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LIFE-HISTORY CHARACTERISTICS OF JUVENILE SPRING CHINOOK SALMON REARING IN WILLAMETTE VALLEY RESERVOIRS

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Executive Summary

We investigated life-history characteristics of juvenile Chinook salmon rearing in Cougar and Lookout Point reservoirs. The study objectives were to provide information on juvenile Chinook salmon distribution, relative growth rate, predator/prey interactions, and other population characteristics. In addition, we tested the feasibility of various gear-types and techniques for sampling juvenile Chinook salmon rearing in a reservoir environment. A variety of techniques were necessary to capture juvenile Chinook salmon as reservoir conditions and fish behavior, size, and distribution within the reservoir changed throughout the year. Nighttime snorkel surveys were the least invasive and most productive method to investigate habitat utilization and fry distribution early in the Spring. Minnow traps, hoop nets, Lampara seining, and mid-water trawling were largely ineffective at sampling fry and larger-sized juveniles. Oneida Lake trap nets were the most effective at capturing larger-sized juvenile Chinook salmon when reservoir surface temperatures remained cool.

Chinook salmon fry were observed during snorkel surveys in shallow nearshore habitat in the reservoirs. Fry abundance in Cougar Reservoir tended to be greatest near the head of the reservoir where the South Fork McKenzie River enters. Similar distribution trends were observed in Lookout Point Reservoir although fewer fry were observed. However, in Lookout Point Reservoir, the head of the reservoir shifted upstream during the reservoir refill period, further complicating interpretation of results. We were unable to detect a significant difference in fry abundance between habitat types during night snorkeling at Cougar Reservoir, although power of tests were low due to small sample sizes. Yearling Chinook salmon were often observed in the same areas as the fry during snorkel surveys.

Subyearlings continued to be more abundant in the upper portion of the reservoir in June. By July catch rates of subyearlings and yearlings in surface-oriented gear decreased, indicating that juvenile Chinook salmon descend to greater depths as reservoir surface temperatures increase in the summer. Information on subyearling and yearling summer distribution was difficult to assess due to the apparent habitat shift, and the associated inaccessibility of Chinook salmon at these depths to most of the gear types that we deployed. There was some evidence that yearling Chinook salmon were more abundant in the lower third of Lookout Point Reservoir, in closer proximity to the dam. Although too few yearlings were captured to allow for statistical tests of abundance by reservoir section, all nine subyearlings caught in Oneida Lake traps were from sets in the lower section of the reservoir. In addition, six of the eight yearlings caught during randomized hook-and-line sampling transects were also in the lower reservoir section.

Juveniles PIT tagged in the reservoir were detected at sites below the dam. Subyearlings were detected at a 6.0% rate while yearlings were detected at a 0.6% rate. This suggests that there may be some size specific mortality associated with dam passage, or a diminished smolting behavior expressed by yearlings that reside in the reservoir for an additional summer. All downstream detections occurred in late fall and early winter

during the reservoir drawdown, as the reservoir was nearing “low pool” elevation. We estimated that approximately 64% of the subyearling cohort exited the reservoir.

Reservoir-rearing subyearlings grew faster throughout the season when compared to their stream rearing counterparts. By the end of the year, reservoir-reared subyearlings were approximately 30 mm larger than fish rearing the entire season (April-Dec) in the upper South Fork McKenzie.

Predation risk from piscivorous fish was greater for juvenile Chinook salmon rearing in Lookout Point Reservoir compared to Cougar Reservoir. Cougar Reservoir was host to five piscivorous fish species capable of eating juvenile Chinook salmon, only one of which was non-native (bass). Predators included bull trout, cutthroat trout, rainbow trout, sculpin, and black bass. Lookout Point Reservoir contained eight piscivorous species, four of which were non-native. Piscivorous species included northern pikeminnow, cutthroat and rainbow trout, sculpin, walleye, white crappie, black crappie, and black bass. Northern pikeminnow were abundant in Lookout Point Reservoir and are capable of preying on juvenile Chinook for the entire duration of reservoir residence.

Diet samples from predatory fish were collected primarily at the end of September when surface water temperatures in both reservoirs were elevated. Diet analysis results indicated that juvenile Chinook salmon did not comprise a substantial portion of the diet of surface-orientated piscivorous fish during the late summer period. Reasons for this could be: 1) Chinook salmon are large enough to evade predators; 2) alternate food sources are abundant elsewhere in the reservoir and occur in an area with temperatures more conducive to their preferred temperature range; and 3) due to the limitations of sampling gear, we were unable to collect adequate diet samples from predators residing at depth where they may have been feeding on Chinook salmon. Zooplankton, primarily daphnia, was abundant in the diet samples collected from Cougar Reservoir. Young of the year crappie were prevalent in samples collected from Lookout Point Reservoir.

Introduction

The National Marine Fisheries Service concluded in the 2008 Willamette Project Biological Opinion (BiOp) that the continued operation and maintenance of the Willamette Valley Project (WVP) would jeopardize the existence of Upper Willamette River spring Chinook salmon (*Oncorhynchus tshawytscha*) and Upper Willamette River steelhead (*O. mykiss*) (NMFS 2008). The BiOp concluded that lack of fish passage through WVP dams and reservoirs has one of the most significant adverse effects on both species and their habitat. Several Reasonable and Prudent Alternatives (RPA) to the action agencies' proposed actions were identified in the BiOp to address downstream fish passage concerns, notably, head-of-reservoir juvenile collection facilities (RPA 4.9) and modification to operation flows to improve conveyance of juvenile fish through the reservoirs (RPA 2.8; 4.8; 4.8.1; 4.9; 4.10). The feasibility of any of these proposed measures is contingent upon a baseline understanding of how juvenile fish use reservoir habitat. Critical information is needed to determine the feasibility of implementing these RPAs. Currently there is little information regarding juvenile Chinook salmon use of reservoirs, including life stage-specific entrance timing, abundance, distribution, migration rate, predator/prey interactions, and growth rates among other population characteristics.

A majority of juvenile Chinook salmon enter WVP reservoirs as fry. Studies conducted on Fall Creek and the North Fork Middle Fork Willamette River showed that a majority of juvenile spring Chinook salmon entered the reservoir at the fry life-history stage (Greg Taylor, USACE, personal comm.). Limited trapping data in 2009 from the South Fork McKenzie River above Cougar Reservoir indicated a similar pattern (Mike Hogansen, ODFW, personal comm.). Although there is evidence that fry migrate into reservoirs during spring, little is known about their habitat use or distribution within reservoirs.

Tabor et al. (2007) found fall Chinook salmon fry were more abundant in Lake Washington near their natal stream in early spring but became more dispersed in the lake by late spring. Fry used shallow (<1 m) littoral habitat upon entering the lake system and only ventured into deeper waters as their size increased. This pattern has been observed in numerous studies in lotic environments (e.g., Lister and Genoe 1970; Dauble et al. 1989), including the lower Willamette River (Friesen et al. 2007). Water temperatures may also contribute to habitat shifts in reservoirs. Ingram and Korn (1969) showed that most juvenile Chinook salmon from Cougar Reservoir captured with gill nets were in the upper 30 feet of the water column during late spring. By summer, as surface temperatures increased, catches were greatest at 30-45 foot depth range. In November when surface temperatures cooled, most juvenile Chinook salmon were captured in the upper 15 feet of the water column.

The degree to which predation affects juvenile Chinook salmon in the WVP reservoirs is unknown. Numerous predatory fish species occur in WVP reservoirs including northern pikeminnow (*Ptychocheilus oregonensis*), bull trout (*Salvelinus confluentus*), and exotics such as smallmouth bass (*Micropterus dolomieu*), and walleye

(*Sander vitreus*). The impact of predatory fish on juvenile Chinook salmon depends on predator abundance, size (mouth gape), distribution in relation to juveniles (spatial and temporal overlap), and growth rates of juvenile Chinook salmon. The negative effects of reservoir residency in terms of delayed migration and increased predation risk may be offset by superior growth rates that could impart a greater survival advantage to adulthood compared to stream-rearing juveniles. To determine potential impact of predation risks and general community structure for each reservoir two aspects of predation within Cougar and Lookout Point reservoirs were addressed during the 2010 field season: 1) species composition and distribution of predators, and 2) diet composition of piscivorous fish during late summer sampling (September).

In 2010 we initiated a pilot study to determine the current community structure and relative abundance of fish species within Cougar and Lookout Point reservoirs. Identifying community structure is the first step in understanding the dynamics of predator/prey relationships. We used Oneida Lake traps (hereafter referred to as Oneida traps) and hook and line sampling to gather information regarding fish community, predatory fish and their diet. This information was required to determine the potential threat to juvenile Chinook salmon rearing in or passing through the reservoirs.

In this study we investigated the distribution, dispersion, relative growth rate, and predation risks of juvenile Chinook salmon rearing in Cougar and Lookout Point reservoirs. Our objectives were to 1) characterize the distribution and habitat use throughout the residence time juvenile spring Chinook salmon are in the reservoirs, and 2) assess the relative risks and benefits of reservoir rearing by comparing growth rates between reservoir and stream rearing juveniles and by assessing the potential for predation in each reservoir. As part of the assessment of juvenile Chinook salmon distribution, we also tested the feasibility of various sampling techniques to non-lethally sample juvenile Chinook salmon in reservoirs.

Methods

This year (2010) was a pilot year for determining which gear types and sampling strategies best address study objectives. We used various sampling techniques reported in the literature to be effective at non-lethally sampling small fish in lakes and reservoirs. For fry (<60 mm fork length; FL), we used snorkel surveys, minnow traps, and beach seines. For larger juveniles we used Oneida traps, hoop nets, large beach seine, and hook-and-line techniques. Lampara seining and trawling were also conducted by the U.S. Geological Survey (USGS) to sample juveniles in the open, pelagic areas of Cougar Reservoir. Sampling gears and techniques evolved as reservoir condition and fish size and distribution changed throughout the season.

Sampling effort was alternated every other week between Lookout Point and Cougar reservoirs during the sampling season (April-November). Reservoir sampling in Cougar Reservoir was halted on October 8, due to inaccessibility of boat ramps when the reservoir water level was drawn down below 498.3 m in elevation. We discontinued reservoir sampling in Lookout Point on November 16 because of decreased catch rates and focused efforts on winter smolt trapping.

Feasibility of various sampling techniques

An assessment for the feasibility of a variety of different gear-types and techniques was conducted as an ad-hoc comparison of catch per unit effort (CPUE) rather than formal experimental comparison tests. Direct comparisons were complicated by limitations in where certain gear types could be used (e.g. beach seining in relatively shallow, unobstructed areas) and by the fact that some gear was passive (Oneida traps, hoop nets, minnow traps) while others were active (beach seine, trawl, lampara seine, hook-and-line). Furthermore, we were adaptive in our selection of new techniques or gears to use as we gained knowledge of fish size and behavior from previously used gear. The result of these limitations was that not all gears were directly comparable in space and time. Catch per unit effort was measured in hours to standardize the various methods for comparison of effectiveness and feasibility. Our CPUE does not account for the volume or area sampled by each method but dimensions of nets are included for relative comparison.

Distribution of juvenile Chinook salmon in reservoirs

Sampling was conducted every other week in each reservoir to assess juvenile Chinook salmon distribution. For fry, snorkel surveys and minnow trapping were conducted at index sites. For larger juveniles, sites were selected using a stratified random sampling design. Reservoirs were stratified into lower, middle, and upper thirds (forebay to head of reservoir). Within each section random shoreline areas were selected for placement of traps or other gear.

Snorkel surveys- Nighttime snorkel surveys were conducted at index sites in Cougar Reservoir (Apr 28-May 12) and in Lookout Point Reservoir (Apr 9-May 5) to assess fry distribution and habitat use. Five index sites were established in Cougar Reservoir and six sites in Lookout Point Reservoir. Sites were generally located in nearshore areas that were accessible by crews from the bank. In addition, we surveyed isolated coves connected to the main reservoir by highway culverts. Surveys began at least 0.5 h after sunset. At each site, two transects were surveyed simultaneously by two snorkelers. Snorkeler #1 surveyed along the transect parallel to the shoreline for 15 minutes, enumerating all fry and yearling Chinook salmon observed using an underwater flashlight, within 2 m of the transect line. Meanwhile, snorkeler #2 surveyed along the second transect in the opposite direction. Fry counts were analyzed in relation to distance from the dam using simple linear regression (α=0.05) to assess dispersion of fry into the reservoir, as measured along the longitudinal axis of the reservoir.

Habitat type for each transect was classified by substrate type (silt/sand, gravel, cobble), bank slope (steep, flat) and presence/absence of vegetation to provide a coarse assessment of habitat used by juvenile Chinook salmon. Usually, a transect could be classified into one habitat type (e.g., steep bank, cobble substrate, no vegetation). In cases where habitat within a transect transitioned from one type to another, we noted how many fry were observed in each habitat type. Abundance of fry observed within each habitat type was analyzed with Kruskal-Wallis one way analysis of variance (α=0.05).

At selected sites, daytime surveys were conducted prior to nighttime surveys to compare techniques and determine the feasibility of daytime surveys. Snorkel surveys were prematurely discontinued in mid-May due to USACE safety protocol requirements.

Minnow trap- Minnow trapping (May 21-June 7) was used to collect length information and additional distribution information on fry after snorkel surveys were discontinued. Minnow traps were set in areas where fry had previously been observed during snorkeling, or in similar accessible habitats along the shoreline. Two types of minnow traps were used: 0.64 cm galvanized steel mesh "gee" traps (0.23 m diam. x 0.44 m) and 0.32 cm nylon mesh square traps (0.25 m x 0.25 m x 0.43 m). Some traps were baited with salmon eggs to attract fish. All fry captured were enumerated and fork length (FL; mm) recorded.

Beach seine- Beach seining could only be carried out in relatively shallow water with few obstructions (e.g., stumps, vegetation). We used a 0.32 cm mesh seine (6 m x 1.2 m) to capture fry in the spring. All juveniles captured were enumerated and measured (FL; mm).

Oneida Lake traps- A floating Oneida Lake trap was used in this study to capture larger sized juveniles. The Oneida trap consisted of a 0.64 cm mesh holding box (2.4 m x 2.4 m x 2.4 m) with a lead net (34.1 m x 3.0 m) extending from shore to the box and two wings (7.2 m x 3.0 m, see Figure 1). Oneida traps are a passive capture gear type designed to intercept fish moving along the shoreline. Sites for trap deployment were selected with a stratified random sampling design. Because Oneida traps only fish the upper 3.0 m of the water column, they were not deployed if surface temperatures approached 20° C. Traps were fished for approximately 24 h. We enumerated all juvenile Chinook salmon by year-class (based on relative size), checked for presence of passive integrated transponder (PIT) tags, and recorded fork length (mm). Weights (g) were taken on a subsample of the juveniles collected. All previously untagged juveniles larger than 65 mm FL were PIT tagged. Recaptured fish provided information regarding growth rate and movement. Differences in the catch per set of subyearlings by reservoir section (lower, middle, upper) were analyzed with Kruskal-Wallis one-way analysis of variance (α=0.05).

Hoop nets- Hoop nets were deployed in the reservoirs beginning in July. Hoop nets (0.9 m diam. x 3.7 m) with 0.64 cm mesh were deployed as either two nets attached to either end of a fyke net (1.2 m x 15 m) running parallel to shore, or as a single net with a fyke lead net extending from shore to the trap. Hoop nets were set in conjunction with Oneida traps beginning in July to investigate whether the juvenile Chinook salmon utilized benthic habitat as surface temperatures increased. Traps were fished for approximately 24 h. We counted all juveniles collected, checked for the presence of PIT tags, and recorded fork length (mm). All unmarked juveniles larger than 65 mm FL were PIT tagged.

Lampara seine-Lampara seining in Cougar Reservoir was conducted by the U.S. Geological Survey (USGS) from August 30-31 to sample juvenile Chinook in the pelagic areas of the reservoir inaccessible to other gear types. The lampara seine was a 305 m encircling net fished using a single boat. The net was deployed by paying out one of the wings while the boat was driven in a large circle. At the halfway point when the middle of the net was reached, the bunt section was deployed followed by the other wing. When the net was fully deployed, the circle was closed and both wings were brought in simultaneously, reducing the net area, and concentrating the fish in the bunt section. The lead line was shorter than the float line and formed the floor of the net as the wings were hauled in. A 7.3 m boat equipped with two large hydraulic drums was used to pull in the two wings of the lampara seine. The two wings each measured 91.4 m long and were connected by a 22.9 m bunt section. The lead line was 30.5 m deep at the bunt, and tapers to the float line at the end of each wing section. The net material is 12.7cm stretch mesh and the bunt material was 0.64 cm delta mesh. The net effectively fished to a depth of about 21 m at the bunt.

Mid-water Trawls- A mid-water trawl was used by USGS in Cougar Reservoir from August 31 – September 1 to sample deeper water of the reservoir. Trawling transects were systematically positioned along the longitudinal axis of the reservoir, and completed at varying depths to determine vertical distribution of juveniles. The trawl had an opening of 8.2 m x 8.9 m and was 14.3 m long. It was constructed of nylon monofilament mesh that tapers with progressively smaller mesh sizes to a cod end made of 0.64 cm knotless mesh. A plastic garbage container was sewn into the cod end to provide a sanctuary for captured fish. The net was attached to two steel cables that ran through pulleys on an A-frame structure on the boat, and then to hydraulic winches. Large steel “doors” were attached to the cable to open the net while it was fishing. The depth of the trawl was determined using a geometric relationship between the amount of cable deployed and the angle of the cable. The net could be fished to a depth of about 34 m. The net was fished from the same boat as the lampara seine.

Hook-and-line via downrigger-Beginning the last week of August we initiated hook-and-line sampling to target yearling and older juvenile Chinook salmon. This sampling focused on investigating distribution, size variability, and potential age of juveniles that had been residing in the reservoir for more than one year. A section within the reservoir was randomly chosen using the stratified random sampling design described above. Downrigging transects were 30 min in duration. A nearshore (~30 m from the bank) and an offshore transect (~100 m) were completed within that section prior to moving to the next section. Estimates for distance from the bank were verified using a range finder. After the first set of transects were completed, we moved in a clockwise direction around the reservoir for a distance of approximately 0.8 km to begin the next transect. During each transect, one rod was set at 9.1 m depth and the other at 3.0 m depth if possible, otherwise both were fished at 3.0 m, or the deepest depth possible. Using temperature profile data from several points within the reservoir we determined that 9.1 m was below the existing thermocline during the summer months. For each fish collected, we recorded location (GPS), distance from shore and depth of downrigger. We also took a scale sample and recorded fork length (mm) of all fish sampled. Juvenile Chinook salmon >65 mm FL were PIT tagged.

Figure 1. Photos depicting lampara seine and Oneida box trap sampling methods used to capture juvenile Chinook salmon in Cougar Reservoir, 2010.

Relative growth of reservoir rearing and stream rearing juvenile Chinook salmon

We used fish length data collected from screw traps and seining above the reservoirs to track cohort growth of subyearlings rearing in the streams. Seining was conducted at various locations in the South Fork McKenzie River above Cougar Reservoir and in the North Fork Middle Fork Willamette River above Lookout Point Reservoir in late summer. Fish lengths from seining efforts were compared to lengths from screw traps during the same time period using a t-test to determine if size of fish caught in screw traps was representative of the cohort rearing in the streams. If no differences were detected, we could assume that fish captured by the screw trap were representative of the stream rearing cohort. Screw trap length data represents a longer time series, and could then be compared to lengths of fish collected during the reservoir sampling, as well as fish collected in screw traps below the dam. Fish captured below the dam that had copepods in their gills were considered as fish that reared in the reservoir.

Fish community structure and predation potential on juvenile Chinook salmon

Predator fish species composition- Oneida box trapping, hoop netting, and hook and line were used primarily to capture juvenile Chinook salmon, but also captured incidental fish species including predators. Methods for these sampling techniques are described in

Distribution of Juvenile Chinook Salmon in Reservoirs, this report. Predatory fish were enumerated and measured, and those > 200 mm (FL) had their stomachs flushed or removed for general analysis.

Boat electro-fishing occurred in late summer in Cougar and Lookout Point reservoirs. Shocking settings were 850 V, 4 amps with a pulse width of 5 ms, and a frequency of 120 DC in Cougar Reservoir. All settings were consistent in Lookout Point Reservoir, except 4.5 amps were used. Sampling occurred along random shoreline areas throughout both reservoirs.

Gill netting was used only in Lookout Point Reservoir. Endangered bull trout (*Salvelinus confluentus*) are present in Cougar Reservoir and are potentially vulnerable to gill netting. The gill nets used were experimental type nets that consisted of four 7.6 m x 3.0 m panels. Each panel contained a different size mesh, and the panels were sewn together with mesh size arranged from largest to smallest (7.6 cm, 6.4cm, 5.1 cm, 3.8 cm). Mesh sizes were selected to avoid subyearling Chinook salmon capture and primarily target large predatory fish species. The first two sets were mid water column sets deployed for two h to gauge the potential catch rate. We attempted five sets (24 h) in the mid-water column, and four sets on the bottom of the reservoir.

Hook and line sampling was conducted in both reservoirs using downriggers to target yearling juvenile Chinook salmon and predator species residing at depth during increased surface water temperatures. Barbs were crimped on all hooks to minimize adverse effects on all fish captured.

Predatory fish encountered using any of the capture methods were measured, and those > 200 mm FL had their stomachs flushed or excised depending on species. Crappie, bass, and walleye had their stomachs completely removed. Northern pikeminnow, which lack a true stomach, had their entire digestive tracts removed and subsequently “milked”. Cutthroat and rainbow trout diet samples were non-lethally extracted using gastric lavage.

Non-salmonid predator fishes were dispatched using a lethal dose of MS-222 (200 mg/L) for stomach removal. An incision was made from the anus to the gills to expose the digestive tract. The stomach was isolated for removal using a hemostat to clamp the esophagus anterior to the stomach, and an additional hemostat clamped on the intestine posterior to the stomach. The stomach was removed and placed in a Whirl Pak® . The process was identical for northern pikeminnow except that the lower hemostat was removed, and thumb and forefinger were pinched near the esophageal hemostat and run down the length of the digestive tract. Diet material was collected in a Whirl Pak® bag. The remaining stomach lining was then discarded.

Gastric lavage has been shown to be an effective, efficient, and non-lethal method for removal of stomach contents (Foster 1977), with removal efficiencies of approximately 98% for several species of salmonids (Light et al. 1983). Fish were anesthetized using standard MS-222 stock solution/water (50 mg/L MS-222 buffered with 125 mg/L

$NaHCO_3$). A 500 ml wash bottle with the appropriate size hose attached (depending on fish size) was used for stomach flushing. Holding the water bottle upside down, the hose was inserted into the mouth of the fish, past the sphincter muscle in the throat and into the stomach. The water bottle was depressed, filling the stomach with water until regurgitation occurred. Diet samples were flushed directly from the stomach into a coffee filter to strain off excess water. The entire filter (with diet sample) was then folded and placed in a Whirl Pak®. Fish were placed in a large cooler and monitored for recovery, and subsequently released.

For both diet sampling methods (removal and lavage) 95% ethanol was added to samples (approximately a 20:1 ratio of fixative to tissue). Use of 95% ethanol enabled the possibility for genetic distinction of prey species to be determined from tissue samples if we were otherwise unable to distinguish using visual observation.

Predatory fish diet analysis- Stomach contents were removed from the Whirl Pak® bags and placed in a petri dish. Items in the diet sample were sorted into six categories: fish, zooplankton, aquatic insects, terrestrial insects, crayfish and miscellaneous. The miscellaneous category included mollusks (e.g. clams), organic matter (e.g. vegetation) and inorganic matter (e.g. small pebbles, plastic, lures, etc). Intestinal parasites (e.g. tapeworms, round worms) were noted but not included as a diet item.

Each individual category was then placed in a previously tared weigh boat and weighed on an Ohaus Scout Pro 200 g x 0.01 g scale. Excess water was removed as we placed them in the weighing tray by dabbing the items on a paper towel, or dabbing near zooplankton to remove moisture. If any sample category weighed < 0.05 g, we recorded that category as 0.05 g on the datasheet and noted that weight was actually less in the comments. We also estimated the approximate percentage of the total volume for each diet category.

Items in the fish category were saved for further analysis of prey item identification. Fish bones were picked from the fish portion of the diet samples using a 20X dissecting scope and tweezers, then cleaned and placed in a labeled glass vial. All other diet items were then discarded. We used visual observation for obvious identifying characteristics of whole fish, and diagnostic bones for determination of species. Taxonomic designation of fish found in diet samples were assigned down to the target species if possible (*Oncorhyncus tschawytscha*), or to family (Salmonidae). Length of prey items and number of Chinook salmon were recorded (where possible).

Bones were emptied into a petri dish with a small amount of water to rinse and keep them moist. The petri dish was placed under the microscope and each bone viewed to distinguish diagnostic bones as described by Hansel et al. (1988), Frost (2000), and Parrish et al. (2006). If diagnostic bones were found, they were placed it into a separate petri dish, other bones were returned to the storage vial. Diagnostic bones include the dentaries (lower jaw bones), cleithra (pectoral bones), pharyngeal arches (gill arch bones), hyomandibulars, opercles, otoliths (ear bones), lamprey jaw pieces, vertebrae, preopercles and spines of some species. Once all of the diagnostic bones had been sorted, several bone identification keys were utilized to identify bones, determine taxonomic group, and the number of Chinook salmon in each sample. For paired bones (dentaries, cleithra, hyomandibulars, opercles, otoliths, and pharyngeal arches), if one from each side was found they were counted as one fish. Two bones from the same side were counted as two fish.

After analysis, all diagnostic bones were placed in a vial with 95% ethanol for future reference. Non-diagnostic bones were discarded. If no diagnostic bones were found in the sample, ‘No Diagnostics’ was written in the comments on the data sheet.

Results and Discussion

Feasibility tests of various sampling techniques

A variety of techniques were necessary to capture juvenile Chinook salmon as reservoir conditions and fish behavior, size, and distribution within the reservoir changed throughout the year. The various methods listed below were compared using catch per unit effort (CPUE) measured in hours to standardize the methods for comparison of effectiveness and feasibility (Table 1). It became evident from our sampling efforts in this study that different methods were more efficient at targeting juveniles from different year classes and the effectiveness of gear changed through the season.

Table 1. Catch per unit effort (CPUE) for various sampling techniques used in Cougar and Lookout Point reservoir, 2010. Effort was measured in hours. Dates are provided below each method to show the temporal duration of use.

Capture Method	Subyearlings captured	Yearlings captured[a]	Effort (h)	CPUE for Chinook	Number of sets	Avg. Chinook per set
Cougar Reservoir						
Oneida box trap 6/8-10/8	2,223	145	720	3.29	30	78.93
Hook and line 8/31-9/28	0	17	17.17	0.99	N/A	N/A
Hoop Net 7/15-10/8	187	0	912	0.21	38	4.92
Lampara seine[b] 8/30-8/31	0	5	9.75	0.51	12	0.42
Trawl [b] 8/31-9/1	0	0	9.0	0.00	9	0
Grand Total	2,410	167	1,668.5	1.54	89	28.76
Lookout Point Reservoir						
Oneida box trap 6/8-10/8	79	9	672	0.13	28	2.82
Hook and line 8/31-9/28	0	13	39.7	0.33	N/A	N/A
Hoop Net 7/15-10/8	0	0	1,176	0.00	49	0.00
Grand Total	79	64	1,887.7	0.05	77	1.86

[a] Includes a few juveniles that were likely two years old or older.
[b] Lampara seining and trawling conducted by U.S. Geological Survey personnel.

Snorkel surveys were the least invasive, and likely the most productive method to investigate habitat utilization and distribution of fry residing in the reservoirs early in the spring. Snorkel surveys allowed coverage of large amount of area in a short amount of time. Many fry and some yearlings were observed using this method, however snorkeling is only effective when clarity is at least two meters. This amount of clarity varies considerably among reservoirs and is limited to early spring in some reservoirs.

Daytime snorkel surveys were not as productive compared to nighttime surveys with the exception of some sites in the upper section of Cougar Reservoir. Therefore, only nighttime surveys were used to assess distribution in the reservoirs. No fry or yearlings were observed during daytime surveys in Lookout Point Reservoir (Table 2). In Cougar Reservoir, no yearlings were observed during daytime surveys and no fry were observed near the dam. However, more fry were observed in daytime surveys in the upper portion of Cougar Reservoir. Daytime fry observations were high in the upper reservoir because fry formed small aggregations (approximately 50-100 individuals) during the day that were easily observable, whereas at night, fry tended to be more dispersed. Overall, fry densities were higher in the upper reservoir and the lack of observed aggregate 'schooling' behavior in the low density, lower portion of the reservoir may reflect a mechanism for predator avoidance that only occurs when densities reach a threshold level.

Table 2. Comparison of daytime versus nighttime snorkel observation for Cougar and Lookout Point reservoirs. Only those surveys where day and night surveys were conducted on the same date are reported.

			Mean fry observed/ transect		
Reservoir	Transect	Date	Day	Night	Transect location
Cougar	A	12-May	0	15.5	Dam face
	C	12-May	0.5	28	Walker Creek arm
	D	12-May	57	25.5	Slide Creek boat ramp
	E	12-May	250	87	Head of reservoir
	X	12-May	0	0	Rider Creek isolated cove (exploratory)
	Total		**61.5**	**31.2**	
Lookout Point	E	22-Apr	0	19.5	Head of reservoir
	A	5-May	0	0	Meridian boat ramp
	C	5-May	0	9	west side 2.7 km from dam
	F	5-May	0	2	Head of reservoir
	Total		**0**	**3.3**	

Nighttime snorkel surveys were used to assess fry distribution in the reservoir because of the limited ineffectiveness of other techniques used to sample fry (minnow traps and beach seining).

Minnow trapping was performed from May 19-27 in Cougar Reservoir and from May 21 through June 7 in Lookout Point Reservoir. Minnow trapping efforts were largely ineffective at capturing juvenile Chinook salmon in both reservoirs. A total of 53 sets (24 h) in Cougar Reservoir captured 103 fry. In Lookout Point Reservoir we set 132 traps and captured only two fry. Overcrowding from numerous longnose dace (*Rhinichthys cataractae*) caught in the traps resulted in many Chinook salmon fry injuries or mortalities.

Beach seining conducted during the same time period provided additional fry collection for length frequency data. However, sites conducive to beach seining were severely limited due to the predominance of steep banks and tree stumps throughout both reservoirs. Seining was limited to the head of the reservoir where slope was gradual enough to allow for seining. A total of 16 fry were collected in Cougar Reservoir in five sets. We collected 108 fry in Lookout Point Reservoir in 18 sets. There was no difference in mean fry size between fry found in the reservoirs in April and May, and those collected in the upstream screw traps during the same time period. Beach seining was not used in assessing fry distribution due to the spatial limitation of this technique.

Oneida traps deployed in 24 h sets produced the majority of the overall juvenile Chinook salmon captures (Table 1). These traps are efficient at capturing fish moving along the shoreline near the surface of the water. However, Oneida traps are limited to fishing within 34.1 m from the shore and in the top 3.0 m of the water column. Because traps were surface oriented, their efficacy was limited as surface water temperatures increased to 20° C during the summer months (July-August). Juveniles appear to descend below the thermocline (where Oneida traps are ineffective) to seek more suitable temperature regimes. Also, elevated temperatures were highly stressful and potentially lethal for salmonids that were captured and held in the trap. For these reasons, we discontinued Oneida trap sets in mid-July and did not return to this sampling method until September when surface temps decreased to approximately 18° C (Figure 6).

Hoop nets were largely ineffective at capturing juvenile Chinook salmon (Table 1) and their efficiency is likely related to the type of habitat in which they are fished. Hoop nets can be fished in deeper water well below the thermocline and are easily deployed and retrieved. We had rare sets late in the spring, in the upper portion of Cougar Reservoir, when juveniles were successfully captured. Successful sets were placed on relatively flat or gradually sloping areas near the head of the reservoirs (mud flats). Steeply angled banks and numerous stumps were common in both reservoirs and likely compromised the effectiveness of many hoop net sets. When hoop nets were set in these deep areas, it was not possible to visually verify that the nets deployed correctly.

Lampara seining was conducted by USGS in Cougar Reservoir to help determine distribution and size of juvenile Chinook salmon residing in pelagic areas beyond the effective fishing range of other gear. This technique has been the standard for collecting juvenile salmonids in the Columbia and Snake rivers. Mid-water trawls were also conducted in Cougar Reservoir. Both techniques proved ineffective at catching juveniles. Five yearlings were collected with the lampara seine over 12 deployments at various locations throughout the reservoir. No juvenile Chinook salmon were captured with the mid-water trawl.

Hook and line sampling was the only method found to be effective at capturing yearling Chinook salmon later in the sampling season (August-November). Seventeen Chinook salmon were captured in Cougar Reservoir using hook and line. The largest juvenile Chinook salmon captured measured 240 mm FL. Thirteen Chinook salmon were captured in Lookout Point Reservoir. The largest measured 326 mm FL. No subyearlings were captured with this method (Table 1).

Distribution of juvenile Chinook salmon in reservoirs

<u>*Fry distribution*</u>

Cougar Reservoir- Screw trap data from the South Fork McKenzie River upstream of Cougar Reservoir showed that the majority of juvenile spring Chinook salmon enter the reservoir as fry (Monzyk et al. 2010). Migration into the reservoir began in mid-February and lasted until June, with a peak in late-April.

The five index sites in Cougar Reservoir were snorkeled at night on April 28 and May 12. All index sites for snorkel surveys were on the east side of the reservoir because of lack of access on the west side. We observed 733 fry and 27 yearling Chinook salmon during a total of 22 transect surveys. Yearlings and fry were observed occupying the same habitat in many locations.

More fry were observed at sites closest to the head of the reservoir where the South Fork McKenzie River enters the reservoir (Table 3). Fry observations within an index site were variable however the number of fry observed had a positive linear relationship with the distance from the dam (P=0.001, adj. r^2=0.42; Figure 2). Surprisingly, fry (approximately 40 mm FL) were observed at the index site on the dam face during both survey dates, indicating very small fry were capable of traversing the entire length of the reservoir. We conducted exploratory snorkel surveys in an isolated cove connected to the main reservoir by a highway culvert (Rider Creek arm) on 12 May and did not observe juveniles occupying this area. Because of the unexpected shortness of the snorkeling season, we were unable to assess trends in abundance through time at index sites.

Yearling Chinook salmon were observed at all sites except site C (Walker Creek arm) but counts were generally low everywhere compared to fry. The greatest number observed was seven yearlings during a 15-min transect survey at site E. The mean number of yearlings observed per transect was 0.5 at site A, 2.5 at sites B and E, and 0.8 at site C.

Table 3. Location and distance from the dam of snorkel survey index sites on Cougar Reservoir, and total number of fry observed during night surveys, arranged by date in 2010. Numbers in parentheses are number of transects surveyed.

Index site	Location	UTM coordinates	Longitudinal distance from dam (km)	Mean number of fry observed by date	
				28 Apr	12 May
A	Dam face (access road)	10 0560883 4886395	0	4.0 (2)	18.5 (2)
B	Echo boat ramp (East. Fork arm)	10 0563072 4885389	1.3	36.5 (2)	8.5 (2)
C	Walker Creek arm	10 0562309 4883582	3.0	-	28.0 (2)
D	Slide Creek boat ramp	10 0561942 4880791	5.5	126.5 (4)	25.5 (2)
E	Head of reservoir	10 0562207 4879870	6.7	35.0 (2)	87.0 (2)

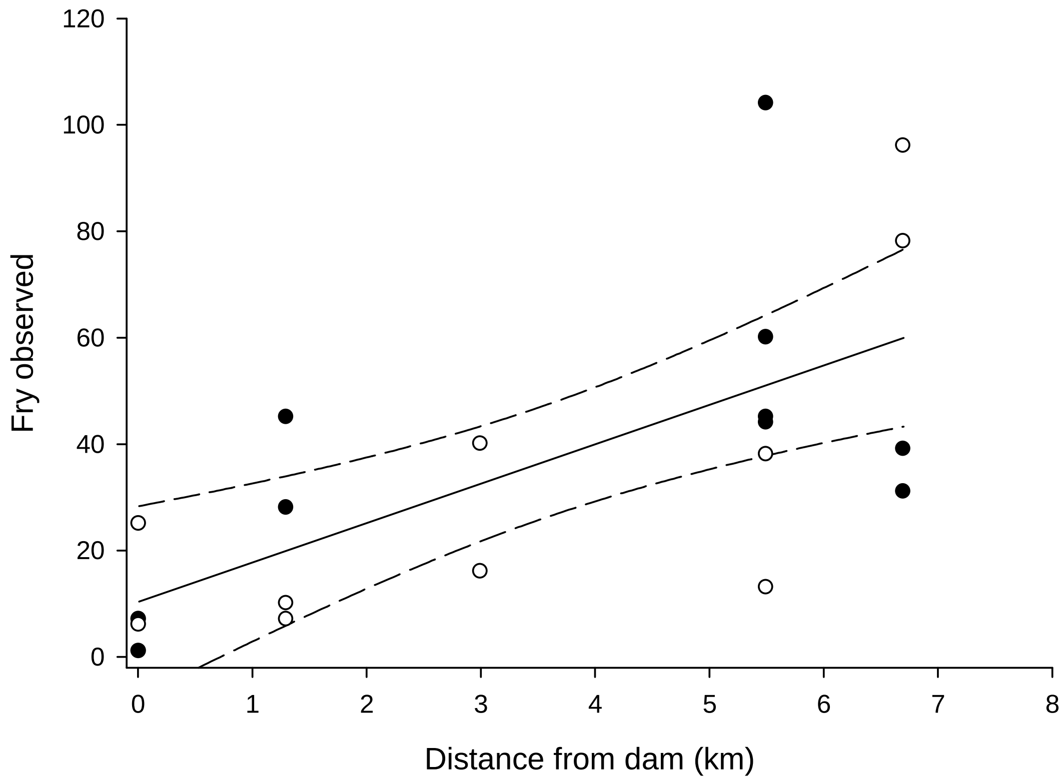


Figure 2. Relationship between fry observations at index sites and distance from the dam at Cougar Reservoir. Distance was measured along the longitudinal axis of reservoir. Solid circles represent fry counts during 28 Apr surveys and open circles refer to fry counts during 12 May surveys. Dashed lines represent the 95% confidence interval for regression line.

Lookout Point Reservoir- Six index sites in Lookout Point Reservoir were surveyed at night on 22 April and 5 May (Table 4). We included site F as an additional transect site in May because, unlike Cougar Reservoir, the area that was considered the 'head of reservoir' shifted approximately 1 km upstream during the snorkel survey timeframe as the reservoir refilled. Overall, fewer fry were observed in Lookout Point Reservoir compared to Cougar Reservoir. This was due, in part, to greater water turbidity and the fact that fewer female adult Chinook salmon were outplanted above Lookout Point Reservoir in 2009 which resulted in less progeny for potential observation in 2010. We observed 150 fry and 9 yearling Chinook salmon during 19 night transect surveys. All yearlings were observed during one transect survey (site C) on May 5.

As with Cougar Reservoir, most of the fry observed in Lookout Point Reservoir were near the head of the reservoir (Table 4). Because the head of the reservoir moved upstream from April through May, interpretation of results of fry abundance in relation to distance from the dam was complicated. Most fry (78%) were observed in April at the head of the reservoir, Site El. By May, Site F had become the head of the reservoir and only four fry were observed at this site. The low incidents of fry at site F on May 5 could be due to most fry having already entered the reservoir and dispersed farther from the entry point by this date. We were unable to detect a significant relationship between fry abundance and distance from the dam when all sites were used in analysis (P=0.051; Figure 3). However, if site F is removed from analysis, there is a significant positive linear relationship between distance from the dam and fry abundance (P=0.008, adj. r^2=0.43).

Table 4. Location and distance from the dam of snorkel survey index sites on Cougar Reservoir, and total number of fry observed during nighttime survey by date in 2010. Numbers in parentheses are number of transects surveyed.

Index site	Location	UTM coordinates	Longitudinal distance from dam (km)	Mean number of fry observed by date 22 Apr	5 May
A	Meridian boat ramp (near dam)	10 0520289 4862431	0.3	-	0.0 (4)
B	2 km above dam, north side	10 0521758 4861517	2.0	-	1.0 (2)
C	Upstream of Minnow Creek	10 0521565 4859801	2.7	-	9.0 (1)
D	Signal Point boat ramp	10 0525211 4858749	6.4	4.5 (2)	4.5 (2)
E	Head of reservoir in April (mud flats)	10 0531135 4852682	15.4	19.5 (6)	-
F	Head of reservoir in May (mud flats)	10 0532362 4852267	16.5	-	2.0 (2)

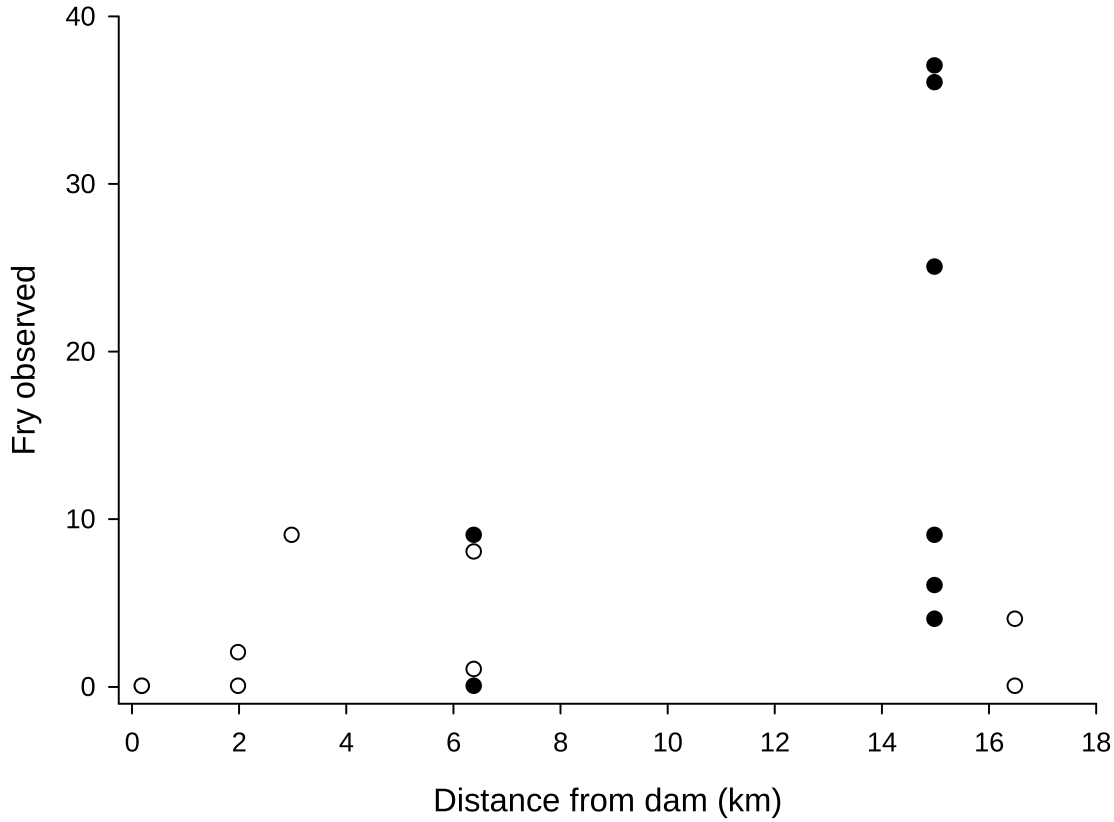


Figure 3. Relationship between fry observations at index sites and distance from the dam at Lookout Point Reservoir. Distance was measured along the longitudinal axis of reservoir. Solid circles represent fry counts during 22 Apr surveys and open circles refer to fry counts during 5 May surveys.

Habitat Use- The habitat classification of transects provided only a coarse assessment of habitat use by fry. We did not attempt to quantify habitat preferences by measuring microhabitat variables where fry were observed in relation to habitat availability throughout the reservoirs. In general, the availability of habitat types in Cougar Reservoir was limited, with much of the shoreline comprised of steep, rocky banks. There were relatively few shallow areas with silt/sand substrate that fry tend to prefer (Tabor and Piaskowski 2001, Garland et al. 2002, Tiffan et al. 2002). Lookout Point Reservoir contained vast areas of shallow, sand/silt habitat (mud flats) at the head of the reservoir. Overall, shoreline habitat in Lookout Point Reservoir was not as steep and contained more gradually sloping, sand/silt habitat than Cougar Reservoir.

We were unable to detect a significant difference in fry abundance (for fish observed during night snorkeling) among habitat types at Cougar Reservoir. The power to detect differences were likely low due to small sample sizes (n=22). Although areas with gradual slopes and sand/silt substrate had slightly higher mean fry observations, we observed numerous fry in steep sloped, rocky (cobble) habitat as well (Figure 4). Given the rarity of shallow, silt/sandy habitat and the large fry abundance in this reservoir, it is not surprising to find fry in steep, rocky habitat. Fry would have to occupy these habitats at some point as they disperse along the shoreline of the reservoir.

Observations of fry at Lookout Point reservoir were too few to conduct statistical tests comparing fry abundance by habitat type. Most fry observed in Lookout Point Reservoir (80%) were in the mud flats at the head of the reservoir.

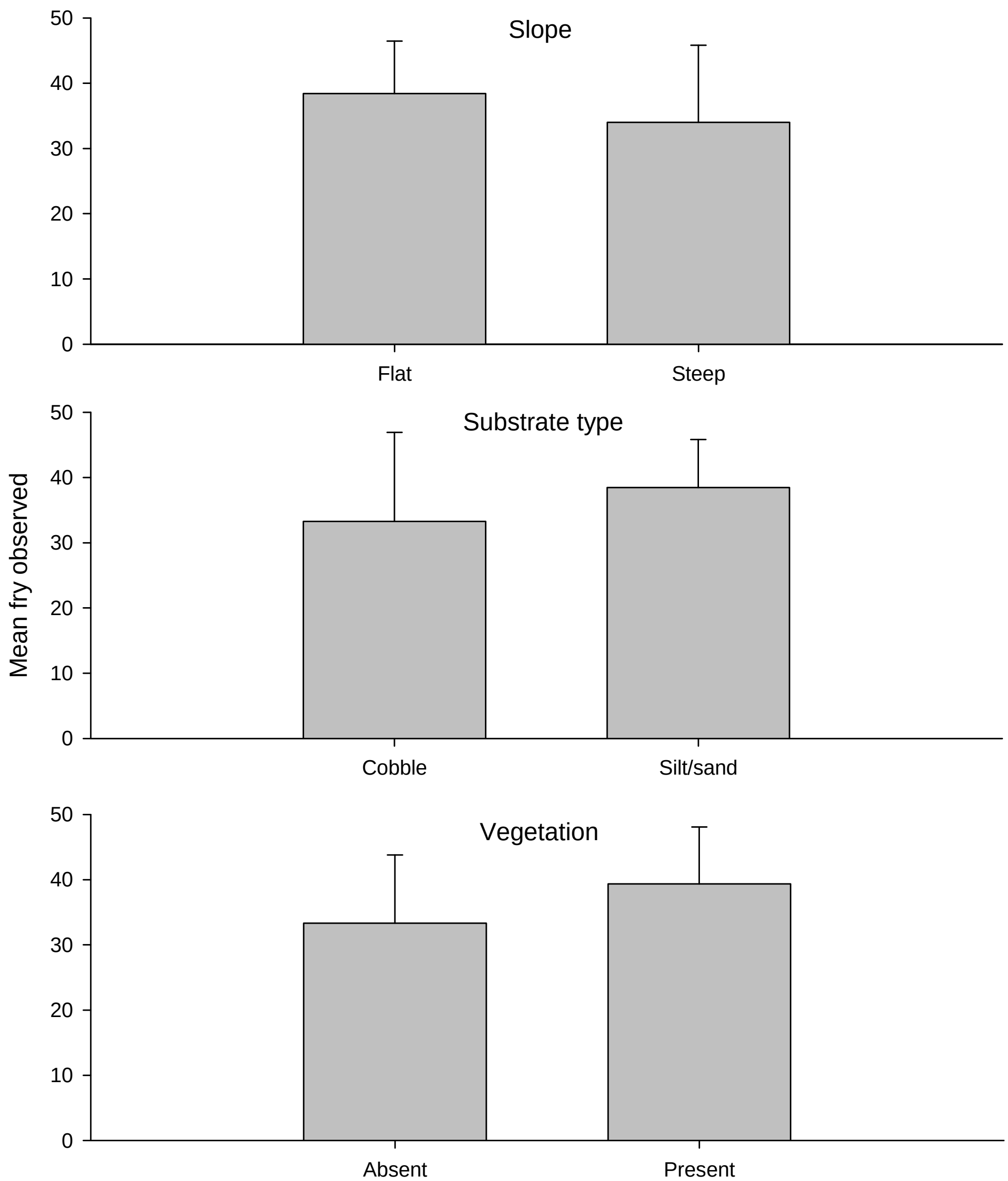


Figure 4. Mean number of fry observed per transect and habitat type in Cougar Reservoir. Error bars represent standard error.

Subyearling parr and yearling distribution

Different ontological stages of juvenile Chinook salmon development require a variety of capture methods. As fry develop and their distribution, size and behavior change, they become vulnerable to different gear types throughout the sampling season. Oneida traps were the most effective gear for capturing subyearlings.

Cougar Reservoir- Oneida traps were set in 29 locations in Cougar Reservoir from June through October. A total of 2,223 subyearling and 145 yearling Chinook salmon were captured with this method. There was no difference in catch among reservoir sections for subyearling or yearlings. The highest catch of subyearling parr was in the upper section of the reservoir in June (Figure 5), although this was based on two sets with high catches near the head of the reservoir. It may be that the Oneida trap was more efficient in the shallow upper section of the reservoir. Information on subyearling distribution in the summer and fall was further complicated by a precipitous decline in catch rates for all gear types beginning in July. The decline in catch rates coincided with an increase in surface temperatures over 20°C (Figure 6).

Starting in July hoop nets were deployed along with Oneida traps at a depth range of 4.3-12.1 m. Hoop nets caught more subyearlings than the surface-oriented Oneida traps in July despite having a smaller effective fishing area. This suggests juvenile Chinook salmon descended to greater depths as surface temperatures increased. It should be noted however, that hoop nets were not used in conjunction with Oneida traps in June. So, it is not known whether catch rates between gears types were similar prior to surface temperatures increasing. We caught 187 subyearlings in hoop nets during July compared to 101 subyearlings during the same month using Oneida traps. We were unable to fish Oneida traps in August due to high surface temperatures but continued to fish hoop nets with limited success. Lampara seining and mid-water trawling in the open, pelagic water of the reservoir by USGS from 30 August to 1 September did not catch any subyearlings. In early September, we began to observe numerous schools of subyearlings (~50 individuals /school) throughout the reservoir in nearshore habitat. The fish appeared to be actively feeding on the surface between 1-7 m from the shore during the day. Surface temperatures at this time of year had decreased to 17°C. Collectively, these observations suggest subyearlings reside relatively close to shore, and during periods of increased surface temperatures they descend below the thermocline to rear. We started capturing a few subyearlings in the tailrace screw trap below the dam in August with catches increasing in November and December (drawdown period), suggesting that subyearlings may be distributed in the lower section of the reservoir in the fall.

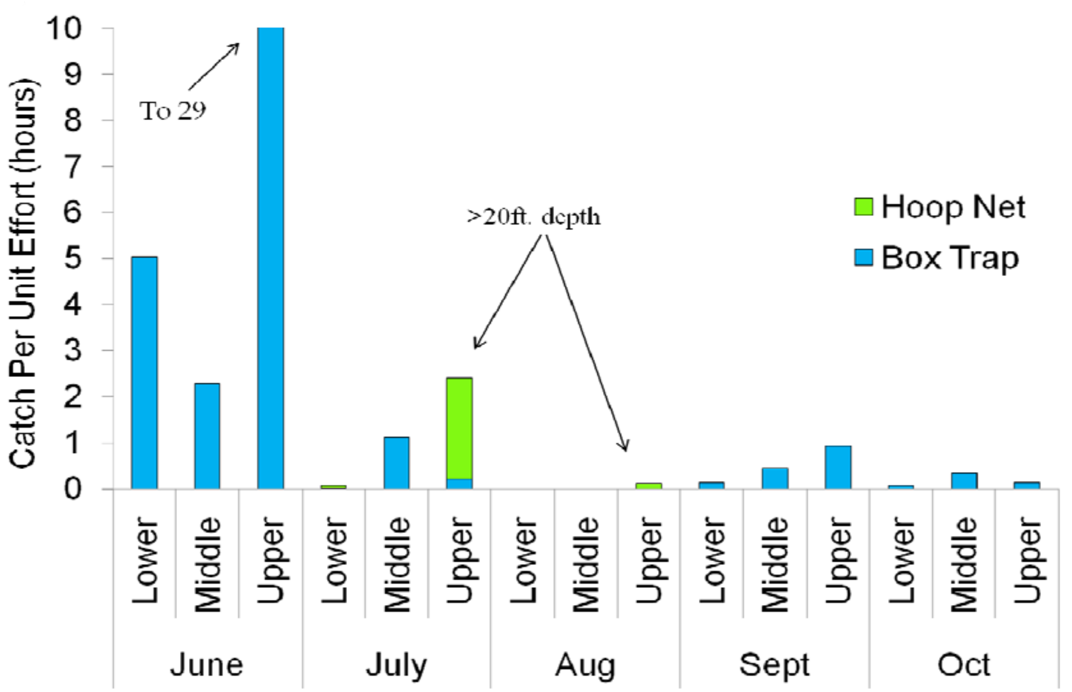


Figure 5. Catch per unit effort per month for each zone within Cougar Reservoir. Oneida traps were not fished in August due to high surface temperatures.

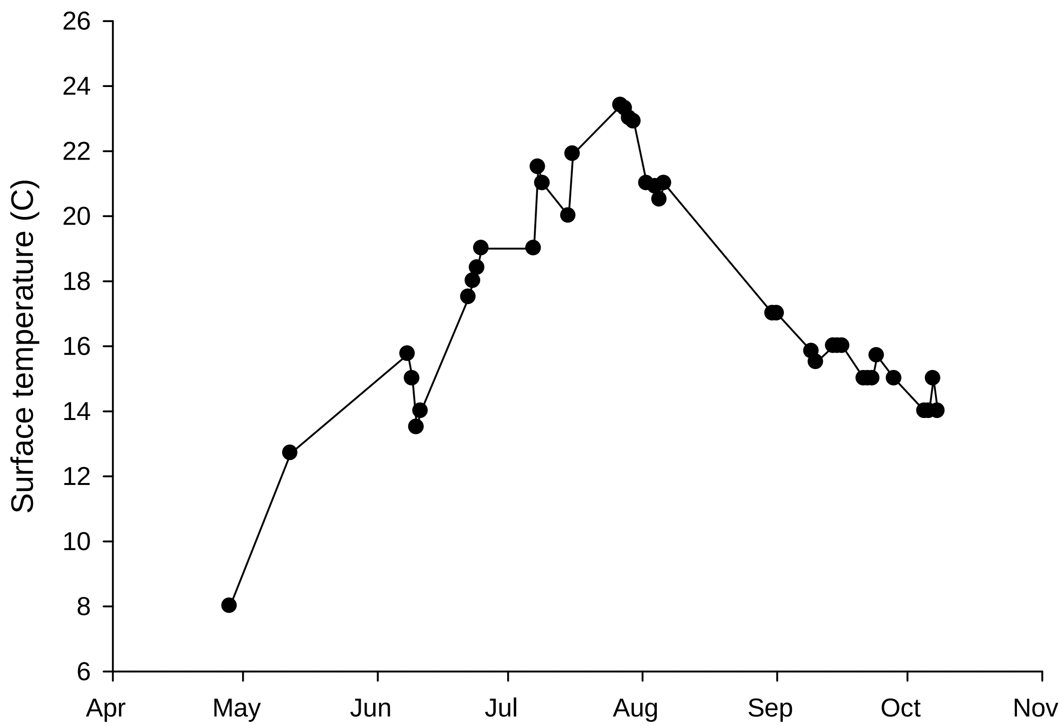


Figure 6. Surface temperatures in Cougar Reservoir during 2010. Temperatures were recorded in various locations during trap sets and other work conducted in the reservoir.

Overall, yearlings were much less abundant than subyearlings within Cougar Reservoir. Information on yearling Chinook salmon distribution was limited due to their lower abundance and highly variable catch. Of the 145 yearlings collected, >90% were caught in two Oneida trap sets in the East Fork arm of the reservoir during early June. This indicates that Oneida traps were effective at capturing this year-class of fish when they are present in nearshore habitat. It is unclear why we were then unable to collect yearlings in the same habitat during late summer and fall. Trawling in the pelagic areas was unsuccessful and lampara seines captured only five yearlings during 12 sets. All five yearlings were collected near the Slide Creek boat ramp in the upper section of the reservoir. This area of the reservoir had steep banks, allowing the lampara seine to sample relatively close to shore. Therefore, it is unclear whether the captured yearlings were residing in relation to the shore.

Lookout Point Reservoir- Oneida traps were set in 27 locations in Lookout Point Reservoir from June through October. We collected 79 subyearlings and nine yearlings. Capture of both subyearling and yearling juvenile Chinook salmon in Lookout Point Reservoir was very sparse when compared to Cougar Reservoir. This was likely because fewer female adult Chinook salmon were outplanted above Lookout Point Reservoir in 2009, combined with high numbers of piscivorous fishes in the reservoir. Distribution data was further complicated this year by the unusual early reservoir drawdown which resulted in the uppermost section of the reservoir being available for sampling only in June. High surface temperatures in the upper reservoir precluded further sampling until October. No juveniles were captured via hoop nets in the reservoir.

As with Cougar Reservoir, catch rates decreased after June (Figure 7). There was no clear pattern in subyearling catch by reservoir section. Too few fish were collected to test for significant differences in catch by reservoir section, or between different age classes.

There was some evidence that yearling Chinook salmon were more abundant in the lower section of the reservoir. Although too few yearlings were captured to allow for statistical tests of abundance by reservoir section (Upper, middle, lower), all nine subyearlings caught in Oneida traps were from sets in the lower section of the reservoir. In addition, six of the eight yearlings caught during randomized hook and line sampling transects were in the lower reservoir section (Appendix Figure A2). Yearlings were caught both close to shore (~30 m) and in the pelagic areas (~100 m from shore) during hook and line sampling.

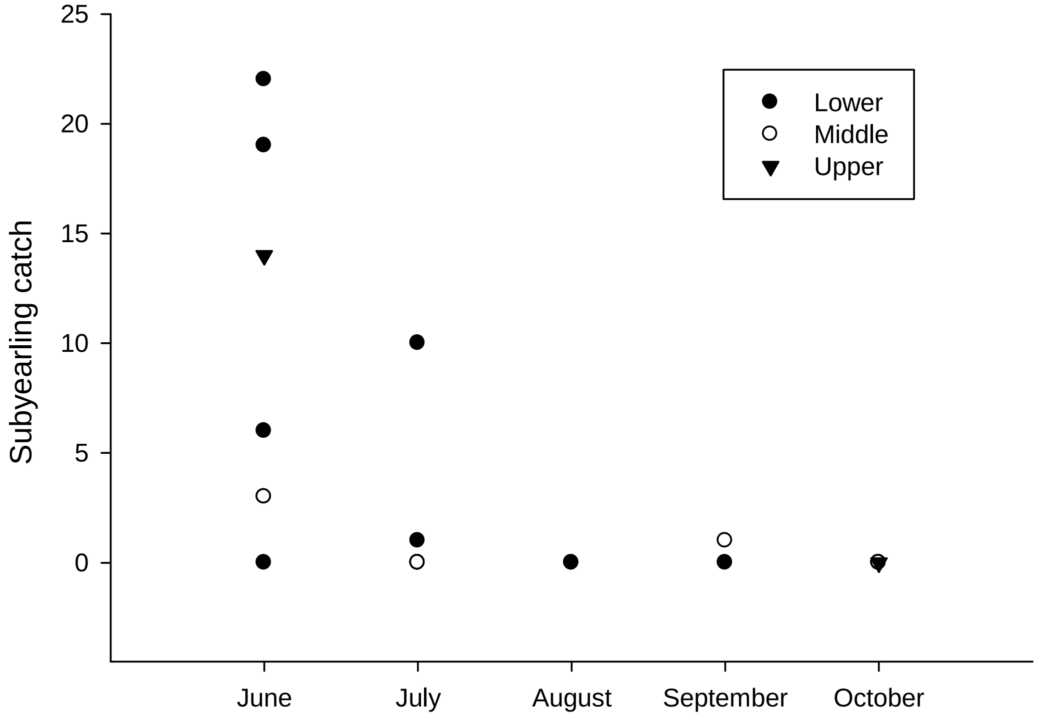


Figure 7. Subyearling Chinook salmon catch in Oneida traps in Lookout Point Reservoir by month.

PIT tags- We PIT tagged juvenile Chinook salmon in the reservoirs with the expectation that subsequent recaptures would provide information on in-reservoir movement and detections below the reservoirs would provide information on reservoir emigration. Downstream detection sites included the Leaburg Canal fish bypass, Walterville Canal fish bypass, and the Sullivan Plant at Willamette Falls. Only fish from Cougar Reservoir could be detected at the Leaburg and Walterville sites.

We tagged 282 subyearlings and 159 yearlings in Cougar Reservoir from June 8 through September 6, 2010. The only fish recaptured in the reservoir was a subyearling originally tagged on September 15 near the head of the reservoir (rkm 14) and subsequently recaptured on September 22 approximately 3.3 km down-reservoir. At detection sites below the dam, we detected 17 subyearlings (6.0%) and one yearling (0.6%). This suggests that there may be some size-specific mortality associated with dam passage, or less smolting behavior expressed by yearlings. Detections at downstream sites were monitored through the end of February 2011. All detections occurred from October 30, 2010 through January 25, 2011 during the reservoir drawdown period (Appendix Table 1).

We calculated an estimated proportion of subyearlings that exited Cougar Reservoir based on estimates of antenna detection efficiency at the Leaburg bypass and passage survival through Cougar Dam. The Leaburg bypass antenna detection efficiency was estimated to range from 24.3 to 38.7% based on detections of control fish released below Cougar Dam during a survival study conducted in January 2010 (Heisey et al. 2011). The minimum passage survival estimated from this same study was 36.4% for fish passing through the turbines. A total of 16 subyearlings that we tagged in the reservoir were detected at the Leaburg bypass antenna through February 28, 2011. We expanded these detections by the estimated minimum antenna efficiency to estimate the total number of tagged fish passing Leaburg and again by the minimum dam passage survival to an estimated 181 PIT-tagged subyearlings exiting the reservoir. Based on the 282 subyearlings originally tagged, this results in approximately 64% of the in-reservoir subyearling population exiting the reservoir through the dam. It should be noted that this percentage could be much less if we assume a greater overall dam passage survival rate or antenna efficiency. The remainder of the subyearling population could presumably emigrate in the spring of 2011 or will remain in the reservoir for at least another year.

In Lookout Point Reservoir, we tagged 69 subyearlings, 12 yearlings, and two fish that were likely age 2 (>300 mm FL). No tagged fish were subsequently recaptured in the reservoir. One subyearling was detected below the dam at Willamette Falls, on June 26, 2010.

Relative growth

We assessed relative growth of stream rearing versus reservoir rearing subyearling Chinook salmon by comparing lengths of fish collected from both locations. Juvenile Chinook salmon sampled upstream of reservoirs were collected in screw traps and seined from rearing habitats within the stream in late summer. We seined subyearlings rearing in the South Fork McKenzie River above Cougar Reservoir from August 3-13, and in the North Fork Middle Fork Willamette River above Lookout Point Reservoir from August 9-12. In the South Fork McKenzie River, comparison of fish lengths between fish seined and those collected in the screw trap during the same time period showed no significant difference in size (t-test, P=0.093), indicating that the size of fish collected in the screw trap were representative of the size subyearlings rearing above Cougar Reservoir. Too few subyearlings were collected in both Lookout Point Reservoir and the screw trap above the reservoir to compare relative growth from this basin.

Size comparisons for subyearlings collected in the South Fork McKenzie River screw trap and subyearlings collected in or below Cougar Reservoir indicated that reservoir rearing subyearlings tended to grow faster through the season when compared to their stream rearing counterparts (Figure 8). By the end of the year, reservoir-reared subyearlings were approximately 30mm larger than fish rearing the entire season in the upper South Fork McKenzie River.

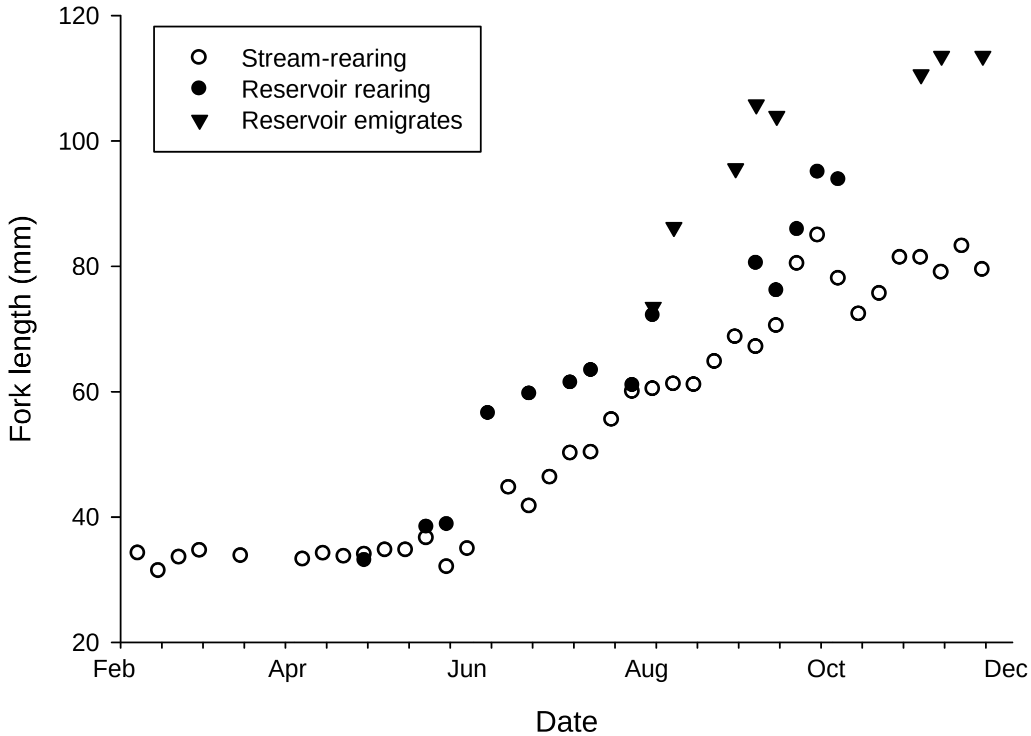


Figure 8. Comparison of mean weekly fork lengths of subyearlings rearing in the South Fork McKenzie River above Cougar Reservoir (open circles), subyearlings rearing in the reservoir (closed circles), and subyearlings emigrating through the dam that presumably reared in the reservoir (triangles). Stream-rearing subyearlings and reservoir emigrates were collected via screw traps.

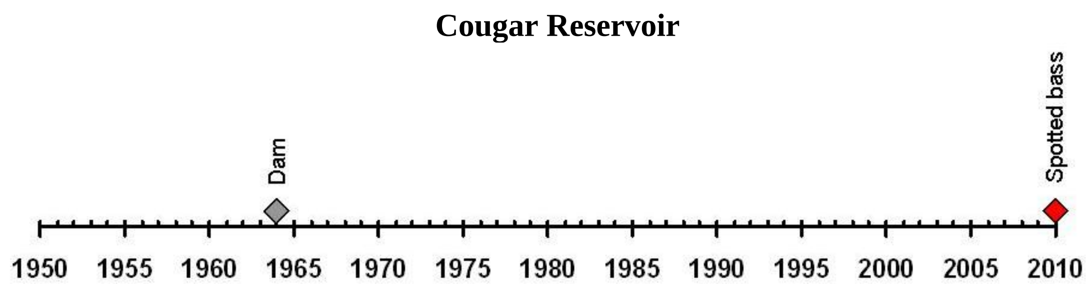
Fish community structure and predation potential on juvenile Chinook salmon

Predatory fish species composition- We collected five piscivorous fish species capable of eating juvenile Chinook salmon in Cougar Reservoir, one of which was non-native (Table 5). Predators were present in relatively low numbers in Cougar Reservoir. There were few bull trout in the reservoir. Cutthroat or rainbow trout are likely unable to catch larger juvenile Chinook. Bass were first documented in 2010 (Figure 9), but were likely introduced several years prior and have established a spawning population, as evidenced by the various size classes observed. Bass were sent to OSU for identification, and preliminary taxonomy is consistent with spotted bass (*Micropterus punctatus*).

Table 5. Relative abundance and size range of each species collected in Cougar and Lookout Point reservoirs, 2010. Fish were captured using Oneida box traps, hoop nets, boat electro-shocking, hook and line, and gill netting. Asterisk designates non-native (exotic) species.

	Lookout Point	Cougar
	Number captured (Fork length range in mm)	
Piscivorous species		
Cutthroat Trout *(Oncorhynchus clarkii)*	10 (322-325)	29 (247-378)
Rainbow Trout *(Oncorhynchus mykiss)*	18 (219-456)	49 (115-335)
Bull Trout *(Salvelinus confluentus)*	0	1 550
Northern Pikeminnow *(Ptychocheilus oregonensis)*	74 (300-500)	0
Sculpin *(Cottus* spp.)	97 Not measured	11 Not measured
Bass* *(Micropterus* spp.)	45 (65-220)	7 (79-315)
Walleye* *(Sander vitreus)*	5 (460-600)	0
White Crappie* *(Pomoxis annularis)*	12,992 (36-285)	0
Black Crappie* *(Pomoxis nigromaculatus)*	2 Not measured	0
Non-piscivorous species		
Mountain Whitefish *(Prosopium williamsoni)*	0	10 (315-410)
Redside Shiner *(Richardsonius balteatus)*	18 Not measured	0
Dace *(Rhinichthys* spp.)	4 Not measured	1,942 Not measured
Sucker *(Catostomus* spp.)	143 Not measured	0
Bluegill* *(Lepomis macrochirus)*	41 Not measured	0
Brown Bullhead* *(Ameiurus nebulosus)*	14 Not measured	0
Yellow Bullhead* *(Ameiurus natalis)*	53 Not measured	0

Predatory fish are abundant in Lookout Point Reservoir (Table 5). Lookout Point Reservoir contained eight piscivorous species, four of which were non-native. Northern pikeminnow are native to the Middle Fork Willamette River, a portion of which became Lookout Point Reservoir following dam completion in 1954. Hasselman and Garrison (1957) captured 910 northern pikeminnow while gill netting for 2,019 h at five locations within the reservoir in 1957. Since then, many other predators and potential competitors have been introduced (Figure 9). The first bass and crappie were documented in 1983, and walleye were found in 2007. Thousands of crappie were encountered in 2010; however, only 130 of them were adults (>100 mm).



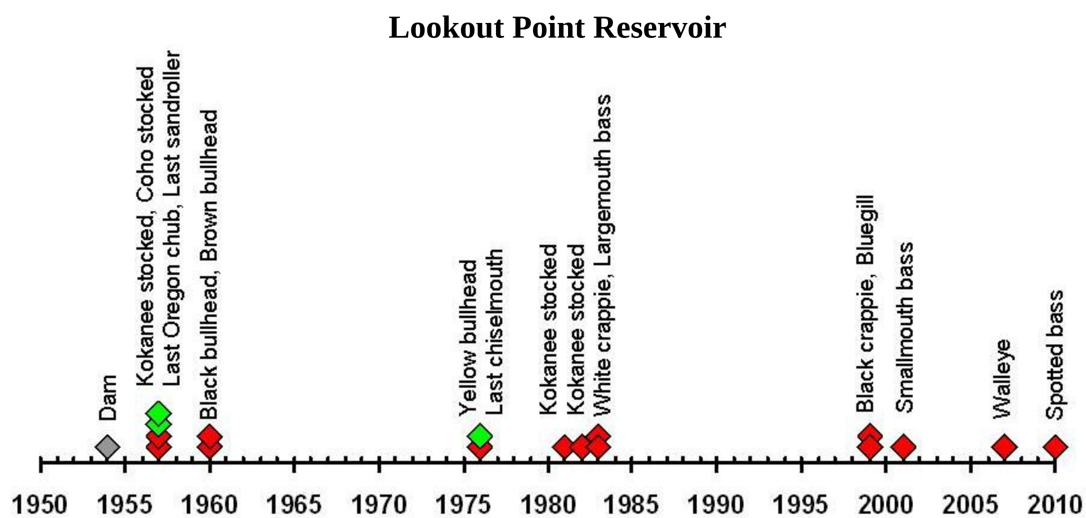


Figure 9. Timeline with date of dam construction and subsequent observation of introduced non-native fish species. Red diamonds indicate date of first observance. Green diamonds indicate last known observance of native species. Data was collected from ODFW and USACE archival records. Spotted bass identification is probable, yet larger specimens may be required for confirmation. Capture of smallmouth bass in Lookout Point Reservoir was only documented in 2001 by USACE.

According to the 1986 ODFW Fish Management Plan for Lookout Point Reservoir, after the reservoir was filled in 1954, it was immediately stocked with rainbow trout. Anglers enjoyed good catches for three years, but because non-game fish were outcompeting and feeding on the trout, ODFW could not generate a productive fishery. In addition, food production for trout was low in the reservoir and there was a lack of suitable habitat. Stocking of rainbow trout was discontinued in 1960, and there have been few anglers at Lookout Point Reservoir since 1961. In 1957 kokanee (*Oncorhynchus nerka*) were stocked (Gustafson et al. 1997), but did not produce a self sustaining population. Again, in 1981, ODFW agreed to stock kokanee fingerlings for up to 4 years. Kokanee were planted in 1981, 1982 and then the program was discontinued. In addition, coho salmon (*Oncorhynchus kisutch*) were planted in the 1950's and 1960's but failed to establish adult returns (Middle Fork Willamette Watershed Council 2002). ODFW declined to authorize experimental stocking of white bass x striped bass hybrids in 1981, to generate a new sport fishery. In 1983, ODFW began planting spring Chinook salmon fingerlings each year in the reservoir.

Distance from human population centers and proximity to major highways are likely contributing factors to the difference in community structure between Cougar and Lookout Point reservoirs. In addition, the environmental variable likely has the greatest influence on the community differences is temperature. Lookout Point Reservoir was warmer than Cougar Reservoir at all depths in late summer (Figure 10). It should be noted that in 2010, Lookout Point Reservoir experienced an atypical drawdown in August and how this affected the temperature regime in the reservoir is unclear.

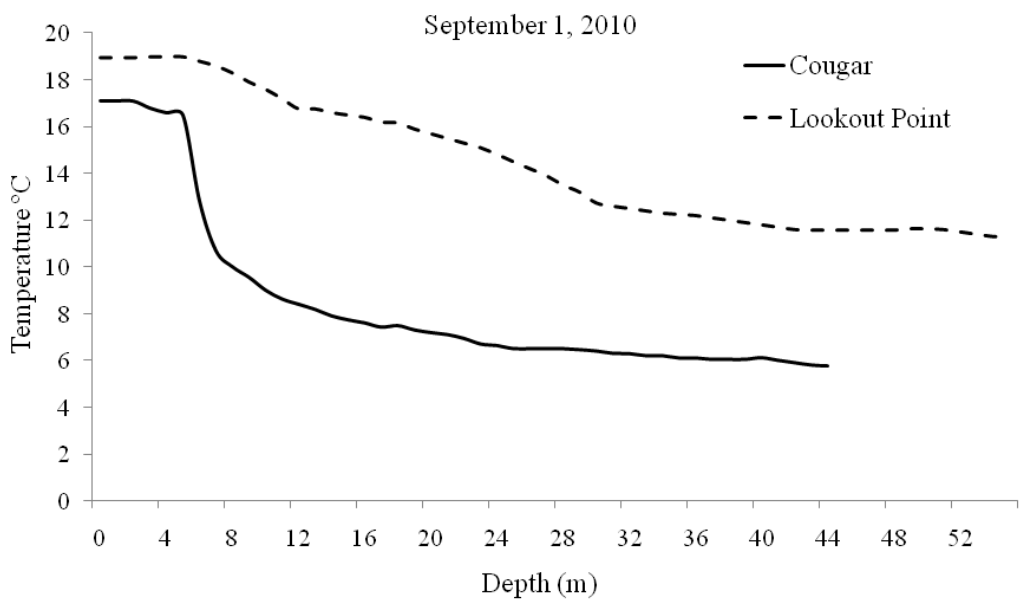


Figure 10. Temperature profile for Cougar and Lookout Point reservoirs on September 1, 2010. Data courtesy of U.S. Army Corps of Engineers.

Different temperature regimes between the reservoirs likely affect juvenile Chinook salmon and piscivorous fish species use of available habitat. In general, juvenile salmonids prefer temperatures in the range 11.7º to 14.7ºC (Richter and Kolmes 2005). Optimal rearing temperatures at natural feeding regimes for juvenile Chinook salmon are in the range of 12.2º to14.8ºC (Hicks 2000), and The Independent Science Group (1996) determined optimal rearing for juvenile Chinook salmon is between 12º–17ºC, with most optimal at 15ºC. The lethal limit for juvenile Chinook salmon is approximately 25ºC (Richter and Kolmes 2005). Juvenile Chinook salmon in Lookout Point Reservoir would need to swim to approximately 24 m depth in mid-summer to find an optimal temperature of 15 ºC, whereas in Cougar Reservoir these temperatures occur at 7 m. Thermal preference range for northern pikeminnow is 16-22°C (Brown and Moyle 1981), with a lethal level between 29-32°C (Black 1953). Walleye prefer temperatures from 21-23°C with a lethal level of 31.6°C (Koenst and Smith 1976; Hokanson 1977). Smallmouth bass have temperature preferences ranging from 12-31°C (Ferguson 1958; Barans and Tubb 1973; Reutter and Herdendorf 1974) and as temperatures increase to the preferred range, activity, and thus consumption rates increase (Vigg et al. 1991).

Predatory fish diet analysis- Samples collected using electrofishing or hook-and-line were the only samples used for diet analysis. Greater than 90% of the diet samples used for analysis were collected on September 27-28 in Lookout Point (42/45) and Cougar (12/13) reservoirs. At this time, surface temperatures were elevated, and we believe that most juvenile Chinook salmon were residing below the thermocline in both reservoirs. Therefore, juveniles were well out the effective range (3.7 m) of the electrical current produced by the electrofishing boat. It is also important to note that diet samples from 2010 are primarily representative of predatory fish residing near the water surface in the late summer. We suspect that diet sampling conducted in the spring would produce different results, with a higher presence of juvenile Chinook salmon. Small fry just entering the reservoir are likely highly vulnerable to predators.

While electrofishing in Cougar Reservoir, we collected one female bull trout and 10 mountain whitefish near the head of the reservoir where temperatures were much cooler. In addition, we also captured one subyearling Chinook salmon near Terwilliger Hot Springs. The Chinook salmon and bull trout were released with minimal handling (i.e. no diet sample). Late summer (Aug-Sept) sampling revealed that zooplankton, particularly daphnia, are abundant in diet samples taken from Cougar Reservoir (Figure 11). Zooplankton, terrestrial insects and crayfish comprised most of the diet from the fish sampled in Cougar Reservoir.

In Lookout Point Reservoir, most of the fish encountered were warm water species. Hundreds of subyearling white crappie were observed in a single cove, where we also encountered 20 northern pikeminnow and two rainbow trout. All of these predators were >400 mm (FL) with stomachs full of subyearling crappie. White crappie subyearlings were abundant near the surface and accounted for a majority of the diet in predatory fishes sampled. Many of the terrestrial insects found in the diet samples from both reservoirs were winged ants.

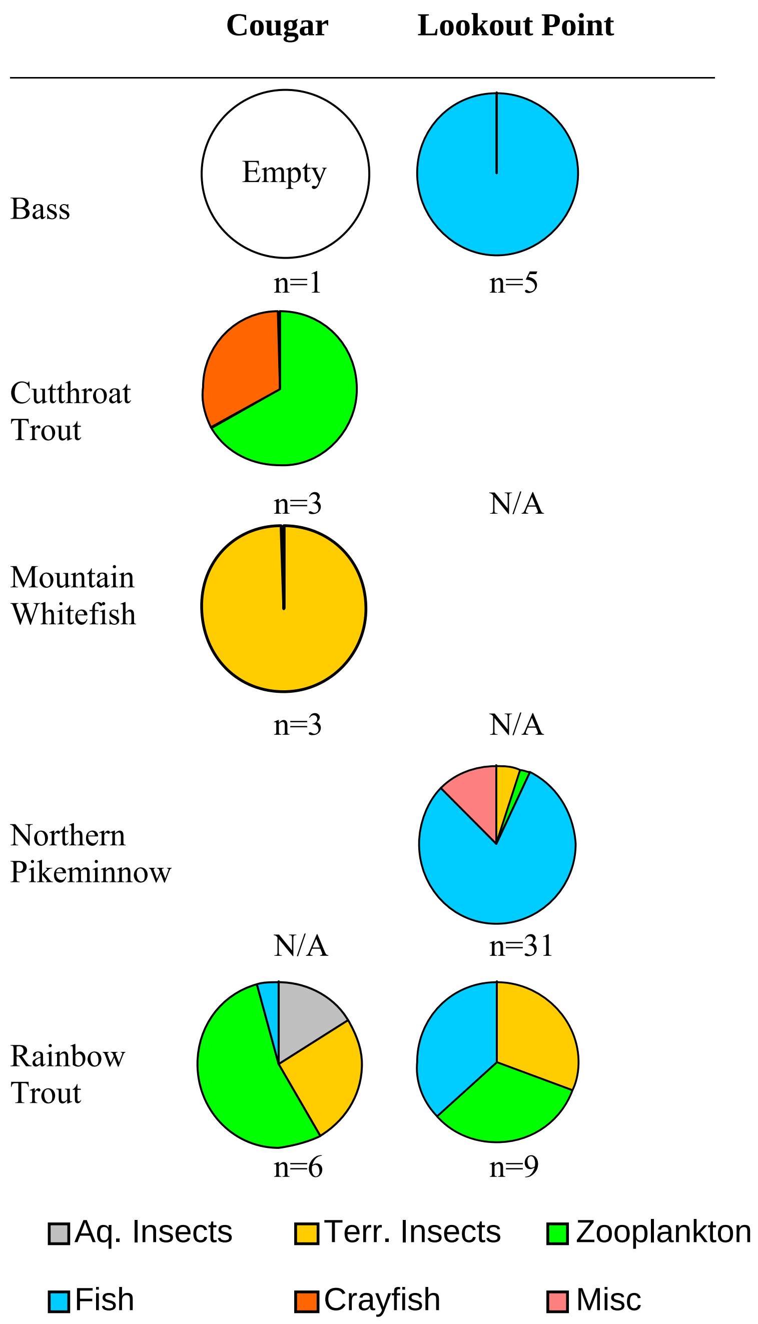


Figure 11. Diet composition for fish captured using boat electrofishing and hook and line sampling in Cougar and Lookout Point reservoirs during September 2010. Proportions from estimated volume of each diet category. n= number of fish diet samples analyzed.

Diet samples, as previously discussed, were collected primarily during summer sampling when surface temperatures were elevated. During this time, our results suggest that juvenile Chinook salmon do not comprise a significant portion of the diet for predatory fish in either reservoir. Reasons for this could be: 1) Chinook salmon are large enough to evade predators, 2) alternate food sources are abundant elsewhere in the reservoir (zooplankton in Cougar, subyearling crappie in Lookout Point), and occur in an area with temperatures more conducive to their preferred temperature range, 3) we were unable to collect adequate diet samples from predators residing at depth that may have been feeding on Chinook salmon in the summer because of limitations of our sampling gear or, 4) we weren't sampling at a time when predator fish and juvenile Chinook were occupying the same habitat.

Diet samples from fish captured in gill nets and Oneida box traps were not used for the diet analysis. Samples collected from predatory fish captured in trap nets are biased because prey fish found in the stomachs of these predators were likely consumed while trapped in the net with the predators. Similarly, fish captured in gill nets are known to evacuate their stomach contents partially or completely while entangled in the nets. Therefore, diet samples from fish captured using these methods are not representative of diet samples from the natural environment. However, these samples provide useful information regarding the size of the fish that the predator can consume, possible preference for certain prey items, and number of fish potentially consumed under optimal conditions.

An adult crappie >200mm (FL) was captured in an Oneida trap on June 3, that had consumed a 72 mm (FL) Chinook salmon. Several other crappie from the trap nets were found to have consumed smaller salmonids. Adult crappie present an imposing potential threat due to their large population size, and the small size of juvenile Chinook salmon at reservoir entry. A northern pikeminnow captured in a gill net deployed at the bottom of the reservoir in early November had a 200 mm (FL) yearling Chinook salmon in its stomach, evidence that juveniles are vulnerable to predation in Lookout Point Reservoir for the duration of their residence. This was the only confirmed Chinook salmon that we found in any of our diet samples, other than those predators that had been captured in trap nets.

Other studies have found that juvenile salmonids generally comprise a small portion of northern pikeminnow diet in lotic habitats (Buchanan et al. 1981; Kirn et al. 1986; Brown and Moyle 1981). However, lentic environments such as those created by dam impoundments present a different scenario with potentially high salmonid consumption. Northern pikeminnow, black bass, and walleye are all predator species that have been shown to be major predators of juvenile salmonids in numerous studies in Columbia River reservoirs (Beamesderfer and Rieman 1991; Poe et al. 1991; Vigg et al. 1991; Tabor et al. 1993).

Bass are especially threatening to juvenile salmonids when both species occupy littoral areas that correspond to preferred bass habitat (Gray and Rondorf 1986; Tabor et al. 2007). From our distribution data, this would correspond to the time period when fry enter the reservoirs (February) to when they begin residence in deeper water (June). There is evidence that exotic black bass species have already contributed to declines in salmonid populations in Oregon (Reimers 1989) and Washington (Fritts and Pearsons 2004). The literature emphasizes that proportions of juvenile salmonids in predatory fish diet are highly variable, and dependant on abundance, water temperature, habitat utilization, and size of both predator and juvenile salmonids. We suspect variability exists on similar spatial and temporal scales in the Upper Willamette Basin reservoirs, and further research is needed to assess the impact on juvenile Chinook salmon survival in these reservoirs.

Cougar Reservoir remains cool at depth throughout the year, contains few predators, and introduced species, and presents a shorter migration distance between the head of the reservoir and the dam (potential passage). In contrast, a culmination of factors in Lookout Point Reservoir, including; high summer temperatures, size of reservoir (longitudinal length), a plethora of predators residing within the reservoir, and dam passage paint a more grim picture for survival of juvenile Chinook salmon attempting to emigrate downstream in the Middle Fork Willamette River. In addition, these fish would still have to navigate Dexter Reservoir, located immediately downstream which is also likely to contain a large predator population, and additional dam passage issues.

Recommended Future Directions

Reservoir sampling will continue in 2011 in both reservoirs, and we will expand sampling to include Detroit Reservoir. Oneida sampling will occur earlier in the year in Cougar Reservoir in support of other research projects occurring there in 2011. We also plan on collecting gill ATP-ase samples from juvenile Chinook salmon in and below Cougar Reservoir to assess smoltification dynamics of fish in the reservoir.

Next field season, predator diets will be collected in the spring and fall, in addition to summer, to add a temporal component to our analysis. We expect that early in the spring when fry are entering the reservoir they are highly vulnerable to all predators, and will be encountered in the predator diets with increased frequency during this time period.

Future efforts will include day and night boat electrofishing methods for predatory fish capture. We suspect that many of the predators in both reservoirs are most active at night. We will also electrofish multiple days in each reservoir, earlier in the year, to better assess juvenile Chinook salmon consumption.

The Northern Pikeminnow Management Program (NPMP) on the Columbia River uses a method for diet analysis described in Tabor et al. (1993) that requires chemical digestion of the entire northern pikeminnow digestive tract. In addition, the NPMP used 2,517 samples to compare the effectiveness of two different methods of removing the bones of prey items from pikeminnow digestive tracts. Digestive tracts were either visually inspected for prey items or the entire tract was chemically digested. No food items were visually found in 40% (999) of the tracts, so based on visual assessment they would have labeled them “empty”. However, after chemical digestion, they found fish bones in 12% (120) of the “empty” samples, and were ultimately able to identify prey species in an additional 4% (109) of the samples (Michele Weaver, ODFW, personal comm.). We plan to conduct a similar comparison between our “milking” method and the chemical digestion next year.

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Appendix

Appendix Table 1. PIT-tagged Chinook salmon tagged in reservoirs and detected at downstream observation sites.

Reservoir	Tag code	Length (mm)	Tag date	Observation date: Leaburg	Observation date: Walterville	Observation date: Willamette Falls
Cougar	3D9.1C2D37F824	75	21-Sep-10	24-Jan-11		
Cougar	3D9.1C2D383FAF	67	22-Jun-10	3-Dec-10		
Cougar	3D9.1C2D38D0F2	72	16-Jul-10			16-Jan-11
Cougar	3D9.1C2D38D1EE	68	16-Jul-10	6-Nov-10		
Cougar	3D9.1C2D38E4B4	65	22-Jun-10	12-Nov-10		
Cougar	3D9.1C2D38F8FD	74	25-Jun-10	6-Dec-10		9-Dec-10
Cougar	3D9.1C2D3915BD	88	24-Sep-10	28-Nov-10		7-Dec-10
Cougar	3D9.1C2D39176F	67	25-Jun-10	5-Dec-10		
Cougar	3D9.1C2D3920C2	79	2-Aug-10	10-Dec-10		
Cougar	3D9.1C2D392F24	70	16-Jul-10	30-Oct-10		
Cougar	3D9.1C2D393C09	66	25-Jun-10	25-Jan-11		
Cougar	3D9.1C2D393D41	74	25-Jun-10	9-Dec-10		
Cougar	3D9.1C2D395C4E	92	4-Aug-10	3-Jan-11		
Cougar	3D9.1C2D397A33	99	22-Sep-10	10-Dec-10	11-Dec-10	
Cougar	3D9.1C2D399223	74	15-Sep-10	26-Dec-10		
Cougar	3D9.1C2D39C49C	68	22-Sep-10	26-Dec-10		
Cougar	3D9.1C2D39EA84	71	16-Jul-10	4-Dec-10	4-Dec-10	
Cougar	3D9.1C2D4F646C	198[a]	31-Aug-10	6-Dec-10		
Lookout Pt.	3D9.1C2D39BBBD	74	16-Jun-10			26-Jun-10

[a] Yearling Chinook salmon