

Progress Report February 19, 2007

Title: Lake Chelan Fisheries
Sub-title: Modeling Food Web Processes in Lake Chelan
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Field sampling was conducted in Lake Chelan between August 2004 and August 2006. The lake is composed of two primary basins: the upper Lucerne basin is longer, deeper, steeper, and more remote, whereas the lower Wapato basin is shallower, wider, and surface waters are warmer during summer stratification (**Figures 1, 2**). Field sampling included intensive gillnetting, hydroacoustic, and limnological sampling activities. Gill net sets were stratified by lake basin and depth (above thermocline, within thermocline, and two depth intervals below the thermocline) with replicate sites sampled within each basin. Zooplankton and mysid shrimp were sampled at replicate sites with vertical hauls from 0-80 m depth. Distribution, diet, size and growth data for key fish species, and vertical temperature profiles, zooplankton density, and mysid density data were collected seasonally during the following sampling periods: summer (August and September 2004, August 2005), autumn (November 2004, 2005), winter (February 2005, 2006), and spring (May 2005, 2006). Supplemental zooplankton, mysid, and hydroacoustic sampling was conducted during June, July, and August 2006 to capture density and distribution changes of kokanee, mysids, and zooplankton on a finer timescale during the summer. During these supplemental periods, additional zooplankton samples were collected from the epilimnion (e.g. 0-30 m) in addition to the standardized (0-80 m) samples to quantify vertical distribution patterns. Fish and invertebrate tissue samples for stable isotope analysis have been dried, ground, homogenized, and weighed, and a subset of samples have been analyzed. The stable isotope signatures for nitrogen and carbon will provide an important supplement to the diet analysis by providing an integrative picture of trophic position (i.e., level of piscivory) and energy pathways (i.e., degree of reliance on benthic or pelagic prey) of key species and life stages in the lake.

Hydroacoustic surveys have been conducted during each season to determine the vertical distribution of pelagic fishes along the long-axis of the lake, and summer hydroacoustic surveys have been designed to estimate abundance of pelagic fishes (assumed to be primarily kokanee). This assumption was supported by focused deployment of mid-water gill nets and larger “curtain” gill nets in the pelagic zone, which yielded catches composed almost exclusively of kokanee.

Standardized gill net sampling yielded good sample sizes for a range of size classes of lake trout, northern pikeminnow, burbot, peamouth, largescale suckers, and hatchery-origin cutthroat trout (**Figure 3**). Small numbers of smallmouth bass, rainbow trout, Chinook salmon, and wild cutthroat trout were also captured in gill nets. Kokanee were collected during late spring by angling, and additional kokanee head and stomach samples were donated by local charter guides and recreational anglers. Kokanee were also captured in midwater and “curtain” gill nets, including valuable samples of fish too small to be caught by anglers.

The Washington Department of Fish and Wildlife collaborated by electrofishing shore zone regions in the Wapato Basin for two nights in August 2004. These efforts provided essential sampling for bass and other warm water fishes that were less vulnerable to capture by gill nets. Their catch data have been provided, and stomach samples have been stored for diet analysis.

Diet analysis is substantially complete, with over 1500 stomach samples analyzed for the species listed above, with special emphasis on lake trout and other piscivores (**Figure 4**). Preliminary stable isotope data have been analyzed and preparation of additional samples is underway. Zooplankton and mysid samples have been counted and individual lengths and egg-to-female ratios have been recorded. Zooplankton standing stock biomass and production rates have been calculated for each basin, during each season. Seasonal consumption demand by the mysid population has been estimated for each basin (**Figure 5**). We are currently analyzing hydroacoustic data and age and growth samples for key fish species. Bioenergetics modeling of key fish species will be conducted once those data become available.

The next step will be to use the bioenergetics model to estimate monthly-seasonal consumption rates by individuals from each size class of the key fish species, then use observed or reconstructed size structures of the species to determine “unit population-level” consumption rates on major prey species. These predation demand estimates will be compared to estimates of prey availability for kokanee, lake trout, Chinook, etc. on a seasonal basis in each basin of the lake, and will determine the predation rates imposed on prey species for use in balancing stocking strategies and species recovery efforts and other management actions with ecological constraints in the basin.

Significant financial and in-kind support has been contributed by some parties, whereas other needed support is still pending. The University of Washington School of Aquatic and Fisheries Sciences provided Erik Schoen with a 2-year graduate stipend to support his thesis research, and NPS/USGS NRPP grant represent the core funding for this project. WDFW provided electrofishing sampling as described above, and access to freezer space at the Lake Chelan Fish Hatchery during sampling trips. U.S. Forest Service provided a warehouse for an essential indoor staging and processing area. The Lake Chelan Sportsman’s Association provided lodging, funding, valuable local knowledge, and supplemental samples of kokanee, Chinook salmon, and lake trout. The National Park Service provided lodging at Stehekin. Washington State Parks and the City of Manson Parks Dept. provided free camping and boat launch facilities. The Chelan PUD funds could not legally be released during the first 2 ½ years of the study, so an important source of supplemental support for UW and WDFW involvement has not been available to date. It will be essential to utilize these funds during the coming year if we are to complete the project goals.

We propose these follow-up analyses to refine and apply the data currently in-hand to address the primary project questions:

- 1. Develop visual foraging models to estimate consumption of pelagic prey by lake trout and Chinook salmon under varying scenarios of predator and prey density and distribution.** The existing dataset and bioenergetics models parameterized during this study will allow a detailed analysis of current interactions in the Lake Chelan food web and the processes that limit focal species. However, if conditions such as prey or predator density change in the future, fish might change their behavior to adjust to those changes. Visual foraging models allow prediction of the behavior of cruising predators like lake trout and Chinook salmon feeding on pelagic prey. While field data and bioenergetics models allow us to answer questions like “How many kokanee does a lake trout consume in each season?” visual foraging models can predict how many kokanee would be consumed if the density or distribution of predators or prey were to change in the future. The ability to estimate changing predator-prey interactions under a range of scenarios is clearly desirable for managers, making foraging models a valuable extension of the existing project. Visual foraging models for lake trout and cutthroat trout have been developed and applied to several large western lake systems (Beauchamp et al. 1999; Mazur and Beauchamp 2003, 2006), and can be adapted to Lake Chelan using existing field data on light penetration, turbidity, and diel hydroacoustic surveys. No such model currently exists for Chinook salmon, but published analyses of Chinook foraging behavior in other systems could allow development of a model to estimate Chinook predation within reasonable bounds. Since little or no additional field sampling or lab work would be required, development of these models represents a high-value supplement to the current study for relatively little additional cost.
- 2. Test fish stocking strategies to determine which techniques allow for the least number of newly stocked fish to be lost to predation.** A pilot study during May 2005 suggested that lake trout eat a substantial proportion of kokanee stocked into Lake Chelan during the first ten days after stocking. A variety of techniques could potentially mitigate these predation losses, including stocking at night, stocking at different locations, or stocking larger fish. To maximize the cost-effectiveness of future stocking efforts, these or other alternative stocking techniques could be evaluated by intensively sampling predators with gill nets during and after stocking trials, in close coordination with the Lake Chelan Fish Hatchery. Diet analysis of captured predators would indicate the intensity of predation and the duration and spatial extent of the predator response. Bioenergetics models using these data could estimate the number of stocked fish consumed by predators following each stocking trial.
- 3. Improve existing diet data by**
 - **Identifying salmonid prey found in predator stomachs to species level using genetic analysis.** Although prey items have already been identified to species level when possible using bone keys, only approximately half of

salmonid prey specimens (n = 19) could be identified to the species level because of similarities in bone structure among species. Species identity of prey is extremely important, especially to determine the vulnerability of species of interest such as westslope cutthroat trout, Chinook salmon, and kokanee to predation. Thus, refining diet data to the species level represents a significant improvement to the existing dataset, and is available for low cost relative to the high initial expense of field sampling and stomach analysis. Collaborators at UW have previously used genetic techniques to identify salmonid prey from Flathead Lake with high success.

- **Analyzing stomach samples of warm water fish collected by WDFW.** Approximately 200 stomach samples were collected from Wapato Basin fish during summer 2004 by electrofishing and gill netting by WDFW. These include samples from species poorly represented in systematic gill net catches during the current study, including smallmouth bass (n = 66) and rainbow trout (n = 25). Further, many of the WDFW samples were collected from the shallow area within 5 km of the lake outlet, an area not extensively sampled during the current study and with potential to exhibit different trophic dynamics from other lake areas. These samples have not yet been analyzed, and could provide a valuable supplement to existing diet data.

We also suggest the following action by the lake managers:

Begin collecting data necessary to track lake trout population and demographic trends in Wapato Basin. Lake trout have become a major predator in Lake Chelan, with the potential to limit populations of other salmonids including kokanee, westslope cutthroat trout, and Chinook salmon. The seasonal, size-specific diet and distribution of lake trout have been determined in the present study, and age and growth analysis are underway. However, since hydroacoustics and gill net sampling cannot accurately measure lake trout abundance, an important piece of the puzzle is missing. We propose that the fishery managers ask lake trout charter guides to keep log books to record daily catch, effort (e.g. number of lines fished per day by depth), and length and weight of each lake trout caught in the Wapato Basin. Since four guides are responsible for the vast majority of lake trout caught in the lake, their catch records represent a potentially consistent and high-quality data source. Virtually all lake trout harvest effort occurs in the Wapato Basin (and the first few miles of Lucerne Basin north of the Narrows) so these data would be limited to this area; however, lake trout densities appear to be much greater in the Wapato Basin so lake trout are expected to have the greatest impact on other species in this area. These data, after being recorded over a number of years, would allow managers to monitor trends in the lake trout population and estimate reproductive, survival, and other vital rates. If more intensive future research (e.g. a mark-recapture study) accurately estimates the absolute size of the lake trout population, the catch-per-unit-effort data series could be used to back-calculate the population size during previous years. This type of logbook program and even a mark-recapture program were highly successful in Lake Tahoe, California-Nevada.

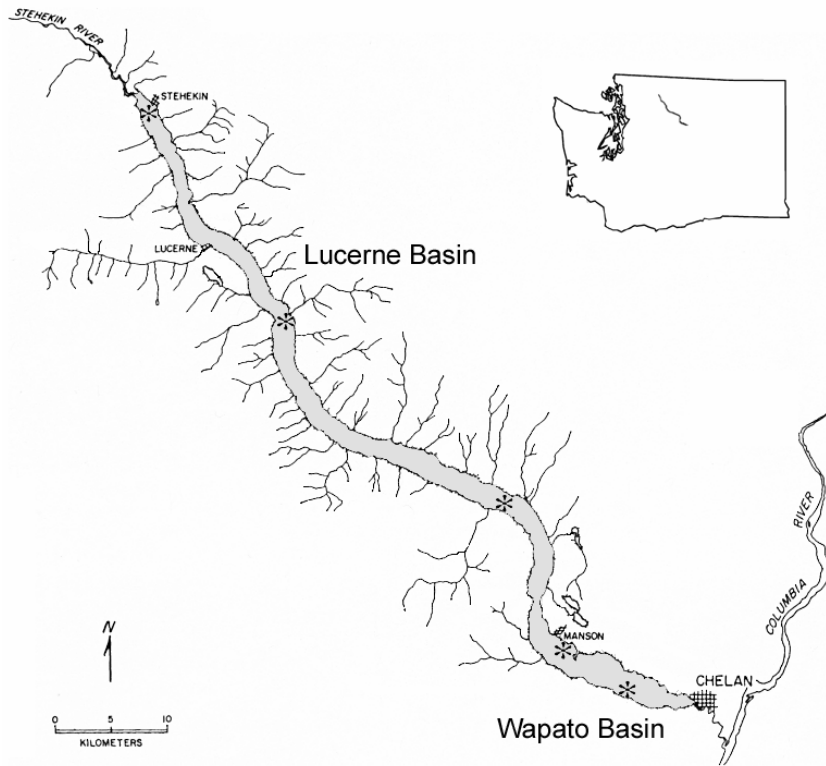


Figure 1. Map of Lake Chelan showing the two lake basins and principal sampling sites (stars). The inset shows the lake's location in the Cascade Range of Washington.

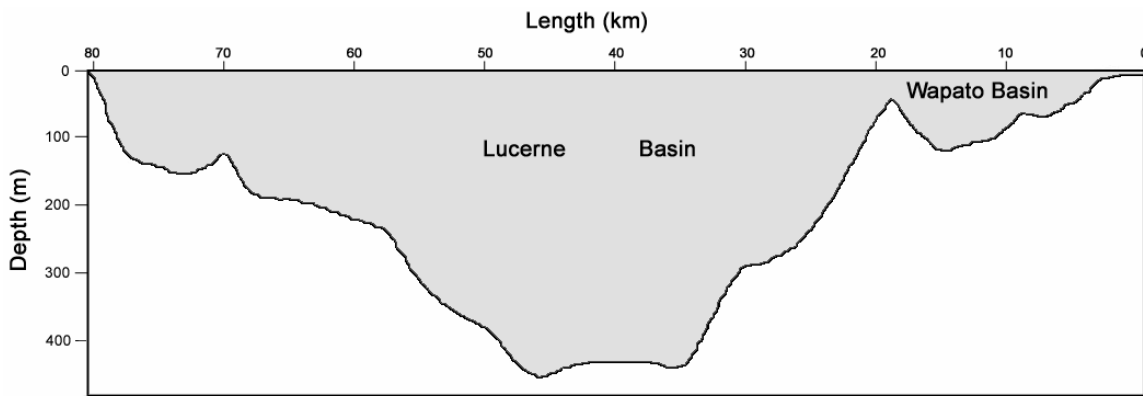


Figure 2. Longitudinal profile of bathymetry of Lake Chelan, with exaggerated vertical axis (modified from Kendra and Singleton 1987). Horizontal dimension represents distance from lake outlet along primary axis of lake.

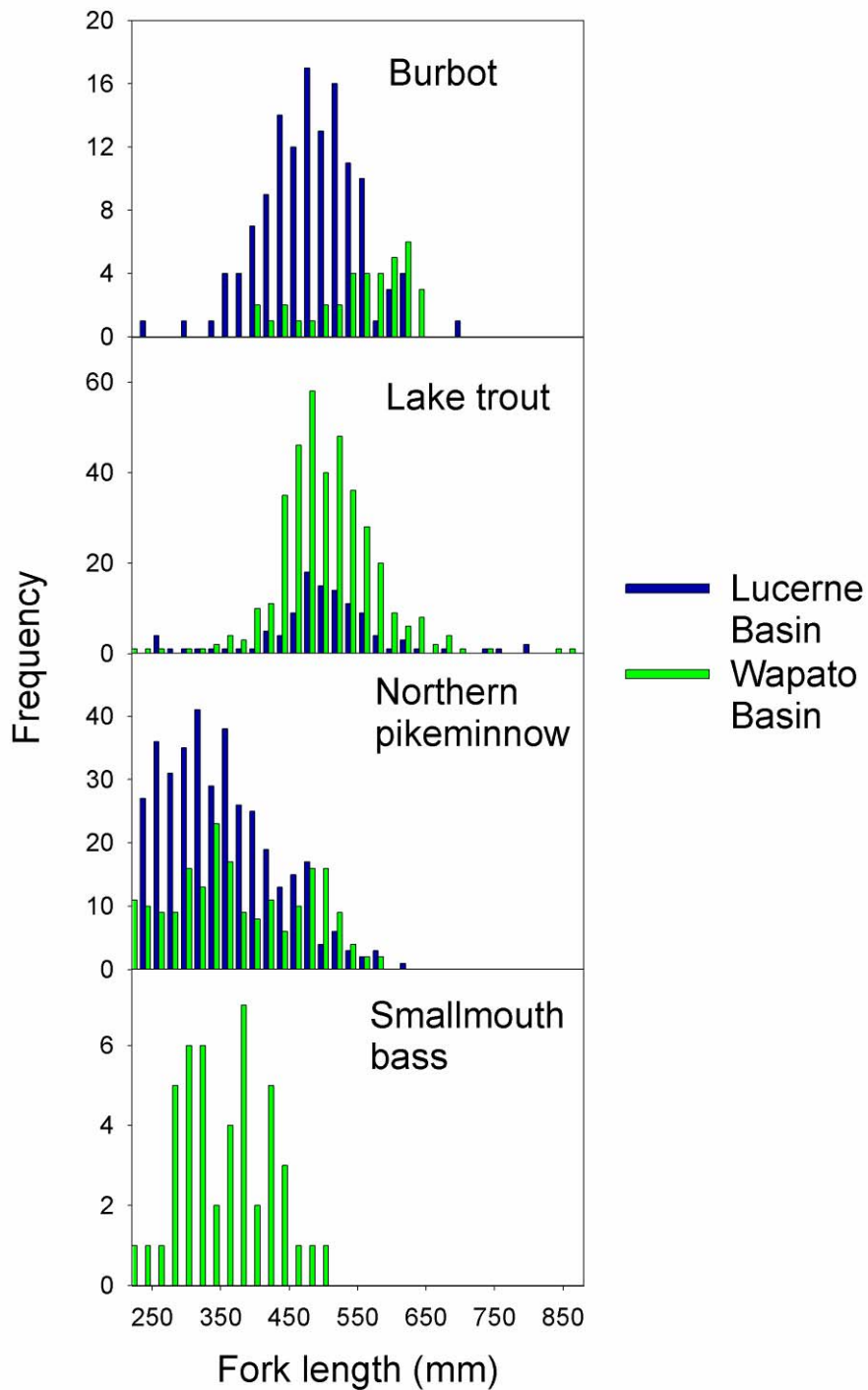


Figure 3. Length-frequency histograms for primary piscivorous fish species captured in gill nets in Lake Chelan, stratified by lake basin. Only fish greater than 220 mm in length are included in this figure because processing is not yet complete on smaller fish, and 220 mm marks the approximate onset of piscivory in northern pikeminnow, the only piscivore for which substantial numbers of small individuals were captured. Length measurements for burbot are total length. Smallmouth bass were captured only in the Wapato Basin. NOTE: Since sampling effort was approximately 3 times higher in the Lucerne Basin, this figure should not be interpreted to indicate relative abundance of species between basins.

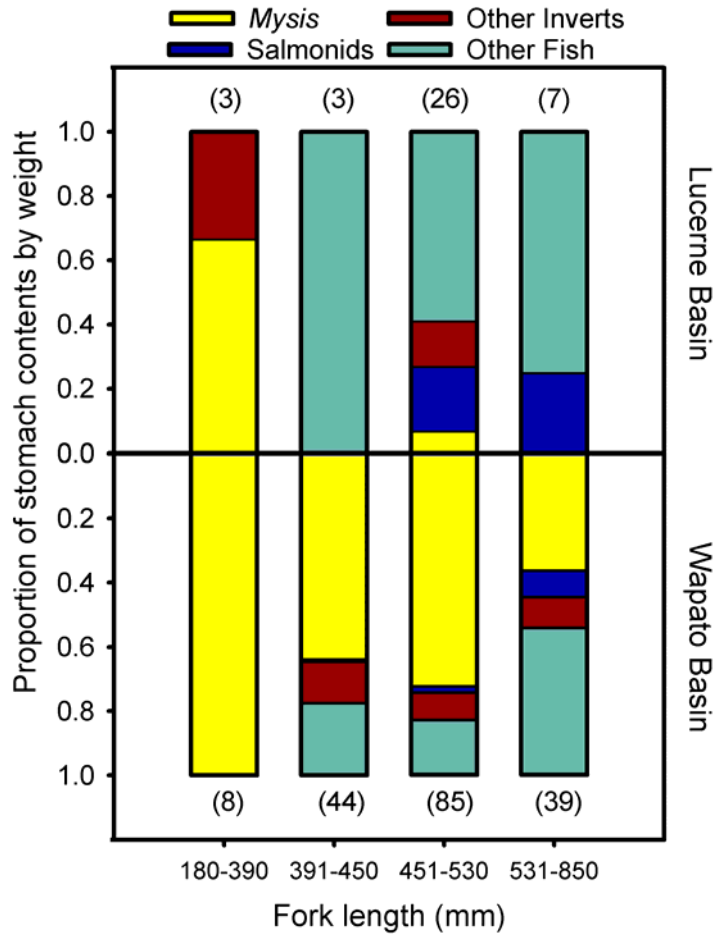


Figure 4. Annual mean lake trout diet content. Lake trout ate primarily cyprinid prey in Lucerne Basin, with the exception of the smallest size-class, which ate mostly mysids. In Wapato Basin, all size classes ate substantial amounts of mysids. Lake trout larger than 450 mm ate salmonid prey, primarily kokanee, in both basins. Most predation on salmonids occurred during spring. Sample sizes are indicated in parentheses. NOTE: Seasonal diet contents were recorded to the finest taxonomic level possible and were combined into broad categories for this overview figure.

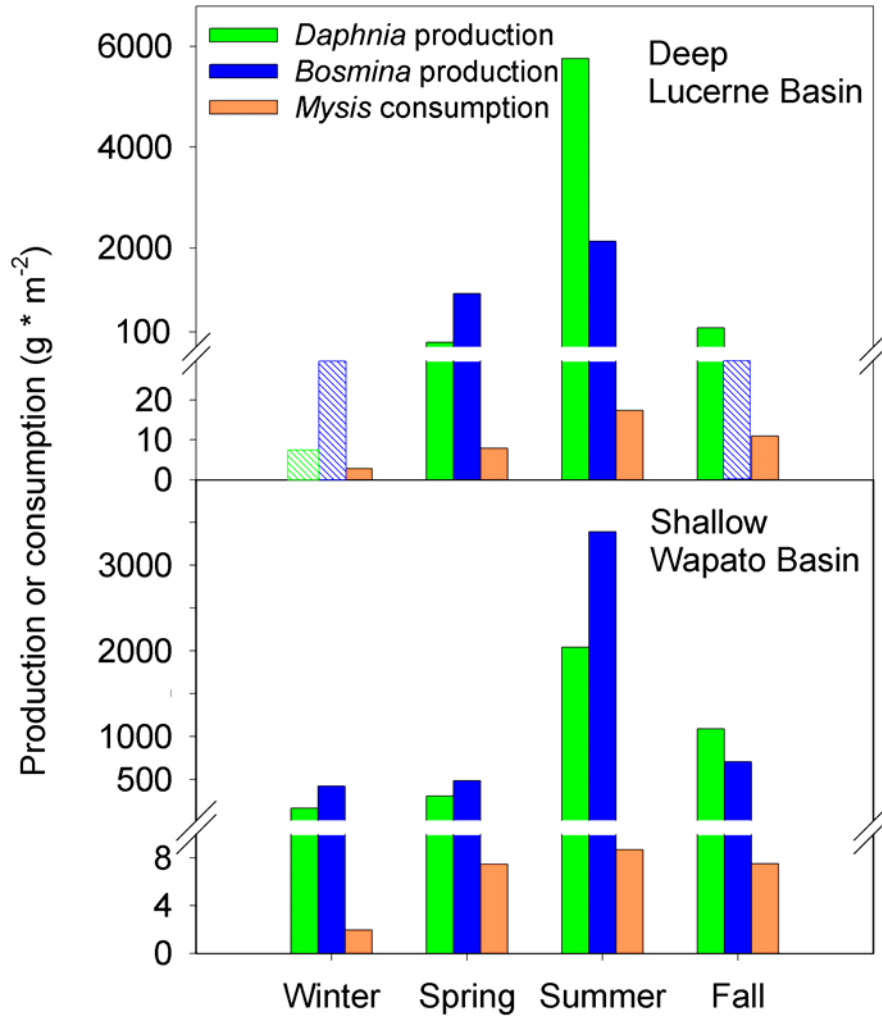


Figure 5. Cladoceran production greatly exceeded estimated *Mysis* population-level consumption during spring, summer, and fall in Lucerne Basin and during all seasons in Wapato Basin. In Lucerne Basin, *Daphnia* and *Bosmina* production rates were near zero during winter, and *Bosmina* production rates were near zero during fall. During these periods, hashed bars indicate standing stock biomass of cladoceran taxa ($\text{g} \cdot \text{m}^{-2}$). Kokanee consumption of zooplankton will be added to this figure as data become available. These results suggest that *Mysis* consumption does not limit cladoceran zooplankton in the Wapato Basin, but that *Mysis* may limit availability of cladocerans in Lucerne Basin during winter, and this period deserves further study in terms of implications for kokanee.