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

Prepared for
U. S. ARMY CORPS OF ENGINEERS
PORTAND DISTRICT – WILLAMETTE VALLEY PROJECT
333 S.W. First Ave.
Portland, Oregon 97204

Prepared by
Fred R. Monzyk
Ryan Emig
Jeremy D. Romer
Thomas A. Friesen

Oregon Department of Fish and Wildlife
Upper Willamette Research, Monitoring and Evaluation Program
Corvallis Research Lab
28655 Highway 34
Corvallis, Oregon 97333

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Executive Summary

We investigated several life-history characteristics of juvenile spring Chinook salmon *Oncorhynchus tshawytscha* rearing in Detroit, Cougar and Lookout Point reservoirs to aid in the development of downstream passage options for Willamette Valley Project (WVP) dams. The study objectives were to provide information on the longitudinal and vertical distribution of juvenile Chinook salmon rearing in reservoirs, relative growth rates among subbasins and between streams and reservoirs, parasitic copepod infection prevalence and intensity, and predator-prey interactions in Lookout Point Reservoir.

The longitudinal distribution of spring Chinook salmon subyearlings was assessed with floating box traps set in nearshore habitat. Spring Chinook salmon subyearlings were collected in all nearshore areas of the reservoirs but catches were greater in the upper ends of the reservoirs where natal streams enter, especially early in the spring. Small subyearlings in Cougar Reservoir dispersed farther towards the dam each consecutive month from April – June resulting in significantly different monthly nearshore distributions. In April, 73% of the subyearlings captured were collected in the upper third of the reservoir with only 2% in the lower third, but by June the proportion in the upper and lower third of the reservoir was 45% and 23%, respectively. The proportion of total subyearling catch occurring in the forebay was estimated at <1% in April and increased to 1.9% by May. Monitoring longitudinal distribution of naturally produced subyearlings in Lookout Point Reservoir was confounded by the release of unmarked hatchery subyearlings at the head of the reservoir in late April. Prior to hatchery releases in mid-April, natural-origin subyearlings were more evenly distributed throughout the reservoir in Lookout Point Reservoir compared to Cougar Reservoir for the same time of year. The proportion of total subyearlings that were captured in the forebay prior to hatchery release was estimated at 1.9%.

We assessed subyearling Chinook salmon vertical distribution with gill nets set at specific depth intervals from July through December in Detroit and Lookout Point reservoirs. In August, most Chinook salmon in Detroit Reservoir (65%) were caught in the 9-14 m depth range. In September, juvenile Chinook salmon descended slightly deeper in the water column but by October were more evenly dispersed throughout all depths sampled. A vertical shift in distribution towards the surface was evident in November and December. Most juvenile Chinook salmon (70%) were caught near the surface (0-5 m) in December. Habitat segregation between juvenile Chinook salmon, rainbow trout *O. mykiss*, and kokanee *O. nerka* was evident in Detroit Reservoir. Rainbow trout were more surface oriented and kokanee generally occupied deeper habitat until the fall when all species were near the surface. Juvenile Chinook salmon in Lookout Point Reservoir followed a similar vertical distribution pattern as in Detroit Reservoir. In July, juvenile Chinook salmon were caught at all depths, but the greatest catch was at the 9-14 m depth range. In August, as surface temperatures reached their maximum, a similar distribution was observed except no Chinook salmon were collected in the surface nets (0-5 m). During September and October, juveniles were more evenly dispersed throughout the water column but in November and December, Chinook salmon showed a trend towards the surface.

Growth was rapid for subyearling Chinook salmon rearing in reservoirs compared to stream-rearing fish. By November, subyearlings in reservoirs were 50-147 mm (fork length) larger than their counterparts in streams among the WVP reservoirs we sampled. We estimated growth rates from May to October of 0.55 mm/d in Cougar Reservoir and 0.99 mm/d in Lookout Point Reservoir. Subyearlings in Fall Creek Reservoir had the greatest growth rate among all WVP reservoirs based on the size attained by late fall.

We assessed the prevalence and intensity of infection by *Salmincola californiensis* among *Oncorhynchus* species rearing in reservoirs and streams above reservoirs from April through December. Parasitic copepods were more prevalent in reservoir-rearing fish than stream-rearing fish. Also, copepods tended to be more common on the gills of salmonids rearing in reservoirs compared to those rearing in streams. We observed an increase in prevalence each month (May-December) for reservoir-rearing subyearling Chinook salmon but the trend was not evident among other salmonids in reservoirs. Intensity of infection on the gills of reservoir-rearing Chinook salmon also increased each month. Fall Creek had the greatest infection intensity among WVP reservoirs we sampled. By late fall, the median number of copepods on the gills of subyearling Chinook salmon was 13 with approximately 23% infected with $\geq$ 20 copepods.

In Lookout Point Reservoir, we assessed the diet of piscivorous fish species suspected to prey on juvenile Chinook salmon. We found eight juvenile Chinook salmon in stomachs of predators and five unidentifiable salmonids suspected to be juvenile Chinook salmon. Species that preyed on juvenile Chinook salmon were white crappie *Pomoxis annularis*, largemouth bass *Micropterus salmoides*, walleye *Sander vitreus* and northern pikeminnow *Ptychocheilus oregonensis*. Most the consumption of Chinook salmon occurred in the spring. Consumption rates were greater for walleye and bass than for northern pikeminnow. However, northern pikeminnow were the most abundant large predator in the reservoir and likely had the greatest impact on Chinook salmon survival.

Introduction

The National Marine Fisheries Service concluded in the 2008 Willamette Project Biological Opinion (BiOp) that the continued operation and maintenance of the U.S. Army Corps of Engineers (USACE) 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 reservoirs and dams has one of the most significant adverse effects on both species and their habitat. The BiOp detailed specific actions, termed Reasonable and Prudent Alternative (RPA) measures that would "…allow for survival of the species with an adequate potential for recovery, and avoid destruction or modification of critical habitat". Several RPA measures to the action agencies' proposed actions were identified in the BiOp to address downstream fish passage concerns, notably, downstream fish passage structures (RPA 2.8; 4.8; 4.8.1; 4.9; 4.10; 4.12), head-of-reservoir juvenile collection facilities (RPA 4.9), and modifications to operational flows to improve conveyance of juvenile fish through the reservoirs. Assessing the feasibility of any of these proposed measures requires a baseline understanding of how juvenile salmonids use reservoir habitat.

Understanding the life-history of juvenile spring Chinook salmon in WVP reservoirs will inform future management actions needed for population recovery. Currently, information is limited regarding juvenile Chinook salmon use of reservoirs, including life stage-specific entrance timing, distribution, migration rate, predator/prey interactions, and growth rates among other population characteristics. In 2010, we began investigations in Cougar and Lookout Point reservoirs to further our understanding of these issues. In 2011, we expanded our scope of sampling to include Detroit Reservoir and refined our techniques to address the critical uncertainties. In 2012, we continued our efforts in these reservoirs and several aspects of juvenile Chinook salmon life-history were investigated in this report.

The four objectives of this study were to: 1) assess the longitudinal and vertical distribution of juvenile Chinook salmon in reservoirs; 2) compare growth rates between stream-rearing and reservoir-rearing juvenile Chinook salmon; 3) assess and compare the prevalence and intensity of infection by the parasitic copepod *Salmincola califoriensis* in salmonid species rearing in reservoirs and streams, and; 4) assess species composition, distribution, and diet of piscivorous fish in Lookout Point Reservoir. We report our findings of each of these objectives in separate sections of this report.

SECTION 1: JUVENILE CHINOOK SALMON DISTRIBUTION AND MOVEMENT IN RESERVOIRS

Background

Improvements to downstream fish passage require an understanding of juvenile Chinook salmon entrance timing and distribution in reservoirs. Previous research demonstrated that the majority of juvenile Chinook salmon enter WVP reservoirs at the fry life-stage (Bureau of Commercial Fisheries 1960; Monzyk et al. 2011a; Keefer et al. 2012; Romer et al. 2012) at an average fork length (FL) of 35 mm (Monzyk et al. 2011a; Romer et al. 2012). Although it is clear that the majority of juveniles enter the reservoirs as fry, less is known about their distribution and dispersion patterns within reservoirs at different life stages. Pilot efforts in 2010 and 2011 revealed that small subyearling "fry" were closely associated with shallow nearshore habitat and not found in deeper waters until attaining a larger size (Monzyk et al. 2012). Subyearling abundance was greater in the upper end of the reservoirs with few fish collected beyond 15 km of shoreline length from natal streams. Given the poor swimming ability of newly emergent fry and the fact that reservoirs are refilling, it is not unexpected that small subyearlings would be concentrated near the entrance of their natal streams in the spring. Tabor et al. (2007, 2011) found a similar result with fall Chinook salmon fry in Lake Washington; those fish were also found in shallow (<1 m) littoral habitat and only ventured into deeper waters as their size increased. This pattern was 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).

The shift to offshore habitat and vertical distribution patterns of parr may be partly attributed to changes in water temperature through the year. Ingram and Korn (1969) observed that most juvenile Chinook salmon captured with gill nets in Cougar Reservoir were in the upper 30 feet of the water column during late spring. The authors reported that by summer, as surface temperatures increased, most fish were caught at 9-14 m (30-45 ft) depth range but returned to the upper 4.6 m of the water column in November as water temperatures decreased. We conducted similar gill netting efforts in Lookout Point and Detroit reservoirs in 2011 and found similar patterns in vertical distribution. Most parr descended into deeper water in late summer when water temperatures reached a maximum and did not return to the surface until the fall when surface temperatures cooled (Monzyk et. al 2012).

In this report, we intensified our efforts to assess changes in subyearling distribution along nearshore habitat through the spring (March-June). We compared subyearling nearshore distributions between 2011 and 2012 and analyzed biological and environmental differences between years. In addition, we conducted a fry mark-recapture study to assess upstream/downstream movement patterns in shallow nearshore habitat to better understand fry distribution patterns. As subyearlings grew larger and moved offshore, we assessed their vertical distribution from summer through fall.

Methods

Subyearling Nearshore Distribution

Sampling efforts to assess fry and small parr distribution along the nearshore habitat were conducted at least every two weeks in Cougar and Lookout Point reservoirs from late March through June. We did not sample in Detroit Reservoir because of the limited number of outplanted adults and subsequent low juvenile production above the dam in 2011 (Sharpe et al. 2013 *in prep*). Weekly sampling was conducted during periods when personnel and equipment were available to provide greater sample size and precision. We sampled subyearlings in nearshore habitat with floating box traps consisting of a 0.61 x 0.61 x 0.91 m (W x H x L) PVC frame wrapped with 0.42-cm delta mesh. A 51-mm throat opening allowed fry and small parr to enter but excluded larger fish. Traps were placed perpendicular to shore with a 5-m lead net (0.91 m deep) extending from the shore to the trap opening. When water depths were greater than 0.61 m, we attached a 'tongue' fyke net below the trap opening to increase capture efficiency.

To ensure traps were deployed evenly throughout the reservoir, we used a stratified random sampling design for daily trap placement. Reservoirs were stratified into lower, middle, and upper thirds (forebay to head of reservoir). Within each section, random shoreline areas (approximately 0.4 km long) were selected for trap placement and a site was chosen within the 0.4-km area that would allow for easy attachment of the lead net to the bank. Each day, nine areas were randomly selected in a reservoir (three per section) and traps fished overnight for approximately 24 h. For each trap set, subyearlings were anesthetized (50 mg/L tricaine methanesulfate [MS-222]) and enumerated. We measured fork length (nearest millimeter) on a minimum of 15 randomly selected fish per trap.

Trap coordinates were recorded for each set and used to estimate distance from the head of the reservoir. Because fry and small parr are closely associated with nearshore habitat, we believed measuring subyearling dispersion in terms of shoreline distance was appropriate. Each bank of a reservoir was digitized using ArcGIS (measured at full pool) and trap coordinates were overlaid on the appropriate digitized shoreline to calculate distance from the head of the reservoir. The confluence of the South Fork McKenzie River with Cougar Reservoir and the Middle Fork Willamette River with Lookout Point Reservoir marked the head of the reservoirs. Because of unequal total shoreline lengths for each bank, the shoreline distance of a trap site was standardized as a percentage of total distance to the dam. The monthly distribution of subyearlings along the nearshore habitat of a reservoir was evaluated by plotting the cumulative proportion of subyearlings caught in floating box traps to shoreline distance. Differences in monthly distributions were evaluated with Kolmogorov-Smirnov tests (α=0.05).

We estimated the proportion of total monthly catch that occurred within the forebay of each reservoir. This metric provided an estimate of the number of subyearlings potentially available for downstream passage through the dam. In Cougar Reservoir, the forebay was defined as the shoreline within the boat-restricted zone (log boom). Due to the asymmetrical shape of the reservoir, the forebay accounts for 2.9% of the east bank shoreline and 6.3% of the west bank shoreline (mean: 4.6%). Because we randomly placed traps in the reservoir, the proportion of monthly trap sets that occurred within the forebay was not proportional to the forebay shoreline length. Therefore, we used the ratio of mean forebay shoreline proportion: proportion of monthly trap sets occurring in the forebay to weight the number of subyearlings caught in forebay traps each month. This weighted catch was used to estimate total monthly catch that occurred in the forebay. In Lookout Point Reservoir, there is no established boat restricted zone to demarcate the forebay. Therefore, we defined the forebay as the lowest 4.6% of shoreline length (approximately 1000 m of shoreline from the dam for each bank). Catch was weighted for the proportion of traps set in the forebay as described above.

The relationship between subyearling size and distance was analyzed with Kruskal-Wallis one-way ANOVA on ranks (α=0.05). Shoreline distance was categorized into upper, middle, and lower thirds of the reservoir. For each month, we compared fish size among each reservoir section.

In Lookout Point Reservoir, unmarked hatchery fry were released at the head of the reservoir on 20 April and could not be distinguished from naturally produced fry. Therefore, analysis of Chinook salmon distribution and size in this reservoir was segregated into pre- and post- hatchery release periods rather than month.

In addition to floating box traps, Oneida Lake traps (Figure 1-1) that fish deeper and farther from shore were placed in Cougar Reservoir in the spring (April-June). Although traps were set mainly to collect yearlings for other research needs, any subyearlings caught were enumerated and fork lengths measured from a representative sample. Subyearlings were differentiated from yearlings based on length-frequency analysis. Oneida traps had a 0.64-cm delta mesh holding box (2.4 m x 2.4 m x 2.4) and were placed 34 m from shore with a 3.0 m deep lead net. Traps were not set in random areas but rather they were repeatedly set in selected areas of each reservoir section (lower, middle and upper) in an attempt to maximize yearling catch. Most traps were sets for 24 h but occasionally traps were fished for 48 h. As such, Oneida traps provided information in subyearling size but had limited usefulness in describing distribution.

Comparisons of subyearling distribution between 2012 and 2011 were complicated due to differences in sampling effort between years. In 2011, sampling with floating box traps did not begin until mid-May in Cougar Reservoir, with the most continuous period of sampling occurring from 7-16 June. Therefore, the only comparison we were able to make was with a similar time period in 2012 (5-19 June). We compared the proportion of subyearlings captured in the lower reservoir section between years (z-test; α=0.05). We also compared mean fork length and reservoir inflows/outflows between years as possible explanatory variables in distribution differences.

Fry Movement

We conducted a pilot study during May and June to determine the upstream/downstream movement patterns of Chinook salmon fry in nearshore habitat of Cougar and Lookout Point reservoirs. Our collection efforts were generally in the upper portion of the reservoirs in order to maximize the number of fry we could capture and mark. Fry were collected with small Oneida nets set for approximately 24 h. Fry were marked with either Bismarck Brown dye or a small caudal clip and released in the nearshore habitat where they were captured. Caudal clips were used in the later part of the study because we suspected the dye was causing unacceptably high mortality. Prior to release of marked fish, floating box traps were placed 15 m and 25 m along the shore in both the ‘upstream’ and ‘downstream’ direction from the release site, for a total of four traps. Traps were checked daily for 1-3 days after release. The number of marked fish in each trap was recorded along with the number of unmarked Chinook salmon and incidental species. Chi-square goodness-of-fit (α=0.05) was used to test if movement patterns were equal in the upstream and downstream directions.

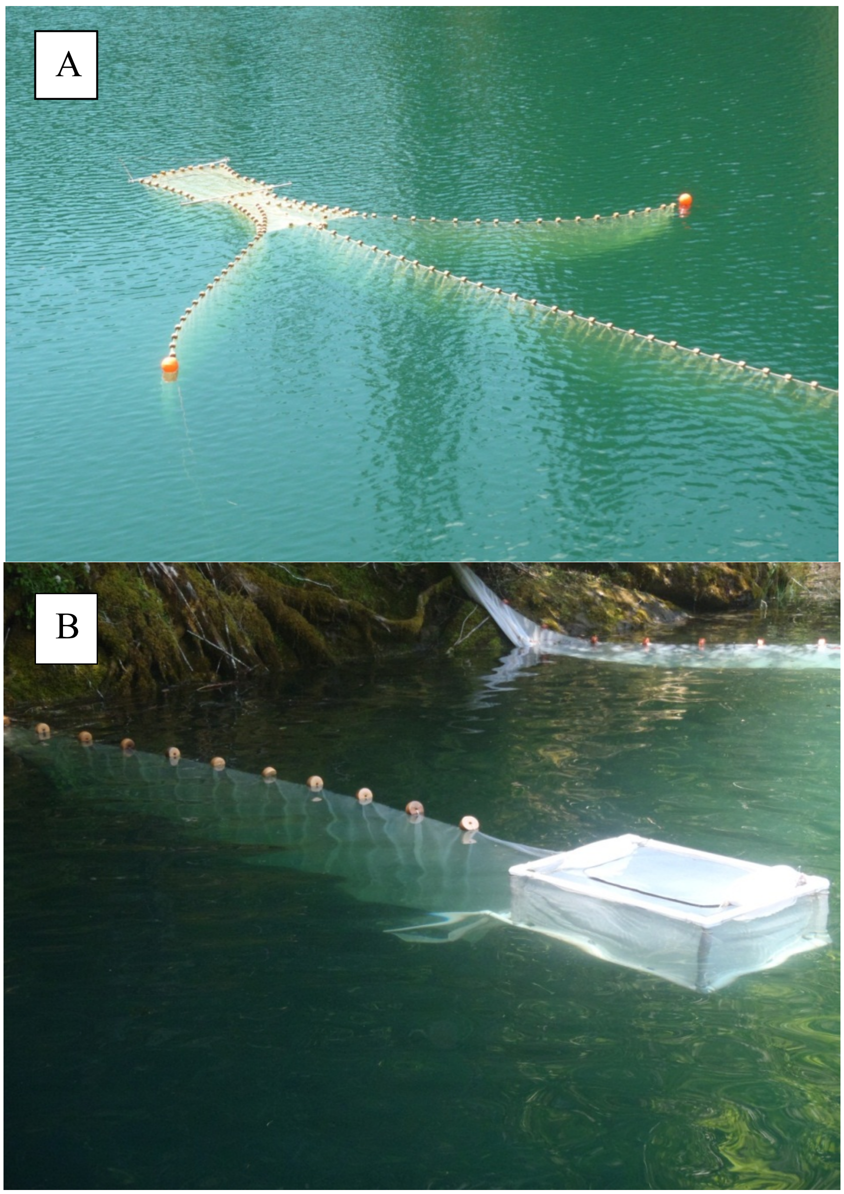

Figure 1-1. Oneida Lake trap (A) and floating box trap (B) used to collect subyearling Chinook salmon in Cougar Reservoir, 2012.

We hypothesized that wind direction could influence the direction of fry movement. Therefore, we recorded the predominant wind direction for each day traps were checked. Wind direction data was downloaded from USACE weather stations at each reservoir. Weather stations recorded wind direction in degrees every 15 minutes. We categorized each wind direction measurement into cardinal coordinates (e.g., east=46 to 135º; south=136 to 225º, etc.), and the cardinal coordinate with the plurality of measurements over the 24-h period was considered the prevailing wind direction for the day. We compared the direction of fry movement (upstream/downstream) to wind direction.

Parr Vertical Distribution

In 2012, we assessed vertical distribution of juvenile Chinook salmon using gill nets deployed at specific depth intervals, similar to the methods of Ingram and Korn (1969). This was the second year of efforts to assess vertical distribution after pilot efforts in 2011 proved successful (Monzyk et al. 2012). Gill netting in 2012 occurred from July to December in Detroit and Lookout Point reservoirs, but not in Cougar Reservoir where threatened bull trout *Salvelinus confluentus* were present. Limited natural production of Chinook salmon occurred above Detroit Reservoir in 2012; however, adipose (AD) fin-clipped hatchery Chinook salmon were released into the reservoir in August.

Gill nets were 24.4 m long by 4.6 m deep (80 x 15 ft), consisting of four 6.1 m panels with square mesh sizes of 9.5, 12.7, 19.1, and 25.4 mm. Gill nets were set at 4.6 m (15 ft) depth intervals from the surface to a maximum depth of 27.6 m (six nets total). This resulted in nets deployed at 0-4.6 m, 4.6-9.2 m, 9.2-13.8 m, 13.8-18.4 m, 18.4-23 m, and 23-27.6 m depth intervals (Figure 1-2). Nets were suspended from the surface using the forebay log boom in Detroit Reservoir and a 'rope boom' constructed in Lookout Point Reservoir that extended perpendicular from the dam face near the spillway. Nets were deployed in the middle of each month and checked daily during eight overnight sets. The exception was in December, when we only deployed nets for four overnight sets. Every two days we changed the order in which we hung nets of specific depth intervals to ensure that nets closest to shore varied in depth. All nets were hung from booms in water at least 30 m deep.

We counted juvenile Chinook salmon captured at each depth interval and recorded fork length for each fish. Fish were inspected for the presence of adipose fins to distinguish between hatchery and natural origin in Detroit Reservoir. In Lookout Point Reservoir, unclipped Chinook salmon could not be distinguished between hatchery and natural origin unless tagged with Passive Integrated Transponder (PIT) tags. Adipose-clipped hatchery Chinook salmon were also collected in Lookout Point Reservoir from releases in Hills Creek Reservoir. Catch of fish at specific depth intervals were compared for each month to assess temporal changes in vertical distribution.

To assess differences in vertical distribution between hatchery and natural-origin Chinook salmon, we compared average depth occupied by each group for each month and reservoir. In Lookout Point Reservoir, we could only compare known hatchery origin Chinook salmon (AD-clipped or PIT-tagged) with unclipped fish that were a combination of natural-origin Chinook salmon and unclipped hatchery Chinook salmon released as fry. We used the midpoint of each depth interval weighted by the number of fish caught at that depth interval to calculate average depth occupied for each rear group each month.

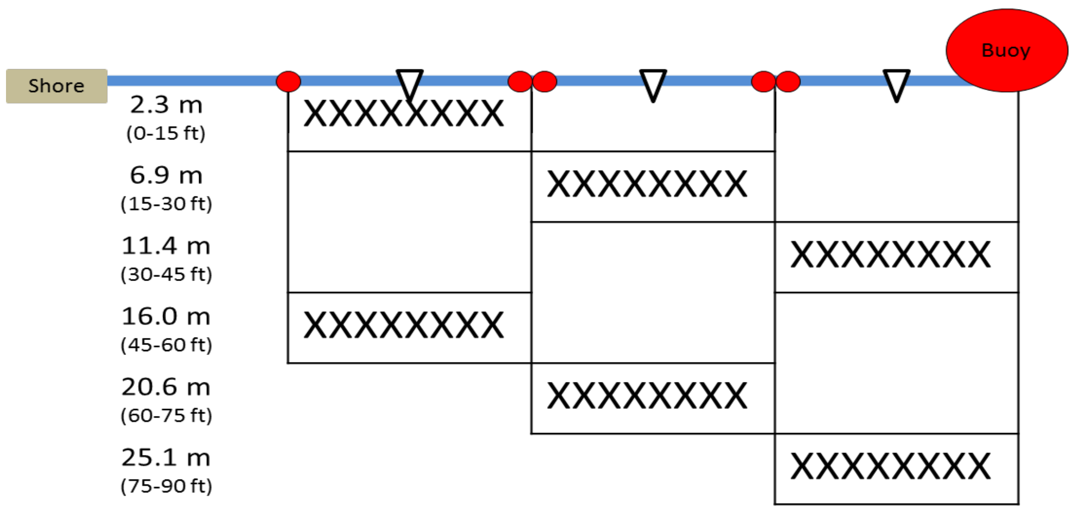

Figure 1-2. Depth midpoints for gill nets set in Detroit and Lookout Point reservoirs, 2012. Each experimental gill net was 24.4 x 4.6 m and consisted of four panels of increasing mesh size. Numbers in parentheses are depth intervals in feet.

We estimated water temperature at each depth interval midpoint using USACE temperature data (Onset HOBO® data logger string). Temperature data loggers are suspended from the log boom in Detroit Reservoir and within 200 m from gill nets in Lookout Point Reservoir. Depths of USACE data loggers were generally positioned at 6.1-m depth increments. We estimated temperature at each gill net midpoint as a linear function of logger temperature directly above and below the net midpoint. This method provided approximate temperatures at each net depth that we could compare to fish catch each month.

Results

Subyearling Nearshore Distribution

We assessed subyearling Chinook salmon distribution in Cougar Reservoir with the deployment of 293 floating box trap sets from 10 April to 29 June and collected 3,989 subyearlings. In Lookout Point Reservoir, 343 traps set were deployed from 28 March to 27 June with 1,519 subyearlings collected. Subyearlings were collected in all nearshore areas of the reservoirs but catches were greater in the upper ends of the reservoirs where natal streams enter, especially early in the spring (Figure 1-3).

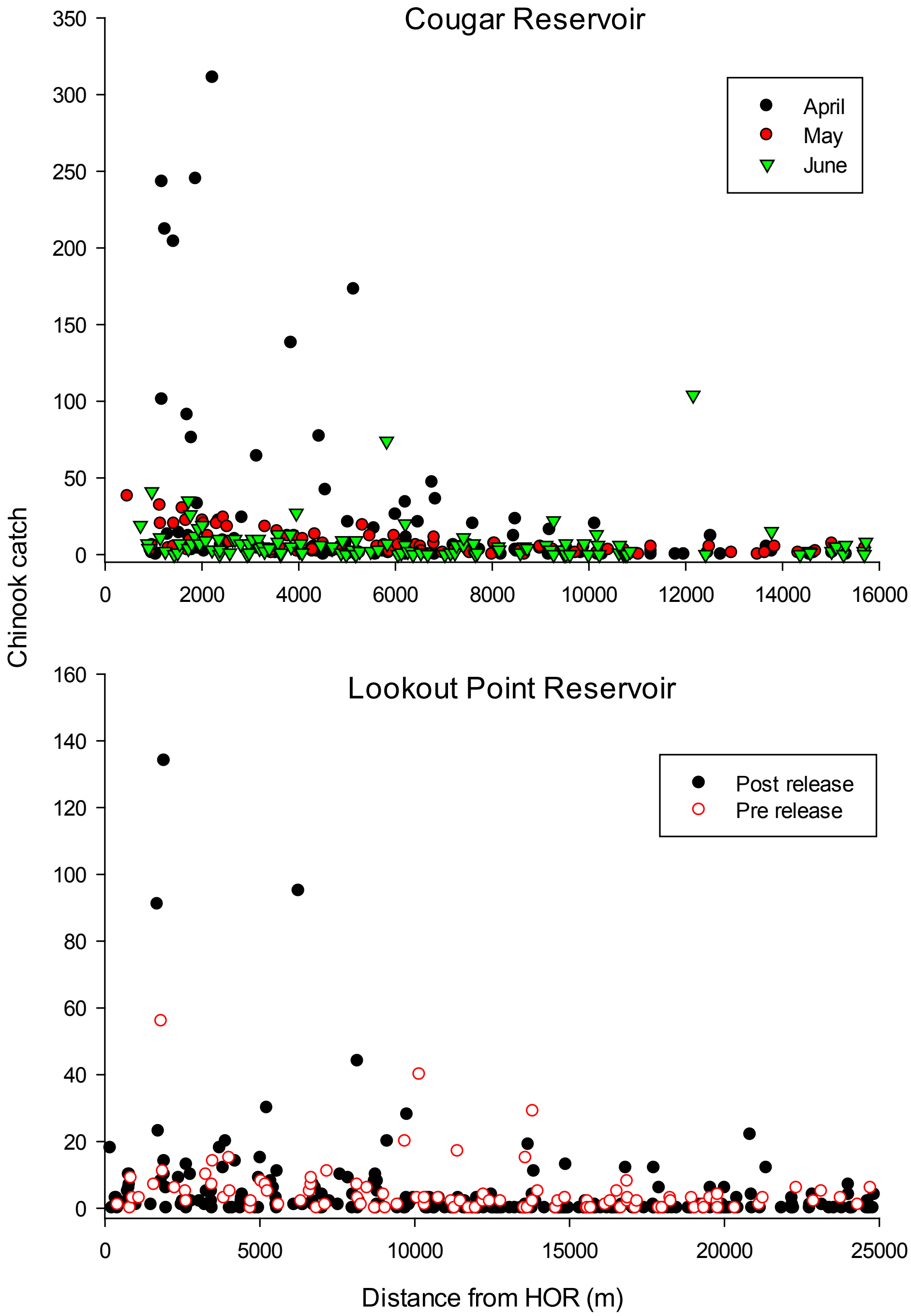

Figure 1-3. Relationship between juvenile Chinook salmon catch in floating box traps and shoreline distance from the head of the reservoir (HOR) for Cougar and Lookout Point reservoirs, 2012. Catch represented as all subyearling Chinook salmon caught in nearshore traps. Hatchery fry release date was 20 April in Lookout Point Reservoir.

Cougar Reservoir- With each consecutive month, small subyearling Chinook salmon dispersed farther into the reservoir towards Cougar Dam, resulting in significantly different monthly nearshore distributions (KS test, $P \leq 0.001$) (Figure 1-4). For instance, in April 73%

of the subyearlings were collected in the upper third of the reservoir and only 2% in the lower third. But by June, the proportion in the upper and lower third of the reservoir was 45% and 23%, respectively. In April, the proportion of total catch occurring within the forebay was estimated at <1% and increased to 1.9% by May. In June, the proportion in the forebay was 1.8%. The slight decrease in June can be partly attributed to subyearlings attaining a larger size and moving offshore, beyond our ability to sample with floating box traps in nearshore habitat.

Catch of larger subyearlings in Oneida traps suggested that the subyearling population may be more evenly distributed in June than our nearshore trapping results indicated. Subyearlings first began to be captured in Oneida traps in June and tended to be larger than subyearlings captured in floating box traps. For instance, in the lower reservoir mean fork length of subyearlings captured in Oneida traps (63 mm) was significantly larger than subyearlings in floating box traps (48 mm) in June (t-test ; $P \leq 0.001$) (Figure 1-4). Although Oneida trap deployments were too limited to assess longitudinal distribution, our largest catches were in the middle and lower sections of the reservoir (Table 1-1), suggesting that subyearlings were probably more numerous in the lower reservoir than the catch from floating box traps indicated.

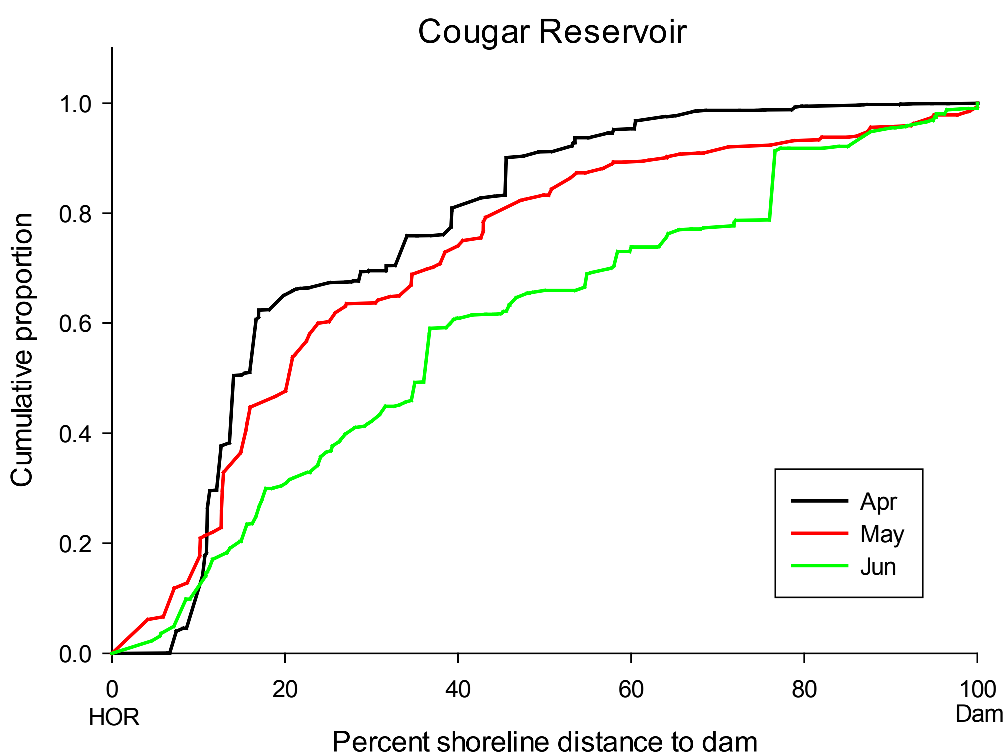

Figure 1-4. Monthly cumulative proportions of subyearling Chinook salmon catch in nearshore floating box traps in relation to percent of shoreline distance to Cougar Dam, 2012. Dotted line represents the cumulative proportion of a theoretical population that is evenly distributed throughout the reservoir.

Table 1-1. Catch per unit effort (CPUE) by reservoir section of subyearling Chinook salmon from Oneida traps set in June 2012.

Section	Number of sets (24 h)	Catch	CPUE
Lower	11	1,313	119.4
Middle	5	1,637	327.4
Upper	8	335	41.9

Subyearlings demonstrated a wide size range in all reservoir sections but were generally smaller in the upper reservoir, owing to the continued influx of newly emergent fry into this section. For instance, median subyearling size was significantly smaller in the upper section than in the middle and lower sections during April (Kruskal-Wallis one-way ANOVA on ranks; $P \leq 0.05$) (Figure 1-5). However, by June, we were unable to detect size differences between reservoir sections for subyearlings collected in nearshore floating box traps. We believe our inability to detect size differences in June was due to two factors: 1) greatly diminished fry migration into the upper section; and 2) larger fish in the lower sections moving farther offshore and beyond the ability of nearshore floating box traps to capture these fish. Evidence of larger fish in lower sections was evident from catch in Oneida traps. Fish caught in Oneida traps from the middle and lower reservoir sections were significantly larger than those from the upper section (Kruskal-Wallis one-way ANOVA on ranks; $P \leq 0.05$) (Figure 1-4).

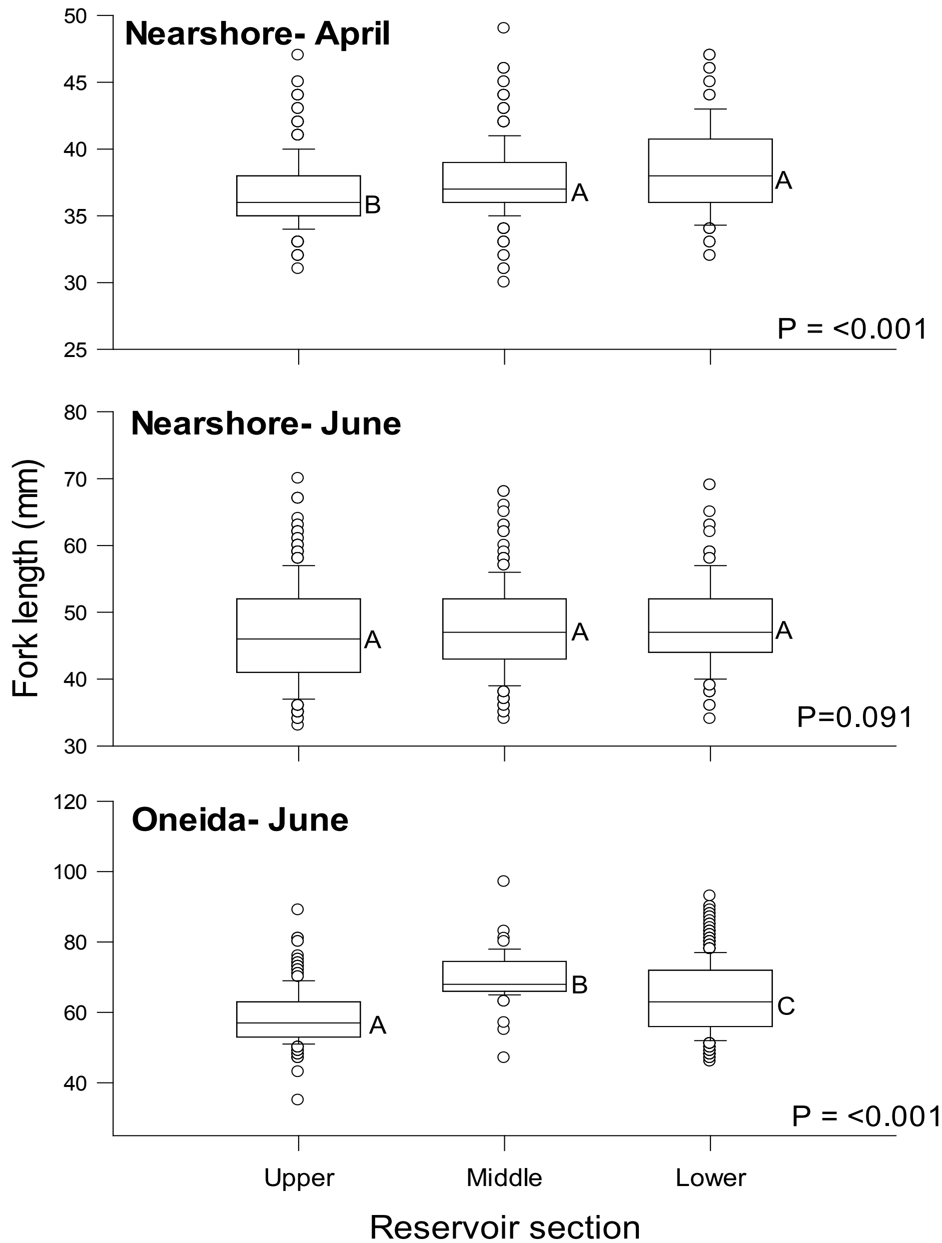

Figure 1-5. Subyearling Chinook salmon fork length in relation to month, gear type, and reservoir section in Cougar Reservoir, 2012. Nearshore traps were floating box traps set 5 m from shore. Oneida traps were set 34 m from shore. *P*-values are from Kruskal-Wallis one-way ANOVA on ranks. Within each plot, boxes with same letter are not significantly different.

Compared to 2011, subyearlings were dispersed farther into the reservoir by early June 2012. A significantly greater proportion of subyearlings in 2012 were in the lower reservoir section (18.9%) than in 2011 (7.1%) (z-test; $P<0.05$). Subyearlings had nearly identical migration timing into the reservoir between years with a median migration date of 16 May each year (Romer et al. 2013). However, by early June 2012 subyearlings were significantly larger (mean FL 44.6 mm) than in 2011 (40.3 mm) (Mann-Whitney Rank Sum test; $P<0.05$).

There were also greater inflows and outflows in late April and early May 2012 that may have aided subyearling dispersion farther into the reservoir (Figure 1-6).

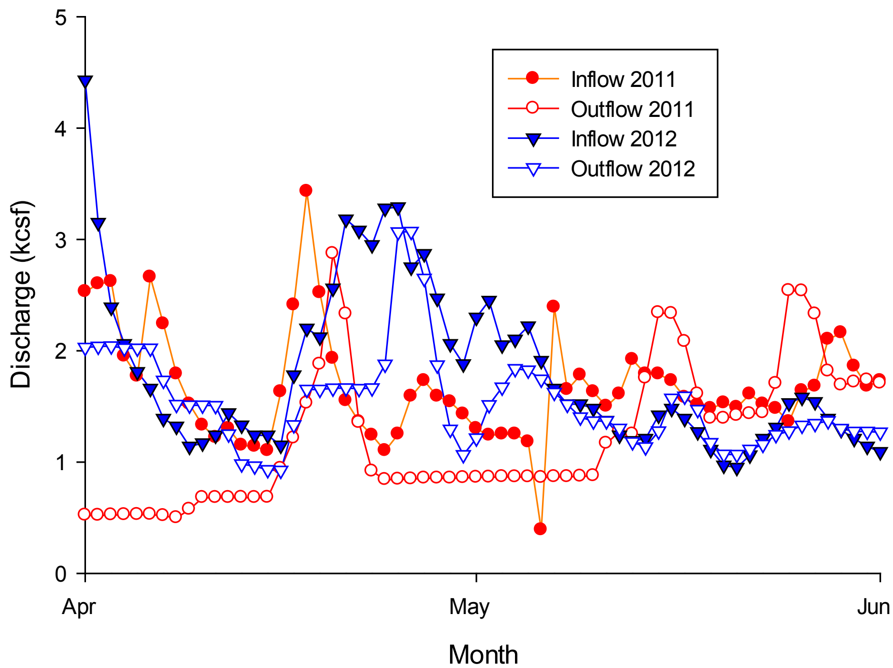

Figure 1-6. Comparison of daily inflows and outflows for Cougar Reservoir in 2011 and 2012.

Lookout Point Reservoir- Describing the longitudinal distribution of naturally-produced subyearling Chinook salmon through time in Lookout Point Reservoir was confounded by the release of unmarked hatchery subyearlings at the head of the reservoir on 20 April. As expected, once hatchery fry were released, the proportion of subyearlings caught in the upper reservoir increased (Figure 1-7).

Prior to the hatchery release, natural-origin subyearlings were dispersed farther into Lookout Point Reservoir compared to Cougar Reservoir for the same time of year (Figure 1-8). Prior to the hatchery release, 48% of the subyearlings were collected in the upper third of the reservoir with 14% in the lower third. This was significantly different from Cougar Reservoir where 63% of the subyearling catch occurred in the upper third of the reservoir and only 10% in the lower section prior to 20 April (KS test, $P \leq 0.001$). The proportion caught in the forebay prior to the hatchery release was estimated at 1.9%. This was a larger proportion than in Cougar Reservoir for the month of April. In Lookout Point Reservoir subyearlings were approximately 1.5 mm larger in mean fork length than Cougar Reservoir subyearlings. Pre-hatchery release, subyearlings were smallest in the upper section of Lookout Point Reservoir compared to the lower sections, similar to Cougar Reservoir.

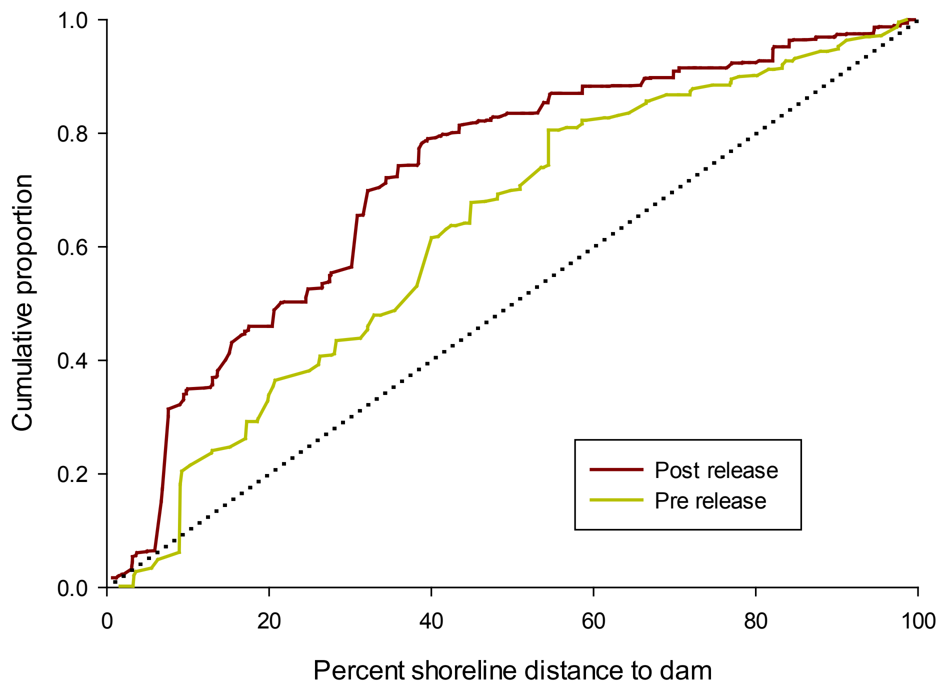

Figure 1-7. Cumulative proportions of subyearling Chinook salmon catch from nearshore floating box traps pre- and post-hatchery release in relation to percent of shoreline distance to Lookout Point Dam, 2012. The dotted line represents the cumulative proportion of a theoretical population that is evenly distributed throughout the reservoir. The first hatchery release occurred on 20 April.

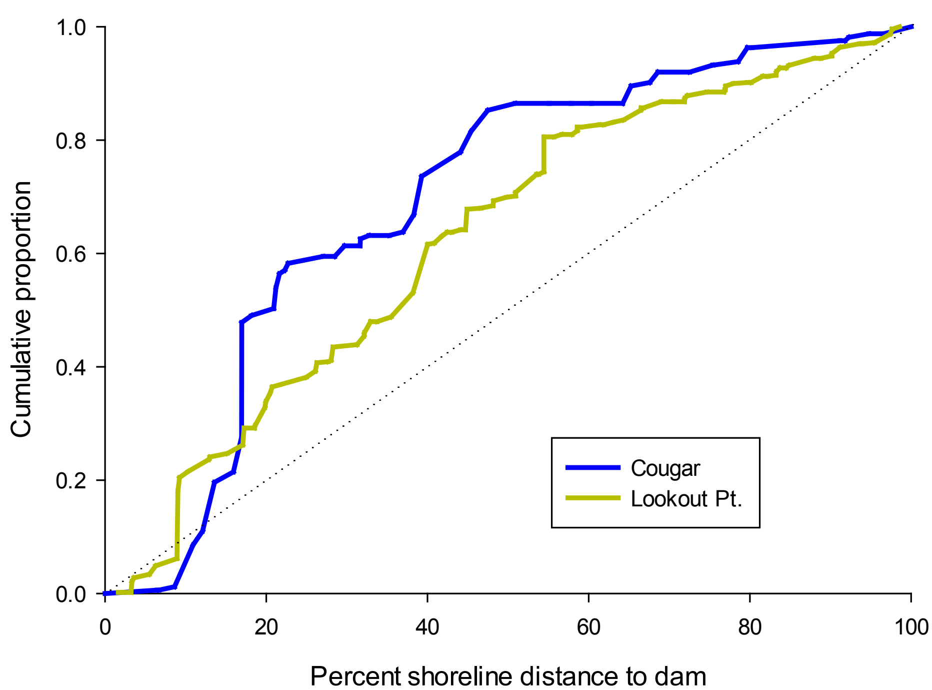

Figure 1-8. Cumulative proportions of subyearling Chinook salmon catch prior to 20 April from nearshore floating box traps in Cougar and Lookout Point reservoirs in relation to percent of shoreline distance to the dam, 2012.

Fry Movement

We conducted eight mark-recapture trials in Cougar Reservoir during our pilot study to assess subyearling movement patterns (Table 1-2). Recapture rates were low (5.7%) with most recaptures in the upstream traps. In Lookout Point Reservoir, only two trials were conducted. Recapture rates were also low (3.4%) with only one trial resulting in recaptures (Table 1-2). The number of subyearlings collected in upstream traps in Cougar Reservoir was significantly greater than the 50:50 ratio expected (Chi-square; $P<0.05$). However, we believe these results reflect a bias caused by the predominant wind direction in the reservoirs and resultant debris fouling traps.

The predominant wind direction at Cougar Reservoir was from the north, which resulted in wind generally blowing upstream towards the head of the reservoir. In Lookout Point Reservoir, the predominant wind direction was from the southwest, which generally resulted in wind blowing downstream towards the dam. In each of these reservoirs, debris (sticks and small logs) tended to accumulate on the lead net on the side with the predominant wind direction. This frequently resulted in the lead net bowing and blocking access to the throat opening on the opposite side of the trap. For example, in Cougar Reservoir, debris generally accumulated on the downstream side of the lead nets, causing nets to bow upstream and potentially block fish upstream of the trap from entering.

Potential trap bias hindered our ability to draw conclusions on subyearling movement patterns from this pilot effort, other than that subyearlings moved in both upstream and downstream directions in nearshore areas. Given the observed distribution patterns that showed greater dispersion of subyearlings into the reservoir each month, subyearling movement in the upstream/downstream direction is likely more equal than results from this study indicate.

Table 1-2. Number of subyearling Chinook salmon released and recaptured in upstream and downstream oriented traps in reservoirs in Cougar and Lookout Point reservoirs, 2012.

Trial	Number released	Mark	Downstream	Upstream
		Cougar		
1	56	Bismarck	0	1
2	140	Bismarck	1	5
3	26	Bismarck	1	2
4	47	Bismarck	0	0
5	18	Bismarck	0	0
6	46	Bismarck	0	2
7	188	Caudal clip	6	9
8	151	Caudal clip	8	11
Total	**672**		**8**	**30**
		Lookout Point		
1	92	Bismarck	3	1
2	24	Bismarck	0	0
Total	**116**		**3**	**1**

Parr Vertical Distribution

As subyearlings grew and moved offshore in Detroit and Lookout Point reservoirs, we assessed their vertical distribution from July through December. Gill nets were set at specific depth intervals in the pelagic zone near the dam forebay in both reservoirs from 17 July to 14 December, 2012. We combined hatchery and natural-origin Chinook salmon when analyzing temporal changes in vertical distribution.

Detroit- We deployed 34 gill net sets (6 nets/set) in Detroit Reservoir and caught 1,061 juvenile Chinook salmopn (962 AD-clipped hatchery, 99 natural-origin), 1,058 rainbow trout, 674 kokanee , five dace *Rhinichthys* spp., two mountain whitefish *Prosopium williamsoni*, and one brown bullhead *Ameiurus nebulosus*. All but two of the juvenile Chinook salmon were subyearlings.

Only one juvenile Chinook salmon was caught in July, therefore we could not assess vertical distribution that month. Catch increased in subsequent months after hatchery Chinook salmon were released into the reservoir on 10 August. Catch in August was comprised almost entirely of hatchery subyearlings, with only one natural-origin subyearling captured. Catch of natural-origin subyearlings increased in September and remained consistent through December, ranging from 21-27 fish/mo. However, the number of hatchery fish decreased from September through December. Natural-origin fish were initially larger than hatchery fish in September (mean fork length: natural 155 mm; hatchery 132 mm) but by late fall, there was no significant difference in size (Mann-Whitney Rank Sum test; $P>0.05$). The decreasing proportion of hatchery Chinook salmon in our catch suggested a disproportionate rate of mortality or dam passage between hatchery and natural-origin fish.

In August, most Chinook salmon (65%) were caught in the 9-14 m (30-45 ft) depth range (Figure 1-9). In September, juveniles descended slightly deeper in the water column but by October were more evenly dispersed throughout all depths sampled. A vertical shift in distribution towards the surface was evident in November and December. Most juveniles (70%) in December were caught near the surface in the 0-5 m (0-15 ft) depth range. There was no significant difference in fish size among depth intervals (Kruskal-Wallis one-way ANOVA on ranks $P>0.05$) within individual months.

Rainbow trout in Detroit Reservoir were composed of AD-clipped hatchery fish and unclipped fish of both hatchery and natural origin. Clipped and unclipped rainbow trout demonstrated similar vertical distribution patterns each month (KS test; $P>0.05$), therefore we combined both groups when analyzing temporal changes in vertical distribution of rainbow trout. Overall, rainbow trout were more surface oriented than juvenile Chinook salmon (Figure 1-10). The majority of rainbow trout were caught near the surface (0-5 m deep) in all months with the exception of August, when only about a third of the rainbow trout were captured at this depth.

Kokanee were generally found deeper in the water column than Chinook salmon. From August through October, most kokanee were caught in the 18-23 m (60-75 ft) depth range

(Figure 1-11). A seasonal shift towards the surface was evident in November and December. Most of the kokanee were subyearlings less than 200 mm FL.

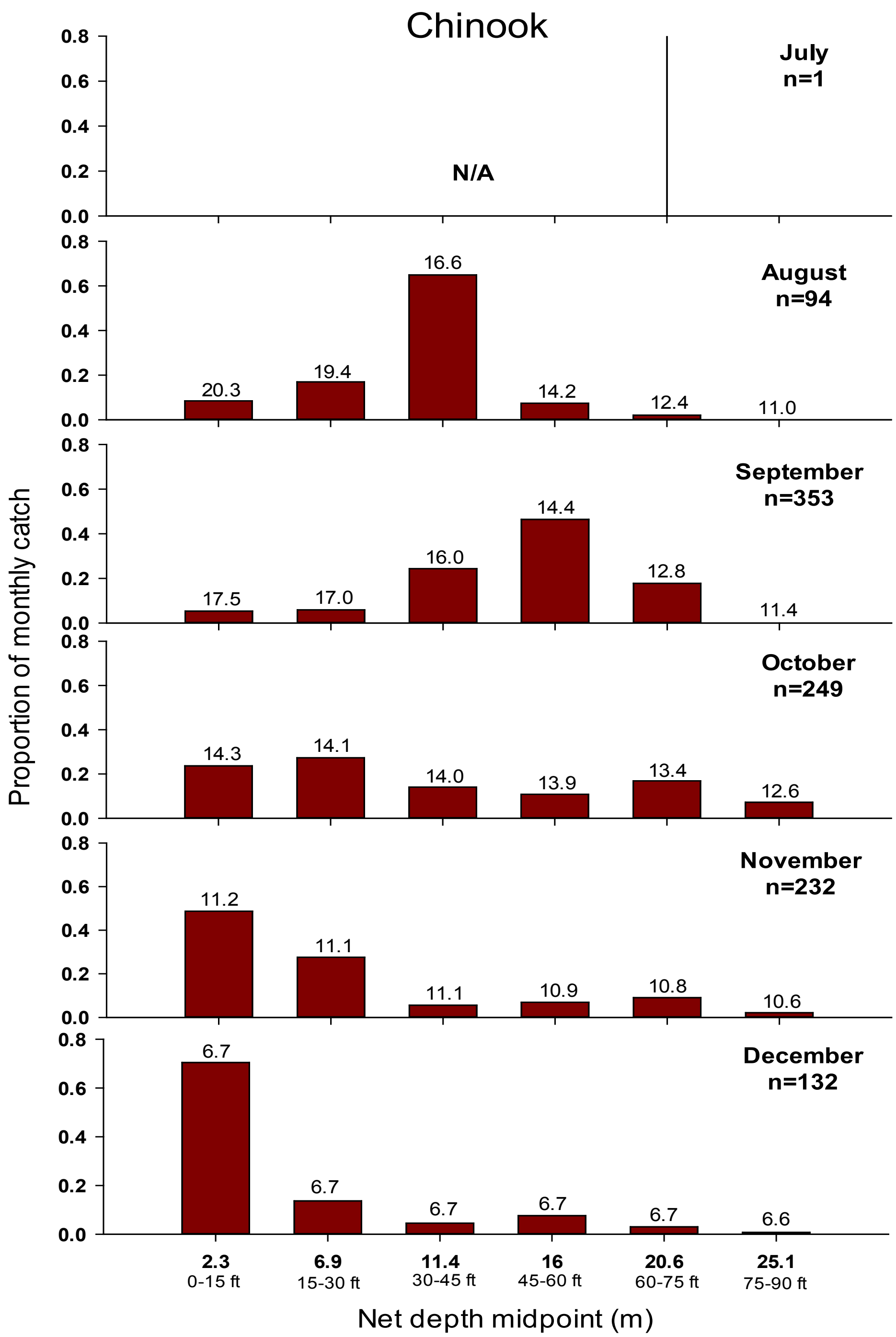

Figure 1-9. Proportion of subyearling Chinook salmon (hatchery and natural origin) caught at specific depth intervals in Detroit Reservoir from July to December 2012. Numbers above bars are mean temperatures at each depth interval calculated from USACE data loggers located on the log boom near the forebay.

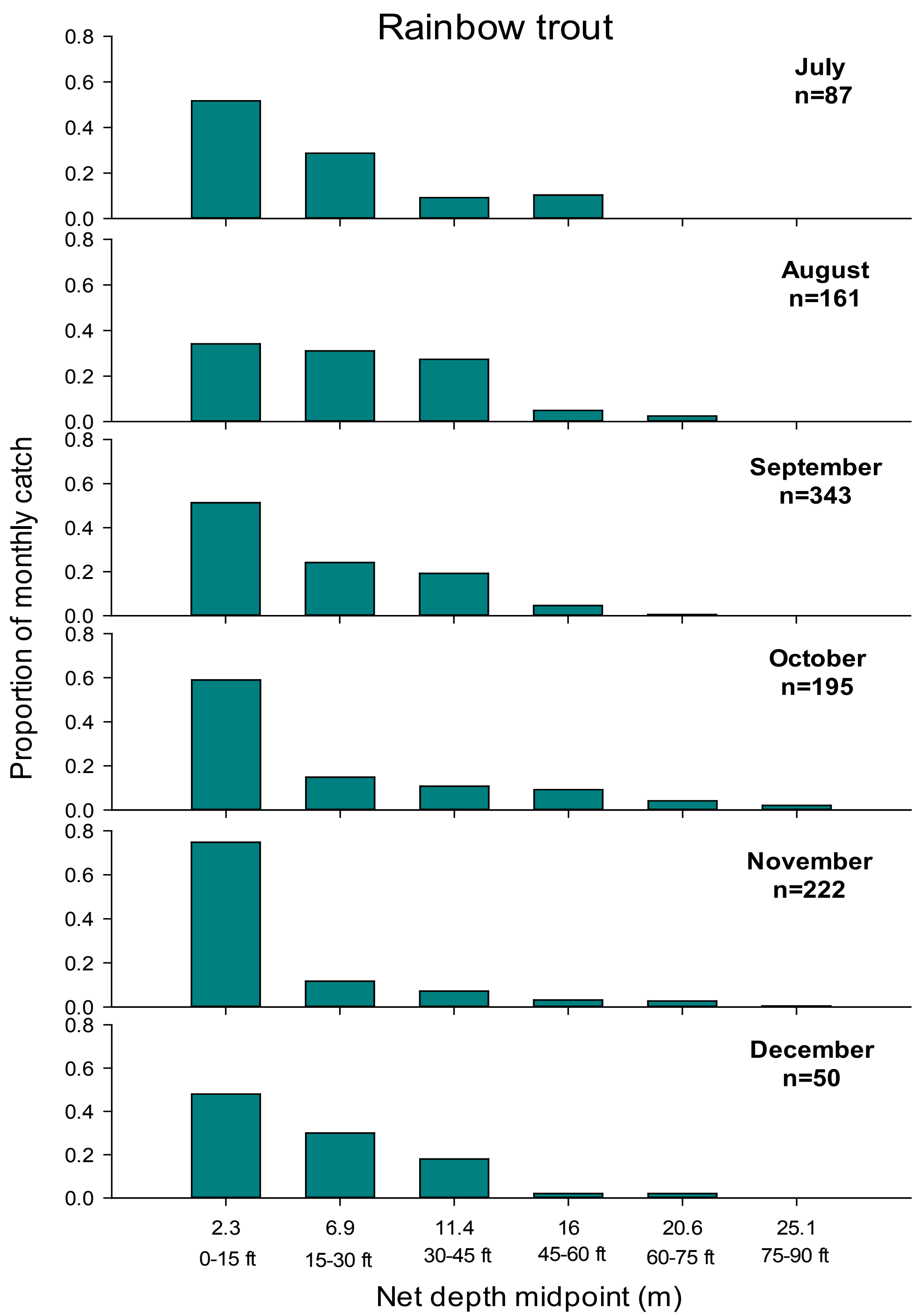

Figure 1-10. Proportion of rainbow trout (hatchery and natural origin) caught at specific depth intervals in Detroit Reservoir from July to December, 2012.

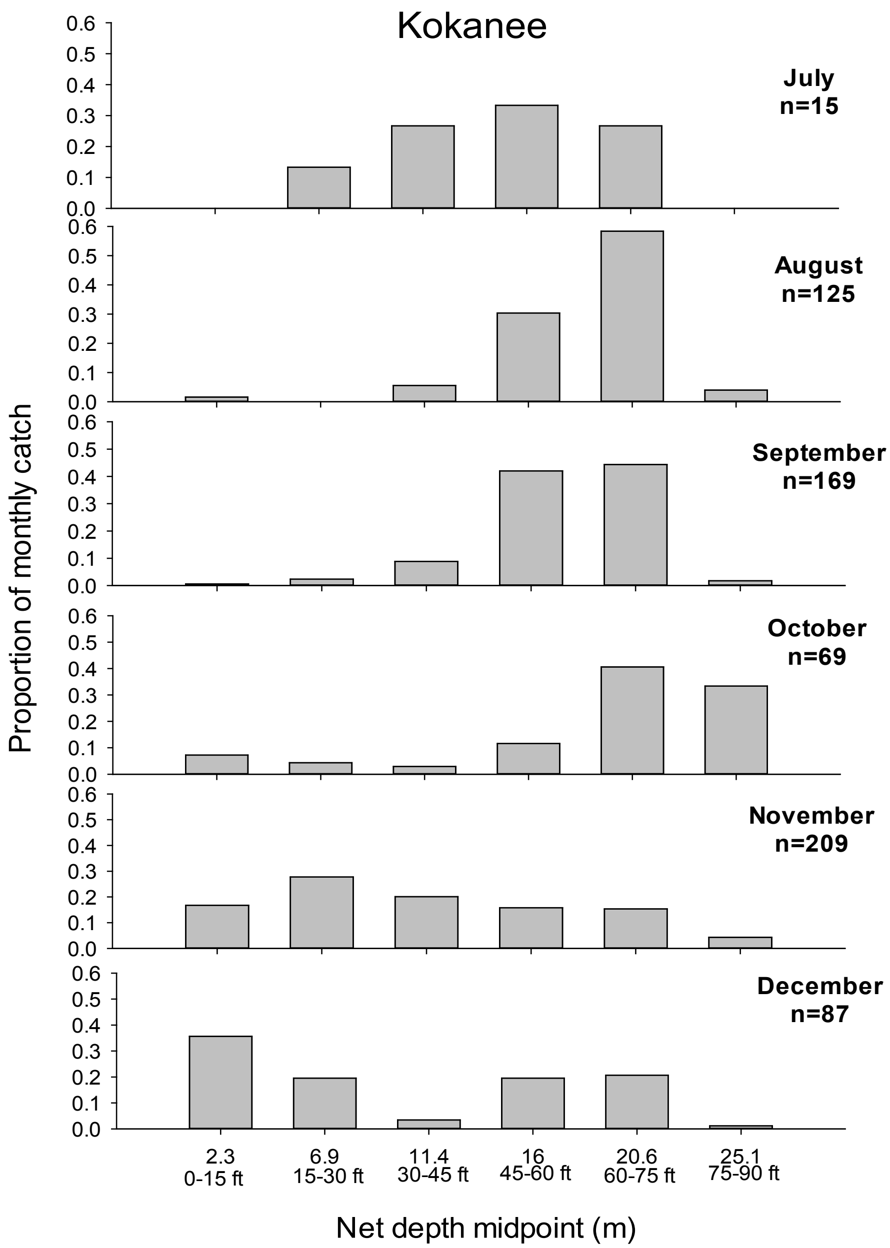

Figure 1-11. Proportion of kokanee caught at specific depth intervals in Detroit Reservoir from July to December, 2012.

Lookout Point- In Lookout Point Reservoir, we deployed 41 gill net sets (6 nets/set) near the dam and caught 1,202 juvenile Chinook salmon (884 unclipped, 215 PIT-tagged hatchery, 103 AD-clipped hatchery). All but two of the juvenile Chinook salmon were subyearlings. The unclipped juveniles included natural-origin Chinook salmon and unclipped hatchery Chinook salmon released as fry. Most of the PIT-tagged hatchery fish (62%) were caught in July with diminished catch in subsequent months (range: 11-27/mo.).

The AD-clipped hatchery fish were rare during the summer but catch increased in the fall (October-December) presumably soon after the fish exited Hills Creek Dam during drawdown. Additionally, 46 rainbow trout, three cutthroat trout *O. clarkii*, 15 crappie *Pomoxis* spp., and 22 redside shiners *Richardsonius balteatus* were collected in our gill nets.

Juvenile Chinook salmon in Lookout Point Reservoir followed a similar vertical distribution pattern as in Detroit Reservoir (Figure 1-12). In July, juveniles were caught at all depths but the greatest catch was at the 9-14 m (30-45 ft) depth range. In August, as surface temperatures reached their maximum, a similar distribution was observed except no Chinook salmon were collected in the surface nets (0-15 ft depth range). During September and October, juveniles were more evenly dispersed throughout the water column. By November and December, juveniles showed a trend towards the surface.

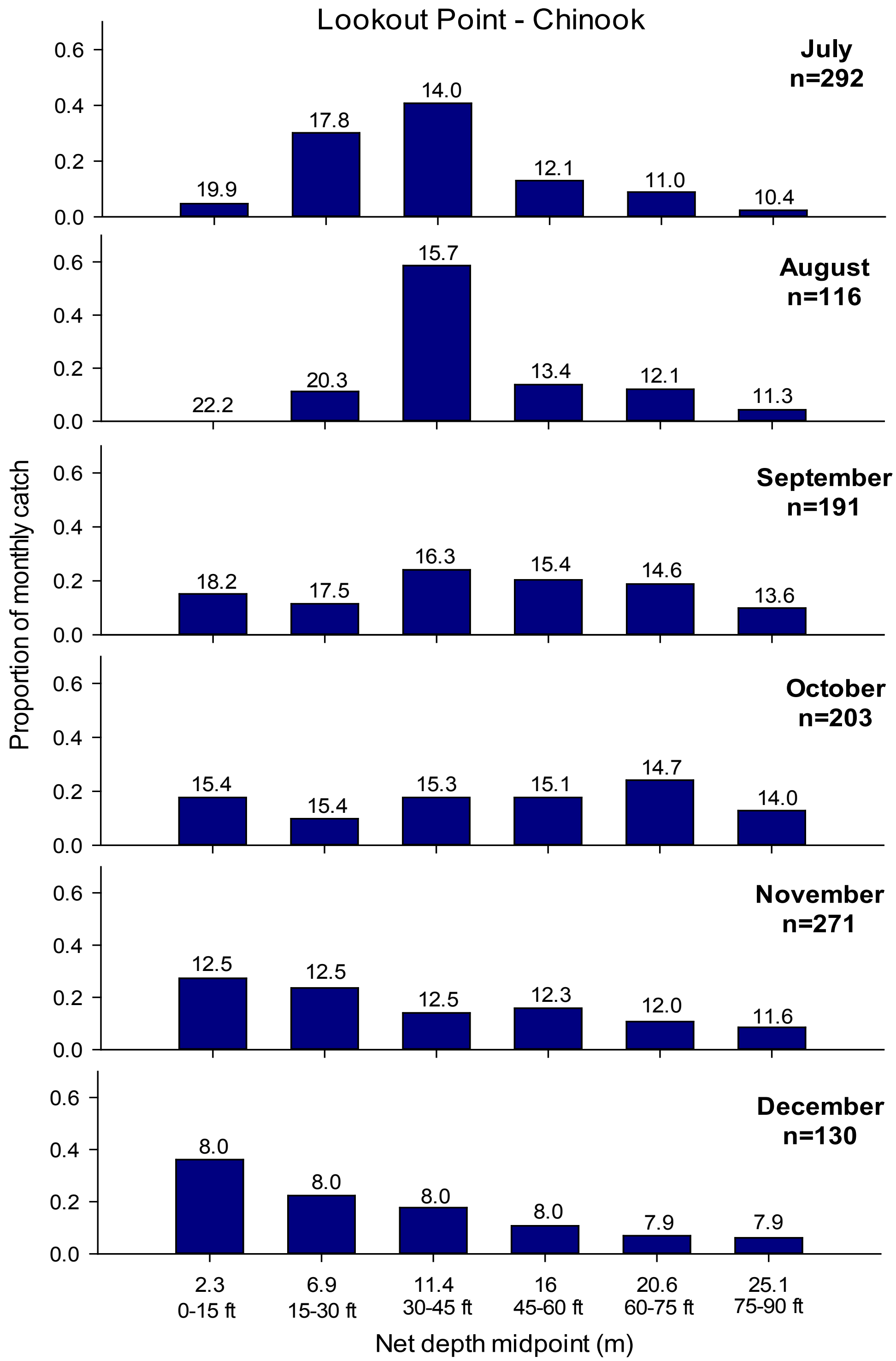

Figure 1-12. Proportion of juvenile Chinook salmon caught at specific depth intervals in Lookout Point Reservoir from July to December, 2012. Numbers on top of bars are mean temperatures at depth interval calculated from USACE thermistors located in the reservoir forebay.

Hatchery- and Natural-origin Comparisons- Comparisons of depths occupied between hatchery and natural-origin Chinook salmon were more easily made in Detroit Reservoir where all unclipped fish were natural-origin and hatchery fish originated from one release in August. For this reservoir, the vertical distribution of hatchery- and natural-origin fish Chinook salmon generally overlapped each month, but the mean depth occupied by hatchery fish was higher in the water column compared to natural-origin fish (Figure 1-13). In other words, the proportion of hatchery fish in the catch increased in nets set closer to the surface.

In Lookout Point Reservoir, there was no consistent pattern in the monthly mean depths occupied by hatchery and natural-origin Chinook salmon. However, it is interesting that from October through December, when AD-clipped fish from Hills Creek Reservoir dominated the hatchery catch, the average depth occupied by hatchery fish was closer to the surface compared to unclipped fish, similar to Detroit Reservoir.

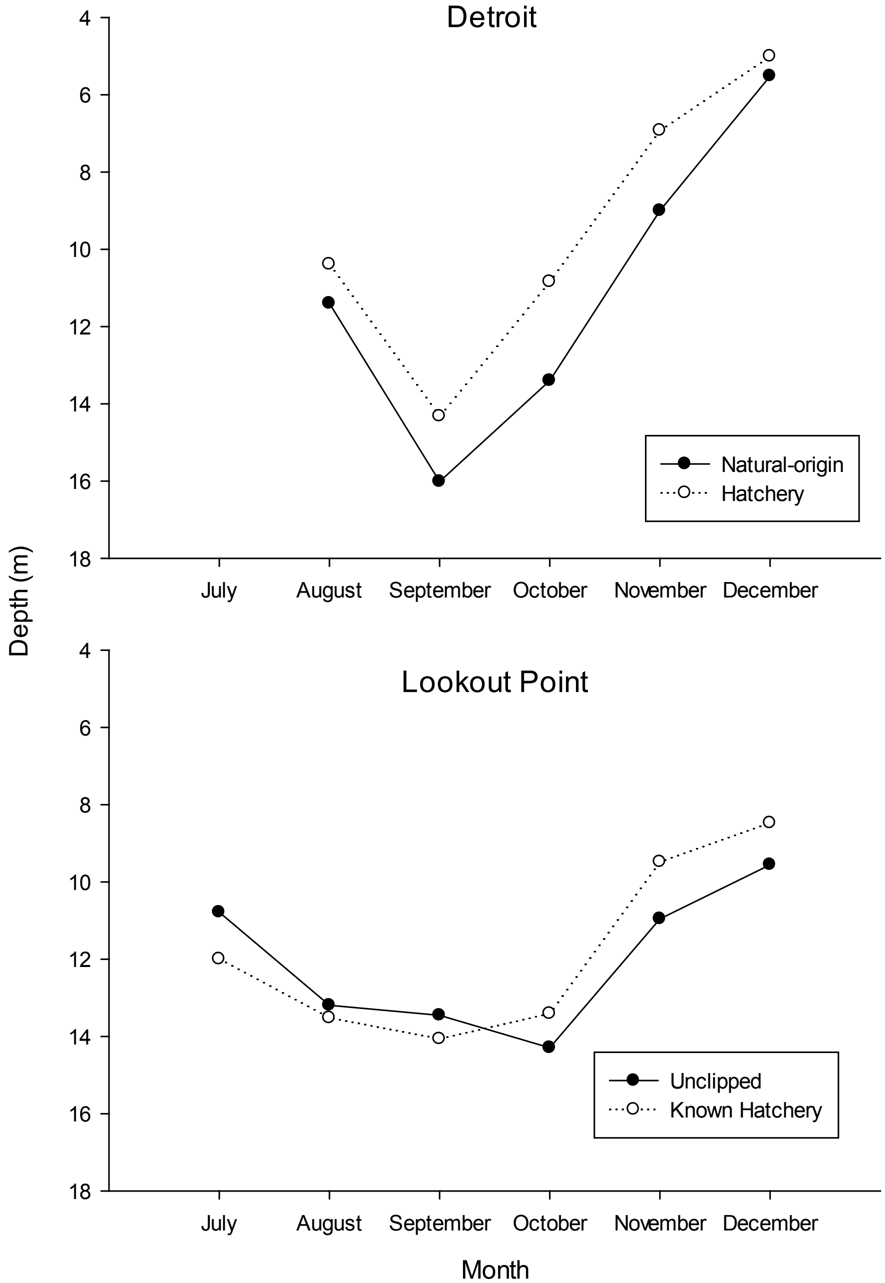

Figure 1-13. Mean depth occupied by hatchery and natural-origin subyearling Chinook salmon each month in Detroit and Lookout Point reservoirs, 2012. In Lookout Point Reservoir, unclipped Chinook included hatchery Chinook released as fry and natural-origin fish.

Discussion

Subyearling Chinook salmon "fry" (<50 mm FL) in Cougar Reservoir dispersed along the nearshore habitat throughout the spring and approached an even distribution in the reservoir by June. A portion of the subyearling population grew large enough by June to occupy deeper water as was evident in our Oneida catch. Subyearlings that transitioned offshore would presumably move throughout the reservoir. Observations of hatchery subyearlings tagged with Juvenile Salmon Acoustic Telemetry System (JSATS) tags and released in July continually traversed the length of the reservoir (Beeman et al. 2013). By July, we would expect most subyearlings to have moved offshore and be evenly distributed, but moving throughout the reservoir. We occasionally observed shoals of subyearlings moving along the shoreline and in the pelagic zone of the reservoirs. This shoaling behavior was also reflected in our highly variable catch numbers in traps with occasionally large numbers of Chinook salmon captured followed by a long period of low catch numbers.

Subyearling Chinook salmon from Lookout Point Reservoir dispersed farther into the reservoir by early spring compared to subyearlings from Cougar Reservoir, despite Lookout Point Reservoir being nearly twice as long. Dispersion patterns in Lookout Point Reservoir were confounded by the release of unmarked hatchery fry, but it is likely the subyearlings attain an even distribution throughout the reservoir earlier in the spring compared to Cougar Reservoir. Subyearlings in Lookout Point Reservoir enter the reservoir approximately one month earlier than Cougar Reservoir subyearlings (Romer et al. 2013), providing more opportunity to grow and disperse. Also, fry entered Lookout Point Reservoir when the Middle Fork Willamette River confluence was approximately 3-4 km closer to the dam than when at full pool. Both of these factors likely contribute to a greater proportion of subyearlings in the lower reservoir by early spring compared to Cougar Reservoir.

Interannual variation in subyearling Chinook salmon dispersion was evident in Cougar Reservoir. Subyearlings dispersed farther into the reservoir by late spring of 2012 compared to 2011, despite nearly identical migration timing into the reservoir between years. Both fish size and magnitude of flows through the reservoir may have influenced distribution patterns between years. Subyearling grew faster in 2012. Also, inflows and outflows in mid-spring were greater in 2012, which may have contributed to dispersion patterns observed in 2012. Preliminary data from Detroit Reservoir in April 2013 showed subyearlings in the lower reservoir section following a high inflow event and a subsequent spill of surface water at the dam. In 2011, we did not observe subyearlings in this section until much later in the spring. It may be that high flow events allow for greater dispersion into the reservoirs.

A seasonal pattern in vertical distribution was evident among subyearling Chinook salmon rearing in reservoirs. Parr descended deeper into the water column in summer, as surface water temperatures reached their maxima, and returned to the surface by late fall. We observed similar vertical distribution patterns in 2011. Ingram and Korn (1969) reported similar vertical distribution patterns for juveniles in Cougar Reservoir, although these authors did not deploy nets below 13.7 m (45 ft) in the summer and fall. Their results showed most fish caught in their deepest sets (9.1-13.7 m) during August and September, whereas in November, most fish were caught in the 0-5 m (0-15 ft) depth range, similar to what we observed in Detroit and Lookout Point reservoirs.

There was evidence that hatchery Chinook salmon were more surface oriented compared to natural-origin Chinook salmon. Surface orientation has been noted for other hatchery salmonids compared to their wild counterparts (Mason et al. 1967; Sosiak et al. 1979). The greater proportion of hatchery fish captured near the surface may partially explain why the number of hatchery fish decreased with each consecutive month, as these surface oriented fish were more likely to exit the reservoir via spill in the summer. Our screw trap below Detroit Dam showed the highest catch of hatchery fish in August and September. Natural-origin Chinook salmon, albeit few in number, were more abundant during October in both 2011 and 2012 (Romer et al. 2012, 2013). Differences in vertical distribution between hatchery and natural-origin fish and their propensity to use summer spill should be considered when evaluating dam passage results based on hatchery fish.

Gill nets fished for 24 hrs and therefore represent an 'average' vertical position occupied by Chinook salmon over the diel period. Studies conducted in Detroit Reservoir using JSATS during the same period showed that Chinook salmon within 20 m of the dam were closer to the surface at night and descended during the day (Beeman et al. 2013, *in prep*). We would expect greater gill net capture efficiency at night if fish were able to see and avoid the clear monofilament nets during the day, so our results may be biased towards Chinook salmon vertical position during night. However, our results showed juvenile Chinook salmon closer to the surface than JSATS fish at night during the fall. Our nets were set in the pelagic zone, farther from the dam than the JSATS study. Vertical distribution patterns of Chinook salmon at the dam may be different than in the pelagic zone, possibly due to daily variability in elevation of discharge through the spill and turbines intakes at the dam.

Generally, it appeared juvenile Chinook salmon occupied depths that were approximately 16°C or less. This is consistent with temperature preference reported in the literature. The Independent Science Group (1996) determined optimal rearing for juvenile Chinook salmon between 12–17ºC, with most optimal at 15ºC. Richter and Kolmes (2005) found juvenile salmonids generally prefer temperatures from 11.7 to 14.7ºC. Optimal rearing temperatures at natural feeding regimes for juvenile Chinook salmon are 12.2 to14.8ºC (Hicks 2000).

Habitat segregation between juvenile Chinook salmon, rainbow trout, and kokanee was evident in Detroit Reservoir. Rainbow trout were more surface oriented than the other species. This is consistent with results from Beeman et al. (2013, *in prep*) that found JSATS tagged summer-run steelhead in the spring were generally closer to the surface than juvenile Chinook salmon. It appears from our results that rainbow trout would be representative of the vertical distribution patterns of juvenile winter steelhead.

SECTION 2: RELATIVE GROWTH OF JUVENILE CHINOOK SALMON IN RESERVOIRS AND STREAMS

Background

The negative effects of reservoir residency due to increased predation risk, delays in migration, and extended exposure to parasites may be offset by superior growth rates that could impart a greater survival advantage to adulthood (ISRP 2011). Juvenile Chinook salmon grow at a greater rate in reservoirs compared to their stream-rearing counterparts upstream of reservoirs (Monzyk et al. 2011b, 2012). Knowledge of the size juveniles attain while rearing in reservoirs will also aid in designing appropriate downstream fish passage. In this report, we compare relative growth rates among reservoirs and between reservoir- and stream-rearing subyearling Chinook salmon.

Methods

We used fish length data recorded from screw traps and seining above the reservoirs to track cohort growth of subyearlings rearing in streams. Seining occurred in late summer at various locations in the South Fork McKenzie River above Cougar Reservoir, the North Fork Middle Fork Willamette River above Lookout Point Reservoir, the South Santiam River above Foster Reservoir, and in the Breitenbush River above Detroit Reservoir. Fish lengths from seining efforts were compared to lengths from screw traps during the same period using t-tests ($\alpha=0.05$) to determine if the size of fish collected in screw traps were similar those rearing in the streams. If no differences in size were detected, we assumed that migrants captured by the screw trap were representative of the stream rearing cohort. Length data from screw trapping represents a longer time series that generally extended into November that we could compare to lengths recorded from fish in reservoirs.

Length information for reservoir-rearing Chinook salmon was collected using a variety of sampling methods including nearshore box traps, Oneida traps, electrofishing, gill nets, and screw traps located below dams. Information on the location and duration of the various sampling methods can be found in the other sections of this report. The USACE provided subyearling length data from screw trap collections below Fall Creek Reservoir.

Fork length was measured to the nearest millimeter for all fish. We used natural-origin subyearlings to compare relative growth between stream- and reservoir-rearing juveniles. However, we could not distinguish unclipped hatchery fish from natural-origin juveniles in Lookout Point Reservoir. Hatchery fish were released as fry early in the spring; therefore, we believe their growth was representative of the growth of natural-origin Chinook salmon.

We designated age based on length-frequency analysis. Yearling and subyearling Chinook salmon generally maintained a clear size difference throughout the year. For each reservoir and stream, we graphed individual fish size by date and assigned age (Figure 2-1).

Juveniles that hatched in spring 2012 were classified as subyearlings (age 0). Yearlings (age 1) were fish that hatched the previous year and remained in the reservoir after 01 January. We believe the aging technique accurately assigned age for most fish and any assignment errors would not have greatly affected the results.

Previous sampling efforts showed that maximum growth occurs from May to October. We used two methods to estimate growth rate during this period. In Cougar Reservoir, we were able to estimate growth rate for subyearlings during the summer using length data from individual fish that had been PIT tagged and subsequently recaptured. Growth rate (mm/d) was calculated as the fork length at recapture minus length at tagging divided by the number of days between initial capture and recapture. From 2011-2012, we tagged subyearlings >60 mm FL that were collected in the reservoir or in the upstream screw trap and presumed to have immediately migrated into the reservoir. We only used fish tagged between April and August and recaptured at least two weeks after tagging. Recaptures came from collection in the reservoir, screw traps below the dam, or at the Leaburg bypass juvenile fish collector.

We also estimated growth rates for subyearlings in reservoirs where we had information on mean size of Chinook in May and October. We estimated growth rate as mean size in October minus mean size in May divided by the number of days between the median capture dates each month.

Results

At least two year classes of juvenile Chinook salmon were present in all WVP reservoirs with subyearlings the most common (Figure 2-1). Yearlings were rarely captured after June in the reservoirs or in upstream screw traps. In Cougar Reservoir, large Chinook salmon (>200 mm FL) caught in the spring and early summer were likely age-2 fish.

Above reservoirs, sample sizes in screw traps during the summer were too limited to compare fish sizes between seining and screw trap, except in the South Fork McKenzie. Here, fork lengths of subyearlings captured with seines during September were not significantly different from lengths of fish collected from the screw trap (t-test; P>0.05). Therefore, we assumed fish captured in screw traps represented fish rearing in streams and we pooled seining and screw trap fish length data to assess the growth of stream-rearing subyearlings.

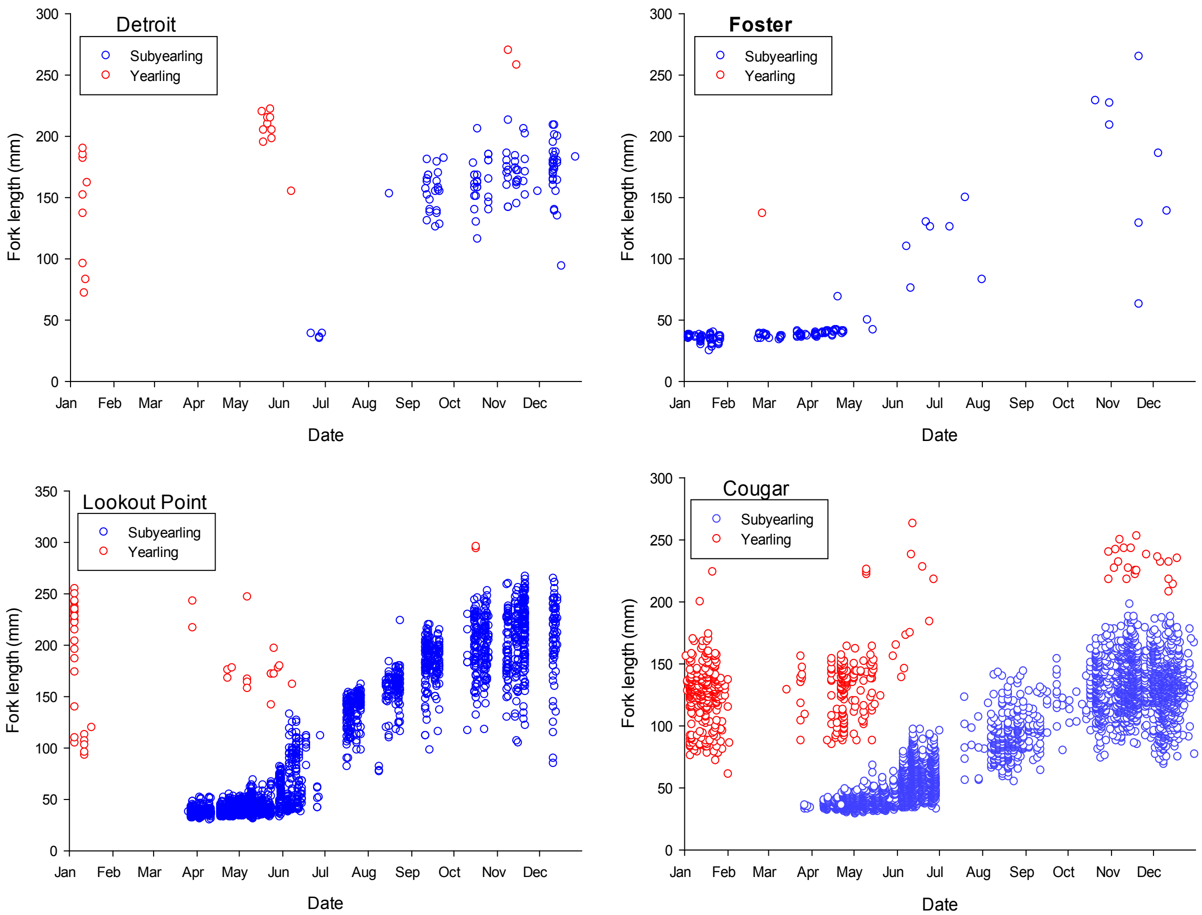

Figure 2-1. Fork lengths of juvenile Chinook salmon collected in WVP reservoirs, 2012. Age classification based on length frequency analysis.

Reservoir-rearing subyearlings grew more rapidly than juveniles rearing in streams above reservoirs (Figure 2-2). Size differences between groups were evident beginning in May and increased through October. By November, subyearlings in reservoirs were 50-147 mm longer than their counterparts in streams with the largest difference occurring in Lookout Point Reservoir.

We PIT tagged and recaptured 13 subyearling Chinook salmon that reared in Cougar Reservoir from which growth rate information could be calculated. Most fish were tagged in the reservoir during June and recaptured late November at screw traps below the dam. Mean growth rate was 0.56 ±0.07 mm/d (SE). This estimate was similar to the growth rate estimate of 0.55 mm/d based on difference in mean size between May and October in Cougar Reservoir. In Lookout Point Reservoir, growth rate based on mean size in May and October was 0.99 mm/d. We did not capture subyearlings in Detroit Reservoir during May to estimate size but growth rate would likely be intermediate between Cougar and Lookout Point reservoirs given the size fish attained by late fall. We were unable to collect enough subyearlings in Foster Reservoir and the South Santiam River to compare differences in size between groups or May-October growth rate in the reservoir.

Although growth was rapid in Lookout Point Reservoir, it appeared to be greater in Fall Creek Reservoir (Figure 2-3). Mean size by late fall (Nov-Dec) for Fall Creek Reservoir subyearlings was approximately 244 mm FL. Comparatively, subyearling fork lengths by late fall in Detroit, Cougar, and Lookout Point reservoirs averaged 171, 134, and 208 mm, respectively. Growth in reservoirs appeared to be consistent between years. In 2011, fork length of subyearlings by late fall in Detroit, Cougar, and Lookout Point reservoirs averaged 174, 134, and 209 mm.

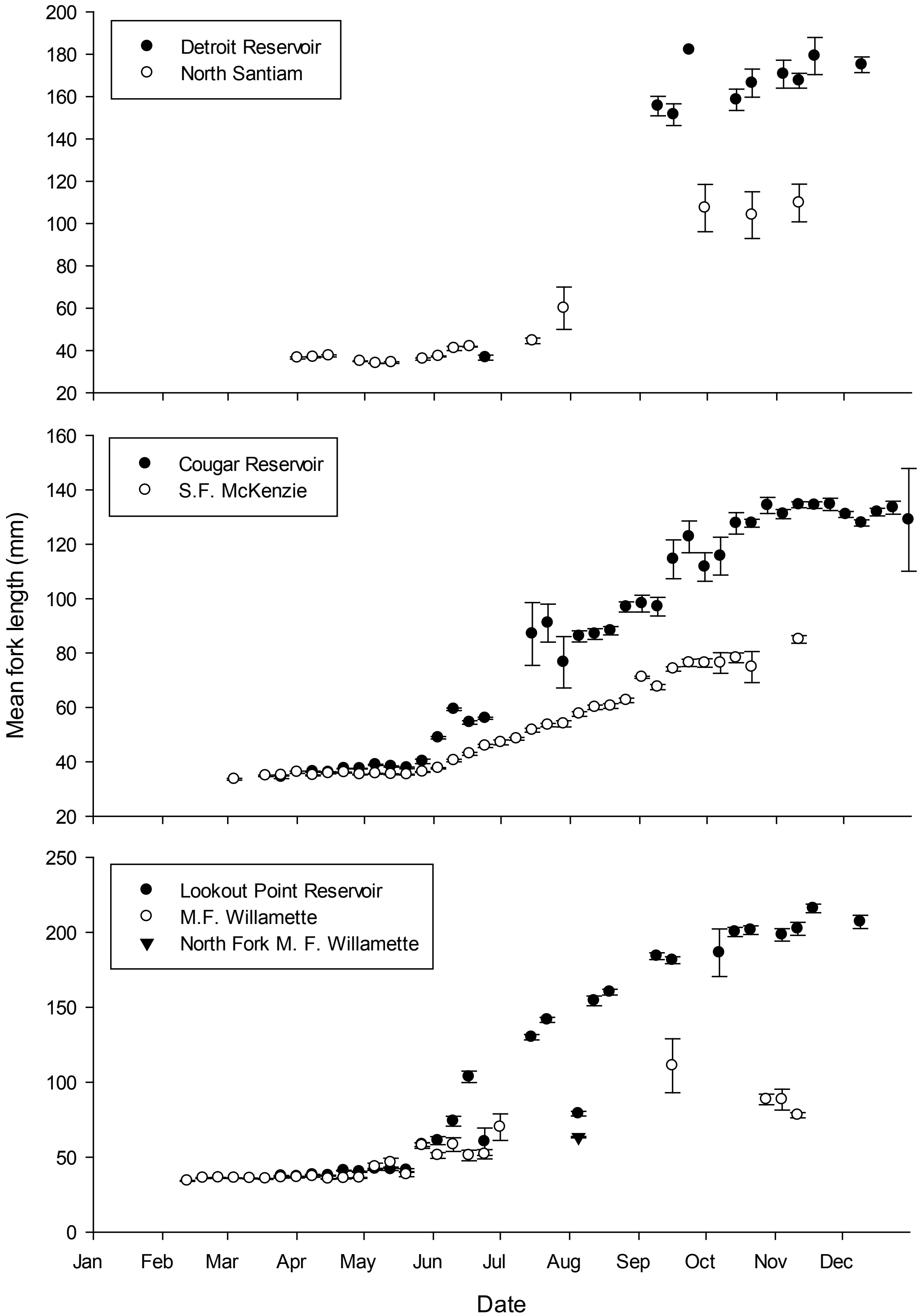

Figure 2-2. Mean fork length by week of natural-origin subyearling Chinook salmon rearing above and within Detroit, Cougar, and Lookout Point reservoirs, 2012. Error bars represent the standard error.

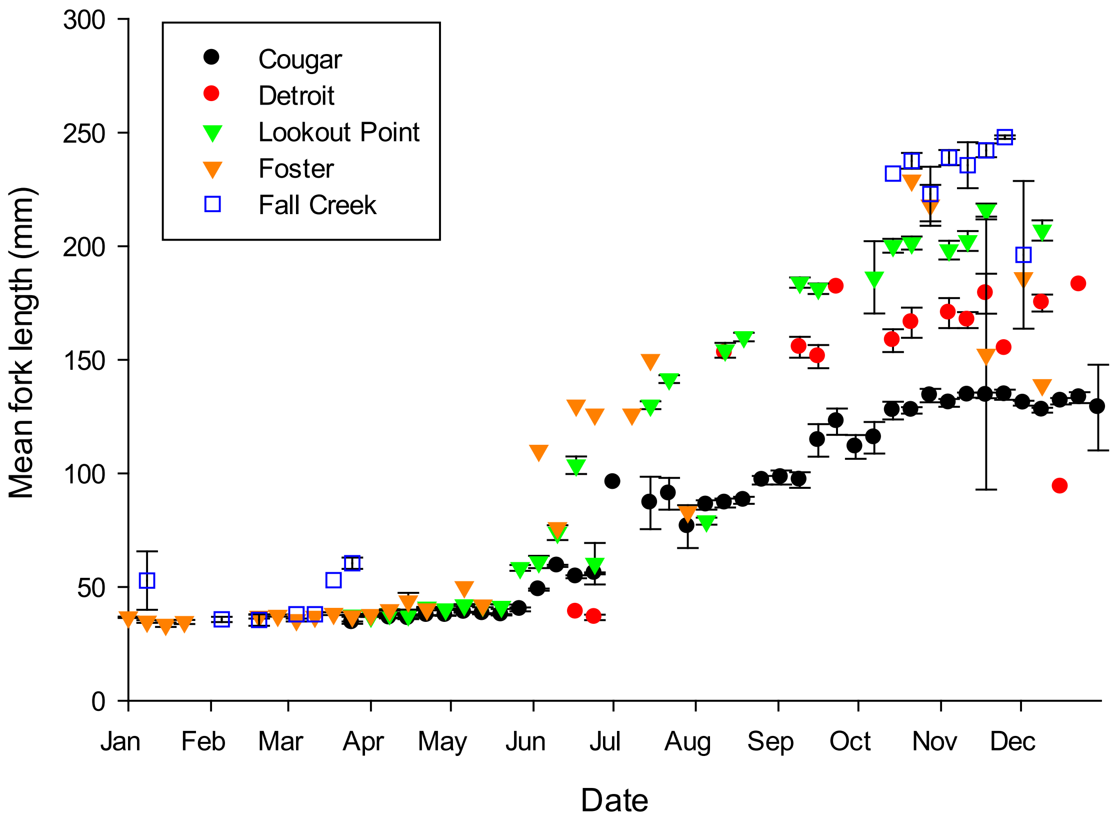

Figure 2-3. Mean fork length by week of natural-origin subyearling Chinook salmon in WVP reservoirs, 2012. Lookout Point Reservoir included hatchery subyearlings released as fry in April.

Discussion

The greater growth rates for subyearling Chinook salmon rearing in reservoirs compared to streams was likely attributable to the greater primary and secondary productivity in reservoirs and temperature regimes that allowed for optimal growth. Vertical distribution results showed that Chinook salmon seasonally changed position in the water column consistent with optimal rearing temperatures. There was a trend toward greater growth rates in lower elevation reservoirs with consequently warmer water temperatures. Generally, lower elevation reservoirs (i.e., Foster, Fall Creek and Lookout Point) have Chinook salmon populations that emerge and migrate into the reservoir earlier. Also, lower elevation reservoirs reach optimal rearing temperatures sooner in the spring, allowing fish to rear for a longer period under optimal temperature conditions. Although surface temperatures in these reservoirs surpass the lethal limit for juvenile Chinook salmon, subyearlings were able to maintain vertical positions within optimal temperature ranges. We would expect that under this relationship, subyearlings in Foster Reservoir would achieve the greatest growth rate among WVP reservoirs since it is the lowest in elevation (641 ft mean sea level).

The greatest mean growth rate we estimated was 0.99 mm/d in Lookout Point Reservoir, although growth rates in Fall Creek and Foster reservoirs are likely greater. Growth rates exceeding 1 mm/d have been reported for juvenile fall Chinook salmon in the Snake River (Connor and Burge 2003). Similarly, summer growth rates for juvenile Chinook salmon rearing in the mainstem Willamette River were estimated between 0.5-1.0 mm/d (Schroeder et al. 2013).

SECTION 3: PARASITIC COPEPOD INFECTION PREVALENCE AND INTENSITY

Background

The copepod *Salmincola californiensis* parasitizes Pacific salmon and trout of the genus *Oncorhynchus* (Kabata and Cousens 1973). The life cycle of *S. californiensis* consists of several stages involving a single host fish (Figure 3-1). Adult females carry two large egg sacs that require approximately one month to hatch. The free-swimming infectious copepodid (~0.69 mm in length) can survive for about two days after hatching in their attempt to find a host (Kabata and Cousens 1973). After attachment to a host, the copepod undergoes several chalimus stages ending with the adult stage within weeks after hatching.

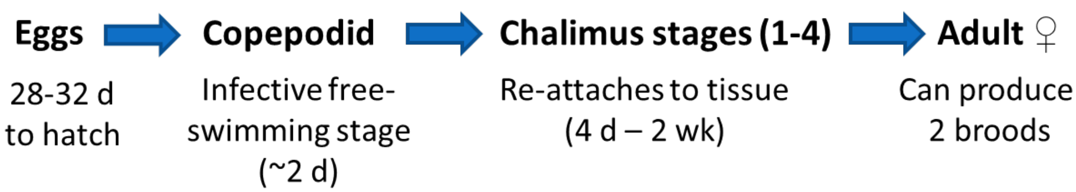

Figure 3-1. Life cycle of female *Salmincola californiensis.*

Suitable copepodid attachment sites consist of solid subdermal support, including fin ray, rod of a gill filament, scale, and bone (Kabata and Cousens 1973). Attachment location is believed to be host size-dependent, with attachment to fins occurring on smaller fish and the gills of larger fish (Kabata and Cousens 1977; Black 1982).

The prevalence and intensity of *S. californiensis* infection has been shown to increase with host body length (Nagasawa and Urawa 2002; Barndt and Stone 2003). In 2011, we observed higher prevalence among larger reservoir-rearing juvenile Chinook salmon compared to their smaller stream-rearing counterparts. In Cougar Reservoir, there was a positive correlation between copepod prevalence and juvenile Chinook salmon fork length (Monzyk et. al 2012). However, larger fish were likely in the reservoir for a longer period of time and therefore experienced extended exposure to parasites.

Low-level infections are generally not believed to be lethal, especially if the parasites are not attached to gill lamellae. However, high intensity infections on gills can cause gill tissue destruction (Kabata and Cousens 1977; Sutherland and Wittrock 1985) causing anemia and mortality during saltwater transition (Sutherland and Wittrock 1985; Pawaputanon 1980). In this report, we tracked the prevalence and intensity of copepod infection through time for reservoir- and stream-rearing juvenile Chinook salmon and other salmonids species.

Methods

In 2012 (April-December), we assessed the prevalence and intensity of infection by *S. californiensis* among salmonids of the genus *Oncorhynchus* rearing in WVP reservoirs and streams above reservoirs. We sampled salmonids in the following reservoirs and streams: Detroit Reservoir and the North Santiam River; Foster Reservoir and the South Santiam River; Cougar Reservoir and the South Fork McKenzie River; and Lookout Point Reservoir and the Middle Fork Willamette River, including the North Fork Middle Fork Willamette River. In addition, USACE personnel provided data from a trap below Fall Creek Reservoir. The salmonids assessed included juvenile Chinook salmon, rainbow trout *O. mykiss*, cutthroat trout *O. clarkii*, and kokanee *O. nerka*. Adipose-clipped hatchery Chinook salmon were present in Lookout Point and Detroit reservoirs and adipose-clipped rainbow trout were present in Foster, Detroit, and Lookout Point reservoirs. Unclipped *O. mykiss* from Foster Reservoir and the South Santiam River were likely progeny of steelhead outplanted above the dam.

We assigned a fish as stream- or reservoir-rearing based on collection location. Reservoir-rearing were fish collected from gill nets, nearshore nets, and Oneida nets set in the reservoirs as well as rotary screw traps located below dams. Stream-rearing fish were collected by seining in streams during August and September and rotary screw traps operated above reservoirs throughout the year.

Captured fish were anesthetized (50mg/L MS-222), examined for an adipose fin clip, and measured (fork length; mm). The fins and gills of each fish were macroscopically examined for the presence for gravid adult female copepods and the attachment location was recorded. We counted copepods at each attachment location from a subset of the fish collected each day (minimum of 5 fish/species/day/gear type). Only gravid adult female copepods were assessed since this life stage was easily visible during field examinations.

We defined prevalence as the percentage of fish infected. Prevalence was compared among species for each reservoir and stream (z-test; $\alpha=0.05$). In cases where multiple comparisons among species were analyzed, we applied a Bonferonni correction to control the family-wise error rate. Hatchery fish may differ from natural-origin fish in size and duration in the reservoir, therefore we analyzed them separately when they were distinguishable from naturally-produced fish.

Intensity was defined as the mean number of copepods per infected fish. We compared copepod intensity by species between reservoir and stream fish with Kruskal-Wallis one-way ANOVA on ranks ($\alpha=0.05$). We also compared intensity among species where collected in the same reservoir and over a similar period of time. We also analyzed copepod intensity on the gills only because of the potential for detrimental effects on fish during saltwater transition.

Results

We macroscopically examined 8,087 salmonids for infection by *S. californiensis* on gills and fins. Copepods were more common on the gills of salmonids rearing in reservoirs than in streams (Table 3-1). For instance, 81% of the copepods observed on reservoir-rearing Chinook salmon were attached to gills, compared to less than 30% for stream-rearing Chinook salmon. The difference in attachment location could partly be attributable to the larger size of salmonids in reservoirs.

Copepods were only observed on gills of stream-rearing Chinook salmon during September and October. These fish tended to be larger than the overall population, suggesting they may have been precocial males that moved into the streams from reservoirs. In the South Fork McKenzie River, the only infected Chinook salmon with copepods on gills (6 of 58) were from collection in September and October and mean fork length for these individuals was 114 mm FL (SE= 9.0) compared 72 mm (SE=0.5) for copepod-free juveniles collected during the same months.

Table 3-1. Percent of *Salmincola californiensis* attached to the gills and fins of infected Pacific salmonids by rearing location in the Willamette basin, 2012.

Rearing location/ Species	Mean fork length (mm)	Gills		Fins	
		Number adult ♀	Percent infected	Number adult ♀	Percent infected
Reservoir	**143.5**	**9,064**	**82.2**	**1,966**	**17.8**
Chinook	130.5	6,347	81.0	1,486	19.0
Hat. Chinook	155.1	2,129	94.5	123	5.5
Rainbow/Steelhead[a]	184.0	266	74.9	89	25.1
Hat Rainbow	209.0	268	61.2	170	38.8
Cutthroat	212.0	45	31.5	98	68.5
Kokanee	145.1	9	100.0	0	0.0
Stream	**68.2**	**48**	**34.5**	**91**	**65.5**
Chinook	67.9	30	29.7	71	70.3
Hat Chinook[b]	121.2	1	100.0	0	0.0
Rainbow/Steelhead[a]	66.5	16	45.7	19	54.3
Cutthroat	181.8	1	50.0	1	50.0

[a] *O. mykiss from the South Santiam River were likely juvenile steelhead.*
[b] *Hatchery Chinook were not released in streams. This fish likely entered North Santiam after release in Detroit Reservoir.*

Prevalence

Overall, copepods were more prevalent among reservoir fish compared to stream fish (z-test $P<0.05$; Table 3-2). Mean prevalence for subyearling Chinook salmon in Cougar Reservoir was 56.2% compared to 4.5% in the South Fork McKenzie River above the reservoir. Higher prevalence was also observed with rainbow trout in Cougar Reservoir compared to the South Fork McKenzie River. Mean prevalence for Chinook salmon in Detroit Reservoir and the North Santiam River was 74.8% and 11.1%, respectively. Mean prevalence for unclipped Chinook salmon in Lookout Point Reservoir and the Middle Fork Willamette was 38% and 4.8%, respectively. For Chinook salmon, differences became greater later in the season as prevalence increased more rapidly in reservoirs compared to streams (Table 3-2; Figure 3-2).

We did not observe the same increasing prevalence with each consecutive month for other salmonids in reservoirs as we observed with Chinook salmon (Table 3-2; Figure 3-2). This was most evident in Detroit Reservoir where prevalence among wild rainbow trout was relatively constant from August through December (range: 15.8-26.3%), however, monthly prevalence among subyearling Chinook salmon increased from 43.5 to 96.6%. Overall, infection prevalence among subyearling Chinook salmon in reservoirs was less than 10% in June but increased to 85.7-100% by December, similar to results observed in 2011. Chinook salmon in Fall Creek Reservoir had the highest prevalence with a 100% infection rate for fish collected in November and December (n=243). The exception was in Foster Reservoir where none of the Chinook salmon sampled were infected in November and December (n=5).

Table 3-2. Infection prevalence of the parasitic copepod *Salmincola californiensis* among salmonid species in WVP reservoirs and streams above reservoirs, 2012. Sample sizes in parentheses. Monthly prevalence proportions reported only if ≥9 fish were examined.

Rearing location	Species	Mean prevalence (%)	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
				Reservoirs						
Cougar	Chinook[a]	56.2	0.0	4.6	16.7	33.3	49.3	84.0	90.1	85.6
		(3,320)	(9)	(975)	(12)	(330)	(73)	(256)	(778)	(917)
	Rainbow	32.5	46.4	35.0	-	-	-	-	-	-
		(77)	(28)	(20)	(5)	(7)	(6)	(2)	(4)	(5)
	Cutthroat	52.3	44.4	67.7	-	-	-	-	-	-
		(65)	(27)	(31)		(1)	(2)	(3)		
Detroit	Chinook	74.8	-	-	-	-	43.5	63.6	92.6	96.6
		(103)		(1)		(1)	(23)	(22)	(27)	(29)
	Hat. Chinook	67.6	-	-	-	0.0	54.2	83.2	94.9	98.7
		(791)	(2)			(105)	(236)	(191)	(178)	(79)
	Rainbow	23.4	-	-	-	20.0	26.3	22.4	26.0	15.8
		(505)		(1)	(8)	(85)	(156)	(98)	(100)	(57)
	Hat. rainbow	43.0	-	-	76.5	33.3	45.3	28.6	44.2	-
		(249)		(1)	(34)	(75)	(53)	(28)	(52)	
	Kokanee[a]	0.7	-	-	0.0	0.0	1.7	0.0	0.0	0.9
		(597)		(5)	(9)	(92)	(120)	(62)	(196)	(113)
Foster	Chinook	6.7	-	-	-	-	-	-	-	-
		(14)	(1)	(4)	(2)	(1)		(1)	(2)	(3)
	O. mykiss	1.4	-	-	-	-	-	-	0.0	7.1
		(69)			(1)	(2)	(1)	(7)	(44)	(14)
Lookout Point	Chinook[b]	38.1	0.0	-	6.5	17.1	21.3	48.2	66.8	86.3
		(939)	(49)		(154)	(105)	(164)	(168)	(226)	(73)
	Hat. Chinook	41.7	2.9	-	8.8	7.7	29.6	75.0	88.1	100
		(350)	(34)		(137)	(13)	(27)	(40)	(42)	(57)
	Rainbow	38.5	-	-	50.0	31.6	-	-	-	-
		(52)	(1)		(14)	(19)	(5)	(8)		(5)
Fall Creek	Chinook	100	-	-	-	-	-	-	100	100
		(249)						(6)	(234)	(9)
				Streams						
Middle Fork Willamette	Chinook	4.8	0.0	0.00	-	4.0	-	-	-	-
		(355)	(30)	(30)	(6)	(273)	(5)	(5)	(6)	
	Rainbow	10.5	-	-	-	-	-	-	-	-
		(19)	(4)	(4)	(1)	(6)	(2)	(1)	(1)	
North Santiam	Chinook	11.1	-	-	0.0	-	-	-	-	-
		(18)		(1)	(9)	(4)			(4)	
South Santiam	Chinook	0.0	-	-	-	-	-	-	-	-
		(12)			(7)	(1)	(1)	(2)	(1)	
	O. mykiss	0.3	-	-	0.0	0.3	1.3	0.0	0.0	-
		(735)	(1)	(7)	(69)	(349)	(80)	(137)	(92)	(2)
South Fork McKenzie	Chinook	4.5	-	0.0	0.0	2.1	5.0	17.7	11.1	-
		(1,299)		(15)	(159)	(235)	(819)	(62)	(9)	
	Rainbow	6.9	-	-	-	-	0.0	-	-	-
		(29)	(1)	(2)	(3)	(5)	(13)	(5)		

[a] *Only includes subyearlings*
[b] *Includes un-clipped hatchery fish released as fry in April.*

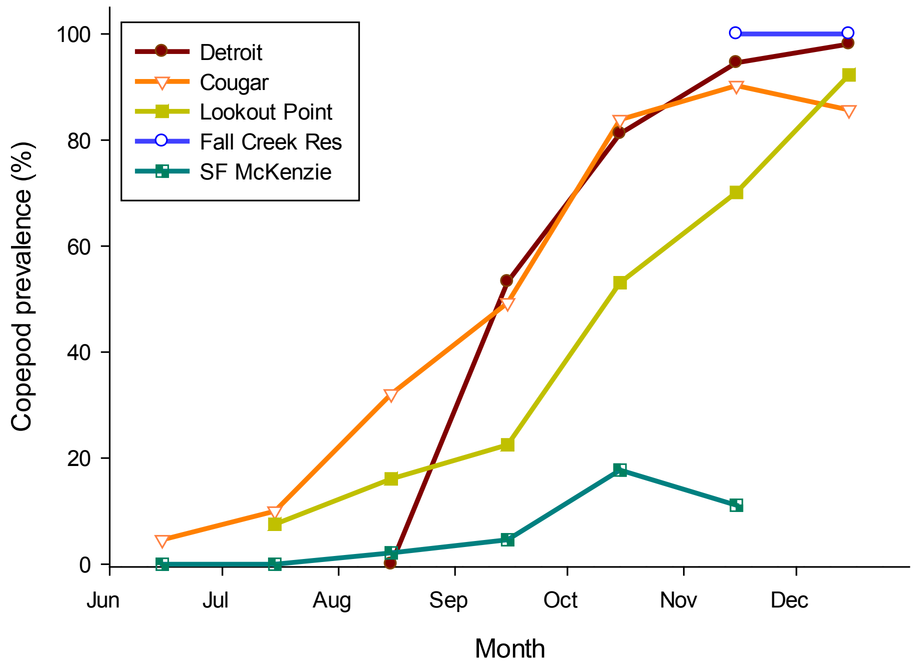

Figure 3-2. Proportion of subyearling Chinook salmon with copepods present by month for WVP reservoirs and the South Fork McKenzie River, 2012.

Differences in susceptibility to infection were evident among salmonid species. Compared to other species in reservoirs, juvenile Chinook salmon were the most susceptible to infection (Figure 3-3). In Detroit Reservoir, infection prevalence was significantly higher for Chinook salmon (mean 73%) compared to hatchery or natural rainbow trout and kokanee (z-test; $P<0.05$; Table 3-2). Kokanee were the least infected by parasitic copepods with a mean prevalence of 0.7% (3 of 597). Comparatively, rainbow trout were intermediate in their susceptibility with a seasonal mean prevalence of 23.4%. Cutthroat trout in Cougar Reservoir were also intermediate in infection prevalence, averaging 20% (n=60).

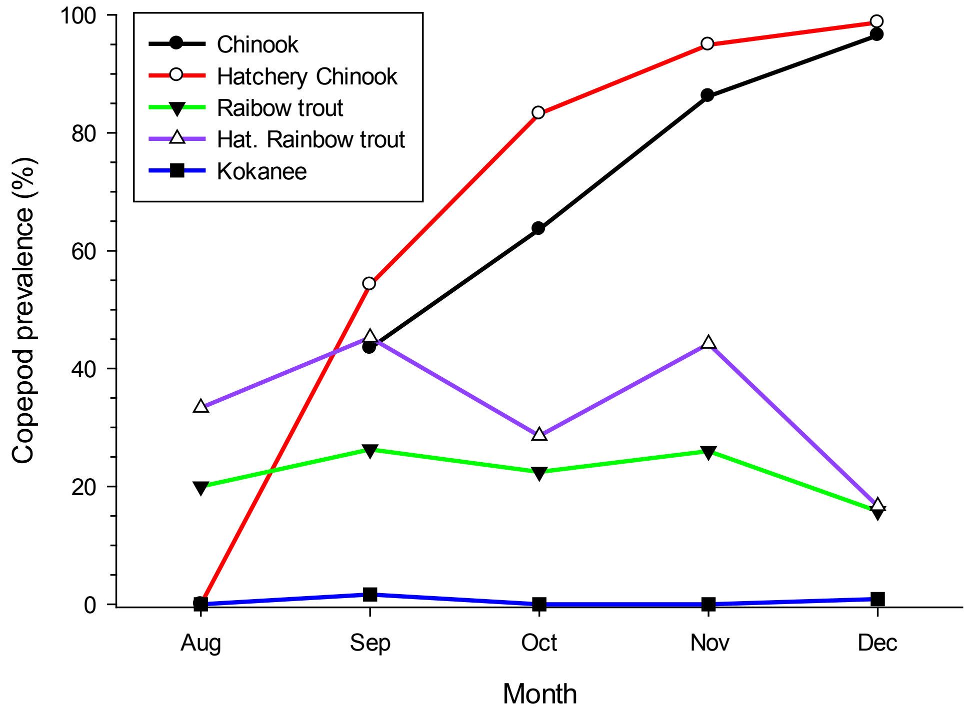

Figure 3-3. Monthly copepod prevalence for salmonid species in Detroit Reservoir, 2012.

Copepod prevalence was not significantly different between AD-clipped and unclipped Chinook salmon in either Detroit or Lookout Point reservoirs (z-test, P>0.05). However, hatchery rainbow trout in Detroit Reservoir had a significantly higher prevalence than unclipped rainbow trout. Hatchery trout were also larger, averaging 205 mm FL compared to 190 mm FL for unclipped trout. In Foster Reservoir, unclipped *O. mykiss* had significantly lower copepod prevalence (z-test, P<0.05) than hatchery rainbow trout, and were also smaller (mean fork length 76 mm and 244 mm, respectively) (Tables 3-2 and Table 3-3).

Table 3-3. Infection prevalence of the parasitic copepod *Salmincola californiensis* attached to gills of salmonids species in WVP reservoirs and streams above reservoirs, 2012. Monthly prevalence proportions reported only if ≥9 fish were examined.

Rearing location	Species	N	Mean gill prevalence (%)	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
				Reservoirs									
Cougar	Chinook	2,754	59.0	-	60.0[b]	46.4[b]	3.1	8.3	17.6	31.5	77.7	84.3	77.2
	Rainbow	76	17.1			25.0	15.8	-	-	-	-	-	-
	Cutthroat	60	20.0		-	22.2	23.1		-	-	-		
Detroit	Chinook	115	71.3			77.8[b]	-		-	43.5	59.1	86.2	93.1
	Hat. Chinook	791	66.9				-		0.0	53.0	81.7	94.9	98.7
	Rainbow	505	21.0				-	37.5	16.5	23.7	20.4	24.0	14.0
	Hat. rainbow	249	33.7				-	50.0	30.7	39.6	17.9	32.7	16.7
	Kokanee[a]	597	0.7				-	0.0	0.0	1.7	0.0	0.0	0.9
Foster	Chinook	15	6.7		-	-	-	-	-		-	-	-
	O. mykiss	69	1.4					-	-	-	18.2	0.0	6.7
	Hat. rainbow	11	27.3					-	-	-	-	-	-
Lookout	Chinook[a]	906	38.2			0.0		4.5	15.2	20.7	45.6	66.2	86.3
Point	Hat Chinook	332	42.2			0.0		5.8	7.7	29.6	77.5	88.1	100
	Rainbow	52	32.7			.		50.0	26.3	.	-		.
Fall Creek[c]	Chinook	51	100								-	100	-
				Streams									
Middle Fork	Chinook	355	1.7			0.0	0.0	-	0.0	-	-	-	
Willamette	Rainbow	19	0.0			-	-	-	-	-	-	-	
	Cutthroat	11	0.0			-	-	-	-		-		
North Santiam	Chinook	18	5.6				-	0.0	-		-	-	
South Santiam	Chinook	12	0.0					-	-	-	-	-	
	O. mykiss	737	0.3			-	-	0.0	0.3	1.3	0.0	0.0	
South Fork	Chinook	1,299	0.5				0.0	0.0	0.0	0.4	4.8	0.0	
McKenzie	Rainbow	29	6.9			-	-	-	-	0.0	-		

[a] *Includes both hatchery and natural origin fish.*
[b] *Includes yearlings and subyearlings during April and May in Cougar Reservoir. All Chinook were yearlings in Detroit during May.*
[c] *Data provided by USACE personnel.*

Intensity

As with prevalence, infection intensity was greater for Chinook salmon in reservoirs than in streams (Figure 3-4). The majority of stream-rearing fish (87%) had only one parasite that was generally attached to a fin. Most reservoir-rearing subyearling Chinook salmon had multiple parasites that were usually attached to gills.

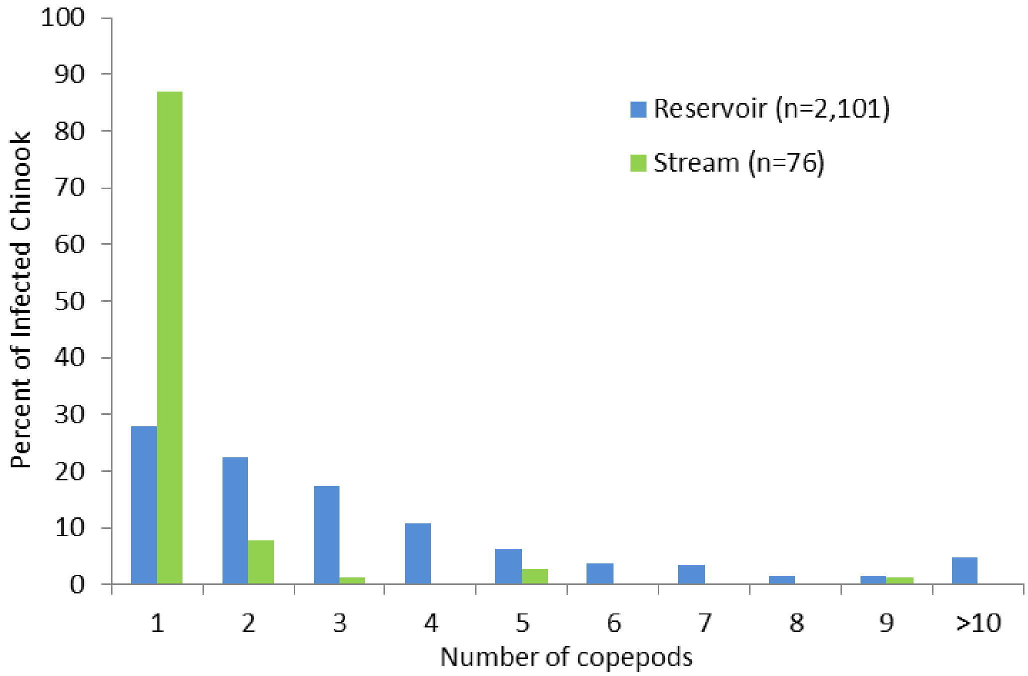

Figure 3-4. Copepod intensity among reservoir- and stream-rearing subyearling Chinook salmon, 2012. Copepod attachment location includes both gills and fins.

Infection intensity on the gills of reservoir-rearing subyearling Chinook salmon increased each month from late spring through fall (Figure 3-5). During the summer, less than five copepods were observed on the gills of subyearlings in Cougar and Lookout Point reservoirs but intensity increased through the fall culminating with maximum intensity in November and December. In Detroit Reservoir, hatchery Chinook salmon were released in mid-August and some individuals had up to eight gravid female copepods by September, suggesting that infection occurred almost immediately after release.

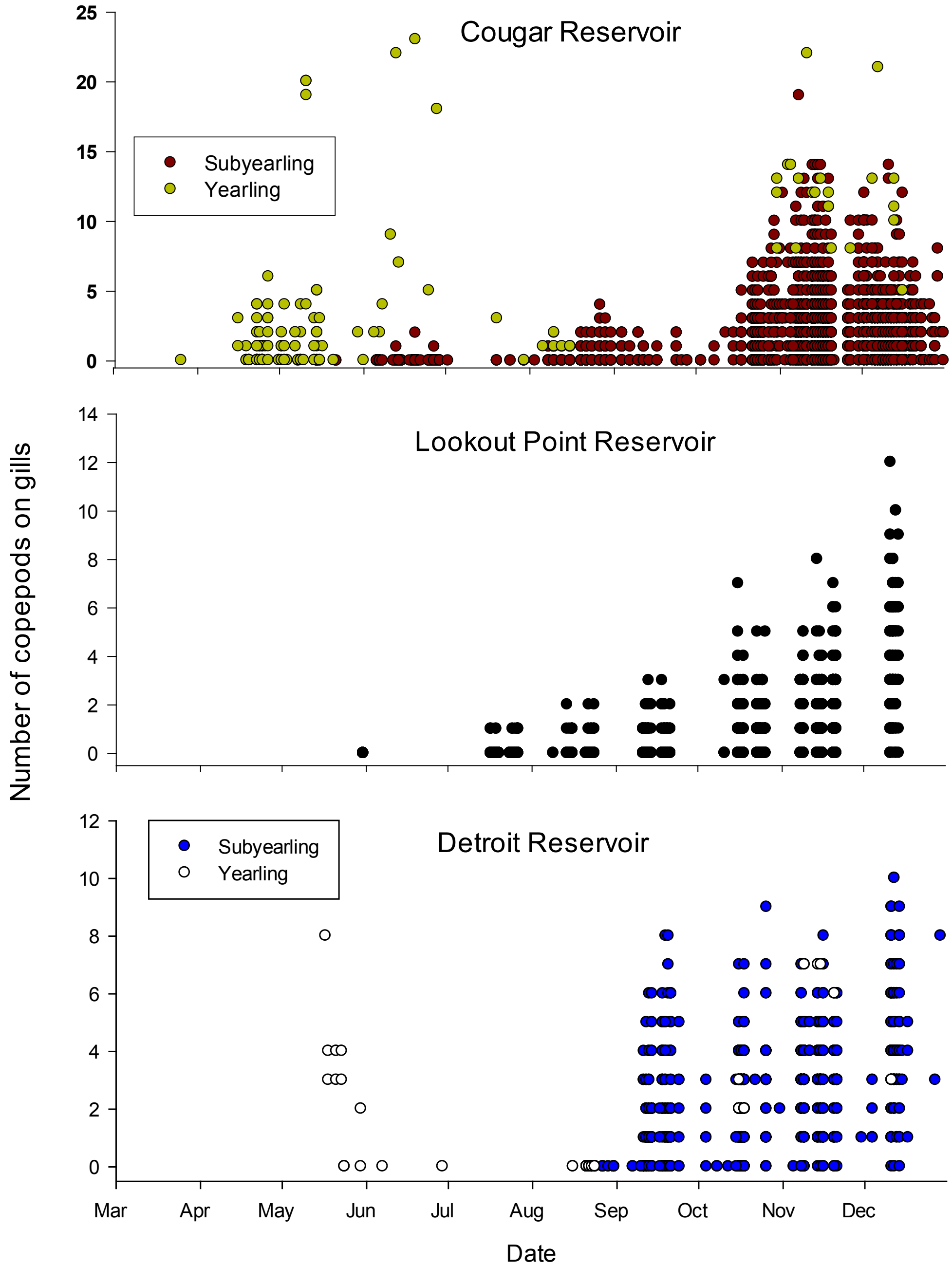

Figure 3-5. Number of parasitic copepods observed on gills of juvenile Chinook salmon examined in Cougar, Lookout Point, and Detroit reservoirs by month, 2012. Chinook from Cougar Reservoir were primarily sampled via rotary-screw traps below the dam. Lookout Point and Detroit sampling was primarily with gill nets set in the reservoirs.

Among all the WVP reservoirs sampled, Fall Creek exhibited the greatest infection intensity. By late fall, the median number of copepods on gills of subyearling Chinook salmon was 13 (Table 3-4). Approximately 23% of these fish were infected with ≥ 20 copepods on their gills (Figure 3-6). Juvenile Chinook salmon in Fall Creek Reservoir were also larger than those rearing in other WVP reservoirs, averaging 244 mm FL (SE=2.4) by late fall. Yearling Chinook salmon in Cougar Reservoir were the only other group that had ≥ 20 copepods on their gills with approximately 7% infected at this level of intensity.

Table 3-4. Copepod infection intensity and size of subyearling Chinook salmon in reservoirs during late fall (November-December) 2012. Cougar and Fall Creek samples were collected from screw traps below dams; Detroit and Lookout Point samples were collected with gill nets.

			Copepod infection intensity	
Reservoir	N	FL (mm)	Range	Median
Cougar	1,421	132	1-19	2
Detroit	315	169	1-10	3
Lookout Point	397	210	1-12	2
Fall Creek[a]	47	244	5-25	13

[a] Data from USACE

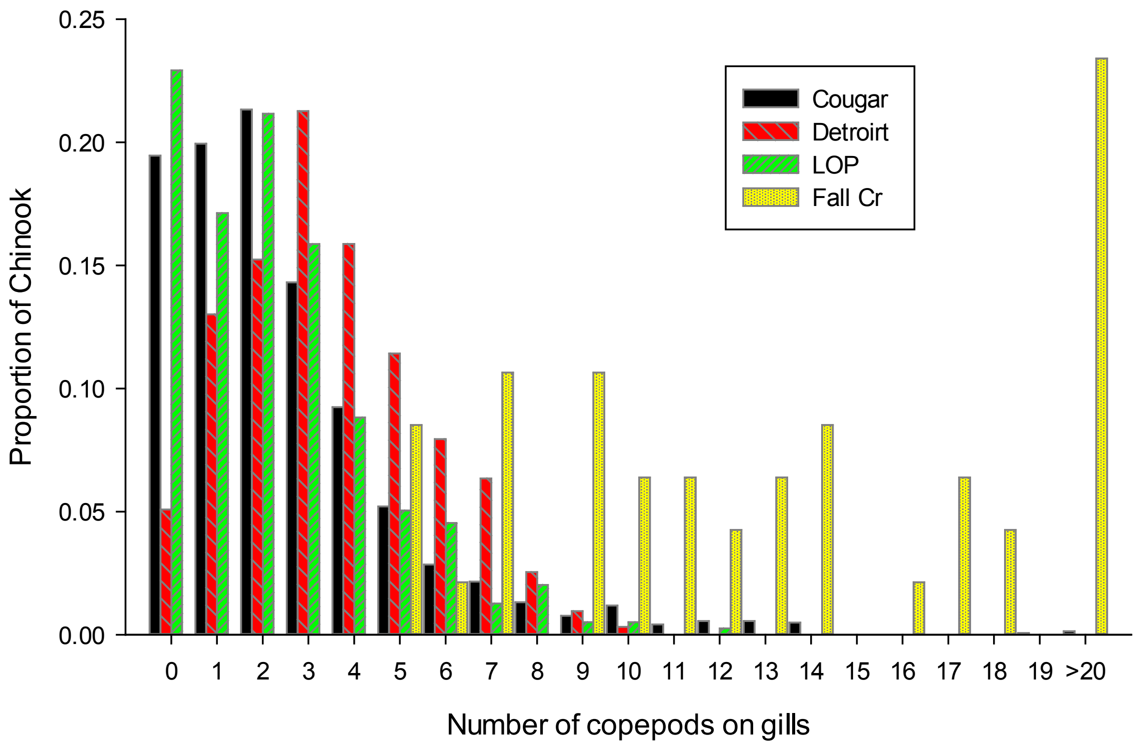

Figure 3-6. Copepod intensity on the gills of subyearling Chinook salmon in four WVP reservoirs during November and December, 2012. Chinook salmon from Detroit and Lookout Point (LOP) were collected primarily from gill nets in the reservoirs. Cougar and Fall Creek samples were from screw traps below dams. Fall Creek data courtesy of USACE.

Discussion

The higher prevalence and intensity of copepod infection observed from reservoir-rearing fish compared to stream-rearing fish can partly be attributed to the larger size fish attain in reservoirs. Several studies have attributed host size to infection prevalence (Nagasawa and Urawa 2002; Barndt and Stone 2003; Amundsen et al. 1997). Poulin et al. (1991) demonstrated in a laboratory study that a closely related copepod species, *S. edwardsii*, was more likely to infect larger brook trout *Salvelinus fontinalis* due to the greater host surface area and longer period of exposure. The importance of host size rather than exposure time was evident in our study. Exposure time was approximately equal for all reservoir-rearing Chinook salmon since almost all enter as fry in the spring. However, Fall Creek Reservoir Chinook salmon were the largest size and also had the highest copepod infection prevalence and intensity by late fall.

We also observed a greater propensity for reservoir-rearing fish to be infected on the gills which is consistent with results from Kabata and Cousens (1977) and Black (1982) that reported that attachment to gills was more likely for larger fish. The higher infection prevalence and intensity among reservoir fish may also be related to low water flow in reservoirs. McGladdery and Johnston (1988) suggested that copepodids may be retained in the gills if water flow rates in hatcheries are insufficient to flush copepodid eggs out of the opercular cavity, thereby allowing copepodids to re-infect the same host. The relationship between higher transmission rates and low water flow environments has also been noted in wild salmon (Friend 1941).

Increasing prevalence and intensity of copepod infection through time was evident for subyearling Chinook salmon rearing in reservoirs, resulting in the highest infection levels in late fall. This was also observed among subyearlings in Cougar Reservoir during 2011. The seasonal increase was specific to Chinook salmon and resulted in a greater prevalence and intensity later in the season compared to other salmonid species in reservoirs.

There are several possible reasons for the greater prevalence and intensity for subyearling Chinook salmon compared to rainbow trout and kokanee such as habitat overlap between parasite and host, schooling behavior of particular host (lateral transmission), feeding behavior (i.e. if a host targets copepods as a food item), morphological difference among host species, or a combination of these factors. In the summer, habitat segregation based on depth was evident among the three salmonid species in Detroit Reservoir. Rainbow trout occupied the surface habitat (0-9 m), Chinook salmon were generally at 9-14 m depths, and kokanee were at 18-23 m (see Section 1: Juvenile Chinook Salmon Distribution and Movement in Reservoirs). Although the vertical distribution of copepodids is not known, Poulin (1990) reported copepodids of *S. edwardsii* responded to passing shadows of fish as a means to locate hosts. This suggests that they attempt to maintain position in the upper water column of the reservoir during their brief infectious stage. If copepodids are rare at greater depths, this could explain the low infection rate for kokanee. Kokanee also differ morphologically with more narrowly-spaced gill rakers than Chinook salmon and rainbow trout (Townsend 1944; Foote et al 1999) which may prevent ingested copepodids from attaching to gill filaments.

Rainbow trout and Chinook salmon were both present near the surface but Chinook salmon had a much greater infection rate, despite being smaller in size. Feeding behavior differences between the species may explain the differences observed. Budy et al. (2005) demonstrated that rainbow trout in reservoirs select prey items ≥ 1 mm in length which suggests they may not be targeting copepodids (mean length= 0.69 mm) as a food source. In contrast, Rondorf et al. (1990) observed subyearling Chinook salmon occasionally consuming small prey items (daphnia) that were approximately 0.7 mm in length, similar to the mean length of copepodids. If juvenile Chinook salmon feed on copepodids, this could explain their increasing infection rate through time.

The very high level of infection for Chinook salmon in Fall Creek Reservoir was surprising given that 2012 was one year after a deep reservoir drawdown. It appears copepods were not completely flushed from the reservoir system during the winter drawdown. Some infected salmonids may have also remained in the stream or isolated pools above the dam and infected the cohort of subyearling Chinook salmon that entered the reservoir the following spring. Alternatively, adult Chinook outplanted above the dam may have carried copepods and copepodids were flushed into the reservoir.

The intensity of infection for some of the subyearling Chinook salmon exiting Fall Creek Reservoir exceeded levels reported to cause increased mortality during saltwater transition. Pawaputanon (1980) demonstrated that juvenile sockeye salmon *O. nerka* with a mean gill infection level of 23 copepods experienced 90% mortality during salinity tolerance tests compared to 10% mortality for non-infected control fish. If similar mortality rates occur for juvenile Chinook salmon, then about 20% of Fall Creek Chinook would not survive their migration to sea due to infection by *S. californiensis*. The effect of lower-intensity infection on juvenile Chinook salmon survival is not known but merits further investigation.

SECTION 4: SPECIES COMPOSITION AND CHINOOK SALMON PREDATION IN LOOKOUT POINT RESERVOIR

Background

In 2010, we initiated a pilot study in Cougar and Lookout Point reservoirs to characterize fish community structure and diet of piscivorous fish species. In 2011, we expanded this effort to include Detroit Reservoir. This work, along with fish collections in screw traps located below dams (Monzyk et al. 2011; Romer et al. 2011), revealed numerous predatory fish species occupying all WVP reservoirs including northern pikeminnow *Ptychocheilus oregonensis*, bull trout *Salvelinus confluentus*, and exotics such as smallmouth bass *Micropterus dolomieu*, largemouth bass *M. salmoides*, yellow perch *Perca flavescens*, crappie *Poxomis* spp., bullhead *Ameirurus* spp., and walleye *Sander vitreus*. Predation in reservoirs may impart a greater mortality rate for juvenile Chinook salmon than would otherwise occur if WVP dams did not exist. Studies in the Columbia River have shown that predation rates on juvenile Chinook salmon by smallmouth bass and northern pikeminnow can be substantial (Rieman et al. 1991; Poe et al. 1991; Tabor et al. 1993). 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 impact of predatory fish on juvenile Chinook salmon depends on predator abundance, water temperature, predator size and mouth gape, spatial and temporal overlap, and size of juvenile Chinook salmon.

Based on our 2011 efforts, we concluded that juvenile salmonids in Lookout Point Reservoir were at greater risk of predation than any of the other WVP reservoirs we studied based on the abundance and type of predators in this reservoir (Monzyk et al. 2012). Piscivorous species collected in Lookout Point Reservoir included rainbow trout *Oncorhynchus mykiss*, cutthroat trout *O. clarkii*, bullhead spp., largemouth bass, northern pikeminnow, walleye, and crappie. Northern pikeminnow, largemouth bass, and walleye had the highest occurrence of prey fish in their diet. Although walleye had the greatest overall consumption rate for juvenile Chinook salmon, northern pikeminnow were more abundant in Lookout Point Reservoir and likely present the greatest predation risk.

Detroit and Cougar reservoirs demonstrated less potential for predation since few predatory species occur in these reservoirs. In Detroit Reservoir, the only potential predators we collected were rainbow trout and bullhead. Rainbow trout were the most abundant predator in the reservoir. Five potentially piscivorous fish species were observed in Cougar Reservoir: rainbow trout, cutthroat trout, bull trout, largemouth bass, and sculpin *Cottus* spp.; however, all predators were found in relatively low numbers. Although we did not sample bull trout, we would expect this species to prey on juvenile Chinook salmon. Largemouth bass were rare and would not likely impact juvenile Chinook salmon at their current population level. Rainbow and cutthroat trout we captured fed primarily on zooplankton and macroinvertebrates.

Our sampling in 2012 focused on predation in Lookout Point Reservoir. Objectives of this study were to: 1) assess species composition of piscivorous fish in the reservoir; 2) determine species-specific consumption rates; and 3) determine seasonal changes in predation risk to juvenile Chinook salmon.

Methods

Species Composition

We assessed fish species composition in Lookout Point Reservoir in 2012 using a variety of gear types to limit the potential for gear selectivity and bias. Primary sampling methods included boat electrofishing and gill nets. In addition, we collected species information from any incidental bycatch with the gear types used primarily for juvenile Chinook salmon collections (i.e., fry floating box traps, Oneida traps, and small-mesh gill nets).

Boat electrofishing was conducted in spring (May), summer (August), and fall (October) in Lookout Point Reservoir. The electrofisher settings were direct current at 850-1000 V, 4 amps with a pulse width of 5 ms, and a frequency of 120 PPS. We conducted both day and night electrofishing. For each period, sampling occurred along two shoreline areas in each of the upper, middle, and lower sections of the reservoir with areas chosen based on habitat potential for predatory fish. Each shoreline area was sampled for 30 minutes shock time.

We deployed experimental type gill nets during spring, summer, and fall in Lookout Point Reservoir at randomly selected sites. Each net consisted of four 7.6 m x 3.0 m panels of increasing mesh size (square mesh size: 3.8 cm, 5.1 cm, 6.4 cm, 7.6 cm). The mesh sizes were large enough to avoid capturing subyearling Chinook salmon but were effective with larger predatory fish species. Gill nets were set perpendicular to shore and fished for approximately 24 h over a period of 6 – 15 d each month from April through October except during July when we did not set gill nets.

Predatory Fish Diet Analysis

Only predators sampled from gill nets or electrofishing were used for diet analysis. Predators collected in Oneida Lake traps and nearshore traps were not used because prey fish were confined with predators in the traps, potentially biasing diet results.

We collected and analyzed stomach samples from all predatory fish >150 mm FL. Stomachs were removed from all predator species collected except for northern pikeminnow where the entire digestive tract was removed since this species lacks a true stomach. To remove stomachs, predator fishes were dispatched using a lethal dose of MS-222 (200 mg/L). 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 (anterior to the anal vent in northern pikeminnow). The stomach was removed and placed in a Whirl Pak® and preserved with 95% ethanol at approximately a 20:1 ratio of fixative to tissue.

We processed each diet sample according to methods described in Monzyk et al. (2012). Briefly, we removed any identifiable items in a stomach samples including whole fish. Stomachs or digestive tracts were then chemically digested to reveal any fish bones that may have been missed during picking. Diagnostic bones were identified as described by Hansel et al. (1988), Frost (2000), and Parrish et al. (2006). Prey fish were identified to species if whole or via diagnostic bones to the lowest taxonomic group possible. We recorded the number of prey fish and measured fork lengths when possible.

Prey items found in diet samples were sorted into five taxonomic categories: fish, zooplankton, macroinvertebrates, crayfish, mollusks, and miscellaneous items. The miscellaneous category included amphibians, 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.

To characterize diet, we determined the frequency of occurrence of prey taxonomic categories for each predator species. Frequency of occurrence was defined as the number of stomachs containing a prey taxonomic category divided by the total number of non-empty stomachs, expressed as a percentage. A stomach sample could have multiple categories present, resulting in a sum of prey taxonomic categories > 100%. Therefore, we scaled frequency of occurrence results to 100%.

Numerous diet samples in 2012 contained PIT tags originating from the release of tagged hatchery Chinook salmon at the head of the reservoir in May (T. Friesen, ODFW, *personal communication*). Artificially high predation rates may have occurred on these fish due to high density and disorientation of the hatchery fish upon release. In addition, PIT tag evacuation rates are unknown for many of the predator species found in Lookout Point Reservoir. Therefore, we analyzed a PIT tag as evidence of fish consumption separately.

Consumption Rates

We estimated juvenile Chinook salmon consumption rates for piscivorous species based on meal turnover method. The formula for simple meal turnover rate was:

$$C = \frac{n}{N} ,$$

where C = rate of predator species consumption of Chinook salmon (fish/d), n = number of juvenile Chinook salmon consumed, and N = number of predators sampled, including those with empty stomachs.

Based on observed water temperatures and size of predators and prey, we predicted that a portion of Chinook salmon prey would remain in predator stomachs 24 h after capture, except for northern pikeminnow in the spring and summer. Evacuation rates of consumed prey are species specific and influenced by prey size, water temperatures and predator size (Beyer et al. 1988; Rogers and Burley 1991) with northern pikeminnow evacuation rates faster than black bass (Rogers and Burley 1991). We estimated the time required for complete evacuation of stomach contents based on average size of available Chinook salmon prey, predator size, and water temperatures for each season. Average size of available

Chinook salmon prey was estimated from length information in Section 2 of this report and weights (g) calculated from length-weight relationship of Viggs et al. (1991). We used the evacuation model developed by Beyer et al. (1988) for northern pikeminnow. For largemouth bass and crappie, we used the evacuation model developed by Rogers and Burley (1991) for smallmouth bass, assuming evacuation rates were similar between these species. Walleye evacuation rates were based on models developed by Swenson and Smith (1973) and modified by Wahl and Nielsen (1985). If the time (h) required for complete evacuation was < 24 h, we calculated a correction factor (i.e., correction factor is 24 h/time required for complete evacuation) and multiplied it to the seasonal consumption rate to provide an estimate of Chinook salmon consumed per day.

Results

Species Composition

We captured 14 species other than Chinook salmon in Lookout Point Reservoir during 2012 (Table 4-1). We did not capture black crappie *P. nigromaculatus*, pumpkinseed *L. gibbosus* or mountain whitefish *Prosopium williamsoni*, although they were collected in low numbers during 2011. However, we did collect four Oregon chub *Oregonichthys crameri*, a species not verifiably documented in Lookout Point Reservoir since 1957. All these species were rare in our collections. White crappie *P. annularis* were the most numerous predator species captured in our sampling; however, most crappie collected were subyearlings less than 60 mm FL. Among large predators (>150 mm FL), northern pikeminnow were the most numerous predator sampled with most >200 mm FL. Walleye were the largest predator collected in the reservoir, ranging from 196-760 mm FL. The age-class for walleye appeared to be skewed toward older fish as only one walleye collected was less than 200 mm FL. However, this may be an artifact of the gear we used to collect walleye and the habitat used by younger age classes.

Table 4-1. Number and fork length range (mm) of species collected in Lookout Point Reservoir in 2012. Fish were captured using nearshore traps, mini-Oneida traps, boat electrofishing, hook and line, and gill netting. Asterisks denote non-native (exotic) species.

Species	Number captured	Fork length range (mm)
Cutthroat trout *(Oncorhynchus clarkii)*	38	72-380
Rainbow trout *(Oncorhynchus mykiss)*	134[a]	31-420
Northern pikeminnow *(Ptychocheilus oregonensis)*	272	32-570
Sculpin *(Cottus* spp.*)*	102	34-75
Largemouth bass *(Micropterus salmoides)**	89	44-540
Walleye *(Sander vitreus)**	37	196-790
White crappie *(Pomoxis annularis)**	317[b]	35-395
Brown bullhead *(Ameiurus nebulosus)**	20	210-315
Yellow bullhead *(Ameiurus natalis)**	13	185-285
Non-piscivorous		
Chinook salmon (*Oncorhynchus tshawytscha*)	2,891[c]	30-296
Redside shiner *(Richardsonius balteatus)*	140	50-118
Dace *(Rhinichthys* spp.*)*	85	n/a
Largescale sucker *(Catostomus macrocheilus)*	1,154	n/a
Bluegill *(Lepomis macrochirus)**	10	135-175
Oregon chub *(Oregonichthys crameri)*	4	42-58

[a] Includes seven hatchery rainbow trout (from plantings in Hills Creek Reservoir, Salt Cr., or Salmon Cr.).
[b] Includes 200 subyearlings <60 mm FL captured on 8/9/12.
[c] Gear types used were selective for Chinook salmon.

Predatory Fish Diet Analysis

We collected 191 diet samples in Lookout Point Reservoir during spring (12 April – 31 May), 115 in summer (12 June – 24 August), and 73 in fall (18 September – 17 October). Of the 379 samples, 45% were empty, leaving 208 used for diet composition analysis. Most samples came from northern pikeminnow and white crappie during the spring (Table 4-2). Trout were among the smallest predators sampled and walleye were the largest (Table 4-3).

Table 4-2. Total number of diet samples collected and percent empty by predator species in Lookout Point Reservoir, 2012.

			Spring		Summer		Fall	
Species	Total samples	% empty	N	% empty	N	% empty	N	% empty
Rainbow trout[a]	25	24.0%	10	30.0%	3	0.0%	12	25.0%
Cutthroat trout	11	45.5%	9	33.3%	2	100%	0	0.0%
Bullhead spp.	22	54.5%	17	64.7%	4	25.0%	1	0.0%
White crappie	86	58.1%	58	53.4%	22	72.7%	6	50.0%
N. pikeminnow	163	38.7%	74	45.9%	62	35.5%	27	25.9%
Largemouth bass	38	36.8%	16	37.5%	14	35.7%	8	37.5%
Walleye	33	63.6%	6	33.3%	8	50.0%	19	78.9%

[a] Includes both naturally-produced and hatchery rainbow trout.

Table 4-3. Mean fork length (range) of predatory species collected for diet sampling and size of fish that consumed juvenile Chinook salmon in Lookout Point Reservoir, 2012.

Species	Mean fork length (mm)	Minimum predator size with fish in diet (mm)	Fork lengths of predators with Chinook (mm)
Rainbow trout	294 (120 – 395)	322	
Hatchery rainbow trout	333 (245 – 395)		
Cutthroat trout	258 (168 – 380)		
Bullhead spp.	255 (185 – 315)	185	
White crappie	290 (260 – 395)	270	290
Largemouth bass	354 (158 – 540)	158	315, 320, 355
Northern pikeminnow	380 (135 – 570)	145	315
Walleye	583 (366 – 790)	410	590, 600, 625

We collected stomachs from eight species that could be potential predators of juvenile Chinook salmon: rainbow trout, cutthroat trout; brown bullheads; yellow bullheads (*A. natalis*); white crappie; largemouth bass; northern pikeminnow; and walleye. For analysis we combined brown bullheads (n=15) and yellow bullheads (n=7) into a single group. All predator species, except cutthroat trout, contained fish in their diets. However, fish comprised the dominant prey item for northern pikeminnow, largemouth bass, and walleye.

Trout- Both rainbow and cutthroat trout were largely insectivorous and their diet composition changed little between spring and fall. Cutthroat trout are reported to be more piscivorous than rainbow trout (Baldwin et al. 2000), but we only captured 11 cutthroat trout during the spring and summer, none of which contained a fish prey item. Cutthroat trout diet samples most frequently contained macroinvertebrates (89%) and miscellaneous other food items. Rainbow trout primarily consumed macroinvertebrates in the spring and summer (Figure 4-1). By fall, rainbow trout had a more diverse diet including fish. Fish bones were identified in stomachs of two individual rainbow trout >300 mm FL, but the bones were non-diagnostic to identify taxa.

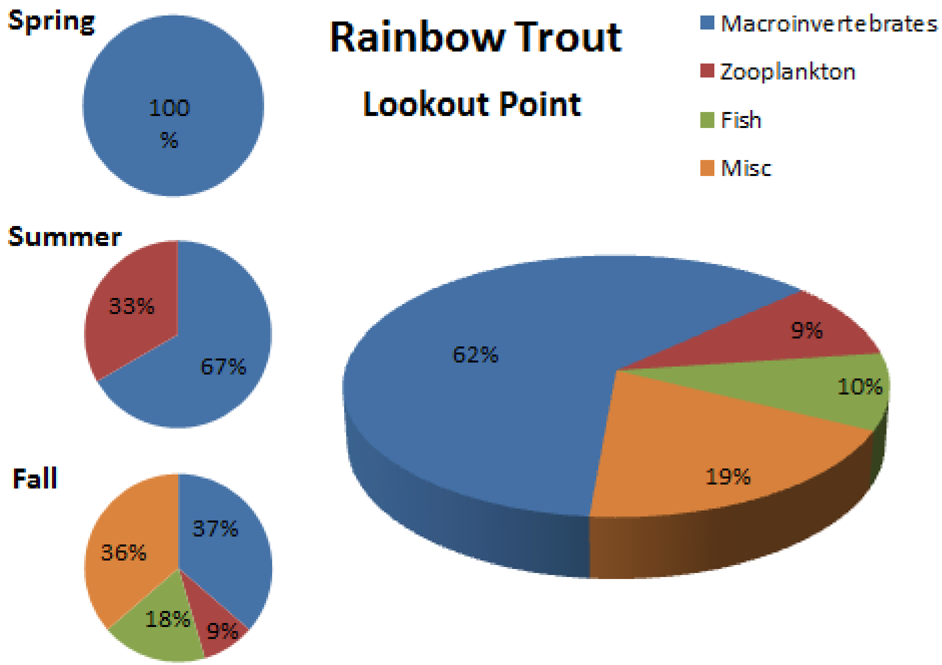

Figure 4-1. Occurrence frequency of prey taxon in rainbow trout diets in Lookout Point Reservoir, 2012. Frequencies were scaled to 100%.

Bullheads- Most of the 22 bullheads captured in 2012 were in the spring (n=17), but 65% contained no diet items (Table 4-2). Bullhead diet was primarily fish, crayfish, and miscellaneous prey items (Figure 4-2). Bullheads are opportunistic piscivores that are typically nocturnal in their feeding activity and benthic oriented. It is not surprising that crayfish and miscellanious prey items dominated their diet during all seasons (Figure 4-2). Most fish items present in bullhead samples were collected in April- June when Chinook salmon fry are present in Lookout Point Reservoir (Monzyk et al. 2013; this report) but we could not confirm that the fish in diet samples were Chinook salmon fry. The prey fish in bullhead diet samples were a cottid, a cyprinid, and three unidentifiable species.

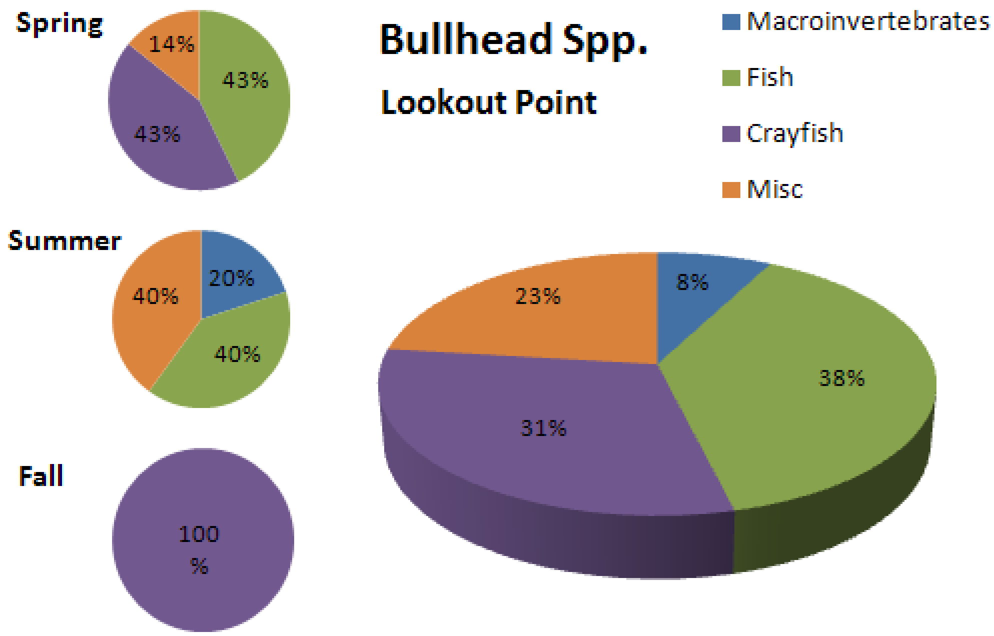

Figure 4-2. Occurrence frequency of prey taxon in bullhead spp. diets in Lookout Point Reservoir, 2012. Frequencies were scaled to 100%.

White Crappie- The 86 white crappie diet samples were largely comprised of macroinvertebrates and fish prey items (Figure 4-3). Fish were found in 36% of the non-empty stomachs examined. The frequency of occurrence of fish prey increased each season with 30% in spring, 50% in summer and 67 % in fall. The high frequency of fish items in the fall may be inflated because of the low fall sample size (n = 6); however, a seasonal trend was evident in 2011 as well. Fifteen crappie had fish items in their diet, but nine contained prey fish that were not assignable to a family or species taxonomic level. The other six crappie had a combination of suckers, crappie, and salmonids in their diet sample (Table 4-4). A Chinook salmon and an unidentifiable salmonid were identified in two different crappie diet samples, both in the spring.

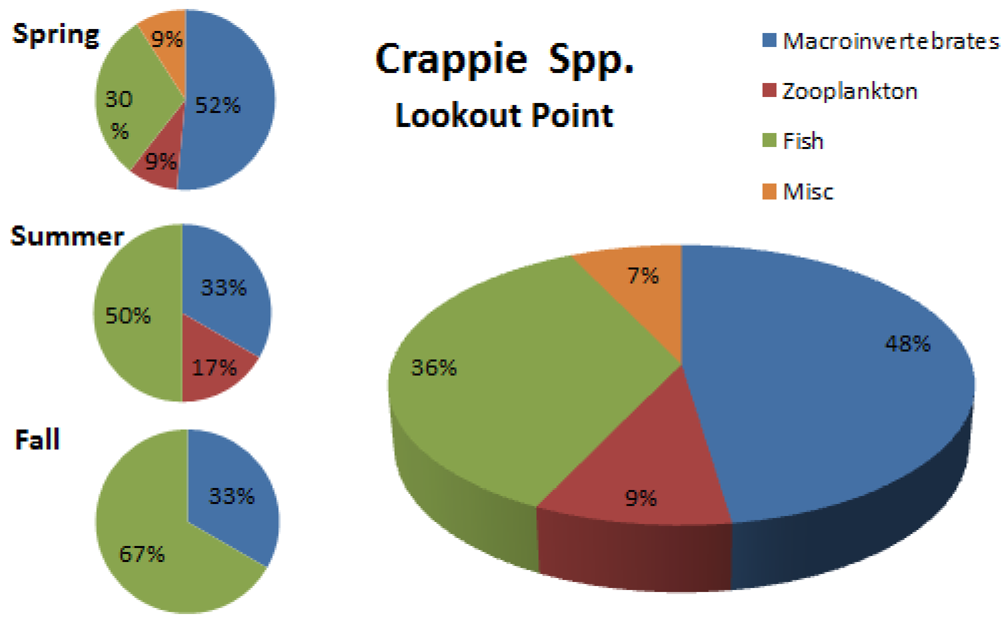

Figure 4-3. Occurrence frequency of prey taxon in crappie spp. diets in Lookout Point Reservoir, 2012. Frequencies were scaled to 100%.

Table 4-4. The number of prey fish by species/group found in the diet samples of piscivorous fish in Lookout Point Reservoir, 2012.

Prey Species	Piscivorous Species					
	Rainbow Trout	White Crappie	Bullhead spp.	Bass spp.	Northern Pikeminnow	Walleye
Chinook		1		3	1	3
Salmonid spp.		1		1	3	
Sucker		7		3	6	6
Sculpin			1	52	49	4
Crappie spp.		8			376	5
Centrarchid spp.				4		
Cyprinid spp.			1			
Unk Fish spp.	2	9	3	2	13	3

We captured 10 crappie with PIT tags from hatchery Chinook salmon in their stomachs. If we included these PIT tags in our analysis, it increased the overall frequency of fish in diet samples from 36% to 46%. Additionally, by including PIT tags as evidence for consumption of Chinook salmon, we found that crappie consumed 21 Chinook salmon in the spring and early summer. This is a large increase from the one Chinook salmon that we found in crappie stomachs based on fish bones. Most PIT tags were recovered from samples that were otherwise empty and some samples contained up to six PIT tags.

Northern Pikeminnow- Although northern pikeminnow had a diversity of prey items in their diet, the most frequently occurring diet category (56%) was fish (Figure 4-4). Macroinvertebrates and fish occurred with relatively equal frequency in the diet during spring, but by summer and into the fall, fish were the most frequently occurring diet category found in the diet of northern pikeminnow. During the summer, fish were found in 81% of the pikeminnow stomachs with crappie the most common species consumed (Figure 4-4).

Northern pikeminnow had the highest number of individual prey fish in diet samples (Table 4-3). We observed 376 juvenile crappie in pikeminnow diet samples during August with twelve pikeminnow consuming >10 juvenile crappie. The greatest number of crappie consumed by a single pikeminnow was 73. One Chinook salmon was identified in the diet samples along with three unidentifiable salmonids. Additionally, three PIT tags were found in pikeminnow stomachs: two with unidentifiable salmonid bones and one with Chinook salmon bones. If PIT tags are included in the analysis, pikeminnow consumed a least three Chinook salmon, all during the spring.

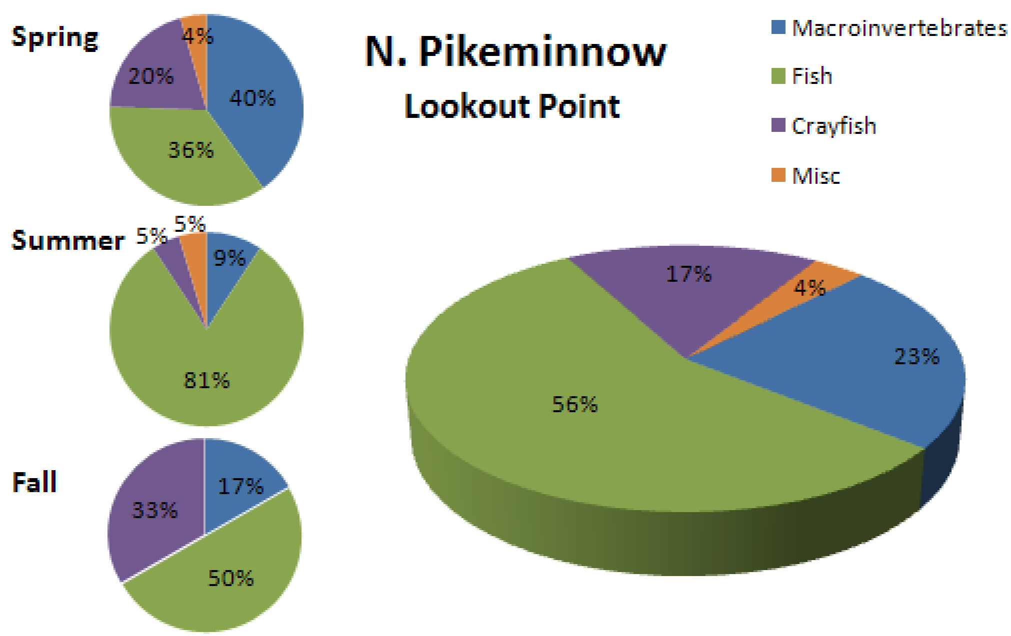

Figure 4-4. Occurrence frequency of prey taxon in northern pikeminnow diets in Lookout Point Reservoir, 2012. Frequencies were scaled to 100%.

Largemouth Bass- A total of 38 largemouth bass were sampled, with 24 having food items in their stomachs. Largemouth bass had the second highest frequency of occurrence of fish (78%) in diet samples (Figure 4-5), consistent with results from 2011 (see Appendix). Summer and fall samples had a higher frequency of occurrence of fish prey items than spring samples. The most common fish found in bass stomachs were sculpin (Table 4-3). One 325-mm largemouth bass consumed 26 individual sculpin. Three juvenile Chinook salmon were consumed, all in late May.

Largemouth bass stomachs also contained PIT tags. Seven PIT tags were found in five largemouth bass. The frequency of occurrence of prey fish found in bass stomachs did not change with the inclusion of PIT tags as evidence for additional fish consumed since each bass that had a PIT tag also had other fish material in their stomachs, but it did increase the known number of Chinook salmon consumed by largemouth bass from three to eight.

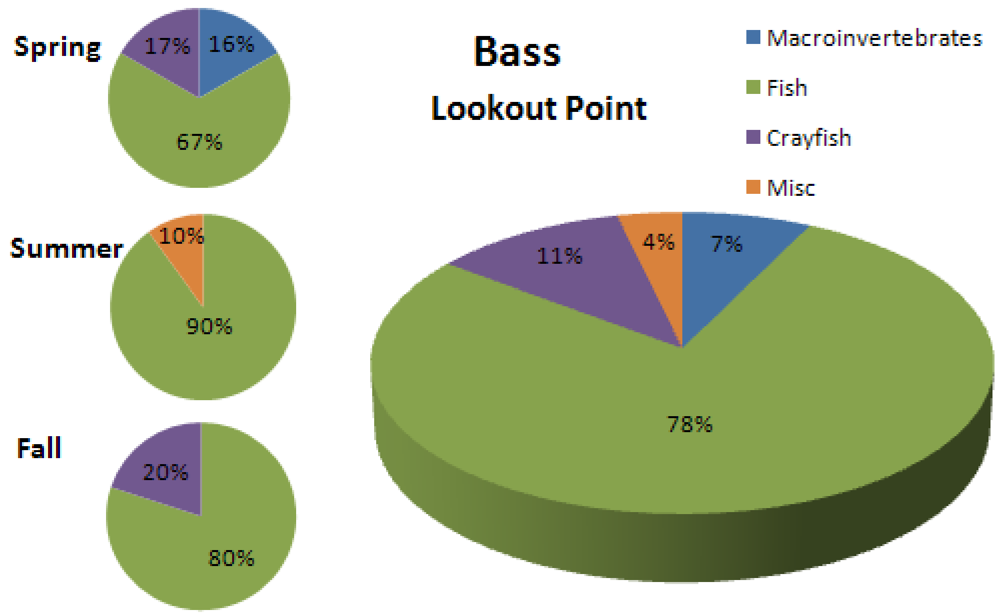

Figure 4-5. Occurrence frequency of prey taxon in largemouth bass diets in Lookout Point Reservoir, 2012. Frequencies were scaled to 100%.

Walleye- A total of 33 walleye were sampled with 12 containing food items in their stomach. Walleye had the highest percentage of empty stomach (64%), especially those sampled in the fall (Table 4-2). Similar to 2011, diet samples provided additional evidence that walleye preyed almost exclusively on fish (see Appendix). All of the walleye that had at least one prey item in their stomach also contained fish. Fish occurred more frequently (86%) in walleye stomachs compared to other predator species (Figure 4-6). The lengths of walleye that contained fish in their diet ranged from 410-680 mm FL. Three juvenile Chinook salmon were identified in walleye samples, along with suckers, crappie and sculpins (Table 4-3). The three Chinook salmon were consumed in spring, summer, and fall.

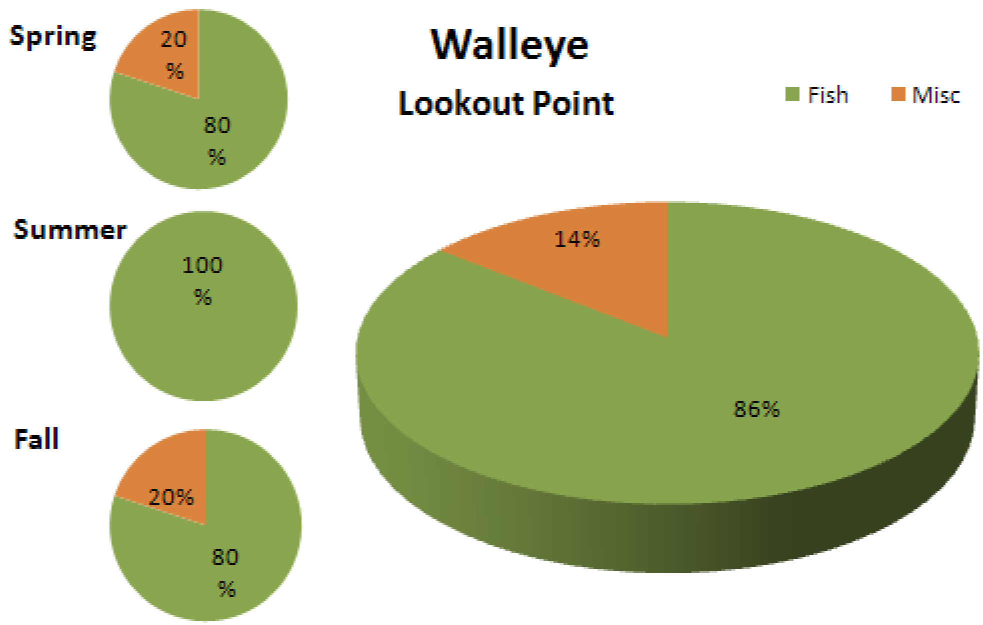

Figure 4-6. Occurrence frequency of prey taxon in walleye diets in Lookout Point Reservoir, 2012. Frequencies were scaled to 100%.

We collected one walleye stomach that was completely empty except for a a PIT tag from a hatchery Chinook salmon. Other than a PIT tag this walleye had an empty stomach. Inclusion of this PIT tag as a fish item would make four Chinook salmon found in walleye diet samples, and increase the proportion of fish found in walleye stomachs by 1%.

Consumption Rates

We estimated juvenile Chinook salmon consumption rates for white crappie, largemouth bass, northern pikeminnow, and walleye. Chinook salmon were the only known salmonids identified in diet samples, therefore we assumed unidentifiable salmonids were all Chinook salmon. The validity of this assumption was supported by the detection of two PIT tags among the five unknown salmonids in the diet samples.

Calculation of evacuation rates showed that only northern pikeminnow in spring and summer were likely to completely evacuate Chinook salmon prey in less than 24 h after consumption. The average-sized Chinook salmon available as prey during spring (65 mm FL, 2.8 g @ T=14º C) was estimated to be completely evacuated by within 6.2 h for an average-sized northern pikeminnow (FL=380 mm, weight=631 g). In the summer, a Chinook salmon (125 mm, 20g @ T=16º C) consumed by a northern pikeminnow would be evacuated in 17 h. Therefore consumption rates for northern pikeminnow (Chinook/d) were multiplied by a factor of 3.9 in the spring and 1.4 in the summer.

Most of the Chinook salmon consumption occurred in the spring (Table 4-5). All of the known Chinook salmon consumed by crappie, bass, and northern pikeminnow occurred in the spring. Most of the unidentified salmonids (3/5) also occurred in the spring.

White crappie consumption rate of juvenile Chinook salmon during spring was 0.017 fish/d based on known fish species in samples and 0.034 fish/d when unknown salmonids were included. Largemouth bass had a consumption rate in the spring of 0.188 fish/d with no unidentifiable salmonids in the samples. The estimate in the summer was based on one unknown salmonid. Walleye had a consumption rate of 0.167 fish/d in the spring. No unidentified salmonids were found in walleye samples. Northern pikeminnow consumption rate in the spring was based on one known Chinook salmon and two unknown salmonids. The fall consumption rate was based on one unknown salmonid. Northern pikeminnow, largemouth bass and walleye had similar consumption rates during the spring.

Table 4-5. Daily consumption rates (fish/d) of juvenile Chinook salmon by predator species in Lookout Point Reservoir, 2012. All unidentified salmonids in diet samples were assumed to be Chinook salmon.

Species	Spring	Summer	Fall
White crappie	0.034	0	0
Northern pikeminnow	0.160[a]	0	0.037
Largemouth bass	0.188	0.071	0
Walleye	0.167	0.125	0.053

[a] The consumption rate uncorrected for evacuation rate was 0.041 fish/d.

Discussion

We confirmed that northern pikeminnow, white crappie, largemouth bass, and walleye consumed juvenile Chinook salmon in Lookout Point Reservoir. The occurrence frequency of fish in the diets of northern pikeminnow, white crappie, and largemouth bass increased throughout the year but most juvenile Chinook salmon were consumed in the spring.

Predation on juvenile Chinook salmon depends on predator size as well as mouth gape, spatial and temporal overlap in distribution in relation to juveniles, and growth rates of juvenile Chinook salmon. Crappie were likely seasonally limited by mouth gape and only able to feed on juvenile Chinook salmon in the spring when prey were still small in size. Bass predation on Chinook salmon is likely driven by habitat overlap. Bass prey on 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 spring period before Chinook salmon begin to move to more pelagic habitat. Tags from hatchery Chinook salmon found in diet samples also corroborate this spatial and temporal overlap. Of the five bass that ate PIT-tagged Chinook salmon, four were captured in the littoral areas of the upper end of Lookout Point Reservoir at the end of May. The small size of juvenile Chinook salmon in the spring likely increased their vulnerability to a greater variety and size range of piscivorous fish species.

Northern pikeminnow appeared to be opportunistic feeders, shifting to juvenile crappie when they were abundant in the summer. In previous years, we observed thousands of subyearling white crappie in Lookout Point Reservoir from the end of August through

October (Monzyk et al 2011b; unpublished ODFW data) suggesting that the crappie in northern pikeminnow diet samples were mainly subyearlings. Petersen and DeAngelis (1992) reported northern pikeminnow predation occurs during distinct 'feeding bouts' rather than random feeding occasions on individual prey over long periods of time. The large number of juvenile crappie found in northern pikeminnow diet during summer is evidence of this phenomenon.

Walleye and northern pikeminnow were the largest predators in the reservoir and the only species observed to feed on large Chinook salmon in the fall. Poe et al. (1991) developed a linear relationship between the fork length of northern pikeminnow and the maximum size of juvenile salmonids consumed in John Day Reservoir. Assuming their model is valid for Lookout Point Reservoir, northern pikeminnow over 410 mm FL (35% of our catch) could consume a juvenile Chinook salmon >208 mm FL, the mean juvenile size by late fall. Knight et al. (1984) developed a similar relationship for walleye size and maximum size of soft-rayed fish consumed in Lake Erie. Based on their model, a juvenile Chinook salmon at 208 mm FL would be vulnerable to predation by a walleye >975 mm FL, and we did not capture walleye this size in Lookout Point Reservoir. However, walleye averaged 583 mm FL and this size fish could consume juvenile Chinook salmon up to 173 mm FL. Juvenile Chinook salmon demonstrated large variability in size during the fall and many would be small enough to be consumed by walleye (Figure 2-1).

Northern pikeminnow, walleye and largemouth bass have been shown to prey on juvenile Chinook salmon in other lentic systems (Brown and Moyle 1981; Beamesderfer and Rieman 1991; Poe et al. 1991; Tabor et al. 1993; Zimmerman 1999). Northern pikeminnow were major predators of juvenile Chinook salmon in John Day Reservoir when compared to walleye and smallmouth bass (Poe et al. 1991; Vigg et al. 1991). The highest consumption rate of all predators in that reservoir occurred in July (Vigg et al. 1991). Tabor et al. (2007) reported largemouth and smallmouth bass predation on juvenile Chinook salmon in Lake Washington but concluded that the impact on salmonid populations was minimal. In all of these studies, the juvenile Chinook salmon were larger than those we observed in the spring in Lookout Point Reservoir.

The impact of predators on the juvenile Chinook salmon survival in the reservoir depends on the population size of predators. We currently do not have population estimates of predator species in Lookout Point Reservoir. However, northern pikeminnow appear to the most abundant large predator in the reservoir based on our catch data, collected using a variety of gear types. Walleye were first reported in Lookout Point Reservoir in 1998 with natural production documented in 2007. Walleye are also abundant in the reservoir and their population may still be increasing. Given the uncertainty in northern pikeminnow consumption rates during spring and the population size of predators, it is unknown which predator has the greatest impact on juvenile Chinook salmon survival. If we can successfully estimate population sizes for each predator species and develop detailed consumption rates based on evacuation models, we hope to be able to estimate the total number of juvenile Chinook salmon consumed by the predator population present in Lookout Point Reservoir.

The small size of juvenile Chinook salmon during spring complicated our analysis of diet habits of predators in Lookout Point Reservoir not only due to the rapid digestion rate, but also because we suspect smaller prey fish would be more likely to be missed during the processing of diet samples. Our chemical digestion process may dissolve already partially digested fine bones from small fish thereby biasing our sample towards larger size prey. Another potential bias was the use of gill nets for collecting predator diet samples. Predator species caught in gill nets are known to evacuate their stomach contents partially or completely while entangled in the nets (Treasurer 1998; Sutton et al. 2004). This year we did not find this to be the case with our samples; there was not a significant difference in the proportion of empty stomach samples from gill net samples compared to electrofishing samples (z-test, $P = 0.998$, $z = 0.002$). Partially evacuated stomachs would be difficult to determine in the field, and may result in non-empty diet samples that are incomplete representations of a predator's recent diet. For these reasons, the amount of juvenile Chinook salmon predation reported here should be considered a conservative estimate.

Conclusions and Recommended Future Directions

The conditions juvenile spring Chinook salmon currently encounter while rearing in freshwater is vastly different than existed before construction of WVP dams. Historically, most fry from spawning areas above present-day dam sites would have migrated in the spring to lower river reaches, including the mainstem Willamette River, with some entering the Columbia Estuary as subyearlings (Bureau of Commercial Fisheries 1960; Zakel and Reed 1984; Mattson 1962; Schroeder et al. 2007). Currently, most fry that are progeny of adults outplanted above the dams now rear in the reservoirs for a period of approximately seven months until reservoir drawdown in the fall. The purpose of this study was to provide information on juvenile Chinook salmon use of reservoirs and the risks and benefits of reservoir rearing to aid management decisions on future adult outplanting strategies and juvenile downstream passage.

We studied several life-history characteristics of juvenile Chinook salmon rearing in WVP reservoirs. Generally, juveniles entered the head of reservoirs in early spring as fry. Fry were concentrated in the upper end of the reservoirs and slowly dispersed along nearshore habitat towards the dam over the course of the spring. Very few fry size Chinook salmon (<50 mm FL) reach the dams by spring. Movement towards the dam does not appear to be directional, rather the result of local upstream and downstream movements in nearshore habitat. Subyearlings grew rapidly and by late spring/early summer began to move into deeper water, coinciding with warming surface water temperatures. By this time of year, juveniles were better able to swim and were more evenly dispersed in the reservoir. As surface water temperatures increase by late summer, juveniles descend into deeper, cooler water and did not return to the surface until water temperatures cooled in the fall. During this period, juveniles were able to occupy optimal temperature for growth and attained a large size. Also in summer, the subyearling population started to become infected with parasitic copepods. By late fall, nearly all fish are infected and the intensity varied between individuals and reservoirs. We did not evaluate the impact of infection on juvenile Chinook fitness in this study but suggest this be investigated.

One benefit from reservoir rearing is the rapid summer growth compared to stream-rearing juveniles and the survival advantage to adulthood larger size can impart (ISRP 2011). However, before the rearing potential of reservoirs can be fully realized, risks of reservoir rearing will need to be mitigated. Current passage conditions at WVP dams are poor (Duncan 2011) and larger fish appear to incur a higher mortality rate (Taylor 2000; Normandeau 2010; Keefer et al. 2011; Zymonas et al. 2012 *in prep*). In a retrospective analysis of balloon-tag studies conducted at Columbia/Snake river dams, Skalski et al. (2002) found that turbine passage mortality increased with fish size. Reservoir residence was also accompanied by an increase incidence of parasitic copepod infections. Increased mortality from gill tissue damage associated with infection needs to be assessed. The only study that we could find that evaluated saltwater transition of infected salmonid smolts showed very high mortality. We strongly recommend this aspect of copepod infection be more fully assessed. If the intensity of copepod infection we observed causes similar mortality, then efforts would be needed to pass juvenile Chinook salmon before they become highly infected.

We evaluated predation risk to juvenile Chinook salmon by piscivorous fish species in Lookout Point Reservoir. This was our second year of diet sampling. Most diet studies are carried out over several years to provide large enough sample sizes to make meaningful conclusions. Also, we did not perform evacuation rate calculations in this report due to time constraints. We archived our diet samples so we could perform a more thorough evaluation in the future. We recommend a third year of predator diet sampling in Lookout Point Reservoir, preferably during a year when hatchery juveniles are not released into the reservoir. We are currently conducting sampling in Lookout Point Reservoir to estimate northern pikeminnow population size. Information on consumption rate and population size of predators should provide a quantitative estimate of Chinook consumed each year in the reservoir.

In Lookout Point Reservoir, dam passage along with predation risk, copepod infection, and relatively long travel distance associated with two dams and reservoirs certainly impacts survival and delays downstream movement of fry and older age class juveniles. Preliminary data from paired releases of hatchery Chinook salmon > 60 mm FL in the Middle Fork Willamette River supports this assertion; fish that were released below Lookout Point and Dexter dams were detected more 4.5 times more frequently at Willamette Falls than those released above the projects (Friesen et al. 2013 *in prep*). Subyearlings in Lookout Point Reservoir likely reduce their vulnerability to predation by the fall after attaining a large size but these larger fish have an increased risk to dam passage mortality. If predation impacts on small subyearlings and dam passage mortality of larger fish are found to be too large to meet management objectives, project operations could be altered to reduce these impacts such as (e.g.) a run-of-river drawdown (Miller and Friesen 2012).

Currently, efforts are underway to improve passage survival for juvenile Chinook salmon of all sizes through operational or structural modifications at dams. These improvements will likely take several years to accomplish. In the interim, overall passage survival for a cohort could be improved by passing more fish at a smaller size earlier in the year. This management strategy would also hedge against the potential risks of copepod infection and predation associated with reservoir rearing until the impact of these risks are better known.

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Appendix

Table A-1. Frequency of occurrence and weighted mean of prey items, expressed as a proportion of the total prey items consumed per predatory species at Lookout Point Reservoir, 2011-2012.

	2011 (%)	2012 (%)	Weighted Mean (%)		2011 (%)	2012 (%)	Weighted Mean (%)
Cutthroat Trout				N. Pikeminnow			
Zooplankton	33	0	8.3	Zooplankton	4	0	1.7
Macroinvert.	33	89	75.0	Macroinvert.	19	23	21.3
Crayfish	0	0	0.0	Crayfish	22	17	19.1
Fish	34	0	8.5	Fish	46	56	51.7
Miscellaneous	0	11	8.3	Miscellaneous	8	4	5.7
Rainbow Trout				Mollusks	1	0	0.4
Zooplankton	53	8	33.0	Largemouth Bass			
Macroinvert.	47	67	55.9	Zooplankton	0	0	0.0
Crayfish	0	0	0.0	Macroinvert.	16	7	9.8
Fish	0	8	3.6	Crayfish	17	11	12.8
Miscellaneous	0	17	7.6	Fish	67	78	74.6
Crappie Spp				Miscellaneous	0	4	2.8
Zooplankton	46	9	29.1	Walleye			
Macroinvert.	40	48	43.7	Zooplankton	0	0	0.0
Crayfish	2	0	1.1	Macroinvert.	15	0	8.8
Fish	10	36	21.9	Crayfish	5	0	2.9
Miscellaneous	2	7	4.3	Fish	80	86	82.5
Bullhead Spp				Miscellaneous	0	14	5.8
Zooplankton	0	0	0.0				
Macroinvert.	78	8	36.6				
Crayfish	0	31	18.3				
Fish	0	38	22.5				
Miscellaneous	11	23	18.1				
Mollusks	11	0	4.5				