Development of New Information to Inform Fish Passage Decisions at the Yale and Merwin Hydro Projects on the Lewis River

Annual Progress Report

May 2014

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Introduction

The reintroduction of extirpated salmonids to historically-occupied areas is becoming increasingly common as a conservation and recovery strategy (Marcot et al. 2012; Temple and Pearsons 2012; Anderson et al. 2014). Often reintroductions are implemented after the factors which originally led to species extirpation have been reduced, eliminated, or mitigated. For species of Pacific Salmon (*Oncorhynchus* spp.) and steelhead (i.e., anadromous; *O. mykiss*), addressing barriers to migration, which have been a primary factor in the declines and extirpation of many populations (Sheer and Steel 2006; McClure et al. 2008), has been an integral component of recovery efforts. Mitigation has included barrier removals (e.g., Weigel et al. 2013), developing fish passage opportunities (e.g., Kiffney et al. 2009), and/or actively trapping and hauling juvenile and adult anadromous salmonids around barriers (e.g., Serl and Morrill 2010).

With any reintroduction there are a number of concerns regarding the ecological impact of the reintroduction efforts (see Anderson et al. 2014 for review). Anderson et al. (2014) identify three main tenets to consider when assessing reintroductions: 1) potential benefits if reintroduction is successful; 2) biological risk through interactions of reintroduced strains with existing populations; and 3) factors potentially limiting a successful reintroduction. Here we focus on the 2nd and 3rd factors outlined by Anderson et al. (2014) for the Upper North Fork Lewis River in Washington. The Upper North Fork Lewis River historically contained wild populations of Coho salmon, Chinook salmon, and Steelhead. These populations were extirpated with the completion of the Merwin (1932), Yale (1953), and Swift (1958) hydropower facilities, which were built without full passage. However, recent settlement agreements with Federal Energy Regulatory Commission (FERC) included consultation with the National Marine Fisheries Service (NMFS) for proposed reintroductions of the extirpated anadromous species above Merwin Dam (NMFS 2005). The overarching goal of this project is to establish viable, self-sustaining, naturally-reproducing, harvestable populations of spring Chinook, winter steelhead, and late-run Coho salmon at levels higher than minimum viable populations.

The reintroduction within the NF Lewis River has already commenced (2012) for the portions of the basin upstream of Swift Dam. Here, the specific objectives of this project were to collect new information to inform passage decisions specifically at the Yale and Merwin Hydro projects. In particular, this project focuses specifically on: 1) collecting data to ground-truth the amount and quality of habitat for anadromous species spawning and rearing in tributaries to Yale Lake and Lake Merwin; 2) assessing adult potential for spawning success in tributaries to Yale Lake and Lake Merwin; 3) evaluating juvenile production potential and emigration success; 4) evaluating likely predator impacts in Lake Merwin; and 5) assessing anadromous/resident interactions in Yale Lake and Lake Merwin and the tributaries to these reservoirs. In 2014, we initiated field research to help inform passage decisions related these specific objectives and the preliminary results of this project are presented below.

Methods

Study area

The study area for this project includes portions of the Upper North Fork Lewis River in Washington including areas upstream of Merwin Dam (Figure 1). Coastal Cutthroat Trout (*O. clarkii clarkii*) are distributed throughout much of study area as well as unique populations of Rainbow Trout (*O. mykiss*). Each reservoir is unique in its assemblage of aquatic species and physical characteristics. Lake Merwin is characterized by a high abundance of Northern Pikeminnow (*Ptychocheilus oregonensis*), and is stocked with Kokanee (*O. nerka*), Rainbow Trout, and Tiger Muskie (*Esox masquinongy* x *E. Lucius*) for sport fisheries. Yale Lake supports a self-sustaining population of Kokanee, as well as Northern Pikeminnow. Both Yale Lake and Swift Reservoir host populations of Bull Trout (*Salvelinus confluentus*) which, like Chinook and Steelhead, are listed under the Endangered Species Act (ESA). Swift Reservoir also contains Chinook (*O. tshawytscha*) and Coho salmon (*O. kisutch*), Steelhead Trout, Mountain Whitefish (*Prosopium williamsonii*), and is stocked with Rainbow Trout. All three reservoirs have populations of naturally producing Rainbow and Cutthroat Trout as well as Largescale Suckers (*Catastomus macrocheilus*)(Tables 1 and 2).

Assessment of available habitat (Task 2)

During 2013, we initiated efforts to quantify the extent and quality of stream habitat available for potential reintroductions of anadromous species in Lake Merwin and Yale Lake. The study streams include Marble Creek, Canyon Creek, Cape Horn Creek, Jim Creek, Indian George Creek, Buncombe Hollow Creek, Rock Creek, Brooks Creek, Lower Speelyai, Siouxon Creek, Upper Speelyai Creek, Dog Creek, Ole Creek, Rain Creek, Cougar Creek, Panamaker Creek, and the Swift Bypass Channel. Our objectives in 2013 were to evaluate the quantity of available habitat by identifying individual barriers in each of the streams and the discharge and temperature patterns in each of the tributaries. The habitat data from this component will be integrated with the Ecosystem Diagnosis and Treatment method (Lestelle et al. 1996) to ground truth estimates of species production potential. Production estimates from EDT will be completed by December 2014.

Available habitat.—To quantify the amount of available habitat, we walked each stream from river mouth upstream to the first observed fish barrier and recorded the GPS location. For streams where an obvious barrier was not available, we continued upstream to the next potential barrier and continued to record the position of each barrier. We then calculated the quantity of stream available to anadromous species by measuring the flow-path distance of each stream up to each barrier in ArcGIS.

In each tributary (except the Swift Bypass Channel, where discharge is known), we quantified stage discharge relationships and measured ambient stream temperature profiles. We installed pressure transducers (Solinst Levelogger) in each tributary for hourly measurements of the stage (i.e., river height) and stream temperatures. In addition, we installed a barometric pressure logger to control for basin-specific changes in barometric pressure from ambient weather. From July through October, we measured discharge at least three times per tributary to establish stream-specific stage-discharge relationships.

Habitat quality.—Beginning in July 2014, we will perform continuous habitat surveys within each of the tributaries to identify overall habitat quality as it pertains to salmon and Steelhead production. Given the considerable changes in discharge observed in some tributaries during the summer-fall, we will conduct two surveys during 2014: 1) early summer, to correspond to the minimum available rearing habitat; and 2) fall, to correspond to the minimum available spawning habitat. Surveys will be conducted using protocols derived from the Columbia Habitat Monitoring Program (CHaMP 2013) that are currently be employed in anadromous salmon and Steelhead research in the Columbia River Basin (N. Bouwes, Unpublished data).

Prior to collecting habitat data, each tributary will be delineated using a high resolution (10 cm) GPS unit to allow for accurate stream mapping and for changes in elevation for gradient estimates. Once completed, habitat data will be collected continuously including estimates of: substrate composition, percent fine sediment, water quality (temperature, conductivity, alkalinity, dissolved oxygen), large woody debris, water depth, wetted and bankfull widths, pool volume, cover, and amount of habitat in different channel units (e.g. pools, runs, backwater, etc.). All channel units will geo-referenced and attributes (e.g., substrate) will be linked with each individual channel unit; methods will allow for reach-based and comprehensive assessments of habitat quality as it pertains to production.

Assess juvenile production potential and emigration success (Task 4)

Given that anadromous species have yet to be reintroduced into the Lake Merwin and Yale Lake systems, we focused our efforts on Clear Creek, which is a tributary to the Muddy River above Swift Dam. We selected Clear Creek due to the current population of wild Coho and the use of this system as a release site for hatchery Chinook juveniles. Our study area in Clear Creek encompassed 11.7 km from the confluence with Muddy River upstream to the first known upstream barrier. We used a systematic sampling design with reach lengths of a minimum of 250 m and a minimum target of 33% sampling rate for 2013. Reach lengths varied, however, as we began each reach at a pool tail and continued sampling until the first pool beyond 250 m.

During 2013, we used a variety of sampling techniques to capture fish including backpack electrofishing, minnow traps, seining, and herding fish with a snorkeler into a seine (hereafter snerding). All sampling occurred during August through September and each year we will continue to mark wild Coho to increase sample size for interannual comparisons. Once captured we anesthetized fish using Aqui-S and weighed and measured all salmonids (fork length). We marked all salmonids >80 mm with a 12-mm full duplex PIT-tag in the dorsal sinus. Each marked fish is linked with a specific sampling reach to allow for analyses of spatial and temporal movement patterns.

In late August 2013, we installed a ‘pass by’ PIT-tag antennae system with Biomark biologists on Clear Creek (latitude 46.11818, longitude -121.9995) approximately 0.75 km upstream from the confluence with Muddy River. The reader can detect fish tagged with both half duplex and full duplex that pass by the antennae location. At the antennae site we additionally installed a pressure transducer for real-time, continuous measurements of streamflow (i.e., stage) and stream temperature and a modem to allow for cellular connection to the system for real-time information gathering. All equipment are powered by solar panels installed adjacent to the site and all PIT-tag data, antennae and receiver diagnostics, streamflow, and stream temperature can be remotely accessed.

Ultimately, integrating data from individual marking and recapture events will allow for robust estimates of production to the collector in Swift Reservoir. Survival estimates for wild and acclimation fish will be possible using individual capture (or release data) and recapture events at the Clear Creek antennae, the smolt screw trap, and the smolt collector at Swift Dam within mark-recapture analytical framework (e.g., Skalski et al. 1998).

Evaluating the Lake Merwin predator impacts (Task 5)

Physical properties and the predatory fish community in Lake Merwin were examined seasonally during 2013 with sampling scheduled to continue through summer of 2014. Sampling was conducted using gill-nets, hook and line, mark-recapture techniques, and limnological methods. The distribution, feeding habits, abundance and growth of Northern Pikeminnow were evaluated, and these parameters were used to parameterize the Wisconsin Bioenergetics Model to evaluate consumption demand in response to ambient thermal regimes and food supply. The outputs of the bioenergetics model were used to evaluate potential predator-prey interactions. Tiger Muskie will be evaluated later in the course of the study. Potential predation on juvenile salmonids in Lake Merwin will be the focus of Task 5, however many of the methods discussed for this task will also be used to evaluate resident/anadromous interactions in Task 6.

Limnology.—Limnological samples and measurements were taken in Lake Merwin in June, August, and November 2013. All measurements were taken at two stations roughly one third and two thirds up the reservoir (from the dam) in June and August; only the lower station was assessed in November because autumn is a less dynamic season. Temperature was measured at one meter intervals from zero to thirty meters. Temperature is an important determining factor for fish distribution and metabolic rates, which in turn affect predator's spatial overlap and consumption of juvenile salmonids. Limnology will be conducted monthly from April to November 2014.

Fish sampling.—Multiple methods were used to sample fish, however, the majority were captured using multi-panel variable mesh sinking gill nets in the littoral zone. Fish samples were collected in Lake Merwin with paired small mesh (2.5, 3.2, 3.8, 5.1, 6.4, and 7.6 cm stretched mesh) and large mesh nets (8.9, 10.2, 11.4, 12.7, and 15.2 cm stretched mesh) set perpendicular to shore for roughly 24 hours. Pairs of nets were set in four locations around Merwin at variable depths when possible, and additional nets were set as needed to gather samples from certain species or size classes. Gill netting occurred in June, August, and November in 2014. Mid-water trawling was conducted in June and August; however, submerged standing timber limited the depths that could be effectively sampled. Some additional samples were gathered opportunistically by hook and line, dip netting juveniles in backwaters, minnow trapping, and creel surveys of anglers. Fish samples collected include whole bodies, whole stomachs or stomach contents from gastric lavage, scales from the preferred region, and fin tissue for stable isotope analysis. Fish were euthanized according to UW-IACUC protocol #3286-21. Fish were counted, measured using fork length, and weighed. In addition, some snails and clams were also taken by hand while snorkeling. All samples were placed on ice in the field and later frozen for preservation and analysis.

Northern Pikeminnow mark-recapture.—Multiple methods were attempted to catch and tag Northern Pikeminnow in Lake Merwin. The most effective method used was short-set gill nets in the littoral zone. Fyke nets were not effective during June or July, and hook and line at the inlet of Canyon Creek during July was effective but to a lesser degree than gill nets. Small mesh gill nets with the smallest mesh bundled (5.1, 6.4, and 7.6 cm stretched mesh) were used to target pikeminnow greater than 200 mm. Nets were soaked for 30 minutes to 2 hours to minimize mortalities and injuries. Catch rates were found to dramatically increase at dusk during July, so the final days of marking were preferentially conducted at that time. Pikeminnow greater than 200 mm were targeted for recapture during November 2013 with small mesh gill nets set for 24 hours with the smallest mesh bundled. Northern Pikeminnow were anesthetized with MS222, measured, and tagged with one inch individually numbered floy tags. A subsample of fish was weighed and had a scale sample taken.

Additional tagging and recapture effort will begin in spring 2014 using Merwin Trap nets, gill nets, and hook and line sampling. Northern Pikeminnow will be intercepted on their migration to spawning grounds with Merwin Trap nets with the goal of tagging an additional 1,000 individuals. A final recapture effort will be conducted during the summer after the fish have had time to mix and redistribute into the lake.

*Age and growth.—A*ge and growth were estimated for salmonids and Northern Pikeminnow based on length frequency histograms, scales, opercles and hatchery release records. Scales were analyzed by two readers and opercles were analyzed for Northern Pikeminnow to corroborate scale ages. The Fraser-Lee method (Isely and Grabowski 2007) was used to back calculate length at age for Northern Pikeminnow and Kokanee in Yale and Merwin, and hatchery Rainbow Trout in Swift Reservoir. Lengths at past ages can be back calculated using the Fraser-Lee Method

$L_i = a + (L_c - a)(S_i/S_c)$,

where *i* corresponds to age, *L* is fork length at age, L_c is fork length at capture, *S* is the scale radius at an annuli *i*, and *c* denotes the scale radius at capture (S_c). Length at scale formation (a) is determined as the y-intercept of the fork length to scale radius regression. Regressions were made for each species and reservoir to account for different growth rates. The Fraser-Lee method was applied to all scales analyzed, then the back calculated lengths at each annulus were averaged to determine the mean length at age. Fork length to weight relationships were also made to enable conversion of a change in fork length with age to a change in weight with age. Empirically measured weights and length-weight relationships were used to evaluate changes in mass over time intervals, and these growth increments were used to feed bioenergetics models. The starting lengths of age-0 fish of each species (excluding Northern Pikeminnow) used as inputs to the bioenergetics model were chosen arbitrarily based on knowledge of the size at which fish typically enter lakes. Due to larger sample size, it was possible to determine the starting length of age-0 Northern Pikeminnow rearing in the reservoirs to be the length of first scale formation (a).

Diet analyses.—Seasonal diet composition by wet weight contribution of each prey category was evaluated for each species and size class of consumer. All stomach contents were examined under a dissecting microscope. Invertebrate prey items were classified to at least a functional group such as zooplankton, immature aquatic insects, or adult insects, which share a common energy density. Fish prey were identified to species and measured for standard length and weight, or length was reconstructed based on measurements of hard parts when possible. Stomach contents were blotted dry and weighed to the nearest 0.001 g, and preserved in 95% ethanol for long-term storage. Initial sample sizes were five to ten non-empty stomachs per size class of each species per season as available. Some sample sizes have or will be increased to better the precision of diet weight contribution, and more samples will be collected during the 2014 season.

Stable isotope analyses.—Stable isotope analysis provides a time-integrated indicator of an organism's trophic position and energy source(s) within a food web. This information is useful for constructing food webs, evaluating ontogenetic shifts in diet composition, and providing a baseline with which to evaluate changes in the food web in response to anadromous salmonid reintroduction. Samples of fin tissue from five randomly selected individuals of each strategically selected size class and species were analyzed from organisms captured in August 2013, subject to availability of samples. Stable isotope values of $\delta^{13}C$ are generally similar in predators and their prey, and are therefore used to evaluate the flow of energy through the food web (Vander Zanden and Rasmussen 2001). Ratios of ^{15}N generally increase by approximately 3.4‰ per trophic level and are therefore used to assess the trophic position of species and size classes of fishes (Minagawa and Wada 1984; Vander Zanden and Rasmussen 2001). Samples were analyzed using a Costech Elemental Analyzer, Conflo III, MAT253 for continuous flow based measurement of solid organic material. The reference material for carbon was Vienna Pee Dee belemnite and for nitrogen it was atmospheric N_2.

Bioenergetics modeling.—The Wisconsin Bioenergetics Model (Hanson 1997) was used to estimate growth performances and consumption demands of species and size or age classes of fishes that might interact with juvenile anadromous salmonids. Species specific physiological parameters were used for Chinook and Coho salmon (Stewart and Ibarra 1991), Steelhead-Rainbow Trout (Rand et al. 1993), Kokanee (Beauchamp et al. 1989), and Northern Pikeminnow (Petersen and Ward 1999). Simulations will be conducted for Bull Trout (Mesa et al. 2013), Cutthroat Trout, and Tiger Muskie after this season of sampling and data collection. The model fitted daily consumption demand to satisfy observed growth of an average fish of a given age or size class and species. In addition to growth, monthly thermal experience and seasonal diet composition were the main empirically derived inputs to the model. The percent of a fish's maximum consumption (% Cmax) given its physiological parameters, thermal experience, and diet composition is also reported by the model and serves as an indicator of feeding and growth performance. The %Cmax also serves as a baseline to evaluate whether species will compete for food with reintroduced anadromous salmonids, which would cause their %Cmax to decline. Consumption demand of planktivores was compared to prey supply to evaluate potential food limitations, and consumption demand of piscivores was used to evaluate potential predation risk.

The starting date for simulations of Northern Pikeminnow bioenergetics was June 1st which was the best estimate of 15 days after the median spawning date. Simulations of hatchery Kokanee bioenergetics in Lake Merwin began on May 1st; the actual release dates in 2013 were February 15th and October 22nd. Simulations of Kokanee bioenergetics in Yale Lake began on April 1st which was chosen arbitrarily to represent the peak fry migration into the reservoir. Hatchery Rainbow Trout were released in Swift Reservoir in late May, so simulations started on June 1st.

Juvenile anadromous salmonids were scarce in Swift Reservoir and almost completely absent in Merwin and Yale lakes, so feeding habits and thermal experiences had to be partially inferred. Timing of migrations into and out of Swift Reservoir by juvenile Chinook and Coho were estimated by determining the median days of the runs for each species at the migrant screw trap operated on the mainstem North Fork Lewis River directly above Swift Reservoir, and at the Floating Surface Collector (FSC) at Swift Dam. It is inferred that the residence time in Swift Reservoir for each species was the difference between the median day at the screw trap and the median day at the FSC. A cohort of juvenile Chinook captured in summer and fall in Swift Reservoir was presumed to be residualized hatchery smolts based on their size. Their growth, diet, and thermal experience was used to approximate the % Cmax for age-0 Chinook fry simulations, assuming that %Cmax would be approximately similar between age classes. Kokanee were used as a model organism to examine Chinook and Coho growth potential in Yale and Merwin, although Chinook and Coho are likely less efficient at feeding on zooplankton than Kokanee. The experiment to see if Merwin could be used to rear juvenile Coho in the late 1960’s also may provide information on the growth potential of Chinook and Coho in Merwin (Hamilton et al. 1970), although conditions may have changed since these experiments.

The starting date for age-0 Chinook was April 2nd, which was the median date of catch at the screw trap, and the end date was November 11th, which was the last day that Chinook were sampled in Swift Reservoir in 2013 and therefore the last day that an approximation of their %Cmax was available. Simulations of age-1 Chinook also began on April 2nd, and ended on May 17th which was the median date of catch at the FSC. The median date of age-1 Coho catch at the screw trap and the start date for the simulation of age-1 Coho bioenergetics was May 9th. The end date was May 28th, the median date of age-1 Coho outmigrating at the FSC. Bioenergetics simulations of age-2 Coho began on May 28th and went to the following April 9th, which was the median catch date of the second smallest size mode of fish caught at the FSC (Table 3).

The growth of age-0 Chinook was simulated using a fixed %Cmax obtained from bioenergetics models of age-1 Chinook feeding and growth. Growth in weight for these simulations of age-1 Chinook were based on mean observed weights of hatchery smolts prior to release, those captured in gill nets in August, and those captured in gill nets in November. Growth of age-1 Chinook as measured by the mean length at the screw trap and mean length at the FSC was also modeled and reported for the bioenergetics of age-1 Chinook. Age-1 Coho starting weight for bioenergetics simulations was estimated based on the mean fork length of Coho in the smallest mode captured at the screw trap and length-weight regressions for Chinook. The fork length to weight regression for Chinook captured in the reservoir was used to convert length of Coho to weight because there was not enough data to make a length–weight model for Coho. Age-1 Coho ending weight, age-2 starting weight and age-2 ending weight were estimated based on the mean fork lengths of the smallest mode and the second smallest mode in the catch at the Floating Surface Collector (FSC) at Swift Dam and the length-weight relationship for Chinook (Table 3).

Thermal experience was inferred by combining water temperature information from multiple sources and depth distribution of fishes from hydroacoustic survey results, direct observations, and information on distribution from the literature. In addition to the seasonal temperature profiles collected for this study, strings of temperature recording sensors were deployed by PacifiCorp in the forebay of each reservoir from May through October 2013 (Figure 2). Temperature loggers were also in place in the tailraces of each dam year round, and provided an approximation of reservoir temperatures during isothermal conditions (Figure 3). Combining these sources of temperature data with fishes' depth distribution allowed for estimation of monthly thermal experience (Table 4).

Diet proportions were derived from empirical data whenever possible, however diet composition had to be inferred when there was little or no data on certain species, size classes, seasons, or reservoirs. Diet data from similar species or size classes, or the same species and size class in a different reservoir was used to extrapolate diet composition in these instances.

The energy density (joules/gram) of consumers and prey items were taken from literature values, which enable the models to produce annual energy budgets to evaluate the importance of different prey types during different life stages (Table 5). The bioenergetics model used the biomass of each prey category consumed and the energy density of each prey category to estimate the daily contribution of each prey type to the energy budget of an average individual from an age or size class of a population of a fish species.

The two outputs of the bioenergetics model were the %Cmax and daily consumption demand for each prey group. Feeding rate and growth performance were approximated by %Cmax, and were used to evaluate the foraging environment for juvenile anadromous salmonids. Comparing the foraging environment between the lentic and lotic habitat, or before and after reintroduction will help identify potential bottlenecks to production and direct habitat restoration measures (Naiman et al. 2002). Feeding rate can also be varied in the model to evaluate consumption demand at different feeding rates. This is a useful tool for evaluating different scenarios of predator behavior, such as an intensive feeding bout in response to a pulse of prey. Consumption demand on plankton was estimated and will be compared with zooplankton biomass to evaluate the carrying capacity for juvenile anadromous salmonids rearing in each reservoir, and to identify potential competitive interactions. Consumption demand by piscivores was estimated to evaluate predation losses that would occur on juvenile anadromous salmonids, and consumption by piscivorous salmonids such as Bull Trout and Cutthroat Trout will be modeled once more data is available.

The bioenergetics model produced estimates of consumption demand for an average individual, which was then expanded based on estimated population abundances and size structures. The abundances of limnetic fishes less than 300 mm, such as Kokanee, will be estimated from hydroacoustic survey results once the species composition of the pelagic fish community has been better characterized. Northern Pikeminnow abundance in Lake Merwin was estimated based on preliminary mark-recapture results which will be refined in the next year. Other benthic fish populations in Lake Merwin will be evaluated by comparing catch rates to those of Northern Pikeminnow, assuming constant catchability. Stocking records provided information on abundances at times of releases. Survival will be either estimated arbitrarily or fitted to seasonal Cohort abundance estimates. When evaluating carrying capacity for juvenile anadromous salmonid rearing, hypothetical future population abundances will be varied to determine a population which would consume approximately 50% of the standing stock biomass of daphnia during the month of peak growth. Such a metric is a logical and conservative measure of potential carrying capacity, because it leaves half of the zooplankton to satisfy the consumption demand of other species and allows for reproduction.

Assess anadromous-resident interactions (Task 6)

Stream habitat

During 2013, we initiated studies to quantify resident-anadromous interactions in the study area. Given that reintroductions have not occurred in the Lake Merwin and Yale Lake, efforts were largely focused in tributaries to Swift Reservoir. Our specific objectives in 2013 were to quantify : 1) the distributional overlap between Bull Trout and juvenile Coho salmon; 2) the spatial and temporal overlap between hatchery released juveniles (i.e., juvenile Chinook); and 3) identify potential community interactions. Data will continue to be collected to assess anadromous-resident interactions in stream habitat during 2014 and 2015. Methods to assess such interactions will be expanded considerably during 2014 and continue through 2015 and will include assessments of redd superimposition by anadromous species on Bull Trout (Pine Creek and P8) and Kokanee (Yale) redds, diet overlap between wild Coho and hatchery Chinook, and an overall integration of measures of stream productivity, species-specific diet data, isotope data, and bioenergetics modeling.

Distributional overlap.—We quantified distributional overlap of Bull Trout and juvenile Coho using primarily snorkel surveys in Pine Creek and P8. We selected these streams due to the relatively high abundance of Bull Trout in these streams in comparison to other streams occupied by Bull Trout (e.g., Rush Creek). While snorkeling studies can substantially underestimate the abundance of Bull Trout, particularly during daytime studies (Thurow et al. 2006), we selected daytime snorkeling surveys due to the understanding that Bull Trout commonly use Pine Creek and P8 and the need to quantify juvenile Coho distribution, which is unlikely to have pronounced diel bias. To assess the distribution of both species, we used a systematic sampling approach as both species are likely clumped in distribution (e.g., Al-Chokhachy et al. 2009; Figure 4). Reach lengths varied by stream with reaches of at least 200 m used in Pine Creek and 150 m in P8. During snorkel surveys, two individuals progressed upstream, remaining relatively parallel to each other; all side channels and channel units were included in each survey. All fish were recorded into 50-mm categories, and reported to a third individual on the streambank. Snorkelers carried flashlights to improve visibility in shaded areas and in sections with large numbers of woody debris.

In addition to overlap with Bull Trout, we considered the potential interactions between acclimation Chinook and wild Coho in Clear Creek. Specifically, we evaluated the spatial and temporal overlap of acclimation fish using location of tagging information and emigration patterns (i.e., through recapture events at the fixed antennae on Clear Creek) of marked Coho (Task 4) and PIT-tagged acclimation Chinook. With additional time for migration (i.e., within this year), this data will help identify ‘residence’ time of acclimation Chinook and migration patterns of wild Coho in response to the population of acclimation fish.

Foodweb and community interactions.—During 2014, we assessed community interactions using a combination of stable isotope data and diet analyses. We revisited sites previously sampled during 2009 as part of a ‘baseline’ assessment of community interactions prior to large-scale anadromous reintroductions in the Upper Lewis River (Figure 5). We focused our efforts on tributaries to Swift Reservoir, given that anadromous reintroductions have been initiated and included sites on: Swift Creek, Drift Creek, Rush Creek, P8, Cussed Hollow, and the Upper Lewis (above Lower Falls; Figure 5). In addition, we also collected diet and isotope data at two sites on Clear Creek upstream of the confluence with Muddy River.

At each site, we sampled macroinvertebrates, collected tissue samples from fish, and collected diet data. We used a variety of sampling techniques to capture fish including backpack electrofishing, electrofishing down to a seine, snorkel herding fish into a seine, and minnow traps. Once captured, we anesthetized fish with AQUI-S, weighed and measured each fish. We took tissue and diet samples from up to five individuals for each 100-mm size class of each species. Tissue samples were taken from the anal fin (3-mm x 3 mm) and frozen for isotopic analyses. To collect diet data, we used gastric lavage methods for all fish >60 mm. After sampling, we placed fish in flow-through recovery tanks within the sample stream; upon full recovery of equilibrium fish were released at their point of capture. We sampled for macroinvertebrates using drift nets set in the thalweg at the bottom of each reach with set times of approximately one hour.

Reservoir habitat

Physical properties, zooplankton, predatory fish, and non-predatory fish communities were examined seasonally in Swift, Yale, and Merwin Reservoirs in 2013. Sampling is scheduled to continue through summer 2014. Task 6 focuses on the growth environment for juvenile anadromous salmonids, and potential competitive interaction, in addition to predation in each reservoir. Methods for fish sampling, diet analysis, evaluating age and growth, and bioenergetics modeling described in task 5 were also used in task 6.

Limnology.—Limnological measurements were conducted in Swift Reservoir and Yale Lake at identically configured stations and at the same time as in Lake Merwin. At each station and during each sampling period, three depth stratified oblique zooplankton tows were conducted with a Clarke-Bumpus sampler fitted with a 154 micron mesh net. The tows were conducted at depths that represented the epilimnion, metalimnion, and hypolimnion during stratification and similar depths during spring and fall.

Fish sampling.—Gill netting in Yale and Swift Reservoirs was conducted in August and November 2013 with 30 minutes to two hour long sets in order to reduce the risk of harming ESA listed Bull Trout. No gill netting was conducted in these reservoirs in June 2013 because the permitting process for handling Bull Trout was still underway. One Bull Trout was seemingly injured and one mortality occurred during summer sampling; however, no further injury or mortality occurred with reduced set times in subsequent surveys. Creel surveys were an effective means of collecting samples in Yale and Swift Reservoirs as well. Mid-water trawling was conducted in June and August in these reservoirs and was restricted by submerged standing timber, as in Lake Merwin. Minnow traps were used to obtain Sculpin (*Cottus* spp.) in Swift Reservoir. Mortalities of pelagic fishes at the FSC, including salmon smolts, were also obtained for analyses.

Fish in Yale and Swift Reservoirs will be sampled in spring 2014, and in all three reservoirs throughout the 2014 season directed toward filling data gaps. More systematic and extensive angler surveys may be the best way to characterize the species and age composition of the pelagic fish community. Hook and line sampling will likely be utilized to obtain data on predatory salmonids such as Cutthroat Trout and Bull Trout. Mortalities, scale samples, and length measurements will be collected at the FSC and the screw trap as well.

Hydroacoustics.—Hydroacoustic surveys were conducted in June, August and November 2013 to evaluate the abundance and distribution of fishes. Quantitative surveys of fish abundance and distribution in August consisted of 15-25 zigzag transects across, and one long transect along the center axis of each reservoir. The more qualitative surveys in June and November consisted of 5-15 loose zigzag transects across, and one transect along the center axis of each reservoir. A portion of each of the surveys was repeated during daylight, dusk, and night to evaluate diel vertical migrations. The upper quarter of Swift Reservoir was not surveyed with hydroacoustics due to insufficient depth.

Two multiplexed split-beam 200 kHz transducers were towed in side-looking (12.8°full beam angle) and down-looking (6.8° full beam angle) orientations. The transducers were connected to a Biosonics DE-6000 scientific echosounder (Noise threshold -65 dB, bottom threshold 60-100 m, ping rate 2-3 pps, pulse width .3ms, and target acceptance criteria using minimum and maximum normalized pulse lengths of .6-1.5 at -6 dB from peak amplitude). Fish schools were not encountered, so single target counts were used to analyze acoustic data. Standard echo counting techniques (Beauchamp et al. 1997; Beauchamp et al. 2009) with EchoView 5.4 software (Myriax Pty. Ltd.) were used to evaluate depth specific densities of fish targets by size class. Fish target strengths measured by the downlooking transducer were converted to fork lengths based on Love’s (1971) equation.

Fish targets were then binned by size class and compared to gill net catch data, creel reports, stocking records, and other sources of local knowledge in an attempt to examine densities by species and size class. Verification of species and size using trawling was not possible due to submerged trees within the reservoirs. Estimates of the species composition and abundance of fish have not yet been generated because of the uncertainty surrounding the species composition of acoustic targets. Sampling in 2014 will be directed to fill this knowledge gap. Targets measured by the side-looking oriented transducer were used to evaluate fish densities within the upper 4.6 -18.2 m of the water column over a range of 0-40 m from the survey vessel. Side aspect target strengths cannot be reliably converted to fish lengths, however, so the observed densities represent total targets surveyed. Densities of large limnetic fishes (i.e., salmonids >300 mm), and benthically oriented fishes (i.e., Sucker spp., Tiger Muskie, Northern Pikeminnow) cannot be reliably evaluated with hydroacoustic surveys because these species are too variable. Hydroacoustic estimates of abundance of large pelagic and benthic species can lead to inaccurate estimates of abundance in multi-species communities (Yule 2000; Gangl and Whaley 2004; Beauchamp et al. 2009). Therefore, abundance estimates based on hydroacoustic surveys will be for small limnetic fishes. Depth and size stratified target densities from August have been generated, however, June and November surveys are still being analyzed. Abundance of large limnetic or benthically oriented fishes can be inferred from mark-recapture results, stocking records, and other local sources of information, but should be considered very rough and potentially biased at this early point of the study.

Zooplankton.—Standing stock biomass of the primary crustacean zooplankton species was estimated based on empirical measurements of density, distribution, and length combined with literature values for length-weight relationships (Dumont et al. 1975). Individual organisms within each sample were identified to genus and counted. The first thirty individuals of each genus from each sample were measured (from the top of the helmet to the base of the tail spine for cladocerans, and from the top of the helmet to the base of the caudal rami for copepods). Individual mass was estimated with taxon-specific length-wet weight relationships (Dumont et al. 1975; Garton et al. 1990). Zooplankton biomass density (g/L) was calculated based on density and biomass, and whole reservoir standing stock biomass of zooplankton was calculated by expanding depth stratified biomass density based on the water volume in each depth layer.

Bioenergetics modeling.—Bioenergetics modeling for Task 6 was completed in the same manner as for Task 5.

Results

Assessment of available habitat (Task 2)

Surveys of available habitat indicated a total of 29.5 km of available habitat in tributaries to Yale Lake and Lake Merwin (Table 6; Figure 6). The majority (23.5 km) were in tributaries to Yale Lake with Siouxon Creek (and tributary; total = 6.43 km), Speelyai Creek (and tributaries; total = 7.46 km), the Swift Bypass Channel (4.89 km), and Cougar Creek (2.68 km) having the majority of available habitat. Within Lake Merwin, Brooks Creek (2.45 km) and Indian George Creek (1.35 km) contain the most available habitat.

Average temperatures and streamflows ranged considerably across tributaries. As expected, the largest range of temperatures occurred during August (monthly mean = 6.8 – 17.0°C; Table 7). Streamflows reduced substantially during August, and Panamaker Creek became intermittent in early September. Speelyai Creek and Cougar Creek maintained considerably higher streamflows than the other tributaries (See below for Siouxon Creek), which had average discharge values below 3 cfs for both July and August (Table 8). However, streamflows rose during September in all streams as a result of the high precipitation event in 2013; during this high discharge event, the stage-discharge/temperature logger was lost in Siouxon Creek.

Assess juvenile production potential and emigration Success (Task 4)

During 2013, we sampled a total of 20 reaches on Clear Creek for a total of 5,416 km. We captured 370 juvenile Coho salmon with an average fork length = 97 mm (SD = 10.1; range = 67 – 129 mm; Figure 7) and 124 Coastal Cutthroat Trout with and average fork length = 116 mm (SD = 48.4; range = 43 – 231 mm; Figure 8). The number of Coho captured by reach varied considerably and juvenile Coho were captured as high as 7.0 river km upstream from the confluence with the Muddy River (Figure 9). Within the sample reaches we PIT-tagged 357 individual Coho and 51 Coastal Cutthroat Trout.

As of May 5th, 2014 72 of the 328 PIT-tagged Coho had emigrated downstream past the antennae. The majority of these movements occurred during September (Figure 10). The average length of fish moving in September (mean = 100 mm; range = 86 – 112 mm) is similar to the overall distribution of Coho lengths at capture. Albeit early, this pattern does not indicate any patterns of size influencing Coho emigration timing. The majority (93%) of the Coho emigrating in September originated (i.e., were tagged) within ½ km of the antennae. Coho emigrating during the period of October 1, 2013 through May 5th, 2014 displayed a wider range of location of origin (i.e., tagging), with the furthest distance of 3.5 km.

In addition to wild Coho salmon, we also detected three Chinook from the 3,500 acclimation fish planted in the Muddy River/Clear Creek systems. The individuals were detected on August 29th and September 30th, 2013 and March 23rd 2014. We also detected two supplementation Coho salmon on August 29th and September 30th, 2013. Finally, we detected three Coastal Cutthroat Trout emigrating past the antennae (105 – 184 mm). One of these individuals (105 mm) migrated over 6.5 km from point of capture in Clear Creek.

Evaluating the Lake Merwin predator impacts (Task 5)

Seasonal abundance and distribution of fish

Limnology.—Lake Merwin was thermally stratified from June through August 2013. Epilimnetic temperatures reached 23° C at the upper limnology site during August, and the thermocline was located at approximately 10 m deep and was 19° C (Figure 11).

Northern Pikeminnow mark-recapture.—Northern Pikeminnow were observed in schools at the surface of Canyon Creek bay during early July, and directly below the waterfall at the inlet of Canyon Creek in mid-July. Small fyke nets were not an effective means of capturing Northern Pikeminnow. Schools of fish were observed rising to the surface, and hook and line sampling confirmed that they were Northern Pikeminnow. Hook and line sampling conducted directly below the waterfall at the inlet of Canyon Creek with small pieces of trout as bait provided an effective means of capturing Northern Pikeminnow in early through mid-July. Schools of age-0 Pikeminnow less than 50 mm were observed in backwater areas in the confined upper stretch of Lake Merwin ("The Canyon") between the Yale tailrace and Cresap Bay Park during late June. Throughout the year, Northern Pikeminnow were highly vulnerable to sinking gill nets in the littoral zone. They were captured at the highest rate of any species in sinking gill nets by at least a factor of four in each season sampled, suggesting that they are the most abundant species in the littoral zone.

A total of 1,125 Northern Pikeminnow greater than 200 mm were tagged with individually numbered Floy anchor tags between June 12th and August 1st 2013. Four fish were recaptured during the tagging effort although one fish was recaptured on the same day near the location where it was tagged and was discarded. These opportunistic recaptures were used to estimate the abundance of Northern Pikeminnow in Lake Merwin, using the Schnabel method (Seber 1982). Twenty-one days of tagging (not continuous) were conducted, which corresponds to 20 days of potentially recapturing fish. A point estimate of 176,506 Northern Pikeminnow was generated based on the three legitimate recaptures, although the spatial extent of sampling did not cover the entire lake. An algorithm for generating variance for Schnabel estimates with a small number of recaptures produced a 95% confidence interval of 51,963 to 868,410. Routine seasonal sampling was conducted in Lake Merwin in late-July and mid-November, with an increased effort directed at capturing Northern Pikeminnow greater than 200 mm in November. In July, 101 Northern Pikeminnow greater than 200 mm were captured in gill gets, of which zero had been tagged. A total of 168 Northern Pikeminnow of predatory size were captured during November, of which one had been tagged and one had an obvious tagging scar but no tag. A second point estimate was generated using the Lincoln-Peterson method based on the number of fish captured during routine summer and fall sampling and the number of recaptures (including the fish with the appearance of a shed tag)(Bailey 1951). The abundance of Northern Pikeminnow greater than 200 mm in Lake Merwin was 147,950 based on these numbers. Both of these estimates should be considered very rough at this point because of the small number of recaptures, however, the best estimate of predatory Northern Pikeminnow in Lake Merwin at this point is likely approximately 160,000 (Table 9), somewhere between the estimates generated by the Schnabel and Lincoln-Peterson methods.

Age and growth.—Northern Pikeminnow in Lake Merwin exhibited a strong linear relationship between fork length and scale radius. The equation for the relationship was

$$FL = 95.356 * S_r + 9.5582$$

Where *Fl* is fork length and S_r is scale radius (n=63, min 34.2, max 560, R^2=0.98). Lengths at ages 0-14 were estimated for bioenergetics simulations using the Fraser-Lee method. Sample sizes of Northern Pikeminnow that were 14 or 15 years old were too small to accurately estimate length at these ages (Figure 12). The length to weight relationship for Northern Pikeminnow in Lake Merwin was:

$$Weight = 7E\text{-}06 * FL^{3.0988}$$

where *FL* is fork length (n=68, min=34.2, max=560 mm, R^2=0.997) (Table 10).

Diet composition.—Smaller size classes of Northern Pikeminnow (<299 mm) had a high proportion of daphnia in their diet, as well as significant amounts of plant material and terrestrial insects. Larger size classes of Northern Pikeminnow (>300 mm) had high proportions of crayfish, and fish in their diet. Sculpin, Northern Pikeminnow, unidentified salmonids, salmonid eggs, and unidentified fish were all consumed by the larger size class of Northern Pikeminnow. Three Tiger Muskie (>600 mm) diets from spring all contained exclusively Northern Pikeminnow, with two of the three diets containing Pikeminnow of predatory size (222mm and 235 mm) (Tables 11, 12).

Stable isotope analyses.—Northern Pikeminnow and Tiger Muskie exhibited positive relationships between fork length (FL) and $\delta^{15}N$, while $\delta^{13}C$ was not as strongly associated with length for both species in Lake Merwin. There was a distinct positive relationship, however, between $\delta^{13}C$ and FL for Northern Pikeminnow. This suggests that Northern Pikeminnow increase their trophic level and switch prey types as they grow larger. Tiger Muskie exhibited a weak positive trend in $\delta^{13}C$ with increasing FL, indicating that their prey also change somewhat with size. At the very largest sizes of Northern Pikeminnow, trophic level appears to decrease, possibly explained by a shift to a diet favoring crayfish (i.e., less fish in diet; Figures 13, 14).

Population-level consumption demand of Northern Pikeminnow

Annual consumption of unidentified salmonids by an age structured population of 160,000 Northern Pikeminnow in Lake Merwin was 3.85 metric tonnes, or 192,427 twenty gram fish. This does not include unidentified fish, of which a proportion could have been salmonids (Table 13).

Assess anadromous-resident interactions (Task 6)

<u>*Stream habitat*</u>

We conducted 17 snorkel surveys totaling 3.2 km within Pine Creek and P8. Bull Trout, Coastal Cutthroat Trout, and young-of-year (YOY) Steelhead and/or Coastal Cutthroat Trout comprised the majority of fish observed in the surveys (Figure 15). The relative abundance of Bull Trout generally increased when moving from the mouth of Pine Creek up through the highest reach in P8. The majority of Bull Trout observed during snorkel surveys were age-1 and age-2 fish (Al-Chokhachy and Budy 2008); large migratory individuals were also observed (Figure 16). The actual numbers of Bull Trout remained relatively consistent across reaches (Figure 17). Only 2 juvenile Coho were observed during surveys and these individuals were observed in a reach proximate to the tributary P3 (see Figure 15), suggesting spatial overlap during 2013 in the Pine Creek systems was relatively low.

During the spring of 2014 (April 24th and May 1-2nd) 7,576 PIT-tagged, hatchery spring Chinook were released into Clear Creek. At the point of the last release, 42 (35%) of the 119 wild Coho that were PIT-tagged in 2014 between the Chinook release site (highway bridge/acclimation channel) and the antennae had emigrated downstream of the PIT-tag antennae. As of May 5th, 1,806 (24%) of the 7,576 acclimation Chinook released into Clear Creek had emigrated downstream past the PIT-tag antennae on Clear Creek. Despite the large number of hatchery-reared spring Chinook released into Clear Creek, we did not observe additional emigration of wild Coho during or immediately after the release of acclimation fish. However, at the time of this report we were unable to evaluate detection efficiency, which will be possible using recapture events at the rotary screw trap and/or the FSC. Qualitative snorkel surveys during late May 2014 suggested most (if not all) acclimation fish had migrated downstream and out of Clear Creek. Estimates of antenna collection efficiency will be updated in 2014, which will provide additional insights in residence time of acclimation Chinook and consequently, potential impacts on wild fish.

Isotopic and diet analyses for samples collected in the stream habitats have not been completed at this point. The data to address these objectives are currently being analyzed and an Interim Updated Report will be circulated once completed (~spring 2014).

Reservoir habitat

Limnology

Both Swift Reservoir and Yale Lake were thermally stratified from June through August 2013. Epilimnetic temperatures in Swift Reservoir and Yale Lake reached 22° C and 22.5° C respectively in August. The thermocline in Swift Reservoir was located at approximately 10 m and was 18° C, and in Yale Lake the thermocline was located at approximately 7 m and was 20° C in August (Figure 11).

Hydroacoustics

Diel vertical migration was evident in offshore regions of Merwin and Yale lakes, but mostly absent in Swift Reservoir (Figures 18-20). Analysis of hydroacoustic surveys is still underway. Surveys conducted in June and November 2013 will be analyzed, and population estimates of small limnetic fishes will be generated in 2014.

Fish sampling

Swift Reservoir.—Swift reservoir was planted with roughly 50,000 hatchery Rainbow Trout of catchable size (approx. 200-250 mm) in late May of 2013 (Kevin Young, Personal Communication). Roughly 105,000 juvenile spring Chinook salmon were planted in the Muddy River and Clear Creek off of the upper North Fork Lewis River on April 3rd, after which many of these fish moved into Swift reservoir. They either transited directly to the FSC or spent time in the reservoir. The median date of the Chinook migration into Swift Reservoir was April 2nd, as measured at the smolt trap directly above Swift Reservoir. The median date of Chinook migration out of the reservoir was April 17th, as measured by catch at the FSC. Spring Chinook and Coho appear to be using Swift reservoir as at least a temporary feeding station during their outmigration, and are rearing for more extended periods in the reservoir to an unknown degree. Age-1 spring Chinook were captured in Swift Reservoir in August and November, although these were presumably hatchery smolts released in spring and expected to have outmigrated during early summer (Figure 21).

Largescale Suckers were caught at the highest rate of any species in gill nets during both summer and fall in Swift Reservoir. Suckers were caught at approximately one per net in summer and 0.4 per net in fall. The next most captured fishes in gill nets in summer were juvenile Chinook salmon at 0.26 per net, and Bull and Rainbow Trout which were each caught at 0.07 per net. In fall the second most captured fish after suckers in gill nets was Rainbow Trout at 0.25 per net, followed by juvenile Coho salmon at 0.09 per net, and mountain whitefish and Cutthroat Trout which were each caught at 0.06 per net. The gill nets used selected for larger sized benthic or littoral fishes. No Northern Pikeminnow were captured in Swift Reservoir (Table 14; Figures 22,23).

Yale Lake.—Multiple sampling techniques suggest that the most abundant limnetic species in Yale Lake is Kokanee. Informal creel surveys indicated that the predominant species caught was Kokanee at a depth of roughly 13 m where most trolling anglers fished. Mid-water trawling conducted in June 2013 in the upper 15 meters of the water column captured only Kokanee fry of 36-41 mm (n=23). Trawling conducted in the upper 15 meters in August captured one Kokanee fry (51 mm), one Threespine Stickleback (*Gasterosteus aculeatus)* (31 mm), and one juvenile Sculpin (30 mm).

Short set seasonal sinking gill nets in the littoral zone of Yale Lake captured Largescale Suckers, Northern Pikeminnow, Kokanee, and Rainbow, cutthroat and Bull Trout. Largescale Suckers were the most abundant species captured in summer at 1.2 per net. Northern Pikeminnow were caught at 1 per net, and Rainbow and Bull Trout at 0.1 per net in summer. In fall, the most commonly caught species were Northern Pikeminnow at 0.25 per net and Kokanee at 0.1 per net. Most of the Kokanee captured in fall were in spawning colors near the mouths of Cougar and Siouxon Creeks (Table 15; Figures 24, 25).

The only hatchery releases in Yale Lake were 500 Coho smolts planted on April 5th for a hydroacoustic survey to help identify potential suitable locations for a surface collector.

Lake Merwin.—Gill net catches and informal creel surveys suggest that Northern Pikeminnow are the most abundant fish in the littoral zone, while Kokanee and Rainbow Trout are the most common fishes in the limnetic zone. Northern Pikeminnow had the highest average catch per gill net (CPUE) in spring, summer, and fall. Largescale Suckers were the second most commonly captured species in spring and summer, and Tiger Muskie were the second most commonly caught species in fall. Kokanee, Rainbow Trout, and Tiger Muskie all had significantly higher CPUE in fall than spring or summer, and suckers had a lower CPUE in fall than spring or summer. Anglers in Lake Merwin caught mostly Kokanee and the occasional Rainbow Trout. Approximately 93,000 hatchery Kokanee were released in Merwin, as well as 5,000 Rainbow Trout released for a children's fishing derby (Table 16; Figures 22, 24, 25, 26).

Age and growth

Northern Pikeminnow in Yale Lake showed a strong linear relationship between fork length and scale radius:

$$FL = 90.15 * S_r + 13.509$$

where FL is fork length and S_r is scale radius ($n=39$, $R^2 =0.96$).

Hatchery Rainbow Trout in Swift Reservoir and Kokanee in Yale and Merwin Reservoirs had weaker relationships between fork length and scale radius. Additional scale samples will be analyzed in 2014 to increase the precision of these relationships. Fork length to weight relationships were generally strong for all populations modeled, and sample sizes will be increased in 2014.

Diet Composition

Swift Reservoir.—Chinook, Coho, and Rainbow Trout fed predominantly on zooplankton and insects, while Bull Trout, Cutthroat Trout, and large hybrid trout fed largely on fish prey. Daphnia were the most common zooplankton consumed, followed by Leptodora.

The predominant aquatic insects consumed were diptera pupae. Some plant material was consumed by chinook and hatchery Rainbow Trout as well. Two Bull Trout diets were analyzed from summer in Swift Reservoir, of which one contained entirely Sculpin and the other contained an unidentified trout species. One large hybrid trout (325 mm) diet from summer contained entirely Sculpin. Three large Cutthroat Trout (300-399 mm) diets from fall contained mostly unidentifiable fish (Table 17).

Yale Lake.—Kokanee diets contained mostly zooplankton, Northern Pikeminnow diets changed ontogenetically, and Bull Trout, Cutthroat Trout, and Rainbow Trout all contained at least some fish in their diet. Zooplankton was the predominant diet item for all size classes and in all seasons that Kokanee were sampled. The most often consumed zooplankton was daphnia, although copepods and holopedium were also commonly eaten. Dipteran larvae and pupae were another common prey item found in Kokanee stomachs. Small Northern Pikeminnow (100-199 mm) consumed mostly zooplankton in summer and a combination of zooplankton and insects during fall. Larger size classes of Northern Pikeminnow incorporated less zooplankton and more unidentified fish, crayfish, and insects into their diet. Large Northern Pikeminnow (300-399 mm) diets also contained salmonid eggs in November. Small Bull Trout (300-499 mm) were observed feeding on Sculpin and unidentified salmonids in fall. Larger Bull Trout (600-699) were observed feeding on salmonid eggs and unidentified fish. Cutthroat Trout diets contained mostly salmonid eggs in fall, and Rainbow Trout diets contained Sculpin, plant material, and insects in summer and fall (Table 18).

Lake Merwin.—The most commonly found prey items in Lake Merwin were daphnia, copepods, immature aquatic insects, terrestrial insects, fish, and crayfish. Kokanee diets contained predominantly daphnia with some copepods. The smaller size class of Kokanee (<300 mm) consumed terrestrial insects and immature aquatic insects in addition to zooplankton. Rainbow Trout stomach contents contained terrestrial insects, unidentified fish, and plant material (see above).

Zooplankton

Swift Reservoir.—The most abundant zooplankters in Swift reservoir were copepods in June, and daphnia in August and November. In June, the total zooplankton biomass was significantly greater up near the surface than that of deeper strata. In August, total biomass increased by an order of magnitude compared to spring. Biomass was similar in the epilimnion and the metalimnion, although it was slightly greater in the metalimnion. Zooplankton densities were lowest in the hypolimnion, and corresponding depths during isothermal conditions, in all seasons. In November the highest zooplankton biomass was in the upper 17 meters (Table 19).

Yale Lake.—Standing stock zooplankton biomass in Yale Lake was greatest in summer (August) with Leptadora comprising the majority of the biomass. The zooplankters with the greatest biomass in spring were copepods, and in fall were daphnia. Holopedium were the most abundant zooplankton in spring (June) and were highly abundant in summer as well, but were not included in the biomass estimates because they are not a preferred prey item for most fishes. Total zooplankton biomass was greatest in shallow depths in each season, however biomass was similar between epilimnetic and metalimnetic depths in spring and summer (Table 20).

Lake Merwin.—Zooplankton standing stock biomass was greatest in summer in Lake Merwin. Daphnia composed the majority of zooplankton biomass in each season. Biomass was greatest in the epilimnion and equivalent depths in all three seasons sampled (Table 21).

Stable isotope analyses

Swift Reservoir.—The top level consumers, Bull Trout, and Cutthroat Trout had positive trends in $\delta^{15}N$ with fork length (FL). Mid-level consumers were distributed over a range of δ13C values. Bull Trout were represented by only three samples, but exhibited a positive relationship between both $\delta^{15}N$ and FL, and $\delta^{13}C$ and FL. Cutthroat Trout also exhibited positive relationships between both $\delta^{15}N$ and FL, and $\delta^{13}C$ and FL but with high variability. Chinook were represented by two age-0 samples, of which one was released from the hatchery in October, and eight age-1 samples which had been released from the hatchery in April. The age-0 Chinook sampled in November had $\delta^{15}N$ and $\delta^{13}C$ values similar to Chinook sampled from the hatchery. The age-1 Chinook which had been sampled in August had slightly greater $\delta^{13}C$ values than the presumed wild age-0 chinook, and similar $\delta^{15}N$ values. Coho $\delta^{15}N$ values increased slightly with FL, and had no clear relationship between length and $\delta^{13}C$. There were weak positive relationships between $\delta^{15}N$ and FL, and $\delta^{13}C$ and FL in Rainbow Trout. Rainbow Trout samples consisted of mostly hatchery fish greater than 250 mm, which may have still had some of the isotopic values of their hatchery feed. The hatchery Rainbow Trout sampled in spring 2009 were highly enriched in both of the heavy isotopes which was also seen in fish sampled directly from the hatchery. Large Bull Trout (>300mm), a large hybrid trout (325 mm), and Cutthroat Trout (>250 mm) had the highest $\delta^{15}N$, and Largescale Suckers had the lowest $\delta^{15}N$ values of all the species and size classes sampled in Swift Reservoir. Mountain whitefish, a small Largescale Sucker (52 mm), and a small hybrid trout (136 mm) had the greatest $\delta^{13}C$ of all species and size classes, and stickleback, large Sculpin (>50 mm), and the presumed wild age-0 Chinook had the lowest $\delta^{13}C$ values (Figures 27-32).

Yale Lake.—The top level consumers in Yale Lake appeared to be Bull Trout, Cutthroat Trout, and large Northern Pikeminnow (300-399 mm), and there were a number of mid-level consumers with a range of $\delta^{13}C$ values which indicate that they are feeding on multiple different energy sources. Bull Trout $\delta^{15}N$ and $\delta^{13}C$ both increased with FL, although $\delta^{13}C$ values were more variable. Cutthroat Trout $\delta^{15}N$ and $\delta^{13}C$ decreased slightly with FL although the sample size was very small (n=4). Northern Pikeminnow exhibited a very strong positive relationship between $\delta^{15}N$ and FL, and a weak positive relationship between $\delta^{13}C$ and FL. All Kokanee samples analyzed were either age-0 or age-2. The age-2 Kokanee had slightly higher $\delta^{15}N$ and $\delta^{13}C$ than the age-0, although the sample size of age-2 Kokanee was only 2 fish. The pelagic energy pathway appeared to be depleted in $\delta^{13}C$ relative to the benthic energy pathway in Yale Lake. Kokanee, pelagic juvenile Sculpin, and stickleback were relatively depleted in $\delta^{13}C$ indicating that they were consuming mostly pelagic food. Small Largescale Suckers (<300mm) and large Northern Pikeminnow (300-399 mm) were more enriched in $\delta^{13}C$ indicating that they were consuming benthic food (Figures 33-37).

Lake Merwin.—The $\delta^{15}N$ and $\delta^{13}C$ values of Kokanee were both highly variable and decreased slightly with length on average. All of the Rainbow Trout greater than 300 mm that were analyzed had isotopic values more similar to that of hatchery fish than any fish living in Lake Merwin. Rainbow Trout that were less than 300 mm exhibited a weak positive relationship between $\delta^{15}N$ and length, and a weak negative relationship between $\delta^{13}C$ and length (Figures 38, 39).

There appears to have been a pelagic energy pathway characterized by lower $\delta^{13}C$ values and a benthic energy pathway characterized by greater $\delta^{13}C$ values in Lake Merwin. Benthic scraping snails were most enriched in the heavy carbon isotope, while zooplankton and filter feeding clams were most depleted in carbon. Sculpin, small Largescale Suckers, largemouth bass, large Northern Pikeminnow (>300 mm), and Tiger Muskie exhibited greater $\delta^{13}C$ values suggesting that they consume a significant amount of benthically derived carbon. Small Northern Pikeminnow (100-199 mm), large Largescale Suckers (>300 mm), juvenile Coho, Kokanee, and pelagic juvenile Sculpin generally had lower $\delta^{13}C$ values suggesting that they consumed a large proportion of pelagically derived carbon (Figure 40).

Population-level consumption demand of Northern Pikeminnow.—No salmonids were identified in diets of Northern Pikeminnow in Yale Lake, however a significant portion of the annual consumption of ages 3-9 Northern Pikeminnow consisted of unidentified fish. An age structured population of 1,000 Northern Pikeminnow in Yale Lake consumed 0.37 metric tonnes of unidentified fish annually according to bioenergetics simulations, which corresponds to 18,611 twenty gram fish. The proportion of these fish that was salmonids is unknown (Table 22).

Feeding and growth of salmonids.—Bioenergetics models of salmonid feeding and growth in each reservoir showed that salmonids were feeding at the greatest proportion of their maximum consumption rate (% Cmax) in Swift Reservoir, and at the lowest proportion of Cmax in Yale Lake. Salmonids in Swift reservoir fed at 64 to 112 % of Cmax. Age-0 spring Chinook fed at 77% of Cmax based on bioenergetics simulations and grew to 54.1 g or approximately 170 mm at the end of their first year. Yale kokanee fed at 38 to 55 % of Cmax depending on the age class. Kokanee in Lake Merwin fed at 44 to 55 % of Cmax. A cohort of 1,000 age-0 Chinook consumed 0.06 metric tonnes of zooplankton from April through November according bioenergetics simulations (Table 23).

Acknowledgements

We would like to thanks Frank Shrier and Jeremiah Doyle (PacifiCorp) for logistical assistance. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Table 1. Physical characteristics of Swift, Yale and Merwin Reservoirs.

	Swift	Yale	Merwin
Surface area (km^2)	16,187	15,378	16,187
Length (km)	23.3	16.9	23.3
Mean depth (m)			
Max depth (m)			
Mean Secchi depth transparency (m)	5.75	7.5	7
Water residence time			
Total phosphorus (mg/L)	<.02		<.02
Trophic status			
Months stratified	July-Aug.	July-Aug.	June-Sept.
Depth of thermocline (m)	8	7	8
Month of ice cover			
Range of surface temps. (°C)	22-4	22-5	23-?

Table 2. Relative abundance of fish species and predominant summer crustacean zooplankton found in each reservoir.

	Swift	Yale	Merwin
Northern Pikeminnow		High	High
Largescale Suckers	High	High	High
Kokanee		High	High
Rainbow Trout	Moderate	Rare	Moderate
Cutthroat Trout	Rare	Rare	Rare
Bull Trout	Rare	Rare	
Hybrid Trout	Rare	Unknown	Rare
Tiger Muskie			Moderate
Sculpin	Moderate	Unknown	Moderate
Threespine Stickleback	Rare	Rare	Unknown
Mountain Whitefish	Rare	Unknown	Unknown
Bluegill Sunfish			Rare
Largemouth Bass			Rare
Juvenile Coho Salmon	Rare		
Juvenile Chinook Salmon	Rare		
Predominant summer zooplankton	Daphnia	Leptodora	Daphnia

Table 3. Initial and final day, starting and ending weight, growth, consumption, % of maximum consumption, and spawning parameters from bioenergetics simulations for each lake, species and age class.

Species	Age	Location	% Cmax	Initial day	Final day	Initial fork length (mm)	Initial weight (g)	Final weight (g)	Growth (g)	Consum-ption (g)	Spawning loss	Start date/ spawn date
HRBT	1	Swift	64%	1	185	227.22	121.77	284.19	162.43	2448		1-Jun
S-CHK	0	Swift	77%	1	225	25.00	0.16	54.1	53.94	338.3		2-Apr
S-CHK	1	Swift	66%	1	46	151.20	40.92	55.86	14.94	104		2-Apr
COHO	1	Swift	112%	1	19	125.24	23.72	37.29	13.58	59		9-May
COHO	2	Swift	69%	19	336	151.28	37.29	215.58	178.28	1560		1-Jun
NPM	0	Yale	249%	1	365	13.51	0.02	15.26	15.24	379		1-Jun
NPM	1	Yale	142%	1	365	114.31	15.26	46.72	31.46	1146		1-Jun
NPM	2	Yale	127%	1	365	165.43	46.72	91.26	44.54	1937		1-Jun
NPM	3	Yale	92%	1	365	206.38	91.26	138.20	46.94	2093		1-Jun
NPM	4	Yale	91%	1	365	236.71	138.20	214.79	76.59	2822	4%	1-Jun
NPM	5	Yale	85%	1	365	273.83	214.79	281.47	66.68	3445	4%	1-Jun
NPM	6	Yale	87%	1	365	299.41	281.47	427.98	146.51	4593	4%	1-Jun
NPM	7	Yale	56%	1	365	343.87	427.98	458.65	30.67	3473	6%	1-Jun
NPM	8	Yale	57%	1	365	351.83	458.65	521.35	62.71	3795	6%	1-Jun
NPM	9	Yale	56%	1	365	367.04	521.35	585.39	64.03	4114	6%	1-Jun
KOK	0	Yale	55%	1	365	25.00	0.09	41.46	41.38	245		1-Apr
KOK	1	Yale	42%	1	365	159.67	41.46	147.92	106.45	903		1-Apr
KOK	2	Yale	38%	1	235	234.17	147.92	228.66	80.74	998		1-Apr
NPM	0	Merwin	246%	1	365	9.56	0.01	18.19	18.19	305		1-Jun
NPM	1	Merwin	131%	1	365	117.52	18.19	75.80	57.61	1228		1-Jun
NPM	2	Merwin	113%	1	365	186.25	75.80	142.42	66.62	2622		1-Jun
NPM	3	Merwin	106%	1	365	228.29	142.42	216.76	74.34	3604	4%	1-Jun
NPM	4	Merwin	101%	1	365	261.42	216.76	293.70	76.94	4527	4%	1-Jun
NPM	5	Merwin	79%	1	365	288.35	293.70	399.14	105.44	3796	4%	1-Jun
NPM	6	Merwin	57%	1	365	318.36	399.14	499.12	99.97	3929	6%	1-Jun

NPM	7	Merwin	55%	1	365	342.17	499.12	595.39	96.27	4461	6%	1-Jun
NPM	8	Merwin	55%	1	365	362.21	595.39	735.60	140.21	5184	6%	1-Jun
NPM	9	Merwin	57%	1	365	387.79	735.60	932.78	197.18	6383	6%	1-Jun
NPM	10	Merwin	54%	1	365	418.68	932.78	1003.46	70.67	6719	9%	1-Jun
NPM	11	Merwin	54%	1	365	428.66	1003.46	1091.09	87.63	7134	9%	1-Jun
NPM	12	Merwin	55%	1	365	440.40	1091.09	1268.17	177.08	7970	9%	1-Jun
NPM	13	Merwin	55%	1	365	462.30	1268.17	1544.26	276.09	9215	9%	1-Jun
H-KOK	1	Merwin	44%	1	365	144.50	36.63	142.42	105.79	983		1-May
H-KOK	2	Merwin	50%	1	365	225.90	142.42	378.51	236.09	2485		1-May
H-KOK	3	Merwin	55%	1	62	311.61	378.51	497.04	118.53	1127		1-May

Table 4. Thermal experience inputs for bioenergetics simulations based on thermal profiles and tailrace temperatures, and inferred vertical distribution from literature accounts of habitat use, direct observation, and diel hydroacoustic target distributions during summer stratification.

		Lake Merwin			Yale Lake				Swift Reservoir			
		NPM Age-0	Ages 1-13	H-KOK Ages 1-3	NPM Age-0	Age 1-9	KOK Age-0	KOK Ages 1-2	HRB Age-1	CHK Age-0	Age-1	COHO Ages 1-2
	Day	Temp	Temp	Temp	Temp	Temp	Temp	Temp	Temp	Temp	Temp	Temp
1-Jun	1	17	15.5	10.5	16	14	8	8.5	12	12	10	10
1-Jul	30	20	18.5	12.5	20	18.5	8	9	15	13	13	13
1-Aug	60	24	22	13	23	22	8	9.5	18	15	15	15
1-Sep	90	20	20	14.5	20	20	8	9.5	17	15	15	15
1-Oct	120	15	15	16	14.5	14.5	9	9	14	13	13	13
1-Nov	150	13	13	13.5	10	10	8.5	8.5	10	10	10	10
1-Dec	180	9	9	9	7.5	7.5	7	7	6.5	6.5	6.5	6.5
1-Jan	210	7	7	7	6	6	6	6	5	5	5	5
1-Feb	240	6	6	6	5	5	5	5	4	4	4	4
1-Mar	270	7	7	7	6	6	6	6	5	5	5	5
1-Apr	300	8	8	8	7	7	7	7	6	6	6	6
1-May	330	11	11	9	10	10	8	8	9	9	9	9
31-May	365	15.5	15.5	11	14	14	8	8.5	12	12	10	10

Table 5. Energy density values (J/g wet weight) of prey used for bioenergetics simulations.

Day	Zooplankton	Plant material	Terrestrial insects	Immature aquatic insect	Sculpin	Unid fish	Crayfish	Unid salmonid	Salmonid eggs	Other
1	2250	1435	5000	3400	5369	5200	4506	5200	8000	2000
365	2250	1435	5000	3400	5369	5200	4506	5200	8000	2000

Table 6. Length (km) of available habitat to anadromous salmon in Yale Lake and Lake Merwin as a result of natural and manmade barriers.

Reservoir	Stream	Length (km)
Lake Merwin	Brooks Creek	2.45
	Buncombe Hollow Creek	0.48
	Marble Creek	0.04
	Cape Horn Creek	0.5
	Indian George Creek	1.35
	Jim Creek	0.97
	Lower Speelyai	0.25
	Canyon Creek	0.00
Total		**6.04**
Yale lake	Ole Creek	1.35
	Rock Creek	0
	Dog Creek	0.26
	Cougar Creek	2.68
	Panamaker Creek	0.38
	Siouxon Creek	5.81
	North Siouxon Creek	0.62
	Rain Creek	0
	Speelyai Creek	5.55
	Swift Bypass Channel	4.89
	West Fork Speelyai Creek	0.89
	West Tributary Speelyai Creek	1.02
Total		**23.45**

Table 7. Mean and range of stream temperatures for July[1], August, September, and October 2013 in Clear Creek (Swift Reservoir) and each of the tributary study streams in Yale Lake and Lake Merwin. Note: the logger and data for Siouxon Creek were lost during the high flow event during September.

	July		August		September		October	
Stream	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Clear Creek	14.0	(10.7 - 17.8)	14.5	(12.6 - 17.9)	13.1	(7.6 - 17.2)	7.3	(6.1 - 8.9)
Brooks Creek	13.0	(10.6 - 15.5)	13.0	(11.4 - 15.1)	12.6	(10.1 - 15.3)	9.5	(7.7 - 11.2)
Indian George	14.3	(11.5 - 16.5)	15.2	(13.5 - 16.7)	13.8	(9.7 - 16.7)	9.0	(7.4 - 10.6)
Cougar Creek	6.8	(6.2 - 7.9)	6.8	(6.4 - 7.9)	6.8	(6.2 - 8.1)	6.8	(6.5 - 7.2)
Panamaker Creek	12.8	(10.5 - 14.9)	14.0	(12.2 - 16.5)		na	na	na
Speelyai Creek	15.3	(11.6 - 19.2)	16.2	(13.6 - 19.5)	13.7	(9 - 18.5)	8.7	(7.1 - 10.4)
Dog Creek	13.0	(10.5 - 14.9)	17.0	(12.9 - 23.3)	14.6	(9.1 - 20.5)	9.3	(8.2 - 10.7)
Jim Creek	13.8	(11.2 - 15.7)	14.6	(12.9 - 15.8)	13.4	(10 - 16)	9.1	(7.4 - 10.4)
Ole Creek	13.8	(11.6 - 15.8)	14.8	(13.2 - 16)	13.2	(8.9 - 15.6)	8.4	(7.5 - 9.3)
Buncombe Hollow	16.3	(14.2 - 18.7)	16.4	(14.2 - 18.4)	14.7	(11.3 - 17.6)	10.2	(8.3 - 11.6)

[1] July values include period from July 10 – July 31st.

Table 8. Monthly average streamflows (cfs) for July[1], August, September, and October 2013 in Clear Creek (Swift Reservoir) and each of the tributary study streams in Yale Lake and Lake Merwin. Note: the logger and data for Siouxon Creek were lost during the high flow event during September.

Stream	July	August	September	October
Clear Creek	43.6	31.3	57.9	141.4
Brooks Creek	2.6	1	8.1	16.4
Indian George	1.3	1	18	25.5
Cougar Creek	67.1	54.8	67	169.9
Panamaker Creek[2]	na	na	na	na
Speelyai Creek[3]	10.7	3.92	95.6	na
Dog Creek	1.4	0.2	0.8	1.9
Jim Creek	2.9	1.7	10.3	24.6
Ole Creek	2.4	1.6	7.7	12.4
Buncombe Hollow	1.2	0.8	2.2	7.2

[1] July values include period from July 10 – July 31st.

[2] Panamaker Creek values were not available as creek went dry during early September.

[3] Values taken from the USGS stream gage (142198000).

Table 9. Age structured population estimate of 160,000 northern pikeminnow greater than 200 mm in Lake Merwin. All individuals equal to or greater than estimated length of age-13 fish were grouped into the age-13 population abundance for this estimate.

Age	N
2	47,222
3	85,474
4	8,969
5	5,672
6	4,880
7	1,847
8	2,506
9	923
10	264
11	132
12	132
13	1,979

Table 10. Mean back-calculated fork length at age (mm) for hatchery Rainbow Trout (HRBT), Kokanee (KOK) and Northern Pikeminnow (NPM) found in the Lewis River Reservoirs. Length at age measurements were calculated using scale annuli measurements and the Fraser-Lee method of back-calculating fork length. Number of scale annuli analyzed (N) and standard deviation (SD) are reported.

		Mean back-calculated fork length at age (mm)														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Species	Site	Fork length (mm)														
HRBT	Merwin	189	477													
	n	11	5													
	SD	31	47													
HRBT	Swift	227														
	n	10														
	SD	14														
KOK	Merwin	145	226	312												
	n	16	14	4												
	SD	26	30	5												
KOK	Yale	160	234													
	n	20	18													
	SD	13	11													
NPM	Merwin	118	186	228	261	288	318	342	362	387	419	429	440	464	493	473
	n	58	47	39	38	35	33	30	24	22	17	11	8	4	2	1
	SD	24	38	41	44	46	53	59	61	67	72	64	59	46	70	na
NPM	Yale	114	165	206	237	274	299	344	352	367	381					
	n	33	27	22	15	7	6	3	1	1	1					
	SD	16	23	26	24	32	36	18	na	na	na					

Table 11. Diet proportions for northern pikeminnow and kokanee in Lake Merwin used as inputs for bioenergetics simulations of consumption demand. Values of zero were omitted.

Age-0 Northern pikeminnow (NPM) (10–118 mm)

	Day	Zooplankton	Plant material	Terrestrial insects	Immature aquatic insect	Other
June	1	0.42		0.16	0.40	0.02
August	60	0.49	0.50		0.01	
May	365	0.84	0.02	0.13	0.01	

Age-1 NPM (118–186 mm)

	Day	Zooplankton	Plant material	Terrestrial insects	Immature aquatic insect	Unid fish
June	1	0.84	0.02	0.13	0.01	
August	60	0.49	0.50		0.01	
November	165	0.20	0.17	0.40		0.23
May	365	0.84	0.02	0.13	0.01	

Age-2 NPM (186–228 mm)

	Day	Zooplankton	Plant material	Terrestrial insects	Immature aquatic insect	Sculpin	Unid fish	Crayfish	Other
June	1	0.84	0.02	0.13	0.01				
August	60	1.00							
November	165	0.43	0.20			0.09	0.14		0.14
May	365	0.79	0.03	0.01	0.01	0.04	0.06	0.06	

Ages 3 &4 NPM (228–261 mm & 261–288 mm)

	Day	Zooplankton	Plant material	Terrestrial insects	Immature aquatic insect	Sculpin	Unid fish	Crayfish	Other
June	1	0.79	0.03	0.01	0.01	0.04	0.06	0.06	

August	60	1.00							
November	165	0.43	0.20			0.09	0.14		0.14
May	365	0.79	0.03	0.01	0.01	0.04	0.06	0.06	

Age-5 NPM (288–318 mm)

	Day	Zooplankton	Plant material	Terrestrial insects	Immature aquatic insect	Sculpin	Unid fish	Crayfish	Unid salmonid
June	1	0.79	0.03	0.01	0.01	0.04	0.06	0.06	
August	60	1.00							
November	165	0.13	0.03	0.13		0.23		0.26	0.22
May	365							1.00	

Ages 6-8 NPM (318-342 mm, 342-362 mm, & 362–388 mm)

	Day	Zooplankton	Plant material	Terrestrial insects	Immature aquatic insect	Sculpin	Crayfish	Unid salmonid
June	1						1.00	
August	60				0.50		0.50	
November	165	0.13	0.03	0.13		0.23	0.26	0.22
May	365						1.00	

Age-9 NPM (388-419 mm)

	Day	Zooplankton	Plant material	Immature aquatic insect	Sculpin	Unid fish	Crayfish
June	1						1.00
August	60			0.50			0.50
November	165	0.09	0.15		0.30	0.28	0.18
May	365		0.01	0.24			0.75

Ages 10-13 NPM (419-429 mm, 429-440 mm, 440-462 mm, >462 mm)

	Day	Zooplankton	Plant material	Immature aquatic insect	Sculpin	Unid fish	Crayfish
June	1		0.01	0.24			0.75
August	60			0.5			0.50
November	165	0.09	0.15		0.30	0.28	0.18
May	365		0.01	0.24			0.75

Ages 1-3 Hatchery kokanee (145-226 mm, 226-312 mm, >312 mm)

	Day	Zooplankton	Plant material	Terrestrial insects	Immature aquatic insects
June	1	0.77		0.2	0.03
August	60	0.50		0.10	0.40
November	165	0.80	0.04	0.15	0.01
May	365	0.89		0.10	0.01

Table 12. Diet proportion (average percent contribution by wet weight) by reservoir, species, size class, and season. Note: zeroes have been left blank, Rainbow$_h$ = hatchery Rainbow Trout, whitefish = Mountain Whitefish, T. muskie = Tiger Muskie, and N. Pikem. = Northern Pikeminnow.

Reservoir	Spp.	Size class	Season	n	Sculp.	N. Pikem	Un. salm	Salm. eggs	Un. fish	Zoop.	Plant	Terr. invert	Imm. aquat. invert	Cray.	Muss.	Other
Swift	Bull Trout	200-399	summer	2	0.5		0.5									
Swift	Chinook	100-199	summer	3	0.33					0.67						
Swift	Chinook	100-199	fall	1						0.64		0.1	0.26			
Swift	Chinook	200-299	summer	5						0.8	0.2					
Swift	Chinook	200-299	fall	5						0.78			0.22			
Swift	Coho	100-199	summer	5						0.4		0.6				
Swift	Coho	100-199	fall	3					0.07	0.61		0.21	0.11			
Swift	Coho	200-299	fall	1						1						
Swift	Sculpin	50-150	summer	2							0.83	0.17				
Swift	Cutthroat	300-399	fall	3					0.71	0.08		0.21				
Swift	Rainbow$_H$	200-299	summer	1						1						
Swift	Rainbow$_H$	200-299	fall	3						0.999		0.0005	0.0005			
Swift	Rainbow$_H$	300-399	fall	10						0.6	0.29	0.05	0.06			
Swift	Rainbow	100-199	summer	1						1						
Swift	Rainbow	200-299	summer	4						1						
Swift	Rainbow	200-299	fall	1								1				
Swift	hybrid trt.	100-199	summer	1						0		1				
Swift	hybrid trt.	300-399	summer	1	1											
Swift	whitefish	200-399	fall	2							0.23	0.04	0.66		0.07	
Yale	Bull Trout	300-499	fall	2	0.44		0.5		0.06		0.01					
Yale	Bull Trout	600-699	fall	2				0.49	0.51							

Yale	Sculpin	0-50	summer	1						0.5			0.5			
Yale	Cutthroat	300-399	fall	2				0.98			0.02					
Yale	Kokanee	0-100	spring	10						0.74		0.08	0.18			
Yale	Kokanee	0-100	summer	1						0.67			0.33			
Yale	Kokanee	100-199	fall	1						1						
Yale	Kokanee	200-299	summer	13						0.87		0.03	0.03			0.08
Yale	Kokanee	200-299	fall	4						0.99		0.01				
Yale	N. Pikem.	100-199	summer	5						0.99	0		0.01			
Yale	N. Pikem.	100-199	fall	8						0.37	0.1	0.12	0.25	0.04		0.11
Yale	N. Pikem.	200-299	summer	8					0.13	0.57	0.02	0.13	0.03	0.13		
Yale	N. Pikem.	200-299	fall	4					0.28	0.24	0.01	0.06	0.41			
Yale	N. Pikem.	300-399	fall	4				0.21	0.46		0.08			0.25		
Yale	Rainbow	200-300	summer	2	0.25								0.75			
Yale	Rainbow	200-300	fall	1							0.41	0.42	0.17			
Yale	Stickleback	0-49	summer	1						1						
Merwin	blugill	100-200	spring	2					0.06	0.52	0.24	0.18				
Merwin	bluegill	100-200	fall	1							1					
Merwin	Coho	200-250	summer	1						1						
Merwin	Sculpin	15-30	summer	9						0.72			0.28			
Merwin	Sculpin	50-100	spring	3						0.03	0.22		0.42		0.29	0.04
Merwin	Sculpin	50-100	summer	1							0.5		0.5			
Merwin	Sculpin	100-150	spring	1							0.5	0.01	0.5			
Merwin	Rainbow$_H$	300-399	fall	4							0.23	0.61	0.11			0.06
Merwin	Rainbow$_H$	500-600	fall	3							0.33	0.67				
Merwin	Kokanee	<300	spring	4						0.77		0.2	0.03			
Merwin	Kokanee	<300	summer	2						0.5		0.1	0.4			
Merwin	Kokanee	<300	fall	7					0	0.65	0.14	0.2	0			
Merwin	Kokanee	>300	spring	3						1						
Merwin	Kokanee	>300	summer	1						1						
Merwin	Kokanee	>300	fall	3						1						
Merwin	N. Pikem.	30-50	spring	5						0.42		0.16	0.4			0.02

Merwin	N. Pikem.	100-199	spring	11						0.85	0.02	0.13	0.01			
Merwin	N. Pikem.	100-199	summer	2						0.5	0.5		0			
Merwin	N. Pikem.	100-199	fall	5					0.23	0.2	0.17	0.4				
Merwin	N. Pikem.	200-299	spring	18	0.04				0.06	0.8	0.03	0.01	0.01	0.06		
Merwin	N. Pikem.	200-299	summer	1						1						
Merwin	N. Pikem.	200-299	fall	7	0.09				0.14	0.43	0.2					0.14
Merwin	N. Pikem.	300-399	spring	3							0.004			0.996		
Merwin	N. Pikem.	300-399	summer	2									0.5	0.5		
Merwin	N. Pikem.	300-399	fall	8	0.24		0.22			0.13	0.03	0.13		0.26		
Merwin	N. Pikem.	400-499	fall	11	0.03	0.06	0.09	0.09	0.31	0.09	0.15			0.18		
Merwin	N. Pikem.	500-599	spring	2									0.5	0.5		
Merwin	N. Pikem.	500-599	fall	2		0.5								0.5		
Merwin	Rainbow	100-199	summer	1						0		1				
Merwin	Rainbow	200-299	summer	1					0.66			0.34				
Merwin	Rainbow	200-299	fall	1					0.12			0.88				
Merwin	T. Muskie	>600	spring	3		1										

Table 13. Annual estimates of prey biomass (metric tonnes) consumed by 1,000 individuals of each age class 1-2 of hatchery Kokanee (H-KOK), each age class 0-2 of Northern Pikeminnow (NPM), and an age structured population of 160,000 ages 2-13 NPM of predatory size in Lake Merwin. Zeroes are omitted for ease of reading.

Species	Age	Plant material	Immature aquatic insects	Terrestrial insects	Zoop-lankton	Unid fish
H-KOK	1	0.02	0.08	0.12	0.76	
	2	0.04	0.23	0.32	1.90	
	3		0.30	0.15	0.67	
NPM	0	0.08	0.01	0.02	0.20	
	1	0.30	0.01	0.21	0.61	0.10

Species	Age	Plant material	Immature aquatic insects	Terrestrial insects	Zoop-lankton	Crayfish	Sculpin	Unid fish	Unid salmonid	Adjusted spawning loss
NPM	2	8.42	0.33	2.21	96.08	1.03	4.10	6.34		0%
	3	20.80	0.83	0.83	238.53	4.96	11.55	17.78		4%
	4	2.69	0.11	0.11	31.56	0.66	1.50	2.31		4%
	5	0.29	0.03	0.81	12.48	4.91	1.50	0.20	1.31	4%
	6	0.19	4.22	0.71	0.71	10.87	1.26		1.21	6%
	7	0.08	1.82	0.30	0.30	4.68	0.54		0.51	6%
	8	0.13	2.86	0.48	0.48	7.39	0.85		0.81	6%
	9	0.26	1.49	0.15		3.01	0.51	0.47		6%
	10	0.08	0.51	0.04		0.85	0.15	0.14		9%
	11	0.04	0.27	0.02		0.45	0.08	0.07		9%
	12	0.05	0.30	0.03		0.50	0.09	0.08		9%
	13	0.82	5.22	0.46		8.74	1.55	1.44		9%

Table 14. Seasonal catch per unit effort (mean # fish/net set) in Swift Reservoir in 2013.

Season	Net sets (n)	Juv. Chinook	Juv. Coho	Large-scale Suckers	Bull Trout	Cutthroat Trout	Rainbow Trout	Hybrid Trout	Mountain Whitefish
Summer	43	0.256	0.000	1.093	0.070	0.047	0.070	0.023	0.000
Fall	32	0.031	0.094	0.375	0.031	0.063	0.250	0.000	0.063

Table 15. Seasonal catch per unit effort (mean # fish/net set) in Yale Lake in 2013.

Season	Net sets (n)	Kokanee	Northern Pikeminnow	Large-scale Suckers	Bull Trout	Cutthroat Trout	Rainbow Trout
Summer	22	0.045	1.045	1.227	0.091	0.000	0.091
Fall	59	0.119	0.254	0.102	0.068	0.034	0.017

Table 16. Seasonal catch per unit effort (mean # fish/net set) in Lake Merwin in 2013.

Season	Net sets (n)	Kokanee	Tiger Muskie	Northern Pikeminnow	Large-scale Suckers	Bluegill Sunfish	Rainbow Trout
Spring	10	0.10	0.20	12.50	2.10	0.00	0.00
Summer	28	0.18	0.00	16.75	3.79	0.00	0.11
Fall	15	0.33	0.73	15.40	0.07	0.07	0.33

Table 17. Diet proportions for hatchery Rainbow Trout, juvenile Chinook, and juvenile Coho in Swift Reservoir used as inputs for bioenergetics simulations of consumption demand. Values of zero were omitted.

Swift

Age-1 Hatchery rainbow trout (>227 mm)

	Day	Zooplankton	Terrestrial insects	Immature aquatic insects	Other
June	1	0.75	0.16	0.04	0.05
August	60	1.00			
November	165	0.75	0.16	0.04	0.05
May	365	0.75	0.16	0.04	0.05

Age-0 Chinook (25-170 mm)

	Day	Zooplankton	Terrestrial insects	Immature aquatic insects
April	1	0.77	0.20	0.03
August	60	0.75	0.20	0.05
November	165	0.71	0.05	0.24

Age-1 Chinook (151 mm)

	Day	Zooplankton	Plant material	Terrestrial insects	Immature aquatic insects	Sculpin
April	1	0.77		0.20	0.03	
May	46	0.75	0.10			0.15

Ages 1 & 2 Coho (125 mm, 151 mm)

	Day	Zooplankton	Terrestrial insects	Immature aquatic insects	Unid fish
June	1	0.77	0.20	0.03	
August	60	0.40	0.60		
November	165	0.80	0.10	0.06	0.04
May	356	0.77	0.20	0.03	

Table 18. Diet proportions for Northern Pikeminnow and Kokanee in Yale Lake used as inputs for bioenergetics simulations of consumption demand. Values of zero were omitted.

Yale Lake
Age-0 Northern pikeminnow (NPM) (14-114 mm)

	Day	Zooplankton	Plant material	Terrestrial insects	Immature aquatic insect	Other
June	1	0.42		0.16	0.40	0.02
August	60	0.49	0.50		0.01	
November	365	0.84	0.02	0.13	0.01	
May						

Ages 1-2 NPM (114-165 mm & 165-206 mm)

	Day	Zooplankton	Plant material	Terrestrial insects	Immature aquatic insect	Crayfish	Other
June	1	0.84	0.02	0.13	0.01		
August	60	0.99		0.01			
November	165	0.38	0.10	0.12	0.25	0.04	0.11
May	365	0.84	0.02	0.13	0.01		

Ages 3-6 NPM (206-237 mm, 237-274 mm, 274-299 mm & 299-344 mm)

	Day	Zooplankton	Plant material	Terrestrial insects	Immature aquatic insect	Sculpin	Unid fish	Crayfish	Other
June	1	0.79	0.03	0.01	0.01	0.04	0.06	0.06	
August	60	0.56	0.02	0.13	0.03		0.13	0.13	
November	165	0.24	0.05	0.10	0.30		0.22	0.04	.05
May	365	0.79	0.03	0.01	0.01	0.04	0.06	0.06	

Ages 7-9 NPM (344-352 mm, 352–367 mm, >367 mm)

	Day	Plant material	Immature aquatic insect	Unid fish	Crayfish	Salmonid eggs
June	1				1.00	
August	60		0.50		0.50	
November	165	0.08		0.46	0.25	0.21
May	365				1.00	

Age-0 Kokanee (25-160 mm)

	Day	Zooplankton	Terrestrial insects	Immature aquatic insects
June	1	0.74	0.08	0.18
August	60	0.67		0.33
November	165	1.00		
May	360	0.75	0.05	0.20

Ages 1 & 2 Kokanee (160-234 mm, >234 mm)

	Day	Zooplankton	Terrestrial insects	Immature aquatic insects	Other
June	1	0.74	0.08	0.18	
August	60	0.87	0.03	0.03	0.08
November	165	0.99		0.01	
May	360	0.75	0.05	0.20	

Table 19. Estimates of Swift Reservoir standing stock biomass of zooplankton (metric tonnes) in 2013.

Season	Depth (m)	Daphnia	Bosmina	Copepods	Leptodora	Total
Spring	0-9m	4.17	0.00	5.32	0.00	9.49
(June)	9-25m	0.19	0.00	1.18	0.00	1.37
Summer	0-7m	49.18	0.00	0.50	31.11	80.79
(August)	7-19m	101.90	0.00	0.73	0.00	102.63
	19-30m	5.19	0.00	0.12	0.00	5.32
Fall	0-17m	7.51	0.00	2.09	0.00	9.60
(November)	17-34m	1.81	0.01	0.33	0.00	2.15
	34-42m	0.27	0.00	0.06	0.00	0.33

Table 20. Estimates of standing stock zooplankton biomass (metric tonnes) in Yale Lake in 2013.

Season	Depth (m)	Daphnia	Bosmina	Copepods	Leptodora	Total
Spring	0-8m	0.966	0.886	1.351	0.000	3.203
(June)	8-22m	0.526	0.426	2.148	0.000	3.099
Summer	0-6m	3.517	0.000	0.800	30.552	34.868
(August)	6-15m	2.016	0.000	1.684	21.877	25.577
	15-29m	0.241	0.026	0.928	25.087	26.281
Fall	0-17m	3.443	0.215	1.490	0.000	5.148
(November)	17-34m	2.335	0.000	0.458	0.000	2.793
	34-38m	0.041	0.002	0.003	0.000	0.045

Table 21. Estimates of standing stock biomass of zooplankton in Lake Merwin (metric tonnes) in 2013.

Season	Depth (m)	Daphnia	Bosmina	Copepods	Leptodora	Total
Spring	0-10m	35.39	0.78	7.41	0.00	43.57
(June)	10-30 m	3.08	6.08	1.81	0.00	10.97
	30-40m	0.57	0.12	0.61	0.00	1.31
Summer	0-9m	34.79	0.00	13.95	0.08	48.82
(August)	9-22m	15.09	0.00	8.60	0.00	23.69
	22-37m	4.20	0.00	5.33	0.46	9.99
Fall	0-17	1.45	0.15	0.77	0.00	2.38
(November)	17-34	0.57	0.23	0.32	0.00	1.12

Table 22. Annual estimates of prey biomass (metric tonnes) consumed by 1,000 individuals of each age class 0-2 of Northern Pikeminnow (NPM), an age structured population of 1,000 total NPM ages 3-9, and 1,000 fish of each age class 0-2 of Kokanee (KOK) in Yale Lake modeled with bioenergetics. Zeroes are omitted for ease of reading.

Species	Age	Plant material	Immature aquatic insect	Zoop-lankton	Crayfish	Other	Terrestrial insects	Sculpin	Unid fish	Salmonid eggs
NPM	0	0.12	0.01	0.23			0.02			
	1	0.04	0.09	0.89	0.01	0.04	0.08			
	2	0.06	0.13	1.53	0.02	0.06	0.13			
	3	0.02	0.07	0.36	0.06	0.01	0.06	0.01	0.09	
	4	0.04	0.11	0.63	0.11	0.02	0.11	0.01	0.16	
	5		0.01	0.06	0.01		0.01		0.02	
	6		0.01	0.08	0.01		0.01		0.02	
	7		0.03		0.06				0.01	0.01
	8		0.06		0.14				0.03	0.01
	9	0.01	0.10		0.23				0.04	0.02
KOK	0		0.03	0.21			0.01			
	1		0.12	0.76			0.02			
	2		0.14	0.85			0.01			

Table 23. Annual estimates of prey biomass (metric tonnes) consumed by 1,000 individuals of three planktivores (HRBT = hatchery Rainbow Trout; CHK = Chinook) in Swift Reservoir. Individual consumption is scaled up to 1,000 individuals of each age class. Zeroes are omitted for ease of reading.

Species	Age	Immature aquatic insect	Plant material	Terrestrial insects	Zoop-lankton	Sculpin	Unid fish
HRBT	1	0.06	0.21	0.05	2.13		
CHK	0	0.03		0.02	0.06		
	1	0.00	0.01	0.01	0.08	0.01	
Coho	1			0.02	0.04		
	2	0.06		0.38	1.08		0.03

Figure 1. A general map of the study area for stream and reservoir investigations; the study area included portions of the North Fork Lewis River upstream of Merwin Dam.

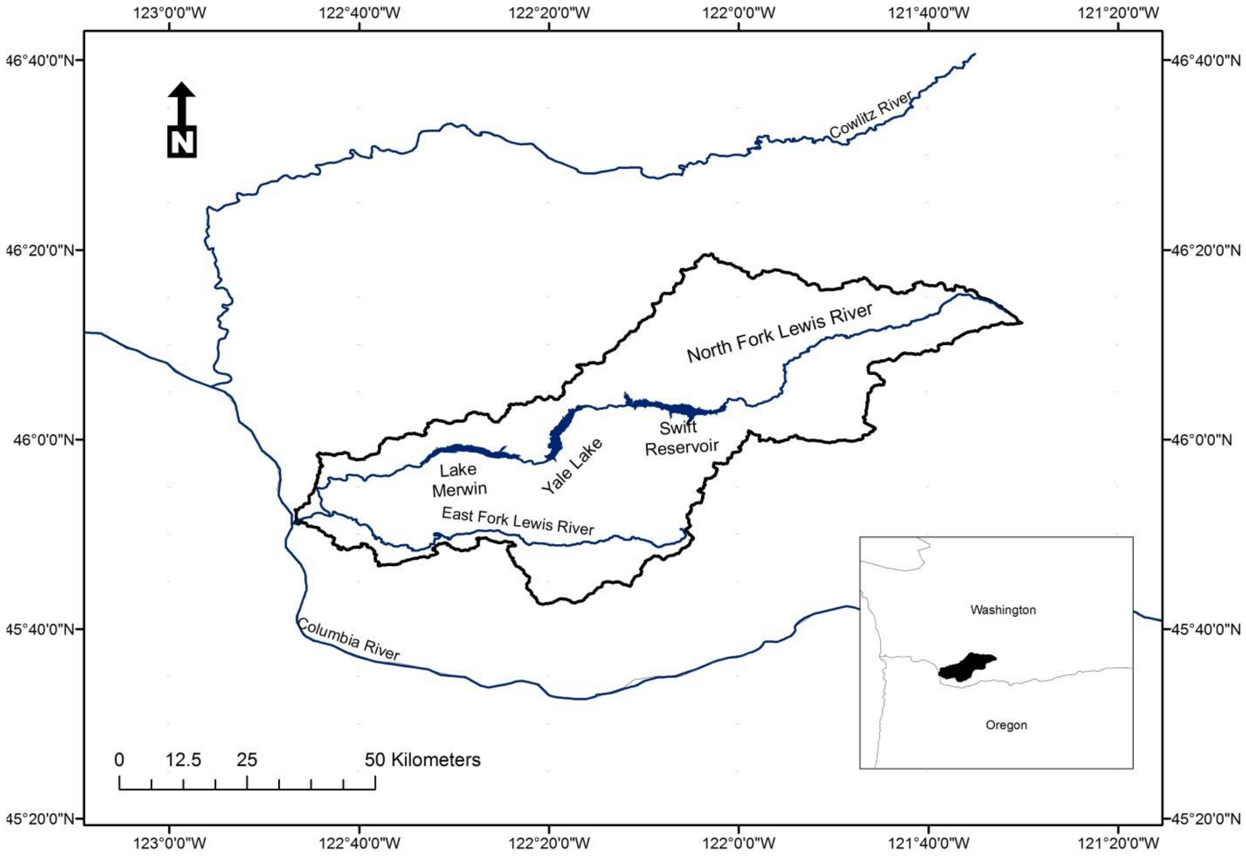
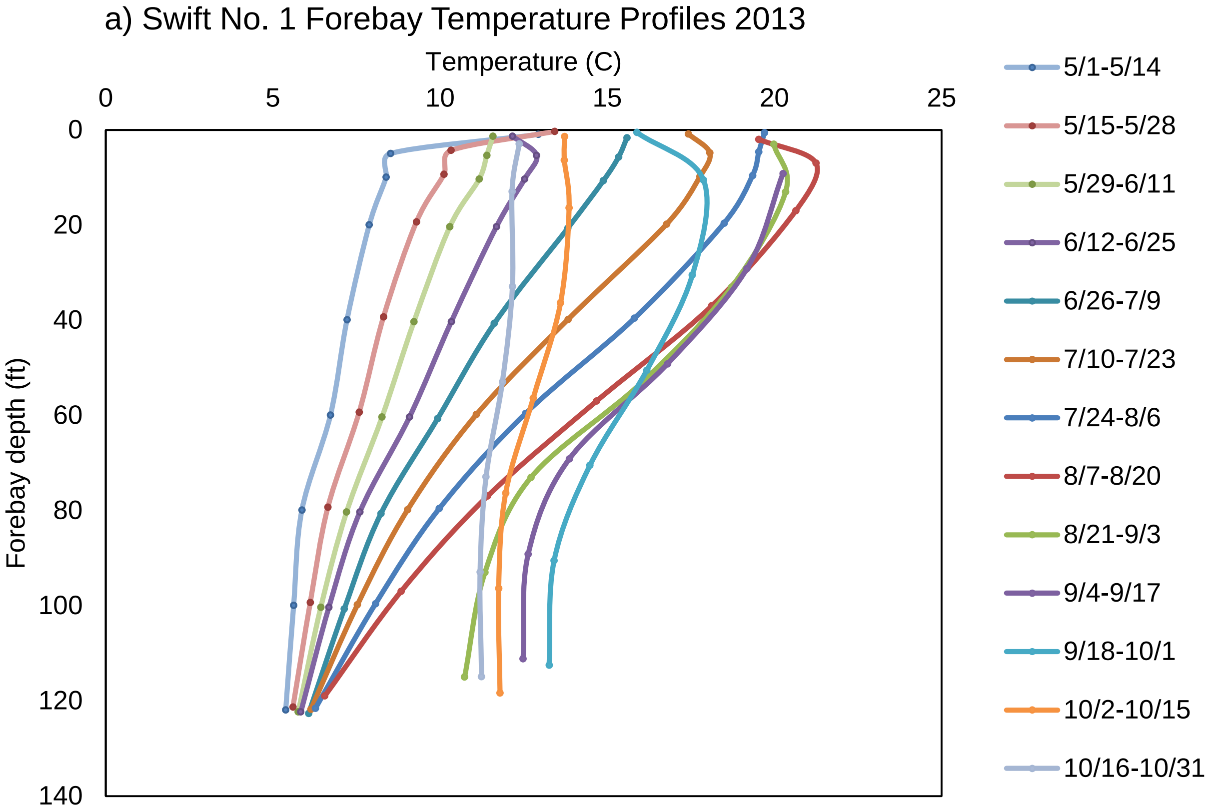
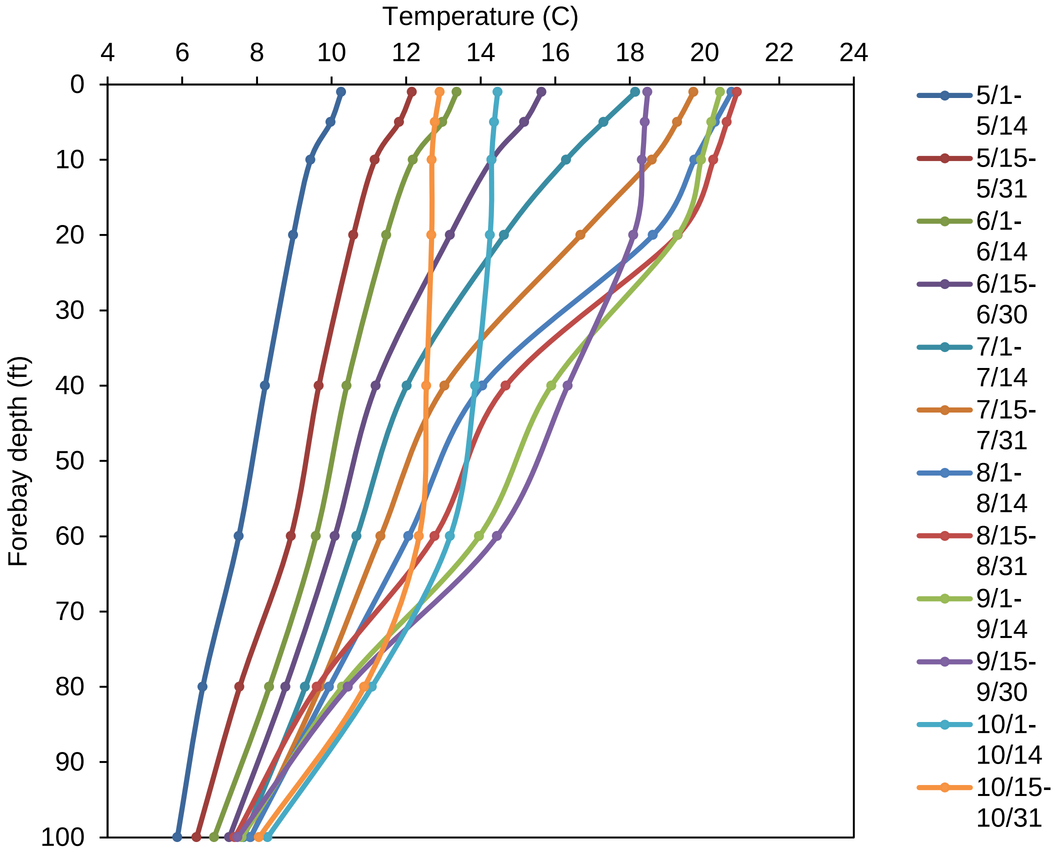
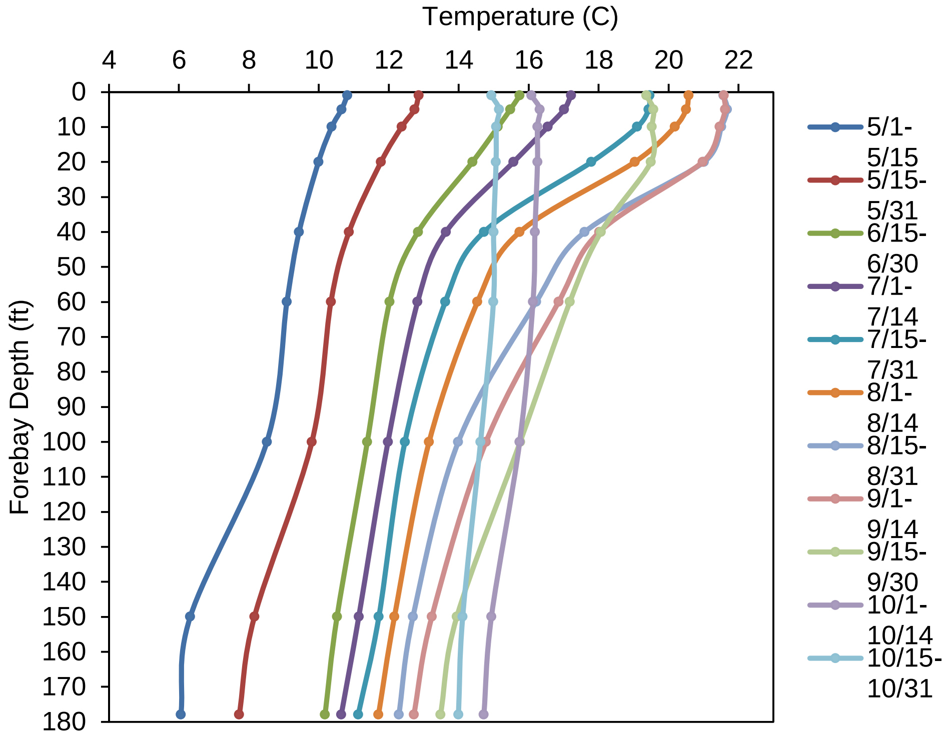


Figure 2. Temperature profiles from the forebays of Swift Reservoir (a), Yale Lake (b), and Lake Merwin (c).



b) Yale forebay temperature profiles - 2013





c) Merwin forebay temperature profiles - 2013

Figure 3. Daily temperature readings from the tailraces of Yale and Swift Dams in 2012; note, a malfunction in the temperature logger prohibited available data from the Merwin Dam tailrace.

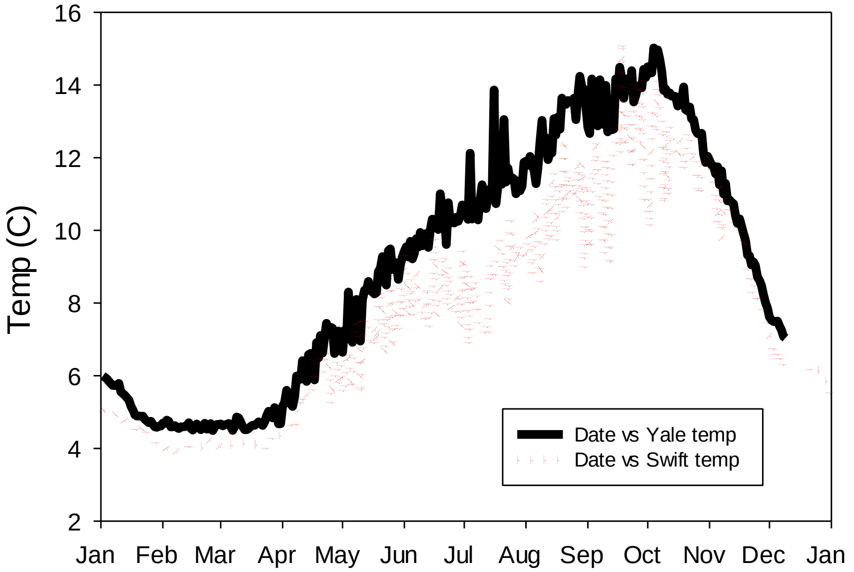


Figure 4. A map indicating the distribution of sampling sites in Pine Creek and P8 to identify potential distributional overlap between Bull Trout and juvenile anadromous salmon.

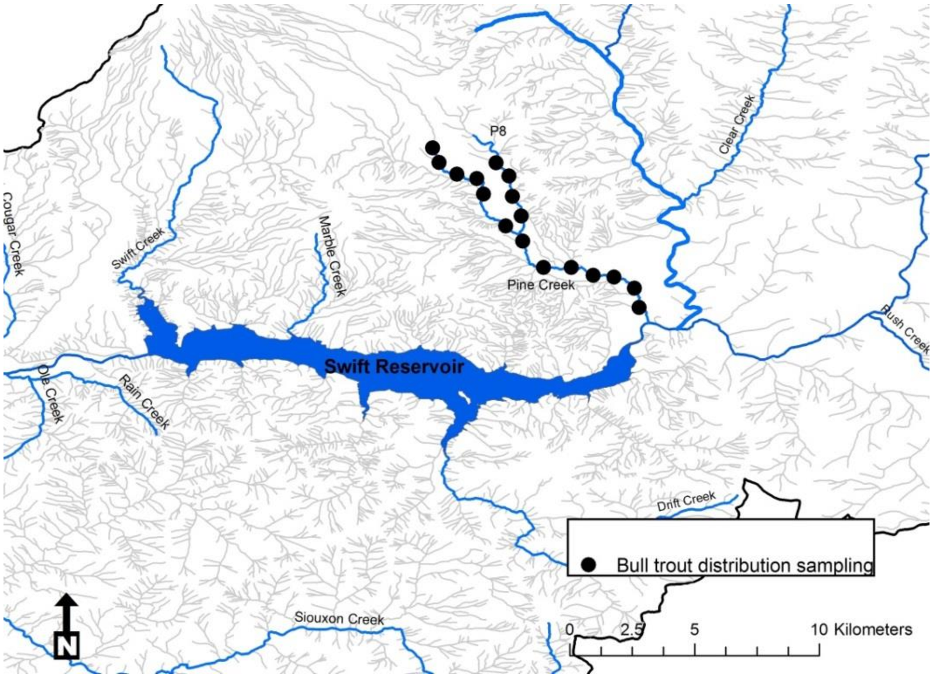


Figure 5. The locations where stable isotope and diet data were collected in 2013 to evaluate potential foodweb and community-level effects of anadromous reintroductions in the Upper Lewis River Basin.

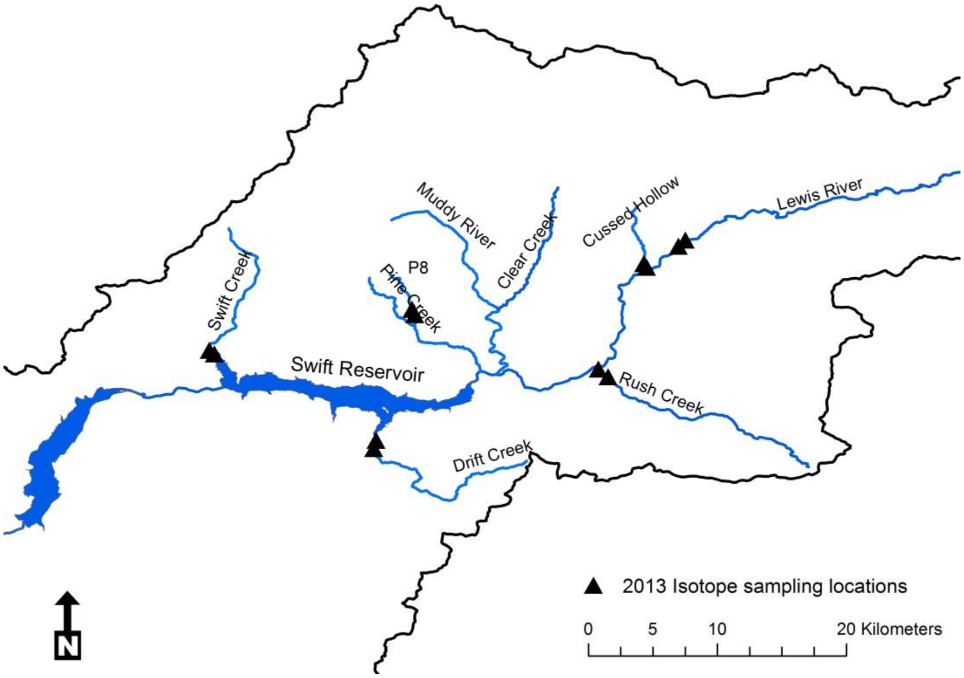


Figure 6. Stream habitat potentially available to anadromous salmon (blue) due to upstream barriers (red) in tributaries to Yale Lake and Lake Merwin.

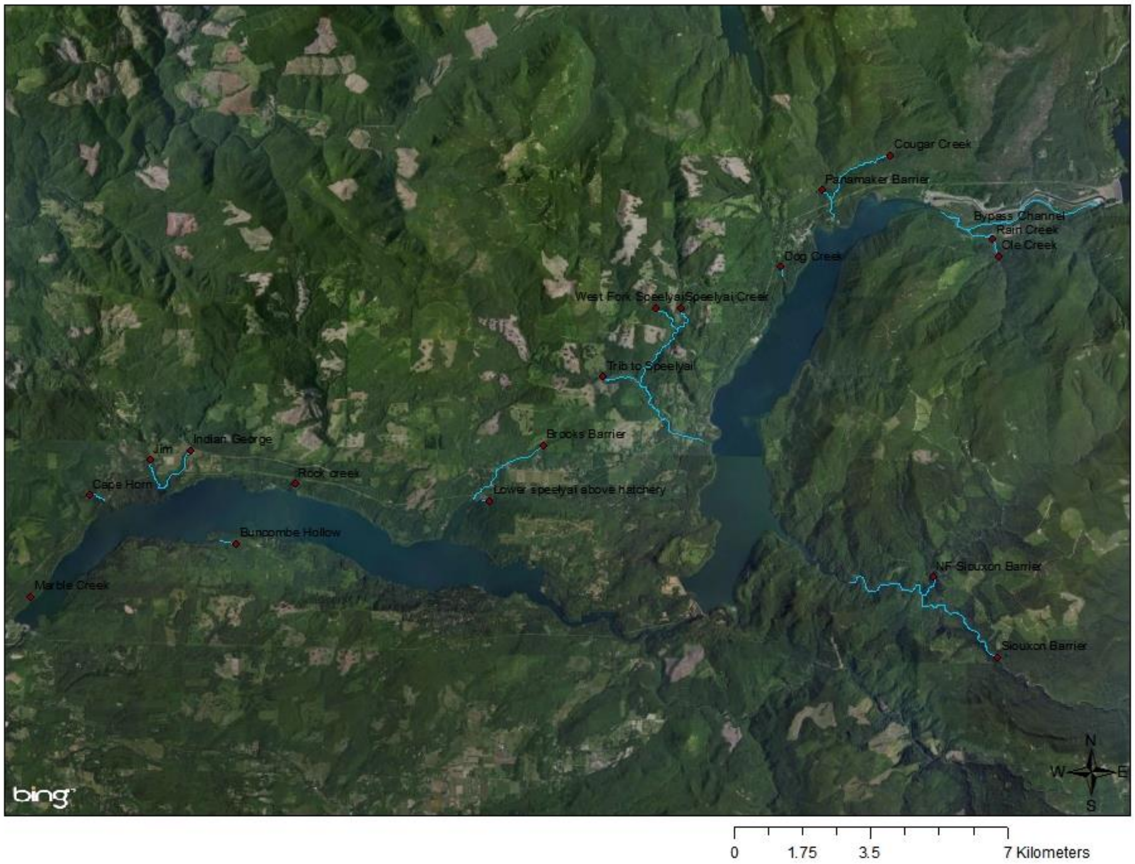


Figure 7. A length-frequency histogram of juvenile Coho captured during the 2013 field season in Clear Creek.

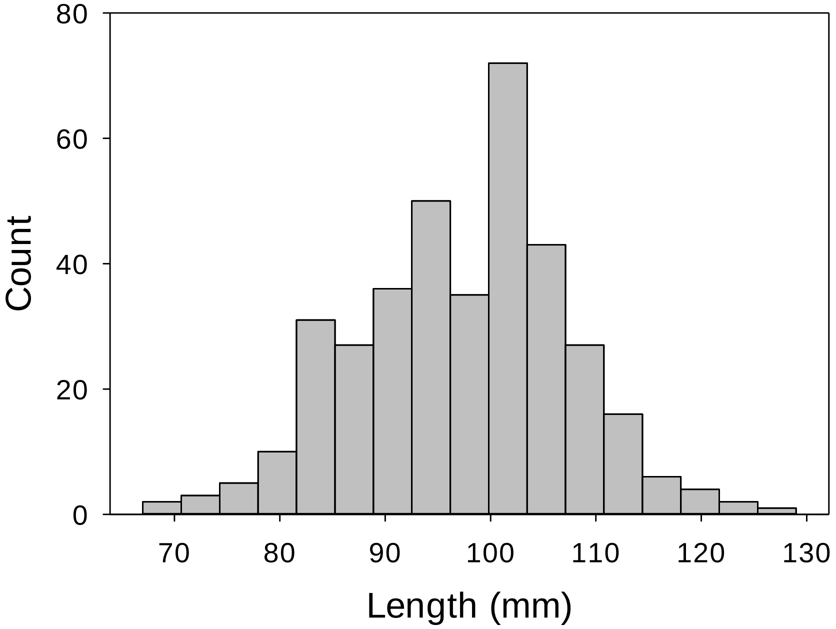


Figure 8. A length-frequency histogram of Coastal Cutthroat Trout captured during the 2013 field season in Clear Creek.

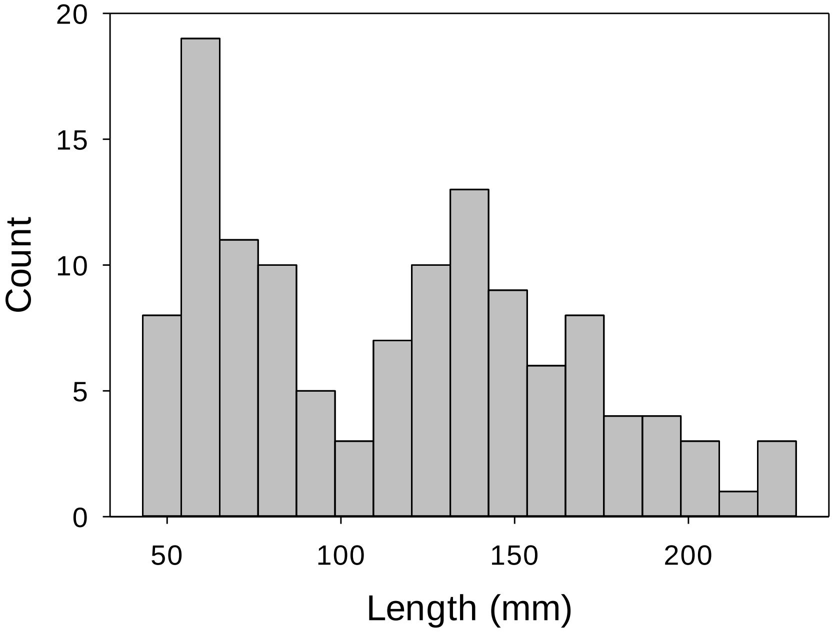


Figure 9. A map indicating the locations of sample reaches on Clear Creek in 2013 with vertical bars depicting the number of juvenile Coho captured in each reach.

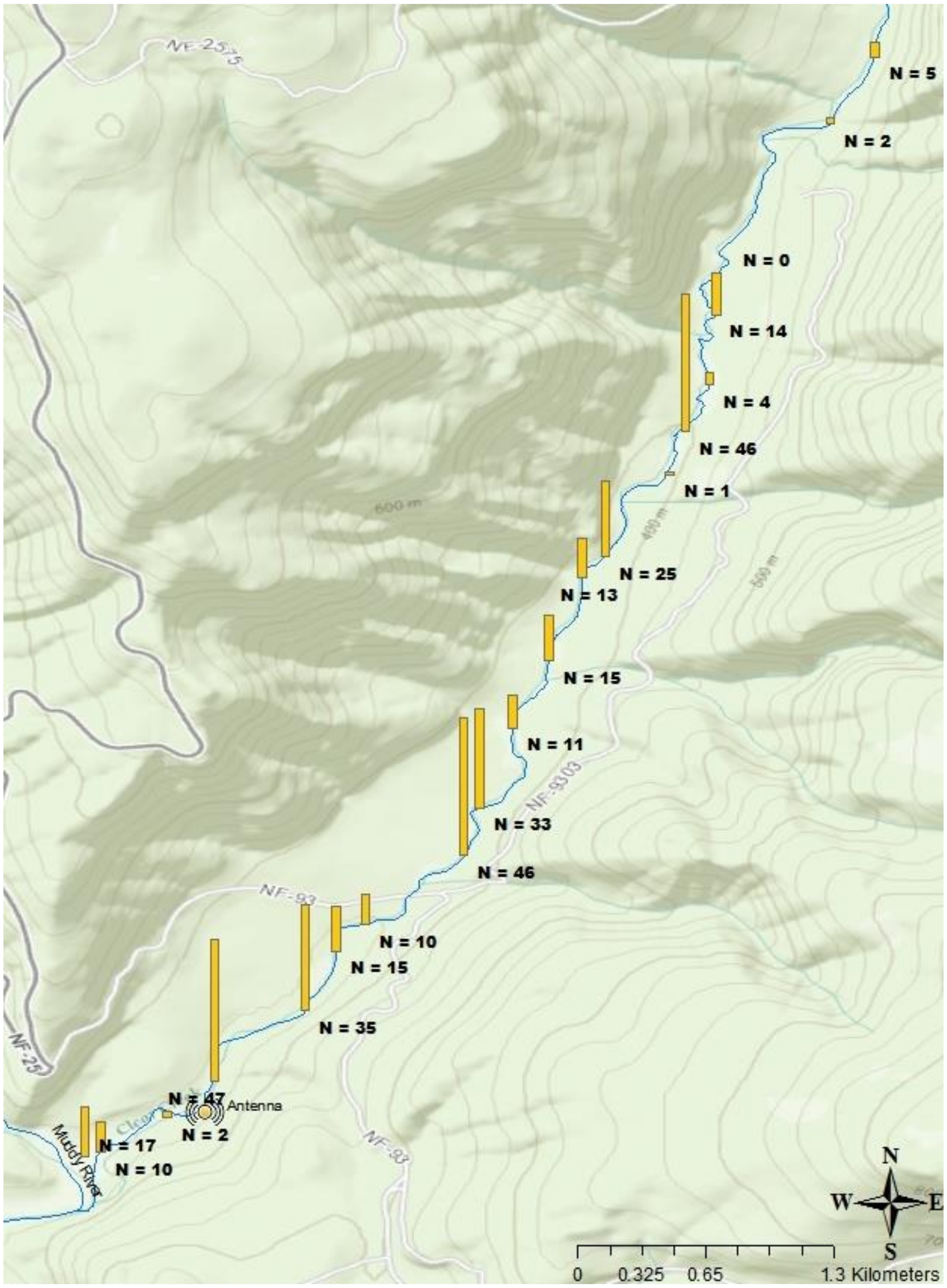


Figure 10. The number of Coho salmon smolts emigrating downstream past the PIT-tag antennae on Clear Creek from September 1st 2013 and through May 5th, 2014 (a) and the average daily water temperature (grey) and water level (black) at the Clear Creek antennae.

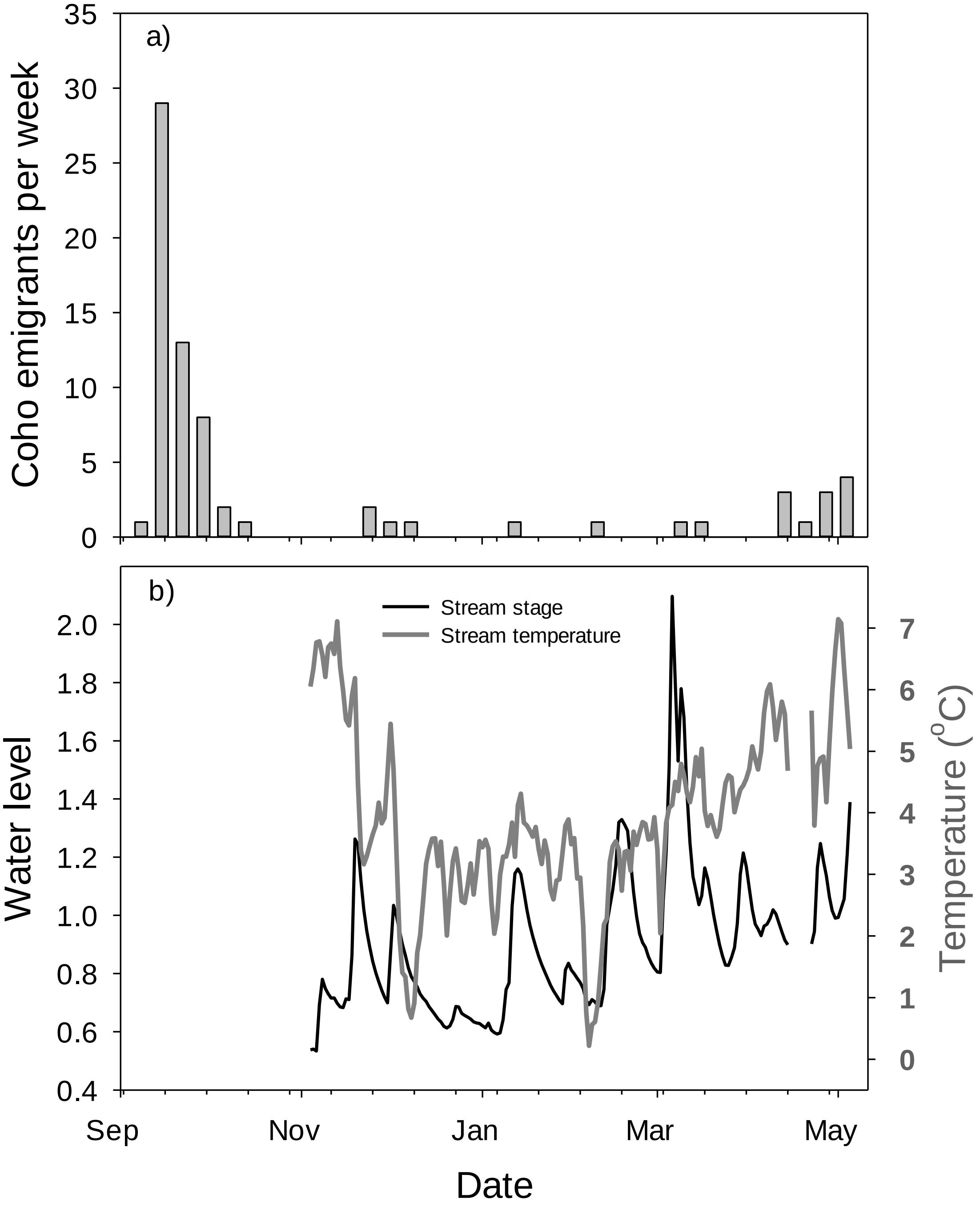


Figure 11. Seasonal temperature profiles taken in Lake Merwin (a), Yale Lake (b), and Swift Reservoir (c) at two stations in June and August and one station in November 2013. The temperature sounder malfunctioned while sampling Swift Reservoir in November, which is why the profile only goes to 10 m depth.

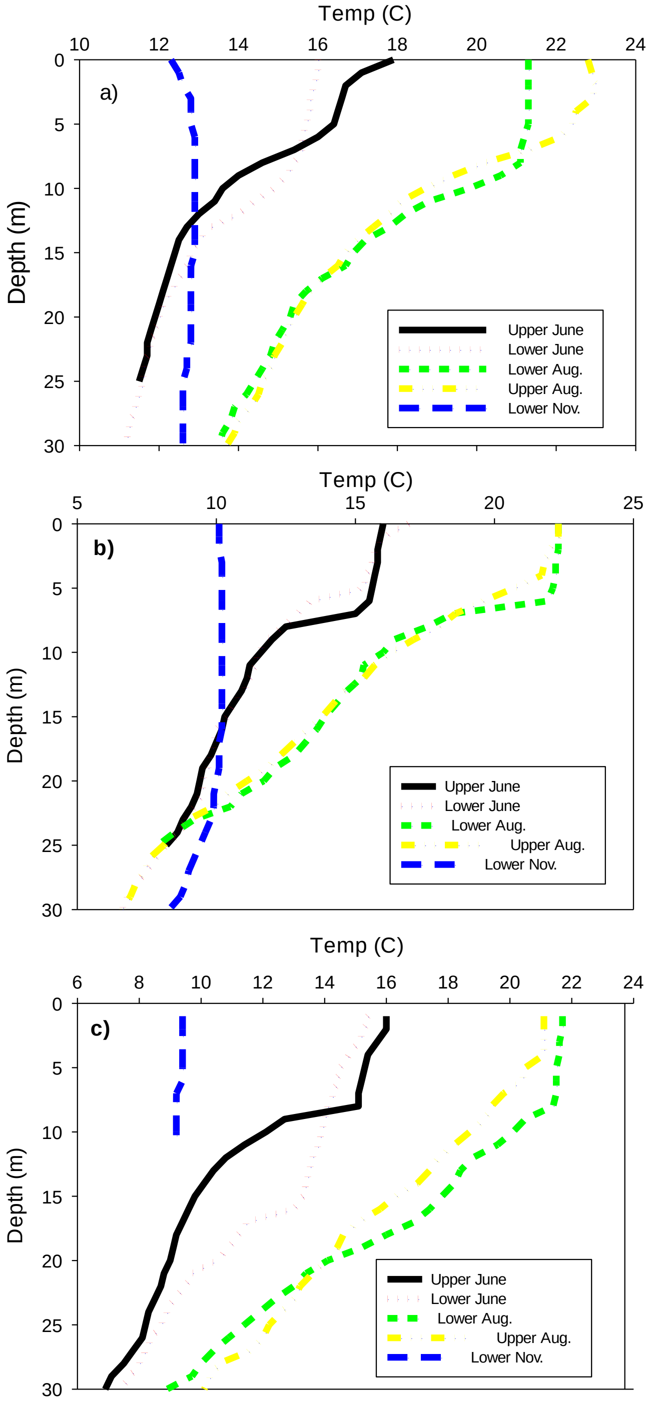


Figure 12. Northern pikeminnow (NPM) fork length at age, back-calculated from scale annuli data using the Fraser-Lee Method, for Lake Merwin (a) and Yale Lake (b). Mean back-calculated fork length is reported with standard deviation error bars. No NPM were captured in Swift Reservoir.

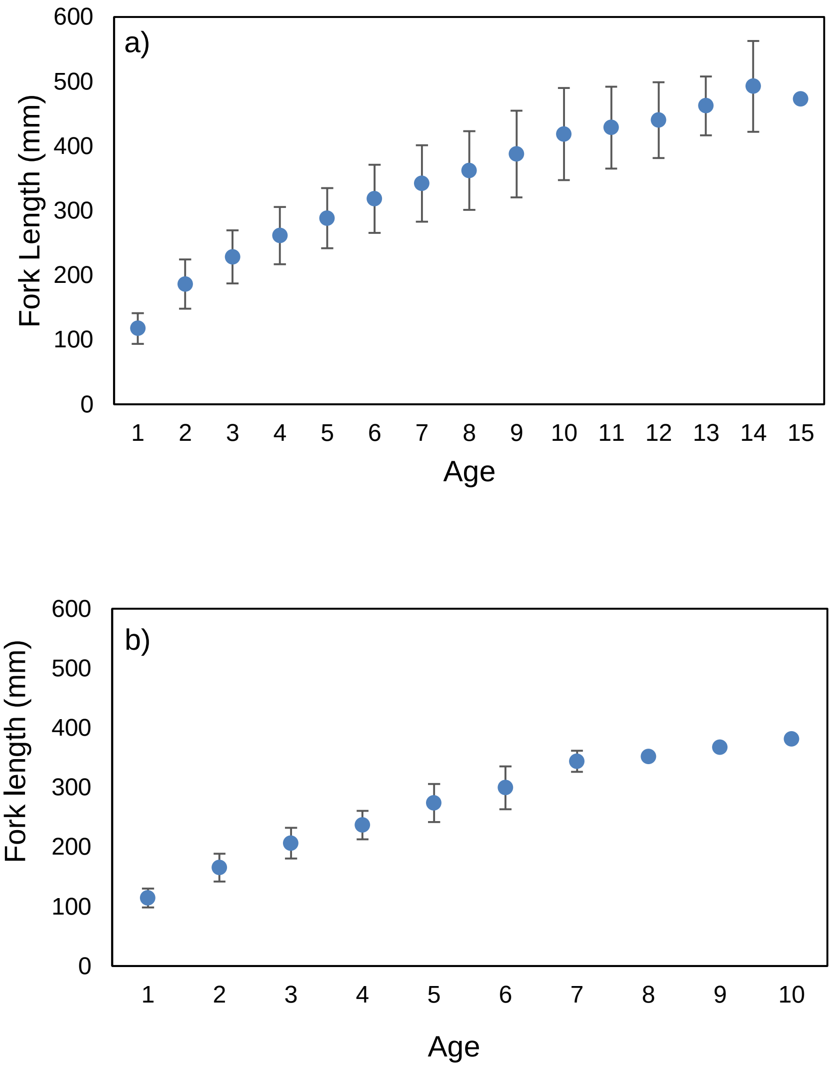


Figure 13. $\delta^{13}C$ and $\delta^{15}N$ versus fork length for Northern Pikeminnow in Lake Merwin.

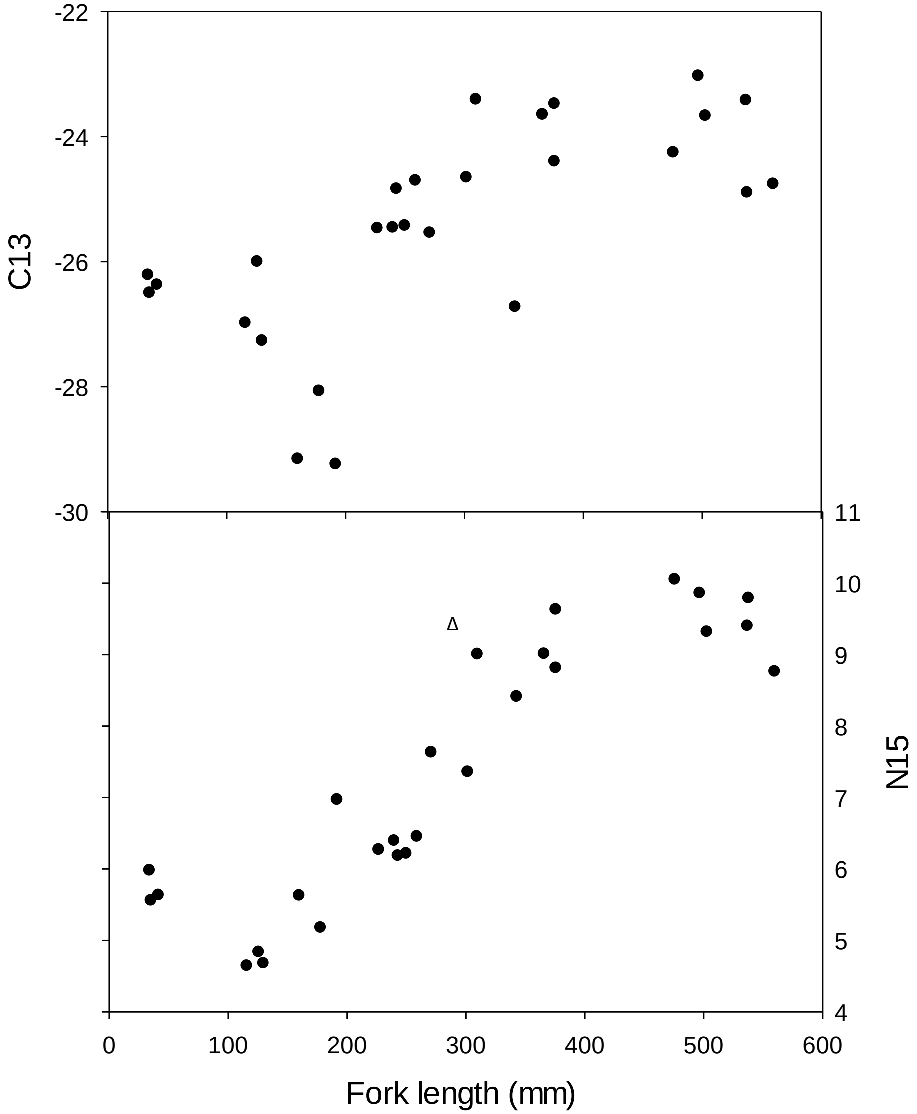


Figure 14. $\delta^{13}C$ and $\delta^{15}N$ versus fork length for Tiger Muskie in Lake Merwin.

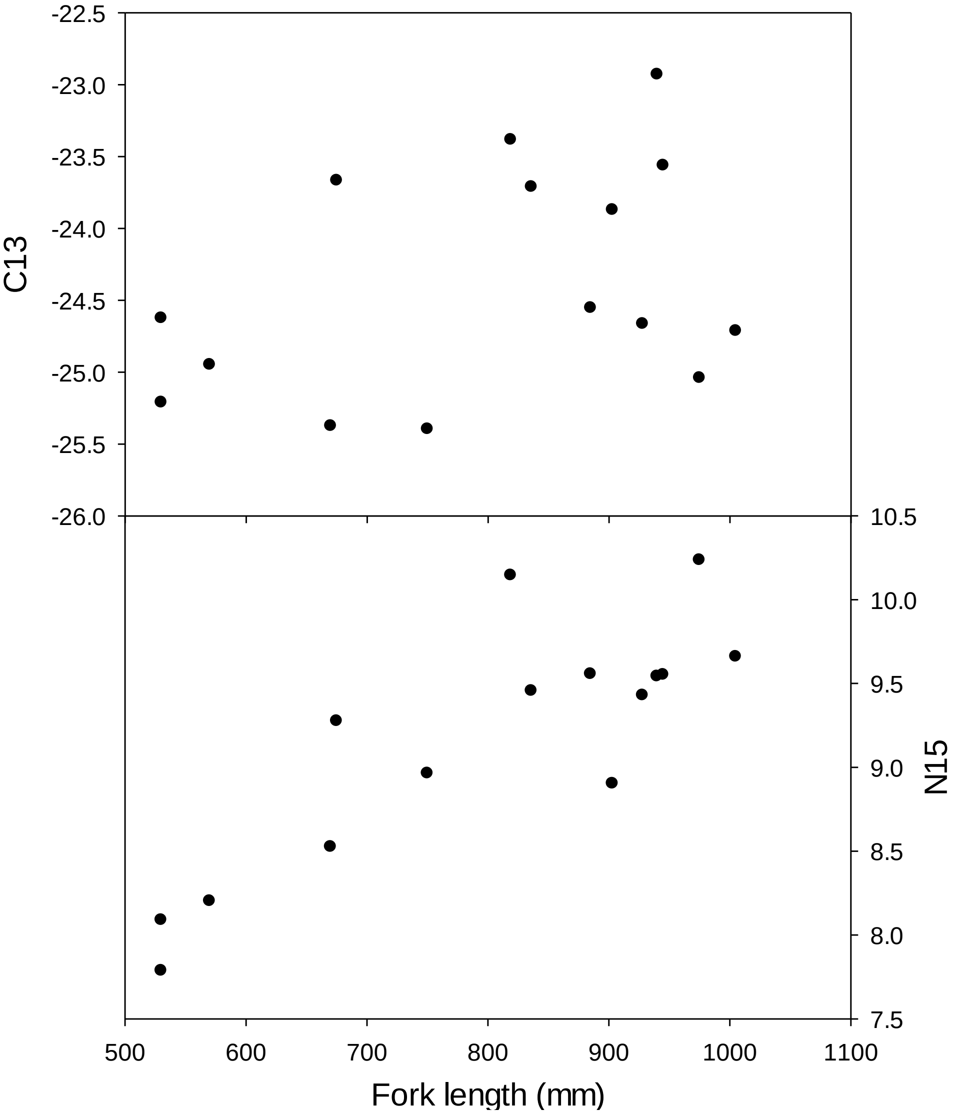


Figure 15. The proportion of each species observed during daytime snorkel surveys in 2013 in Pine Creek and P8. The order of bars progresses from downstream to upstream (left to right) for both Pine Creek and P8 (see Figure 10 for reach locations). Note: YOY corresponds to young-of-year *Oncorhynchus* spp., likely either Coastal Cutthroat Trout or Steelhead, which are difficult to delineate so were combined.

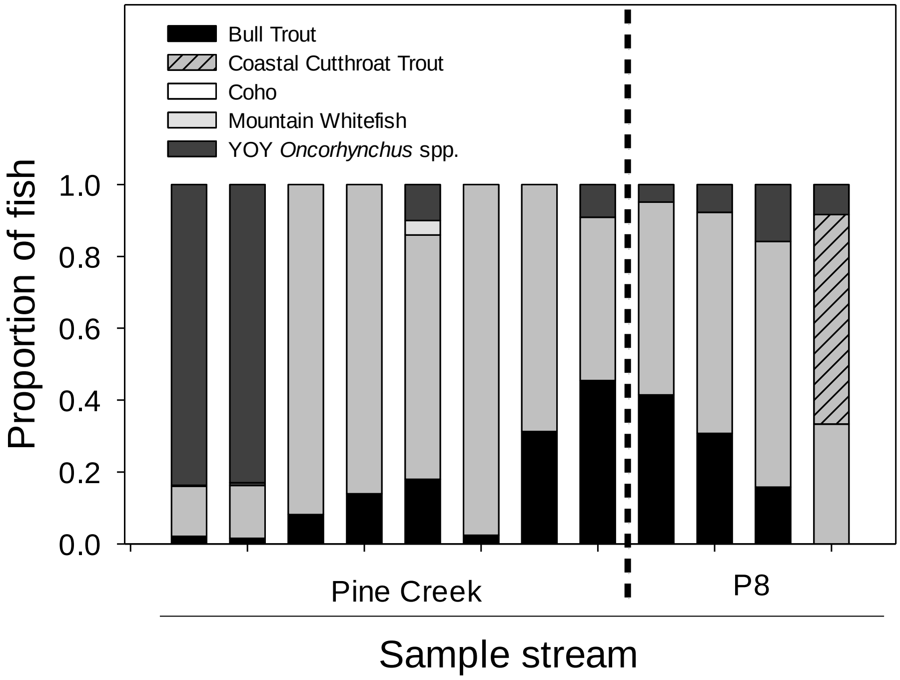


Figure 16. Number of Bull Trout observed during snorkel surveys in Pine Creek during 2013.

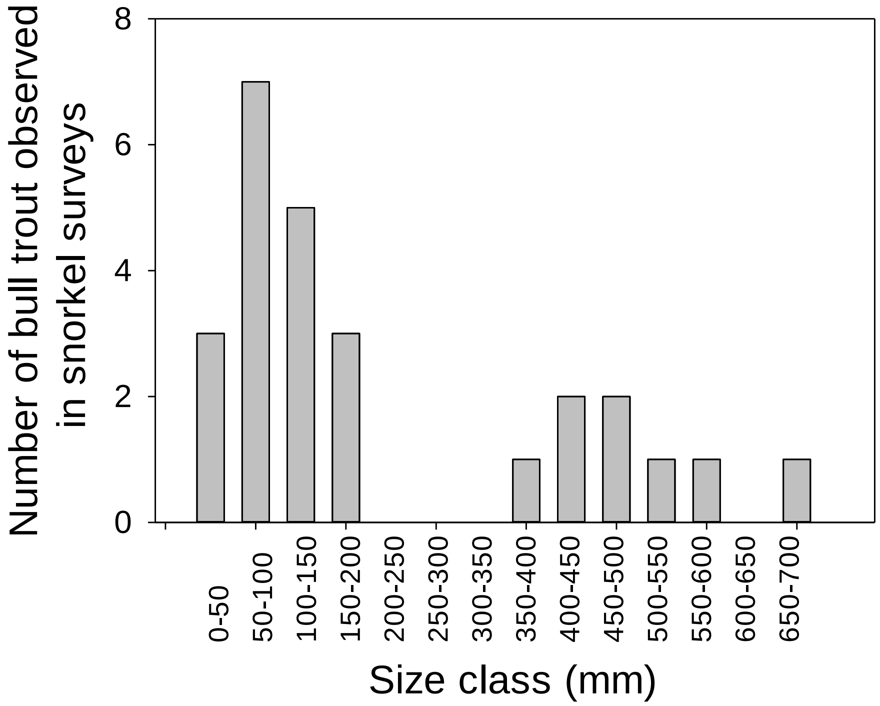


Figure 17. A map indicating the locations and totals of Bull Trout observed during distributional surveys in 2013 in Pine Creek and P8.

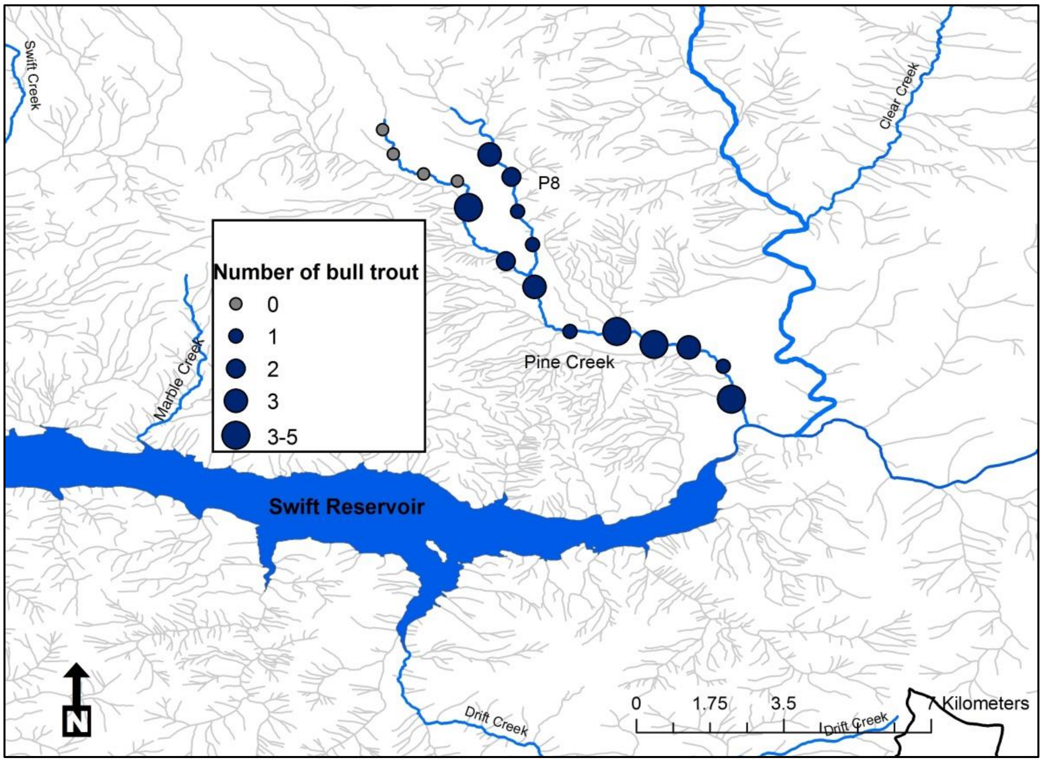


Figure 18. Nearshore and offshore diel hydroacoustic fish target densities by meter depth intervals in Swift Reservoir, August 2013.

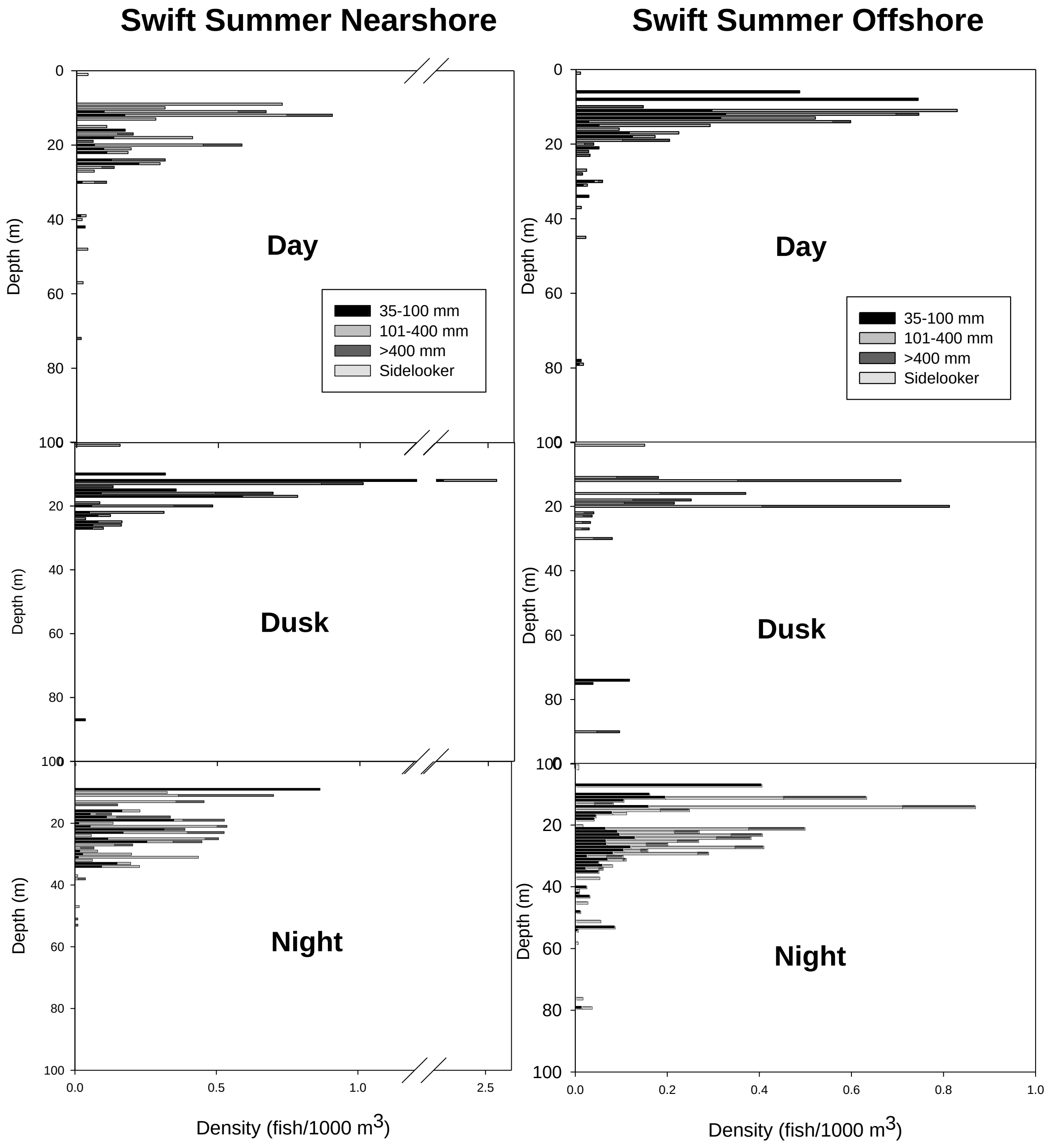


Figure 19. Nearshore and offshore diel hydroacoustic fish target densities by meter depth intervals in Yale Lake, August 2013.

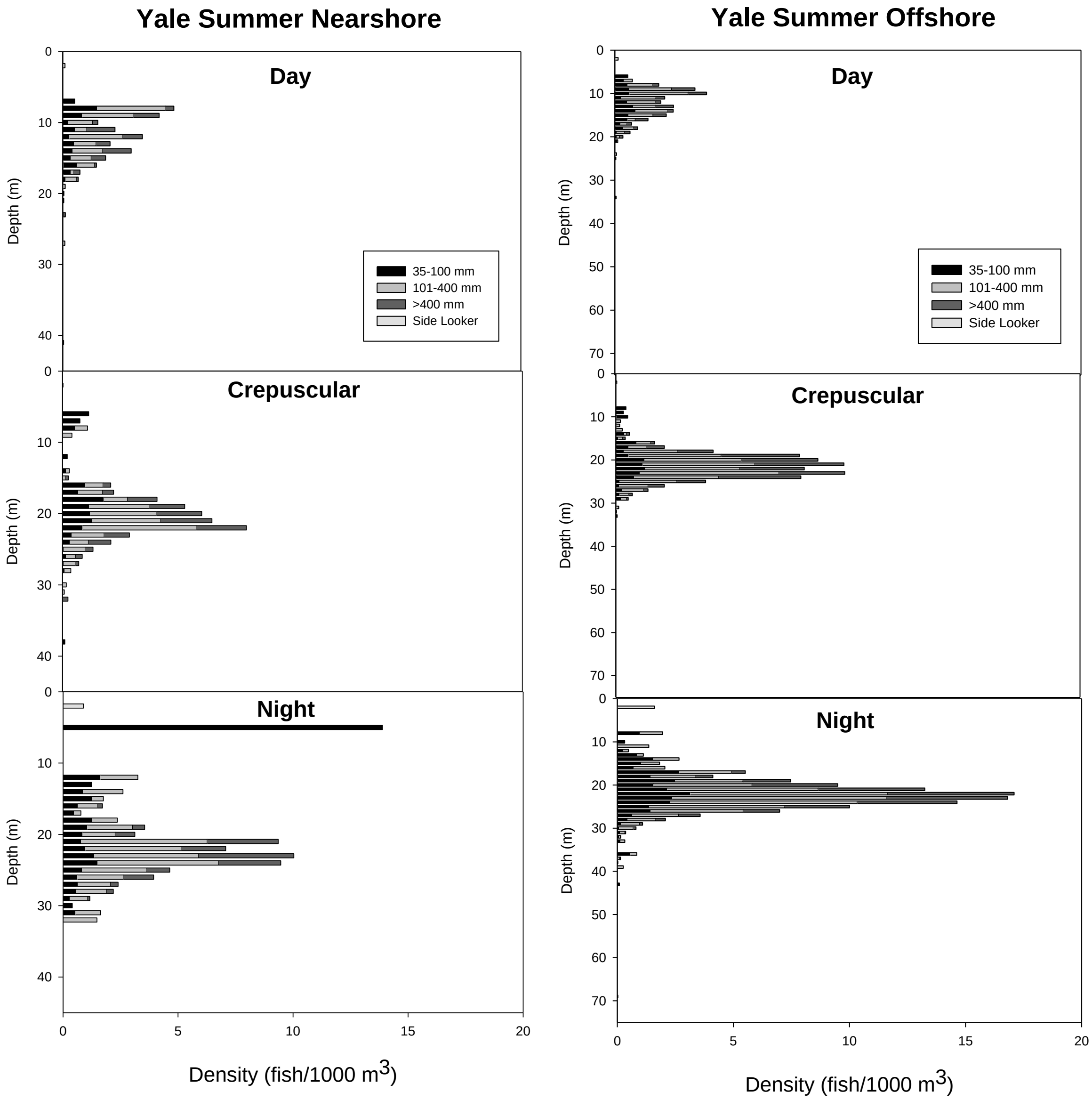


Figure 20. Nearshore and offshore diel hydroacoustic fish target densities by meter depth intervals in Lake Merwin, August 2013.

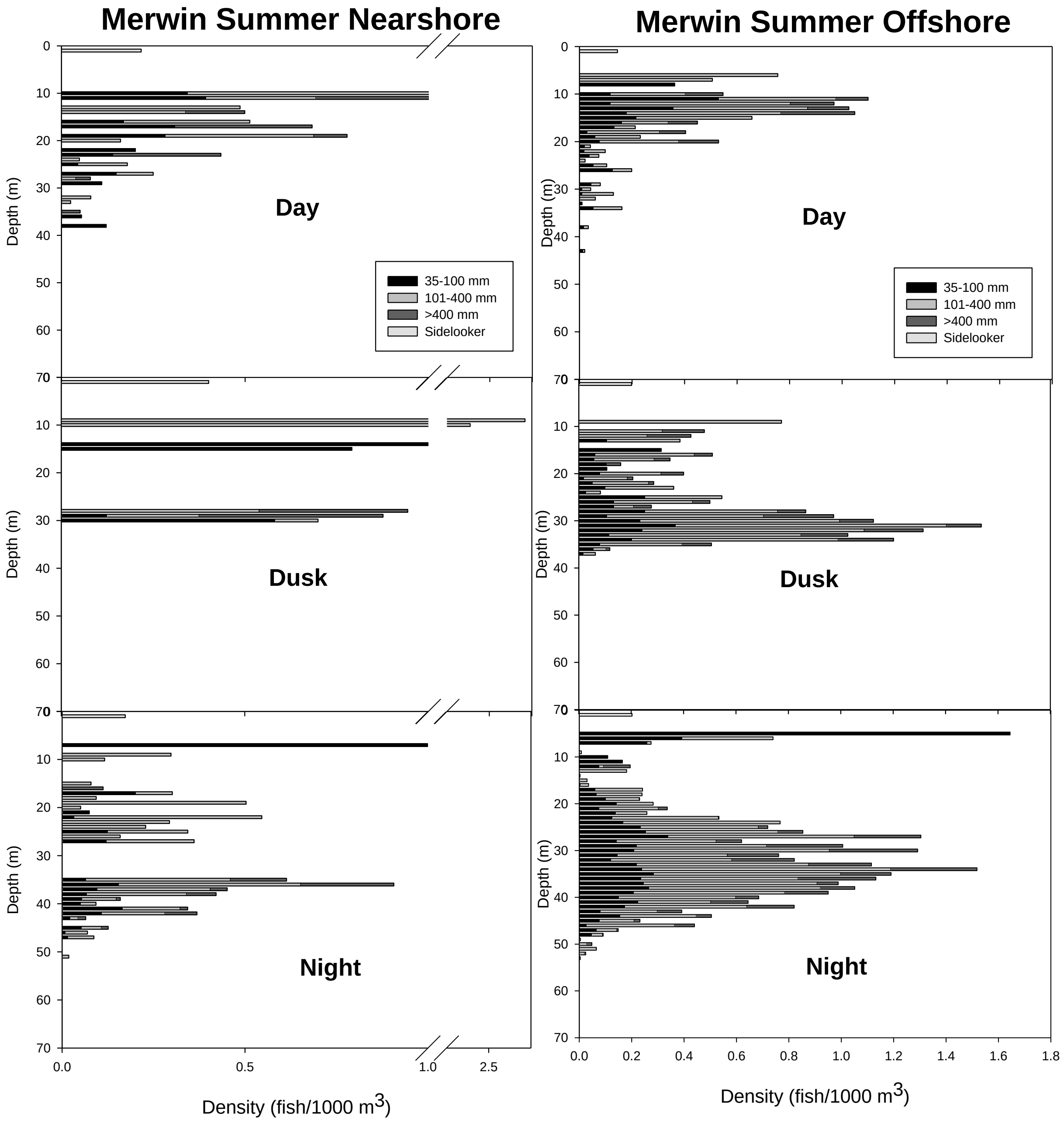
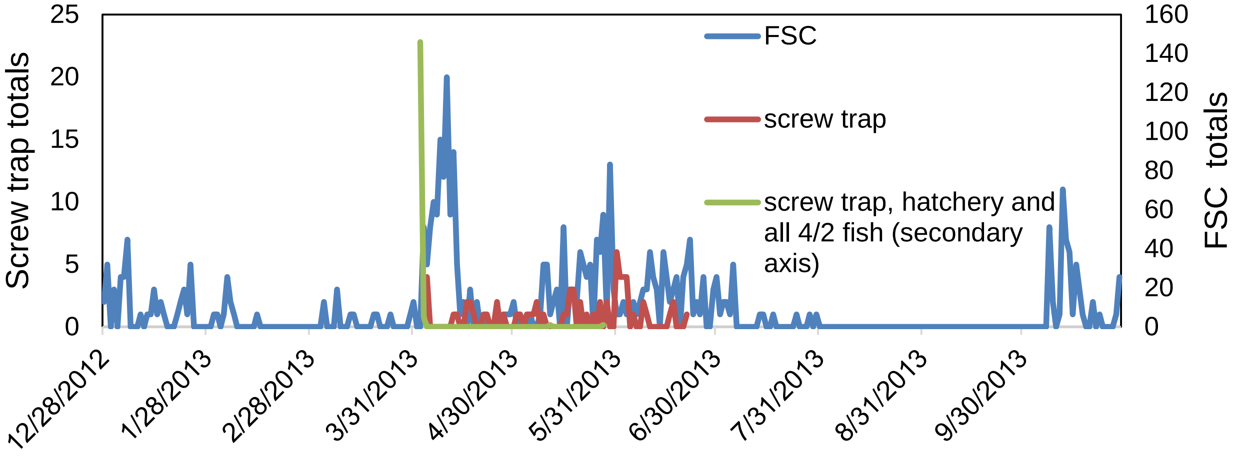
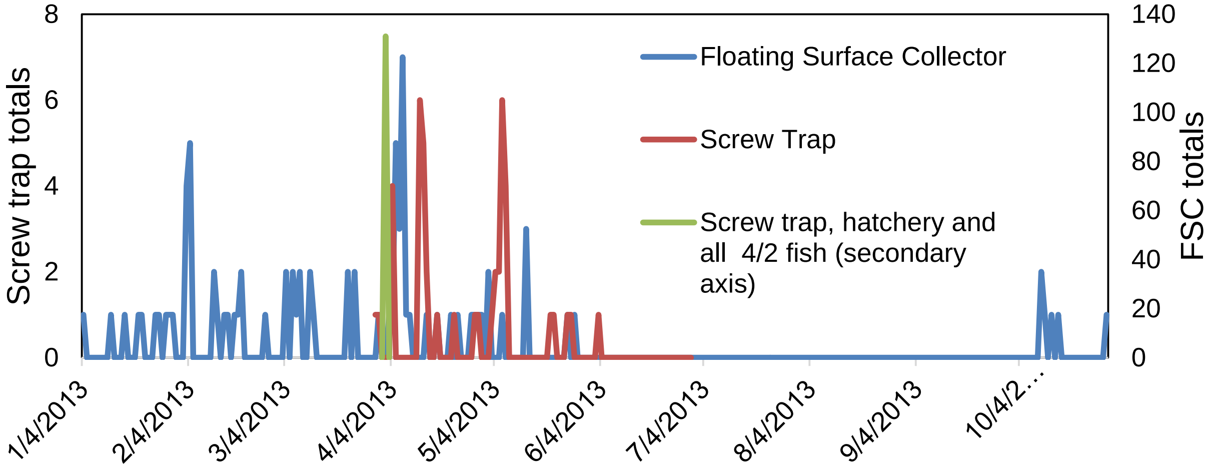


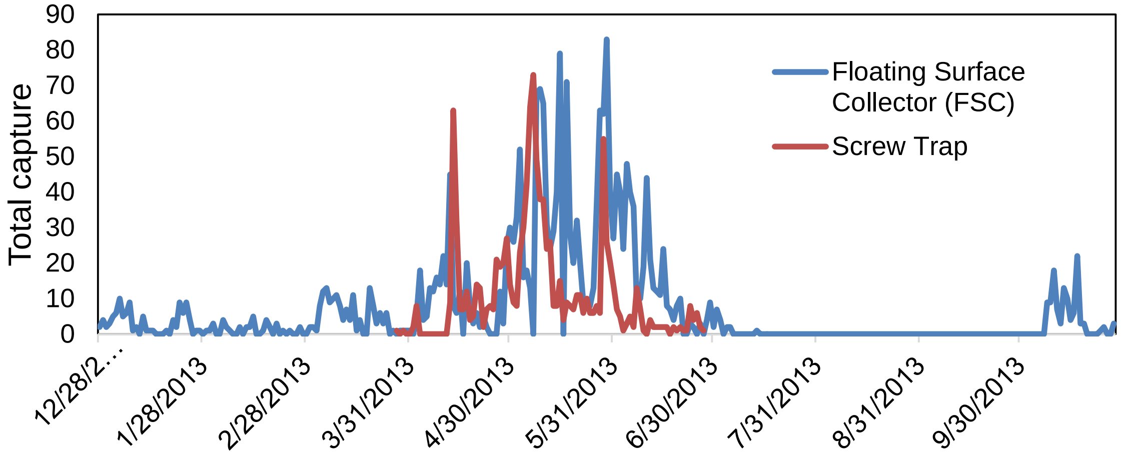
Figure 21. Daily catch at the screw trap operated above Swift Reservoir at Eagle Cliffs, with a different line and secondary axis for days of large hatchery releases, and at the floating surface collector (FSC) at Swift Dam. Catch rates are broken out into different panels for each size mode of Chinook (a, b) and Coho (c, d, e) observed at the screw trap. The screw trap was operated from late march through June 28, 2013. Most hatchery fish were released in early April. The FSC did not operate during September 2013.

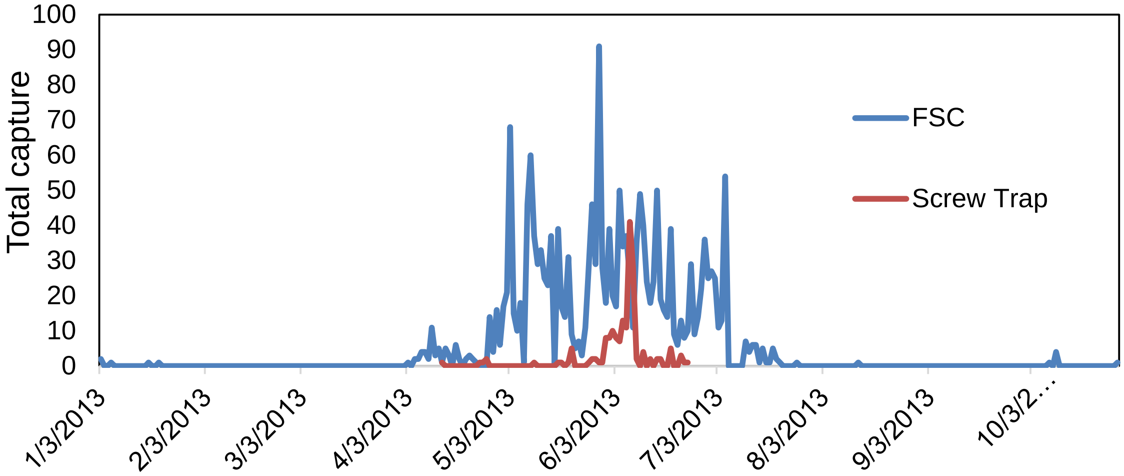
a) Spring Chinook < 145 mm



b) Spring Chinook >145 mm




c) Coho <156 mm


d) Coho 156-230 mm

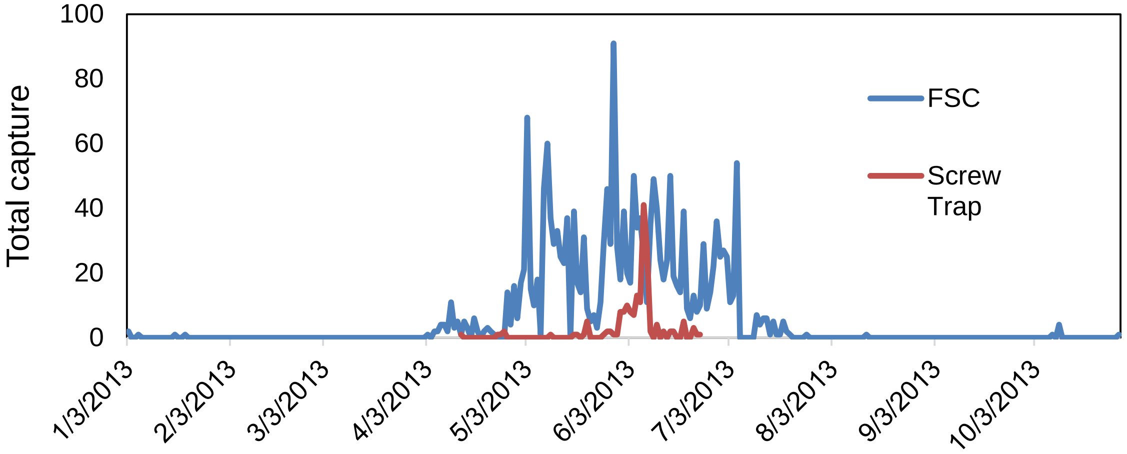

e) Coho 156-230 mm

Figure 22. Seasonal length frequency histograms for Rainbow Trout, including hatchery and wild fish, captured in Swift Reservoir and Lake Merwin.

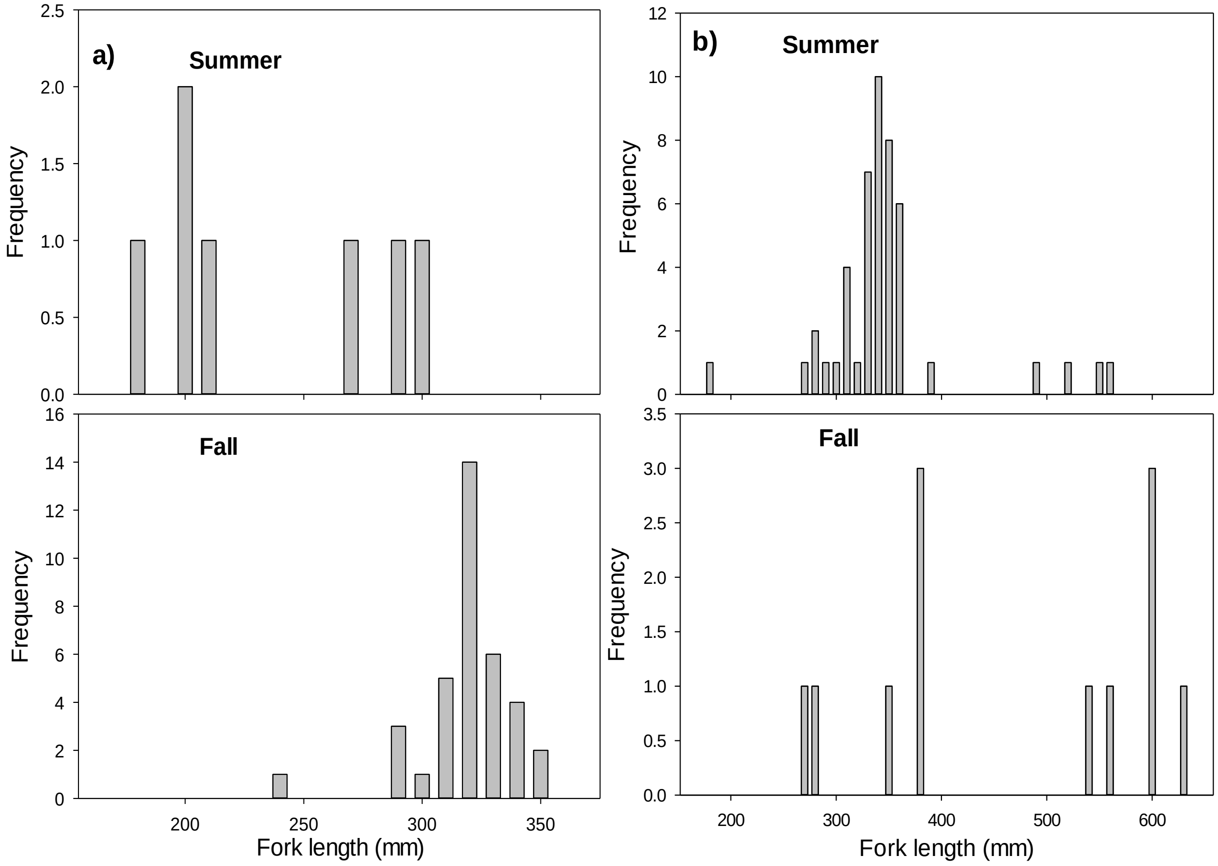


Figure 23. Seasonal length frequency histograms for Chinook (a) and Coho (b)salmon captured in Swift Reservoir.

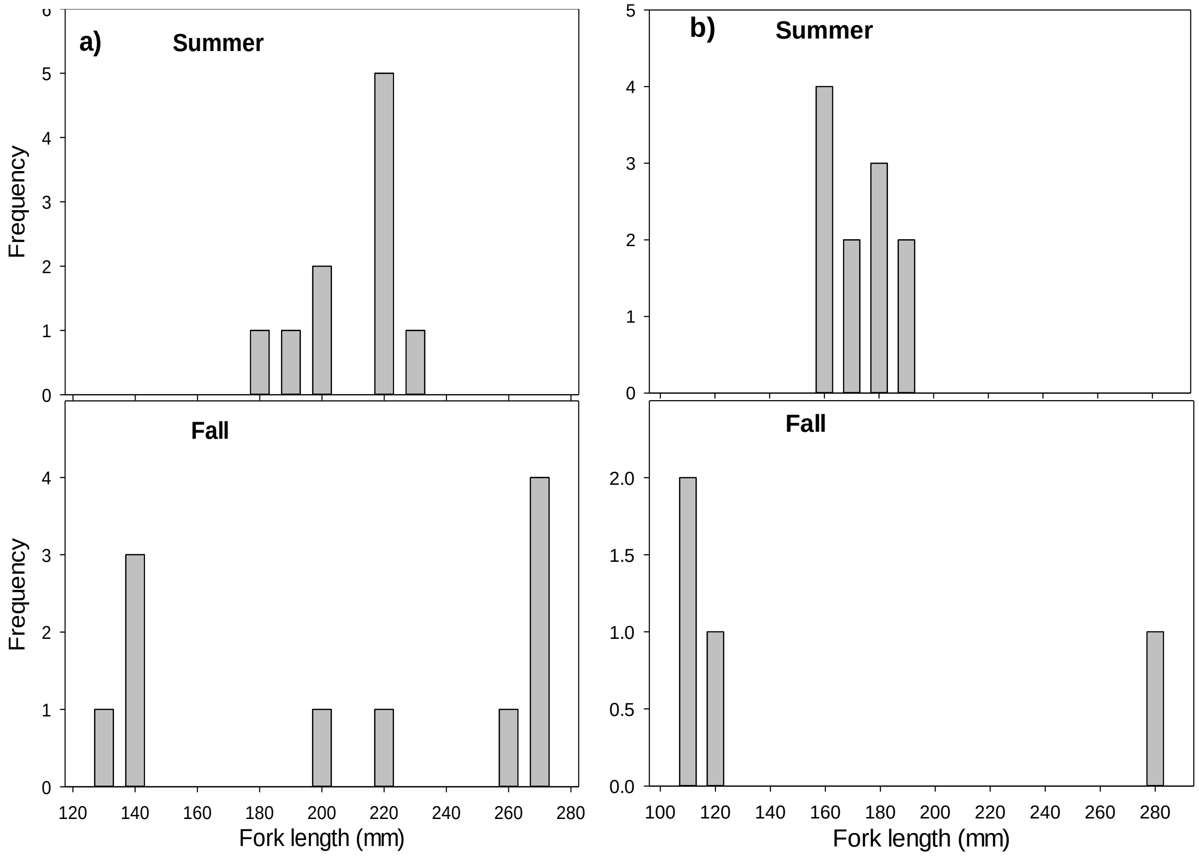


Figure 24. Seasonal length frequency histogram for Northern Pikeminnow captured in Yale Lake (a) and Lake Merwin (b).

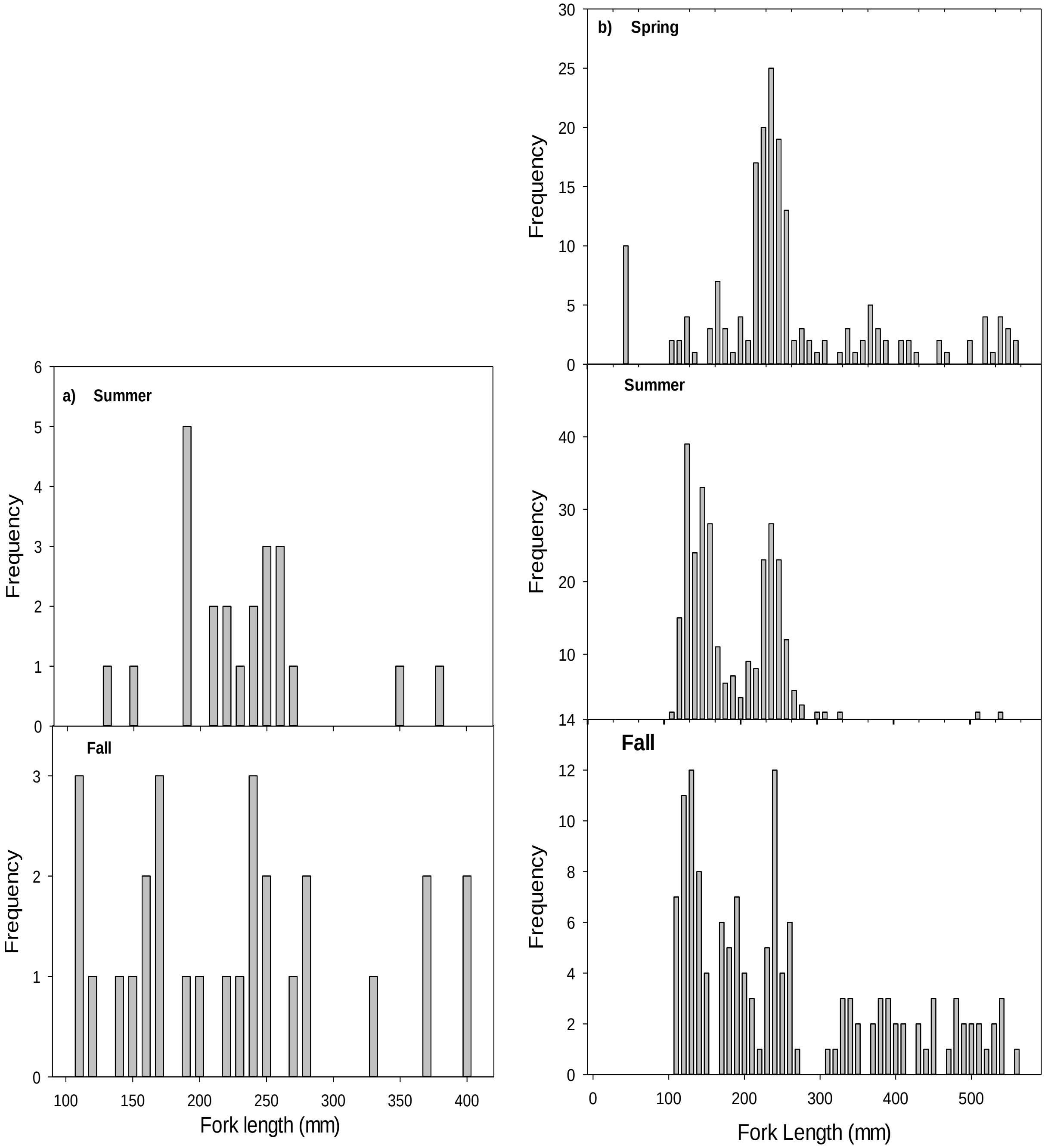


Figure 25. Seasonal length frequency histogram for kokanee captured in Yale Lake (a) and Lake Merwin.

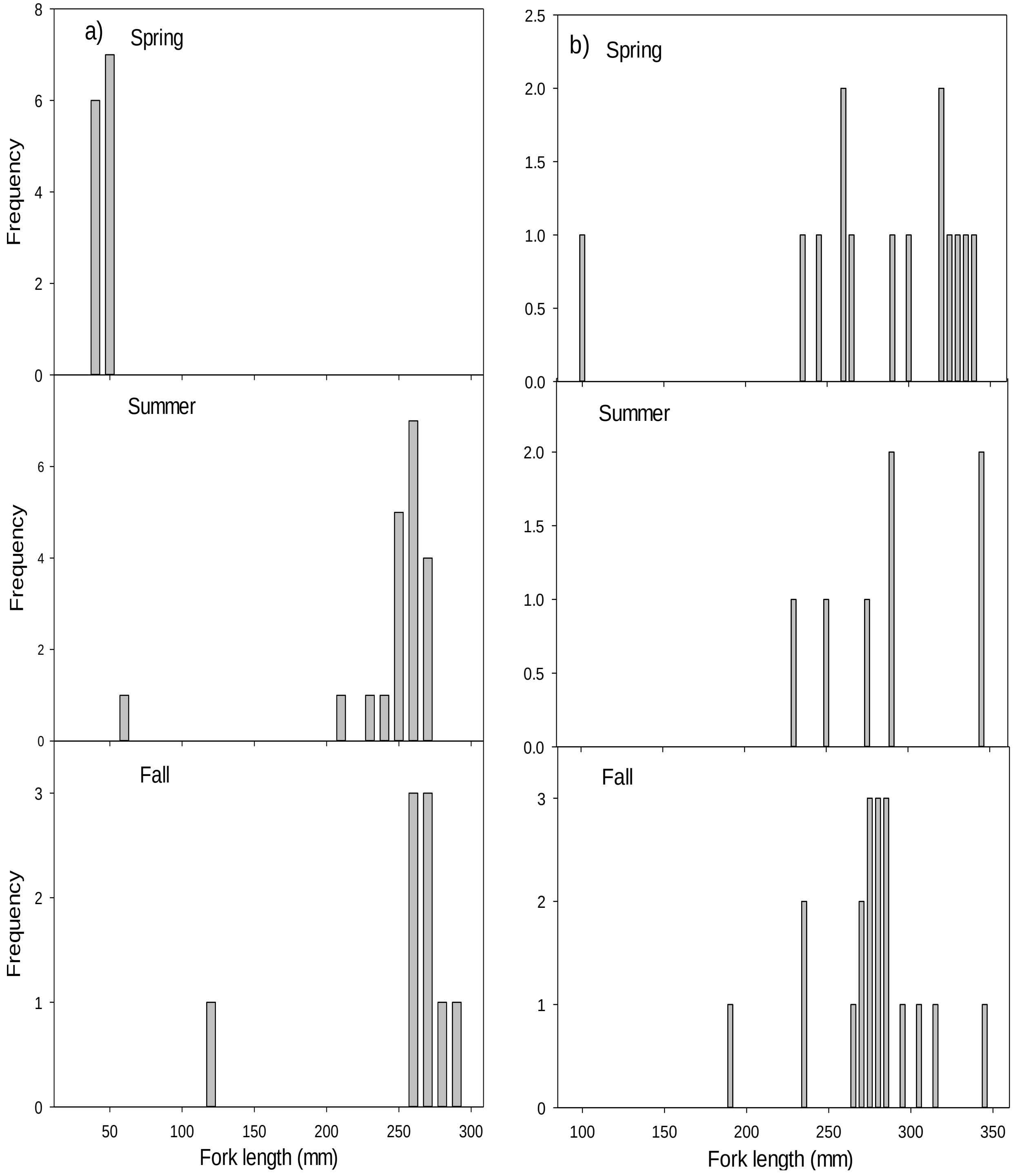


Figure 26. Seasonal length frequency histogram for Tiger Muskie captured in Lake Merwin.

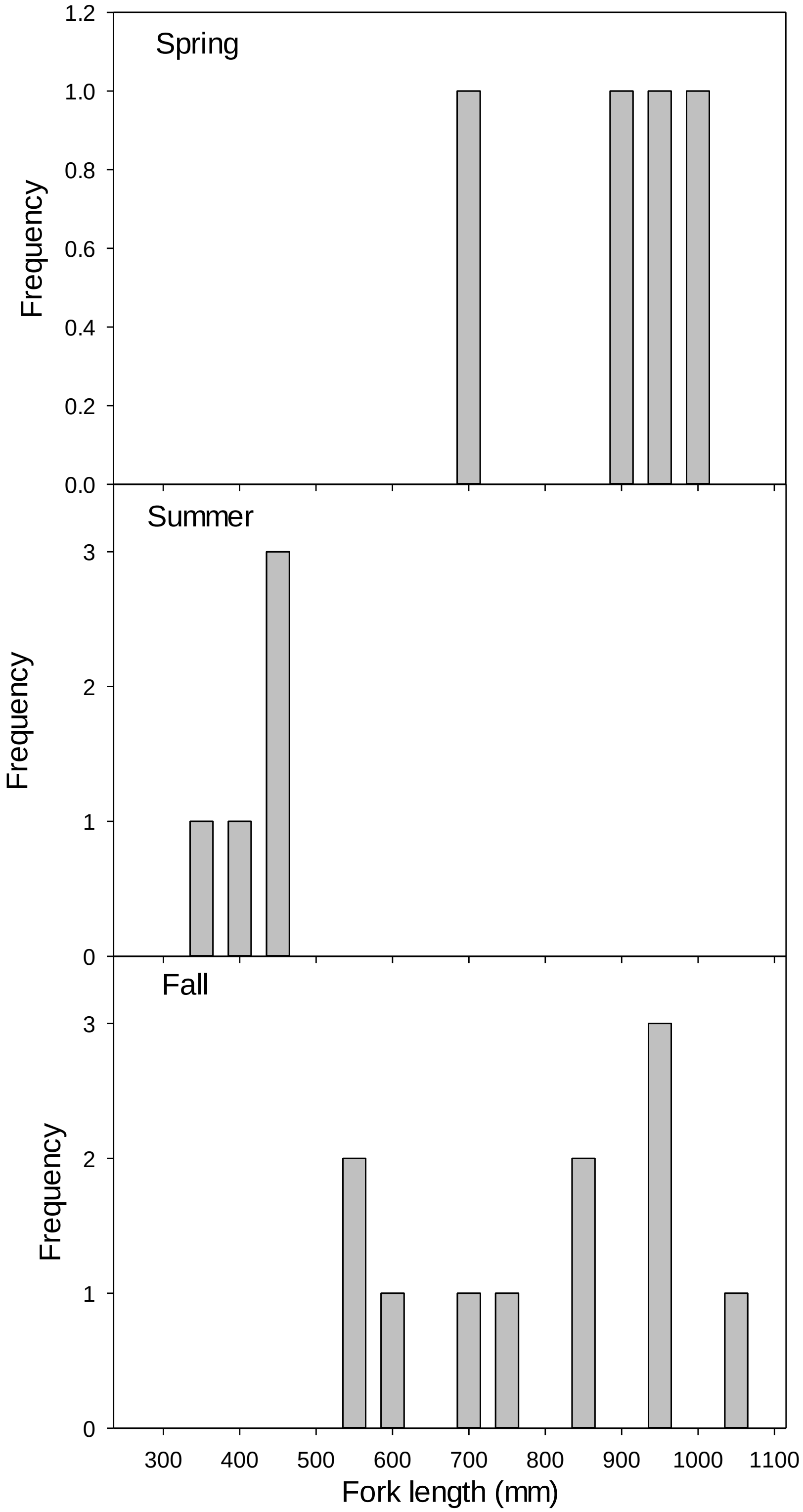


Figure 27. $\delta^{13}C$ and $\delta^{15}N$ versus fork length for Bull Trout in Swift Reservoir.

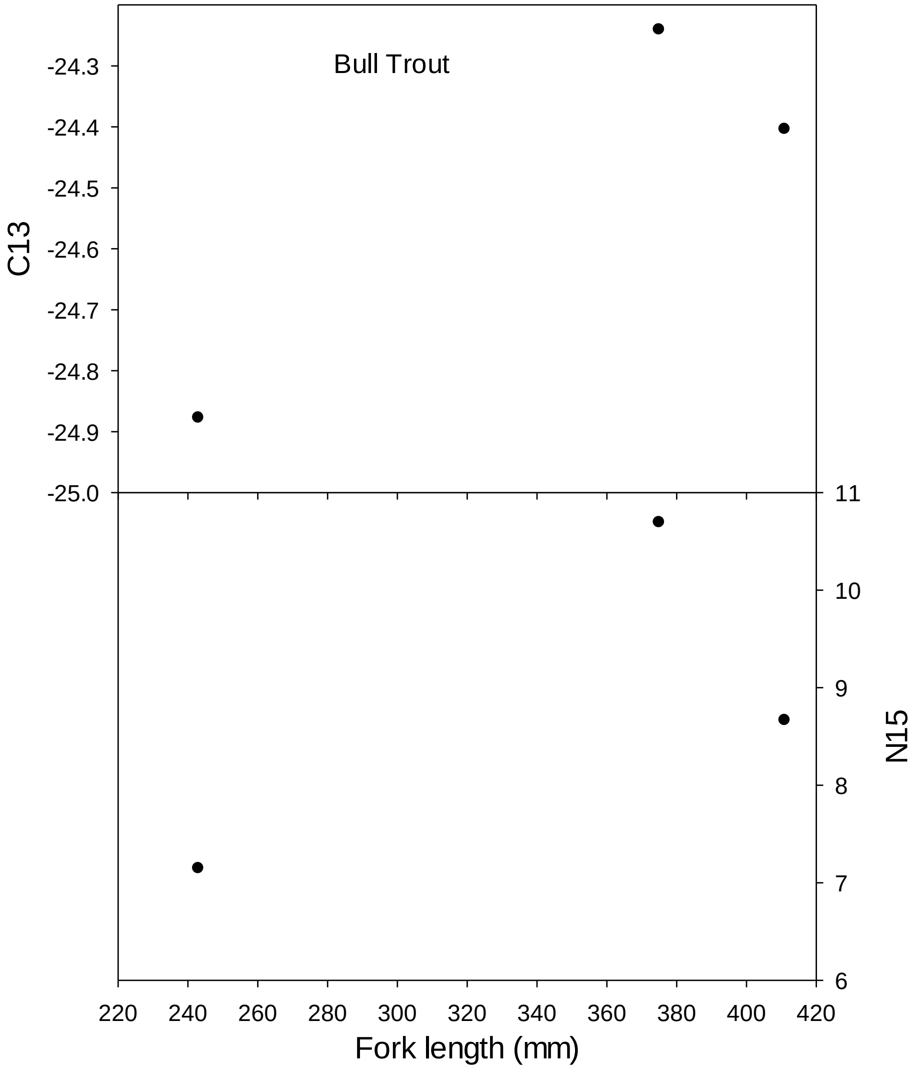


Figure 28. $\delta^{13}C$ and $\delta^{15}N$ versus fork length for Chinook salmon in Swift Reservoir. The outlier, which is highly enriched in both the carbon and nitrogen isotope, likely still has some of its hatchery feed signal. It was caught in November one month after a hatchery release in October. The other larger samples were caught in summer, four months after the last hatchery release.

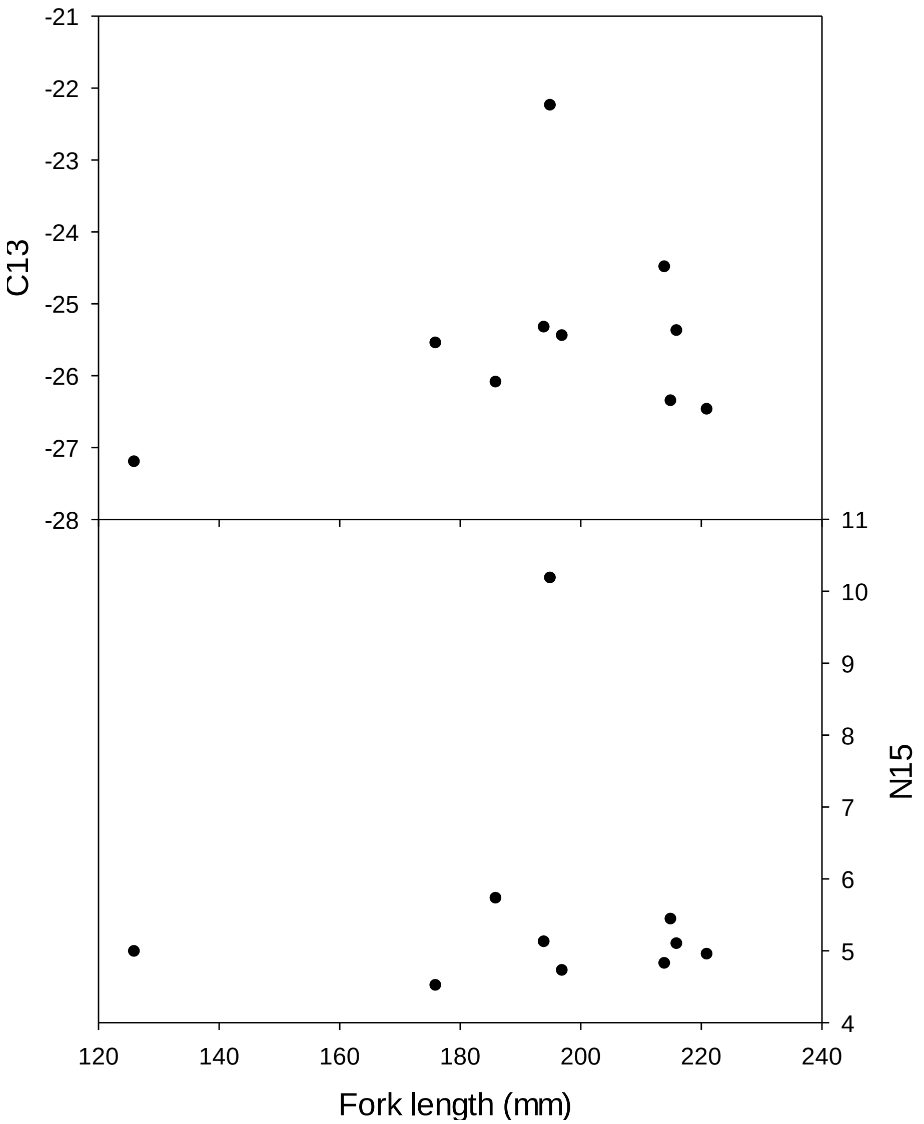


Figure 29. $\delta^{13}C$ and $\delta^{15}N$ versus fork length for Coho Salmon in Swift Reservoir.

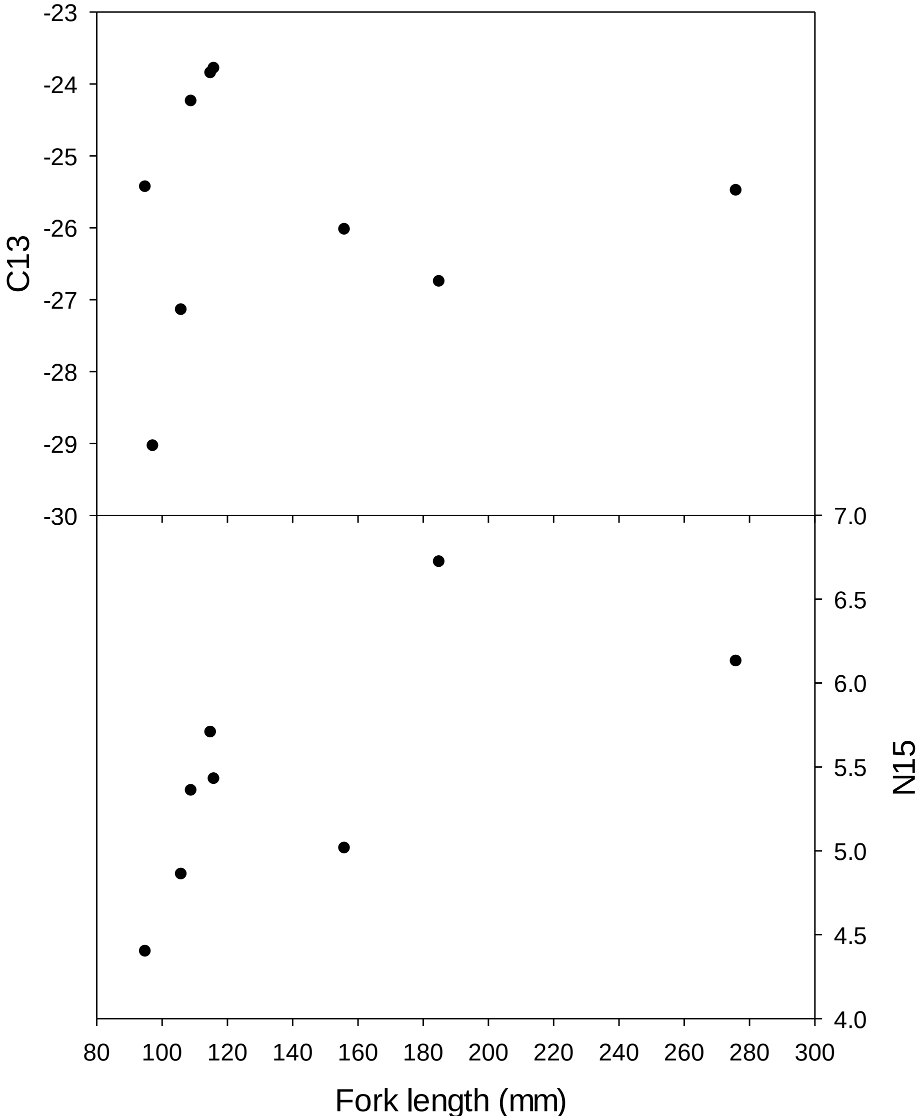


Figure 30. δ^{13}C and δ^{15}N versus fork length for Cutthroat Trout in Swift Reservoir.

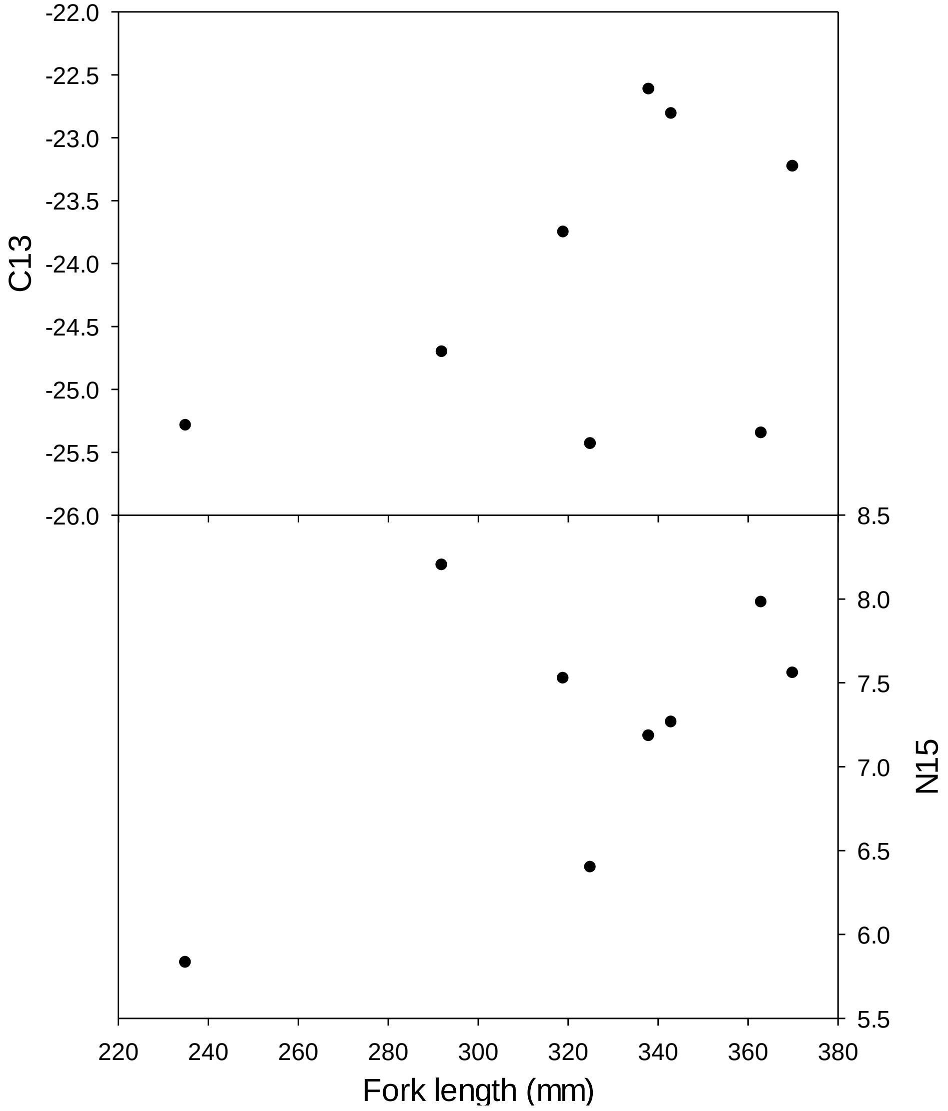


Figure 31. δ^{13}C and δ^{15}N versus fork length for rainbow trout in Swift Reservoir. The three fish with highly enriched signatures of the carbon and nitrogen isotope are likely still displaying the values of their hatchery feed. They were captured in spring 2009, likely soon after being released from the hatchery, and are still within the average size at which hatchery Rainbow Trout are planted. These outliers were discarded for later analysis.

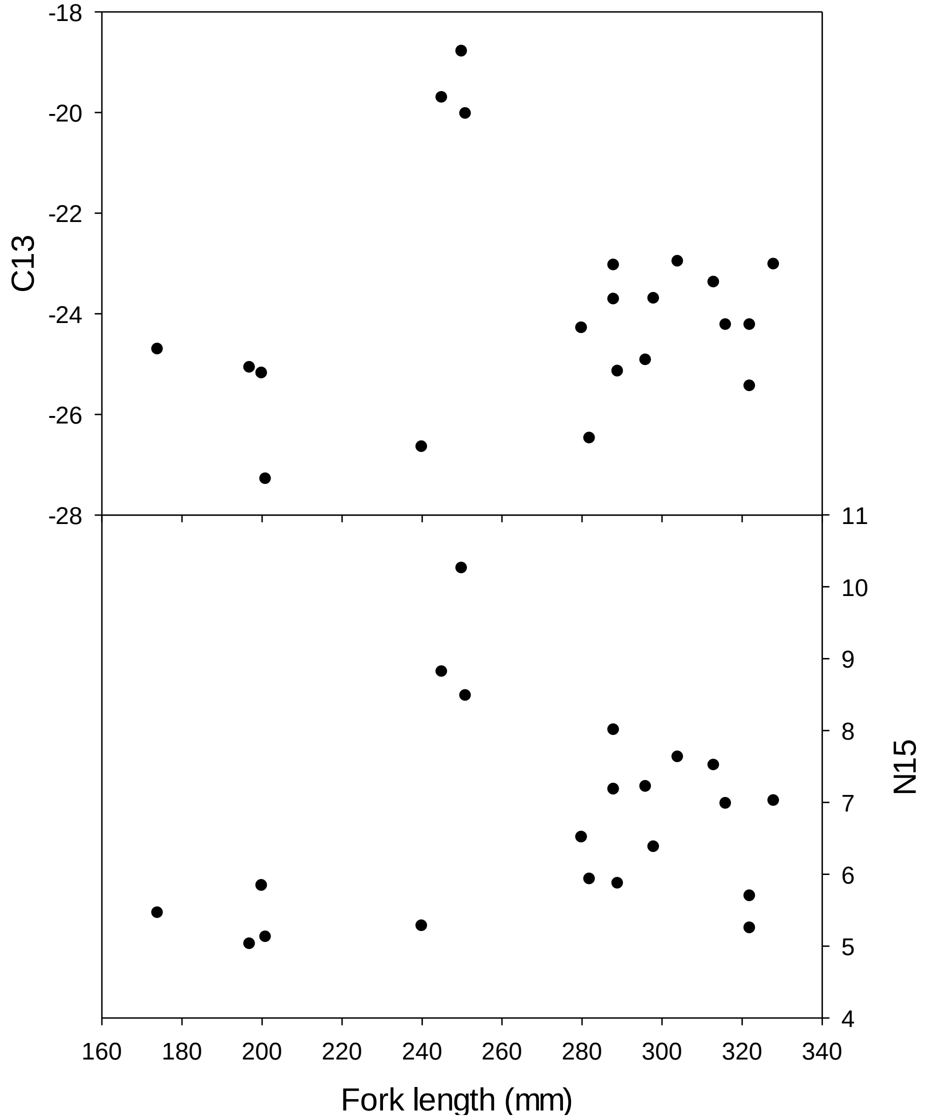


Figure 32. δ^{13}C versus δ^{15}N for the species and size classes sampled in Swift Reservoir. Size class or fork length is in parenthesis. LSS = Largescale Sucker; M whitefish = Mountain Whitefish; and RBT = Rainbow Trout. The densely clustered data points in the upper panel are expanded and labeled in the lower panel. None of the outliers which presumable retained their hatchery feed isotope values were included in calculating the mean isotopic signatures of each species and size class. RBT (>250) may also have retained part of their hatchery feed values.

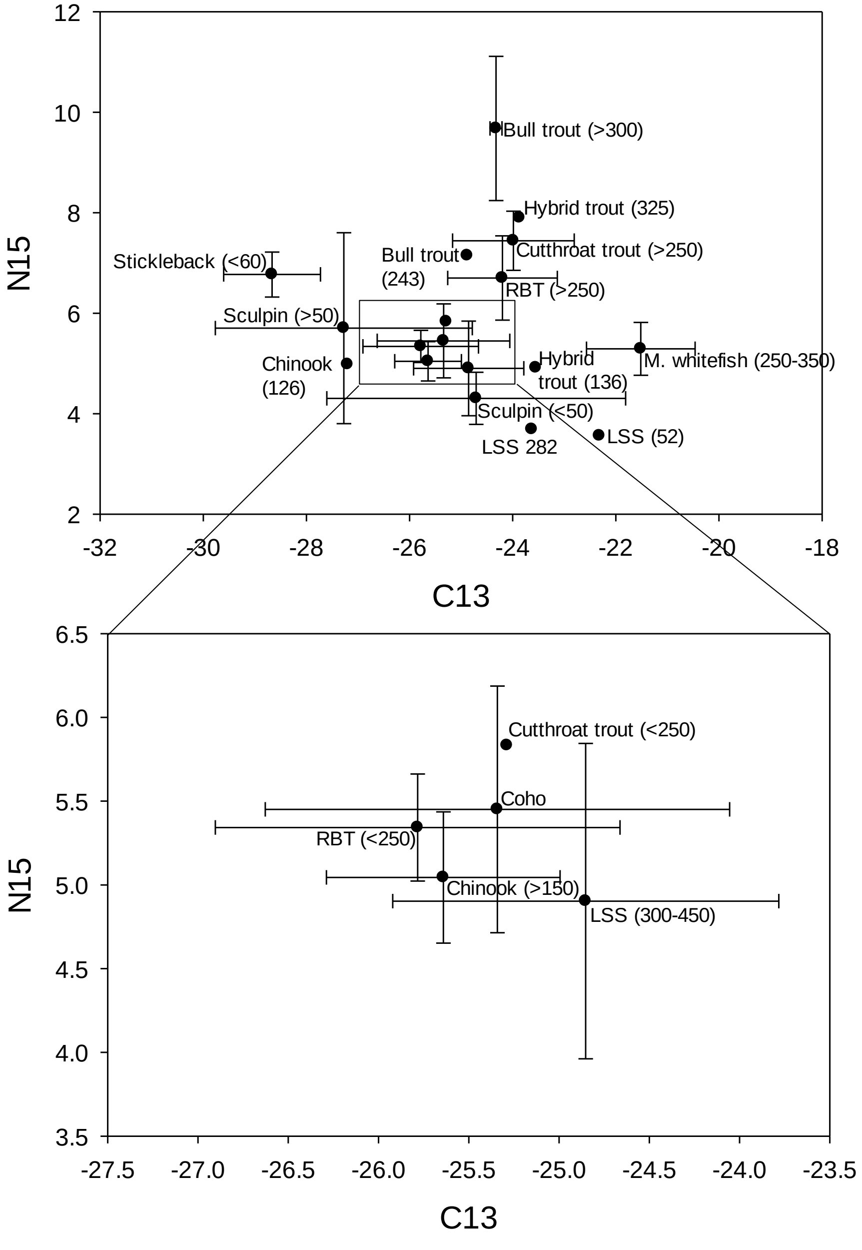


Figure 33. $\delta^{13}C$ and $\delta^{15}N$ versus fork length for Bull Trout in Yale Lake.

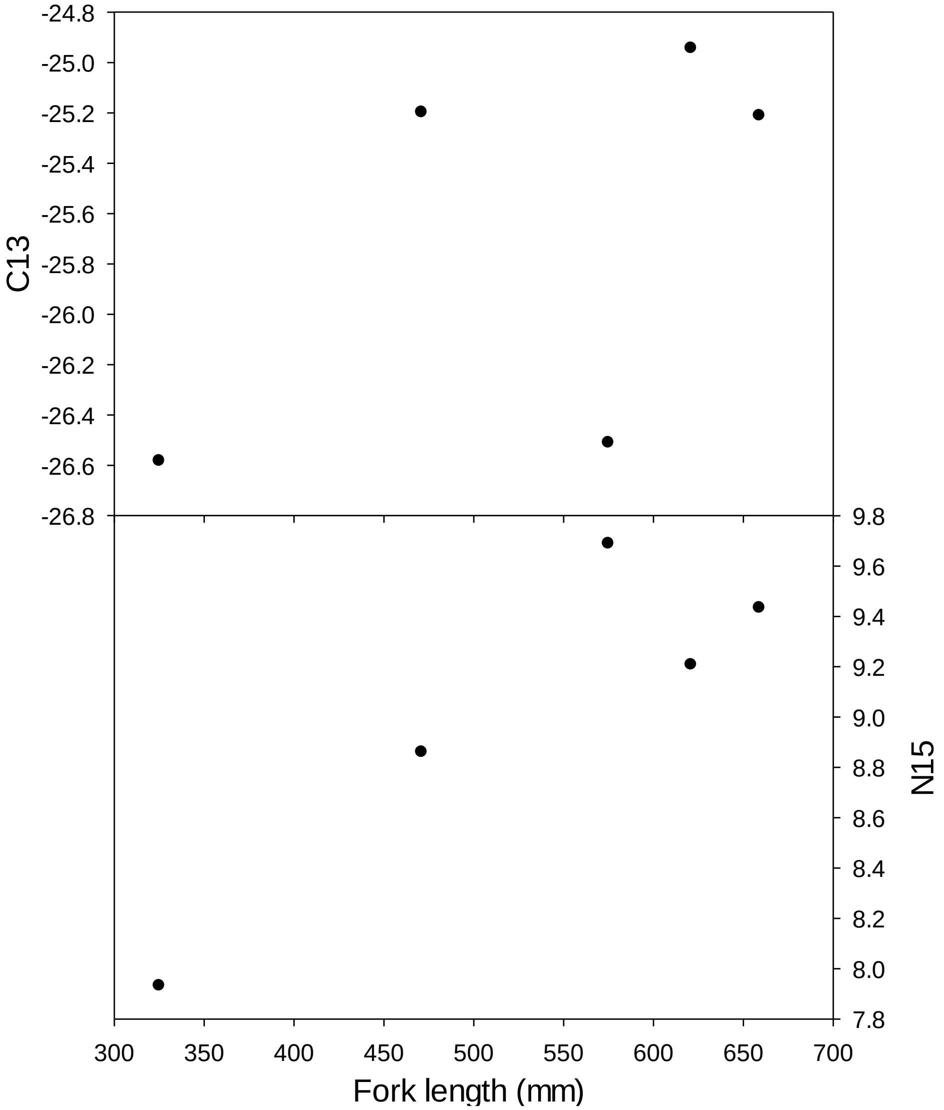


Figure 34. $\delta^{13}C$ and $\delta^{15}N$ versus fork length for cutthroat trout in Yale Lake.

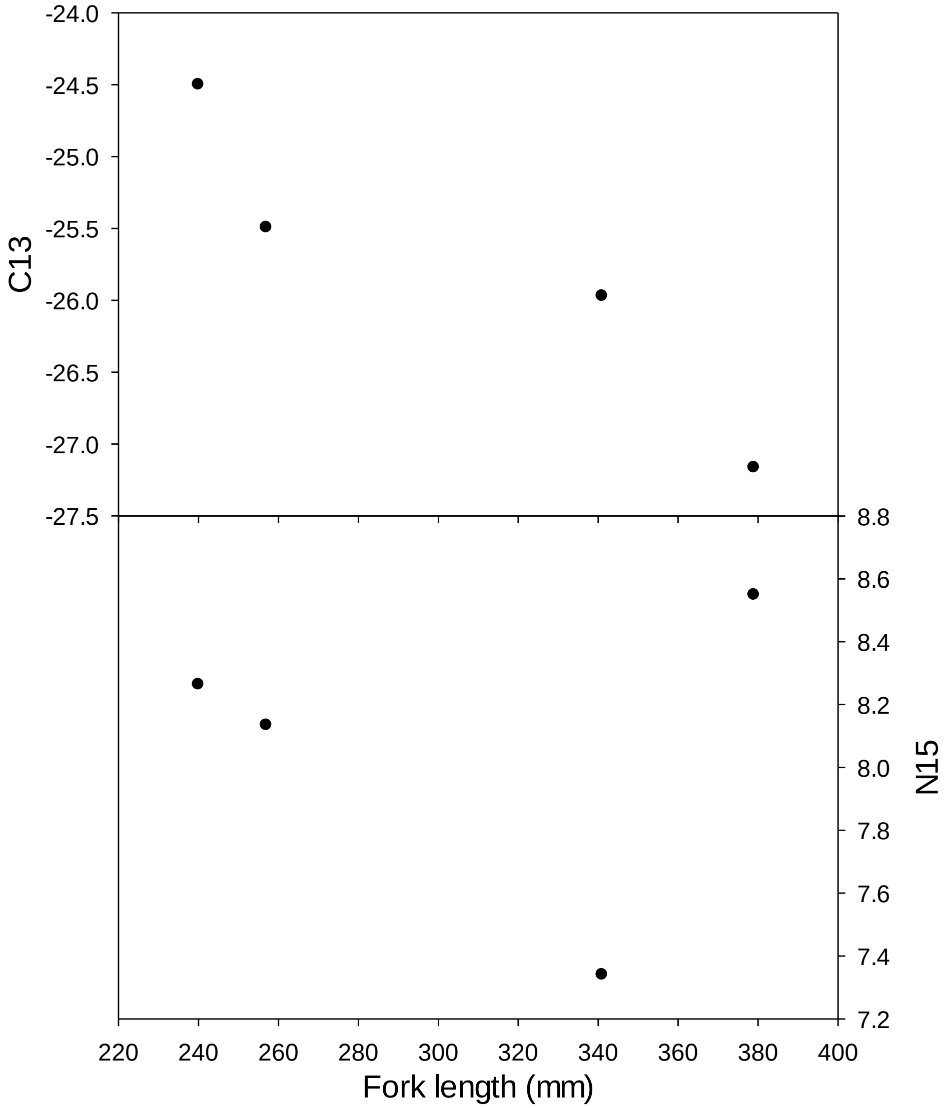


Figure 35. $\delta^{13}C$ and $\delta^{15}N$ versus fork length for Kokanee in Yale Lake.

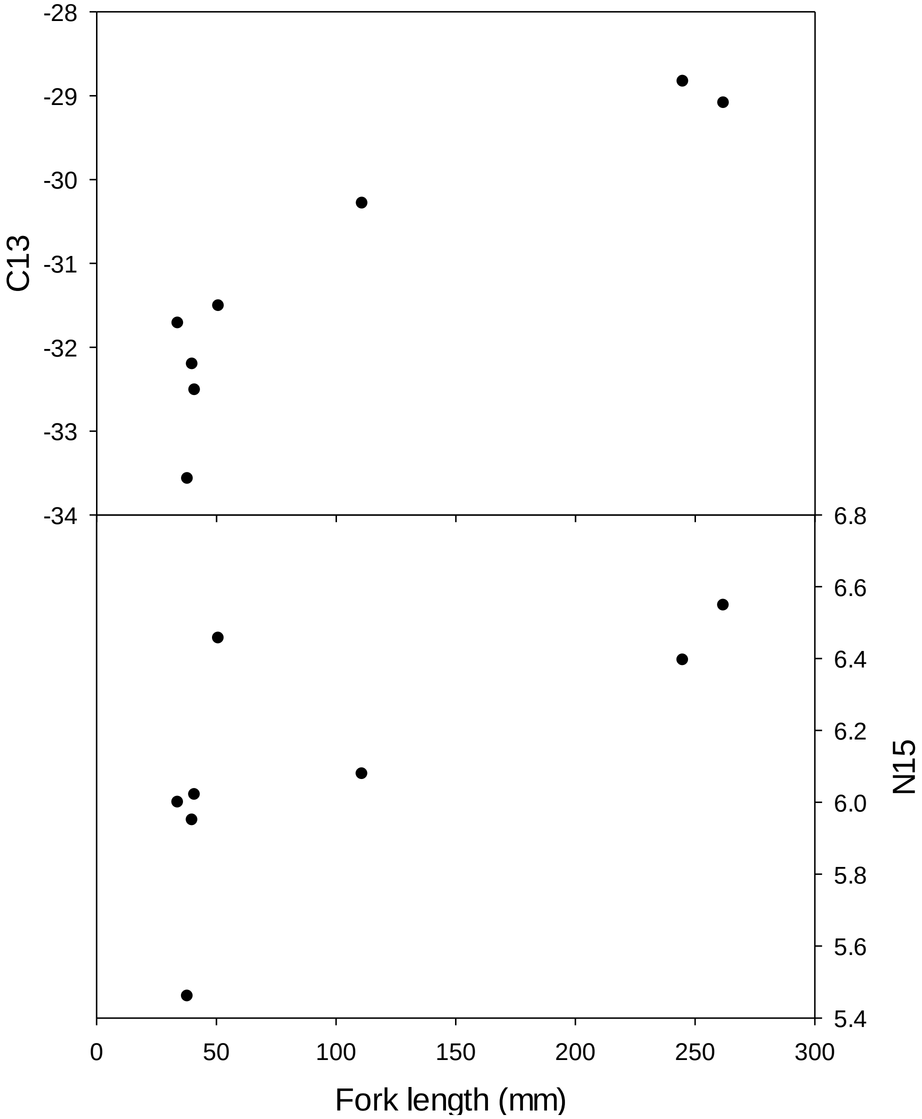


Figure 36. $\delta^{13}C$ and $\delta^{15}N$ versus fork length for Northern Pikeminnow in Yale Lake.

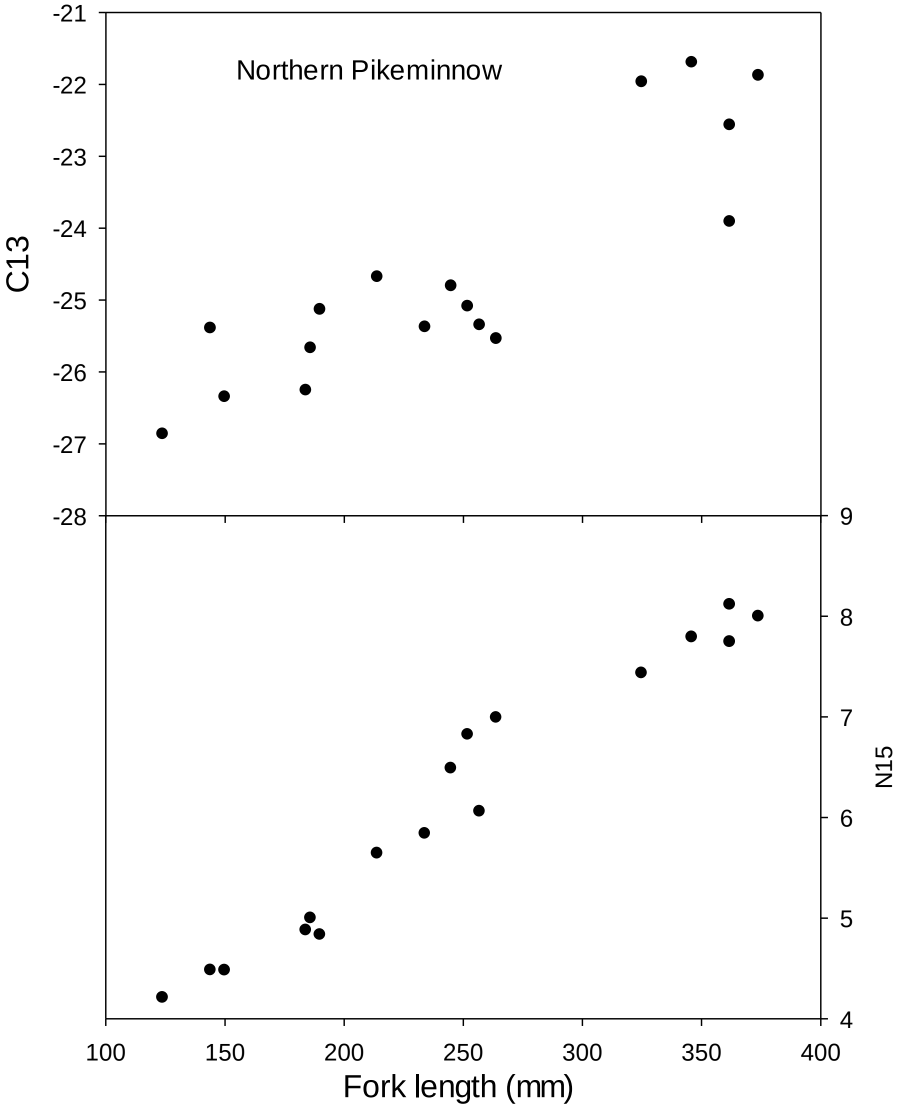


Figure 37. δ^{13}C versus δ^{15}N for the species and size classes sampled in Yale Lake. NPM = Northern Pikeminnow; LSS = Largescale Sucker; and RBT = Rainbow Trout. Size class (fork length) is in parenthesis.

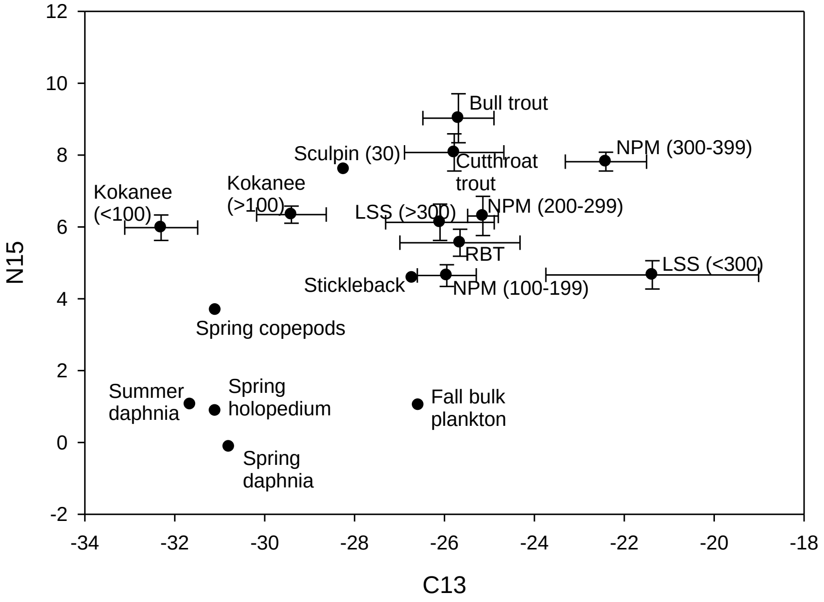


Figure 38. δ^{13}C and δ^{15}N versus fork length for kokanee in Lake Merwin.

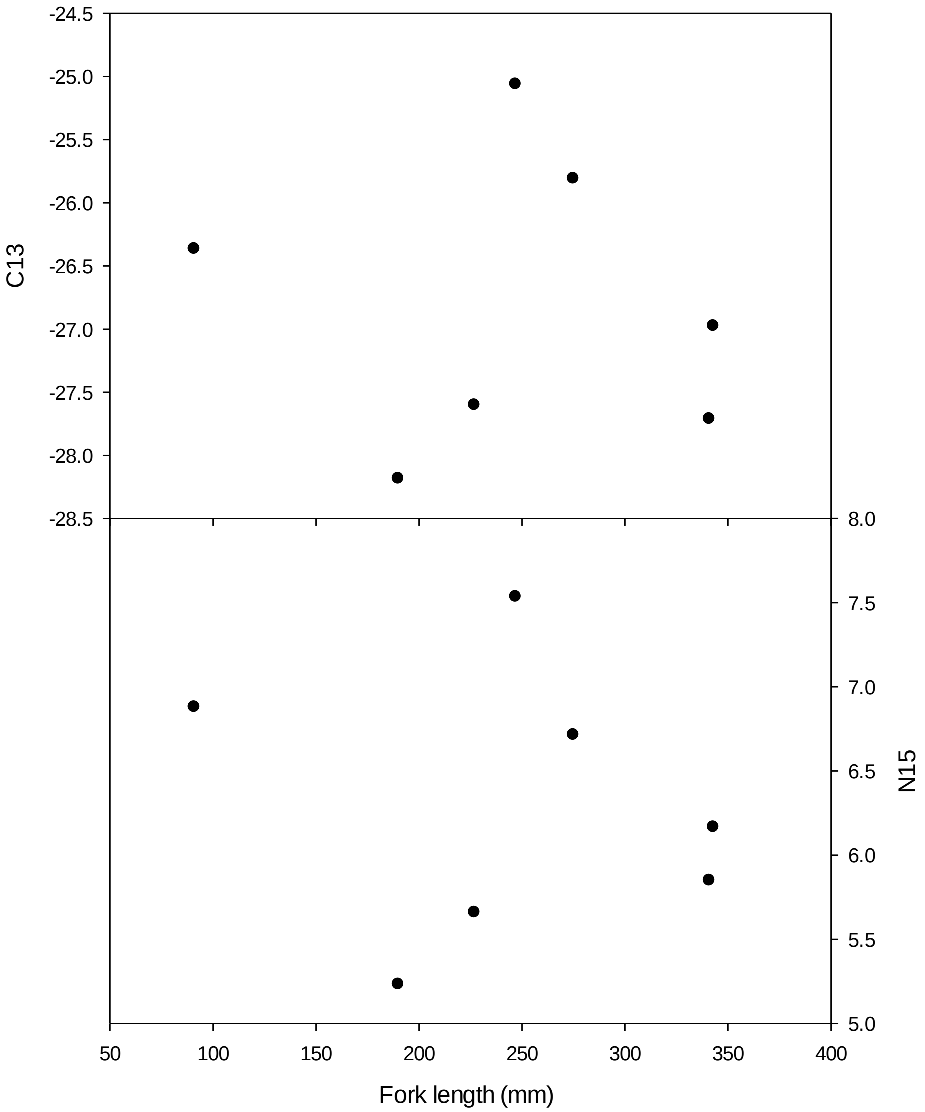


Figure 39. $\delta^{13}C$ and $\delta^{15}N$ versus fork length for Rainbow Trout in Lake Merwin. The highly enriched signal of both isotopes is the result of residual hatchery feed values, with the largest fish requiring more time to turnover their tissue to lose the hatchery values.

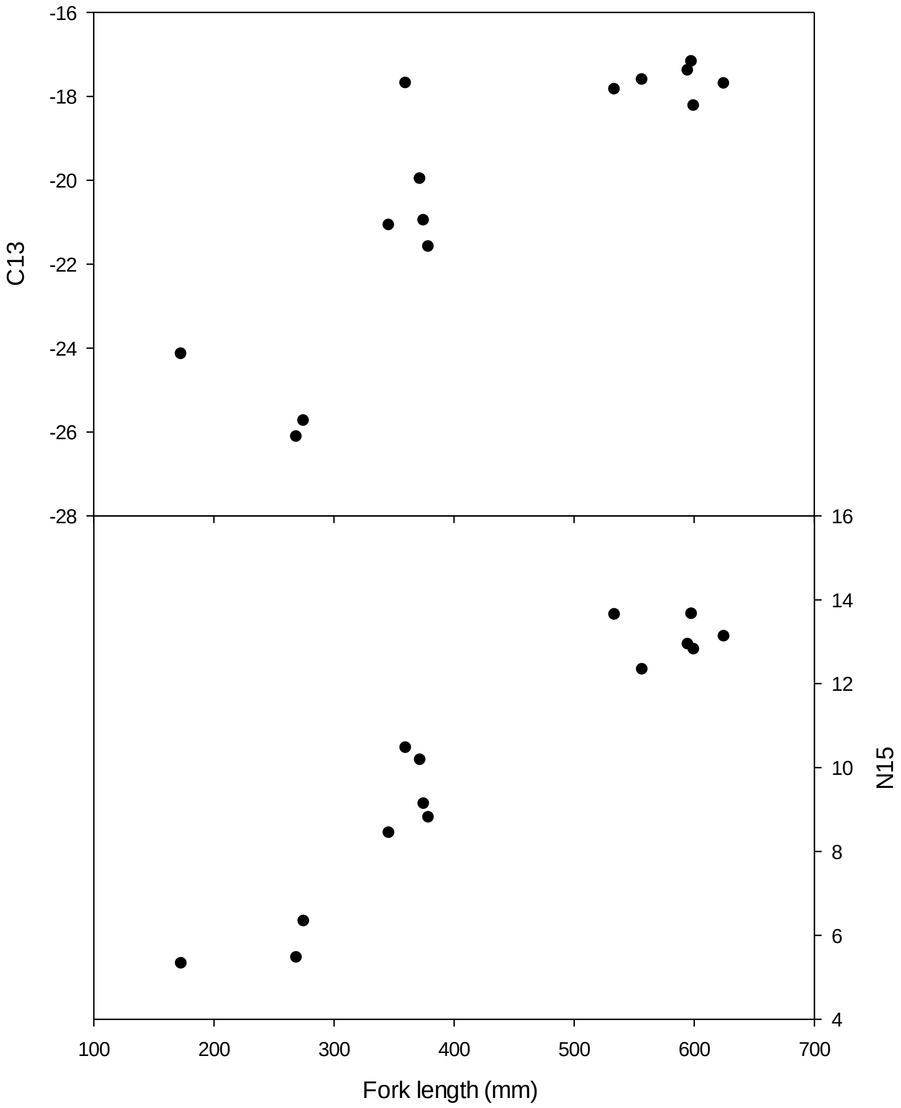
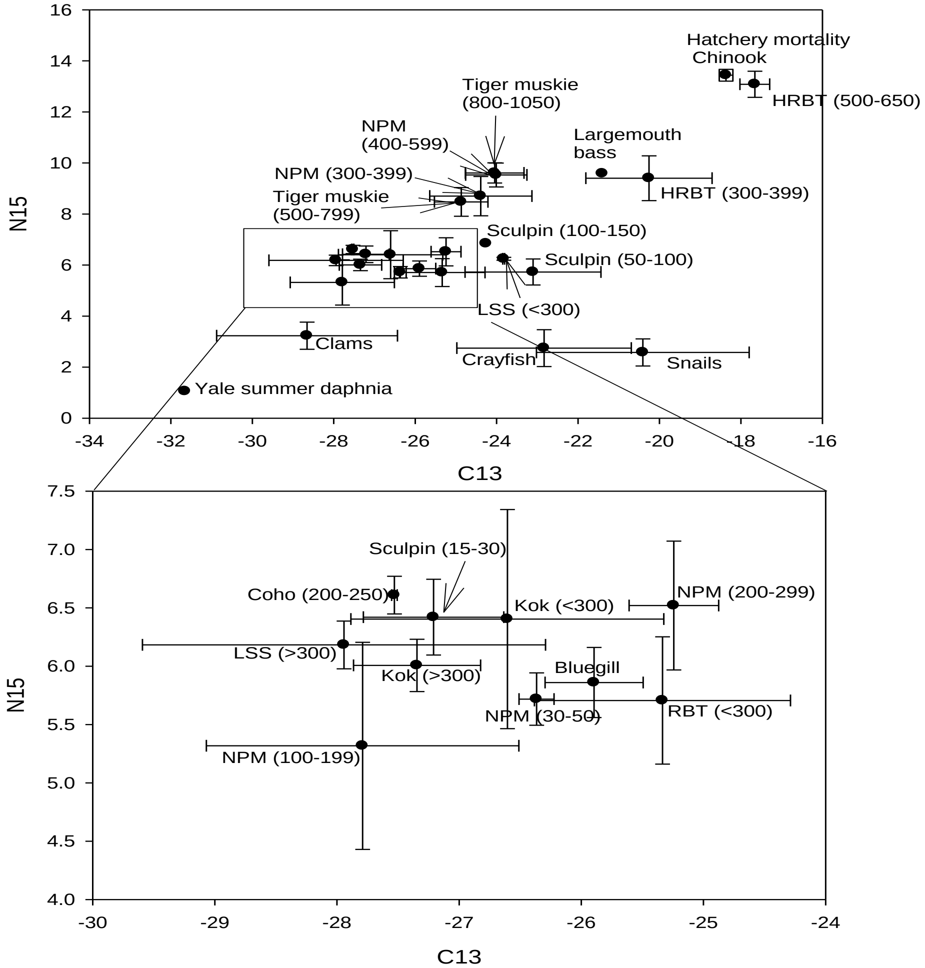


Figure 40. δ^{13}C versus δ^{15}N for the species and size classes sampled in Lake Merwin. Size class or fork length is in parenthesis. HRBT = hatchery Rainbow Trout; NPM = Northern Pikeminnow; LSS = Largescale Sucker; Kok = Kokanee; and RBT = Rainbow Trout. The densely clustered data points in the upper panel are expanded and labeled in the lower panel. The isotope values of large rainbow trout were highly similar to Chinook taken directly from the hatchery. The top predators in the lake appear to be Tiger Muskie greater than 800 mm and Northern Pikeminnow greater than 400 mm.



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