODS

Study area.

Buffalo Bill Reservoir is located at the confluence of the North and South forks of the Shoshone River in northwest Wyoming (Figure 1). The North Fork Shoshone River provides spawning habitat for both Rainbow and Cutthroat trout, and the reservoir is an important rearing site for these fish (WGFD 2011). The dam was completed in 1910 and was raised 8 m in 1993, increasing the reservoir's surface elevation to 1,644 m above sea level, its surface area to 3,365 ha, and its maximum depth to 61 m (USBR 2013). The reservoir's watershed is bounded by mountains and wilderness of the Shoshone National Forest and Yellowstone National Park. Buffalo Bill Reservoir is a relatively turbid system. Heavy silt inputs from the two major tributaries are compounded by regular draw-downs and a windy climate that promote re-suspension of fines (Blanton 1991; Stene 1996). The reservoir is dimictic and stratification lasts from June through September.

Environmental conditions.

To describe environmental conditions and to determine potential habitat constraints on predator-prey interactions we collected data on zooplankton, dissolved oxygen, temperature, Secchi depths monthly at three locations throughout the reservoir (Figure 1; limnology stations). Because zooplankton, particularly *Daphnia* spp., are a critical prey resource for *Oncorhynchus* spp. in many western reservoirs (Beauchamp 1990; Tabor et al. 1996; Baldwin et al. 2000; Johnson and Martinez 2012), we measured zooplankton density monthly at three sites from April–October, 2012 and 2013. Duplicate tows were made at each site with a 153-μm Wisconsin net towed from 5 m to the surface and from 10 m to the surface. Samples were preserved in 10% sugar buffered formalin. Each sample was diluted and three replicate 1-ml aliquot sub-samples were placed in a Sedgwick-Rafter counting cell where taxa were identified and enumerated (Lind 1979) under a compound microscope. Dissolved oxygen and temperature profiles were obtained with a YSI Model ProODO meter. Measurements were taken at 1-m intervals from 0 to 20 m and at 5-m intervals from 20 m to the bottom. Secchi depth measurements were made with a standard 20-cm diameter limnological Secchi disk (Wetzel and Likens 1991) taken on the shaded side of the boat during midday.

Because Buffalo Bill Reservoir is a relatively turbid system, we were interested in how temperature and turbidity might interact to affect predator-prey interactions during the stratified period. The optimum temperature for Lake Trout is 10°C (Stewart et al. 1983), and several studies have indicated that Lake Trout tend to avoid temperatures above 14°C (Martin 1957; Snucins and Gunn 1995; Venard and Scarnecchia 2005). The average optimum temperature for Rainbow Trout (Rand et al. 1993) and Yellowstone Cutthroat Trout (Gresswell 2011) is 17.5°C. Thus, warm surface temperatures in summer may segregate predator and prey as Lake Trout are forced into deeper, cooler water. Lake Trout predation may be further limited in summer by turbidity, reducing their ability to detect prey. Vogel and Beauchamp (1999) showed that reaction distance of Lake Trout to fish prey decreased rapidly as turbidity increased and light intensity decreased:

$$RD = 26.84 + 2.81(L) - 6.09ln(T) - 0.025ln(T)(L) \quad (1)$$

where RD is reaction distance (cm), L is light intensity (lx) and T is turbidity (NTU). We used equation (1), turbidity estimated from Secchi depth (Lind 1986), and light intensity at various depths estimated from the light extinction coefficient (Idso and Gilbert 1974; Wetzel and

Likens 1991) to examine the effect of depth on Lake Trout reaction distance. We also estimated the depth of the photic zone, where we expected herbivorous zooplankton to be concentrated, from Secchi depth (Horne and Goldman 1994). Because Walleye have a higher optimum temperature (22°C; Kitchell et al. 1977a) and keen low-light vision (Ali et al. 1977) we expected them to be found in shallower water and be less hindered by light conditions than Lake Trout.

Fish sampling.

Sampling occurred throughout the reservoir in April, July, August, and October 2012, and monthly during April–October 2013. We used a combination of experimental gill nets, trap nets, and electrofishing to gather samples for aging, diet, and energy density analysis. Experimental gill nets were sinking multi-mesh nets consisting of eight 6 m × 1.8 m panels of monofilament mesh ranging from 19-mm to 57-mm bar measure, and were used April, July, and October 2012 and 2013, as well as May, June and September 2013. Trap nets were (6.4 mm knotless mesh, with either a 0.9 m × 1.2 m frame and 15.25 m lead or a 0.67 m × 0.98 frame and 7.6 m lead, and were set in October, 2012, and April, June, and July, 2013. Pulsed-DC electrofishing (frequency = 60 Hz, duty cycle = 30%) was conducted at night from a boat equipped with a Smith-Root VVP-15B electrofisher in October 2012, and April, May, and September 2013. Because Cutthroat Trout × Rainbow Trout hybrids can be somewhat cryptic we did not attempt to distinguish hybrids from the parent species, referring to them all collectively simply as *Oncorhynchus* spp. All fish were measured for TL (nearest mm) and weighed (nearest g). Saggital otoliths and stomachs were removed from all Lake Trout and *Oncorhynchus* spp. that died during sampling. In addition, all Walleye captured were sacrificed and otoliths and stomachs were removed. Otoliths were rinsed with distilled water and stored in microcentrifuge tubes. Whole stomachs (esophagus to pyloric sphincter) were excised and placed in individual gauze bags and fixed in 10% formalin immediately after removal.

We used two additional gill net protocols to determine fish abundance and spatial distribution, and to supplement our samples of biological materials described above. Summer Profundal Index Netting protocol (SPIN; Sandstrom and Lester 2009) was used to estimate Lake Trout size and depth distributions during July and August 2012, and in August 2013 for both depth distribution and abundance. SPIN protocol uses a depth-stratified, randomized sampling design during peak summer water temperatures when Lake Trout are assumed to be concentrated below the epilimnion. SPIN nets are sinking multi-mesh gill nets that consist of eight 8-m × 1.8-m panels ranging from 28.5-mm to 63.5-mm bar measure. Nets were set in series of three to sample up to seven different depth strata in a lake: 2–10 m, 10–20 m, 20–30 m, 30–40 m, 40–60 m, 60–80 m, and >80 m. The number of net sets per stratum each day was determined based on the number of Lake Trout sampled the previous day, the relative area of each stratum, and the number of strata in the lake. The total number of net sets was calculated based on the area of the water body that is deeper than 10 m. The method has been calibrated extensively with independent Lake Trout abundance estimates, and it was recently corroborated in a similar-sized reservoir in Colorado (Pate et al. 2014). Estimated Lake Trout density (fish/ha) is calculated from the following equation:

$$\widehat{D} = \sum_{h} W_h \times \frac{\sum V_{hi}}{n\ sets_h} \times 4.86 \qquad (2)$$

where $\widehat{D}$ is density; W_h is proportion of stratum *h* of the total area sampled; V_{hi} is gill-net selectivity score for fish caught in stratum *h* of net set *i*; *n* is number of fish caught; and $sets_h$ is number of net sets in stratum *h*. See Sandstrom and Lester (2009) for further details. Catch-per-unit-effort was computed for each species in each 6-m depth stratum to determine the depth distribution of fish residing near the bottom.

To determine depth distribution of pelagic fish during the unstratified period (April, May 2012) and stratified period (July 2012, and August 2012 and 2013), and to partition hydroacoustics targets (described below) to species in August 2013, we used a Wyoming Game and Fish Department standardized gill net protocol using mid-water curtain (MWC) nets (Neebling 2014). The MWC nets are almost neutrally buoyant 48.8-m × 6.1-m gill nets that consisted of eight 6.1-m panels ranging in size from 19- to 63.5-mm bar measure mesh. Over a 4 day period, nets were set at 40 locations for 12 h (Figure 1). Nets were set to sample from the surface to a maximum depth of 30 m, but never to within 2 m of the bottom. Catch-per-unit-effort was computed for each species in each 6-m depth stratum to determine the depth distribution of pelagic fish species.

Hydroacoustics survey.

A hydroacoustics survey was used to estimate abundance of pelagic fishes from August 13 to 16, 2013, concurrent with the SPIN abundance estimate of Lake Trout. The survey was composed of 67 equally spaced, parallel transects, totaling 112.4 km in length (Figure 1). Surveys occurred during daylight hours because previously collected data indicated that *Oncorhynchus* spp. were not schooling during daylight hours and individual fish could be counted (Yule 2000; Gangl and Whaley 2004). Sampling was conducted from a 6.1-m boat built specifically for stability during hydroacoustics surveys and equipped with a Hydroacoustic Technology Incorporated (HTI) Model 241 portable, split-beam echo sounder. A 15°, 200 KHz transducer was pointed downward (down-looking) and was used to track fish below the boat.

Due to the narrow beam width near the surface, a 6°, 200 KHz transducer pointed out to the side (side-looking) was used to sample the top 6 m of the water column. Littoral areas shallower than 8 m were not surveyed. Boat speed was maintained between 5 and 6 km/hr and data were acquired using a minimum target strength threshold of -55dB and a ping rate of 5 pings per second for each transducer, for a total ping rate of 10 pings per second.

Targets were partitioned to species using MWC net catch. Density estimates were calculated by 3-m depth strata for the side-looking (surface to 6 m) and down-looking (below 6 m) data, for each transect. The fish density estimates from individual transects were then weighted by transect length before being averaged to estimate fish density in a given depth strata across the whole lake. Density estimates for each 3-m depth stratum were then multiplied by the area of that depth stratum (determined from the bathymetric map accounting for the lake elevation at the time of sampling) to calculate population estimates. Finally these population estimates were partitioned to species by the MWC net catch data for that depth stratum.

We quantified the biomass and production of the *Oncorhynchus* population to compare with our estimates of predator consumptive demand derived from bioenergetics models (below). The estimated abundance of *Oncorhynchus* population was converted to biomass with the length distribution of fish captured in the MWC during the hydroacoustics survey and a weight-length relationship developed from *Oncorhynchus* spp. measured and weighed during the study (r^2 = 0.99, n = 632):

$$W = (9.182 \times 10^{-6}) \times TL^{3.009} \quad (3)$$

where W is fish weight in g, TL is total length in mm. Neither the population estimate nor the biomass estimate included *Oncorhynchus* spp. < 150 mm TL because they were probably invulnerable to the gill nets and none were captured. Age and growth information indicated that fish < 150 mm TL in August were mostly age-0 fish so our estimates of biomass and production did not include this age-class. We assumed that by age-3 *Oncorhynchus* spp. were too large (mean ± *SD* = 368 ± 66 mm) to be vulnerable to predation because they exceeded 50% of the length of all Walleye and nearly all Lake Trout in the reservoir; other studies with Walleye and Lake Trout have found that these predators rarely chose prey > 50% of their own length (Mittelbach and Persson 1998; Wahl et al. 2007). The biomass of age-1 and age-2 *Oncorhynchus* spp. was obtained by partitioning the hydroacoustics estimate of the entire population using the relative frequency of these age-classes captured in MWC nets and the weight-length relationship above. Annual production of age-1 and age-2 *Oncorhynchus* spp. was calculated using the following equation:

$$P_i = G_i \times \bar{B}_i$$

where P_i is annual production of age-class *i*, G_i is the instantaneous growth rate during age-i, and $\bar{B}_i$ is mean biomass of age-class *i* (Hayes et al. 2007).

Age, growth and mortality.

We determined length-at-age from sectioned otoliths. One otolith from each individual was randomly chosen for aging, embedded in epoxy and sectioned transversely with a low speed saw fitted with diamond wafering blades. Each section was polished to expose annuli and ages were determined independently by at least two experienced readers. If a disagreement occurred, readers would re-evaluate until consensus was achieved. Growth was described by fitting the von Bertalanffy growth function (VBGF) to the mean lengths at age to reduce bias due to unequal sample sizes (Isely and Grabowski 2007). The VBGF was fitted by minimizing residual sum of squares in Excel (Allen and Hightower 2010):

$$l_t = L_\infty \times (1 - e^{-k(t - t0)}) \quad (4)$$

where l_t is length at time t, L_∞ is the asymptotic length (or maximum length if growth continued indefinitely), k is the von Bertalanfffy growth coefficient (the rate at which L_∞ is approached) and t_0 is the hypothetical age when the fish had zero length. We computed relative weight (W_r) of Lake Trout, Walleye, and *Oncorhynchus* spp. using equations presented in Neumann et al. (2012).

Age-length keys were constructed from the otolith age data, and were coupled with representative length-frequency distributions to determine population age structure (Isely and Grabowski 2007). Age structure of the Lake Trout population was used to estimate total mortality rate because that information was required for population level analyses with the bioenergetics model. Total mortality was estimated as the negative of the post-peak slope of the descending limb of a linearized catch curve (Miranda and Bettoli 2007). The data were truncated after age-15 because beyond that age there were no fish sampled for 7 out of 12 age-classes > age-15 in the age sample. Data were insufficient to determine unbiased age distributions of Walleye so their mortality rate was not estimated.

Diet.

Fish prey in stomach samples were identified to species when possible. Because we were primarily interested in predation on the *Oncorhynchus* spp., we conservatively assumed that all salmonids that could not be identified to genus were *Oncorhynchus* spp. Other fish prey were aggregated as "other fish" (including Longnose and White suckers, and Yellow Perch). Invertebrates were identified to order or family. Invertebrate prey were subsequently aggregated as zooplankton, crayfish (*Orconectes virilis*), or insects. Prey items were briefly blotted to remove excess liquid and quantified volumetrically via displacement in water. Whole fish were measured (TL) and incomplete fish remains were converted to TL based on relationships in Carlander (1969, 1997) or from vertebral column lengths (VL), vertebrae counts and TL:VL relationships derived from preserved fish specimens. We computed the prey:predator size ratio as the total length of a fish prey item divided by the total length of the consumer. We hypothesized that Lake Trout diet would be more affected by thermal stratification than Walleye because Lake Trout could be confined to the hypolimion during most of the stratified period (surface temperature >14°C; June–September). We used binary logistic regression in SAS 9.3 (SAS Institute 2011) to determine if season, predator species, or predator length had an effect on the incidence of piscivory in Lake Trout and Walleye.

Bioenergetics modeling.

Biomass of *Oncorhynchus* spp. and other prey consumed by Lake Trout and Walleye was estimated with the Fish Bioenergetics 3.0 modeling package (Hanson et al. 1997). The bioenergetics model computes consumption required to balance metabolic costs, wastes and growth. The program's default physiological parameters were used for both species; the models for both species have recently been corroborated by independent laboratory studies (Madenjian et al. 2013; Madenjian and Wang 2013). The inputs required to run the model included: energy densities of predator and prey, water temperature experienced by the consumer (thermal experience), energy losses due to spawning, growth, and diet composition.

We used the dry:wet weight ratio and the combined species model of Hartman and Brandt (1995) to estimate energy density of fishes from Buffalo Bill Reservoir:

$$ED = 45.29 \times DW^{1.507} \quad (5)$$

where *ED* is energy density (J/g wet weight), *DW* is dry:wet weight ratio (%). Wet weights were measured in the field. Dry weights were obtained after drying specimens to constant weight at 60°C (Lantry and O'Gorman 2007). Fish were assumed to be potential prey if they appeared in diet samples, and were smaller than 300 mm TL, which was selected somewhat arbitrarily before any diet data were available. Energy densities of invertebrate prey taxa were obtained from published literature: *Daphnia ED* = 3,860 J/g (Luecke and Brandt 1993), crayfish *ED* = 3,706 J/g (Pate et al. 2014), aquatic insects *ED* = 4,090 (Johnson et al. 2015).

Thermal experience was derived from temperature profiles measured during April-November, and the assumption that both species occupied the warmest water available during winter (4°C, December-March) when no temperature measurements were available (Table 1). Mean water column temperatures were used during April, May, October, and November when the reservoir was essentially isothermal. During summer thermal stratification we used the temperatures corresponding to the effort-weighted mean depths that fish were captured in depth-stratified gill net sets. The bioenergetics model linearly interpolated between measured temperature values. Simulations were run for a duration of one year, starting on 1 January (model day 1). Simulations of Walleye included ages 1–18, and Lake Trout ages 1–28. The final ages were equal to the maximum ages observed for each species. We accounted for energy losses due to spawning by reducing weight of mature fish by 9% for age-6 and older Lake Trout (Pate et al. 2014) and 12% for age-5 and older Walleye (Carlander 1997).

We modeled per capita lifetime consumption by one cohort of Walleye and two cohorts of Lake Trout because growth, body condition and diet differed between fish < 600 mm TL and fish ≥ 600 mm TL. Growth inputs were derived from the mean lengths at age described by the

VBGF, and weight at age was computed from weight-length relationships for Walleye (r^2=0.99, n = 483):

$$W = 0.00000289 \times L^{3.202} \tag{6}$$

for slow-growing Lake Trout (r^2=0.93, n = 542):

$$W = 0.00002221 \times L^{2.832} \tag{7}$$

and for fast-growing Lake Trout (r^2=0.91, n = 48):

$$W = 0.00000031 \times L^{3.525} \tag{8}$$

where W is weight (g) and L is total length in mm. A single diet composition was used for all age-classes of Walleye because diet did not differ with Walleye size/age or season. Diet inputs differed for the two size classes of Lake Trout, and during stratified and unstratified periods (described in Results). We assumed that diets of both species during winter were the same as observed during the unstratified, open-water period. Results of the simulations were used to compare the relative per capita impact of Lake Trout and Walleye on the *Oncorhynchus* population. Small samples sizes of Walleye precluded population level estimates of their consumptive demand. Total annual consumption of *Oncorhynchus* spp. by Lake Trout was estimated using the abundance, age structure, and total mortality rate of Lake Trout estimated during the study as inputs to the bioenergetics model. To estimate the impact of predation by the Lake Trout population on the *Oncorhynchus* population, we compared population level consumptive demand by Lake Trout with the biomass and production of age-1 and age-2 *Oncorhynchus* spp.

RESULTS

Environmental conditions and fish distributions.

The mean density of *Daphnia* spp. was significantly higher (P = 0.04) in the 0–5 m stratum (3.80 animals/L, SD = 1.41) than in the 1–10 m stratum (1.62 animals/L, SD = 0.69) suggesting that *Daphnia* spp. were more abundant in the top 5 m of the water column compared to the 5 m below. The depth of the photic zone was 5 m. Dissolved oxygen concentrations exceeded 4.0 mg/L at all depths, sites, and dates and exceeded 5.5 mg/L throughout the hypolimnion during stratification. The reservoir was thermally stratified from June through September in both 2012 and 2013. Surface temperatures exceeded 14°C beginning in June and were >18°C during July through September. The warmest recorded surface temperature was 23.5°C at the North Fork station in 2013. The 14°C isotherm occurred at 22 m in July and increased to 40 m in September, with a distinct thermocline at 20 m in August and at 26 m in September. The reservoir became isothermal in October each year. Secchi depth was highly variable but averaged 1.9 m (range 0.5–4.1 m) overall. Secchi depth declined to 1.6 m during July–September when thermal profiles indicated that Lake Trout would need to occupy depths >20 m to avoid temperatures >14°C. Turbidity during this time (5.5 NTU) reduced light penetration to 0.000001 % of incident light (or to about 0.001 lx) at 20 m, limiting predicted Lake Trout reaction distance to the minimum observed in the laboratory (16 cm) by Vogel and Beauchamp (1999).

The depth distribution of *Oncorhynchus* spp., Lake Trout, and Walleye captured in MWC nets (n = 104 sets) changed as thermal stratification intensified. The CPUE of *Oncorhynchus* spp. was always highest in the top 6 m of the water column (Figure 2); but, by August *Oncorhynchus* spp. were captured over the greatest range of depths (0–30 m). The depth distribution of Lake Trout showed the greatest seasonal change, with fish found in the top 24 m of the water column in April and May, and almost exclusively below 24 m in July and August. By August, Lake Trout CPUE was highest in the deepest stratum sampled (24–30 m), just below the thermocline. Few Walleye were captured in MWC nets, but the majority co-occurred with *Oncorhynchus* spp. in the upper 12 m of the water column in all periods. Only in August were any Walleye captured below 12 m. The depth distribution of *Oncorhynchus* spp. and Walleye captured in SPIN nets in August (Figure 3) was similar to that observed in the MWC, with both species concentrated in the epilimnion (≤18 m). The epilimnion was slightly warmer than optimum for *Oncorhynchus* spp. and slightly cooler than the optimum for Walleye at this time. A few fish of each taxon were captured in the next deeper stratum than in the MWC nets. The SPIN nets indicated that a substantial portion of the Lake Trout population was distributed below the 30 m maximum depth sampled by the MWC nets in August (Figures 2, 3). About 80% of the effort weighted catch of Lake Trout occurred below the epilimnion and 56% within the hypolimnion; but the entire water column was warmer than their optimum temperature.

Abundance and size of predators and prey.

We set 72 SPIN nets in August 2013 (Figure 1) to estimate the abundance of Lake Trout. We captured 195 Lake Trout ranging in size from 210 to 935 mm TL. The area-weighted catch per unit effort (CPUE) was 1.63 Lake Trout/net (corrected for gill net selectivity and stratum area), yielding a density estimate of 7.93 Lake Trout/ha. Total area sampled was 2,256 ha, resulting in an abundance estimate of 17,894 Lake Trout >210 mm TL (68% CI: 13,765–22,531). This estimate is higher than the abundance estimated from hydroacoustics: 9,268 fish (90% CI:

6,567–11,970). However, some fraction of the Lake Trout population was likely close enough to the bottom to be unsampled by the MWC nets and undetectable with hydroacoustics, but still vulnerable to the SPIN nets. Although catches in MWC and SPIN nets are not strictly comparable, the CPUE of Lake Trout was about twice as high in SPIN compared to MWC nets (Figure 2, 3), suggesting that many Lake Trout were distributed near the bottom. The size distribution of Lake Trout captured in SPIN nets showed that just 3.3% of the catch was of fish ≥ 600 mm TL, and these were all > 800 mm TL. Although some 600—800 mm Lake Trout were captured in spring and fall with other sampling methods, none were captured during SPIN netting of either year. Therefore, the SPIN method likely underestimated the abundance of large Lake Trout. The largest Lake Trout sampled during SPIN sampling was 968 mm TL, and four larger fish (998, 999, 1089, 1134 mm TL) were sampled with other methods during the study.

The abundance of Walleye was estimated from hydroacoustics data and that estimate was 1,053 fish (90% CI: 555–1,551). However, we captured 453 Walleye with all gear types during 2013. Since capturing ~ 50% of the population seems improbable, the hydroacoustics survey likely underestimated Walleye abundance. All of the Walleye sampled in gill nets in summer were <600 mm TL (range 191–592 mm TL, n = 64).

The abundance of *Oncorhynchus* spp. estimated with hydroacoustics data (using MWC to delineate targets) in August was 43,872 fish (90% CI: 33,627-54,118 fish or 10.0–16.1 fish/ha), and their size ranged 152–536 mm TL. The total biomass of *Oncorhynchus* spp. in August was 26,301 kg (20,159–32,444 kg, or 5.99–9.64 kg/ha). The biomass of age-1 and age-2 *Oncorhynchus* spp. in August was 1,377 kg (1,056–1,699 kg, or 0.31–0.50 kg/ha), and their estimated production was 3,936 kg/year (1.17 kg/ha/year).

Age, growth and mortality.

The size of Lake Trout in our aging sample (n = 210) ranged from 176 mm to 968 mm, with the oldest fish aged at 28 years (n = 2). No Lake Trout of ages 16, 19, 21, 22 or 26 were captured, and about 90% of the fish sampled for aging were ≤ age-12. The estimated total instantaneous mortality rate, Z, estimated from the catch curve was 0.657 (S = 0.518, r^2 = 0.957, n = 6 age-classes). There appeared to be two ecotypes of Lake Trout, slow growers and fast growers (Figure 4). To capture the two apparent growth trajectories for use in bioenergetics modeling, we fit a hypothetical VBGF to each group by setting t_0 = 0.0 and setting L_∞ for the fast growers to the largest fish captured, which are often recommended as initial values (Allen and Hightower 2010). The von Bertalanffy growth coefficient, k, for both groups was estimated from the equation of Pauly et al. (1998):

$$k = \frac{3}{(t_{max} - t_0)} \qquad (9)$$

where t_{max} is maximum age in the population (years), and t_0 is as described above. We found that Lake Trout <600 mm TL were thinner than larger Lake Trout (mean W_r = 84.8, 97.8, respectively; P <0.001), and their diet contained fewer fish (below), consistent with the different growth rates among the two classes of fish. Thus, L_∞ for the slow growers was set to 600 mm. The growth trajectory of Walleye (n = 305) fell between the fast- and slow-growing Lake Trout curves (Figure 4). There were only two Walleye > age-10 in our samples (age-16, age-18) and strontium isotope analysis showed that these fish were probably founders that had been stocked illegally (Carleton et al. in prep). Recruitment of Walleye appeared to have occurred each year during the 10 years preceding our study, because all those year-classes were represented in the aging sample. *Oncorhynchus* spp. (n = 127) grew faster than either Lake Trout or Walleye until about age-5; the oldest *Oncorhynchus* spp. in our sample was age-9.

Diet and energy density.

We analyzed stomach samples from 332 Lake Trout, 127 Walleye, and 213 *Oncorhynchus* spp. The incidence of piscivory by Lake Trout varied by Lake Trout size (P = 0.001, logistic regression) so we compared diet of small (<600 mm) and large (≥600 mm) size classes. The 600 mm threshold for small Lake Trout corresponded with L_∞ for the slow growing subgroup.

Lake Trout diet also differed by season (mixed vs. stratified periods; P = 0.03). Small Lake Trout consumed very few fish (≤6.7%) and almost no *Oncorhynchus* spp. (≤1.2 %) in both periods (Figure 5). Zooplankton were important during the mixed period and aquatic insects (primarily dipterans) and crayfish during stratification. Diet of large Lake Trout was about 75% fish during both periods, but *Oncorhynchus* spp. appeared in stomachs only during the mixed period (40% of diet). The proportion of empty stomachs for small and large Lake Trout was higher during stratification than during April, May and October. The median and 95th percentile prey:predator size ratios in Lake Trout diets were 0.28 (n = 26, SD = 0.13) and 0.50, respectively. There was no effect of size (P = 0.62) or season (P = 0.11) on Walleye diets. Walleye consumed mostly fish (93.4%) and 64% was *Oncorhynchus* spp. (Figure 5). Walleye consumed proportionately smaller fish prey than Lake Trout. The median and 95th percentile prey:predator size ratio in Walleye diets were 0.25 (n = 98, SD = 0.090) and 0.40, respectively. The diet of *Oncorhynchus* spp. consisted mostly of zooplankton (55.7 %) and aquatic insects (42.3%). About 1.4% of the diet consisted of fish, and the remainder was crayfish (0.6%).

The mean *ED* of Lake Trout was 5,253 J/g (n =33, SD = 1,571 J/g); however, our Lake Trout *ED* sample included only two fish >550 g wet weight (4.6 kg, 10.6 kg) and Lake Trout *ED* increases greatly with size so it is usually simulated as a function of body weight in Fish

Bioenergetics 3.0 (Hanson et al. 1997). Thus, we modeled Lake Trout consumption using the weight-dependent *ED* function provided with the software. The mean *ED* of Walleye was 5,357 J/g (*n* = 113, *SD* = 1,570 J/g). The mean *ED* of *Oncorhynchus* spp. was 4,822 J/g (*n* = 139, *SD* = 1,411 J/g), and that of other fish was 4,644 J/g (*n* = 186, *SD* = 1,108 J/g).

Consumptive demand of Lake Trout and Walleye.

The bioenergetics model estimated that slow-growing Lake Trout individuals consumed only a trace (<1 kg) of fish over their lifetime, and more invertebrates (27.72 kg) than fast-growing Lake Trout (20.03 kg) over their lifetime. The lifetime per capita consumption of *Oncorhynchus* spp. was similar for fast-growing Lake Trout (17.16 kg) and Walleye (13.43 kg), despite the 56% greater lifespan of Lake Trout (Figure 6). When per capita consumption of Lake Trout was prorated to the lifespan of Walleye (18 years), then Lake Trout consumed about half (6.89 kg) of the biomass of *Oncorhynchus* spp. consumed by Walleye. Fast-growing Lake Trout consumed more other fish (13.09 kg) than Walleye (6.17 kg) over an equal time span. Because the diet of Lake Trout <600 mm TL contained very few fish, 99% of the lifetime consumption of *Oncorhynchus* spp. by Lake Trout was consumed by large Lake Trout ≥ 600 mm TL. When predation was scaled up to the lakewide population of Lake Trout ≥ 600 mm TL the estimated biomass of *Oncorhynchus* spp. consumed by all Lake Trout ≥ 600 mm TL in 2013 was 556.7 kg (68% CI: 428.2–700.9 kg), which was about 50% of the biomass of prey-sized *Oncorhynchus* spp. (1,112 kg, 90% CI: 852–1,372 kg) estimated in August 2013.

DISCUSSION

We found that environmental conditions at Buffalo Bill Reservoir result in habitat partitioning (Magnuson et al. 1979; Coutant 1987) that reduces Lake Trout predation on *Oncorhynchus* spp. As thermal stratification progressed, Lake Trout moved to cooler water in the hypolimnion, as they typically do throughout their native range (Scott and Crossman 1973). In contrast, *Oncorhynchus* spp. remained near the surface of the reservoir in all seasons (where zooplankton densities were highest), despite somewhat higher than optimal temperatures in mid-summer. We speculate that the system's high turbidity reinforced the thermal segregation of Lake Trout and *Oncorhynchus* spp. by controlling food availability for *Oncorhynchus* spp. during summer. We found that *Daphnia* spp. were most abundant in top 5 m of the water column, which also corresponded with the depth of photic zone. Thus, production of both phytoplankton and zooplankton were concentrated in the upper 5 m of the water column. This implies that zooplanktivorous fish would find the highest food concentrations near the surface. Our netting confirmed that *Oncorhynchus* spp. were most abundant in this upper stratum during April–October, and well separated vertically from Lake Trout.

Although a few *Oncorhynchus* spp. were found at depths containing Lake Trout during summer, visibility at those depths would limit encounter rate and predation success and none were found in Lake Trout diets during this period. Vogel and Beauchamp (1999) found that Lake Trout reaction distance to *Oncorhynchus* prey decreased precipitously as light decreased below about 25 lx, which at Buffalo Bill Reservoir occurred at about 10 m where water temperatures exceeded 17°C in mid to late summer. They further showed that turbidity compounded the effect of low light on Lake Trout reaction distance. Similar conclusions were drawn by Mazur and

Beauchamp (2003), but when light level was not limiting the asymptotic reaction distance was 65% greater for Lake Trout than for Rainbow and Cutthroat Trout. Thus, in clearer systems Lake Trout react to prey at greater distances than Rainbow and Cutthroat Trout, which may in part explain the decline of *Oncorhynchus* spp. following Lake Trout introductions in western North America (Mazur and Beauchamp 2003).

As has been found elsewhere (Shuter et al. 1998; Vander Zanden et al. 2000; Zimmerman et al. 2007) we observed two apparent ecotypes of Lake Trout that exhibited different growth trajectories. Most of the fish were slow-growing, leaner and small-bodied, but a few fast-growing, plumper fish attained large body size (>600 mm). We believe this variation was related to differential use of fish as prey. Smaller Lake Trout consumed few fish and almost no *Oncorhynchus* spp., consuming instead smaller, lower energy invertebrates. The rapid growth of *Oncorhynchus* spp. in Buffalo Bill Reservoir may have contributed to a negative feedback that perpetuated the smaller, more gape-limited ecotype. *Oncorhynchus* spp. exceeded 100 mm TL during their first year of life, and exceeded 270 mm TL in their second year. By fall, after the midsummer period of thermal segregation, many *Oncorhynchus* spp. probably exceeded the gape limit of most Lake Trout. Piscivorous Lake Trout grew faster and were thus less gape-limited by the fast growth of their prey. It has been shown for many fish species that individual differences in size and behavior contribute to differential trophic ontogeny and divergence in fish size distributions (Keast and Eadie 1985; Mittelbach and Persson 1998).

It appears that relatively few Lake Trout in Buffalo Bill Reservoir adopted feeding behavior that allowed them to cope with the constraints of temperature, water clarity, and prey growth while maximizing their feeding potential. Lake Trout are known to migrate vertically despite warmer temperatures to feed on shallower prey (Sellers et al. 1998; Hrabik et al. 2006), but low visibility and warm water would reduce the benefit of possible vertical migrations by Lake Trout at Buffalo Bill Reservoir. During the stratified period no *Oncorhynchus* spp. were found in diets from Lake Trout of any size, and the number of empty stomachs was high. Non-empty stomachs from some of the largest Lake Trout sampled in summer contained small insects such as dipteran larvae suggesting that availability of fish prey was limited. The diet of large Lake Trout sampled before and after summer stratification did contain about 40% *Oncorhynchus* spp., but bioenergetics simulations that expanded that information into annual consumptive demand estimated that large Lake Trout consumption represented <50% of the biomass of age-1 and age-2 *Oncorhynchus* spp. measured in August and <20% of the annual production of these two age-classes.

Several uncertainties make it difficult to precisely determine the effects of Lake Trout predation on the *Oncorhynchus* population. First, we were unable to estimate the abundance of age-0 *Oncorhynchus* spp. but given the rapid growth of *Oncorhynchus* spp. in the reservoir, the biomass and production of this age-class could be substantial. Thus, Lake Trout may have consumed a smaller proportion of *Oncorhynchus* production than we estimated. Alternatively, we know our size-structured abundance estimate of Lake Trout did not include some size-classes of fish >600 mm TL that were sampled at other times of year by other methods. Further, Hansen et al. (1997) showed that the relative selectivity of five mesh sizes of gill nets for Lake Trout peaked at 638 mm TL. Thus, we may have underestimated the abundance of piscivorous (≥600 mm) Lake Trout and their predation on the *Oncorhynchus* population. Independent validation of Lake Trout abundance estimates (e.g., mark-recapture) and development of a method for estimating age-0 *Oncorhynchus* spp. should be considered in future studies at Buffalo Bill Reservoir.

Before the arrival of Walleye, Buffalo Bill Reservoir was essentially a two-story fishery (Budy et al. 2009) with a hypolimnetic piscivore and an epilimnetic omnivore segregated by thermal stratification. This configuration provided a self-sustaining fishery for both taxa for decades. The apparent stability of Lake Trout and Cutthroat Trout populations in Buffalo Bill Reservoir is unusual compared with many other lakes in the region where Lake Trout are considered a threat to wild Cutthroat Trout populations (Table 2). Temperature alone does not explain why Lake Trout coexist with Cutthroat Trout at Buffalo Bill Reservoir. Several other waters in the region attain similar or higher epilimnetic temperatures, but Lake Trout have been harmful to Cutthroat Trout populations there (Martinez et al. 2009; Ellis et al. 2011; Schoen et al. 2012). Many of the other similar lakes in the region contain *Mysis diluviana* (Table 2), which can be an important forage base for Lake Trout (Ellis et al. 2011), and could provide a forage subsidy during stratified periods. Interestingly, Jackson and Yellowstone Lakes do not contain *Mysis*, and Lake Trout have impacted Cutthroat Trout stocks there (Behnke 2002; Martinez et al. 2009). Buffalo Bill Reservoir stands out from all the other waters in two respects: low water clarity and high Cutthroat Trout growth rate. Water clarity is 2.5 to 7 times higher in the other waters, contributing to a greatly enhanced visual field and potential encounters with prey (Beauchamp et al. 1999). Even in systems with relatively warm epilimnia, clear water could allow vertically migrating Lake Trout to forage successfully and quickly descend to cooler water, thereby preserving their physiological scope.

Cutthroat Trout in Buffalo Bill Reservoir grew faster, and thus outgrew predators more quickly, than at all the other waters (Table 2), perhaps due in part to introgression with Rainbow Trout which can grow better at high temperatures than Cutthroat Trout (Bear et al. 2007). Data on first year growth were not available for most of these waters, but by age-2 *Oncorhynchus* spp.

in Buffalo Bill Reservoir were 34–100 % larger than elsewhere. Based on the 95th percentile of the prey:predator size ratio we observed, age-2 *Oncorhynchus* spp. exceeded the gape limit of nearly all Lake Trout <600 mm TL, which included the majority of Lake Trout in Buffalo Bill Reservoir.

The very conditions that appear to have tempered Lake Trout piscivory may make Buffalo Bill Reservoir more favorable for the invading Walleye population. Although Buffalo Bill temperatures rarely reach the Walleye's optimum, Walleye were not functionally limited to the extent that Lake Trout were. As one would predict based on Walleye life history and thermal preferences (Kitchell et al. 1977b), we found that Walleye predominately inhabited the epilimnion. But, Walleye could inhabit deeper, cooler water without adverse physiological effects; natural populations of Walleye occur at much colder thermal regimes than at Buffalo Bill Reservoir (Bozek et al. 2011). Water temperature and clarity in Buffalo Bill Reservoir should not have constrained Walleye foraging behavior the way it did for Lake Trout. Walleye always co-occurred with *Oncorhynchus* spp., where light was less limiting and temperatures were favorable. Scotopic vision allows Walleye to forage efficiently in turbid water (Bozek et al. 2011) and, in fact, they prefer moderate turbidity (Kitchell et al. 1977b).

Unlike Lake Trout which typically exhibit a transition to a fish diet at a relatively large size (Mittelbach and Persson 1998; Johnson and Martinez 2000), Walleye can begin eating other fish when they are as small as 20 mm TL (Mathias and Li 1982; Chipps and Graeb 2011). In Buffalo Bill Reservoir all sizes of Walleye examined (122–589 mm TL) were found to be consuming *Oncorhynchus* spp. throughout the open water period, depriving *Oncorhynchus* spp. of the opportunity to grow out of the gape limit of predators while Lake Trout were confined to deep water. Thus, morphological and spatial availability of *Oncorhynchus* spp. as a prey source was greater for Walleye than for Lake Trout. The predation refuge that *Oncorhynchus* spp. once experienced with Lake Trout was eliminated when Walleye arrived; *Oncorhynchus* spp. are now trapped between both shallow water and deep water predators.

The outcome of this restructuring of the food web is uncertain at this time. Although Walleye did not appear to be very abundant during our study, we believe our abundance estimate from hydroacoustics was negatively biased because the survey did not cover littoral areas that Walleye might favor based on their demersal habits (Bozek et al. 2011) and the turbidity and temperature regime at Buffalo Bill Reservoir. Further, many introduced species exhibit a lag phase before they become invasive (Crooks 2005). Given that Lake Trout were already consuming a sizeable fraction of *Oncorhynchus* biomass, and because the per capita consumptive demand of Walleye and Lake Trout were similar, we speculate that a growing Walleye population would pose a predation risk to the *Oncorhynchus* population and compete with Lake Trout for piscine prey. Any reduction in *Oncorhynchus* population productivity, for example from environmental change or reduced reproductive success, would exacerbate predation impacts. Our study provides a baseline to compare with future monitoring work at the reservoir.

Considerable differences in habitat preferences probably explain why co-occurrence of Lake Trout and Walleye within their shared native range is somewhat rare (Johnson et al. 1977; Bertolo and Magnan 2006). However, illegal introductions and subsequent natural dispersal are bringing these species together and creating novel assemblages of apex predators in coldwater lakes and reservoirs of the western U.S. Numerous illegal introductions of Walleye have occurred in the Flathead and Clark Fork river systems of Montana and Idaho, increasing concerns about impacts to native Cutthroat Trout (McMahon and Bennett 1996; Montana AFS

2004). Illegal stocking of Walleye has also been widespread in the Southern Rockies (Johnson et al. 2009) including at least four reservoirs in Wyoming. If illegal introductions and facilitated invasions continue, co-occurrence of Walleye and Lake Trout may become more prevalent, to the potential detriment of prey fish species. Individually, both piscivores have been found to adversely affect *Oncorhynchus* spp. populations and fisheries (Poe et al. 1991; Baldwin et al. 2003; Ruzycki et al. 2003; Martinez et al. 2009). Our work on Buffalo Bill Reservoir suggests that the co-occurrence of Lake Trout and Walleye could amplify these adverse effects as their combination eliminates morphological and spatial refugia, making prey fish particularly vulnerable.

Table 1. Seasonal thermal experience of Walleye and Lake Trout in Buffalo Bill Reservoir, Wyoming determined from water temperature profiles and effort-weighted catch in depth-stratified gill net sets. Thermal experience is linearly interpolated between data points in the bioenergetics model.

		Temperature (°C)	
Date	Day of year	Walleye	Lake Trout
1-Jan	1	4.0	4.0
1-Mar	60	4.0	4.0
23-Apr	113	6.6	6.6
15-May	135	8.0	8.0
17-Jul	198	19.1	14.1
16-Aug	228	18.5	14.4
9-Sep	252	18.6	14.4
26-Oct	299	10.1	10.1
15-Nov	319	7.2	7.2
28-Nov	332	4.2	4.2
31-Dec	365	4.0	4.0

Table 2. Environmental conditions at Buffalo Bill Reservoir (present study) and seven western United States lakes and reservoirs with introduced Lake Trout and wild Cutthroat Trout. YCT is Yellowstone Cutthroat Trout (hybridized with Rainbow Trout in Buffalo Bill Reservoir), SNR is Snake River Cutthroat Trout *O. c. behnkei*, WCT is Westslope Cutthroat Trout *O. c. lewisi*, LCT is Lahontan Cutthroat Trout *O. c. henshawi*. Mean peak surface temperature measured at 1 m (averaged over years available). Average Secchi depth (range in parentheses) averaged across all sites and open-water dates available.

Water (State)	Cutthroat subspecies	*Mysis* present?	Elevation (m)	Peak surface temp (°C)	Secchi depth (m)	TL at age 2 (mm)
Buffalo Bill (WY)	YCT	N	1,644	20.0 (2)	1.9 (0.5–4.1)	273
Yellowstone (WY)	YCT	N	2,359	17.9 (4)[a]	7.6 (3.3–12.8)[a]	140l
Jackson (WY)	SNR	N	2,062	17.5 (1)[b]	5.1 (1.0–7.5)[h]	203[m]
Flathead (MT)	WCT	Y	881	20.0 (1)[c]	7.8 (0.4–14.9)[i]	203[m]
Pend Oreille (ID)	WCT	Y	629	23.5 (2)[d]	8.0 (2.7–11.5)[j]	148[n]
Priest (ID)	WCT	Y	743	23.4 (2)[e]	8.0 (5.2–9.3)[e]	147[o]
Chelan (WA)	WCT	Y	335	21.7 (4)[f]	10.8 (7.6–14.0)[f]	ND
Fallen Leaf (CA)	LCT	Y	1,953	18.7 (2)[g]	13.0 (6.1–15.2)[k]	ND

[a]J. L. Arnold, National Park Service, unpublished data.
[b]Brewer 1995.
[c]Spencer et al. 1999.
[d]Annear et al. 2006.
[e]Venard, and Scarnecchia 2005; Rieman and Maiolie 1995.
[f]Chelan Public Utility District 2000.
[g]Al-Chokhachy et al. 2009; Allen et al. 2006.
[h]Wurtsbaugh and Luecke 2014.
[i]Ellis and Craft 2008.
[j]PBS&J 2009.
[k]USEPA 1978.
[l] Gresswell 1995.
[m]Trotter 1987.
[n]Young 1995.
[o]McIntyre and Rieman 1995.

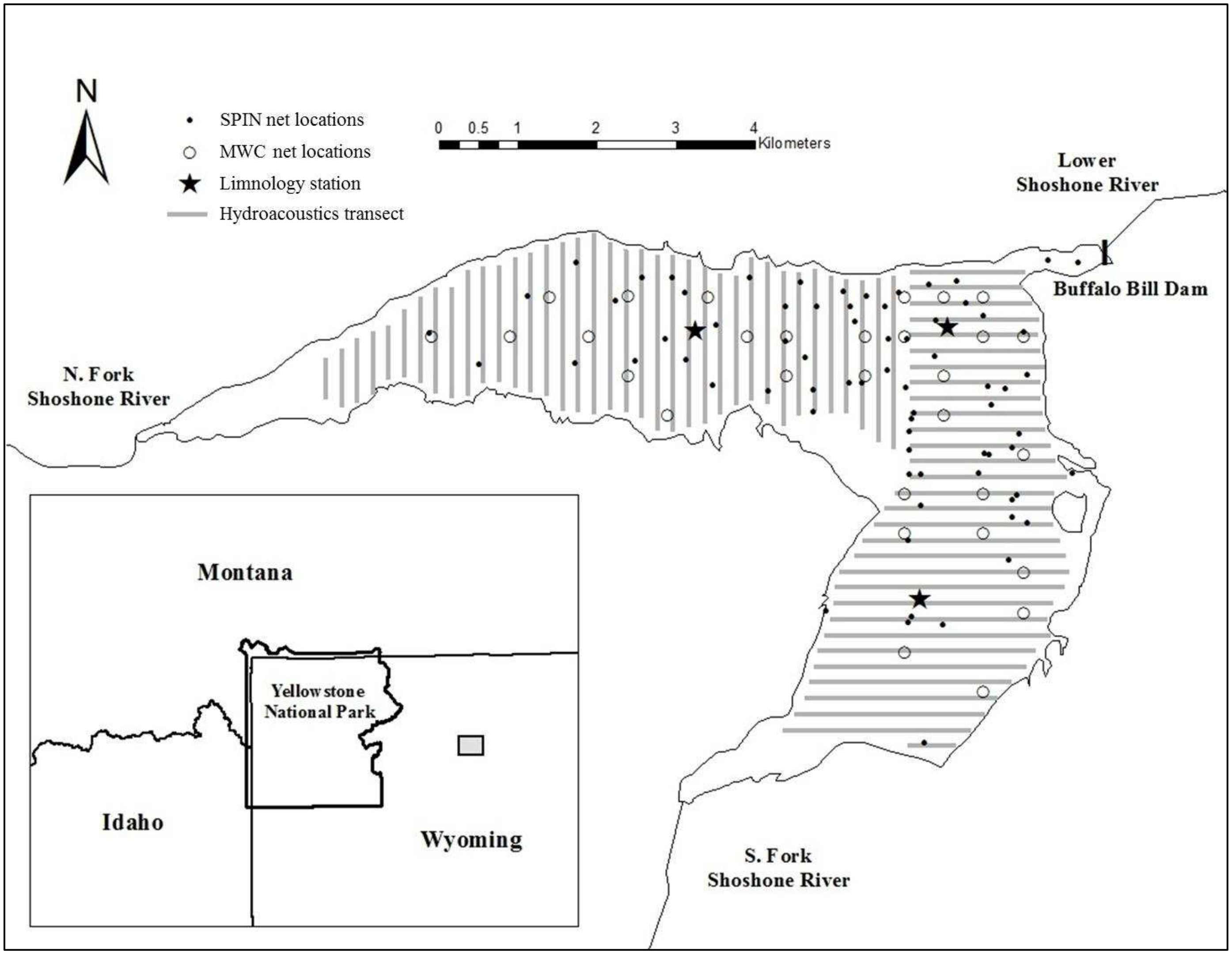

Figure 1. Map of Buffalo Bill Reservoir showing locations of hydroacoustics transects, mid-water curtain (MWC), and summer profundal index nets (SPIN) for August 2013. Limnology sampling locations are also depicted where sampling took place monthly.

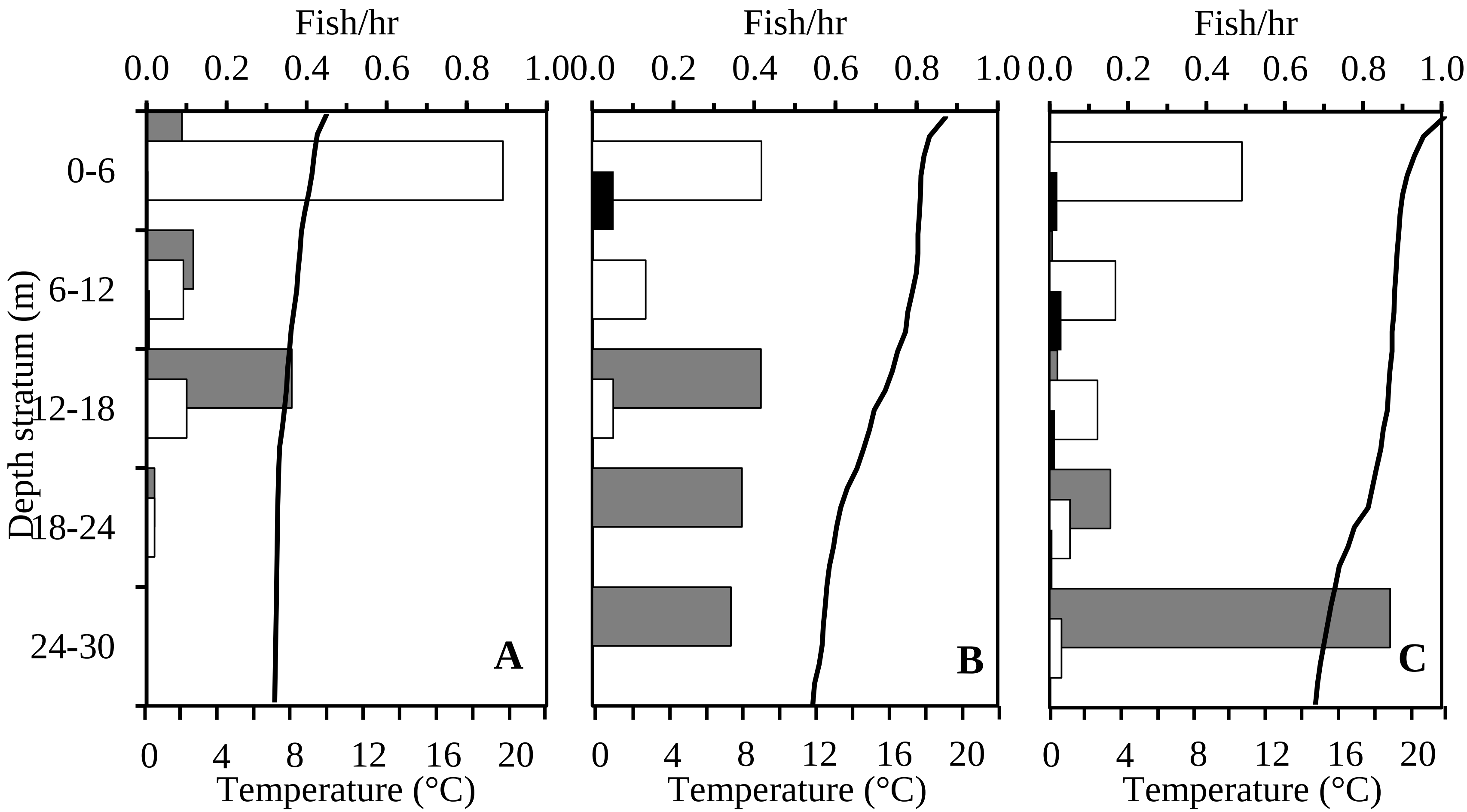

Figure 2. Depth distribution of pelagic *Oncorhynchus* (white bars), Lake Trout (gray bars), and Walleye (black bars) sampled during A) April and May 2012 (*n* = 24 nets), B) July 2012 (*n* = 15 nets) and C) August 2012 and 2013 (*n* = 65 nets) with mid-water curtain (MWC) nets sets on Buffalo Bill Reservoir. The MWC nets were set to a maximum depth of 30 m. The solid lines show the mean temperature profile during each period.

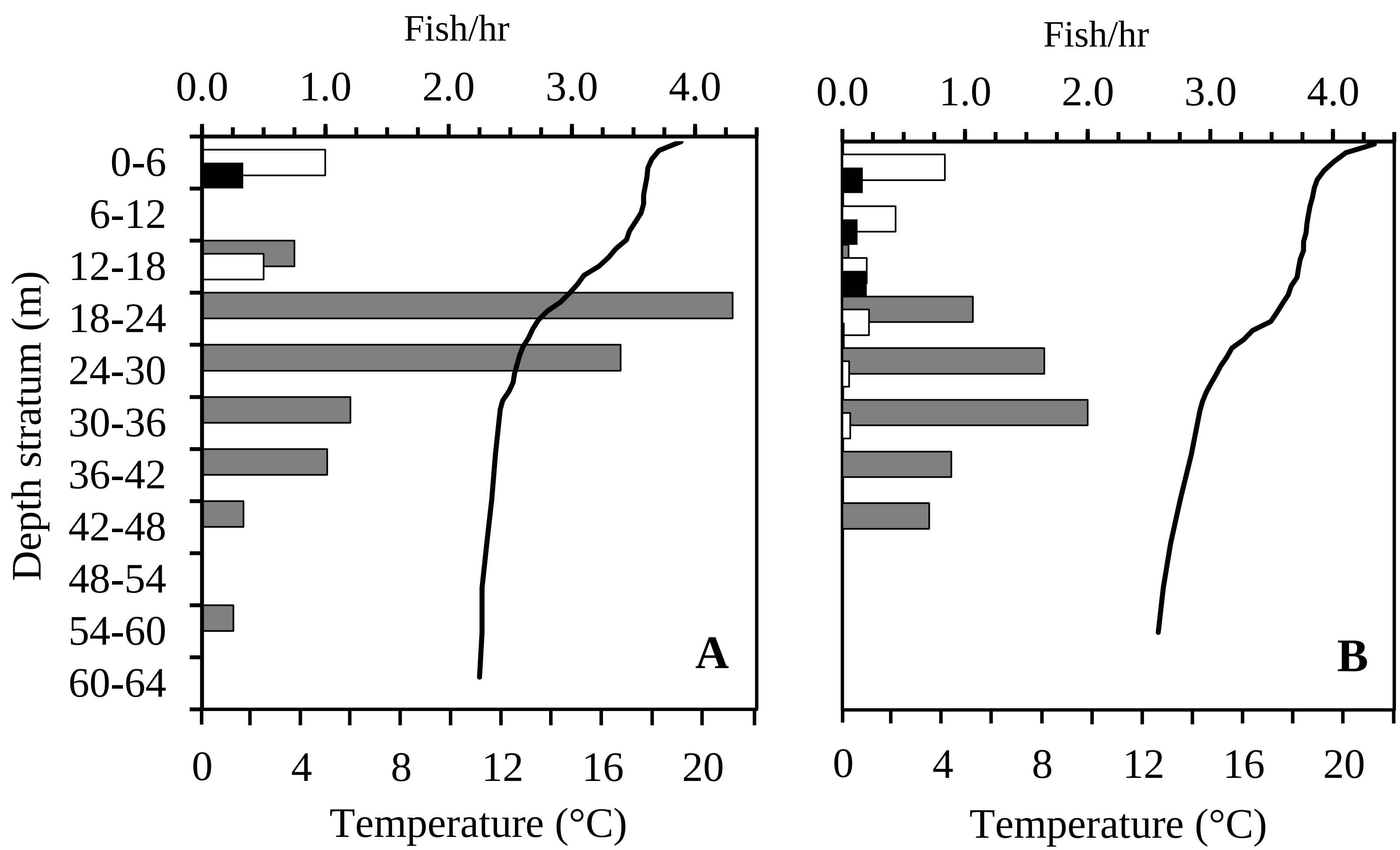

Figure 3. Depth distribution of *Oncorhynchus* (white bars), Lake Trout (gray bars), and Walleye (black bars) sampled during July 2012 (A) and August 2012 and 2013 (B) with summer profundal index net (SPIN) sets (n = 150 sets) at Buffalo Bill Reservoir. The SPIN nets were set to a maximum depth of 64 m. The solid line shows the mean temperature profile during August of both years.

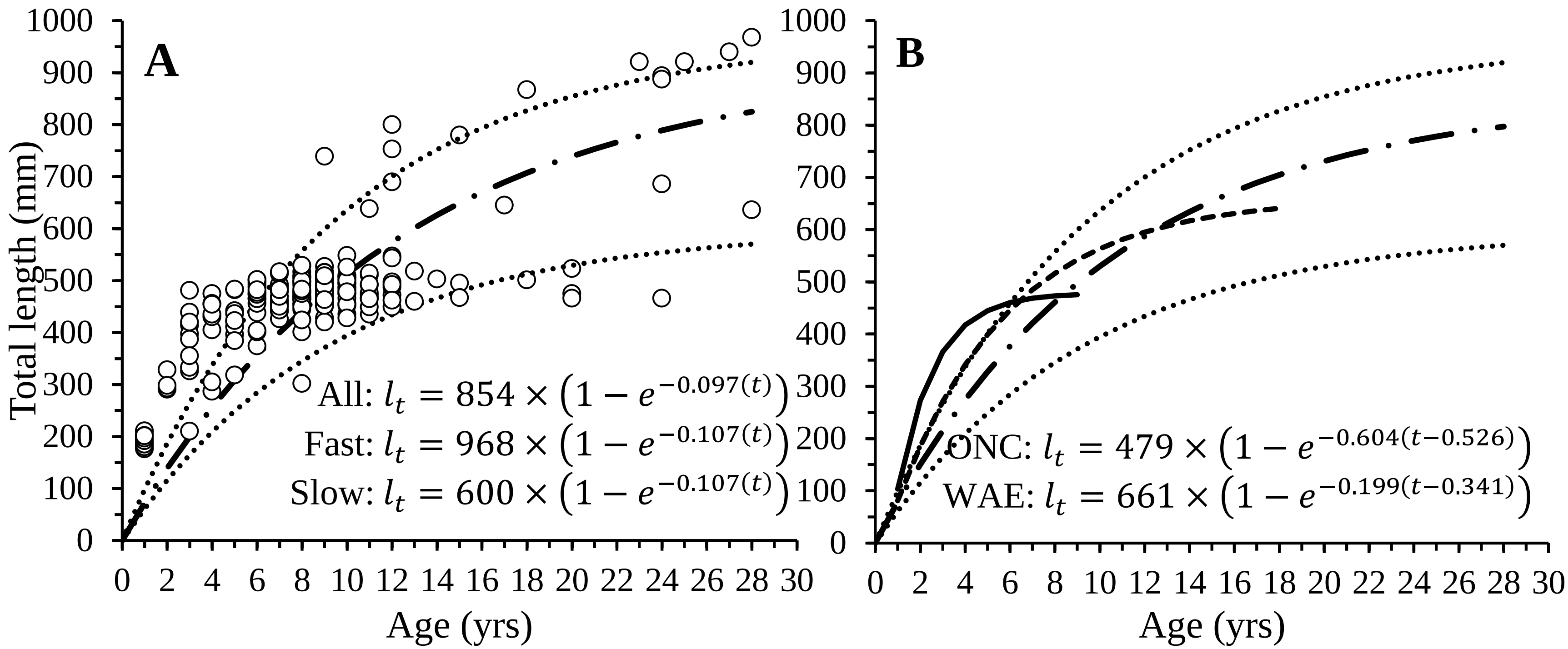

Figure 4. A) Length at age of Lake Trout with von Bertalanffy growth functions fit to all data (dash-dot line, n = 210) and two additional curves (dotted lines) to characterize apparent fast growing and slow growing subpopulations for bioenergetics simulations. B) Growth trajectories of Lake Trout (dash-dot and dotted lines), Walleye (WAE, dashed line, n = 309), and *Oncorhynchus* spp. (ONC, solid line, n = 91.

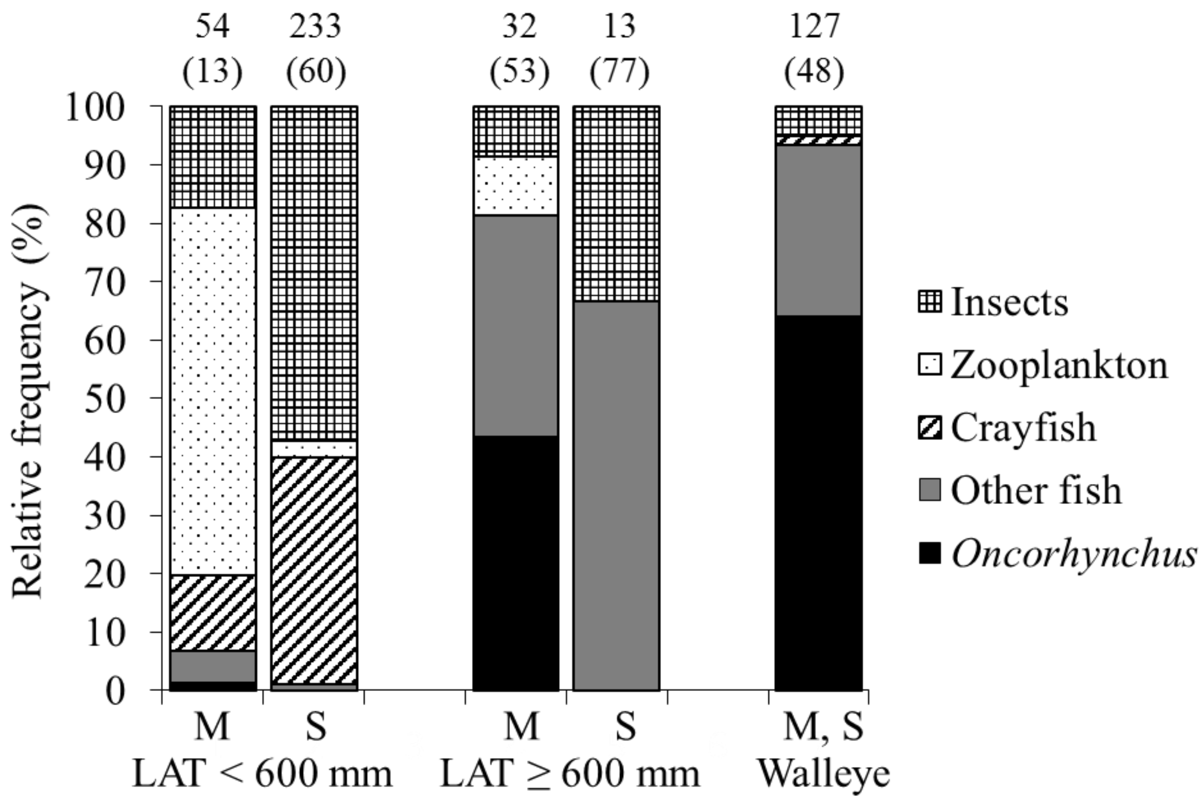

Figure 5. Diet composition (relative frequency by volume) of Walleye (122–589 mm TL) and two size classes of Lake Trout (LAT) when the water column was mixed (M, April–May and October) and stratified (S, June–September). Lake Trout size classes corresponded with two divergent growth trajectories (From Figure 5). "Other fish" category includes, Catostomids, Yellow Perch, and fish that could not be identified to family. Number of stomach samples and percentage of empty stomachs (in parentheses) appear above each bar.

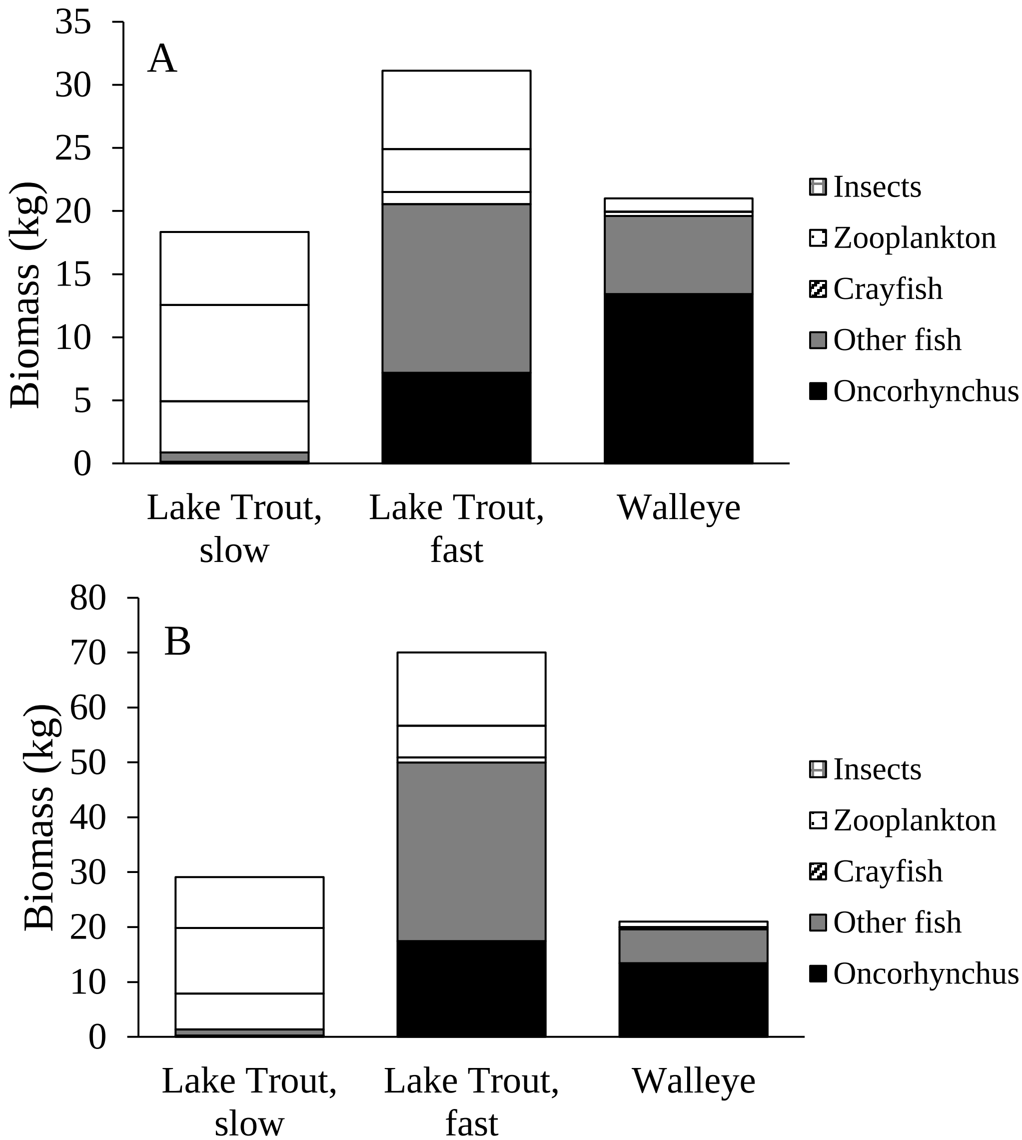

Figure 6. Per capita consumption of prey by two ecotypes of Lake Trout and by Walleye in Buffalo Bill Reservoir, Wyoming, estimated with bioenergetics models. A) Consumption by ages 1–18 of each species; B) lifetime consumption by Lake Trout (28 years) and Walleye (18 years).

REFERENCES

Al-Chokhachy, R., M. Peacock, L. G. Heki, and G. Thiede. 2009. Evaluating the reintroduction potential of Lahontan Cutthroat Trout in Fallen Leaf Lake, California. North American Journal of Fisheries Management 29:1296–1313.

Ali, M., R. Ryder, and M. Anctil. 1977. Photoreceptors and visual pigments as related to behavioral responses and preferred habitat of perches (*Perca* spp.) and pikeperches (*Stizostedion* spp.). Journal of the Fisheries Board of Canada 34:1475–1480.

Allen, B. C., S. Chandra, L. Atwell, J. Vander Zanden, and J. E. Reuter. 2006. Evaluation of the re-introduction of native Lahontan Cutthroat Trout, *Onchorhynchus clarki henshawi*, in Fallen Leaf Lake, California, and development of management strategies for recovery. Final Report, U.S. Fish and Wildlife Service, Reno, Nevada.

Allen, M. S., and J. E. Hightower. 2010. Fish population dynamics: mortality, growth, and recruitment. Pages 43-79 in W. A. Hubert and M. C. Quist, editors. Inland fisheries management in North America, third edition. American Fisheries Society, Bethesda, Maryland.

Annear, R., C. Berger, and S. Wells. 2006. Pend Oreille River model: model development and calibration. Technical Report EWR-02-06, Water Quality Research Group, Portland State University, Portland, Oregon.

Baldwin, C. M., D. A. Beauchamp, and J. J. Van Tassell. 2000. Bioenergetic assessment of temporal food supply and consumption demand by salmonids in the strawberry reservoir food web. Transaction of the American Fisheries Society 129:429–450.

Baldwin, C. M., J. G. McLellan, M. C. Polacek, and K. Underwood. 2003. Walleye predation on hatchery releases of kokanees and rainbow trout in Lake Roosevelt, Washington. North American Journal of Fisheries Management 23:660–676.

Baxter, G. T., and M. D. Stone. 1995. Fishes of Wyoming. Wyoming Game and Fish Department.

Bear, E.A., T. E. McMahon, and A. V. Zale. 2007. Comparative thermal requirements of Westslope Cutthroat Trout and Rainbow Trout: implications for species interactions and development of thermal protection standards. Transactions of the American Fisheries Society 136:1113-1121.

Beauchamp, D.A. 1990. Seasonal and diel food habits of rainbow trout stocked as juveniles in Lake Washington. Transactions of the American Fisheries Society 119:475-482.

Beauchamp, D. A., C. M. Baldwin, J. L. Vogel, and C. P. Gubala. 1999. Estimating diel, depth-specific foraging opportunities with a visual encounter rate model for pelagic piscivores. Canadian Journal of Fisheries and Aquatic Sciences 56:128–139.

Behnke, R. J. 2002. Trout and salmon of North America. The Free Press, New York, New York.

Bertolo, A., and P. Magnan. 2006. Spatial and environmental correlates of fish community structure in Canadian Shield lakes. Canadian Journal of Fisheries and Aquatic Sciences 63:2780–2792.

Billington, N. and B. L. Sloss. 2011. Distribution and population genetics of walleye and sauger. Pages 105–132 in B. A. Barton, editor. Biology management and culture of Walleye and Sauger. American Fisheries Society, Bethesda, Maryland.

Blanton, J. O. 1991. Buffalo Bill Reservoir 1986 sedimentation survey. Bureau of Reclamation. 75pp.

Bozek, M. A., D. A. Baccante, and N. P. Lester. 2011. Walleye and sauger life history. Pages 233–301 in B. A. Barton, editor. Biology, management, and culture of walleye and sauger. American Fisheries Society, Bethesda, Maryland.

Brewer, C. A. 1995. The submersed aquatic plant community in Jackson Lake, Grand Teton National Park, Wyoming. Available: http://repository.uwyo.edu/uwnpsrc_reports/vol19/iss1/4 (December 2015).

Budy, P., G. P. Thiede, C. Luecke, and R. Schneidervin. 2009. Warmwater and coldwater fish in two-story standing waters. Pages 159-170 in S.A. Bonar, W.A. Hubert and D.W. Willis, editors. Standard methods for sampling North American fishes. American Fisheries Society. Bethesda, Maryland.

Carlander, K. D. 1969. Handbook of freshwater fishery biology, volume 1. Iowa State University Press, Ames.

Carlander, K. D. 1997. Handbook of freshwater fishery biology, volume 3. Iowa State University Press, Ames.

Carleton, S. A., W. R. Gould, J. A. Hobbs, J. C. Burckhardt, C. F. Johnson, and B. M. Johnson. 2015. Otolith microchemistry reveals the timing, origins, and reproductive status of illegally introduced Walleye in a Wyoming reservoir. In preperation.

Chelan Public Utility District. 2000. Lake Chelan 1999 water quality monitoring report. Available: http://www.chelanpud.org/relicense/study/reports/3796_1.pdf (December 2015).

Chipps, S. R. and B. D. S. Graeb. 2011. Feeding ecology and energetics. Pages 303-319 in B. A. Barton, editor. Biology management and culture of Walleye and Sauger. American Fisheries Society, Bethesda, Maryland.

Christie, G. C., and H. A. Regier. 1988. Measures of optimal thermal habitat and their relationship to yields for four commercial fish species. Canadian Journal of Fisheries and Aquatic Sciences 45:301–314.

Coutant, C. C. 1987. Thermal preference: when does an asset become a liability. Environmental Biology of Fishes 18:161–172.

Crooks, J. A. 2005. Lag times and exotic species: The ecology and management of biological invasions in slow-motion. Ecoscience 12:316–329.

Ellis, B. K. and J. A. Craft. 2008. Trophic status and trends in water quality for volunteer monitoring program lakes in northwestern Montana, 1993-2007. FLBS Report 200-08, The Flathead Basin Commission, Kalispell, Montana.

Ellis, B. K., J. A. Stanford, D. Goodman, C. P. Stafford, D. L. Gustafson, D. A. Beauchamp, D. W. Chess, J. A. Craft, M. A. Deleray, and B. S. Hansen. 2011. Long-term effects of a trophic cascade in a large lake ecosystem. Proceedings of the National Academy of Sciences 108:1070–1075.

Fuller, P., and M. Neilson. 2015. *Salvelinus namaycush*. Nonindigenous Aquatic Species Database. United States Geological Survey. Available: nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=942 (July 2015).

Gangl, R. S., and R. A. Whaley. 2004. Comparison of fish density estimates from repeated hydroacoustic surveys on two Wyoming waters. North American Journal of Fisheries Management 24:1279–1287.

Gresswell, R. E. 1995. Yellowstone Cutthroat Trout. Pages 36-54 in M. Young, editor. Conservation assessment for inland Cutthroat Trout. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Gresswell, R. E. 2011. Biology, status, and management of the Yellowstone Cutthroat Trout. North American Journal of Fisheries Management 31:782–812.

Hansen, M. J., C. P. Madenjian, J. H. Selgeby, and T. E. Helser. 1997. Gillnet selectivity for lake trout (*Salvelinus namaycush*) in Lake Superior. Canadian Journal of Fisheries and Aquatic Sciences 54:2483–2490.

Hanson, P. C., T. B. Johnson, D. E. Schindler, and J. F. Kitchell. 1997. Fish Bioenergetics 3.0. University of Wisconsin Sea Grant Institute Publication WISCU-T-97-001, Madison, WI.

Hartman, K. J., and S. B. Brandt. 1995. Estimating energy density of fish. Transactions of the American Fisheries Society 124:347–355.

Hasnain, S. S., C. K. Minns, and B. J. Shuter. 2010. Key ecological temperature metrics for Canadian freshwater fishes. Ontario Ministry of Natural Resources, Applied Research and Development Branch, Climate Change Research Report CCCRR-17, Peterborough.

Hayes, D. B., J. R. Bence, T. J. Kwak, and B. E. Thompson. 2007. Abundance, biomass and production. Pages 327–374 *In* Guy, C. S. and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, MD.

Horne, A. J., and C. R. Goldman. 1994. Limnology. 2nd edition. McGraw Hill, Inc.

Hrabik, T. R., O. P. Jensen, S. J. D. Martell, C. J. Walters, and J. F. Kitchell. 2006. Diel vertical migration in the Lake Superior pelagic community. I. Changes in vertical migration of coregonids in response to varying predation risk. Canadian Journal of Fisheries and Aquatic Sciences 63:2286–2295.

Idso, S. B, and R. G. Gilbert. 1974. On the universality of the Poole, Atkins Secchi disk-light extinction equation. Journal of Applied Ecology 11:399–401.

Isely, J. J. and T. B. Grabowski. 2007. Age and growth. Pages 187–228 *In* Guy, C. S. and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, MD.

Johnson, B. M. and P.J. Martinez. 2000. Trophic economics of lake trout management in reservoirs of differing productivity. North American Journal of Fisheries Management 20:115–131.

Johnson, B. M., and P. J. Martinez. 2012. Hydroclimate mediates effects of a keystone species in a coldwater reservoir. Lake and Reservoir Management 28:70–83.

Johnson, B. M., R. Arlinghaus, and P. J. Martinez. 2009. Are we doing all we can to stem the Tide of Illegal Fish Stocking? Fisheries 34:389–394.

Johnson, B. M., J. M. Lepak, and B. A. Wolff. 2015. Effects of prey assemblage on mercury bioaccumulation in a piscivorous sport fish. Science of the Total Environment 506-507:330–337.

Johnson, M. G., J. H. Leach, C. K. Minns, and C. H. Olver. 1977. Limnological characteristics of Ontario lakes in relation to associations of walleye (*Stizostedion vitreum vitreum*), northern pike (*Esox lucius*), lake trout (*Salvelinus namaycush*), and smallmouth bass (*Micropterus dolomieue*). Journal of the Fisheries Research Board of Canada 34:1592–1601.

Kaeding, L. R. 2012. Are Yellowstone Lake temperatures more suitable to nonnative lake trout than to native cutthroat trout? North American Journal of Fisheries Management 32:848–852.

Keast, A. and J. M. Eadie. 1985. Growth depensation in year-0 largemouth bass: the influence of diet. Transactions of the American Fisheries Society 114:204–213.

Kitchell, J. F., D. J. Stewart, and D. Weininger. 1977a. Applications of a bioenergetics model to yellow perch (*Perca flavescens*) and walleye (*Stizostedion vitreum vitreum*). Fisheries Research Board of Canada 34:1922–1935.

Kitchell, J. F., M. G. Johnson, C. K. Minns, K. H. Loftus, L. Greig, and C. H. Olver. 1977b. Percid habitat: the river analogy. Journal of the Fisheries Research Board of Canada 34:1936–1940.

Lantry, B. F. and R. O'Gorman. 2007. Drying temperature effects on fish dry mass measurements. Journal of Great Lakes Research 33:606–616.

Lind, O. T. 1979. Handbook of common methods in limnology, second edition. The C.V. Mosby Company, St. Louis, MO.

Lind, O. T. 1986. The effect of non-algal turbidity on the relationship of Secchi depth to chlorophyll a. Hydrobiologia 140:27–35.

Luecke, C. and D. Brandt. 1993. Notes: estimating the energy density of daphnid prey for use with rainbow trout bioenergetics models. Transactions of the American Fisheries Society 122:386–389.

Madenjian, C. P., S. A. Pothoven, and Y. C. Kao. 2013. Reevaluation of lake trout and lake whitefish bioenergetics models. Journal of Great Lakes Research 39:358–364.

Madenjian, C. P., and C. Wang. 2013. Reevaluation of a walleye (*Sander vitreus*) bioenergetics model. Fish physiology and biochemistry 39:749–754.

Magnuson, J. J., L. B. Crowder, and P. A. Medick. 1979. Temperature as an ecological resource. American Zoologist 19:331–343.

Martin, N. V. 1957. Reproduction of lake trout in Algonquin Park, Ontario. Transactions of the American Fisheries Society 86:231–244.

Martinez, P. J., P. E. Bigelow, M. A. Deleray, W. A. Fredenberg, B. S. Hansen, N. J. Horner, S. K. Lehr, R. W. Schneidervin, S. A. Tolentino, and A. E. Viola. 2009. Western lake trout woes. Fisheries 34:424–442.

Mathias, J. A., and S. Li. 1982. Feeding habits of walleye larvae and juveniles: comparative laboratory and field studies. Transactions of the American Fisheries Society 111:722–735.

Mazur, M. M., and D. A. Beauchamp. 2003. A comparison of visual prey detection among species of piscivorous salmonids: effects of light and low turbidities. Environmental Biology of Fishes 67:397–405.

McIntyre, J.D., B. E. Rieman. 1995. Westslope Cutthroat Trout. Pages 1-15 in M. Young, editor. Conservation assessment for inland Cutthroat Trout. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

McMahon, T. E. and D. H. Bennett. 1996. Walleye and northern pike: boost or bane to northwest fisheries? Fisheries 21:6–13.

Mittelbach, G. G. and L. Persson. 1998. The ontogeny of piscivory and its ecological consequences. Canadian Journal of Fisheries and Aquatic Sciences 55: 1454–1465.

Miranda, L. E., and P. W. Bettoli. 2007. Mortality. Pages 229–277 in C. S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, MD.

Montana AFS (American Fisheries Society). 2004. Letter to Commissioners. Montana Chapter of the American Fisheries Society. Available: http://www.montanaafs.org/wp-content/uploads/WE_INTRODUCTION_08312004.pdf (July 2015).

Muhlfeld, C. C., J. J. Giersch, and B. Marotz. 2012. Seasonal movement s of non-native lake trout in a connected lake and river system. Fisheries Management and Ecology 19:224–232.

Neebling, T. E. 2014. Standard methods for field collection, post-processing, data analysis, and reporting of hydroacoustics for fisheries assessments. Wyoming Game and Fish Department Administrative Report, Cheyenne.

Neumann, R. M., C. S. Guy, and D. W. Willis. 2012. Length, weight, and associated indices. Pages 637–676 *In* A. V. Zale, D. L. Parrish, T. M. Sutton, editors. Fisheries Techniques. American Fisheries Society, Behesda, MD.

Pate, W. M., B. M. Johnson, J. M. Lepak, and D. Brauch. 2014. Managing for coexistence of kokanee and trophy lake trout in a montane reservoir. North American Journal of Fisheries Management 34:908–922.

Pauly, D., J. Moreau and F. C. Gayanilo, Jr. 1998. Auximetric analyses. Pages 130-134 in R. Froese and D. Pauly, editors. FishBase 1998: concepts, design and data sources. ICLARM, Manila, Philippines.

PBS&J. 2009. Water quality status and trends in the Clark Fork-Pend Oreille watershed. Available: https://www.deq.idaho.gov/media/892772-trends-analysis-1984-2007.pdf (December 2015).

Poe, T. P., H. C. Hansel, S. Vigg, D. E. Palmer, and L. A. Prendergast. 1991. Feeding of predaceous fishes on out-migrating juvenile salmonids in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:405–420.

Quist, M. C., and W. A. Hubert. 2004. Bioinvasive species and the preservation of cutthroat trout in the western United States: ecological, social, and economic issues. Environmental Science and Policy 7:303–313.

Rand, P. S., D. J. Stewart, P. W. Seelbach, M. L. Jones, and L. R. Wedge. 1993. Modeling steelhead population energetics in Lakes Michigan and Ontario. Transactions of the American Fisheries Society 122:977–1001.

Rieman, B. E. and M. A. Maiolie. 1995. Kokanee population density and resulting fisheries. North American Journal of Fisheries Management 15:229-237.

Ruzycki, J. R., D. A. Beauchamp, and D. L. Yule. 2003. Effects of introduced lake trout on native cutthroat. Ecological Applications 13:23–37.

Sandstrom, S. S., and N. P. Lester. 2009. Summer profundal index netting protocol; a lake trout assessment tool. Ontario Ministry of Natural Resources. Peterborough, Ontario. Version 2009.1:22 p. + appendices.

SAS Institute Inc. 2011. SAS/STAT® 9.3 User's Guide. Cary, NC.

Schoen, E. R., D. A. Beauchamp, and N. C. Overman. 2012. Quantifying latent impacts of an introduced piscivore: pulsed predatory inertia of lake trout and decline of kokanee. Transactions of the American Fisheries Society 141:1,191–1,206.

Scott, W. B. and E J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184.

Sellers. T. J., B. R. Parker, D. W. Schindler, and W. M. Tonn. 1998. Pelagic distribution of lake trout (*Salvelinus namaycush*) in small Canadian Shield lakes with respect to temperature, dissolved oxygen, and light. Canadian Journal of Fisheries and Aquatic Sciences 55:170–179.

Shuter, B. J., M. L. Jones, R. M. Korver, and N. P. Lester. 1998. A general, life history based model for regional management of fish stocks: the inland lake trout (*Salvelinus namaycush*) fisheries of Ontario. Canadian Journal of Fisheries and Aquatic Sciences 55:2161–2177.

Snucins, E. J., and J. M. Gunn. 1995. Coping with a warm environment: behavioral thermoregulation by lake trout. Transactions of the American Fisheries Society 124:118–123.

Spencer, C. N., D. S. Potter, R. T. Bukantis, and J. A. Stanford. 1999. Impact of predation by *Mysis relicta* on zooplankton in Flathead Lake, Montana, USA. Journal of Plankton Research 21:51-64.

Stene, E. A. 1996. Shoshone project. Bureau of Reclamation. 29pp.

Stewart, D. J., D. Weininger, D. V. Rottiers, and T. A. Edsall. 1983. An energetics model for lake trout, *Salvelinus namaycush*: application to the Lake Michigan population. Canadian Journal of Fisheries and Aquatic Sciences 40:681–698.

Tabor, R., C. Luecke, and W. Wurtsbaugh. 1996. Effects of Daphnia availability on growth and food consumption of rainbow trout in two Utah reservoirs. North American Journal of Fisheries Management 16:591-599.

Trotter, P. C. 1987. Native Trout of the West. University Press of Colorado, Boulder, Colorado.

USBR (United States Bureau of Reclamation). 2013. Buffalo Bill Dam. Great Plains Region. Available:http://www.usbr.gov/projects/Facility.jsp?fac_Name=Buffalo+Bill+Dam&groupName=General (July 2015).

USEPA (United States Environmental Protection Agency). 1978. Report on Fallen Leaf Lake, El Dorado County, California. Working Paper 746, Corvallis Environmental Research Laboratory, Corvallis, Oregon.

Vander Zanden, M. J., B. J. Shuter, N. P. Lester, and J. B. Rasmussen. 2000. Within- and among-population variation in the trophic position of a pelagic predator, lake trout (*Salvelinus namaycush*). Canadian Journal of Fisheries and Aquatic Sciences 57:725–731.

Venard, J. A., and D. L. Scarnecchia. 2005. Seasonally dependent movement of lake trout between two northern Idaho lakes. North American Journal of Fisheries Management 25:635–639.

Vogel, J. L., and D. A. Beauchamp. 1999. Effects of light, prey size, and turbidity on reaction distances of lake trout (*Salvelinus namaycush*) to salmonid prey. Canadian Journal of Fisheries and Aquatic Sciences 56:1293–1297.

Wahl, D. H., Beauchamp, D. A., and Johnson, B. M. 2007. Predator-prey interactions. Pages 765-842 *In* Guy C. S. and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, MD.

Wetzel, R. G., and G. E. Likens. 1991. Limnological analysis. New York: Springer

WGFD (Wyoming Game and Fish Department). 2010. State wildlife action plan. Available: https://wgfd.wyo.gov/web2011/Departments/Wildlife/pdfs/SWAP_2012_FULL0001898.pdf (July 2015).

WGFD (Wyoming Game and Fish Department). 2011. Fish Division, basin management plan. Wyoming Game and Fish Department, Cheyenne, Wyoming.

Wurtsbaugh, W. and C. Luecke. 2014. Limnological relationships and population dynamics of fishes in Bear Lake (Utah/Idaho). Final report, Utah Division of Wildlife Resources, Salt Lake City, Utah.

Young, M. K., editor. 1995. Conservation assessment for inland Cutthroat Trout. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Yule, D. L. 2000. Comparison of Horizontal Acoustic and Purse-Seine Estimates of Salmonid Densities and Sizes in Eleven Wyoming Waters. North American Journal of Fisheries Management 20:759–775.

Yule, D. L., R. A. Whaley, P. H. Mavrakis, D. D. Miller, and S. A. Flickinger. 2000. Use of strain, season of stocking, and size at stocking to Improve fisheries for rainbow trout in reservoirs with walleye. North American Journal of Fisheries Management 20:10–18.

Zimmerman, M. S., C. C. Krueger, and R. L. Eshenroder. 2007. Morphological and ecological differences between shallow-and deep-water lake trout in Lake Mistassini, Quebec. Journal of Great Lakes Research 33:156–169.

APPENDICES I—VII

APPENDIX I: *GIS-based Map for Buffalo Bill Reservoir*

Buffalo Bill Dam was completed in 1910, before accurate topographic maps of the reservoir basin were available. For this reason, a detailed bathymetric map was not available when I began my project. My project required accurate water area and volumes to more precisely estimate fish abundance in Buffalo Bill Reservoir from hydroacoustics surveys and the summer profundal index netting (SPIN) protocol. I used Esri ArcGIS 10.2 to create a map with points that were collected during hydroacoustics surveys and from Landsat8 satellite imagery.

Because Buffalo Bill Reservoir's elevation is regulated by the dam, water surface elevation is always known to within a fraction of a foot. Buffalo Bill Reservoir typically fills throughout the spring and early summer, and is drawn down through the fall (USBR 2015). Using the water surface elevation from the day the points were collected, depths were converted to the elevations of the reservoir bottom that could be surveyed. In all, 34,826 spatially referenced depth points (x, y, z) were collected during hydroacoustics surveys. The survey took place from August 13 to 16, 2013. The survey was composed of 67 equally spaced, parallel transects, totaling 112.4 km in length (Figure I.2). However, hydroacoustics surveys took place at a time when the reservoir was not full, and the hydroacoustics equipment could not be used in water < 6.1 m deep. This left an area of unknown area and volume around the perimeter of the reservoir.

To construct a complete map that included the water's edge at full pool, points were generated from the water's edge at different reservoir elevations using the Normalized Difference Water Index (NDWI). The NDWI is a remote sensing technique that uses radiances or reflectances from red and near infrared channels to identify water from satellite imagery (Gai

1996). A particular area is photographed by the Landsat 8 satellite every 16 days, and the photographs are available for free download (USGS 2015a, 2015b). I was able to select five clear images from the 2013 satellite imagery that included 99.9% full pool elevation (USBR 2013), to 7.3 meters below full pool.

Once the water (reservoir) was identified with the NDWI, I rasterized the reservoir polygon and created a mask. From the mask, I subtracted one pixel from the edge of the reservoir raster, and converted those pixels to points using the Raster to Point tool. This left me with a series of points at the very edge of the reservoir, from the point in time that the Landsat 8 image was taken. I then assigned an elevation to each of those points that corresponded with the reservoir elevation on the day the Landsat 8 image was taken. After this was done for all of the Landsat 8 images, those points could be added to the points collected from hydroacoustic surveys. This resulted in 38,118 points that account for the whole reservoir up to 99.9% of full pool elevation.

From the GIS points, a 3-dimensional raster surface was created through interpolation (Figure I.1). There are many tools within ArcGIS to interpolate between points to generate a surface (Childs 2004). Also within ArcGIS is the Geostatistical Analyst extension that allows the user to test and create a statistically valid surface (Johnston et al. 2001). Within the Geostatistical Analyst extension, the Geostatistical Wizard allows the user to assess surfaces before moving on to further analyses. Within this wizard, the user can optimize interpolation parameters, plot for cross validation and error, and generate summary reports of how the surface was created. For further information on the Geostatistical Analyst extension, see Johnston et al. (2001). I chose to use the Geostatistical Analyst extension for the above reasons, and used inverse distance weighted interpolation (IDW). I chose IDW because it assumes that close by points are more alike than those that are farther apart (Esri 2013).

Because of the interpolation process, the resulting map did not have "clean" edges. From here I could use the Clip tool to cut away any part of the raster surface that extended beyond the shape file generated from the NDWI when the reservoir was at 99.9% capacity. Once the map was completed, I calculated the area or volume of discrete areas or depth strata of the reservoir. All of this was done using the Surface Volume tool in ArcGIS. This tool calculates volume and area of a space between the map surface and a reference plane. The reference plane can be set at any desired elevation and the area and volume can be calculated above or below the plane. So, I could set the first reference plane to the reservoir elevation on the day the reservoir was sampled and calculate the area and volume of water in specified layers of the reservoir on that day.

I also used the detailed map to create a basemap to visualize the reservoir's surface showing hydroacoustics transect locations, limnology sampling locations, and netting locations (Figure I.2). All files generated from mapping and calculating area and volume will be given to the Wyoming Game and Fish Department for any future use on Buffalo Bill Reservoir.

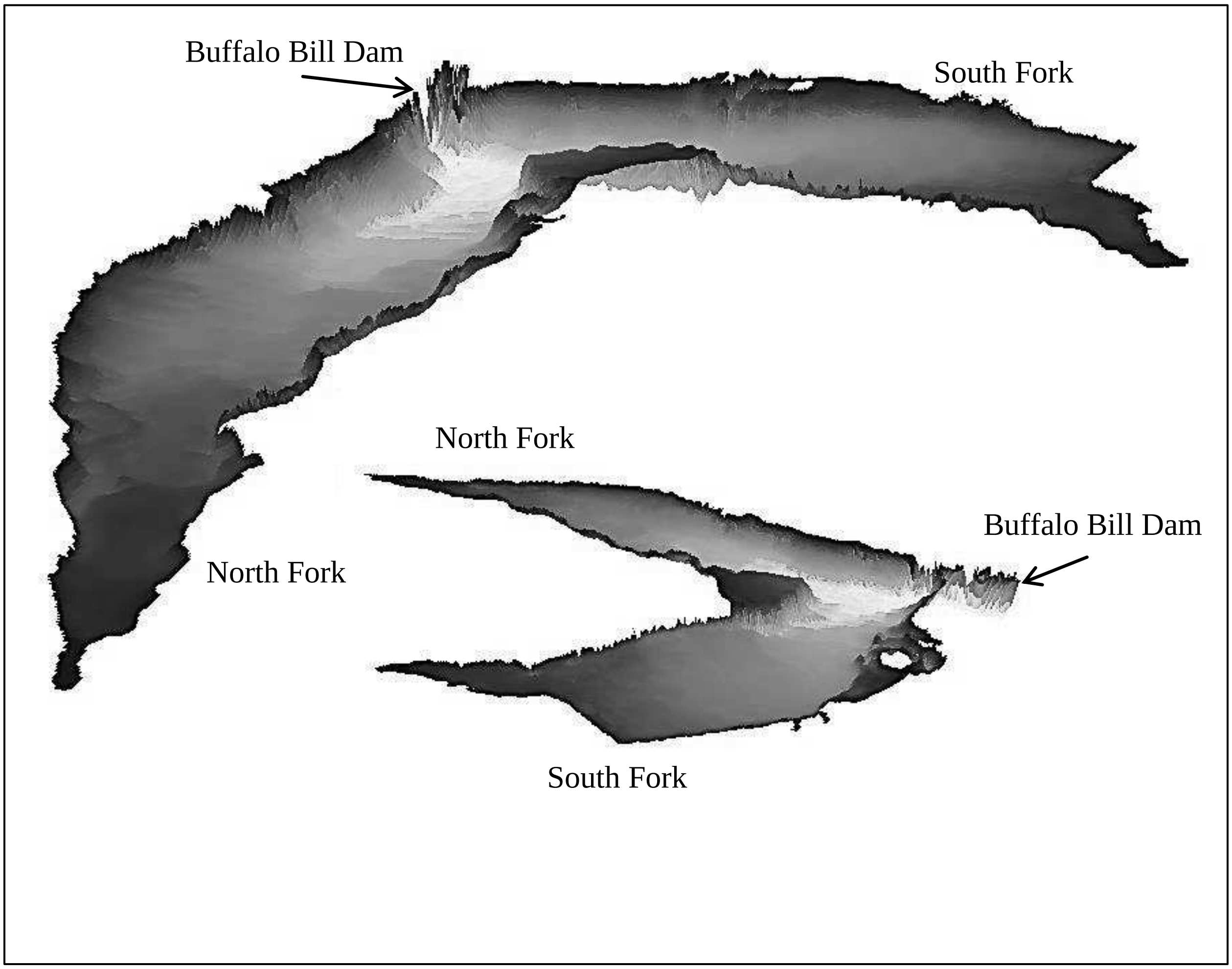

Figure I.1. Two views of the three-dimensional map of Buffalo Bill Reservoir constructed in ArcGIS 10.2 using points collected from Landsat 8 images using Normalized Difference Water Index (NDWI) and hydroacoustics surveys.

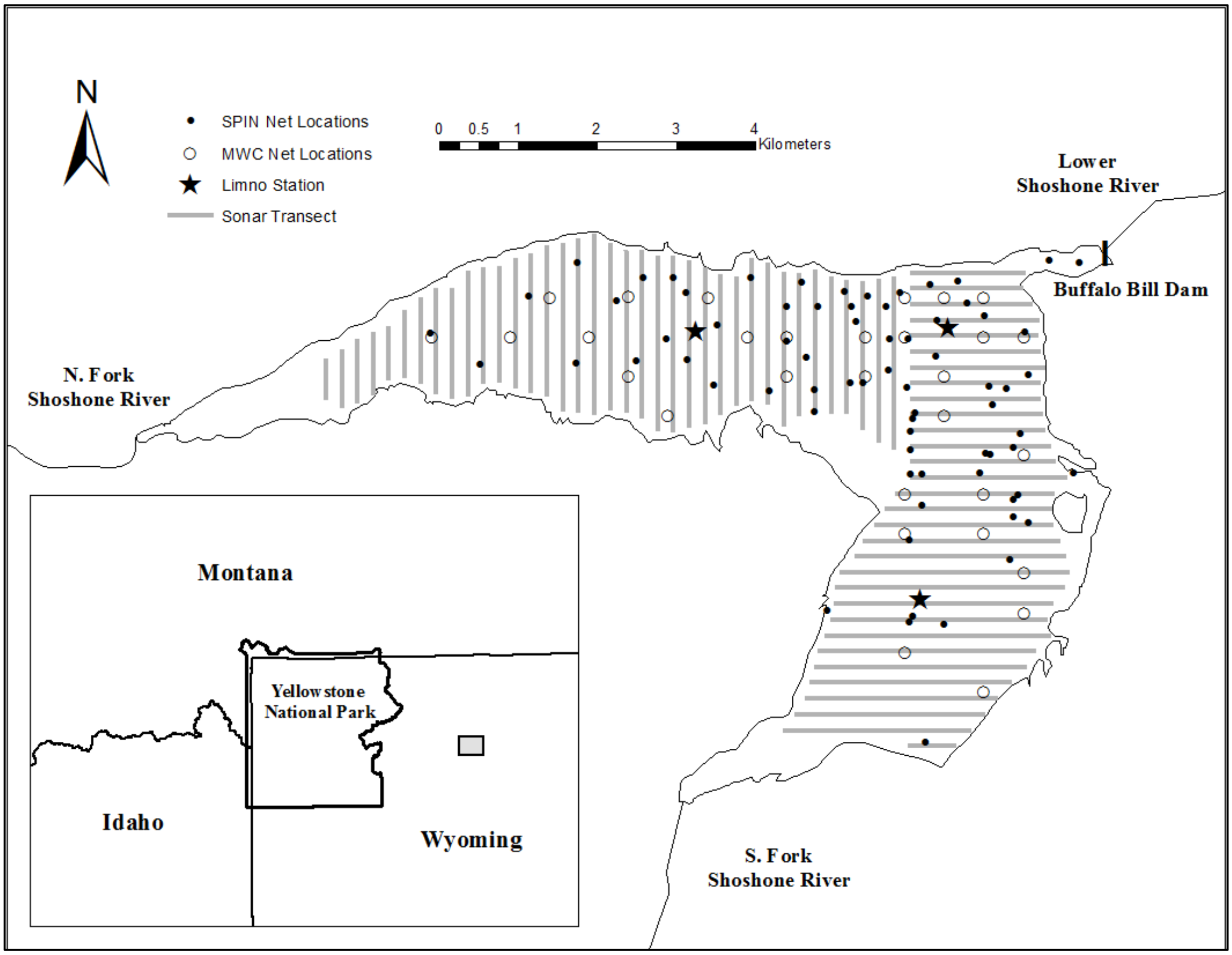

Figure I.2. Map of Buffalo Bill Reservoir showing locations of hydroacoustic transects, mid-water curtain, and summer profundal index nets (SPIN) for August 2013. Limnology sampling locations are also depicted where sampling took place monthly.

APPENDIX II: *Body Condition*

Relative weight can be a useful metric to describe fish body condition and health that does not introduce bias associated with length, as in Fulton's condition factor (Neumann et al. 2012). Trends in W_r over time or between lengths of fish in a stock can be used to gain inference on the health of the population. Values well below 100 may occur when there are problems with food or feeding conditions, or the environment is otherwise unsuitable for consumption and growth.

We computed relative weight, W_r, of Walleye (Murphy et al. 1990), Lake Trout (Piccolo et al. 1993), and *Oncorhynchus* spp. (lentic Cutthroat Trout, Kruse and Hubert 1990) captured during April–October in exploratory gill nets, SPIN sets, and midwater curtain nets. We then plotted W_r as a function of total length to look for potential growth bottlenecks and other ontogenetic changes in body condition

Relative weight is the ratio of a fish's weight (W) to the standard weight (W_s) of a fish of the same length, and expressed as a percentage:

$$W_r = 100 \times W/W_s$$

In Wyoming, Hubert et al. (1994) discovered that Lake Trout with low W_r came from lakes that managers described as oligotrophic and having low densities of zooplankton with few prey fish. In the same study, they found their highest W_r across all sizes occurred where prey abundance and primary production was the highest. Marwitz and Hubert (1997) described a positive relationship between Walleye W_r and the stocking densities of trout in several Wyoming reservoirs.

In Buffalo Bill Reservoir, fish were captured throughout the reservoir in April, July, August, and October 2012, and monthly from April–October, 2013. We used a combination of experimental gill nets, fish were measured for TL (nearest mm) and weighed (nearest g). Relative weights were calculated using W_s equations found in Table I.1, and plotted against fish TL for Lake Trout, *Oncorhynchus* spp., and Walleye (Figure II.1).

In all, we evaluated relative weight for 555 Lake Trout, 513 *Oncorhynchus* spp. and 117 Walleye. Relative weight of Lake Trout was significantly different between our two size categories (< 600 mm and ≥ 600 mm, P = < 0.0001). Relative weight of Lake Trout < 600mm TL decreased as size approached 600mm Individuals ≥ 600mm had an average relative weight of 97.8. *Oncorhynchus* spp. seemed to exhibit the same trend, although average W_r was higher (92.9 vs. 83.9), and no individuals over 600 mm were sampled. Relative weight of Walleye increased with size above ~250 mm TL (Figure II.1), and had an average similar to large Lake Trout (97.0, Table I.1).

<u>Recommendations</u>

Body condition (and growth) of Walleye and large Lake Trout are probably linked to the abundance of fish prey. Periodic monitoring of these parameters may be useful for detecting changes in *Oncorhynchus* spp.. Ongoing work in Brett Johnson's lab showed that relative weight was not a very good indicator of the physiologic state of a fish (i.e., energy density). Therefore, it might be wise to perform energy density analysis with the dry:wet ratio method (Appendix VI) if concerns arise about body condition and general health of BBR fishes.

Table II.1: Relative weight equation sources, parameters, and variations.

	Parameters derived from	Min size for equation (mm)	Max size sampled (mm)	Sample size	Relative weight	
					Mean	Standard error
LAT <600mm	Piccolo et al. (1993)	280	584	509	83.9	0.47
LAT ≥600mm	Piccolo et al. (1993)	280	999	46	97.8	1.95
ONC	Kruse and Hubert (1997)	130	554	513	92.9	0.62
WAE	Murphy et al. (1990)	150	592	117	97.0	0.86

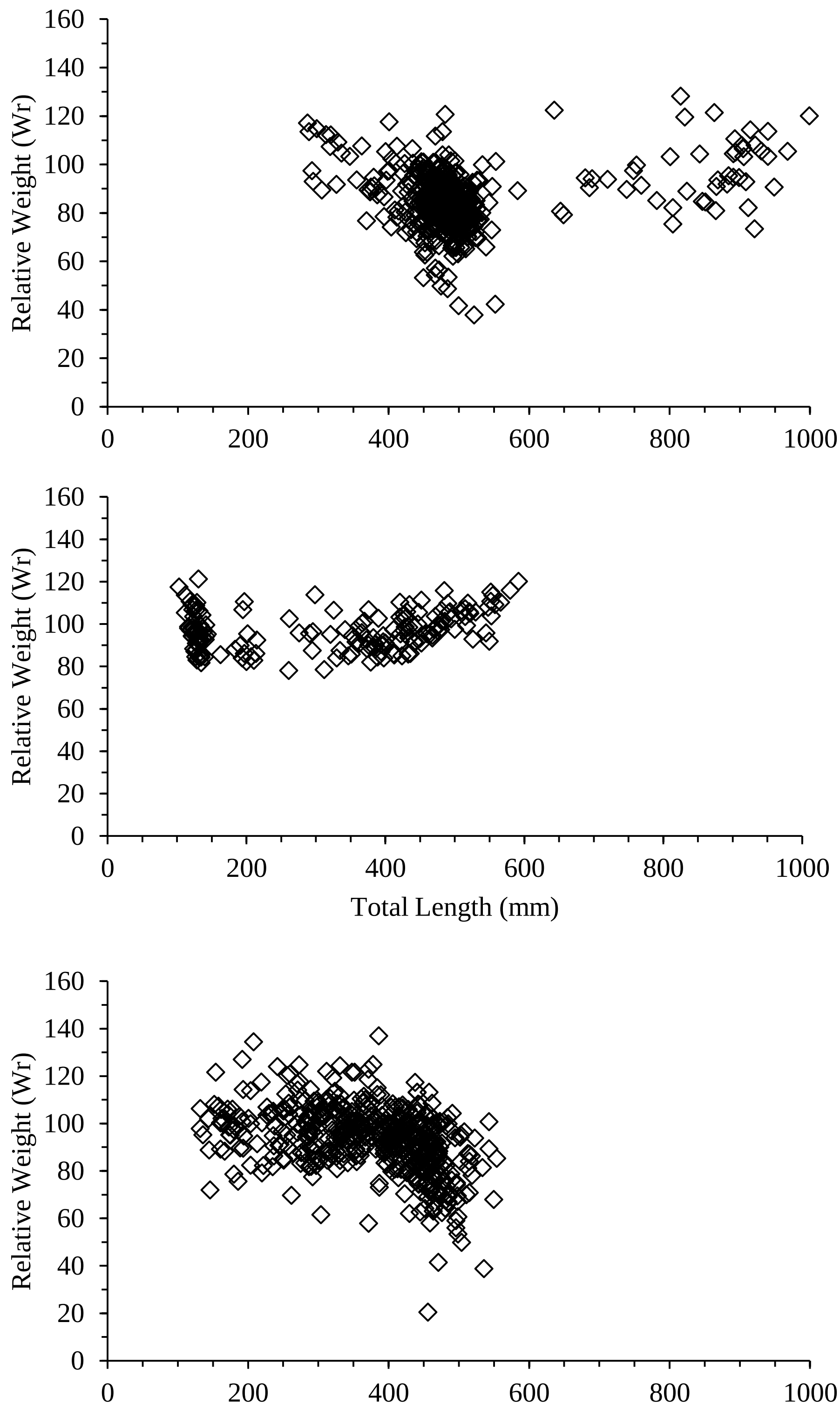

Figure II.1: Relative weight (Wr) plotted against total length (mm) for Lake Trout (top), Walleye (middle) and *Oncorhynchus* spp. (bottom).

APPENDIX III: *Diet*

Stomach samples were collected from fish sampled in April, July, August, and October, 2012 and monthly from April to October, 2013. Fish were sampled by gill netting, trap netting, electrofishing, and angling. Stomachs were fixed in 10% formalin immediately after being removed (*n* = 332 for Lake Trout, *n* = 127 for Walleye, and *n* = 213 for *Oncorhynchus* spp.). Contents were identified to at least family, and to species whenever possible, and separated into the following categories: salmonids; non-salmonids (includes *Catostomus* spp., Yellow Perch, or fish too digested to identify); crayfish (*Orconectes virilis*); zooplankton; or insects. Prey items were briefly blotted to remove excess liquid and measured volumetrically. Diet compositions were computed for each season and for two Lake Trout size categories, proportionally by volume. When possible, partial fish prey were converted to TL using vertebral column length to vertebrae count ratios based on regression equations derived from preserved fish specimens. Binary logistic regression in SAS 9.3 was used to determine if season, species, and fish size had an effect on piscivory.

Fish prey were rare for Lake Trout <600 mm and no salmonids were found in diets of Lake Trout of any size during the stratified period. Walleye diet was made up predominantly of fish prey (93.4%), the majority of which were salmonids (Table III.1). Quantile regression was used (0.1, 0.5, and 0.9 quantiles) to describe minimum and maximum prey sizes as a function of predator length (Figure III.1). Walleye and Lake Trout chose similar size ranges of fish prey.

Recommendations

Given the ambiguities we found in the stable isotope data (Appendix VII), we believe diet analysis will be more useful in future work examining predator-prey relations and food web structure at Buffalo Bill Reservoir. Because we found that Lake Trout diet differed between small and large fish, and the diet of both also differed seasonally, future Lake Trout diet work should strive to sample a broad size range of fish, during stratified and thermally homogenous lake conditions. Although we did not analyze our Walleye diet data by fish size, stable isotopes suggested that age-2 and younger Walleye may be feeding on different resources than older Walleye so future diet work with Walleye should also strive to sample a wide range of fish sizes.

Table III.1. Diet composition (relative frequency by volume) of Walleye (WAE, 122–589 mm TL) and two size classes of Lake Trout (LAT, 176–599, 600–999 mm TL) when the water column was mixed (M) and stratified (S). Lake Trout size classes corresponded with two divergent growth trajectories. “Other fish” category includes Catostomids, Yellow Perch, and fish that could not be identified to family. “Empty” is the percentage of stomachs examined that contained no prey. The number of non-empty stomachs, *n*, is shown in parentheses.

	All WAE	LAT < 600 mm		LAT ≥ 600 mm	
Prey type	M, S (*n* = 127)	M (*n* = 54)	S (*n* = 233)	M (*n* = 32)	S (*n* = 13)
Salmonids	64.0	1.2	0.0	43.3	0.0
Other fish	29.4	5.6	1.1	38.1	66.7
Crayfish	1.6	13.1	38.8	0.0	0.0
Zooplankton	0.2	62.8	2.9	10.0	0.0
Insects	4.9	17.4	57.2	8.6	33.3
Empty	48.0	13.0	60.0	53.1	77.0

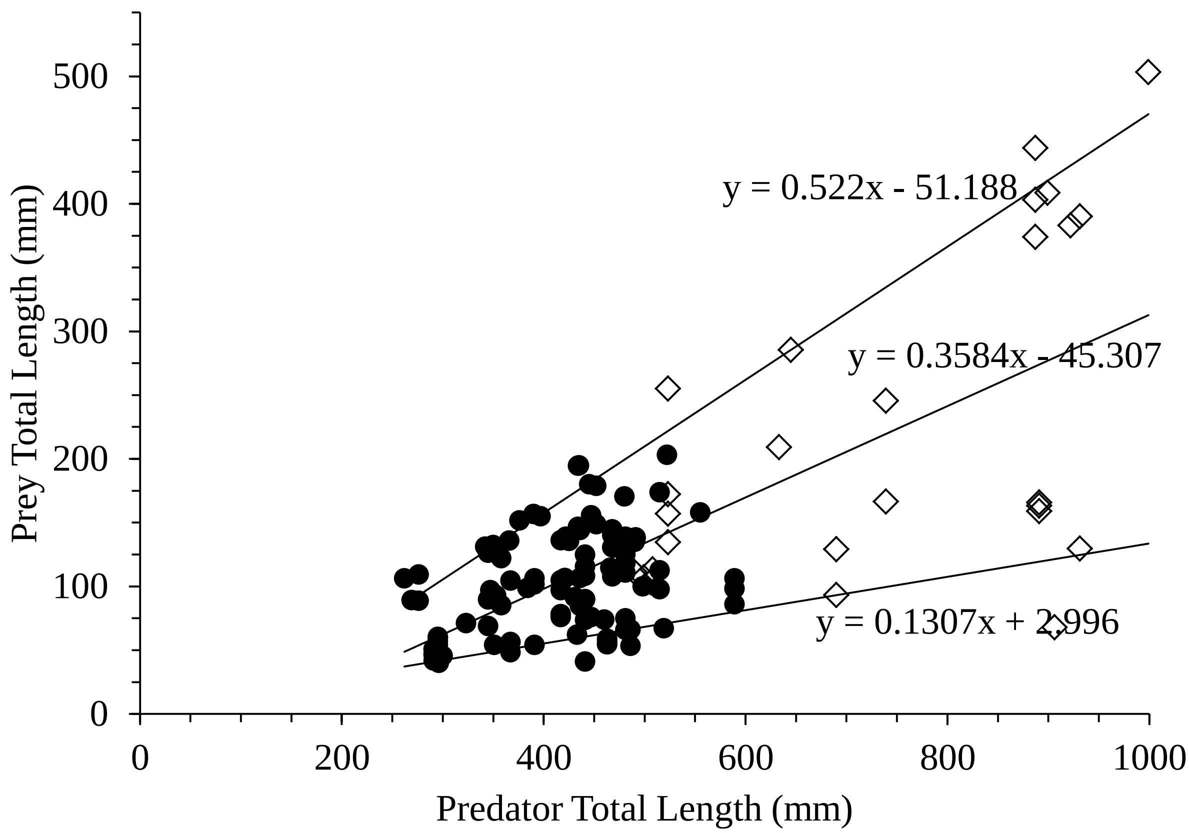

Figure III.1. Fish prey total length plotted against predator (Walleye—solid circles, and Lake Trout—open diamonds) total length. Regression lines from quantile regression indicate 10%, 50%, and 90% quantiles.

APPENDIX IV: *Limnology*

Limnological characteristics (i.e., temperature, dissolved oxygen, Secchi depths) were collected monthly from Buffalo Bill Reservoir at three sites: North Fork arm, South Fork arm, and mid lake in Buffalo Bill Reservoir in April–August and October, 2012, and April–October, 2013. Temperature and dissolved oxygen profiles were obtained using a YSI Model ProODO meter. Measurements were taken at 1-m intervals from 0 to 20 m and at 5-m intervals from 20 to the bottom. Secchi depth measurements were made with a standard 20-cm diameter limnological Secchi disk (Wetzel and Likens 1991) taken on the shaded side of the boat during midday hours.

In both years, Buffalo Bill Reservoir was fully stratified in July, August, and September, and became isothermal again in October (Figure IV.1). Average temperature (Table IV.1) and dissolved oxygen (Table IV.2) data are included for each month they were collected. We believe dissolved oxygen data from July–October 2013 are suspect due to a faulty or improperly calibrated meter because they exceed predicted saturation levels for water at Buffalo Bill Reservoir temperature and elevation (Table IV.2).

Recommendations

If more work with bioenergetics modeling is done in the future, regular temperature profile measurements will be needed. Placing a temperature logger near the surface (e.g., 1 m) in a mid-reservoir location would be a good way to capture surface temperatures during the mixed period in early spring and late fall when temperatures will likely be similar top to bottom. Because we believe turbidity is an important factor mediating Lake Trout predation on

Oncorhynchus spp. regular measurements of Secchi depth should be made to monitor for changes in water clarity.

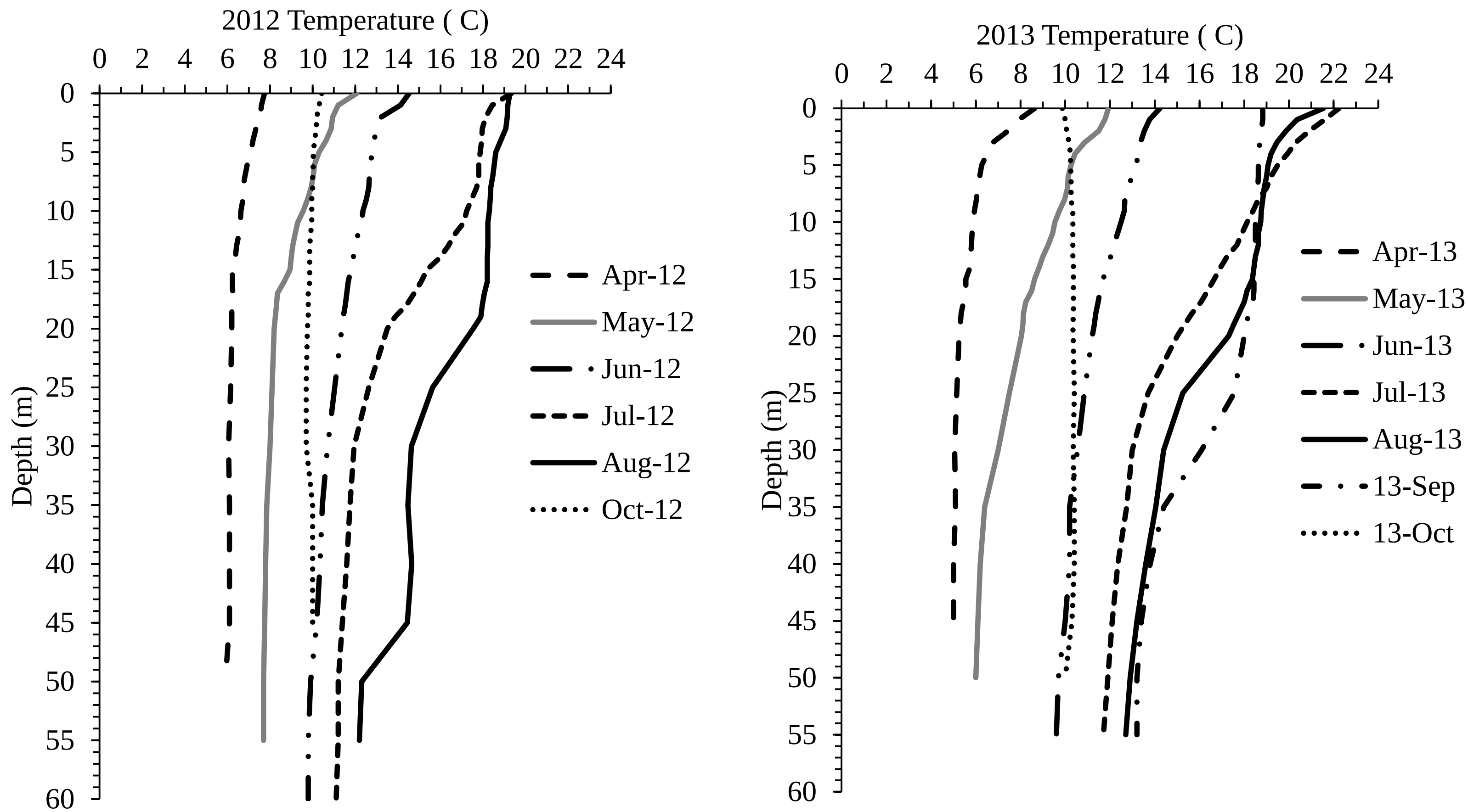

Figure IV.1. Average water temperatures (°C) measured at three sites on Buffalo Bill Reservoir during 2012, 2013.

Table IV.1. Average water temperatures (°C) measured at three sites on Buffalo Bill Reservoir during 2012, 2013.

Depth (m)	4/23/12	5/16/12	6/12/12	7/17/12	8/16/12	10/30/12	5/6/13	5/21/13	6/17/13	7/17/13	8/16/13	9/9/13	10/23/13
0	7.7	12.1	14.5	19.3	19.3	10.4	8.6	11.9	14.2	22.2	21.5	18.8	9.9
1	7.6	11.2	14.1	18.4	19.2	10.3	7.9	11.8	13.8	21.6	20.4	18.8	10.0
2	7.5	10.9	13.2	18.1	19.1	10.2	7.4	11.5	13.5	20.9	19.9	18.8	10.1
3	7.3	10.9	13.0	18.0	19.1	10.2	6.8	10.9	13.4	20.3	19.5	18.7	10.2
4	7.2	10.6	12.9	17.9	18.8	10.1	6.5	10.4	13.3	19.9	19.2	18.6	10.2
5	7.1	10.3	12.8	17.9	18.6	10.0	6.3	10.3	13.2	19.5	19.1	18.6	10.2
6	6.9	10.1	12.7	17.8	18.5	10.0	6.2	10.1	13.0	19.2	19.0	18.6	10.3
7	6.8	10.0	12.7	17.8	18.5	10.0	6.1	10.1	12.8	19.0	18.9	18.6	10.3
8	6.7	9.9	12.6	17.7	18.4	10.0	6.0	10.0	12.7	18.6	18.8	18.6	10.3
9	6.7	9.8	12.5	17.5	18.3	10.0	5.9	9.7	12.6	18.4	18.8	18.5	10.3
10	6.6	9.6	12.4	17.2	18.3	10.0	5.9	9.5	12.5	18.1	18.7	18.5	10.3
11	6.6	9.3	12.3	17.1	18.2	10.0	5.8	9.4	12.3	17.9	18.6	18.5	10.3
12	6.5	9.2	12.1	16.7	18.2	9.9	5.8	9.2	12.2	17.7	18.6	18.5	10.3
13	6.4	9.1	12.0	16.4	18.2	9.9	5.8	9.0	12.0	17.2	18.5	18.5	10.3
14	6.4	9.0	11.9	16.0	18.2	9.9	5.7	8.8	11.8	16.9	18.4	18.5	10.4
15	6.2	8.9	11.8	15.4	18.2	9.9	5.6	8.6	11.7	16.7	18.4	18.4	10.4
16	6.2	8.7	11.7	15.1	18.2	9.9	5.6	8.5	11.6	16.4	18.1	18.4	10.4
17	6.3	8.4	11.6	14.8	18.1	9.8	5.5	8.2	11.5	16.1	18.0	18.4	10.4
18	6.2	8.3	11.5	14.4	18.0	9.8	5.4	8.1	11.4	15.7	17.8	18.2	10.4
19	6.2	8.3	11.4	13.9	17.9	9.8	5.3	8.1	11.3	15.3	17.5	18.1	10.3
20	6.2	8.2	11.4	13.5	17.5	9.8	5.3	8.0	11.2	15.0	17.3	18.0	10.4
25	6.2	8.1	11.0	12.6	15.6	9.7	5.2	7.5	10.9	13.7	15.3	17.6	10.4
30	6.1	8.0	10.7	12.0	14.6	9.7	5.1	7.0	10.6	13.0	14.4	16.1	10.4
35	6.1	7.9	10.5	11.8	14.5	10.0	5.1	6.4	10.2	12.8	14.1	14.4	10.4
40	6.1	7.8	10.4	11.6	14.7	10.0	5.0	6.2	10.2	12.4	13.6	13.8	10.4
45	6.1	7.8	10.2	11.4	14.5	10.0	5.0	6.1	10.0	12.1	13.2	13.4	10.3
50	5.9	7.7	9.9	11.2	12.3		5.0	6.0	9.7	11.9	12.9	13.2	10.0
55		7.7	9.8	11.2	12.2				9.6	11.7	12.7	13.2	
60			9.8	11.1									

Table IV.2. Average dissolved oxygen concentrations (mg/L) measured at three sites on Buffalo Bill Reservoir during 2012, 2013. Concentrations above 11 mg/L are suspect because they exceed the expected saturation level for the elevation and temperatures at BBR.

Depth (m)	4/23/12	5/16/12	6/12/12	7/17/12	8/16/12	10/30/12	5/6/13	5/21/13	6/17/13	7/17/13	8/16/13	9/9/13	10/23/13
0	5.75	9.42	7.03	7.86	7.51	8.47	9.68	8.70	9.16	6.37	7.54	7.91	8.27
1	7.80	9.50	7.63	7.89	7.50	8.47	9.72	8.73	9.14	6.47	7.75	7.89	8.30
2	9.50	9.50	8.50	7.85	7.48	8.44	9.80	8.74	9.14	6.62	7.93	7.89	8.39
3	10.45	9.55	8.90	7.80	7.44	8.44	9.80	8.75	9.12	6.76	8.10	7.89	8.55
4	10.55	9.56	9.13	7.77	7.40	8.41	9.85	8.73	9.05	6.91	8.26	7.87	8.69
5	10.60	9.60	8.83	7.74	7.36	8.39	9.86	8.72	8.97	7.09	8.40	7.84	8.82
6	10.25	9.56	8.70	7.72	7.34	8.55	9.84	8.70	8.91	7.22	8.54	7.81	8.99
7	9.90	9.56	8.67	7.71	7.29	8.34	9.87	8.67	8.86	7.42	8.70	7.77	9.15
8	9.45	9.56	8.63	7.69	7.23	8.31	9.86	8.67	8.82	7.57	8.90	7.75	9.34
9	9.10	9.51	8.57	7.66	7.18	8.29	9.83	8.66	8.80	7.41	9.06	7.74	9.54
10	8.90	9.43	8.47	7.64	7.14	8.28	9.80	8.67	8.77	7.90	9.24	7.73	9.71
11	8.65	9.37	8.33	7.59	7.13	8.26	9.82	8.66	8.74	8.07	9.40	7.71	9.92
12	8.35	9.36	8.27	7.56	7.11	8.25	9.76	8.66	8.74	8.27	9.56	7.68	10.07
13	8.20	9.34	8.17	7.54	7.10	8.24	9.74	8.67	8.72	8.47	9.78	7.64	10.31
14	7.90	9.30	8.13	7.48	7.09	8.22	8.04	8.67	8.70	8.67	9.93	7.60	10.48
15	7.75	9.27	7.97	7.44	7.07	8.19	9.73	8.68	8.69	8.88	10.12	7.57	10.66
16	7.50	9.11	7.90	7.46	7.03	8.19	9.69	8.67	8.67	9.08	10.38	7.55	10.88
17	7.40	9.09	7.73	7.43	6.97	8.19	9.65	8.67	8.66	9.29	10.59	7.43	11.07
18	7.30	9.04	7.63	7.41	6.91	8.18	9.62	8.67	8.65	9.51	10.82	7.19	11.25
19	7.10	9.04	7.60	7.40	6.78	8.16	9.62	8.66	8.65	9.72	11.04	7.11	11.40
20	6.80	9.00	7.30	7.39	6.65	8.16	9.59	8.67	8.65	9.99	11.25	6.95	11.52
25	6.70	8.92	6.47	7.26	6.05	8.13	9.56	8.67	8.59	11.00	12.58	6.60	12.69
30	6.50	8.81	9.20	7.18	6.02	8.07	9.52	8.61	8.50	12.05	13.69	6.08	13.68
35	6.00	7.53	8.50	7.10	5.91	7.93	9.28	8.66	8.40	12.71	14.46	5.87	14.00
40	5.30	7.17	5.25	6.99	5.84	7.86	9.82	8.66	8.35	13.11	15.26	5.53	14.04
45	4.60	6.94	7.40	6.65	5.78	7.79	0.43	8.62	8.25	13.47	15.76	5.29	13.75
50	4.00	5.18	7.20	6.51	5.91			8.56	8.13	13.75	16.19	4.96	15.00
55		4.93	6.90	6.34	5.80				8.01	13.98	16.71	3.34	
60			1.00	2.72									

APPENDIX V: *Zooplankton*

Because zooplankton, particularly *Daphnia* spp., are a critical prey resource for *Oncorhynchus* spp. in many western reservoirs (Baldwin et al. 2000; Johnson and Martinez 2012), we measured zooplankton density monthly at three sites during April–October. Duplicate tows were made at each site with a 153-µm Wisconsin net towed from 5 m and 10 m to the surface. Samples were preserved in 10% sugar buffered formalin. Each sample was diluted and three replicate 1-ml aliquot sub-samples were placed in a Sedgwick-Rafter counting cell where taxa were identified and enumerated (Lind 1979) under a compound microscope.

The species composition of the zooplankton assemblage in BBR (Table V.1) was similar to that observed at many coldwater reservoirs in Colorado (Martinez et al. 2010). The mean June–August density of *Daphnia* spp. in BBR (0–5 m stratum) was 4.53 animals/L (Table V.2). We did not have zooplankton data on other Wyoming waters but this was lower than at three of Colorado's most productive coldwater reservoir fisheries without Mysis shrimp: Blue Mesa Reservoir (12.2/L), Elevenmile Reservoir (11.3/L) and Vallecito Reservoir (9.5/L) (B. Johnson, unpublished data). The mean June–August density of copepods (all species) in BBR (0–5 m stratum) was 12.02 animals/L. The 10 year average density of copepods at Blue Mesa Reservoir was 20.9/L (*SD*=7.2/L) (Johnson and Koski 2005).

Density of *Daphnia* spp. was nearly always higher in the 0–5 m hauls compared to 0–10 m hauls suggesting that *Daphnia* were more abundant in the top 5 m compared to the 5 m below. This distribution is probably explained by the relatively high turbidity at Buffalo Bill Reservoir. *Daphnia* consume phytoplankton which require sunlight to grow. Thus, production of both phytoplankton and zooplankton are concentrated in the upper 5 m of the water column at Buffalo

Bill Reservoir. This also implies that planktivorous fish would find the highest food concentrations near the surface. Our netting showed that *Oncorhynchus* spp. were most abundant in this upper stratum during April–October.

Recommendations

Given the importance of zooplankton in the diet of *Oncorhynchus* spp. but relatively modest *Daphnia* spp. density in Buffalo Bill Reservoir, it may not be prudent to stock other species of planktivorous fish at BBR that might compete with *Oncorhynchus* spp. Increased competition for zooplankton could slow the growth of *Oncorhynchus* spp. and increase predation mortality from Walleye and Lake Trout. From a food web monitoring standpoint, a sudden increase in the density (and size structure) of *Daphnia* spp. could be indicative of a decline in planktivorous fish abundance, particularly *Oncorhynchus* spp..

Table V.1. Zooplankton taxa sampled with a 153-µm Wisconsin net at three sites on Buffalo Bill Reservoir in 2012 and 2013.

CLADOCERANS	COPEPODS
Daphnia galeata mendotae	*Leptodiaptomus judayi*
Daphnia pulex/pulicaria	*Leptodiaptomus nudus*
Daphnia longiremis	*Diacyclops thomasi*
Daphnia rosea	Unidentified *Leptodiaptomus* spp.
Bosmina longirostris	Unidentified *Diacyclops* spp.
Unidentified *Bosmina* spp.	
Unidentified *Ceriodaphnia* spp	
Unidentified *Diaphanosoma* spp.	

Table V.2. Average density (*n*/L) and standard deviation (*SD*) of *Daphnia* (*D. galeata, D. longiremis, D. pulex/pulicaria*, and *D. rosea*) and copepods (*Leptodiaptomus* and *Diacyclops* spp) sampled at three sites and in two depth strata with a 153-µm Wisconsin net on Buffalo Bill Reservoir in 2012 and 2013. Peak is the mean annual peak abundance of each taxon.

	Daphnia spp.				Copepods			
	0–5 m		0–10 m		0–5 m		0–10 m	
Date	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
04/23/12	1.126	0.666	0.710	0.432	6.157	2.523	4.376	0.418
05/16/12	3.363	2.617	0.334	0.177	7.626	5.552	1.000	0.241
06/21/12	2.384*	0.000	6.260	1.775	3.505*	0.000	2.879	1.437
07/17/12	7.631	4.091	2.352	1.559	13.583	4.451	5.660	4.452
10/30/12	3.316	0.290	1.810	1.043	8.462	2.166	3.973	1.007
05/06/13	8.273	3.162	1.339	1.582	6.473	2.370	1.913	2.158
05/23/13	1.263	0.398	0.721	0.170	1.416	0.208	0.834	0.043
08/16/13	3.573	0.400	0.134	0.042	18.977	3.545	0.984	0.141
09/09/13	5.628	1.016	1.816	1.612	10.033	0.368	4.100	3.059
10/23/13	1.421	1.161	0.782	0.563	2.568	1.859	2.292	1.625
June-Aug	4.529	2.751	2.916	3.101	12.022	7.853	3.174	2.352
All dates	3.798	1.405	1.626	0.693	7.880	1.838	2.801	1.436
Peak	7.952	0.454	3.800	3.143	16.280	3.814	4.880	1.103

*only South Fork site sampled on this date and stratum

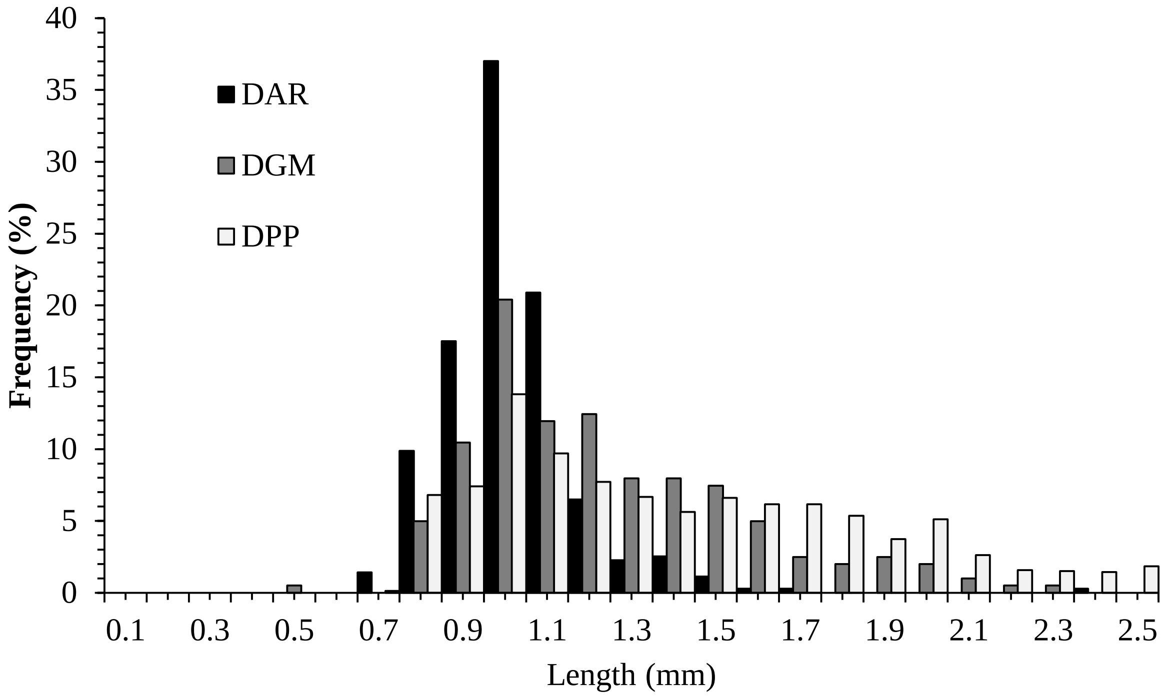

Figure V.1. Size distribution of three species of Daphnia sampled with a 153-µm Wisconsin Net in the top 10 m of the water column at Buffalo Bill Reservoir during April–October, 2012, and May–October, 2013. DAR = *Daphnia rosea*, DGM = *D. galeata mendotae*, and DPP = *D. pulex/pulicaria*.

APPENDIX VI: *Energy Density*

We used the dry:wet weight ratio and the combined model of Hartman and Brandt (1995) to estimate energy density of fishes from Buffalo Bill Reservoir:

$$ED = 45.29 \cdot DW^{1.507}$$

where *ED* is energy density (J/g wet weight), *DW* is dry:wet weight ratio (%).

Wet weights were measured in the field. Dry weights were obtained by cutting fish specimens into ~2 cm^3 pieces and drying to a constant weight at 60°C. We estimated energy density of all sizes of Lake Trout and Walleye. Other species of fish were assumed to be potential prey if they appeared in diet samples, and were smaller than 300 mm TL. Energy densities of invertebrate prey taxa were obtained from published literature: *Daphnia ED* = 3,860 J/g (Luecke and Brandt 1993), crayfish *ED* = 3,706 J/g (Pate et al. 2014), aquatic insects *ED* = 4,090 (Johnson et al. 2015). Mean energy densities are summarized in Table VI.1, and raw data is included in Table VI.2.

Adult Walleye and Lake Trout had the highest mean energy densities, and Catostomids (White and Longnose suckers) had the lowest energy densities (Table VI.1). As inputs for the bioenergetics model (Hanson et al. 1997), fish prey were lumped into one of two categories: Salmonid (average of *Oncorhynchus* spp. and Brown Trout); or other fish (average of Catostomids and Yellow Perch).

Recommendations

Energy density is needed for bioenergetics modeling and it is another indicator of fish condition, and presumably prey resource availability. In other work in Brett Johnson's lab we verified that the dry:wet weight ratio approach is very accurate. Getting dry:wet weight ratio to estimate energy density is much easier and cheaper than bomb calorimetry and we recommend that approach if energy density information is needed in the future.

Table VI.1. Energy density (J/gWW) of prey-sized (<300 mm TL) fishes and piscivores estimated from dry:wet weight ratio. Catostomids were mostly White Sucker (*Catostomus commersonii*), but included some Longnose Sucker (*C. catostomus*).

Taxon	*n*	Mean	Standard deviation	Standard error
Prey sized fish				
Oncorhynchus spp	139	4,822	1,395	118
Brown Trout	15	4,887	971	251
Catostomids (CAT)	114	4,462	1,066	100
Yellow Perch (YEP)	57	4,904	1,175	156
All other prey (CAT & YEP)	179	4,644	1,107	81
Piscivores				
Lake Trout (<300 mm)	21	4,492	907	198
Walleye (<300 mm)	75	4,525	688	79
Lake Trout (all)	33	5,253	1,571	273
Walleye (all)	113	5,357	1,570	148

Table VI.2. Energy densities calculated from wet weight/ dry weight ratios and using equation 2 (combined model) from Hartman and Brandt (1995). Fish were cut into ~2 cm^3 pieces and dried until a constant weight at 60°C. “Group” refers to fish groups used in bioenergetics models (see above) and contain Lake Trout (LAT), Walleye (WAE), salmonids (SAL; Brown Trout, Mountain Whitefish, and *Oncorhynchus* spp.), and other fish (OTF; White and Longnose suckers and Yellow Perch). Wet weight is live weight of fish, and final dry weight is the ending weight of fish after drying was complete. Energy density is expressed in Joules per gram of wet weight (J/gWW).

Sample number	Sample date	Species code	Group	Total Length (mm)	Wet weight (g)	Final dry weight (g)	% dry weight	Energy density (J/gWW)
BBR061913144	6/19/13	LAT	LAT	157	28.60	5.63	19.69	4,039
BBR081212008	8/12/12	LAT	LAT	176	50.00	9.00	18.00	3,529
BBR081313513	8/13/13	LAT	LAT	180	49.56	9.57	19.31	3,924
BBR081313544	8/13/13	LAT	LAT	185	48.92	10.25	20.95	4,437
BBR081313508	8/13/13	LAT	LAT	187	52.96	10.40	19.64	4,024
BBR081313563	8/13/13	LAT	LAT	192	54.73	11.47	20.96	4,439
BBR081313550	8/13/13	LAT	LAT	193	59.43	10.56	17.77	3,461
BBR091013007	9/10/13	LAT	LAT	197	74.00	15.60	21.08	4,478
BBR091013073	9/10/13	LAT	LAT	201	81.00	13.90	17.16	3,284
BBR081313505	8/13/13	LAT	LAT	202	63.98	13.09	20.46	4,281
BBR081313510	8/13/13	LAT	LAT	202	66.82	13.32	19.93	4,116
BBR081313537	8/13/13	LAT	LAT	202	58.79	11.36	19.32	3,928
BBR091013071	9/10/13	LAT	LAT	202	80.00	14.92	18.65	3,723
BBR081313536	8/13/13	LAT	LAT	203	64.14	13.40	20.89	4,418
BBR081313574	8/13/13	LAT	LAT	206	62.24	12.36	19.86	4,093
BBR081413026	8/14/13	LAT	LAT	210	79.00	18.00	22.78	5,035
BBR081313548	8/13/13	LAT	LAT	211	78.71	17.12	21.75	4,694
BBR071812040	7/18/12	LAT	LAT	287	225.00	56.00	24.89	5,752
BBR081213313	8/12/13	LAT	LAT	291	202.00	52.22	25.85	6,090
BBR081313540	8/13/13	LAT	LAT	293	197.00	52.00	26.40	6,284
BBR081412034	081412	LAT	LAT	298	257.00	68.00	26.46	6,307

Sample number	Sample date	Species code	Group	Total Length (mm)	Wet weight (g)	Final dry weight (g)	% dry weight	Energy density (J/gWW)
BBR071912256	7/19/12	LAT	LAT	302	453.00	98.00	21.63	4,656
BBR081313072	8/13/13	LAT	LAT	305	216.00	52.00	24.07	5,470
BBR081412041	8/14/12	LAT	LAT	311	289.00	74.00	25.61	6,003
BBR071812503	7/18/12	LAT	LAT	318	310.00	89.00	28.71	7,133
BBR081313055	8/13/13	LAT	LAT	326	275.00	78.00	28.36	7,003
BBR071812029	7/18/12	LAT	LAT	328	334.00	95.00	28.44	7,033
BBR081413027	8/14/13	LAT	LAT	333	336.00	93.00	27.68	6,750
BBR081512252	8/15/12	LAT	LAT	355	370.00	103.00	27.84	6,809
BBR081312531	081312	LAT	LAT	362	453.00	124.00	27.37	6,638
BBR081413535	8/14/13	LAT	LAT	467	550.00	99.00	18.00	3,529
BBR061913156	6/19/13	LAT	LAT	743	4635.00	1434.00	30.94	7,983
BBR081412900	8/14/12	LAT	LAT	940	10600.00	3810.00	35.94	10,007
BBR061913128	6/19/13	WAE	WAE	81	14.13	2.49	17.62	3,418
BBR061813055	6/18/13	WAE	WAE	112	12.52	2.51	20.05	4,152
BBR061813059	6/18/13	WAE	WAE	112	13.50	2.63	19.48	3,976
BBR061813060	6/18/13	WAE	WAE	117	13.20	3.15	23.86	5,398
BBR061913129	6/19/13	WAE	WAE	117	13.30	2.75	20.68	4,349
BBR061913126	6/19/13	WAE	WAE	119	15.66	2.58	16.48	3,089
BBR061813064	6/18/13	WAE	WAE	120	14.04	2.91	20.73	4,365
BBR061813056	6/18/13	WAE	WAE	122	14.95	3.40	22.74	5,021
BBR061813061	6/18/13	WAE	WAE	122	14.33	3.24	22.61	4,977
BBR061913149	6/19/13	WAE	WAE	123	14.60	2.25	15.41	2,793
BBR061813054	6/18/13	WAE	WAE	124	15.32	3.65	23.83	5,385
BBR061913101	6/19/13	WAE	WAE	124	14.06	3.13	22.26	4,862
BBR061813302	6/18/13	WAE	WAE	125	15.94	3.66	22.96	5,094
BBR061913140	6/19/13	WAE	WAE	125	15.47	3.41	22.04	4,790
BBR061913147	6/19/13	WAE	WAE	126	14.50	3.81	26.28	6,241

Sample number	Sample date	Species code	Group	Total Length (mm)	Wet weight (g)	Final dry weight (g)	% dry weight	Energy density (J/gWW)
BBR061913105	6/19/13	WAE	WAE	127	18.54	3.87	20.87	4,412
BBR061913151	6/19/13	WAE	WAE	127	14.40	3.31	22.99	5,102
BBR061813304	6/18/13	WAE	WAE	128	15.36	2.28	14.84	2,639
BBR061913103	6/19/13	WAE	WAE	128	15.83	3.29	20.78	4,383
BBR061913150	6/19/13	WAE	WAE	129	14.80	3.30	22.30	4,873
BBR061913113	6/19/13	WAE	WAE	130	17.14	3.27	19.08	3,853
BBR061813305	6/18/13	WAE	WAE	131	16.85	3.58	21.25	4,531
BBR061813332	6/18/13	WAE	WAE	131	18.04	3.29	18.24	3,600
BBR061913110	6/19/13	WAE	WAE	131	22.59	4.49	19.88	4,098
BBR061813052	6/18/13	WAE	WAE	132	16.06	3.53	21.98	4,769
BBR061913107	6/19/13	WAE	WAE	132	17.59	4.03	22.91	5,077
BBR061913125	6/19/13	WAE	WAE	132	20.21	4.67	23.11	5,143
BBR061913130	6/19/13	WAE	WAE	132	18.06	3.34	18.49	3,676
BBR061913107	6/19/13	WAE	WAE	132	17.59	4.27	24.28	5,539
BBR061813051	6/18/13	WAE	WAE	133	18.09	4.24	23.44	5,254
BBR061913109	6/19/13	WAE	WAE	133	19.34	4.09	21.15	4,500
BBR061913119	6/19/13	WAE	WAE	133	16.83	3.42	20.32	4,237
BBR061813053	6/18/13	WAE	WAE	135	17.36	3.55	20.45	4,278
BBR061913100	6/19/13	WAE	WAE	135	17.15	3.70	21.57	4,637
BBR061913148	6/19/13	WAE	WAE	135	16.60	3.45	20.78	4,383
BBR061813058	6/18/13	WAE	WAE	137	20.70	4.43	21.40	4,581
BBR061813303	6/18/13	WAE	WAE	139	21.32	4.68	21.95	4,760
BBR061913139	6/19/13	WAE	WAE	141	21.32	4.63	21.72	4,683
BBR061913108	6/19/13	WAE	WAE	142	23.37	4.83	20.67	4,347
BBR091013117	9/10/13	WAE	WAE	163	32.60	6.17	18.93	3,807
BBR090913037	9/9/13	WAE	WAE	169	37.00	8.00	21.62	4,652

Sample number	Sample date	Species code	Group	Total Length (mm)	Wet weight (g)	Final dry weight (g)	% dry weight	Energy density (J/gWW)
BBR090913256	9/9/13	WAE	WAE	174	37.70	8.00	21.22	4,523
BBR090913261	9/9/13	WAE	WAE	175	37.60	7.00	18.62	3,713
BBR090913033	9/9/13	WAE	WAE	175	37.80	9.00	23.81	5,380
BBR090913500	9/9/13	WAE	WAE	182	43.20	9.00	20.83	4,399
BBR090913541	9/9/13	WAE	WAE	182	42.00	9.00	21.43	4,590
BBR090913276	9/9/13	WAE	WAE	184	48.70	11.00	22.59	4,969
BBR091013102	9/10/13	WAE	WAE	184	49.40	9.20	18.62	3,715
BBR090913027	9/9/13	WAE	WAE	188	52.80	11.00	20.83	4,399
BBR090913274	9/9/13	WAE	WAE	188	46.10	11.00	23.86	5,397
BBR081313520	8/13/13	WAE	WAE	191	56.77	11.17	19.68	4,036
BBR090913040	9/9/13	WAE	WAE	192	52.80	13.00	24.62	5,659
BBR090913291	9/9/13	WAE	WAE	192	50.40	11.00	21.83	4,719
BBR091013101	9/10/13	WAE	WAE	194	55.70	11.10	19.93	4,114
BBR091013314	9/10/13	WAE	WAE	195	72.00	12.00	16.67	3,143
BBR091013291	9/10/13	WAE	WAE	197	60.00	10.58	17.63	3,422
BBR091013325	9/10/13	WAE	WAE	197	77.00	13.58	17.64	3,422
BBR090913285	9/9/13	WAE	WAE	198	54.20	12.00	22.14	4,822
BBR091013103	9/10/13	WAE	WAE	200	60.20	13.12	21.79	4,708
BBR091013323	9/10/13	WAE	WAE	202	72.00	14.66	20.36	4,250
BBR090913041	9/9/13	WAE	WAE	203	67.10	13.00	19.37	3,943
BBR090913252	9/9/13	WAE	WAE	206	67.10	15.00	22.35	4,892
BBR091013100	9/10/13	WAE	WAE	211	71.80	15.26	21.25	4,534
BBR090913025	9/9/13	WAE	WAE	213	82.00	18.00	21.95	4,760
BBR090913264	9/9/13	WAE	WAE	214	73.30	17.00	23.19	5,171
BBR091013262	9/10/13	WAE	WAE	214	78.00	18.00	23.08	5,132
BBR090913294	9/9/13	WAE	WAE	215	85.00	17.00	20.00	4,137
BBR090913254	9/9/13	WAE	WAE	220	69.80	15.00	21.49	4,610

Sample number	Sample date	Species code	Group	Total Length (mm)	Wet weight (g)	Final dry weight (g)	% dry weight	Energy density (J/gWW)
BBR090913258	9/9/13	WAE	WAE	223	86.00	19.00	22.09	4,806
BBR050812103	5/8/12	WAE	WAE	262	176.90	39.00	22.05	4,791
BBR081512288	8/15/12	WAE	WAE	276	195.00	43.00	22.05	4,792
BBR060612003	6/6/12	WAE	WAE	290	208.65	52.00	24.92	5,763
BBR081512280	8/15/12	WAE	WAE	291	230.00	54.00	23.48	5,267
BBR081512289	8/15/12	WAE	WAE	295	220.00	51.00	23.18	5,167
BBR060612002	6/6/12	WAE	WAE	300	235.87	50.00	21.20	4,516
BBR060612001	6/6/12	WAE	WAE	302	272.16	80.00	29.39	7,391
BBR060612005	6/6/12	WAE	WAE	323	317.51	54.00	17.01	3,240
BBR061813326	6/18/13	WAE	WAE	326	368.00	100.00	27.17	6,566
BBR090913272	9/9/13	WAE	WAE	335	330.00	88.00	26.67	6,382
BBR081512777	8/15/12	WAE	WAE	342	392.00	96.00	24.49	5,613
BBR042513707	4/25/13	WAE	WAE	344	357.00	97.00	27.17	6,564
BBR060612012	6/6/12	WAE	WAE	345	453.59	124.00	27.34	6,625
BBR060612014	6/6/12	WAE	WAE	351	408.23	100.00	24.50	5,615
BBR081512285	8/15/12	WAE	WAE	351	375.00	102.00	27.20	6,575
BBR090913011	9/9/13	WAE	WAE	351	349.00	92.00	26.36	6,272
BBR060612027	6/6/12	WAE	WAE	353	489.88	126.00	25.72	6,044
BBR042513703	4/25/13	WAE	WAE	357	506.00	87.00	17.19	3,294
BBR050812104	5/8/12	WAE	WAE	358	426.38	100.00	23.45	5,259
BBR061813300	6/18/13	WAE	WAE	363	443.00	126.00	28.44	7,033
BBR042513406	4/25/13	WAE	WAE	365	462.00	136.00	29.44	7,407
BBR061813313	6/18/13	WAE	WAE	366	479.00	129.00	26.93	6,477
BBR090913029	9/9/13	WAE	WAE	374	473.00	129.00	27.27	6,602
BBR042513252	4/25/13	WAE	WAE	379	458.00	159.00	34.72	9,497
BBR042513704	4/25/13	WAE	WAE	380	533.00	147.00	27.58	6,714
BBR090913016	9/9/13	WAE	WAE	381	498.00	140.00	28.11	6,910

Sample number	Sample date	Species code	Group	Total Length (mm)	Wet weight (g)	Final dry weight (g)	% dry weight	Energy density (J/gWW)
BBR090913034	9/9/13	WAE	WAE	388	480.00	128.00	26.67	6,382
BBR060612015	6/6/12	WAE	WAE	391	653.17	186.00	28.48	7,045
BBR042113002	4/21/13	WAE	WAE	404	616.00	134.00	21.75	4,695
BBR050812102	5/8/12	WAE	WAE	412	626.00	165.00	26.36	6,271
BBR050812101	5/8/12	WAE	WAE	413	626.00	169.00	27.00	6,501
BBR060612006	6/6/12	WAE	WAE	417	798.32	257.00	32.19	8,476
BBR060612011	6/6/12	WAE	WAE	417	907.18	305.00	33.62	9,049
BBR060612013	6/6/12	WAE	WAE	422	789.25	256.00	32.44	8,573
BBR090913049	9/9/13	WAE	WAE	424	712.00	218.00	30.62	7,859
BBR102912283	10/29/12	WAE	WAE	431	889.00	283.00	31.83	8,334
BBR060612025	6/6/12	WAE	WAE	434	861.82	233.00	27.04	6,515
BBR060612010	6/6/12	WAE	WAE	445	943.47	254.00	26.92	6,474
BBR060612007	6/6/12	WAE	WAE	452	1052.33	330.00	31.36	8,147
BBR060612008	6/6/12	WAE	WAE	460	1124.91	390.00	34.67	9,478
BBR103012273	10/30/12	WAE	WAE	485	1415.00	476.00	33.64	9,057
BBR103112001	10/31/12	WAE	WAE	486	1247.00	399.00	32.00	8,398
BBR060612009	6/6/12	WAE	WAE	498	1406.14	487.00	34.63	9,463
BBR102912258	10/29/12	WAE	WAE	580	2504.00	846.00	33.79	9,116
BBR103112040	10/31/12	RBT	SAL	55	1.20	0.29	24.17	5,502
BBR103112025	10/31/12	RBT	SAL	71	2.90	0.63	21.72	4,686
BBR061913512	6/19/13	RBT	SAL	77	3.60	0.50	13.89	2,388
BBR061913516	6/19/13	RBT	SAL	83	5.20	0.82	15.77	2,891
BBR103112026	10/31/12	RBT	SAL	86	4.70	1.33	28.30	6,979
BBR061913544	6/19/13	RBT	SAL	94	5.80	1.14	19.66	4,030
BBR061913522	6/19/13	RBT	SAL	94	6.30	1.15	18.25	3,605
BBR061913523	6/19/13	RBT	SAL	96	7.70	1.00	12.99	2,158
BBR061913502	6/19/13	RBT	SAL	96	8.40	1.32	15.71	2,876

Sample number	Sample date	Species code	Group	Total Length (mm)	Wet weight (g)	Final dry weight (g)	% dry weight	Energy density (J/gWW)
BBR061913501	6/19/13	RBT	SAL	99	7.80	1.00	12.82	2,116
BBR061913520	6/19/13	RBT	SAL	102	8.50	1.80	21.18	4,509
BBR061913142	6/19/13	RBT	SAL	107	12.70	2.00	15.75	2,886
BBR061913509	6/19/13	RBT	SAL	109	11.50	2.00	17.39	3,351
BBR061913120	6/19/13	RBT	SAL	110	13.47	2.00	14.85	2,641
BBR091013132	9/10/13	RBT	SAL	123	18.00	3.62	20.11	4,171
BBR091013133	9/10/13	RBT	SAL	127	21.60	4.07	18.84	3,781
BBR061913116	6/19/13	RBT	SAL	132	23.88	5.45	22.82	5,047
BBR091013123	9/10/13	RBT	SAL	132	22.00	4.43	20.14	4,179
BBR061913500	6/19/13	RBT	SAL	135	19.70	3.00	15.23	2,743
BBR103012039	10/30/12	RBT	SAL	135	20.00	5.32	26.60	6,358
BBR040412052	4/4/12	RBT	SAL	141	24.00	6.00	25.00	5,790
BBR061913506	6/19/13	RBT	SAL	141	20.10	4.00	19.90	4,106
BBR061913504	6/19/13	RBT	SAL	142	24.60	6.00	24.39	5,579
BBR091013125	9/10/13	RBT	SAL	144	30.00	5.16	17.20	3,296
BBR103112003	10/31/12	RBT	SAL	146	30.50	7.68	25.18	5,853
BBR081313511	8/13/13	RBT	SAL	152	37.55	7.63	20.32	4,237
BBR103012040	10/30/12	RBT	SAL	152	32.40	7.70	23.77	5,365
BBR081512782	8/15/12	RBT	SAL	158	42.00	8.00	19.05	3,843
BBR090913004	9/9/13	RBT	SAL	158	32.80	10.00	30.49	7,809
BBR090913006	9/9/13	RBT	SAL	160	44.50	11.00	24.72	5,692
BBR081313567	8/13/13	RBT	SAL	162	44.79	7.35	16.41	3,070
BBR061913180	6/19/13	RBT	SAL	164	44.00	9.00	20.45	4,279
BBR042413005	4/24/13	RBT	SAL	165	38.80	8.80	22.68	5,000
BBR091013253	9/10/13	RBT	SAL	167	41.00	9.55	23.29	5,205
BBR091013056	9/10/13	RBT	SAL	171	53.00	11.67	22.02	4,782
BBR081313561	8/13/13	RBT	SAL	174	50.20	9.20	18.33	3,626

Sample number	Sample date	Species code	Group	Total Length (mm)	Wet weight (g)	Final dry weight (g)	% dry weight	Energy density (J/gWW)
BBR071812513	7/18/12	RBT	SAL	178	60.00	12.00	20.00	4,137
BBR102113814	10/21/13	RBT	SAL	180	57.00	14.00	24.56	5,638
BBR081313522	8/13/13	RBT	SAL	181	58.86	10.93	18.57	3,699
BBR042413001	4/24/13	RBT	SAL	185	44.50	8.83	19.84	4,088
BBR090913005	9/9/13	RBT	SAL	186	69.30	18.00	25.97	6,134
BBR103012030	10/30/12	RBT	SAL	192	81.00	21.00	25.93	6,116
BBR090913003	9/9/13	RBT	SAL	193	66.90	18.00	26.91	6,468
BBR090913539	9/9/13	RBT	SAL	193	70.60	18.00	25.50	5,964
BBR102213787	10/22/13	RBT	SAL	193	83.00	16.00	19.28	3,913
BBR081513250	8/15/13	RBT	SAL	193	65.00	15.00	23.08	5,132
BBR081313571	8/13/13	RBT	SAL	194	69.85	15.33	21.95	4,758
BBR090913001	9/9/13	RBT	SAL	199	68.60	17.00	24.78	5,714
BBR103012014	10/30/12	RBT	SAL	199	78.00	18.00	23.08	5,132
BBR081313568	8/13/13	RBT	SAL	201	84.00	18.45	21.96	4,764
BBR103012024	10/30/12	RBT	SAL	203	85.00	20.42	24.02	5,453
BBR042413077	4/24/13	RBT	SAL	204	71.00	16.26	22.90	5,074
BBR071812506	7/18/12	RBT	SAL	204	98.00	19.00	19.39	3,947
BBR103012026	10/30/12	RBT	SAL	205	97.00	23.00	23.71	5,346
BBR103012017	10/30/12	RBT	SAL	207	103.00	24.00	23.30	5,208
BBR091013025	9/10/13	RBT	SAL	208	123.00	15.13	12.30	1,989
BBR103012011	10/30/12	RBT	SAL	211	101.00	24.00	23.76	5,364
BBR103012027	10/30/12	RBT	SAL	212	99.00	25.00	25.25	5,879
BBR102113803	10/21/13	RBT	SAL	213	90.00	20.00	22.22	4,849
BBR103012015	10/30/12	RBT	SAL	213	86.57	21.87	25.26	5,882
BBR103012022	10/30/12	RBT	SAL	213	96.01	26.70	27.81	6,798
BBR103012029	10/30/12	RBT	SAL	217	116.00	28.00	24.14	5,492
BBR103012023	10/30/12	RBT	SAL	218	119.00	31.26	26.27	6,239

Sample number	Sample date	Species code	Group	Total Length (mm)	Wet weight (g)	Final dry weight (g)	% dry weight	Energy density (J/gWW)
BBR081512781	8/15/12	RBT	SAL	219	126.00	30.00	23.81	5,380
BBR090913002	9/9/13	RBT	SAL	221	107.40	30.00	27.93	6,844
BBR103012028	10/30/12	RBT	SAL	221	117.40	30.00	25.55	5,985
BBR103012013	10/30/12	RBT	SAL	226	128.00	31.00	24.22	5,520
BBR061913179	6/19/13	RBT	SAL	227	128.00	27.00	21.09	4,482
BBR081512778	8/15/12	RBT	SAL	230	130.00	29.00	22.31	4,877
BBR103012016	10/30/12	RBT	SAL	232	137.00	36.00	26.28	6,242
BBR103012019	10/30/12	RBT	SAL	232	141.00	37.00	26.24	6,229
BBR091013035	9/10/13	RBT	SAL	234	137.00	28.30	20.66	4,343
BBR081313572	8/13/13	RBT	SAL	236	142.00	34.54	24.32	5,556
BBR103012012	10/30/12	RBT	SAL	237	159.00	41.00	25.79	6,067
BBR103012021	10/30/12	RBT	SAL	240	142.00	36.00	25.35	5,914
BBR102912251	10/29/12	RBT	SAL	246	133.00	36.45	27.41	6,650
BBR103012020	10/30/12	RBT	SAL	249	163.00	45.90	28.16	6,928
BBR103012018	10/30/12	RBT	SAL	252	155.00	39.60	25.55	5,983
BBR081512779	8/15/12	RBT	SAL	258	193.00	50.00	25.91	6,110
BBR081312525	081312	RBT	SAL	260	220.00	55.00	25.00	5,790
BBR061913184	6/19/13	RBT	SAL	270	204.00	44.00	21.57	4,635
BBR081313560	8/13/13	RBT	SAL	270	239.00	62.00	25.94	6,122
BBR042513026	4/25/13	RBT	SAL	271	199.00	59.00	29.65	7,487
BBR040312076	4/3/12	RBT	SAL	274	235.00	69.00	29.36	7,378
BBR061913183	6/19/13	RBT	SAL	276	192.00	45.00	23.44	5,254
BBR091013057	9/10/13	RBT	SAL	282	257.00	71.00	27.63	6,731
BBR061913165	6/19/13	RBT	SAL	287	239.00	51.00	21.34	4,561
BBR091013318	9/10/13	RBT	SAL	289	267.00	74.00	27.72	6,764
BBR091013041	9/10/13	RBT	SAL	305	310.00	79.00	25.48	5,960
BBR061913167	6/19/13	RBT	SAL	306	320.00	84.00	26.25	6,232

Sample number	Sample date	Species code	Group	Total Length (mm)	Wet weight (g)	Final dry weight (g)	% dry weight	Energy density (J/gWW)
BBR061913173	6/19/13	RBT	SAL	314	288.00	89.00	30.90	7,969
BBR102213796	10/22/13	RBT	SAL	315	354.00	92.00	25.99	6,139
BBR061913511	6/19/13	RXC	SAL	96	7.20	1.00	13.89	2,388
BBR061813309	6/18/13	RXC	SAL	106	10.80	1.46	13.52	2,293
BBR061913104	6/19/13	RXC	SAL	109	8.79	1.94	22.07	4,799
BBR061813068	6/18/13	RXC	SAL	110	13.65	2.30	16.85	3,195
BBR061913134	6/19/13	RXC	SAL	112	12.19	2.00	16.41	3,069
BBR061813308	6/18/13	RXC	SAL	113	11.95	1.69	14.14	2,454
BBR061913132	6/19/13	RXC	SAL	114	13.96	2.01	14.40	2,521
BBR061913133	6/19/13	RXC	SAL	114	15.07	3.00	19.91	4,108
BBR061913117	6/19/13	RXC	SAL	115	15.39	3.20	20.79	4,386
BBR061813330	6/18/13	RXC	SAL	116	15.75	3.00	19.05	3,843
BBR061913135	6/19/13	RXC	SAL	116	23.24	3.43	14.76	2,617
BBR040412029	4/4/12	RXC	SAL	119	13.00	3.00	23.08	5,132
BBR061813331	6/18/13	RXC	SAL	119	15.24	3.00	19.69	4,039
BBR061813070	6/18/13	RXC	SAL	122	18.58	3.36	18.08	3,554
BBR061813306	6/18/13	RXC	SAL	122	15.12	3.00	19.84	4,087
BBR061813066	6/18/13	RXC	SAL	124	16.12	3.00	18.61	3,711
BBR061913513	6/19/13	RXC	SAL	124	19.00	4.00	21.05	4,469
BBR040412028	4/4/12	RXC	SAL	127	17.00	3.00	17.65	3,426
BBR061813333	6/18/13	RXC	SAL	130	17.10	3.21	18.77	3,760
BBR061913111	6/19/13	RXC	SAL	146	22.09	4.66	21.10	4,483
BBR103112022	10/31/12	RXC	SAL	160	38.00	9.36	24.63	5,662
BBR061813320	6/18/13	RXC	SAL	171	52.00	10.00	19.23	3,899
BBR081513297	8/15/13	RXC	SAL	173	51.00	10.00	19.61	4,015
BBR061913181	6/19/13	RXC	SAL	186	49.00	12.00	24.49	5,613
BBR061913172	6/19/13	RXC	SAL	188	69.00	14.00	20.29	4,227

Sample number	Sample date	Species code	Group	Total Length (mm)	Wet weight (g)	Final dry weight (g)	% dry weight	Energy density (J/gWW)
BBR061913182	6/19/13	RXC	SAL	192	72.00	14.00	19.44	3,965
BBR040312062	4/3/12	RXC	SAL	194	94.00	14.00	14.89	2,653
BBR102113772	10/21/13	RXC	SAL	204	86.00	19.00	22.09	4,806
BBR081313534	8/13/13	RXC	SAL	227	124.00	30.48	24.58	5,645
BBR040412046	4/4/12	RXC	SAL	235	109.00	25.00	22.94	5,085
BBR081512780	8/15/12	RXC	SAL	251	174.00	41.00	23.56	5,296
BBR061913185	6/19/13	RXC	SAL	253	172.00	38.00	22.09	4,806
BBR040412047	4/4/12	RXC	SAL	257	158.00	43.00	27.22	6,581
BBR091013257	9/10/13	RXC	SAL	260	195.00	51.00	26.15	6,198
BBR040412043	4/4/12	RXC	SAL	293	224.00	61.00	27.23	6,587
BBR091013322	9/10/13	RXC	SAL	294	291.00	83.00	28.52	7,063
BBR040412011	4/4/12	RXC	SAL	297	226.00	62.00	27.43	6,660
BBR081313054	8/13/13	RXC	SAL	303	309.00	98.00	31.72	8,287
BBR040312075	4/3/12	RXC	SAL	310	277.00	80.00	28.88	7,197
BBR102113763	10/21/13	RXC	SAL	321	320.00	92.00	28.75	7,148
BBR061913519	6/19/13	YSC	SAL	70	2.80	0.50	17.86	3,487
BBR103112046	10/31/12	YSC	SAL	101	7.60	1.62	21.32	4,554
BBR061913510	6/19/13	YSC	SAL	102	8.60	1.00	11.63	1,827
BBR103112002	10/31/12	YSC	SAL	119	13.70	3.27	23.87	5,400
BBR061813329	6/18/13	YSC	SAL	126	19.65	4.00	20.36	4,248
BBR061913507	6/19/13	YSC	SAL	130	17.50	3.30	18.86	3,786
BBR061913532	6/19/13	YSC	SAL	134	17.80	5.00	28.09	6,902
BBR061913118	6/19/13	YSC	SAL	145	26.69	4.37	16.37	3,060
BBR081212007	8/12/12	YSC	SAL	154	44.00	7.00	15.91	2,930
BBR081513058	8/15/13	YSC	SAL	175	51.00	11.00	21.57	4,635
BBR103012031	10/30/12	YSC	SAL	210	82.60	19.00	23.00	5,107
BBR040312084	4/3/12	YSC	SAL	283	223.00	72.00	32.29	8,513

Sample number	Sample date	Species code	Group	Total Length (mm)	Wet weight (g)	Final dry weight (g)	% dry weight	Energy density (J/gWW)
BBR081213046	8/12/13	YSC	SAL	286	235.00	65.00	27.66	6,743
BBR102213810	10/22/13	YSC	SAL	296	246.00	67.00	27.24	6,588
BBR081413268	8/14/13	YSC	SAL	313	273.00	76.00	27.84	6,809
BBR040312108	4/3/12	YSC	SAL	315	281.00	81.00	28.83	7,176
BBR102213778	10/22/13	YSC	SAL	324	338.00	87.00	25.74	6,050
BBR040312047	4/3/12	YSC	SAL	328	325.00	97.00	29.85	7,562
BBR081213301	8/12/13	YSC	SAL	340	389.00	129.00	33.16	8,864
BBR061813065	6/18/13	BNT	SAL	123	19.12	3.17	16.58	3,118
BBR061813069	6/18/13	BNT	SAL	133	20.50	3.89	18.98	3,822
BBR091013124	9/10/13	BNT	SAL	152	37.90	7.67	20.24	4,211
BBR071812505	7/18/12	BNT	SAL	176	53.00	10.00	18.87	3,789
BBR040412049	4/4/12	BNT	SAL	195	77.00	20.15	26.17	6,203
BBR103012032	10/30/12	BNT	SAL	195	71.00	16.00	22.54	4,952
BBR040412012	4/4/12	BNT	SAL	198	74.00	17.16	23.19	5,170
BBR061913164	6/19/13	BNT	SAL	214	95.00	19.94	20.99	4,449
BBR091013023	9/10/13	BNT	SAL	217	109.00	21.46	19.69	4,040
BBR091013030	9/10/13	BNT	SAL	227	131.00	29.48	22.50	4,941
BBR040412050	4/4/12	BNT	SAL	234	109.00	24.73	22.69	5,003
BBR091013032	9/10/13	BNT	SAL	243	154.00	36.88	23.95	5,427
BBR091013033	9/10/13	BNT	SAL	248	173.00	45.00	26.01	6,147
BBR081512759	8/15/12	BNT	SAL	286	248.00	62.00	25.00	5,790
BBR081512760	8/15/12	BNT	SAL	294	274.00	72.00	26.28	6,242
BBR040312201	4/3/12	BNT	SAL	300	246.00	60.00	24.39	5,579
BBR102912262	10/29/12	BNT	SAL	305	263.00	72.00	27.38	6,639
BBR040312202	4/3/12	BNT	SAL	316	307.00	87.00	28.34	6,994
BBR040412042	4/4/12	BNT	SAL	331	317.00	76.00	23.97	5,436
BBR103012035	10/30/12	MWF	SAL	127	17.90	4.26	23.80	5,376

Sample number	Sample date	Species code	Group	Total Length (mm)	Wet weight (g)	Final dry weight (g)	% dry weight	Energy density (J/gWW)
BBR103012036	10/30/12	MWF	SAL	132	19.90	4.66	23.42	5,247
BBR103012047	10/30/12	MWF	SAL	140	21.50	5.74	26.70	6,393
BBR103012008	10/30/12	MWF	SAL	142	22.00	6.06	27.55	6,701
BBR103012038	10/30/12	MWF	SAL	142	22.00	5.97	27.14	6,552
BBR103012033	10/30/12	MWF	SAL	143	22.40	5.56	24.82	5,728
BBR103012034	10/30/12	MWF	SAL	146	24.50	6.29	25.67	6,027
BBR102912028	10/29/12	MWF	SAL	309	288.00	91.70	31.84	8,337
BBR103112021	10/31/12	WHS	OTF	39	0.30	0.05	16.67	3,143
BBR103112020	10/31/12	WHS	OTF	45	0.67	0.12	17.91	3,503
BBR103112019	10/31/12	WHS	OTF	46	0.70	0.16	22.86	5,059
BBR103112018	10/31/12	WHS	OTF	54	1.10	0.27	24.55	5,632
BBR103112037	10/31/12	WHS	OTF	55	1.20	0.31	25.83	6,084
BBR103112017	10/31/12	WHS	OTF	56	1.33	0.33	24.81	5,725
BBR103112045	10/31/12	WHS	OTF	56	1.10	0.24	21.82	4,716
BBR103112011	10/31/12	WHS	OTF	58	1.40	0.35	25.00	5,790
BBR103112016	10/31/12	WHS	OTF	58	1.40	0.31	22.14	4,822
BBR103112049	10/31/12	WHS	OTF	58	1.30	0.31	23.85	5,392
BBR103112038	10/31/12	WHS	OTF	60	1.60	0.41	25.63	6,010
BBR103112012	10/31/12	WHS	OTF	63	1.97	0.40	20.30	4,232
BBR103112014	10/31/12	WHS	OTF	63	2.01	0.39	19.40	3,952
BBR103112044	10/31/12	WHS	OTF	63	2.00	0.47	23.50	5,275
BBR103112013	10/31/12	WHS	OTF	64	2.00	0.45	22.50	4,940
BBR103112035	10/31/12	WHS	OTF	66	1.94	0.48	24.74	5,701
BBR103112008	10/31/12	WHS	OTF	67	2.31	0.46	19.91	4,110
BBR103112034	10/31/12	WHS	OTF	69	2.10	0.51	24.29	5,543
BBR103112006	10/31/12	WHS	OTF	70	2.90	0.57	19.66	4,030
BBR103112033	10/31/12	WHS	OTF	70	2.70	0.66	24.44	5,597

Sample number	Sample date	Species code	Group	Total Length (mm)	Wet weight (g)	Final dry weight (g)	% dry weight	Energy density (J/gWW)
BBR103112029	10/31/12	WHS	OTF	71	2.90	0.68	23.45	5,257
BBR103112031	10/31/12	WHS	OTF	71	2.93	0.59	20.14	4,179
BBR103112048	10/31/12	WHS	OTF	73	2.70	0.62	22.96	5,094
BBR103112007	10/31/12	WHS	OTF	75	3.80	0.92	24.21	5,517
BBR103112030	10/31/12	WHS	OTF	78	3.80	0.85	22.37	4,897
BBR103112032	10/31/12	WHS	OTF	82	4.50	0.90	20.00	4,137
BBR103012046	10/30/12	WHS	OTF	92	6.90	1.38	20.00	4,137
BBR103012045	10/30/12	WHS	OTF	94	6.90	1.51	21.88	4,738
BBR061813307	6/18/13	WHS	OTF	110	11.35	1.95	17.18	3,290
BBR091013126	9/10/13	WHS	OTF	112	15.20	2.34	15.39	2,789
BBR061913543	6/19/13	WHS	OTF	112	18.70	2.50	13.37	2,254
BBR103012043	10/30/12	WHS	OTF	113	14.70	3.02	20.54	4,308
BBR091013122	9/10/13	WHS	OTF	114	14.90	2.29	15.37	2,782
BBR103012041	10/30/12	WHS	OTF	115	15.10	3.76	24.90	5,756
BBR103112005	10/31/12	WHS	OTF	115	13.70	2.70	19.71	4,046
BBR103112054	10/31/12	WHS	OTF	115	15.30	3.67	23.99	5,440
BBR061813301	6/18/13	WHS	OTF	116	15.05	2.97	19.73	4,054
BBR061913102	6/19/13	WHS	OTF	117	18.17	2.78	15.30	2,763
BBR091013127	9/10/13	WHS	OTF	117	16.80	2.83	16.85	3,194
BBR091013128	9/10/13	WHS	OTF	117	17.20	2.53	14.71	2,604
BBR061913115	6/19/13	WHS	OTF	118	22.15	3.48	15.71	2,875
BBR061913145	6/19/13	WHS	OTF	118	16.60	2.72	16.39	3,063
BBR061913112	6/19/13	WHS	OTF	119	19.64	3.83	19.50	3,982
BBR103112028	10/31/12	WHS	OTF	119	13.80	2.98	21.59	4,644
BBR040412030	4/4/12	WHS	OTF	120	14.00	2.85	20.36	4,249
BBR091013129	9/10/13	WHS	OTF	121	18.30	3.17	17.32	3,331
BBR061913136	6/19/13	WHS	OTF	122	16.14	2.25	13.94	2,401

Sample number	Sample date	Species code	Group	Total Length (mm)	Wet weight (g)	Final dry weight (g)	% dry weight	Energy density (J/gWW)
BBR103112004	10/31/12	WHS	OTF	124	16.10	3.50	21.74	4,691
BBR103012042	10/30/12	WHS	OTF	125	18.90	4.17	22.06	4,796
BBR103012044	10/30/12	WHS	OTF	125	17.60	4.62	26.25	6,232
BBR103112052	10/31/12	WHS	OTF	126	17.50	3.63	20.74	4,370
BBR061913542	6/19/13	WHS	OTF	129	20.60	4.19	20.34	4,243
BBR103112053	10/31/12	WHS	OTF	130	19.70	3.81	19.34	3,933
BBR061913541	6/19/13	WHS	OTF	135	24.30	5.10	20.99	4,448
BBR103112027	10/31/12	WHS	OTF	154	36.20	7.96	21.99	4,772
BBR061913540	6/19/13	WHS	OTF	157	36.60	7.62	20.82	4,395
BBR061813319	6/18/13	WHS	OTF	164	54.00	8.04	14.89	2,652
BBR091013276	9/10/13	WHS	OTF	164	48.00	6.92	14.42	2,526
BBR091013275	9/10/13	WHS	OTF	165	48.00	7.59	15.81	2,903
BBR091013259	9/10/13	WHS	OTF	178	62.00	9.65	15.56	2,835
BBR103112043	10/31/12	WHS	OTF	180	71.00	13.00	18.31	3,621
BBR091013277	9/10/13	WHS	OTF	183	68.00	11.72	17.24	3,306
BBR090913542	9/9/13	WHS	OTF	189	69.50	14.00	20.14	4,182
BBR061913538	6/19/13	WHS	OTF	197	71.20	16.73	23.50	5,274
BBR090913557	9/9/13	WHS	OTF	203	94.20	20.00	21.23	4,526
BBR081613503	8/16/13	WHS	OTF	218	120.00	23.00	19.17	3,880
BBR061813317	6/18/13	WHS	OTF	219	118.00	28.82	24.42	5,590
BBR091013014	9/10/13	WHS	OTF	222	134.00	19.81	14.78	2,623
BBR042413007	4/24/13	WHS	OTF	231	114.30	28.92	25.30	5,896
BBR061813315	6/18/13	WHS	OTF	236	180.00	40.89	22.72	5,012
BBR090913269	9/9/13	WHS	OTF	236	142.00	28.00	19.72	4,049
BBR061913121	6/19/13	WHS	OTF	237	175.00	36.15	20.66	4,343
BBR090913267	9/9/13	WHS	OTF	246	160.00	33.00	20.63	4,333
BBR090913293	9/9/13	WHS	OTF	246	155.00	31.00	20.00	4,137

Sample number	Sample date	Species code	Group	Total Length (mm)	Wet weight (g)	Final dry weight (g)	% dry weight	Energy density (J/gWW)
BBR061913137	6/19/13	WHS	OTF	248	177.00	39.24	22.17	4,831
BBR091013135	9/10/13	WHS	OTF	250	171.00	36.00	21.05	4,469
BBR091013134	9/10/13	WHS	OTF	262	219.00	44.00	20.09	4,165
BBR090913282	9/9/13	WHS	OTF	270	199.00	39.00	19.60	4,012
BBR081313045	8/13/13	WHS	OTF	271	235.00	55.00	23.40	5,242
BBR061913123	6/19/13	WHS	OTF	271	265.00	65.00	24.53	5,626
BBR061813314	6/18/13	WHS	OTF	281	268.00	67.00	25.00	5,790
BBR081313030	8/13/13	WHS	OTF	294	294.00	72.00	24.49	5,613
BBR090913569	9/9/13	LNS	OTF	114	14.80	2.00	13.51	2,291
BBR061913530	6/19/13	LNS	OTF	117	20.20	3.17	15.69	2,870
BBR061913503	6/19/13	LNS	OTF	123	16.50	3.68	22.30	4,875
BBR091013119	9/10/13	LNS	OTF	125	19.20	3.17	16.51	3,099
BBR061913527	6/19/13	LNS	OTF	131	20.10	3.76	18.71	3,740
BBR091013131	9/10/13	LNS	OTF	131	23.40	4.14	17.69	3,439
BBR091013120	9/10/13	LNS	OTF	132	20.70	3.37	16.28	3,034
BBR091013121	9/10/13	LNS	OTF	134	20.80	3.64	17.50	3,383
BBR061913529	6/19/13	LNS	OTF	137	24.90	5.57	22.37	4,897
BBR091013130	9/10/13	LNS	OTF	144	24.80	4.49	18.10	3,560
BBR091013118	9/10/13	LNS	OTF	147	29.40	5.46	18.57	3,700
BBR090913250	9/9/13	LNS	OTF	192	66.80	15.00	22.46	4,925
BBR090913573	9/9/13	LNS	OTF	198	77.50	17.00	21.94	4,755
BBR042513100	4/25/13	LNS	OTF	202	68.30	13.22	19.36	3,938
BBR061913528	6/19/13	LNS	OTF	218	103.30	26.89	26.03	6,154
BBR061913153	6/19/13	LNS	OTF	225	127.00	29.08	22.90	5,072
BBR103012048	10/30/12	LNS	OTF	225	97.00	19.65	20.26	4,217
BBR091013136	9/10/13	LNS	OTF	229	112.00	23.00	20.54	4,305
BBR061813318	6/18/13	LNS	OTF	234	139.00	34.60	24.89	5,753

Sample number	Sample date	Species code	Group	Total Length (mm)	Wet weight (g)	Final dry weight (g)	% dry weight	Energy density (J/gWW)
BBR061813316	6/18/13	LNS	OTF	235	148.00	35.92	24.27	5,537
BBR081412502	8/14/12	LNS	OTF	238	144.00	33.00	22.92	5,079
BBR061913122	6/19/13	LNS	OTF	245	170.00	36.32	21.36	4,569
BBR061913152	6/19/13	LNS	OTF	248	175.00	45.16	25.81	6,074
BBR061813284	6/18/13	LNS	OTF	255	182.00	45.00	24.73	5,695
BBR061913268	6/19/13	LNS	OTF	258	195.00	53.82	27.60	6,721
BBR061913154	6/19/13	LNS	OTF	261	179.00	45.04	25.16	5,847
BBR061913259	6/19/13	LNS	OTF	278	254.00	66.00	25.98	6,137
BBR081413040	8/14/13	LNS	OTF	282	244.00	53.00	21.72	4,685
BBR061913003	6/19/13	LNS	OTF	286	265.00	65.00	24.53	5,626
BBR090913296	9/9/13	LNS	OTF	287	245.00	55.00	22.45	4,923
BBR081313064	8/13/13	LNS	OTF	290	264.00	64.00	24.24	5,528
BBR061813321	6/18/13	LNS	OTF	290	282.00	71.00	25.18	5,852
BBR090913549	9/9/13	YEP	OTF	55	2.70	0.35	12.96	2,152
BBR103112042	10/31/12	YEP	OTF	67	2.80	0.59	21.07	4,475
BBR103112047	10/31/12	YEP	OTF	71	2.80	0.59	21.07	4,475
BBR060612021	6/6/12	YEP	OTF	94	9.07	2.34	25.79	6,070
BBR061913146	6/19/13	YEP	OTF	98	10.70	2.02	18.88	3,792
BBR061813063	6/18/13	YEP	OTF	99	13.85	2.41	17.40	3,354
BBR102912001	10/29/12	YEP	OTF	99	11.00	2.97	27.00	6,502
BBR060612024	6/6/12	YEP	OTF	99	9.07	2.80	30.86	7,955
BBR103012006	10/30/12	YEP	OTF	100	9.00	2.80	31.11	8,051
BBR091013107	9/10/13	YEP	OTF	101	12.00	2.52	21.00	4,452
BBR061813062	6/18/13	YEP	OTF	101	10.86	2.30	21.18	4,510
BBR090913532	9/9/13	YEP	OTF	102	12.70	2.00	15.75	2,886
BBR091013113	9/10/13	YEP	OTF	104	12.20	2.79	22.87	5,063
BBR060612017	6/6/12	YEP	OTF	107	18.14	3.06	16.87	3,200

Sample number	Sample date	Species code	Group	Total Length (mm)	Wet weight (g)	Final dry weight (g)	% dry weight	Energy density (J/gWW)
BBR091013108	9/10/13	YEP	OTF	111	15.70	3.54	22.55	4,956
BBR103112051	10/31/12	YEP	OTF	111	12.00	3.56	29.67	7,494
BBR091013112	9/10/13	YEP	OTF	112	15.00	3.36	22.40	4,907
BBR090913530	9/9/13	YEP	OTF	114	17.00	3.00	17.65	3,426
BBR091013105	9/10/13	YEP	OTF	114	17.00	4.12	24.24	5,525
BBR090913545	9/9/13	YEP	OTF	116	18.70	5.00	26.74	6,407
BBR091013111	9/10/13	YEP	OTF	116	19.20	4.62	24.06	5,466
BBR091013110	9/10/13	YEP	OTF	117	20.20	3.94	19.50	3,983
BBR091013114	9/10/13	YEP	OTF	117	18.40	4.24	23.04	5,121
BBR091013115	9/10/13	YEP	OTF	117	19.20	4.31	22.45	4,923
BBR091013116	9/10/13	YEP	OTF	118	18.80	4.34	23.09	5,135
BBR090913509	9/9/13	YEP	OTF	119	19.80	4.00	20.20	4,200
BBR061913114	6/19/13	YEP	OTF	120	15.20	2.68	17.63	3,421
BBR090913552	9/9/13	YEP	OTF	121	19.90	4.00	20.10	4,168
BBR060612022	6/6/12	YEP	OTF	122	27.22	5.87	21.57	4,635
BBR091013106	9/10/13	YEP	OTF	122	19.50	4.32	22.15	4,826
BBR090913575	9/9/13	YEP	OTF	123	20.90	4.00	19.14	3871
BBR091013109	9/10/13	YEP	OTF	128	23.10	5.38	23.29	5,204
BBR091013104	9/10/13	YEP	OTF	131	27.80	6.12	22.01	4,780
BBR060612019	6/6/12	YEP	OTF	132	27.22	6.82	25.06	5,811
BBR091013313	9/10/13	YEP	OTF	133	36.00	7.78	21.61	4,649
BBR091013265	9/10/13	YEP	OTF	140	38.00	8.92	23.47	5,266
BBR090913288	9/9/13	YEP	OTF	144	35.00	7.00	20.00	4,137
BBR060612018	6/6/12	YEP	OTF	145	36.29	7.98	21.99	4,773
BBR060612023	6/6/12	YEP	OTF	145	27.20	3.75	13.79	2,361
BBR091013273	9/10/13	YEP	OTF	145	38.00	7.73	20.34	4,244
BBR090913275	9/9/13	YEP	OTF	147	43.00	10.00	23.26	5,192

Sample number	Sample date	Species code	Group	Total Length (mm)	Wet weight (g)	Final dry weight (g)	% dry weight	Energy density (J/gWW)
BBR091013319	9/10/13	YEP	OTF	147	39.00	8.91	22.85	5,055
BBR090913297	9/9/13	YEP	OTF	159	50.00	12.00	24.00	5,445
BBR091013324	9/10/13	YEP	OTF	161	51.00	11.61	22.76	5,028
BBR060612020	6/6/12	YEP	OTF	163	54.43	14.80	27.19	6,572
BBR091013317	9/10/13	YEP	OTF	173	65.00	14.85	22.85	5,055
BBR042513415	4/25/13	YEP	OTF	175	72.00	12.91	17.93	3,509
BBR091013264	9/10/13	YEP	OTF	177	75.00	17.77	23.69	5,340
BBR091013320	9/10/13	YEP	OTF	183	78.00	17.57	22.53	4,949
BBR042513264	4/25/13	YEP	OTF	185	75.00	18.00	24.00	5,445
BBR091013309	9/10/13	YEP	OTF	187	92.00	20.31	22.08	4,801
BBR090913263	9/9/13	YEP	OTF	190	85.00	21.00	24.71	5,688
BBR042513255	4/25/13	YEP	OTF	212	104.00	24.00	23.08	5,132
BBR081413066	8/14/13	YEP	OTF	219	153.00	41.00	26.80	6,429
BBR091013292	9/10/13	YEP	OTF	220	130.00	32.00	24.62	5,657
BBR042513254	4/25/13	YEP	OTF	252	220.00	47.00	21.36	4,569
BBR060612016	6/6/12	YEP	OTF	269	254.01	58.00	22.83	5,051

APPENDIX VII: *$\delta^{13}C$ and $\delta^{15}N$ stable isotope analyses of the Buffalo Bill Reservoir food web.*

Stable isotope ratios, particularly carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$), have become increasingly useful for understanding aquatic food web structure and energy flow in ecosystems (Vander Zanden and Rasmussen 2001). Carbon isotope ratio, $\delta^{13}C$, is used for tracing energy sources to the food web. For example, benthic sources of primary production (algae) typically exhibit less fractionation during carbon fixation, and are generally enriched in ^{13}C compared to pelagic sources (phytoplankton) in lentic systems (Vander Zanden and Rasmussen 1999) so the $\delta^{13}C$ of a consumer can indicate whether it derives energy from benthic or pelagic food chains. Carbon isotopes are also useful for determining the particular prey of consumers because of their small amount of fractionation (<1‰; Vander Zanden et al. 1999). Nitrogen isotope ratio can be used to infer the trophic position of a consumer, and together with $\delta^{13}C$ data, additional insight into that particular prey taxa consumed. Due to digestive processes, consumers become enriched in the heavy ^{15}N isotope by 1.5-4‰ with each step in the food chain (Vander Zanden and Rasmussen 2001, McCutchan et al. 2003). Stomach content analysis is useful because it provides direct observation of diet composition, but this is a short term depiction of a fish's diet at the time of sampling, and stomachs are commonly empty. Used together, stable isotope and stomach content data can deliver a better overall assessment of a fish's diet over a growing season or longer.

We collected samples for stable carbon and nitrogen isotope analysis from Lake Trout and Walleye, and from all of their potential prey items in Buffalo Bill Reservoir. Epaxial muscle tissue plugs (1 cm^3) were removed from fish between lateral line and dorsal fin. Samples were also analyzed from bulk samples of whole zooplankton, and muscle tissue from tails of crayfish.

Samples were dried at 60°C for 72 hours before being ground to a powder with mortar and pestle. Samples were analyzed by the Cornell University Stable Isotope Laboratory with a Thermo Delta V isotope ratio mass spectrometer interfaced with an NC2500 elemental analyzer.

Differences in C and N isotopes were expressed as δ values in parts per thousand (‰) relative to reference standards of PeeDee belemnite for ^{13}C and nitrogen gas in ambient air for ^{15}N, where R is the carbon or nitrogen isotopic ratio ($^{13}C/^{12}C$ or $^{15}N/^{14}N$, Fry 2006):

$$\delta_{sample} = \left(\frac{R_{sample}}{R_{standard}} - 1\right) \times 1000$$

Because lipids are ^{13}C-depleted lipid, we normalized $\delta^{13}C$ ratios using the equation described by Post et al. (2007):

$$\delta^{13}\mathrm{C}_{\mathrm{normalized}} = \delta^{13}\mathrm{C}_{\mathrm{measured}} - 3.32 + 0.99 \times \mathrm{C{:}N}$$

where C:N is the carbon to nitrogen ratio.

We collected and analyzed tissue samples of Brown Trout (34), Catostomids (81), crayfish (10), lake Trout (164), *Oncorhynchus* spp. (188), Walleye (135), Yellow Perch (22) and zooplankton (3; Table VII.1). We planned to use stable isotopes signatures to corroborate gut content analysis; we were particularly interested in the incidence of piscivory by Lake Trout and Walleye. If either predator was feeding on other fish, the stable isotope signature of the predator should be ~0.5–1.0 unit higher in carbon and ~3 units higher in nitrogen than the prey fish. We encountered some difficulties in interpreting the stable isotope data. First, approximate 95% confidence intervals on the mean carbon and nitrogen signatures of most prey fish species and crayfish overlapped. Only zooplankton and age-0 *Oncorhynchus* spp. had unique isotopic signatures (Figure VII.1). Apparently several prey organisms at Buffalo Bill Reservoir share resources to a great extent. This makes parsing the predators' diet composition with isotope data difficult. Second, gut content analysis showed that all sizes of Walleye, Lake Trout, and *Oncorhynchus* spp. consumed some aquatic insects, but we did not obtain any samples of aquatic insects for isotopic analysis, partly because diet was unknown until after we had already collected tissue samples from predators for isotope analysis. Because the isotopic signature of aquatic insects at Buffalo Bill Reservoir is unknown, we can't use isotope mixing models (e.g., MIXSIR, Semmens and Moore 2008) to estimate the diet composition.

The stable isotope analysis did provide some interesting insights. Isotopes supported our contention that small (<600 mm) and large Lake Trout have different diets, and large Lake Trout had a significantly higher trophic position than small Lake Trout. We also found that small (<200 mm) Walleye had a different diet than larger Walleye, but both groups had the same trophic position, above that of all the prey fish species. Finally, the isotopic signatures of *Oncorhynchus* spp. changed dramatically with total length (Figure VII.1). Thus, the signatures of age-0+ and age-1+ *Oncorhynchus* spp. are probably different from those of older, larger *Oncorhynchus* spp. Speculating, this could occur if young *Oncorhynchus* spp. fed on prey in the rivers and gradually switched to a reservoir-based diet. The wide range in carbon signatures across size of *Oncorhynchus* spp. makes it difficult to use isotopes to understand the diet of piscivores that might consume different sizes of *Oncorhynchus* spp.

Recommendations

If there is interest in conducting stable isotope analysis in the future we recommend that investigators gather samples of aquatic insects as well as the prey taxa examined in this study.

Further, the pattern in *Oncorhynchus* spp. signatures could be investigated by focusing sampling on fish < 300 mm TL, and by sampling riverine prey items. Because it appears that zooplankton are an important diet item for some *Oncorhynchus* spp., and because zooplankton signatures probably change seasonal with cycles of stratification and phytoplankton succession, it would be wise to sample zooplankton for isotope analysis monthly or every two weeks. It would also be important to collect the size fraction/taxa of zooplankton consumed by fish (mainly *Daphnia* spp. during our study). However, if food web structure is unchanged, it will still be difficult to use stable isotopes to parse the diet of piscivores into specific prey fish species for the reasons outlined above.

Table VII.1. Stable carbon (**δ^{13}C**) and nitrogen (**δ^{15}N**) isotope measurements and carbon:nitrogen (C:N) ratio of samples collected from Buffalo Bill Reservoir in 2012 and 2013. All fish samples were from epaxial muscle tissue without skin attached, zooplankton were amalgamated whole specimens, and crayfish were flesh samples from tails. Species codes are as follows: BNT = Brown Trout, CRF = crayfish (*Orconectes virilis*), LAT = Lake Trout, LNS = Longnose Sucker, LND = Longnose Dace, RBT = Rainbow Trout, RXC = Rainbow Trout/Cutthroat Trout hybrid, WAE = Walleye, WHS = White Sucker, YEP = Yellow Perch, YSC = Yellowstone Cutthroat Trout, and ZOO = zooplankton. Normalized δ^{13}C is value obtained by correcting for lipid depletion as described by Post et al. (2007).

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR061813069	6/18/13	BNT	133	20.5	3.45	8.80	-24.15	-24.1
BBR091013124	9/10/13	BNT	152	37.9	3.40	5.37	-20.77	-20.7
BBR040412049	4/4/12	BNT	195	77.0	3.59	5.75	-23.14	-22.9
BBR091013023	9/10/13	BNT	217	109.0	3.30	7.63	-24.86	-24.9
BBR091013030	9/10/13	BNT	227	131.0	3.58	7.69	-26.26	-26.0
BBR040412050	4/4/12	BNT	234	109.0	3.37	9.09	-24.48	-24.5
BBR091013032	9/10/13	BNT	243	154.0	3.64	7.99	-26.27	-26.0
BBR091013035	9/10/13	BNT	256	173.0	3.40	8.84	-25.54	-25.5
BBR091013003	9/10/13	BNT	291	267.0	3.37	7.94	-26.18	-26.2
BBR042513014	4/25/13	BNT	292	223.0	3.52	11.57	-25.60	-25.4
BBR042513268	4/25/13	BNT	318	300.0	3.31	10.63	-23.69	-23.7
BBR071613047	7/16/13	BNT	326	356.0	3.48	9.35	-27.24	-27.1
BBR040412042	4/4/12	BNT	331	317.0	3.29	9.68	-24.07	-24.1
BBR081512757	8/15/12	BNT	334	385.0	3.36	6.96	-23.48	-23.5
BBR042513266	4/25/13	BNT	342	320.0	3.73	10.20	-27.37	-27.0
BBR042513259	4/25/13	BNT	353	391.0	3.37	9.96	-25.90	-25.9
BBR081213271	8/12/12	BNT	354	433.0	3.36	9.44	-26.64	-26.6
BBR081512758	8/15/12	BNT	377	523.0	3.46	8.28	-24.21	-24.1
BBR102213821	10/22/13	BNT	377	472.0	3.38	9.83	-26.46	-26.4
BBR090913255	9/9/13	BNT	397	528.0	3.29	10.39	-26.78	-26.8
BBR081313566	8/13/13	BNT	409	627.0	3.48	9.71	-25.04	-24.9
BBR042513002	4/25/13	BNT	413	603.0	3.98	9.73	-26.13	-25.5

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR061913138	6/19/13	BNT	414	601.0	3.25	9.32	-25.12	-25.2
BBR042513302	4/25/13	BNT	423	610.0	3.29	9.29	-25.09	-25.1
BBR081413289	8/14/13	BNT	440	529.0	3.35	10.50	-25.77	-25.8
BBR081213303	8/12/12	BNT	448	770.0	3.29	10.39	-24.30	-24.4
BBR052213035	5/22/13	BNT	452	751.0	3.55	11.46	-26.65	-26.5
BBR052213024	5/22/13	BNT	455	720.0	3.17	10.27	-24.88	-25.1
BBR090913262	9/9/13	BNT	461	863.0	3.26	9.18	-22.83	-22.9
BBR090913262 REP2	9/9/13	BNT	461	863.0	3.33	10.61	-24.91	-24.9
BBR052213017	5/22/13	BNT	470	869.0	3.32	10.36	-25.13	-25.2
BBR052213023	5/22/13	BNT	486	1034.0	3.29	10.88	-24.43	-24.5
BBR081313504	8/13/13	BNT	487	951.0	3.55	10.40	-24.11	-23.9
BBR090913260	9/9/13	BNT	510	1145.0	3.36	11.20	-24.18	-24.2
BBR071812801	7/18/12	CRF			3.24	10.22	-24.07	-24.2
BBR071812806	7/18/12	CRF			3.25	10.08	-24.90	-25.0
BBR071812828	7/18/12	CRF			3.21	9.36	-23.87	-24.0
BBR071812835	7/18/12	CRF			3.21	8.07	-22.75	-22.9
BBR071812838	7/18/12	CRF			3.41	6.26	-20.44	-20.4
BBR071812842	7/18/12	CRF			3.14	9.27	-24.62	-24.8
BBR071912802	7/19/12	CRF			3.36	9.82	-24.13	-24.1
BBR071912804	7/19/12	CRF			3.21	8.31	-24.21	-24.4
BBR071912805	7/19/12	CRF			3.17	6.49	-23.27	-23.5
BBR071912807	7/19/12	CRF			3.30	8.87	-22.72	-22.8
BBR061913144	6/19/13	LAT	157	28.6	3.39	12.64	-26.59	-26.6
BBR081212008	8/12/12	LAT	176	50.0	3.47	7.55	-23.33	-23.2
BBR081313544	8/13/13	LAT	185	48.9	3.82	12.41	-26.85	-26.4
BBR081313508	8/13/13	LAT	187	53.0	3.42	12.97	-26.14	-26.1
BBR081313563	8/13/13	LAT	192	54.7	5.31	12.39	-28.01	-26.1
BBR091013007	9/10/13	LAT	197	74.0	4.25	12.01	-27.41	-26.5
BBR081313505	8/13/13	LAT	202	64.0	3.76	12.30	-27.21	-26.8

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR081313510	8/13/13	LAT	202	66.8	3.87	12.74	-26.99	-26.5
BBR081313537	8/13/13	LAT	202	58.8	3.88	12.15	-27.36	-26.8
BBR091013071	9/10/13	LAT	202	80.0	3.29	12.18	-25.66	-25.7
BBR081413026	8/14/13	LAT	210	79.0	3.80	12.21	-27.13	-26.7
BBR081313548	8/13/13	LAT	211	78.7	3.52	11.54	-26.70	-26.5
BBR071812040	7/18/12	LAT	287	225.0	3.86	10.43	-24.45	-24.0
BBR081213313	8/12/12	LAT	291	202.0	4.65	12.41	-26.85	-25.6
BBR081313540	8/13/13	LAT	293	197.0	3.31	12.41	-25.38	-25.4
BBR081412506	8/14/12	LAT	298	257.0	3.25	9.90	-23.12	-23.2
BBR071912256	7/19/12	LAT	302	453.0	3.19	11.37	-25.24	-25.4
BBR081313072	8/13/13	LAT	305	216.0	3.36	11.46	-25.31	-25.3
BBR081313055	8/13/13	LAT	326	275.0	3.32	12.43	-25.37	-25.4
BBR071812029	7/18/12	LAT	328	334.0	3.80	10.30	-24.27	-23.8
BBR081413027	8/14/13	LAT	333	336.0	4.29	12.21	-26.68	-25.8
BBR081512252	8/15/12	LAT	355	370.0	8.32	10.18	-27.66	-22.7
BBR071712030	7/17/12	LAT	374	415.0	3.11	11.26	-24.63	-24.9
BBR081213049	8/12/12	LAT	384	446.0	3.58	12.26	-25.95	-25.7
BBR081313311	8/13/13	LAT	387	462.0	3.68	11.57	-25.99	-25.7
BBR071912268	7/19/12	LAT	396	593.0	6.00	10.16	-27.29	-24.7
BBR081313255	8/13/13	LAT	397	531.0	3.63	11.70	-26.00	-25.7
BBR071812024	7/18/12	LAT	401	572.0	3.56	10.54	-25.94	-25.7
BBR081412703	8/14/12	LAT	401	690.0	3.19	10.55	-25.11	-25.3
BBR071812004	7/18/12	LAT	405	620.0	3.70	10.12	-24.52	-24.2
BBR081413056	8/14/13	LAT	409	508.0	3.38	11.29	-26.29	-26.3
BBR071812052	7/18/12	LAT	419	603.0	4.14	10.76	-25.67	-24.9
BBR081612047	8/16/12	LAT	420	.	3.63	10.18	-24.49	-24.2
BBR071712005	7/17/12	LAT	421	662.0	3.42	10.24	-24.46	-24.4
BBR040312052	4/3/12	LAT	425	509.0	4.07	11.26	-26.27	-25.6
BBR081313302	8/13/13	LAT	428	642.0	3.34	10.97	-25.40	-25.4

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR071712008	7/17/12	LAT	438	618.0	3.24	10.43	-25.57	-25.7
BBR102912008	10/29/12	LAT	440	550.0	3.07	10.92	-23.86	-24.1
BBR071712010	7/17/12	LAT	443	785.0	3.40	10.82	-26.52	-26.5
BBR071712018	7/17/12	LAT	444	735.0	4.02	10.75	-27.38	-26.7
BBR102213797	10/22/13	LAT	445	706.0	3.48	11.47	-25.44	-25.3
BBR103012265	10/30/12	LAT	445	627.0	3.26	10.62	-26.47	-26.6
BBR081313320	8/13/13	LAT	449	826.0	3.21	11.66	-25.96	-26.1
BBR081512750	8/15/12	LAT	450	862.0	3.37	10.61	-25.79	-25.8
BBR042513500	4/25/13	LAT	452	750.0	3.45	11.46	-26.76	-26.7
BBR081413014	8/14/13	LAT	456	832.0	3.44	11.45	-26.33	-26.2
BBR102912004	10/29/12	LAT	456	700.0	3.77	10.58	-26.37	-26.0
BBR081413294	8/14/13	LAT	457	792.0	3.45	11.50	-26.74	-26.7
BBR081313557	8/13/13	LAT	460	723.0	3.21	11.87	-25.71	-25.8
BBR081313021	8/13/13	LAT	461	678.0	3.26	11.74	-26.30	-26.4
BBR042513502	4/25/13	LAT	462	690.0	3.24	10.83	-25.69	-25.8
BBR102213776	10/22/13	LAT	462	742.0	3.48	11.36	-25.78	-25.7
BBR071812037	7/18/12	LAT	463	882.0	3.68	11.21	-26.71	-26.4
BBR102113061	10/21/13	LAT	463	827.0	4.19	11.67	-26.84	-26.0
BBR042513303	4/25/13	LAT	464	755.0	3.25	11.68	-25.92	-26.0
BBR061913042	6/19/13	LAT	464	853.0	5.02	11.06	-28.30	-26.6
BBR042513029	4/25/13	LAT	465	762.0	3.69	11.07	-27.28	-26.9
BBR071812264	7/18/12	LAT	465	818.0	3.27	11.19	-26.37	-26.5
BBR102912010	10/29/12	LAT	465	.	3.80	10.38	-26.78	-26.3
BBR042513253	4/25/13	LAT	468	665.0	3.15	11.81	-26.12	-26.3
BBR071712015	7/17/12	LAT	470	885.0	3.55	11.30	-26.83	-26.6
BBR042513041	4/25/13	LAT	472	988.0	3.95	11.61	-27.73	-27.1
BBR102912043	10/29/12	LAT	472	.	3.51	11.06	-26.22	-26.1
BBR103012263	10/30/12	LAT	472	825.0	2.60	10.23	-25.70	-26.5
BBR071812508	7/18/12	LAT	473	845.0	4.44	11.69	-27.62	-26.5

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR061913018	6/19/13	LAT	474	930.0	3.34	10.78	-25.68	-25.7
BBR071812034	7/18/12	LAT	475	902.0	3.42	10.53	-26.29	-26.2
BBR102912039	10/29/12	LAT	477	.	3.54	10.88	-26.29	-26.1
BBR102912007	10/29/12	LAT	478	800.0	2.53	10.04	-25.53	-26.3
BBR103012262	10/30/12	LAT	478	794.0	3.20	10.93	-26.26	-26.4
BBR103012271	10/30/12	LAT	478	832.0	3.41	11.20	-26.69	-26.6
BBR042513504	4/25/13	LAT	479	834.0	3.58	11.86	-26.70	-26.5
BBR042513305	4/25/13	LAT	481	822.0	3.54	11.49	-26.38	-26.2
BBR103012272	10/30/12	LAT	481	882.0	3.51	11.49	-26.77	-26.6
BBR081213053	8/12/12	LAT	482	795.0	3.29	11.86	-26.17	-26.2
BBR081512756	8/15/12	LAT	482	914.0	3.28	10.36	-25.69	-25.8
BBR102113009	10/21/13	LAT	482	835.0	3.84	11.60	-27.11	-26.6
BBR042513501	4/25/13	LAT	488	802.0	3.23	11.96	-26.22	-26.3
BBR102912013	10/29/12	LAT	488	.	4.04	11.08	-27.38	-26.7
BBR102912018	10/29/12	LAT	488	.	3.87	10.89	-27.16	-26.6
BBR081413263	8/14/13	LAT	490	930.0	3.56	11.67	-26.61	-26.4
BBR102213792	10/22/13	LAT	490	889.0	3.30	11.06	-25.93	-26.0
BBR102912003	10/29/12	LAT	490	900.0	7.12	12.83	-28.14	-24.4
BBR081413260	8/14/13	LAT	491	907.0	3.96	11.85	-27.34	-26.7
BBR102912015	10/29/12	LAT	492	.	3.47	10.79	-26.61	-26.5
BBR103012264	10/30/12	LAT	494	884.0	3.34	10.15	-25.19	-25.2
BBR040312051	4/3/12	LAT	495	843.0	3.10	11.34	-25.26	-25.5
BBR071812512	7/18/12	LAT	495	1122.0	3.65	10.84	-26.91	-26.6
BBR102213781	10/22/13	LAT	495	910.0	4.34	11.64	-26.67	-25.7
BBR102912032	10/29/12	LAT	496	.	3.29	11.07	-26.57	-26.6
BBR071613002	7/16/13	LAT	497	1036.0	4.55	11.27	-28.13	-27.0
BBR102912014	10/29/12	LAT	497	.	3.38	10.98	-24.34	-24.3
BBR042513505	4/25/13	LAT	498	932.0	3.30	11.61	-26.32	-26.4
BBR042513306	4/25/13	LAT	501	869.0	3.31	11.50	-25.56	-25.6

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR071712027	7/17/12	LAT	501	1081.0	3.42	10.88	-26.59	-26.5
BBR102213795	10/22/13	LAT	501	895.0	3.39	11.96	-25.96	-25.9
BBR040212026	4/2/12	LAT	502	892.0	3.21	10.14	-25.99	-26.1
BBR071613003	7/16/13	LAT	502	1063.0	3.26	11.66	-26.00	-26.1
BBR071712004	7/17/12	LAT	502	998.0	3.33	10.96	-26.27	-26.3
BBR081512283	8/15/12	LAT	503	806.0	3.13	11.22	-25.11	-25.3
BBR102213784	10/22/13	LAT	504	1010.0	3.49	11.89	-26.06	-25.9
BBR102912017	10/29/12	LAT	504	.	3.10	10.75	-26.82	-27.1
BBR102912046	10/29/12	LAT	504	.	3.35	10.88	-26.21	-26.2
BBR040312020	4/3/12	LAT	505	1034.0	5.11	11.38	-29.28	-27.5
BBR042413016	4/24/13	LAT	506	903.0	3.67	12.49	-24.55	-24.2
BBR071812281	7/18/12	LAT	507	1061.0	3.77	10.78	-27.08	-26.7
BBR102912011	10/29/12	LAT	507	.	3.46	11.15	-26.78	-26.7
BBR071812023	7/18/12	LAT	508	1022.0	4.17	11.25	-27.64	-26.8
BBR102912016	10/29/12	LAT	508	.	3.62	11.06	-25.42	-25.1
BBR081413310	8/14/13	LAT	509	976.0	3.79	11.53	-26.53	-26.1
BBR091013072	9/10/13	LAT	509	906.0	3.22	11.36	-26.66	-26.8
BBR102912012	10/29/12	LAT	510	.	3.16	10.95	-25.30	-25.5
BBR103012269	10/30/12	LAT	511	1136.0	3.70	11.29	-24.59	-24.2
BBR061913009	6/19/13	LAT	512	1073.0	3.98	11.36	-27.60	-27.0
BBR040212044	4/2/12	LAT	517	1057.0	6.94	11.06	-29.64	-26.1
BBR102912009	10/29/12	LAT	520	.	3.30	11.07	-26.30	-26.4
BBR042513304	4/25/13	LAT	522	1150.0	3.68	11.05	-26.60	-26.3
BBR061913017	6/19/13	LAT	522	1028.0	4.66	10.75	-27.69	-26.4
BBR040212038	4/2/12	LAT	523	1090.0	3.60	10.83	-24.05	-23.8
BBR081612250	8/16/12	LAT	526	.	3.71	11.37	-26.14	-25.8
BBR040212041	4/2/12	LAT	527	993.0	3.23	11.02	-25.61	-25.7
BBR081612285	8/16/12	LAT	528	.	3.42	11.42	-26.24	-26.2
BBR071812283	7/18/12	LAT	547	1173.0	3.56	11.33	-24.60	-24.4

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR081313008	8/13/13	LAT	548	1470.0	3.68	12.61	-24.95	-24.6
BBR061813023	6/18/13	LAT	553	1686.0	4.06	11.24	-23.30	-22.6
BBR102912253	10/29/12	LAT	584	1774.0	4.39	12.07	-24.86	-23.8
BBR102912253	10/29/12	LAT	584	1774.0	2.47	11.28	-26.19	-27.1
BBR052213006	5/22/13	LAT	636	3212.0	3.83	11.96	-27.57	-27.1
BBR103012267	10/30/12	LAT	649	2219.0	4.31	12.99	-26.33	-25.4
BBR103012266	10/30/12	LAT	680	3077.0	3.83	12.84	-25.02	-24.5
BBR081513254	8/15/13	LAT	686	3030.0	3.93	13.24	-25.37	-24.8
BBR052213004	5/22/13	LAT	690	3215.0	3.95	12.99	-25.70	-25.1
BBR102912021	10/29/12	LAT	712	3550.0	6.75	12.53	-27.61	-24.3
BBR103012250	10/30/12	LAT	720	.	5.64	12.17	-27.16	-24.9
BBR040212001	4/2/12	LAT	739	3830.0	3.19	12.08	-25.49	-25.7
BBR103012268	10/30/12	LAT	749	4344.0	4.05	12.90	-25.91	-25.2
BBR052213003	5/22/13	LAT	753	4526.0	6.60	12.54	-28.18	-25.0
BBR103012256	10/30/12	LAT	805	4250.0	3.44	12.78	-26.08	-26.0
BBR103012255	10/30/12	LAT	825	5430.0	3.91	12.59	-25.75	-25.2
BBR081612288	8/16/12	LAT	843	6830.0	5.86	12.50	-27.28	-24.8
BBR081612288	8/16/12	LAT	843	6830.0	4.83	12.82	-27.32	-25.9
BBR102912020	10/29/12	LAT	851	5700.0	9.13	12.36	-28.72	-23.0
BBR103012253	10/30/12	LAT	866	5780.0	6.15	13.25	-27.65	-24.9
BBR052313006	5/23/13	LAT	867	6521.0	6.21	13.01	-27.79	-25.0
BBR103012257	10/30/12	LAT	869	6760.0	5.62	12.54	-27.33	-25.1
BBR103012251	10/30/12	LAT	870	.	6.30	12.28	-27.46	-24.5
BBR102113811	10/21/13	LAT	879	.	4.23	12.63	-25.72	-24.8
BBR103012260	10/30/12	LAT	882	6970.0	7.29	13.11	-28.50	-24.6
BBR102213780	10/22/13	LAT	883	.	4.61	12.85	-26.15	-24.9
BBR103012254	10/30/12	LAT	884	7280.0	5.03	12.71	-26.71	-25.0
BBR102113050	10/21/13	LAT	888	.	6.04	11.86	-27.40	-24.7
BBR103012258	10/30/12	LAT	891	7420.0	6.39	12.69	-27.89	-24.9

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR071712031	7/17/12	LAT	893	8731.0	6.16	12.97	-27.89	-25.1
BBR052313005	5/23/13	LAT	894	8322.0	7.13	12.97	-28.47	-24.7
BBR102213752	10/22/13	LAT	908	.	3.15	9.79	-21.40	-21.6
BBR103012252	10/30/12	LAT	909	7760.0	4.39	12.60	-26.19	-25.2
BBR081512300	8/15/12	LAT	921	6410.0	4.50	13.09	-26.64	-25.5
BBR081512300	8/15/12	LAT	921	6410.0	5.94	12.71	-27.78	-25.2
BBR071613001	7/16/13	LAT	922	9453.0	6.17	12.84	-27.48	-24.7
BBR081412900	8/14/12	LAT	940	10600.0	6.60	13.09	-28.20	-25.0
BBR103012259	10/30/12	LAT	940	9635.0	7.47	12.28	-27.90	-23.8
BBR103012261	10/30/12	LAT	949	8720.0	3.26	11.00	-24.75	-24.8
BBR081612004	8/16/12	LAT	968	10811.0	5.62	13.08	-27.35	-25.1
BBR081612502	8/16/12	LAT	968	10811.0	4.96	12.68	-26.93	-25.3
BBR061913551	6/19/13	LND	43	0.5	3.60	8.78	-23.53	-23.3
BBR061913550	6/19/13	LND	44	0.6	4.14	8.75	-21.45	-20.7
BBR061913545	6/19/13	LND	46	0.7	3.69	7.60	-22.16	-21.8
BBR061913548	6/19/13	LND	51	0.9	3.67	8.63	-23.90	-23.6
BBR090913569	9/9/13	LNS	114	14.8	3.26	7.49	-22.70	-22.8
BBR061913530	6/19/13	LNS	117	20.2	3.28	7.97	-23.39	-23.5
BBR061913503	6/19/13	LNS	123	16.5	3.36	7.57	-23.57	-23.6
BBR091013119	9/10/13	LNS	125	19.2	3.33	8.07	-24.46	-24.5
BBR061913527	6/19/13	LNS	131	20.1	3.29	8.28	-23.94	-24.0
BBR091013131	9/10/13	LNS	131	23.4	3.27	7.98	-23.39	-23.5
BBR091013120	9/10/13	LNS	132	20.7	3.30	7.79	-22.30	-22.4
BBR091013121	9/10/13	LNS	134	20.8	3.29	7.15	-23.31	-23.4
BBR061913529	6/19/13	LNS	137	24.9	3.49	9.01	-24.30	-24.2
BBR091013130	9/10/13	LNS	144	24.8	3.26	8.09	-24.00	-24.1
BBR091013118	9/10/13	LNS	147	29.4	3.28	7.67	-22.82	-22.9
BBR090913250	9/9/13	LNS	192	66.8	3.29	5.64	-23.05	-23.1
BBR090913573	9/9/13	LNS	198	77.5	3.24	7.89	-24.26	-24.4

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR091013136	9/10/13	LNS	229	112.0	3.35	7.30	-23.46	-23.5
BBR061813318	6/18/13	LNS	234	139.0	3.32	6.58	-24.05	-24.1
BBR061813316	6/18/13	LNS	235	148.0	3.42	8.71	-23.45	-23.4
BBR061913122	6/19/13	LNS	245	170.0	3.46	7.80	-22.98	-22.9
BBR061813284	6/18/13	LNS	255	182.0	3.43	8.54	-25.55	-25.5
BBR061913268	6/19/13	LNS	258	195.0	3.43	9.12	-25.70	-25.6
BBR061913259	6/19/13	LNS	278	254.0	3.39	8.79	-25.65	-25.6
BBR081413040	8/14/13	LNS	282	244.0	3.73	8.82	-25.89	-25.5
BBR061913003	6/19/13	LNS	286	265.0	3.37	8.15	-24.97	-25.0
BBR090913296	9/9/13	LNS	287	245.0	3.25	8.22	-23.93	-24.0
BBR081312255	8/13/12	LNS	290	272.0	3.18	8.57	-25.67	-25.8
BBR081313064	8/13/13	LNS	290	264.0	3.36	9.16	-24.81	-24.8
BBR040212013	4/2/12	LNS	412	767.0	3.61	8.89	-24.17	-23.9
BBR040212016	4/2/12	LNS	425	755.0	3.33	8.66	-24.78	-24.8
BBR040212010	4/2/12	LNS	429	919.0	3.47	7.97	-23.73	-23.6
BBR081412719	8/14/12	LNS	432	804.0	3.62	8.90	-25.11	-24.8
BBR040212012	4/2/12	LNS	460	1009.0	3.48	8.96	-23.74	-23.6
BBR040212014	4/2/12	LNS	472	1122.0	4.68	8.66	-26.05	-24.7
BBR040212014	4/2/12	LNS	472	1122.0	5.13	8.83	-25.54	-23.8
BBR081312532	8/13/12	LNS	472	472.0	3.72	9.78	-26.16	-25.8
BBR040212011	4/2/12	LNS	498	1218.0	4.26	9.07	-25.57	-24.7
BBR042513106	4/25/13	ONC	63	2.2	3.72	6.47	-17.80	-17.4
BBR061913519	6/19/13	ONC	70	2.8	3.26	6.19	-23.15	-23.2
BBR061913512	6/19/13	ONC	77	3.6	3.33	5.49	-22.03	-22.1
BBR042513107	4/25/13	ONC	82	4.6	3.67	6.59	-19.30	-19.0
BBR042413002	4/24/13	ONC	85	5.2	3.83	7.56	-20.08	-19.6
BBR061813068	6/18/13	ONC	110	13.7	3.42	7.36	-22.49	-22.4
BBR061813308	6/18/13	ONC	113	12.0	3.33	6.42	-24.18	-24.2
BBR061813070	6/18/13	ONC	122	18.6	3.61	9.17	-20.50	-20.2

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR091013132	9/10/13	ONC	123	18.0	4.46	5.13	-23.78	-22.7
BBR042513101	4/25/13	ONC	124	13.8	3.37	5.69	-22.14	-22.1
BBR091013133	9/10/13	ONC	127	21.6	3.55	8.94	-25.12	-24.9
BBR061813333	6/18/13	ONC	130	17.1	3.45	8.04	-23.58	-23.5
BBR061913507	6/19/13	ONC	130	17.5	3.40	6.40	-20.00	-20.0
BBR103012039	10/30/12	ONC	135	.	3.44	6.20	-22.12	-22.0
BBR081313511	8/13/13	ONC	152	37.6	4.00	7.46	-24.24	-23.6
BBR081212007	8/12/12	ONC	154	44.0	3.18	6.90	-23.30	-23.5
BBR090913004	9/9/13	ONC	158	32.8	3.42	8.85	-19.88	-19.8
BBR090913006	9/9/13	ONC	160	44.5	4.41	7.25	-24.44	-23.4
BBR081313567	8/13/13	ONC	162	44.8	3.73	7.65	-26.21	-25.8
BBR091013253	9/10/13	ONC	167	41.0	3.44	7.52	-26.16	-26.1
BBR091013056	9/10/13	ONC	171	53.0	3.54	6.39	-22.68	-22.5
BBR081513297	8/15/13	ONC	173	51.0	3.49	7.62	-26.33	-26.2
BBR081313561	8/13/13	ONC	174	50.2	3.35	7.50	-24.04	-24.1
BBR081513058	8/15/13	ONC	175	51.0	3.59	7.71	-26.64	-26.4
BBR102113814	10/21/13	ONC	180	57.0	3.55	9.66	-22.00	-21.8
BBR081313522	8/13/13	ONC	181	58.9	3.56	7.87	-26.06	-25.9
BBR042413001	4/24/13	ONC	185	44.5	3.20	6.28	-21.73	-21.9
BBR090913005	9/9/13	ONC	186	69.3	3.70	8.10	-27.11	-26.8
BBR061913182	6/19/13	ONC	192	72.0	4.01	8.29	-28.19	-27.5
BBR081513250	8/15/13	ONC	193	65.0	3.87	7.65	-26.64	-26.1
BBR090913003	9/9/13	ONC	193	66.9	5.54	7.83	-25.79	-23.6
BBR090913539	9/9/13	ONC	193	70.6	3.47	7.78	-25.67	-25.6
BBR102213787	10/22/13	ONC	193	83.0	3.59	8.46	-24.10	-23.9
BBR081313571	8/13/13	ONC	194	69.9	4.47	7.63	-27.14	-26.0
BBR090913001	9/9/13	ONC	199	68.6	3.49	7.05	-24.50	-24.4
BBR081313568	8/13/13	ONC	201	84.0	3.68	8.24	-26.67	-26.3
BBR103012024	10/30/12	ONC	203	.	3.31	8.73	-25.01	-25.1

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR102113772	10/21/13	ONC	204	86.0	3.55	9.22	-23.71	-23.5
BBR091013025	9/10/13	ONC	208	123.0	3.23	11.02	-24.20	-24.3
BBR102113803	10/21/13	ONC	213	90.0	3.38	8.81	-22.09	-22.1
BBR103012015	10/30/12	ONC	213	.	3.42	8.79	-24.68	-24.6
BBR090913002	9/9/13	ONC	221	107.4	4.02	7.95	-27.09	-26.4
BBR081313534	8/13/13	ONC	227	124.0	4.48	7.79	-27.64	-26.5
BBR081313572	8/13/13	ONC	236	142.0	3.85	8.22	-27.31	-26.8
BBR040212005	4/2/12	ONC	251	138.0	3.22	10.13	-23.97	-24.1
BBR103012018	10/30/12	ONC	252	.	3.56	9.90	-25.73	-25.5
BBR061913185	6/19/13	ONC	253	172.0	3.52	7.98	-25.53	-25.4
BBR042413038	4/24/13	ONC	258	185.0	4.77	11.32	-27.75	-26.4
BBR091013257	9/10/13	ONC	260	195.0	4.83	8.04	-28.77	-27.3
BBR081313560	8/13/13	ONC	270	239.0	4.73	7.71	-28.20	-26.8
BBR042513026	4/25/13	ONC	271	199.0	4.15	10.41	-27.47	-26.7
BBR091013042	9/10/13	ONC	274	252.0	4.57	7.91	-28.36	-27.2
BBR091013057	9/10/13	ONC	282	257.0	5.89	7.25	-29.28	-26.8
BBR091013318	9/10/13	ONC	289	267.0	4.23	8.06	-27.27	-26.4
BBR091013322	9/10/13	ONC	294	291.0	4.24	7.99	-27.72	-26.8
BBR102213761	10/22/13	ONC	294	275.0	3.62	9.22	-26.33	-26.1
BBR102213810	10/22/13	ONC	296	246.0	3.35	8.54	-24.51	-24.5
BBR040212047	4/2/12	ONC	302	296.0	4.49	10.47	-26.10	-25.0
BBR091013041	9/10/13	ONC	305	310.0	4.13	7.87	-27.78	-27.0
BBR081413268	8/14/13	ONC	313	273.0	3.60	7.82	-25.54	-25.3
BBR040212035	4/2/12	ONC	315	308.0	3.50	9.52	-25.18	-25.0
BBR102213796	10/22/13	ONC	315	354.0	4.31	9.53	-28.35	-27.4
BBR081412713	8/14/12	ONC	321	416.0	3.42	8.38	-24.13	-24.1
BBR102213778	10/22/13	ONC	324	338.0	3.51	8.84	-27.11	-27.0
BBR040212006	4/2/12	ONC	326	315.0	4.34	10.24	-26.23	-25.3
BBR102213789	10/22/13	ONC	326	386.0	5.46	9.08	-29.64	-27.5

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR102213782	10/22/13	ONC	327	361.0	3.72	9.40	-25.60	-25.2
BBR081412709	8/14/12	ONC	331	366.0	3.48	8.28	-24.06	-23.9
BBR081412709rep1	8/14/12	ONC	331	366.0	3.42	8.23	-24.07	-24.0
BBR081313523	8/13/13	ONC	334	372.0	4.29	9.25	-30.53	-29.6
BBR090913290	9/9/13	ONC	336	350.0	3.76	9.11	-28.55	-28.1
BBR091013070	9/10/13	ONC	337	418.0	3.95	8.71	-27.17	-26.6
BBR040312131	4/3/12	ONC	342	393.0	4.25	9.95	-25.87	-25.0
BBR040312037	4/3/12	ONC	345	447.0	4.18	10.10	-26.04	-25.2
BBR040312070	4/3/12	ONC	346	416.0	3.72	10.30	-27.05	-26.7
BBR040312006	4/3/12	ONC	347	435.0	6.17	9.75	-27.72	-24.9
BBR040312082	4/3/12	ONC	349	455.0	5.34	9.81	-26.72	-24.8
BBR040312048	4/3/12	ONC	353	414.0	3.85	9.99	-25.67	-25.2
BBR081313283	8/13/13	ONC	354	407.0	3.62	9.29	-26.59	-26.3
BBR102213790	10/22/13	ONC	355	448.0	5.24	9.03	-29.23	-27.4
BBR040312102	4/3/12	ONC	360	496.0	4.59	9.85	-26.16	-24.9
BBR071912039	7/19/12	ONC	360	430.0	3.42	10.97	-26.27	-26.2
BBR071912039rep1	7/19/12	ONC	360	430.0	3.97	8.24	-24.81	-24.2
BBR071513032	7/15/13	ONC	362	467.0	3.69	10.81	-26.82	-26.5
BBR102213759	10/22/13	ONC	364	559.0	3.91	9.38	-27.39	-26.8
BBR040212033	4/2/12	ONC	367	497.0	4.33	9.64	-25.93	-25.0
BBR040312089	4/3/12	ONC	367	566.0	5.10	9.78	-26.98	-25.2
BBR071513030	7/15/13	ONC	368	515.0	4.48	10.97	-28.80	-27.7
BBR040312029	4/3/12	ONC	370	520.0	3.87	10.20	-26.52	-26.0
BBR081312528	8/13/12	ONC	371	647.0	3.80	8.85	-24.50	-24.1
BBR040312083	4/3/12	ONC	372	318.0	5.62	9.64	-27.17	-24.9
BBR071812028	7/18/12	ONC	372	585.0	5.11	8.55	-25.88	-24.1
BBR081412708	8/14/12	ONC	374	552.0	3.52	8.53	-23.92	-23.8
BBR061913162	6/19/13	ONC	375	582.0	3.87	10.87	-27.01	-26.5
BBR042513031	4/25/13	ONC	376	535.0	5.66	10.66	-29.55	-27.3

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR071812511	7/18/12	ONC	378	722.0	5.11	8.93	-25.95	-24.2
BBR071513048	7/15/13	ONC	381	569.0	4.31	10.16	-27.70	-26.7
BBR040312130	4/3/12	ONC	384	621.0	4.94	10.36	-27.59	-26.0
BBR091013281	9/10/13	ONC	387	464.0	3.41	10.72	-24.42	-24.4
BBR081312523	8/13/12	ONC	391	688.0	3.64	8.79	-24.13	-23.8
BBR091013330	9/10/13	ONC	391	588.0	4.15	10.20	-28.06	-27.3
BBR040212031	4/2/12	ONC	393	592.0	4.20	10.02	-25.97	-25.1
BBR040312039	4/3/12	ONC	393	641.0	4.06	10.28	-26.66	-26.0
BBR081313276	8/13/13	ONC	393	599.0	4.13	10.54	-28.35	-27.6
BBR040312034	4/3/12	ONC	394	585.0	4.88	9.94	-27.55	-26.0
BBR071712025	7/17/12	ONC	394	659.0	4.86	9.14	-25.85	-24.4
BBR102213769	10/22/13	ONC	394	573.0	3.64	10.04	-25.45	-25.2
BBR081312527	8/13/12	ONC	395	552.0	3.24	10.05	-24.95	-25.1
BBR081312526	8/13/12	ONC	396	676.0	3.67	8.55	-24.34	-24.0
BBR042513001	4/25/13	ONC	400	690.0	5.44	10.56	-28.32	-26.3
BBR040312021	4/3/12	ONC	401	693.0	4.07	10.39	-26.94	-26.2
BBR052213036	5/22/13	ONC	401	592.0	3.73	9.61	-25.41	-25.0
BBR052213038	5/22/13	ONC	403	663.0	5.91	9.88	-27.92	-25.4
BBR102113813	10/21/13	ONC	403	657.0	3.80	10.41	-27.69	-27.2
BBR081212005	8/12/12	ONC	404	654.0	3.61	8.76	-24.37	-24.1
BBR091013055	9/10/13	ONC	404	670.0	3.53	9.72	-25.87	-25.7
BBR040312013	4/3/12	ONC	405	689.0	3.18	10.80	-23.02	-23.2
BBR071912040	7/19/12	ONC	405	570.0	3.40	9.70	-24.45	-24.4
BBR102213788	10/22/13	ONC	406	679.0	4.13	9.53	-29.12	-28.4
BBR102113029	10/21/13	ONC	408	727.0	4.35	10.65	-27.54	-26.6
BBR040312121	4/3/12	ONC	409	595.0	4.85	9.96	-26.49	-25.0
BBR040312091	4/3/12	ONC	410	794.0	3.29	9.57	-24.94	-25.0
BBR071513031	7/15/13	ONC	410	540.0	3.34	9.98	-24.91	-24.9
BBR102912019	10/29/12	ONC	412	.	3.21	10.16	-25.24	-25.4

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR102213799	10/22/13	ONC	413	614.0	3.62	9.49	-25.29	-25.0
BBR071812025	7/18/12	ONC	419	723.0	3.64	9.82	-25.89	-25.6
BBR042513010	4/25/13	ONC	420	715.0	3.57	9.85	-25.27	-25.1
BBR040312027	4/3/12	ONC	421	805.0	4.77	10.02	-28.08	-26.7
BBR061913163	6/19/13	ONC	421	772.0	3.43	9.98	-24.81	-24.7
BBR102213820	10/22/13	ONC	421	713.0	3.81	10.16	-27.00	-26.6
BBR071812016	7/18/12	ONC	425	872.0	4.53	9.61	-25.99	-24.8
BBR040212040	4/2/12	ONC	427	770.0	4.83	10.03	-27.73	-26.3
BBR102213800	10/22/13	ONC	430	751.0	3.42	10.76	-26.94	-26.9
BBR040312015	4/3/12	ONC	431	806.0	4.19	9.89	-27.17	-26.3
BBR102213808	10/22/13	ONC	432	732.0	3.88	9.86	-26.30	-25.8
BBR040212039	4/2/12	ONC	434	776.0	3.31	9.99	-27.18	-27.2
BBR040312005	4/3/12	ONC	434	791.0	3.62	10.09	-25.60	-25.3
BBR071513045	7/15/13	ONC	435	820.0	3.50	10.05	-25.91	-25.8
BBR081312524	8/13/12	ONC	435	727.0	3.20	9.90	-26.00	-26.2
BBR081312522	8/13/12	ONC	438	1068.0	3.25	9.15	-24.32	-24.4
BBR040212051	4/2/12	ONC	439	708.0	4.78	10.19	-27.98	-26.6
BBR040312028	4/3/12	ONC	440	777.0	4.01	9.90	-25.51	-24.9
BBR071912028	7/19/12	ONC	440	765.0	4.08	9.69	-26.71	-26.0
BBR040312011	4/3/12	ONC	441	785.0	4.37	9.86	-26.69	-25.7
BBR040312023	4/3/12	ONC	442	1013.0	4.57	9.73	-28.31	-27.1
BBR102912005	10/29/12	ONC	442	700.0	3.64	9.71	-27.10	-26.8
BBR102113764	10/21/13	ONC	443	701.0	3.41	10.78	-25.06	-25.0
BBR102213794	10/22/13	ONC	445	805.0	3.82	10.57	-25.99	-25.5
BBR081213325	8/12/12	ONC	446	684.0	3.49	11.22	-25.77	-25.6
BBR071812008	7/18/12	ONC	448	803.0	3.76	9.72	-25.83	-25.4
BBR040312002	4/3/12	ONC	450	930.0	4.69	10.35	-27.78	-26.5
BBR040312004	4/3/12	ONC	451	835.0	3.74	10.29	-26.40	-26.0
BBR061813327	6/18/13	ONC	458	1183.0	5.06	10.00	-27.05	-25.4

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR081212004	8/12/12	ONC	458	866.0	3.40	9.40	-24.66	-24.6
BBR102912040	10/29/12	ONC	458	.	3.14	9.83	-24.81	-25.0
BBR071513047	7/15/13	ONC	460	870.0	3.40	9.80	-24.93	-24.9
BBR081212002	8/12/12	ONC	461	763.0	3.33	9.25	-25.23	-25.3
BBR040312010	4/3/12	ONC	462	1165.0	5.50	10.66	-28.17	-26.0
BBR040212009	4/2/12	ONC	464	840.0	3.59	10.05	-25.50	-25.3
BBR040312026	4/3/12	ONC	465	1064.0	4.13	10.27	-27.17	-26.4
BBR040312035	4/3/12	ONC	465	706.0	4.54	10.20	-27.84	-26.7
BBR081212003	8/12/12	ONC	465	860.0	3.08	10.10	-25.32	-25.6
BBR040312001	4/3/12	ONC	467	929.0	4.49	10.08	-27.17	-26.0
BBR040312014	4/3/12	ONC	468	963.0	3.28	9.80	-25.39	-25.5
BBR071812507	7/18/12	ONC	468	850.0	3.48	10.02	-25.24	-25.1
BBR071513036	7/15/13	ONC	470	936.0	3.57	10.43	-26.33	-26.1
BBR081412706	8/14/12	ONC	473	1040.0	3.26	9.52	-25.04	-25.1
BBR071812006	7/18/12	ONC	474	957.0	3.66	9.38	-25.33	-25.0
BBR081512762	8/15/12	ONC	482	1211.0	3.70	9.98	-25.27	-24.9
BBR102213791	10/22/13	ONC	483	906.0	3.41	10.66	-25.82	-25.8
BBR071513043	7/15/13	ONC	484	953.0	3.44	10.31	-24.94	-24.9
BBR040312007	4/3/12	ONC	485	1245.0	3.85	9.87	-26.59	-26.1
BBR081412503	8/14/12	ONC	485	866.0	3.28	9.83	-25.59	-25.7
BBR102213767	10/22/13	ONC	485	828.0	3.19	10.34	-24.45	-24.6
BBR040212029	4/2/12	ONC	490	980.0	2.93	10.35	-27.00	-27.4
BBR102213798	10/22/13	ONC	495	1248.0	3.97	9.96	-27.45	-26.8
BBR071513033	7/15/13	ONC	496	995.0	3.65	10.27	-26.06	-25.8
BBR102912002	10/29/12	ONC	497	1000.0	3.16	9.28	-24.52	-24.7
BBR061913010	6/19/13	ONC	503	1171.0	3.95	10.29	-26.08	-25.5
BBR040312018	4/3/12	ONC	513	1294.0	3.89	10.29	-26.43	-25.9
BBR071513024	7/15/13	ONC	514	1074.0	3.59	9.60	-25.57	-25.3
BBR081313277	8/13/13	ONC	515	1063.0	3.57	9.95	-25.81	-25.6

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR040312092	4/3/12	ONC	518	1318.0	4.61	10.27	-27.73	-26.5
BBR102912006	10/29/12	ONC	519	1200.0	2.45	10.56	-25.26	-26.2
BBR040312025	4/3/12	ONC	523	1477.0	4.01	9.66	-27.04	-26.4
BBR081412716	8/14/12	ONC	534	1366.0	3.44	9.76	-25.98	-25.9
BBR081412716rep1	8/14/12	ONC	534	1366.0	3.35	9.79	-25.78	-25.8
BBR081313519	8/13/13	ONC	536	658.0	3.36	10.12	-24.39	-24.4
BBR040312214	4/3/12	ONC	554	1603.0	3.75	10.07	-26.61	-26.2
BBR061913128	6/19/13	WAE	81	14.1	3.22	9.41	-24.83	-25.0
BBR061813059	6/18/13	WAE	112	13.5	3.40	10.81	-25.78	-25.7
BBR061813060	6/18/13	WAE	117	13.2	3.31	10.66	-23.95	-24.0
BBR061813064	6/18/13	WAE	120	14.0	3.29	11.25	-24.98	-25.0
BBR061813056	6/18/13	WAE	122	15.0	3.26	11.20	-25.87	-26.0
BBR061913101	6/19/13	WAE	124	14.1	3.30	10.64	-24.05	-24.1
BBR061813304	6/18/13	WAE	128	15.4	3.31	10.33	-24.39	-24.4
BBR061913150	6/19/13	WAE	129	14.8	3.31	9.51	-23.18	-23.2
BBR061813305	6/18/13	WAE	131	16.9	3.24	10.69	-25.70	-25.8
BBR061813058	6/18/13	WAE	137	20.7	3.62	10.78	-24.86	-24.6
BBR061813303	6/18/13	WAE	139	21.3	3.38	10.71	-24.67	-24.6
BBR090913037	9/9/13	WAE	169	37.0	3.25	9.72	-24.91	-25.0
BBR090913541	9/9/13	WAE	182	42.0	3.27	9.79	-24.62	-24.7
BBR090913276	9/9/13	WAE	184	48.7	3.22	9.04	-24.18	-24.3
BBR090913274	9/9/13	WAE	188	46.1	3.24	9.50	-23.32	-23.4
BBR081313520	8/13/13	WAE	191	56.8	3.26	10.96	-24.35	-24.4
BBR091013291	9/10/13	WAE	197	60.0	3.28	9.53	-24.86	-24.9
BBR091013325	9/10/13	WAE	197	77.0	3.25	9.62	-25.35	-25.5
BBR091013323	9/10/13	WAE	202	72.0	3.31	9.46	-23.05	-23.1
BBR081512288	8/15/12	WAE	276	195.0	3.14	9.56	-22.79	-23.0
BBR081512288rep1	8/15/12	WAE	276	195.0	3.12	9.50	-22.67	-22.9
BBR060612003	6/6/12	WAE	289.6	208.7	3.28	10.93	-23.05	-23.1

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR060612004	6/6/12	WAE	289.6	208.7	3.46	10.66	-22.91	-22.8
BBR081512280	8/15/12	WAE	291	230.0	3.20	9.81	-22.73	-22.9
BBR081512280rep1	8/15/12	WAE	291	230.0	3.18	9.93	-22.77	-22.9
BBR081512289	8/15/12	WAE	295	220.0	3.27	10.01	-22.93	-23.0
BBR090913289	9/9/13	WAE	296	245.0	3.24	10.68	-23.44	-23.5
BBR060612002	6/6/12	WAE	299.7	235.9	3.20	10.46	-22.22	-22.4
BBR060612001	6/6/12	WAE	302.3	272.2	3.20	10.90	-22.98	-23.1
BBR071512001		WAE	305	.	3.22	10.69	-23.13	-23.3
BBR060612005	6/6/12	WAE	322.6	317.5	5.06	10.36	-28.01	-26.3
BBR061813326	6/18/13	WAE	326	368.0	3.26	11.02	-22.80	-22.9
BBR050613021	5/6/13	WAE	327.66	308.4	3.29	11.64	-23.22	-23.3
BBR091013302	9/10/13	WAE	330	302.0	3.24	9.55	-22.42	-22.5
BBR050613170	5/6/13	WAE	330.2	317.5	3.31	10.83	-24.13	-24.2
BBR090913272	9/9/13	WAE	335	330.0	3.18	10.38	-22.88	-23.1
BBR042513776	4/25/13	WAE	342	379.0	3.25	10.30	-21.40	-21.5
BBR081213315	8/12/12	WAE	347	358.0	3.24	11.12	-23.38	-23.5
BBR042513782	4/25/13	WAE	351	396.0	3.24	10.73	-22.30	-22.4
BBR081512285a	8/15/12	WAE	351	375.0	3.11	10.36	-22.38	-22.6
BBR081512285b	8/15/12	WAE	351	375.0	3.13	10.28	-22.44	-22.7
BBR090913011	9/9/13	WAE	351	349.0	3.23	10.55	-23.32	-23.4
BBR042513703	4/25/13	WAE	357	506.0	3.30	10.90	-23.33	-23.4
BBR042513781	4/25/13	WAE	362	432.0	3.15	10.70	-22.51	-22.7
BBR091013256	9/10/13	WAE	362	477.0	3.33	10.79	-22.87	-22.9
BBR061813300	6/18/13	WAE	363	443.0	3.21	10.64	-22.33	-22.5
BBR042513705	4/25/13	WAE	365	452.0	3.22	11.25	-22.64	-22.8
BBR061813313	6/18/13	WAE	366	479.0	3.28	10.11	-21.72	-21.8
BBR042513769	4/25/13	WAE	370	503.0	3.18	11.13	-23.41	-23.6
BBR091013299	9/10/13	WAE	374	473.0	3.27	10.23	-22.20	-22.3
BBR071812010	7/18/12	WAE	376	581.0	3.10	10.04	-21.54	-21.8

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR042513741	4/25/13	WAE	378	532.0	3.21	11.55	-23.83	-24.0
BBR090913016	9/9/13	WAE	381	498.0	3.16	10.19	-22.00	-22.2
BBR081313547	8/13/13	WAE	383	540.0	3.28	11.12	-23.12	-23.2
BBR091013261	9/10/13	WAE	384	518.0	3.21	10.18	-22.03	-22.2
BBR091013285	9/10/13	WAE	386	536.0	3.24	11.08	-23.54	-23.7
BBR040212004	4/2/12	WAE	389	512.0	3.21	11.15	-23.15	-23.3
BBR042513773	4/25/13	WAE	390	564.0	3.24	11.40	-22.19	-22.3
BBR042513775	4/25/13	WAE	393	564.0	3.21	10.19	-21.25	-21.4
BBR042513750	4/25/13	WAE	394	572.0	3.23	10.92	-22.24	-22.4
BBR102912278	10/29/12	WAE	394	549.0	3.35	11.00	-25.48	-25.5
BBR102912278rep1	10/29/12	WAE	394	549.0	3.58	10.27	-23.91	-23.7
BBR081413324	8/14/13	WAE	397	592.0	3.19	10.88	-22.28	-22.4
BBR091013294	9/10/13	WAE	397	582.0	3.29	11.28	-23.38	-23.4
BBR042513737	4/25/13	WAE	398	600.0	3.18	10.59	-21.47	-21.6
BBR071512003		WAE	400		3.16	10.91	-22.71	-22.9
BBR042513770	4/25/13	WAE	406	647.0	3.19	11.16	-21.79	-21.9
BBR042513724	4/25/13	WAE	410	695.0	3.33	10.96	-21.57	-21.6
BBR042513722	4/25/13	WAE	415	713.0	3.28	10.88	-22.03	-22.1
BBR081412504	8/14/12	WAE	421	805.0	3.19	10.45	-22.28	-22.4
BBR091013307	9/10/13	WAE	421	860.0	3.23	10.18	-22.10	-22.2
BBR042513772	4/25/13	WAE	422	727.0	3.47	10.54	-22.44	-22.3
BBR081513259	8/15/13	WAE	422	721.0	3.58	11.91	-26.75	-26.5
BBR091013288	9/10/13	WAE	422	749.0	3.25	10.06	-21.69	-21.8
BBR090913049	9/9/13	WAE	424	712.0	3.19	10.37	-22.12	-22.3
BBR042513751	4/25/13	WAE	425	761.0	3.19	10.68	-21.43	-21.6
BBR091013298	9/10/13	WAE	425	820.0	3.42	9.62	-21.10	-21.0
BBR042513728	4/25/13	WAE	429	753.0	3.21	11.03	-22.23	-22.4
BBR071812041	7/18/12	WAE	429	816.0	3.72	10.22	-22.11	-21.7
BBR102213818	10/22/13	WAE	429	849.0	3.26	10.23	-21.51	-21.6

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR102912283	10/29/12	WAE	431	889.0	3.30	9.33	-21.92	-22.0
BBR091013293	9/10/13	WAE	433	731.0	3.31	10.38	-22.54	-22.6
BBR091013254	9/10/13	WAE	434	846.0	3.23	10.97	-22.53	-22.7
BBR091013282	9/10/13	WAE	435	944.0	3.25	9.82	-20.97	-21.1
BBR042513763	4/25/13	WAE	436	841.0	3.26	11.35	-23.06	-23.2
BBR042513758	4/25/13	WAE	437	915.0	3.14	10.47	-21.42	-21.6
BBR040212003	4/2/12	WAE	441	894.0	3.15	10.17	-21.71	-21.9
BBR081512775	8/15/12	WAE	442	830.0	3.22	10.63	-22.54	-22.7
BBR042513740	4/25/13	WAE	445	997.0	3.28	10.65	-20.94	-21.0
BBR081312533	8/13/12	WAE	447	447.0	3.56	10.58	-23.12	-22.9
BBR081512776	8/15/12	WAE	448	1003.0	3.19	9.87	-21.77	-21.9
BBR042513761	4/25/13	WAE	450	973.0	3.23	10.95	-22.39	-22.5
BBR091013270	9/10/13	WAE	450	898.0	3.23	10.18	-21.73	-21.9
BBR071812504	7/18/12	WAE	452	1087.0	3.20	11.15	-25.97	-26.1
BBR071812504	7/18/12	WAE	452	1087.0	3.12	10.26	-21.09	-21.3
BBR042513721	4/25/13	WAE	455	1050.0	3.25	10.44	-21.18	-21.3
BBR042513764	4/25/13	WAE	460	1083.0	3.54	10.92	-22.07	-21.9
BBR042513735	4/25/13	WAE	468	1116.0	3.44	10.88	-22.26	-22.2
BBR052213012	5/22/13	WAE	468	1019.0	3.22	10.70	-22.82	-23.0
BBR091013306	9/10/13	WAE	468	1033.0	3.24	10.05	-22.38	-22.5
BBR042513730	4/25/13	WAE	473	1093.0	3.08	10.09	-21.25	-21.5
BBR042513719	4/25/13	WAE	475	1091.0	3.24	11.08	-22.59	-22.7
BBR040212050	4/2/12	WAE	481	1266.0	3.12	10.66	-21.91	-22.1
BBR042513718	4/25/13	WAE	485	1218.0	3.20	11.14	-22.32	-22.5
BBR042513765	4/25/13	WAE	485	1222.0	3.22	10.55	-22.50	-22.6
BBR103012273	10/30/12	WAE	485	415.0	7.03	9.56	-24.14	-20.5
BBR042513726	4/25/13	WAE	486	1294.0	3.19	10.71	-22.41	-22.6
BBR103112001	10/31/12	WAE	486	1247.0	3.69	10.53	-22.69	-22.4
BBR102213751	10/22/13	WAE	490	1386.0	6.02	12.32	-27.52	-24.9

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR040212002	4/2/12	WAE	491	1338.0	3.13	10.31	-22.51	-22.7
BBR042513716	4/25/13	WAE	491	1357.0	3.42	11.13	-22.49	-22.4
BBR042513777	4/25/13	WAE	492	1223.0	3.24	10.90	-23.82	-23.9
BBR042513739	4/25/13	WAE	493	585.0	3.23	10.81	-21.73	-21.9
BBR042413242	4/24/13	WAE	500	1314.0	3.68	10.20	-22.69	-22.4
BBR050613122	5/6/13	WAE	502.92	1351.7	3.22	10.70	-21.93	-22.1
BBR042513715	4/25/13	WAE	507	1486.0	3.28	11.59	-22.55	-22.6
BBR071512006		WAE	508	.	3.17	10.84	-23.07	-23.3
BBR061813311	6/18/13	WAE	510	1525.0	3.41	10.27	-21.92	-21.9
BBR081213321	8/12/12	WAE	515	1533.0	3.20	10.64	-22.13	-22.3
BBR091013286	9/10/13	WAE	515	1586.0	3.28	10.73	-22.44	-22.5
BBR042513720	4/25/13	WAE	520	1585.0	4.72	11.17	-24.39	-23.0
BBR061913157	6/19/13	WAE	521	1625.0	3.20	10.60	-22.53	-22.7
BBR090913271	9/9/13	WAE	526	1469.0	3.23	10.54	-20.85	-21.0
BBR071512005		WAE	533	.	3.16	10.79	-22.54	-22.7
BBR081413309	8/14/13	WAE	545	1697.0	3.14	10.59	-22.08	-22.3
BBR091013300	9/10/13	WAE	548	1946.0	3.24	10.03	-21.97	-22.1
BBR042113005	4/21/13	WAE	549	1860.0	3.72	10.24	-22.78	-22.4
BBR091013260	9/10/13	WAE	550	1676.0	3.19	10.44	-22.08	-22.2
BBR091013269	9/10/13	WAE	553	1927.0	3.19	10.51	-21.71	-21.9
BBR091013267	9/10/13	WAE	555	2132.0	3.25	10.23	-20.53	-20.6
BBR090913273	9/9/13	WAE	558	2085.0	3.21	10.25	-21.06	-21.2
BBR091013274	9/10/13	WAE	566	2205.0	3.17	10.51	-22.27	-22.4
BBR042513767	4/25/13	WAE	580	2112.0	3.34	11.97	-22.23	-22.2
BBR102912258	10/29/12	WAE	580	2504.0	4.20	10.49	-23.89	-23.1
BBR071512002		WAE	.	.	3.21	10.84	-21.98	-22.1
BBR042513109	4/25/13	WHS	41	0.7	3.94	8.85	-20.65	-20.1
BBR040412051	4/4/12	WHS	48	.	3.48	9.84	-24.68	-24.6
BBR061913552	6/19/13	WHS	48	0.7	3.33	8.74	-22.36	-22.4

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR061913558	6/19/13	WHS	48	0.8	3.47	9.83	-25.69	-25.6
BBR061913556	6/19/13	WHS	54	1.4	3.49	9.80	-24.35	-24.2
BBR061913560	6/19/13	WHS	73	2.7	3.42	15.65	-27.47	-27.4
BBR042513102	4/25/13	WHS	105	10.1	3.59	9.06	-25.76	-25.5
BBR061813307	6/18/13	WHS	110	11.4	3.31	9.12	-24.48	-24.5
BBR091013126	9/10/13	WHS	112	15.2	3.35	7.74	-23.22	-23.2
BBR091013122	9/10/13	WHS	114	14.9	3.22	7.89	-22.60	-22.7
BBR061813301	6/18/13	WHS	116	15.1	3.54	8.86	-25.40	-25.2
BBR061913102	6/19/13	WHS	117	18.2	3.46	9.27	-24.62	-24.5
BBR091013127	9/10/13	WHS	117	16.8	3.39	7.46	-23.23	-23.2
BBR091013128	9/10/13	WHS	117	17.2	3.38	8.32	-24.16	-24.1
BBR061913145	6/19/13	WHS	118	16.6	3.38	8.58	-23.62	-23.6
BBR061913112	6/19/13	WHS	119	19.6	3.40	9.25	-26.04	-26.0
BBR040412030	4/4/12	WHS	120	14.0	3.36	8.60	-22.72	-22.7
BBR061913541	6/19/13	WHS	135	24.3	3.44	8.49	-24.74	-24.7
BBR061913539	6/19/13	WHS	153	37.8	3.29	8.89	-24.23	-24.3
BBR061913546	6/19/13	WHS	156	1.4	3.76	10.42	-29.42	-29.0
BBR061913540	6/19/13	WHS	157	36.6	3.32	8.53	-24.51	-24.5
BBR061813319	6/18/13	WHS	164	54.0	3.30	8.82	-24.72	-24.8
BBR091013276	9/10/13	WHS	164	48.0	3.25	7.74	-24.88	-25.0
BBR091013275	9/10/13	WHS	165	48.0	3.29	7.26	-23.70	-23.8
BBR091013259	9/10/13	WHS	178	62.0	3.28	7.15	-24.52	-24.6
BBR091013277	9/10/13	WHS	183	168.0	3.20	8.29	-23.52	-23.7
BBR090913542	9/9/13	WHS	189	69.5	3.31	7.84	-22.31	-22.3
BBR090913557	9/9/13	WHS	203	94.2	3.36	7.08	-24.31	-24.3
BBR061813317	6/18/13	WHS	219	118.0	3.39	7.67	-22.14	-22.1
BBR091013014	9/10/13	WHS	222	134.0	3.20	8.11	-26.97	-27.1
BBR042413007	4/24/13	WHS	231	114.3	3.36	11.44	-26.10	-26.1
BBR061813315	6/18/13	WHS	236	180.0	3.32	8.41	-23.84	-23.9

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR090913269	9/9/13	WHS	236	142.0	3.31	8.55	-25.61	-25.7
BBR061913121	6/19/13	WHS	237	175.0	3.43	7.72	-24.07	-24.0
BBR090913267	9/9/13	WHS	246	160.0	3.38	9.42	-24.60	-24.6
BBR090913293	9/9/13	WHS	246	155.0	3.40	7.68	-27.08	-27.0
BBR061913137	6/19/13	WHS	248	177.0	3.27	7.87	-24.61	-24.7
BBR091013135	9/10/13	WHS	250	171.0	3.45	6.45	-26.69	-26.6
BBR091013134	9/10/13	WHS	262	219.0	3.42	8.30	-24.97	-24.9
BBR061913123	6/19/13	WHS	271	265.0	3.20	8.39	-23.42	-23.6
BBR081313045	8/13/13	WHS	271	235.0	3.24	6.56	-23.49	-23.6
BBR081313030	8/13/13	WHS	294	294.0	3.81	7.53	-24.81	-24.4
BBR040212028	4/2/12	WHS	367	579.0	3.38	8.75	-23.43	-23.4
BBR040212018	4/2/12	WHS	379	692.0	3.20	9.84	-25.89	-26.0
BBR040212022	4/2/12	WHS	390	678.0	3.88	9.49	-24.74	-24.2
BBR040212021	4/2/12	WHS	395	685.0	3.30	8.59	-22.64	-22.7
BBR040212021	4/2/12	WHS	395	685.0	6.50	9.06	-27.03	-23.9
BBR040212024	4/2/12	WHS	408	762.0	5.53	10.20	-26.87	-24.7
BBR040212015	4/2/12	WHS	427	954.0	3.51	8.17	-23.26	-23.1
BBR061813063	6/18/13	YEP	99	13.9	3.34	10.12	-26.16	-26.2
BBR061813062	6/18/13	YEP	101	10.9	3.32	10.69	-24.70	-24.7
BBR090913530	9/9/13	YEP	114	17.0	3.28	8.62	-25.35	-25.4
BBR090913545	9/9/13	YEP	116	18.7	3.31	8.19	-25.94	-26.0
BBR091013313	9/10/13	YEP	133	36.0	3.25	8.84	-25.85	-26.0
BBR091013265	9/10/13	YEP	140	38.0	3.45	8.91	-26.26	-26.2
BBR091013273	9/10/13	YEP	145	38.0	3.24	8.37	-26.17	-26.3
BBR091013324	9/10/13	YEP	161	51.0	3.26	9.00	-26.24	-26.3
BBR091013317	9/10/13	YEP	173	65.0	3.19	8.92	-24.68	-24.8
BBR091013320	9/10/13	YEP	183	78.0	3.25	8.93	-26.00	-26.1
BBR091013309	9/10/13	YEP	187	92.0	3.25	8.50	-23.86	-24.0
BBR081413066	8/14/13	YEP	219	153.0	3.31	9.74	-24.09	-24.1

Sample ID	Sample date	Species code	Total length (mm)	Live weight (g)	C:N ratio	δ15N	δ13C	Normalized δ13C
BBR091013292	9/10/13	YEP	220	130.0	3.25	9.64	-25.23	-25.3
BBR081612501	8/16/12	YEP	249	244.0	3.29	8.51	-21.38	-21.4
BBR091013303	9/10/13	YEP	276	350.0	3.30	10.03	-23.27	-23.3
BBR052213008	5/22/13	YEP	277	331.0	3.15	10.52	-22.49	-22.7
BBR052213007	5/22/13	YEP	288	390.0	3.19	10.54	-23.01	-23.2
BBR052213010	5/22/13	YEP	288	431.0	3.18	8.93	-21.96	-22.1
BBR091013251	9/10/13	YEP	294	416.0	3.32	10.29	-23.35	-23.4
BBR042513250	4/25/13	YEP	302	410.0	3.18	9.59	-23.22	-23.4
BBR052213016	5/22/13	YEP	306	435.0	3.15	10.11	-22.69	-22.9
BBR091013310	9/10/13	YEP	310	522.0	3.24	10.80	-22.77	-22.9
BBR081613Z00P	8/16/13	ZOOP			4.44	4.83	-28.80	-27.7
BBRZOOP001		ZOOP			5.41	5.10	-32.50	-30.5
BBRZOOP002		ZOOP			5.44	6.17	-30.05	-28.0

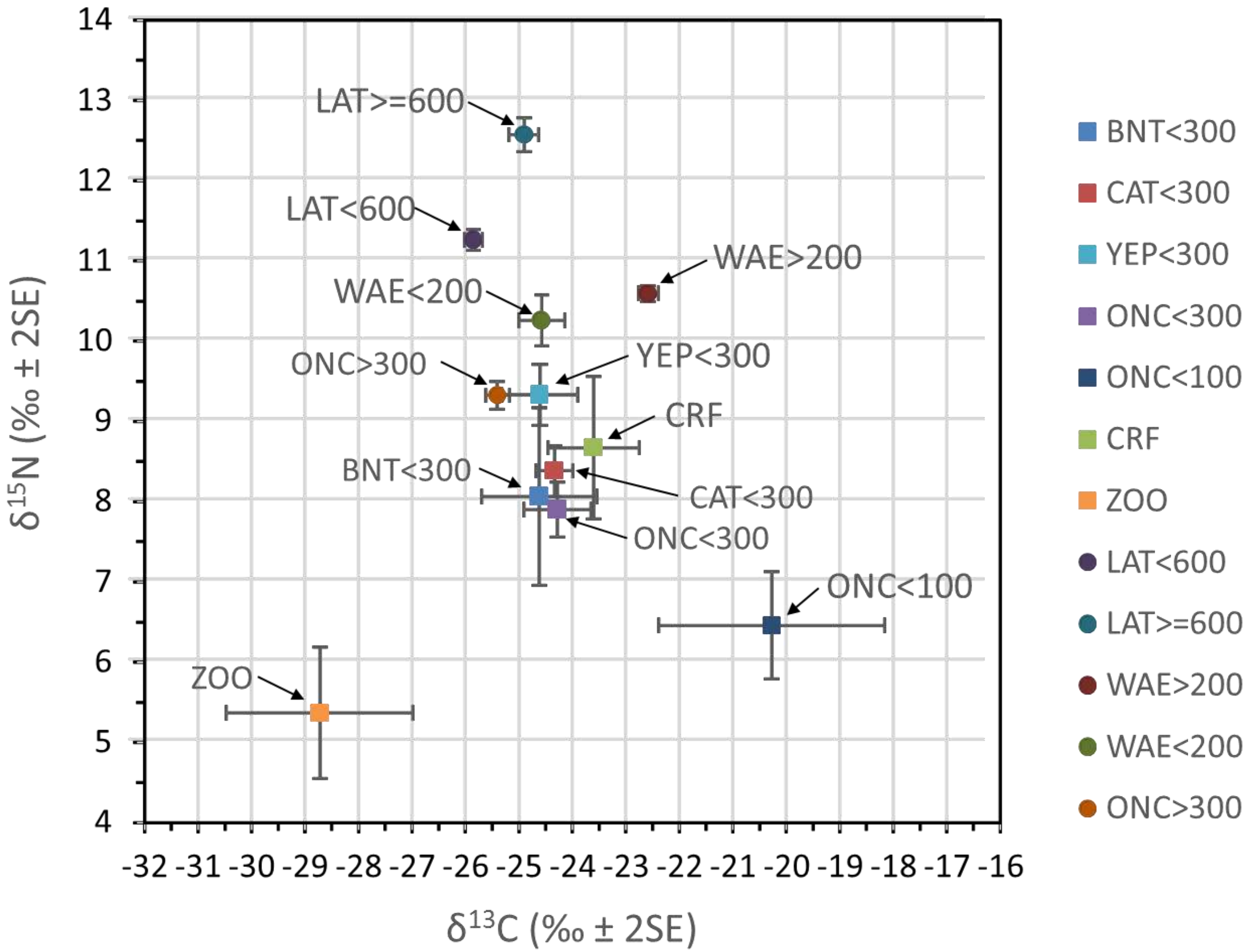

Figure VII.1. Carbon and nitrogen stable isotope signatures of fish and invertebrates sampled at Buffalo Bill Reservoir during April–October, 2012 and 2013.

REFERENCES

Baldwin, C. M., D. A. Beauchamp, and J. J. Van Tassell. 2000. Bioenergetic assessment of temporal food supply and consumption demand by salmonids in the strawberry reservoir food web. Transaction of the American Fisheries Society 129:429–450.

Childs, Colin. 2004. Interpolating Surfaces in ArcGIS Spatial Analyst. ArcUser July-September, 32-35.

Esri. 2013. How inverse distance weighted interpolation works. ArcGIS Resource Center. Available: http://help.arcgis.com/EN/arcgisdesktop/10.0/help/index.html#//00310000002m000000

Fry, B. 2006. Stable Isotope Ecology. Spring Science + Business Media, New York.

Gai, B. 1996. NDWI–A normalized difference water index for remote sensing of vegetation liquid water from space. Remote Sensing of the Environment 58:257–266.

Hanson, P. C., T. B. Johnson, D. E. Schindler, and J. F. Kitchell. 1997. Fish Bioenergetics 3.0. University of Wisconsin Sea Grant Institute Publication WISCU-T-97-001, Madison, WI.

Hartman, K. J., and S. B. Brandt. 1995. Estimating Energy Density of Fish. Transactions of the American Fisheries Society 124:347-355.

Hubert, W. A., R. D. Gipson, and R. A. Whaley. 1994. Interpreting Relative Weights of Lake Trout Stocks. North American Journal of Fisheries Management 14:212-215.

Johnson, B. M. and M. L. Koski. 2005. Reservoir and food web dynamics at Blue Mesa Reservoir, Colorado, 1993-2002. Final report, U.S. Bureau of Reclamation, Grand Junction, Colorado, 186 pages.

Johnson, B. M., J. M. Lepak, and B. A. Wolff. 2015. Effects of prey assemblage on mercury bioaccumulation in a piscivorous sport fish. Science of the Total Environment 506–507:330–337.

Johnson, B. M., and P. J. Martinez. 2012. Hydroclimate mediates effects of a keystone species in a coldwater reservoir. Lake and Reservoir Management 28:70–83.

Johnston, K., J. M Ver Hoef, K. Krivoruchko, and N. Lucas. 2001. Using ArcGIS Geostatistical Analyst. ESRI. United States of America.

Kruse, C. G., and W. A. Hubert. 1997. Proposed standard weight (Ws) equation for interior cutthroat trout. North American Journal of Fisheries Management 17:784–790.

Lind, O.T. 1979. Handbook of common methods in limnology, second edition. The C.V. Mosby Company, St. Louis, Missouri.

Luecke, C., and D. Brandt. 1993. Notes: Estimating the Energy Density of Daphnid Prey for Use with Rainbow Trout Bioenergetics Models. Transactions of the American Fisheries Society 122:386–389.

Martinez P. J., Gross M. D., Vigil E. M. 2010. A compendium of crustacean zooplankton and *Mysis diluviana* collections from selected Colorado reservoirs and lakes: 1991–2009. Special Report 82, Colorado Division of Wildlife, Fort Collins, Colorado.

Marwitz, T. D., and W. A. Hubert. 1997. Trends in Relative Weight of Walleye Stocks in Wyoming Reservoirs. North American Journal of Fisheries Management 17:44–53.

McCutchan, J. H. J., W. M. J. Lewis, C. Kendall, and C. C. McGrath. 2003. Variation in trophic shift for stable isotope ratios of carbon, nitrogen, and sulfur. OIKOS 102:378–390.

Murphy, B. R., M. L. Brown, and T. A. Springer. 1990. Evaluation of the relative weight (Wr) index, with new applications to walleye. North American Journal of Fisheries Management 10:85–97.

Neumann, R. M., C. S. Guy, and D. W. Willis. 2012. Length, Weight, and Associated Indices. . Pages 637–676 in A. V. Zale, D. L. Parrish, and T. M. Sutton, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Pate, W. M., B. M. Johnson, J. M. Lepak, and D. Brauch. 2014. Managing for Coexistence of Kokanee and Trophy Lake Trout in a Montane Reservoir. North American Journal of Fisheries Management 34:908–922.

Piccolo, J. J., W. A. Hubert, and R. A. Whaley. 1993. Standard Weigh equation for lake trout. North American Journal of Fisheries Management 13:401–404.

Post, D. M., C. A. Layman, D. A. Arrington, G. Takimoto, J. Quattrochi, and C. G. Montana. 2007. Getting to the fat of the matter: models, methods and assumptions for dealing with lipids in stable isotope analyses. Oecologia 152:179–189.

Semmens, B. X., and J. W. Moore. 2008. MixSIR: A Bayesian stable isotope mixing model. In Version 1.0.4. http://www.ecologybox.org.

USBR (United States Bureau of Reclamation). 2013. Buffalo Bill Dam. Great Plains Region. Available:http://www.usbr.gov/projects/Facility.jsp?fac_Name=Buffalo+Bill+Dam&groupName=General (July 2015).

USBR (United States Bureau of Reclamation). 2015. HydroMet Monthly Values for Period of Record. Available: http://www.usbr.gov/gp-bin/res070_form.pl?BBR(September 2015).

USGS (United States Geological Survey) 2015a. Landsat 8. Available: http://landsat.usgs.gov/landsat8.php(September 2015)

USGS (United States Geological Survey) 2015b. USGS Global Visualization Viewer. Available: http://glovis.usgs.gov/(September 2015).

Vander Zanden, M. J., J. M. Casselman, and J. B. Rasmussen. 1999. Stable isotope evidence for the food web consequences of species invasions in lakes. Nature 401:464–467.

Vander Zanden, M. J., and J. B. Rasmussen. 1999. Primary consumer δ13C and δ15N and the trophic position of aquatic consumers. Ecology 80:1,395–1,404.

Vander Zanden, M. J., and J. B. Rasmussen. 2001. Variation in 15N and 13C trophic fractionation: Implications for aquatic food web studies. Limnology and Oceanography 46:2,061–2,066.

Wetzel, R., and G. Likens. 1991. Limnological analyses. New York: Springer.