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

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Table of Contents

Executive Summary 1
Introduction 4
SECTION 1: JUVENILE CHINOOK SALMON DISTRIBUTION IN RESERVOIRS 5
  Background 5
  Methods 6
    Subyearling Nearshore Distribution 6
    Parr Vertical Distribution 7
  Results 10
    Subyearling Nearshore Distribution 10
    Parr Vertical Distribution 16
  Discussion 21
SECTION 2: RELATIVE GROWTH OF JUVENILE CHINOOK SALMON IN RESERVOIRS AND STREAMS 24
  Background 24
  Methods 24
  Results 26
  Discussion 29
SECTION 3: PARASITIC COPEPOD INFECTION PREVALENCE AND INTENSITY 31
  Background 31
  Methods 32
  Results 33
    Prevalence 33
    Intensity 35
  Discussion 39
SECTION 4: SPECIES COMPOSITION AND PREDATION ON SALMONIDS IN FOSTER RESERVOIR 42
  Background 42
  Methods 43
    Species Composition 43
    Predatory Fish Diet Analysis 44
    Consumption Rates 45
  Results 46
    Species Composition 46
    Predatory Fish Diet Analysis 46
    Consumption Rates 53
  Discussion 54
SECTION 5: ABUNDANCE OF PISCIVOROUS SPECIES IN LOOKOUT POINT RESERVOIR 57
  Background 57
  Methods 57
    Predator Relative Abundance Indices 57
    Northern Pikeminnow Population Size 58
    Distribution 60
  Results 60

        Predator Abundance Indices 61
        Northern Pikeminnow Population Size.. 62
        Distribution 63
    Discussion 66
Conclusions and Recommended Future Directions.................................. 67
Acknowledgments... 69
References.. 70
Appendix.. 78

List of Tables

Table 1-1. Mean fork length of subyearling Chinook caught in floating box traps and small Oneida traps by month and reservoir section for Cougar, Detroit, Foster, and Lookout Point reservoirs, 2013 10
Table 1-2. Percent of subyearling Chinook salmon captured by reservoir section and month, 2013 13
Table 2-1. Growth rate of subyearlings in WVP reservoirs calculated from mean fork length in May and October, 2013 29
Table 3-1. Percent of *Salmincola californiensis* attached to the gills and fins of infected Pacific salmonids by rearing location in the Willamette basin, 2013 33
Table 3-2. Copepod prevalence between reservoir- and stream-rearing subyearling Chinook salmon during October-November, 2013 34
Table 4-1. Number and size of fish species collected in Foster Reservoir in 2013 47
Table 4-2. Total number of diet samples collected and percent empty by predator species in Foster Reservoir, 2013 47
Table 4-3. Mean fork length and range of predatory species collected for diet sampling and size of fish that consumed juvenile Chinook salmon, *O. mykiss*, or unknown salmonids in Foster in Foster Reservoir, 2013 49
Table 4-4. The number of prey fish by species/group found in the diet samples of piscivorous fish in Foster Reservoir, 2013 50
Table 4-5. Daily consumption rates of juvenile Chinook salmon and *O. mykiss* by predator species during spring in Foster Reservoir, 2013 54
Table 5-1. Number of piscivorous fish caught by gear type in Lookout Point Reservoir, 2013 60
Table 5-2. Number of northern pikeminnow tagged, recaptured, and the associated electrofishing effort summarized by reservoir zone in Lookout Point Reservoir, 2013 62
Table 5-3. Median size of piscivorous fish collected for all gear types by reservoir section in Lookout Point Reservoir, 2013 65
Table A-1. Species composition collected in nearshore traps from four WVP reservoirs, 2013 78
Table A-2. Dimensions of select Willamette Valley Project reservoirs at full and low conservation pool 79

List of Figures

Figure 1-1. Oneida Lake trap (A) and floating box trap (B) used to collect subyearling Chinook salmon in reservoirs, 2013 8
Figure 1-2. Depth midpoints for gill nets set in Detroit and Lookout Point reservoirs, 2013 9
Figure 1-3. Subyearling Chinook salmon catch in nearshore traps in relation to shoreline distance for Cougar, Lookout Point, Detroit, and Foster reservoirs, 2013 11
Figure 1-4. Cumulative proportion of all subyearling Chinook salmon caught during spring in relation to percent of shoreline distance to dam, by reservoir in 2013. 12
Figure 1-5. Monthly cumulative proportions of subyearling Chinook salmon catch in nearshore floating box traps and small Oneida Lake traps in relation to percent of shoreline distance to Cougar Dam, 2013 13
Figure 1-6. Cumulative proportions of subyearling Chinook salmon catch from nearshore traps in Cougar and Lookout Point reservoirs in relation to percent of shoreline distance to the dam, 2012 and 2013 15
Figure 1-7. Mean catch of Chinook from the six gillnets set in Lookout Point Reservoir from the dam to the head-of-reservoir during November, 2013 15
Figure 1-8. Depth of juvenile Chinook captured from vertical gill net in Detroit and Lookout Point reservoirs, 2013 17
Figure 1-9. Mean monthly depths of juvenile Chinook in Detroit Reservoir in 2012 and 2013 18
Figure 1-10. Temperature profiles of Detroit Reservoir from July to November for 2012 and 2013 19
Figure 1-11. Mean depths of juvenile Chinook salmon, kokanee, and rainbow trout collected in gill nets in Detroit Reservoir, 2013 20
Figure 1-12. Mean monthly depths of juvenile Chinook in Lookout Point Reservoir in 2012 and 2013 21
Figure 2-1. Fork lengths of subyearling Chinook salmon captured in WVP reservoirs and streams above reservoirs, 2013 26
Figure 2-2. Mean fork length by week of natural-origin subyearling Chinook salmon in WVP reservoirs, 2013 27
Figure 2-3. Mean size of subyearling Chinook salmon in the fall (Oct-Dec) in relation to reservoir temperature for five WVP reservoirs 28
Figure 3-1. Life cycle of female *Salmincola californiensis* 31
Figure 3-2. Proportion of subyearling Chinook salmon with copepods present by month for WVP reservoirs and the South Fork McKenzie River, 2013 34
Figure 3-3. Monthly copepod prevalence for salmonid species in Detroit Reservoir, 2013 . 35
Figure 3-4. Copepod intensity among reservoir- and stream-rearing subyearling Chinook salmon, 2013 36
Figure 3-5. Number of parasitic copepods observed on gills of juvenile Chinook salmon examined in WVP reservoirs throughout 2013 37
Figure 3-6. Number of copepods on gills of infected subyearling and yearling Chinook salmon in Cougar Reservoir during October through December 38
Figure 3-7. Copepod intensity on the gills of subyearling Chinook salmon in four WVP reservoirs during November and December, 2013 39

Figure 4-1. Foster Reservoir sections used for sampling fish in 2013 44
Figure 4-2. Length frequency of the most common piscivorous fish over 150 mm fork length collected in Foster Reservoir, 2013 48
Figure 4-3. Occurrence frequency of prey taxon in smallmouth bass diets in Foster Reservoir, 2013 49
Figure 4-4. Occurrence frequency of prey taxon in northern pikeminnow diets in Foster Reservoir, 2013 51
Figure 4-5. Occurrence frequency of prey taxon in yellow perch stomachs sampled in Foster Reservoir, 2013 52
Figure 4-6. Occurrence frequency of prey taxon in rainbow trout diets in Foster Reservoir, 2013 53
Figure 5-1. Mean catch per unit effort of piscivorous fish species in Lookout Point Reservoir by gear type used 61
Figure 5-2. Catch per unit effort in relation to shoreline distance for piscivorous fish species caught during electrofishing in Lookout Point Reservoir, 2013 64
Figure 5-3. Length frequency distribution for northern pikeminnow tagged in Lookout Point Reservoir, 2013 65
Figure A-1. Proportion of subyearling Chinook salmon caught at specific depth intervals in Detroit Reservoir from July to November 2013 80
Figure A-2. Proportion of rainbow trout caught at specific depth intervals in Detroit Reservoir from July to November, 2013 81
Figure A-3. Proportion of kokanee caught at specific depth intervals in Detroit Reservoir from July to November, 2013 82
Figure A-4. Fork lengths of kokanee collected from gill nets in Detroit Reservoir, 2013. Age determination based on length-frequency analysis. 2013 83
Figure A-5. Proportion of hatchery and natural-origin juvenile Chinook salmon caught at specific depth intervals in Lookout Point Reservoir from July to November, 2013 84
Figure A-6. Fork lengths of juvenile Chinook salmon caught in Willamette Valley Project reservoirs, 2013 85
Figure A-7. Mean fork length of reservoir-rearing subyearlings in the fall for 2012 and 2013 85

Executive Summary

In this report we investigate aspects of juvenile spring Chinook salmon *Oncorhynchus tshawytscha* life-history and rearing in select Willamette Valley Project (WVP) reservoirs to aid in the development of downstream passage options. In the first section, we assess the distribution of juvenile Chinook salmon in reservoirs. We provide information on the longitudinal distribution (head-of-reservoir to dam) of subyearlings in Detroit, Foster, Cougar, and Lookout Point reservoirs during spring. We also initiated a pilot study investigating longitudinal distribution of fall parr in Lookout Point Reservoir. We investigated changes in vertical distribution from July through November in Detroit and Lookout Point reservoirs. The second section compares growth rates between stream-rearing and reservoir-rearing subyearling Chinook salmon. We compare subyearling growth rates in all reservoirs listed above and Fall Creek Reservoir. In the third section, our objective was to assess and compare the infection prevalence and intensity of the parasitic copepod *Salmincola califoriensis* in salmonid species rearing in reservoirs and streams. In the fourth section, we assess fish species composition and predation rates on juvenile Chinook salmon and steelhead *O. mykiss* by predator species in Foster Reservoir. Finally, we assessed predator species abundance in Lookout Point Reservoir.

Distribution- The longitudinal distribution of spring Chinook salmon subyearlings was assessed with floating box traps and small Oneida Lake traps set in nearshore habitat of reservoirs. Subyearlings were collected in all nearshore areas of the reservoirs but catches were greater in the upper ends of most reservoirs where natal streams enter, especially early in the spring. The exception was Foster Reservoir where subyearling catch was greater in the lower third of the reservoir. The early fry entrance timing and small size of Foster Reservoir likely aids subyearling passage through the reservoir. Small subyearlings in Cougar Reservoir dispersed farther towards the dam each consecutive month from April – June, approaching an even distribution by June. In April, 69% of all subyearlings collected were in the upper third of the reservoir and only 11% in the lower third. But by June, the proportion in the upper and lower third of the reservoir was 42% and 25.5%, respectively. This was similar to the pattern observed in 2012. Few subyearlings were caught in the forebay during spring with the maximum proportion of catch in the forebay estimated at 1.8%. Subyearlings in Lookout Point Reservoir were dispersed farther into the reservoir in April compared to Cougar Reservoir for the same time of year. Fall parr distribution in Lookout Point was skewed in favor of the forebay. In November, nearly half (47%) of the subyearlings were caught in the forebay net with the remaining catch evenly dispersed throughout the reservoir.

Vertical distribution of subyearling Chinook was assessed with gill nets set at specific depth intervals from July through November. 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 peaked, and returned to the surface by late fall. Median depths occupied in August and September were significantly deeper than other months. We observed similar vertical distribution patterns in 2011 and 2012. Chinook salmon parr in 2013 occupied greater depths during the summer than in 2012; this was partly attributed to different temperature profiles between years. 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.

Growth- Growth was rapid for subyearling Chinook salmon rearing in reservoirs compared to stream-rearing fish. By November, subyearlings in reservoirs were 45-117 mm fork length (FL) larger than their counterparts in streams. Growth rate for subyearlings was slowest in Cougar Reservoir at 0.52 mm/d and the fastest in Lookout Point Reservoir at 0.94 mm/d. Although subyearling in Fall Creek Reservoir reached the largest size by late fall, growth rate was intermediate. The large size of subyearlings in this reservoir appears to be a function of early reservoir entrance timing which allows for more growth opportunity rather than a superior growth rate.

Copepod Infection- Trends in infection prevalence and intensity by the parasitic copepod *S. californiensis* among *Oncorhynchus* species rearing in reservoirs and streams was similar to results found last year. 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 streams. We observed an increase in prevalence each month (June-December) for reservoir-rearing subyearling Chinook salmon but the trend was not evident among other salmonid species in reservoirs or stream-rearing Chinook salmon. Copepod infection prevalence in the fall for subyearling Chinook salmon ranged from 59-94% among reservoirs. Intensity of infection on the gills of reservoir-rearing Chinook salmon also increased each month. Subyearlings in Fall Creek Reservoir 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 16% infected with ≥ 20 copepods. Juvenile Chinook salmon in Hills Creek Reservoir and yearlings in Cougar Reservoir also had high infection intensity. This level of infection potentially imposes a high mortality rate on smolting juveniles.

Predation Risk in Foster - In Foster Reservoir, we assessed the diet of piscivorous fish species thought to prey on juvenile Chinook salmon and steelhead. The most common piscivorous species in the reservoir were smallmouth bass *Micropterus dolomieu*, northern pikeminnow *Ptychocheilus oregonensis*, and yellow perch *Perca flavescens*. Few largemouth bass *M. salmoides* were collected, confirming previous observations that smallmouth bass have largely supplanted largemouth bass in the reservoir over the last few decades. Rainbow trout were also numerous but most were below the size (<200 mm FL) where piscivory could be expected. Only smallmouth bass and northern pikeminnow were observed to prey on juvenile salmonids with all consumption observed in the spring. Northern pikeminnow were more abundant in the South Santiam arm of the reservoir and smallmouth bass were more abundant in the lower reservoir and Middle Santiam arm. We could only detect northern pikeminnow consumption of juvenile *O. mykiss* (0.148 fish/d) from our relatively small sample size. Smallmouth bass consumed both juvenile Chinook salmon and *O. mykiss* with consumption rates estimated at 0.119 Chinook/d and 0.104 *O. mykiss*/d.

Piscivorous Species Abundance in Lookout Point Reservoir- Northern pikeminnow were the most numerically abundant predator species in Lookout Point Reservoir. Northern pikeminnow catch per unit effort was greater in surface-oriented gear and in the upper reservoir near the entrance of the Middle Fork Willamette River. We estimated the abundance of large northern pikeminnow (≥150 mm FL) in Lookout Point Reservoir at 7,067 (95% CI 5,466 – 9,224). Based on a consumption rate of 0.160 Chinook/d by northern pikeminnow from previous diet studies, we estimated >100,000 juvenile Chinook salmon are consumed each spring in the reservoir.

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 seasonal distribution, migration rate, predator/prey interactions, growth rates, and the effect of reservoir rearing on parasites loads experienced by juveniles. In 2010, we began investigations in Cougar and Lookout Point reservoirs to further our understanding of these issues. In 2011 and 2012, we expanded our scope of sampling to include Detroit Reservoir and refined our techniques to address the critical uncertainties. In 2013, we included Foster Reservoir and investigated several aspects of juvenile Chinook salmon and steelhead life-history.

The five 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; 4) assess species composition, distribution, and diet of piscivorous fish in Foster Reservoir, and 5) assess predator fish species abundance 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 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, 2013) at an average fork length (FL) of 35 mm (Monzyk et al. 2011a; Romer et al. 2012, 2013). 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. Small subyearling "fry" (<50 mm FL) were closely associated with shallow nearshore habitat in the spring and not found in deeper waters until reaching a larger size (Monzyk et al. 2012). Small subyearlings in Cougar Reservoir dispersed farther towards the dam each consecutive month from April – June approaching an even distribution throughout the reservoir by late spring (Monzyk et al. 2013). Given the poor swimming ability of newly emergent fry and the fact that reservoirs are refilling in the spring, it is not surprising that small subyearlings in reservoirs would be more abundant near the entrance of their natal streams in early 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 is 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 9 m (30 ft) of the water column during late spring, but as surface temperatures increased in the summer, most fish were caught at depths of 9-14 m (30-45 ft). Fish 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 2012 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, 2013).

In this report, we continued our efforts to assess changes in longitudinal distribution of subyearlings along nearshore habitat during spring (March-June) in Cougar, Lookout Point, and Detroit reservoirs and added Foster Reservoir. We compared subyearling nearshore distributions between 2012 and 2013 and analyzed biological and environmental differences between years. In addition, we initiated pilot efforts to assess longitudinal distribution of fall parr in Lookout Point Reservoir. We continued our assessment of vertical distribution of subyearlings from summer through fall in Lookout Point and Detroit reservoirs. Differences between years were compared along with differences in reservoir water temperatures.

Methods

Subyearling Nearshore Distribution

Sampling was conducted at least every two weeks in nearshore habitat of Foster and Lookout Point reservoirs from late March through June. Sampling in Detroit and Cougar reservoirs began in April due to the later emigration timing of fry (Romer et al. 2013). When possible, we conducted weekly sampling to increase sample sizes and precision. We sampled subyearlings 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 (Figure 1-1). A 51-mm throat opening allowed fry and small parr to enter but excluded larger fish. We used a 5-m lead net (0.91 m deep) extending perpendicular from 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. In addition to floating box traps, we set small Oneida Lake traps with 20-m lead nets (1.8 m deep, 1/8 inch mesh) to sample larger subyearlings that have moved further offshore by late spring. Oneida traps were set in May and June, when fish would be expected to begin moving farther offshore.

We used a stratified random sampling design for daily trap placement to ensure representative sampling throughout the reservoirs. Reservoirs were stratified into lower, middle, and upper thirds (forebay to head of reservoir). Within each reservoir section, random shoreline areas (approximately 0.4 km long) were selected for trap placement and a site was chosen within this area that would allow for easy attachment of the lead net to the bank. Nine areas were randomly selected each day (three per section) for placement of floating box traps and three areas selected (one per section) for small Oneida trap placement. All traps were fished overnight for approximately 24 h. Subyearlings were anesthetized (50 mg/L tricaine methanesulfate [MS-222]) and enumerated for each trap. We measured fork length (nearest mm) on a minimum of 15 randomly selected fish per trap. Shoreline depth and substrate type (silt/sand, gravel, or cobble/rock) were recorded at each trap location. Depth was measured at the mouth of the trap and categorized as shallow (0.5 to1.0 m), medium (>1.0 to 2.0 m) or deep (>2 m). Subyearling catches were compared among habitat categories with Kruskal-Wallis one-way ANOVA tests (α=0.05).

Coordinates were recorded for each trap set and used to estimate distance from the head of the reservoir. Because fry and small parr were 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. For Detroit Reservoir, we chose the North Santiam arm near Hoover Campground to mark the head of the reservoir since most natural production in 2013 occurred in this river (Sharpe et al. 2014). Because of unequal shoreline lengths for each bank, trap distances were standardized as a percentage of total distance to the dam. The monthly distribution of subyearlings 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 number of subyearlings potentially available for downstream passage through the dam. In Cougar and Detroit reservoirs, the forebay was defined as the shoreline within the boat-restricted zone (log boom). In Lookout Point and Foster reservoirs, where there was no established boat restricted zone, we defined the forebay shoreline as the dam face plus a shoreline distance of 500 m upstream from the ends of the dam. Because we randomly placed traps in the reservoir, the proportion of monthly trap sets that occurred within the forebay was not always equal to the proportion of total shoreline length comprised of the forebay. Therefore, we standardized the percent of forebay catch as:

$$F = \frac{C_f}{C_T}\left(\frac{\rho_f}{\rho_s}\right) \times 100$$

Where C_f is the monthly catch in the forebay, C_T is the total monthly catch, ρ_f is the proportion of total shoreline length comprised of the forebay, and ρ_s is the proportion of total monthly trap sets occurring in the forebay. In Detroit Reservoir, daily boat access through the log boom was problematic, so traps were not randomly set in the forebay area. Instead, forebay sampling consisted of two traps set daily on each end of the log boom.

We initiated a pilot effort in Lookout Point Reservoir in November 2013 to assess longitudinal distribution of Chinook salmon parr. We set six surface gill nets spaced evenly apart (approximately 2.5 km) from the head-of-reservoir to the dam. Each net was fished for 24 hrs. The net set off the dam was near the southernmost spillway and the remaining nets were set on steeply sloping banks to mimic the bank slope of the net set at the dam. We compared mean catch per net to assess longitudinal distribution.

Parr Vertical Distribution

In 2013 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 third year of effort to assess vertical distribution in the forebay of Detroit and Lookout Point reservoirs. Limited natural production of Chinook salmon occurred above Detroit Reservoir in 2013; however, adipose (AD) fin-clipped hatchery Chinook salmon were released in the reservoir in June. We did not set gill nets in Cougar Reservoir to avoid harming threatened bull trout *Salvelinus confluentus*.

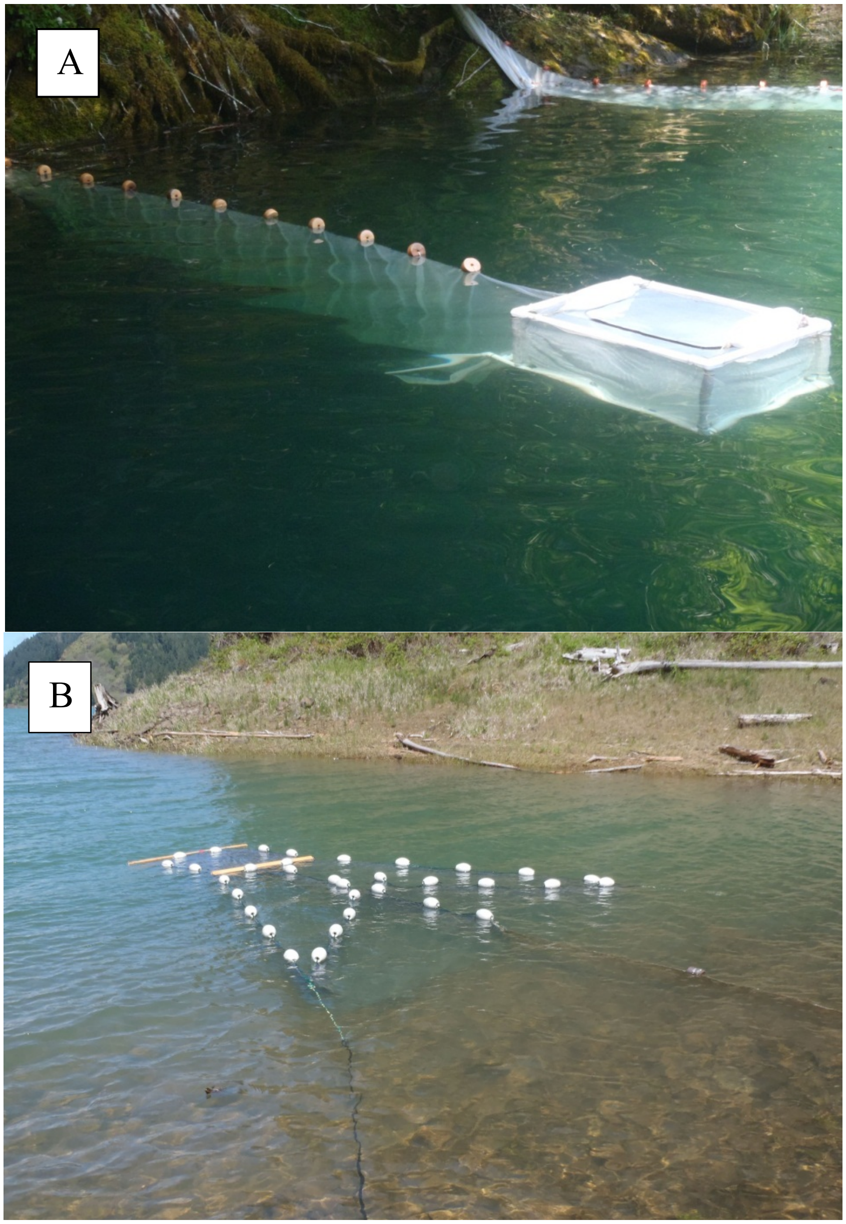

Figure 1-1. Floating box trap (A) and small Oneida Lake trap (B) used to collect subyearling Chinook salmon in reservoirs, 2013.

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. 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 from July to November and checked daily during approximately eight overnight sets. Every two days we changed the order in which we hung nets at 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. Adipose-clipped hatchery Chinook salmon were released in both reservoirs in the spring. Unclipped hatchery Chinook salmon were also released in Detroit Reservoir. Catch of fish at specific depth intervals were compared for each month to assess temporal changes in vertical distribution.

Differences in capture depth between clipped and unclipped Chinook salmon were compared with a paired t-test (α=0.05) based on average daily depths of the two groups. The midpoint of each net depth interval was used to designate depth of individual fish and average daily depth was calculated as the weighted average of midpoint depths, with the number of fish caught at each depth interval as the weighting factor. If no differences were detected, data were pooled for further analysis. We compared differenced in fish depth among months with Kruskal-Wallis one-way ANOVA on ranks (α=0.05).

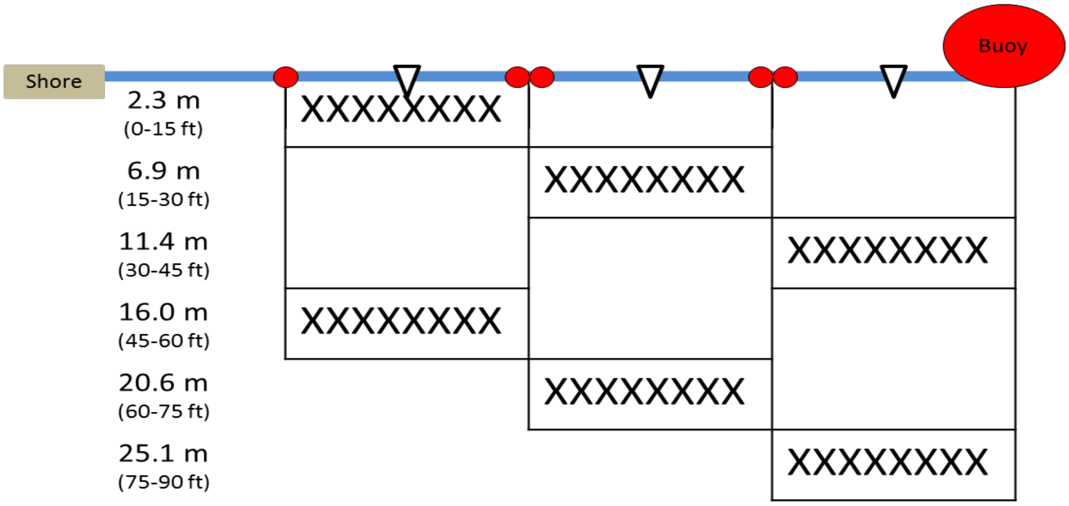

Figure 1-2. Depth midpoints for gill nets set in Detroit and Lookout Point reservoirs, 2013. Each experimental gill net was 24.4 x 4.6 m and consisted of four panels of increasing mesh size. Numbers in parentheses are depth intervals in feet.

Water temperature in each reservoir was obtained from USACE temperature data (Onset HOBO® data logger string). Temperature data loggers were 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 and temperatures were recorded hourly. We calculated mean temperature at each depth increment and developed vertical temperature profiles for the period we sampled fish each month (approximately 10 d in the middle of each month).

Results

Subyearling Nearshore Distribution

We assessed subyearling Chinook salmon distribution in Cougar Reservoir with the deployment of 369 traps (333 floating box trap; 36 small Oneida Lake traps) sets from 03 April to 21 June and collected 14,395 subyearlings. In Detroit Reservoir, 281 traps (279 floating box traps; two small Oneida Lake traps) were set from 10 April to 21 June with 234 subyearlings collected. Unmarked hatchery subyearlings were released at the head of Detroit Reservoir on 15 May and confounded analysis of distribution of natural origin subyearlings. Unmarked hatchery fish were released as part of the separate study comparing smolt-to-adult return rates of paired releases above and below the project (Friesen et al., *in prep*). In Lookout Point Reservoir, 405 traps were deployed (393 floating box traps; 12 small Oneida traps) from 05 March to 21 June with 1,893 subyearlings collected. In Foster Reservoir, 297 traps (236 floating box traps; 61 small Oneida traps) were set from 05 March to 31 May with 398 subyearlings collected. Several other incidental species were also collected in traps (Appendix Table A-1). The differences in subyearling catch per unit effort between reservoirs can likely be attributed to several factors including: the number of adult females outplanted the previous year; the number of successful spawners; reservoir size; predation in reservoirs; the number of subyearlings passing the dam; or a combination of these factors.

Subyearling Chinook salmon demonstrated a wide size range in all reservoir sections but average size was smaller in the upper reservoir, owing to the continued influx of newly emergent fry from upstream (Table 1-1). The small Oneida Lake traps caught larger subyearlings on average than floating box traps (Table 1-1).

Table 1-1. Mean fork length (SE) of subyearling Chinook caught in floating box traps and small Oneida traps by month and reservoir section for Cougar, Detroit, Foster, and Lookout Point reservoirs, 2013.

			Section		
Reservoir	Month	Gear type	Lower	Middle	Upper
Cougar	April	Box trap	37.0 (0.12)	36.8 (0.13)	36.4 (0.10)
	May	Box trap	40.3 (0.22)	38.9 (0.14)	38.3 (0.13)
	June	Box trap	48.8 (0.31)	48.3 (0.33)	44.9 (0.27)
		Small Oneida	53.9 (0.65)	52.5 (0.60)	49.9 (0.46)
Detroit	April	Box trap	38.6 (0.54)	40.2 (0.43)	40.4 (0.52)
	May	Box trap	-	40.0 (0.47)	42.2 (0.31)
	June	Box trap	54.0	49.9 (1.36)	48.5 (1.51)
Foster	March	Box trap	41.7 (0.50)	40.1 (0.42)	37.6 (0.32)
	April	Box trap	42.7 (1.26)	52.8 (3.42)	41.6 (1.57)
	May	Small Oneida	65.0 (1.05)	63.2 (4.82)	72.0 (3.43)
Lookout Point	March	Box trap	44.2 (0.55)	40.7 (0.46)	37.7 (0.18)
	April	Box trap	46.9 (0.83)	40.5 (0.46)	38.3 (0.26)
	May	Box trap	50.6 (3.19)	42.3 (1.19)	41.1 (0.48)
	May	Small Oneida	-	-	54.0 (2.67)
	June	Box trap	62.0	66.5 (11.5)	59.0 (11.0)
		Small Oneida	-	-	65.7 (3.30)

Subyearlings were collected in all nearshore areas of reservoirs, but with the exception of Foster Reservoir, catches were greater in the upper end of reservoirs where natal streams enter, especially early in the spring (Figure 1-3). In Foster Reservoir, catches were greater in the lower reservoir. Less than 20% of the cumulative catch in Foster Reservoir occurred in the upper half of the reservoir, compared to >80% for the other reservoirs (Figure 1-4). Foster Reservoir was the smallest of the reservoirs we sampled, with a length of 7.4 km at full pool (Appendix Table A-2). Subyearling Chinook salmon entered the reservoir in the South Santiam arm (see Figure 4-1) but fish were dispersed along the north and south banks of the reservoir. In the middle and lower sections of the reservoir, catch per unit effort was higher along the north bank (2.8 fish/set) compared to the south bank (1.4 fish/set).

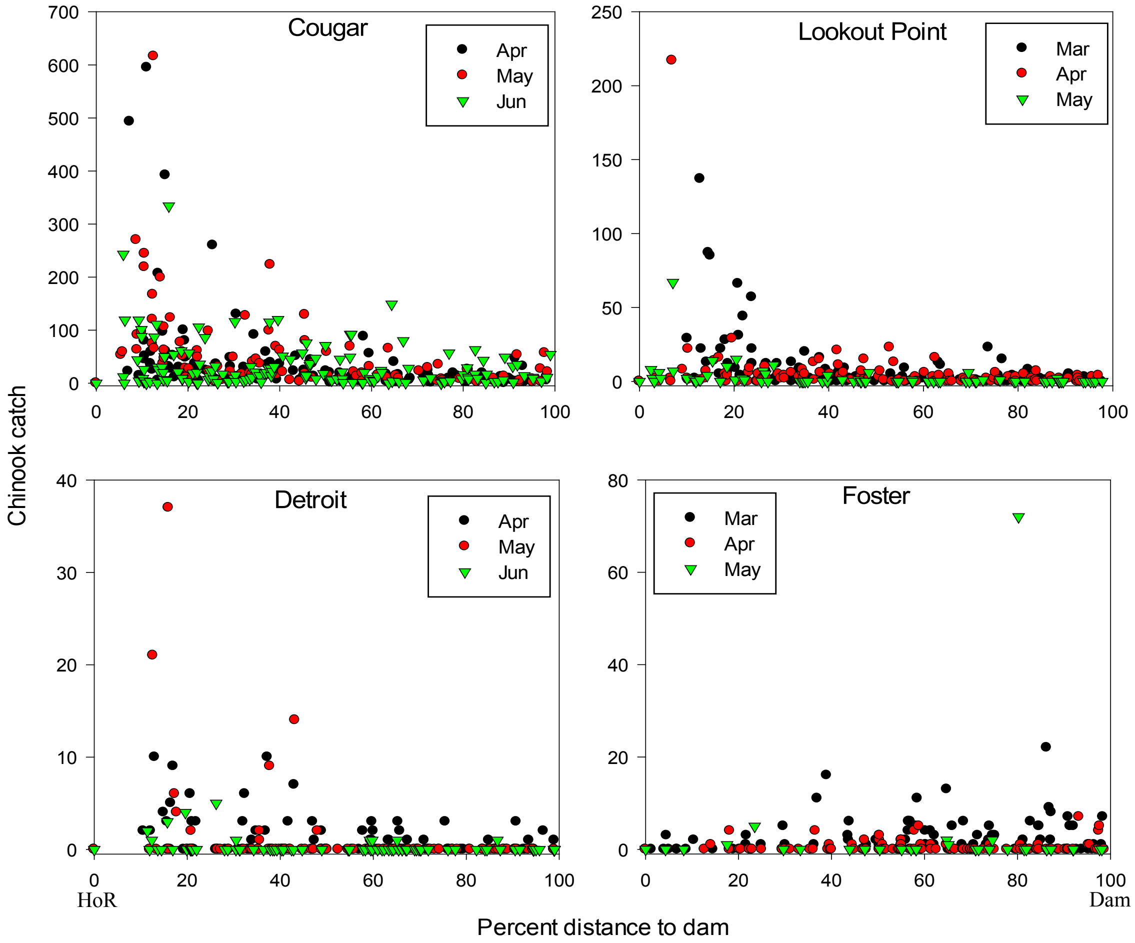

Figure 1-3. Subyearling Chinook salmon catch in nearshore traps in relation to shoreline distance for Cougar, Lookout Point, Detroit and Foster reservoirs, 2013. Includes all subyearling Chinook salmon caught in floating box traps and small Oneida traps. Unmarked hatchery fry were released in Detroit Reservoir in late May.

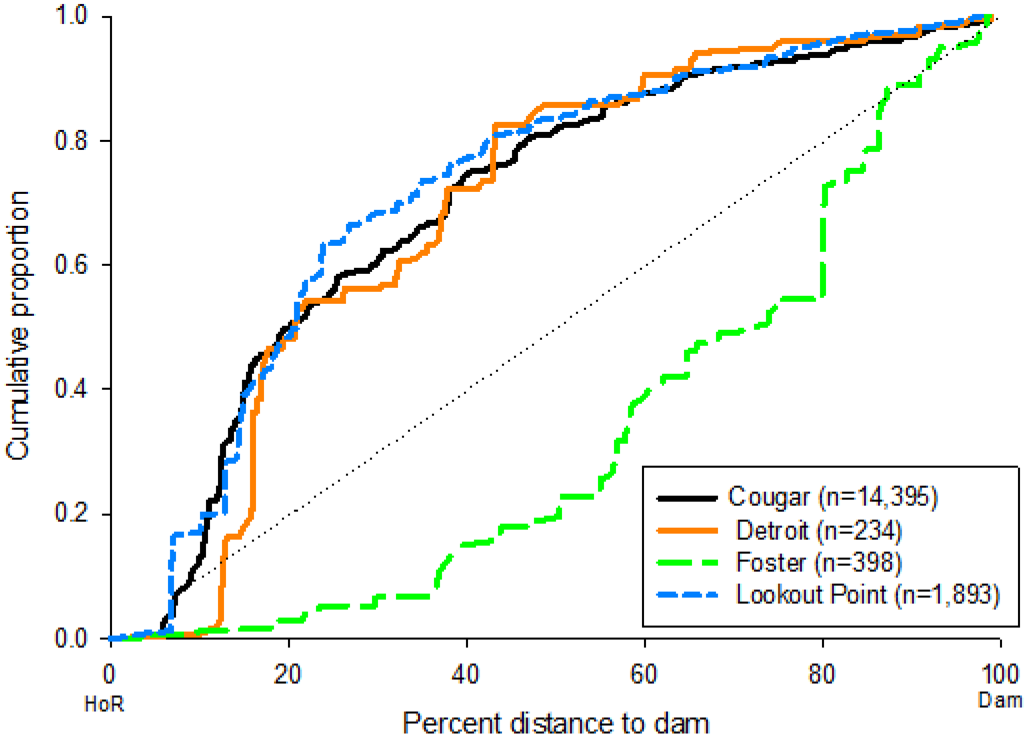

Figure 1-4. Cumulative proportion of all subyearling Chinook salmon caught during spring in relation to percent of shoreline distance to dam, by reservoir in 2013. Dotted line represents the cumulative proportion of a theoretical population that is evenly distributed throughout the reservoir.

Cougar Reservoir- Because of the high catch per unit effort in Cougar Reservoir, we were able to provide more detailed information on monthly distribution of small subyearling Chinook salmon and their relationship with habitat variables in this reservoir. Subyearlings were dispersed farther into the reservoir towards the dam by June (Figure 1-5), similar to patterns observed in 2012. For instance, 69% of all subyearling catch occurred in the upper third of the reservoir and only 11% in the lower third in April. By June, 42% of the monthly catch was in the upper reservoir and 25.5% in the lower (Table 1-2).

The proportion of subyearlings caught in the lower reservoir section in June (25.5%) was similar to results in 2012 (29.7%). Also, the proportion of subyearlings captured in the forebay did not differ between years. In April, the proportion of total catch occurring within the forebay was estimated at 1.0% and increased to 2.5% by May, nearly identical to proportions observed in 2012. In June, the proportion in the forebay was 3.4%. There was no significant difference in subyearling size between years (Mann-Whitney Rank Sum test; *P*>0.05).

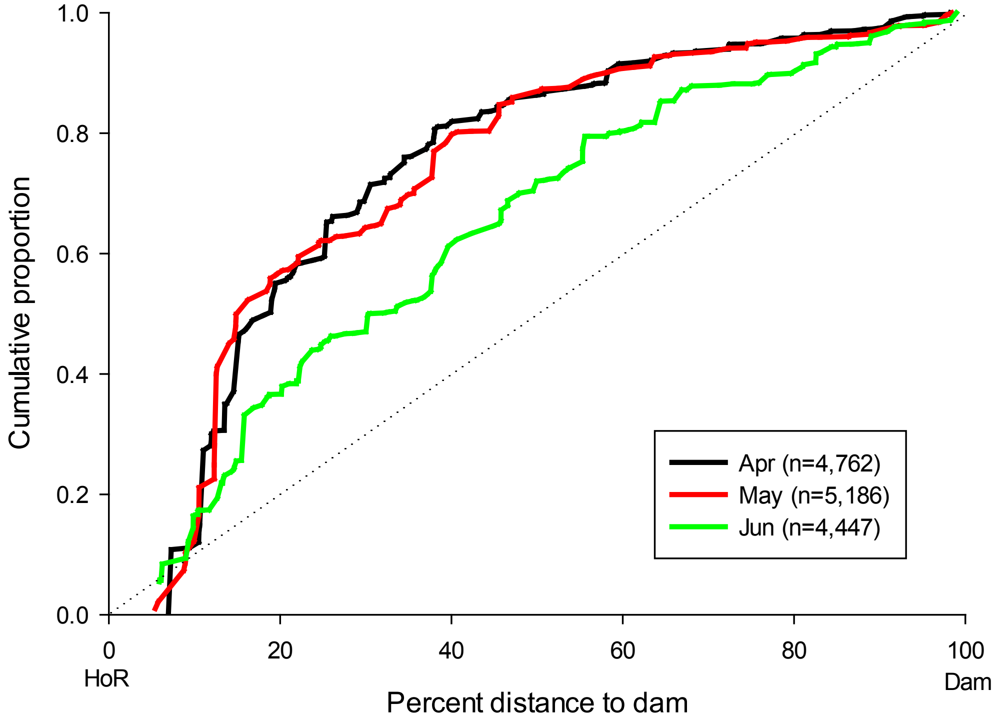

Figure 1-5. Monthly cumulative proportions of subyearling Chinook salmon catch in nearshore floating box traps and small Oneida Lake traps in relation to percent of shoreline distance to Cougar Dam, 2013. Dotted line represents the cumulative proportion of a theoretical population that is evenly distributed throughout the reservoir.

Table 1-2. Percent of subyearling Chinook salmon captured by reservoir section and month, 2013.

				Reservoir section (%)		
Reservoir	Trap	Month	N	Lower	Middle	Upper
Cougar	Floating box trap	April	4,718	11.0	19.9	69.0
	Floating box trap	May	5,186	10.7	26.4	63.0
	Floating box trap	June	2,217	22.1	23.3	54.7
	Small Oneida	June	2,233	29.1	28.8	42.2
Detroit	Floating box trap	April	99	11.1	41.4	47.5
	Floating box trap	May[a]	98	0.0	9.2	90.8
	Floating box trap	June	18	5.6	44.4	50.0
Foster	Floating box trap	March	243	36.6	39.9	23.5
	Floating box trap	April	43	46.5	27.9	25.6
	Small Oneida	May	83	86.7	6.0	7.2
Lookout	Floating box trap	March	1,012	8.7	11.9	79.4
	Floating box trap	April	684	10.1	29.7	60.2
	Floating box trap	May	182	5.5	7.1	87.4
	Floating box trap	June	2	0.0	50.0	50.0
	Small Oneida	June	6	0.0	0.0	100.0

[a] *Unmarked hatchery fry were released at the head-of-reservoir on May 15.*

Habitat - Substrate in Cougar Reservoir was predominately rock or sand/silt. There was no significant difference in trap catch between these substrate categories (Kruskal-Wallis one-way ANOVA on ranks; $P>0.05$). Similarly, there was no difference in catch among depth categories (Kruskal-Wallis one-way ANOVA on ranks $P>0.05$). Our traps were designed to intercept subyearlings actively swimming along the shoreline and, as such, may not accurately reflect habitat preferences of small subyearling Chinook salmon when not actively moving.

Lookout Point Reservoir- Subyearling catch from nearshore traps in Lookout Point Reservoir decreased sharply by May and confounded our ability to assess distribution beyond this month. The proportion of catch in May that occurred in the upper third of the reservoir (87%) was greater than in earlier months, possibly due to subyearlings in other reservoir sections moving offshore beyond our ability to capture them in nearshore traps (Table 1-2). Nevertheless, sample size in April was sufficient to compare to subyearling distribution in Cougar Reservoir. As observed in previous years, subyearlings were dispersed significantly farther into Lookout Point Reservoir than Cougar Reservoir by April (KS test $P\leq0.001$) (Figure 1-6).

A pilot effort in Lookout Point Reservoir to assess fall parr longitudinal distribution was conducted on three days from 6-13 November. We collected 92 natural-origin and 98 hatchery Chinook salmon juveniles, with 47% captured in the net set closest to the dam (Figure 1-7). Variation in daily catch for the net set on the dam was large (range: 2-45). Although this could represent natural daily variation in fish locations, it appeared to be related to RO discharge. The only period of RO discharge in 2013 was from 10-14 November, in the middle of our longitudinal distribution sampling. This deeper discharge may have altered the vertical distribution pattern of Chinook in the forebay, resulting in fewer fish near the surface. Our lowest catch for the net set on the dam occurred during this discharge period, and increased again after the RO discharge ceased.

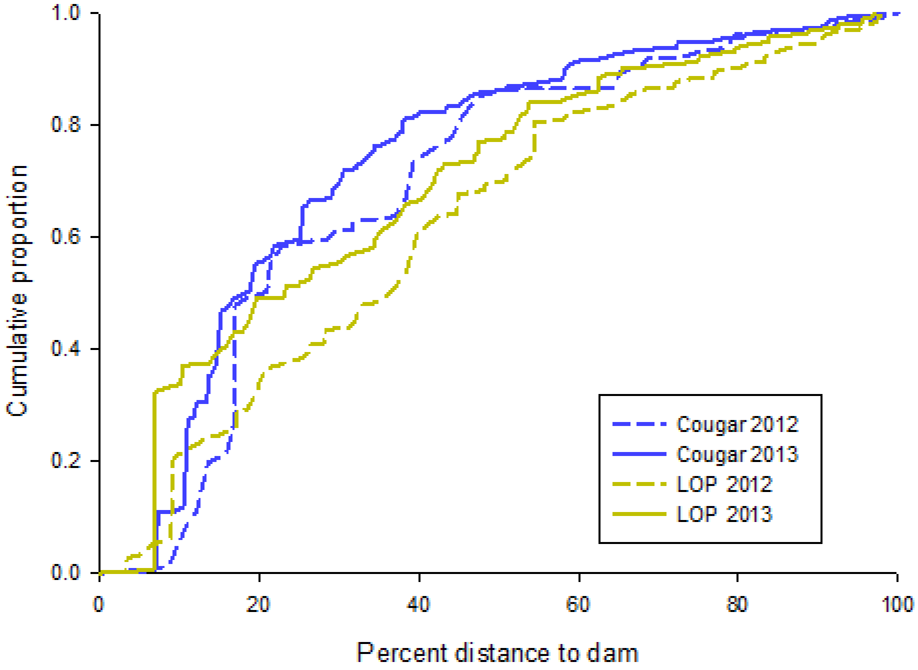

Figure 1-6. Cumulative proportions of subyearling Chinook salmon catch from nearshore traps in Cougar and Lookout Point (LOP) reservoirs in relation to percent of shoreline distance to the dam, 2012 and 2013. Catch data in 2012 were from 05-20 April, prior to hatchery releases. Catch data in 2013 were for the entire month of April.

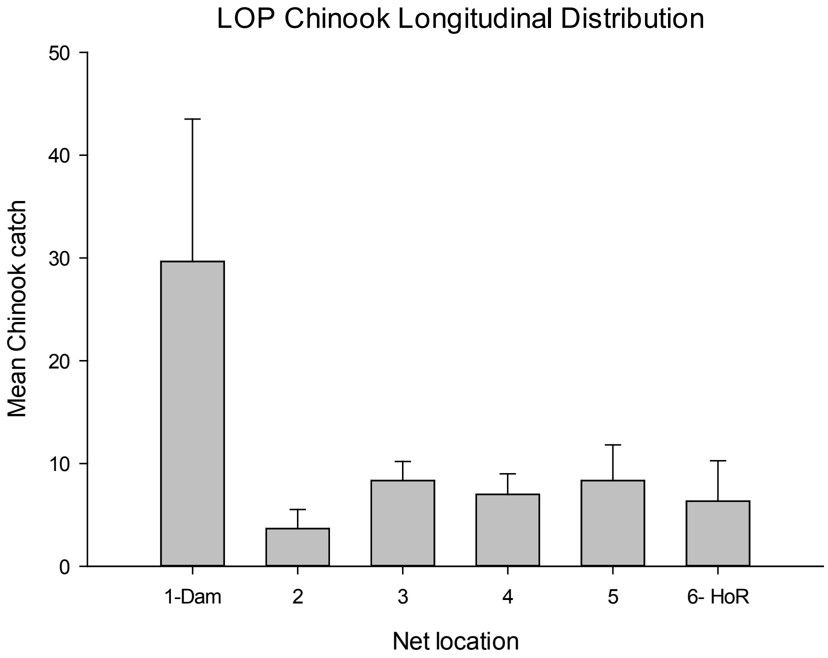

Figure 1-7. Mean catch of Chinook (hatchery and natural combined) from the six gillnet sets in Lookout Point Reservoir from the dam to the head-of-reservoir (HoR) during November, 2013. Error bars are standard error.

Parr Vertical Distribution

As subyearlings grew and moved offshore, we assessed their vertical distribution from July through November in Detroit and Lookout Point reservoirs. Snow and low reservoir elevations prevented us from sampling in December. Gill nets were set at specific depth intervals in the forebays of both reservoirs from 16 July to 22 November, 2013.

Detroit- We deployed 37 gill net sets (6 nets/set) in Detroit Reservoir and caught 919 juvenile Chinook salmon (610 AD-clipped hatchery, 309 unclipped), 814 rainbow trout (155 AD-clipped), 659 kokanee, two mountain whitefish *Prosopium williamsoni*, and three pumpkinseed sunfish *Lepomis gibbosus*. All but two of the juvenile Chinook salmon were subyearlings. An unknown proportion of the unclipped juvenile Chinook salmon and rainbow trout caught in nets were hatchery origin. Unclipped hatchery fish were released in the reservoir as fry. There were no significant differences in mean daily depth between clipped and unclipped Chinook salmon (paired t-test P=0.765) (Appendix Figure A-1), so data were combined for further analysis. Similarly, clipped and unclipped rainbow trout demonstrated similar vertical distribution patterns each month (paired t-test P=0.297) (Appendix Figure A-2) and we combined both groups for further analysis.

Juvenile Chinook salmon descended to greater depths in late summer and returned to the surface in the fall (Figure 1-8). Median depths occupied in August and September (16 m) was significantly deeper than other months (Kruskal-Wallis ANOVA on ranks, $P<0.05$). In October, fish were at depths similar to July. By November, fish were significantly closer to the surface (median depth: 2.3 m) compared to any other month (Kruskal-Wallis ANOVA on ranks, $P<0.05$), with most fish (57%) collected in the surface net. In addition, there were no significant differences in fish size among depth intervals within individual months (Kruskal-Wallis one-way ANOVA on ranks $P>0.05$).

The overall monthly pattern in vertical distribution was similar to 2012, but fish in 2013 were deeper in late summer (Figure 1-9). In September 2013, mean depth of juveniles was 17 m whereas in August 2012 mean depth was 14.4 m. Water temperatures in the summer of 2013 were slightly warmer than in 2012 (Figure 1-10) and may be related to differences in mean depths of fish between years. In September 2013 water temperatures <16˚C were below 17 m depth whereas in September 2012, temperatures <16˚C could be found below 11 m depth.

Overall, rainbow trout were more surface oriented than juvenile Chinook salmon (Figure 1-11). The majority of rainbow trout were caught near the surface (0-5 m deep) in all months with the exception of August and September (Appendix Figure A-2).

Kokanee were caught deeper in the water column than Chinook salmon or rainbow trout (Figure 1-11). In many months, our deepest net (23-27 m) caught the most kokanee, suggesting that our net deployments may not have been deep enough to accurately reflect depths kokanee occupy in Detroit Reservoir (Appendix Figure A-3). The kokanee caught in our nets ranged from 74-350 mm FL and were comprised of at least two year classes (Appendix Figure A-4).

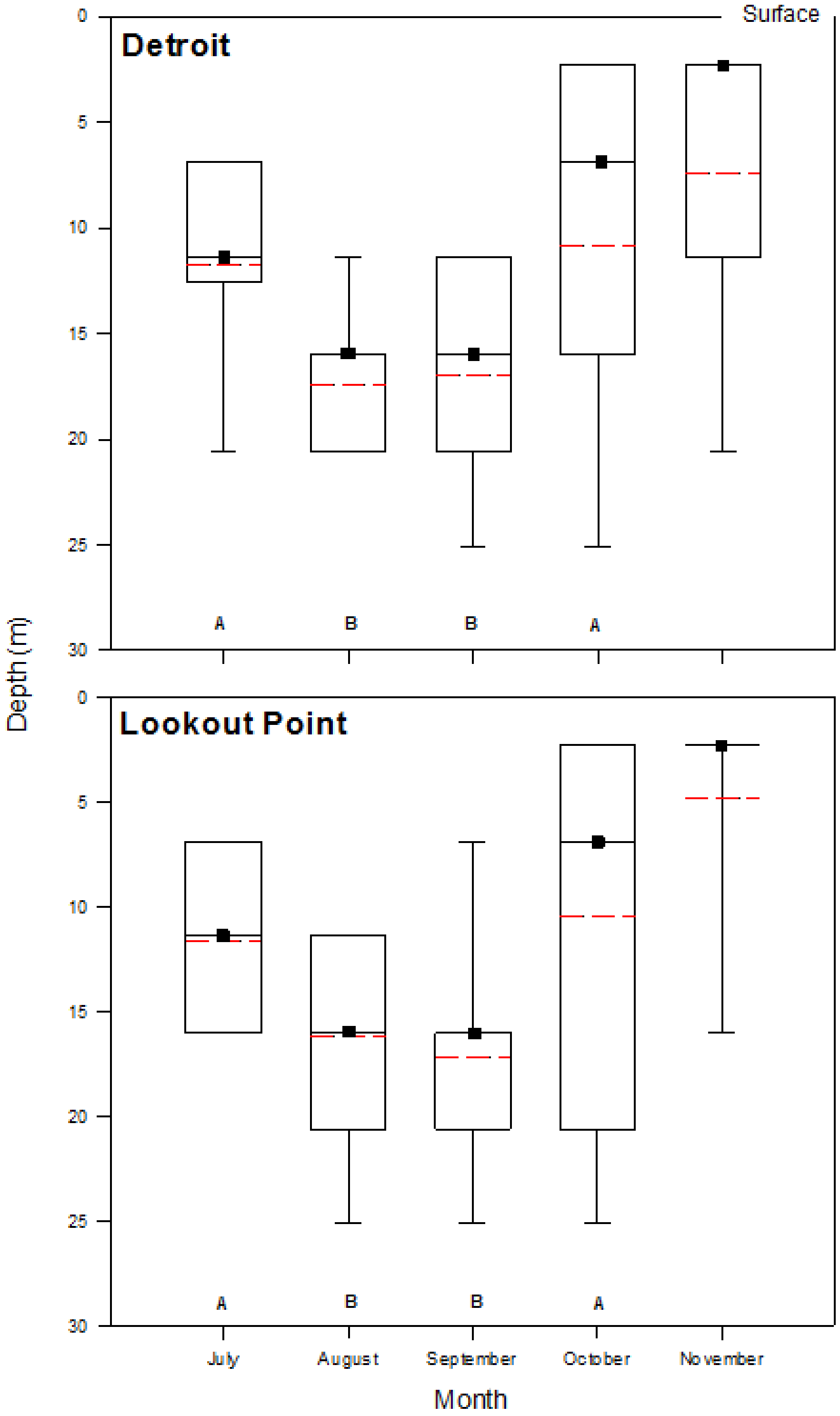

Figure 1-8. Depth of juvenile Chinook captured from vertical gill net in Detroit and Lookout Point reservoirs, 2013. Solid squares are medians, red dashed lines are means, box denotes the 25th -75th percentile, and whiskers are the 10th and 90th percentiles. Bars with a letter in common were not significantly different (Kruskal-Wallis ANOVA on Ranks *P*>0.05).

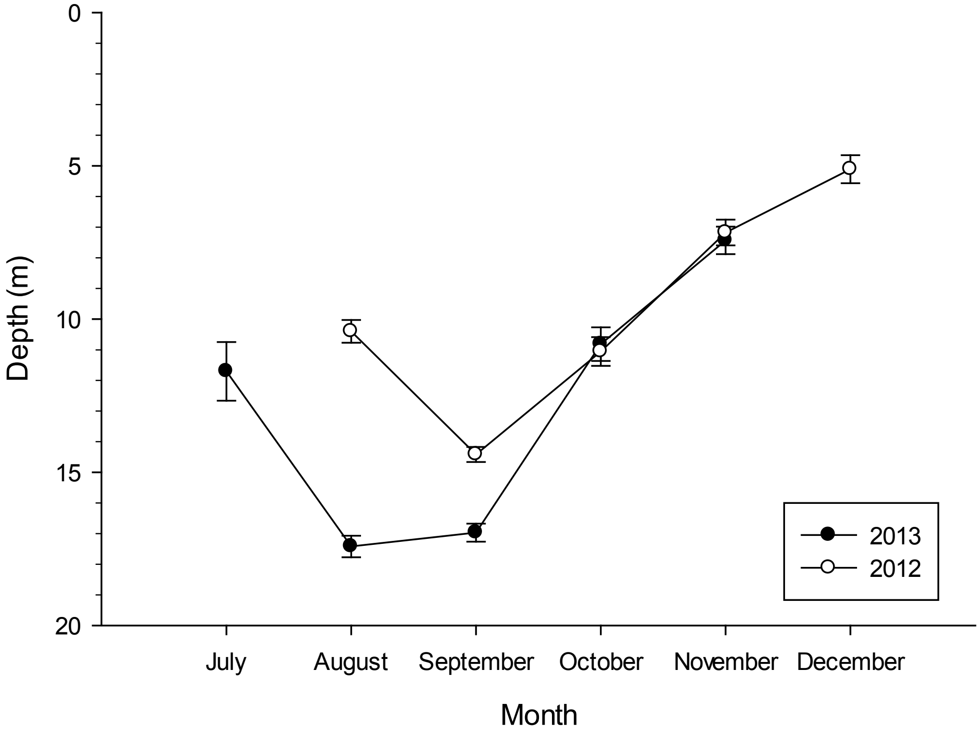

Figure 1-9. Mean monthly depths of juvenile Chinook in Detroit Reservoir, 2012 and 2013. Error bars are standard error.

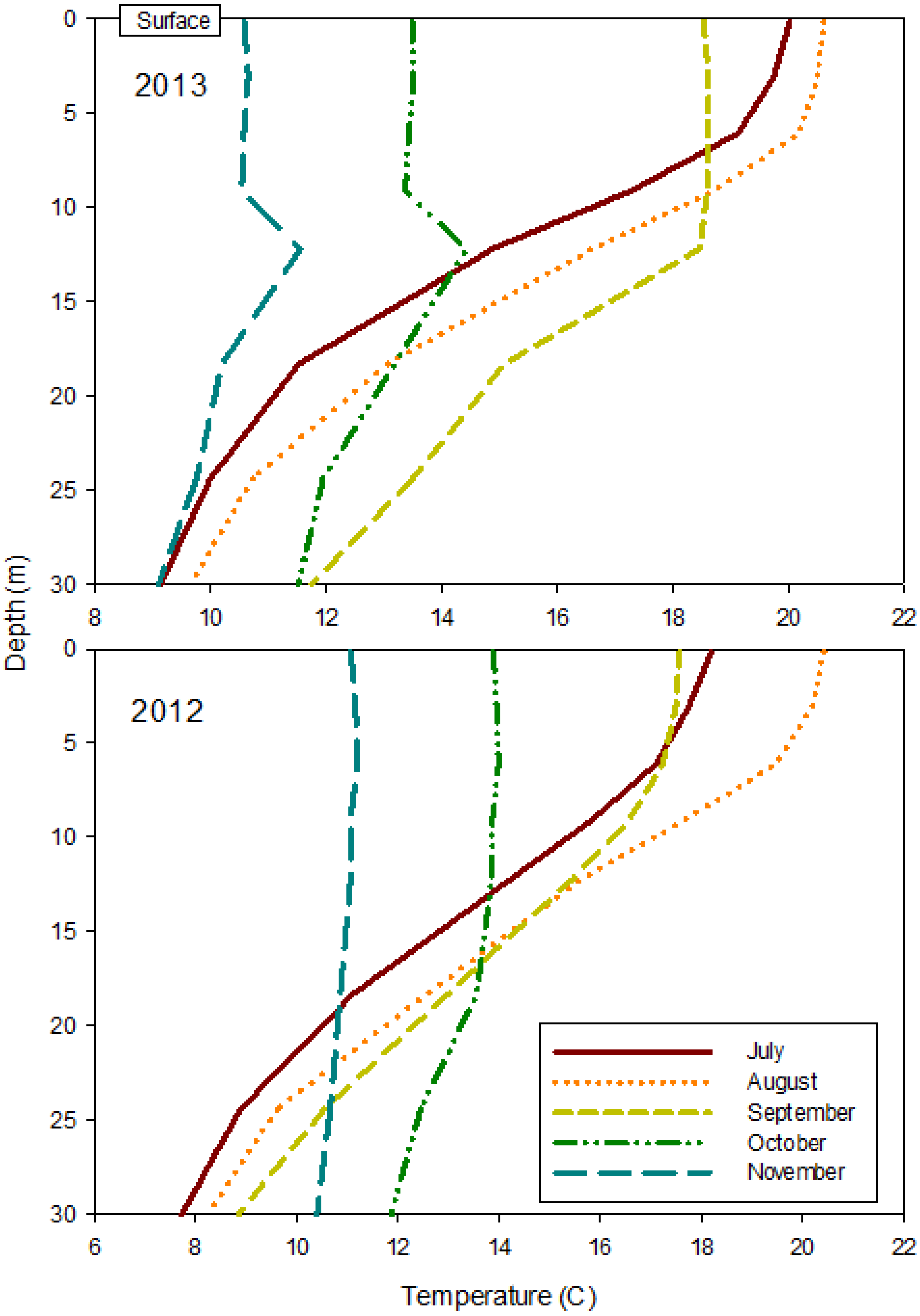

Figure 1-10. Temperature profiles of Detroit Reservoir from July to November, 2012 and 2013. Data are from the USACE temperature string located on the forebay log boom.

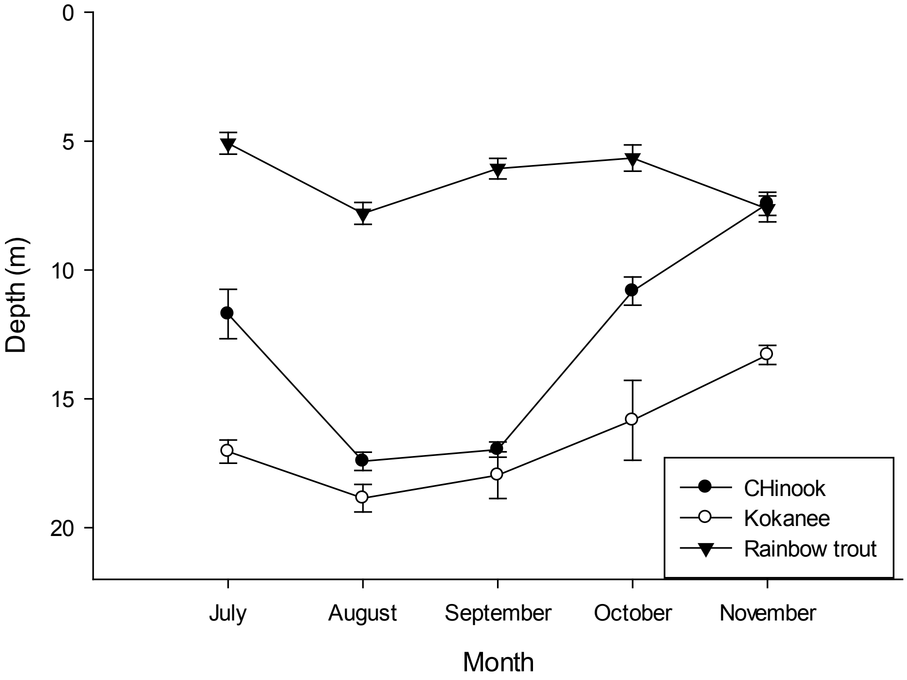

Figure 1-11. Mean depths of juvenile Chinook salmon, kokanee, and rainbow trout collected in gill nets in Detroit Reservoir, 2013.

Lookout Point- We deployed 39 gill net sets (6 nets/set) near Lookout Point Dam and caught 1,487 juvenile Chinook salmon (673 natural-origin, 814 AD-clipped hatchery). Incidental species included 27 rainbow trout (three AD-clipped), 47 crappie, 86 redside shiners *Richardsonius balteatus*, 53 northern pikeminnow, 39 sculpin, 12 yellow bullhead *Ameiurus natalis*, eight suckers, eight largemouth bass, five walleye, and one bluegill *Lepomis macrochirus*. All but one of the juvenile Chinook salmon were subyearlings. There were no significant differences in mean daily depth between natural- and hatchery-origin Chinook salmon (paired t-test; P=0.496), so data were combined for further analysis.

Juvenile Chinook salmon in Lookout Point Reservoir followed a similar vertical distribution pattern as fish in Detroit Reservoir (Figure 1-8). Median depths occupied in August and September (16 m) were significantly deeper compared to other months (Kruskal-Wallis ANOVA on ranks, P<0.05). In October, fish were at depths similar to July. By November, fish were significantly closer to the surface (median depth: 2.3 m) than any other month (Kruskal-Wallis ANOVA on ranks; P<0.05), with most fish (79%) collected in the surface net.

Juvenile Chinook salmon were deeper during summer 2013 compared to summer 2012 (Figure 1-12). As observed in Detroit Reservoir, surface temperatures in Lookout Point Reservoir were warmer in the summer of 2013 and this temperature difference likely explains the greater depths juvenile Chinook occupied in 2013. By mid-September 2013 water temperature of 16° C occurred at 20 m depth, whereas at the same time in 2012 the same temperature was at 11.5 m.

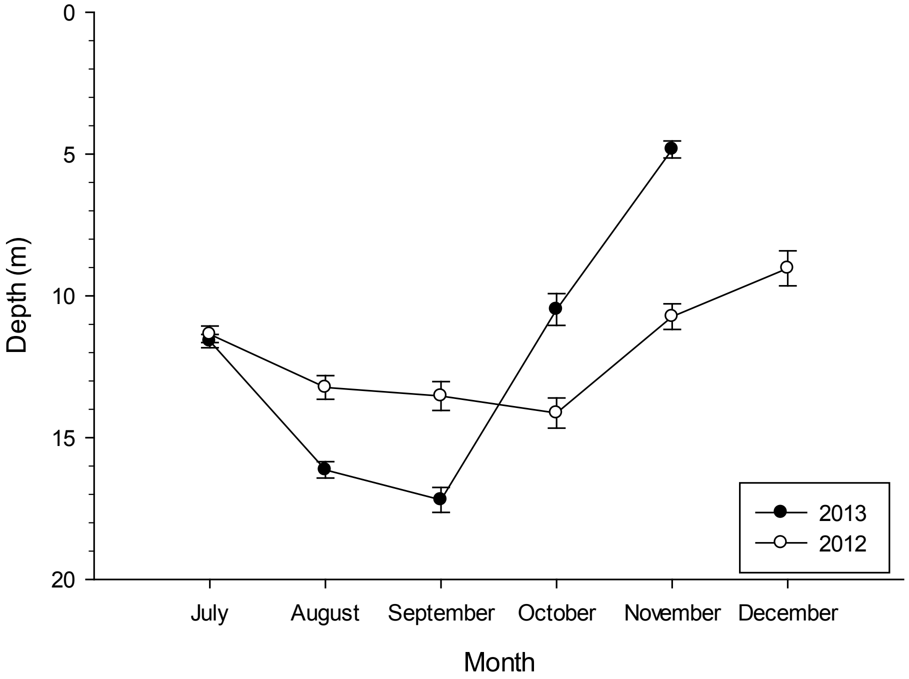

Figure 1-12. Mean monthly depths of juvenile Chinook in Lookout Point Reservoir, 2012 and 2013. Error bars are the standard error.

Discussion

Subyearling Nearshore Distribution – The distribution of subyearling Chinook salmon in Foster Reservoir was unlike that in other reservoirs, with fish more abundant in the lower reservoir in early spring. The timing of subyearlings passing the dam reflected the greater abundance in the lower reservoir, with 75% of the 2013 subyearling catch occurring prior to May (Romer et al. 2014). At our other traps below dams, most subyearling catch occurs in the fall. The small dimensions of Foster Reservoir along with the early fry entrance timing likely aids in reservoir passage. The upper reservoir section is narrow and generally had a slight downstream current throughout the spring. There was at least one occasion (12 March) when a slow-moving current was noticeable throughout the entire reservoir. These conditions were likely conducive to moving small subyearlings through the reservoir. However, this was the first year assessing subyearling distribution in Foster Reservoir and our results are based on relatively low catches compared to other reservoirs, so caution should be used when interpreting results. The distribution patterns observed in 2013 may not be repeated in years with different fry entrance timing and reservoir inflow conditions.

Distribution of subyearlings at Detroit, Cougar, and Lookout Point reservoirs followed a more typical pattern observed in past years with fish more abundant in the upper reservoir.

Although subyearlings were more numerous in the upper section of Cougar Reservoir, they dispersed along nearshore habitat throughout the spring and approached an even distribution by the end of June, similar to patterns observed in 2012 (Monzyk et al. 2013). An even distribution by summer would be expected based on observations of hatchery subyearlings tagged with Juvenile Salmon Acoustic Telemetry System (JSATS) tags. Most of these fish repeatedly traversed the length of the reservoir in the summer (Beeman et al. 2013). It is likely that most natural-origin subyearlings were moving throughout the reservoir by July. We occasionally observed shoals of subyearlings moving along the shoreline and in the pelagic zone of the reservoirs in the spring and summer. This shoaling behavior was also reflected in our highly variable catch numbers with occasionally large numbers of Chinook salmon captured in a single trap.

Lookout Point Reservoir is nearly twice as long as Cougar Reservoir but subyearlings in Lookout Point were dispersed farther into the reservoir by early spring compared to Cougar Reservoir. This dispersion patterns was observed in 2012 as well. Subyearlings in Lookout Point Reservoir enter the reservoir approximately one month earlier than Cougar Reservoir (Romer et al. 2014), providing more time 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 compared to full pool. Both of these factors likely contribute to a greater proportion of subyearlings in the lower reservoir by early spring when compared to Cougar Reservoir.

Pilot efforts in November to assess longitudinal distribution of subyearling parr in Lookout Point Reservoir indicated that nearly half of the subyearlings were in the forebay with the remaining population evenly dispersed throughout the reservoir. A concentration of fish in the forebay is consistent with behavior information from JSATS tagged hatchery fish in Detroit Reservoir (Figure 18 in Beeman et al. 2013). The authors reported that fish near the dam but moving towards the log boom were more likely to return to the forebay than continue up-reservoir. Subyearlings in the Willamette basin naturally express a downstream migration in November (Zakel and Reed 1984). Therefore, the concentration of Chinook salmon in the forebay may reflect this tendency to move downstream and coincides with when most subyearlings pass the dams (Romer et al. 2012, 2013, 2014). Our sampling was limited in scale and scope so results should be interpreted with caution. It is unknown whether subyearlings concentrate in the forebay earlier in the year or just during the fall but this deserves further investigation since it could have important ramifications when designing downstream passage structures at dams.

Parr Vertical Distribution - A seasonal pattern in vertical distribution was evident for subyearling Chinook salmon rearing in reservoirs. Parr descended into the water column in summer, as surface water temperatures peaked, and returned to the surface by late fall. We observed similar vertical distribution patterns in 2011 and 2012 (Monzyk et al. 2012, 2013). However, parr in the summer of 2013 were 7 m deeper on average than in 2012 and this was partly attributed to different water temperature profiles between years. In 2013, reservoir water temperatures were slightly warmer and parr would presumably need to descend to greater depths to find cool water. It appeared juvenile Chinook salmon occupied depths that were ≤16°C. This is consistent with temperature preference reported in the literature. The

Independent Science Group (1996) determined optimal rearing for juvenile Chinook salmon was 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). Differences in depths occupied between years could be important when considering entrainment rates and routes used by subyearlings passing the dam during summer spill operations.

The vertical distribution patterns we observed likely occur in all WVP reservoirs. Ingram and Korn (1969) reported similar vertical distribution patterns for juveniles in Cougar Reservoir, although the authors did not deploy nets below 13.7 m (45 ft) in the summer and fall. Their results showed most fish were caught in their deepest gill net 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.

Gill nets were 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 in 2012 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 even 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 open pelagic zone, possibly due to variability in discharge elevation through the spill and turbines intakes at the dam. Changes in discharge elevation at Lookout Point Dam appear to explain variability in our surface net catches in November during our assessment of parr longitudinal distribution.

Habitat segregation by depth was evident among juvenile Chinook salmon, rainbow trout, and kokanee in Detroit Reservoir. Rainbow trout were more surface oriented than the other species. This is consistent with results from 2012 (Monzyk et al. 2013) and 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. Given their greater surface-orientation, steelhead may be more likely to use summer spill as a route to exit the reservoir.

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). It is well documented that juvenile Chinook salmon rearing in reservoirs grow larger than in streams (Korn and Smith 1971; Monzyk et al. 2011b, 2012, 2013). In Section 1 of this report, we showed that reservoir subyearlings change vertical position in the water column as water temperatures change throughout the year, thereby thermoregulating for optimal growth. In our previous report, we documented differences in subyearling Chinook salmon size among WVP reservoirs. Chinook salmon in Fall Creek, Foster, and Lookout Point reservoirs reached a larger size by fall than in Detroit and Cougar reservoirs (Monzyk et al. 2013). We hypothesized that size differences among reservoirs could be due to longer periods of reservoir growth for populations with earlier fry entrance timing. Also, reservoirs with early fry entrance timing are generally located at lower elevations, and consequently have warmer water temperatures that may increase growth rate.

In this report, we continued to assess growth of subyearlings in WVP reservoirs to determine if size differences observed among reservoirs were consistent between years. We also evaluated fry entrance timing and reservoir water temperatures in relation to juvenile size to further elucidate the mechanism for greater growth in some reservoirs. Knowledge of growth rate and size juveniles attain while rearing in reservoirs will aid in designing appropriate downstream fish passage.

Methods

Length information for reservoir-rearing Chinook salmon was collected using a variety of sampling methods including nearshore box traps, small and large Oneida Lake traps, electrofishing, gill nets, and screw traps located below dams. Information on the location and duration of the various sampling methods in Detroit, Foster, Cougar, and Lookout Point reservoirs can be found in the other sections of this report. Length information for Fall Creek Reservoir subyearlings was provided by USACE personnel operating a screw trap and fish evaluator below the dam (courtesy Todd Pierce, USACE).

We used fish lengths recorded from screw traps and seining captures above the reservoirs to track cohort growth of stream-rearing subyearlings. 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, and the South Santiam River above Foster Reservoir. Previous analyses showed fish lengths from seining efforts were not significantly different from lengths of fish collected in screw traps during the same period, so data were combined for comparisons. Length data from screw trapping represents a longer seasonal time series (generally extending into November) and allowed us to compare to lengths recorded from fish in reservoirs.

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 Detroit 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 from length-frequency analysis. Yearling and subyearling Chinook salmon generally maintained a clear size difference throughout the year. For each reservoir and stream, we plotted individual fish size by date and assigned age (Appendix Figure A-6). Juveniles hatched in spring 2013 were classified as subyearlings (age 0) and yearlings (age 1) were fish that hatched the previous year and remained in the reservoir or stream after 01 January. We believe the aging technique accurately assigned age for most fish and any assignment errors would not greatly affect results.

Subyearling size in the fall was compared among reservoirs with Kruskal-Wallis One-way ANOVA tests (α=0.05) and Dunn's pairwise multiple comparisons. We used average fish size collected from October to December, after summer growth. We also examined the relationship between fish size and reservoir water temperatures. Water temperature data were obtained from USACE temperature stations (Onset HOBO® data logger string). We used average daily temperature on June 1 at 3-m depth because most subyearlings have entered reservoirs by June (Romer et al. 2013, 2014) and generally occupy the upper water column. We used simple linear regression (α=0.05) to describe the relationship between size in fall and average water temperatures for the five reservoirs.

Growth Rate - We used two methods to estimate growth rate, depending on available data. In Cougar and Lookout Point reservoirs, we estimated subyearling growth rate using length data from individual fish that were 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 events. In 2013, we tagged subyearlings >60 mm FL caught in the reservoirs or in the upstream screw traps and presumed to have immediately migrated into the reservoirs. We only used fish tagged between April and August and recaptured at least two weeks after tagging to calculate growth rates. Recaptures reported in the PTAGIS database came from collection in the reservoir, screw traps below the dam, the Leaburg bypass juvenile fish collector, or other collection below dams by various projects.

PIT-tag sample sizes were generally small and limited to specific reservoirs, so we also estimated subyearling growth rates in all reservoirs using information on mean size of subyearlings in May and October. Previous sampling efforts showed maximum growth occurs from May to October. We estimated growth rate as mean size in October minus mean size in May divided by the number of days between months. The number of days between months was calculated as the difference in the mean date of capture each month.

Results

Yearling and subyearling Chinook salmon were present in WVP reservoirs with subyearlings more common (Appendix Figure A-6). Yearlings were rarely captured after June in most reservoirs or in upstream screw traps, with the exception of Cougar Reservoir where 31% of the captured yearlings were in the fall. In this report we limited our growth analyses to the subyearling cohort.

Reservoir-rearing subyearlings grew more rapidly than juveniles rearing in streams above reservoirs (Figure 2-1), as we observed in previous years (Monzyk et al. 2013). By November, subyearlings in reservoirs were 45-117 mm larger than their counterparts in streams with the largest difference occurring in Lookout Point Reservoir. Variation in weekly mean lengths of reservoir-rearing subyearling was greater in the fall, likely attributable to smaller stream-rearing fish entering the reservoir in the fall. This was especially evident in Foster Reservoir were sample sizes were small.

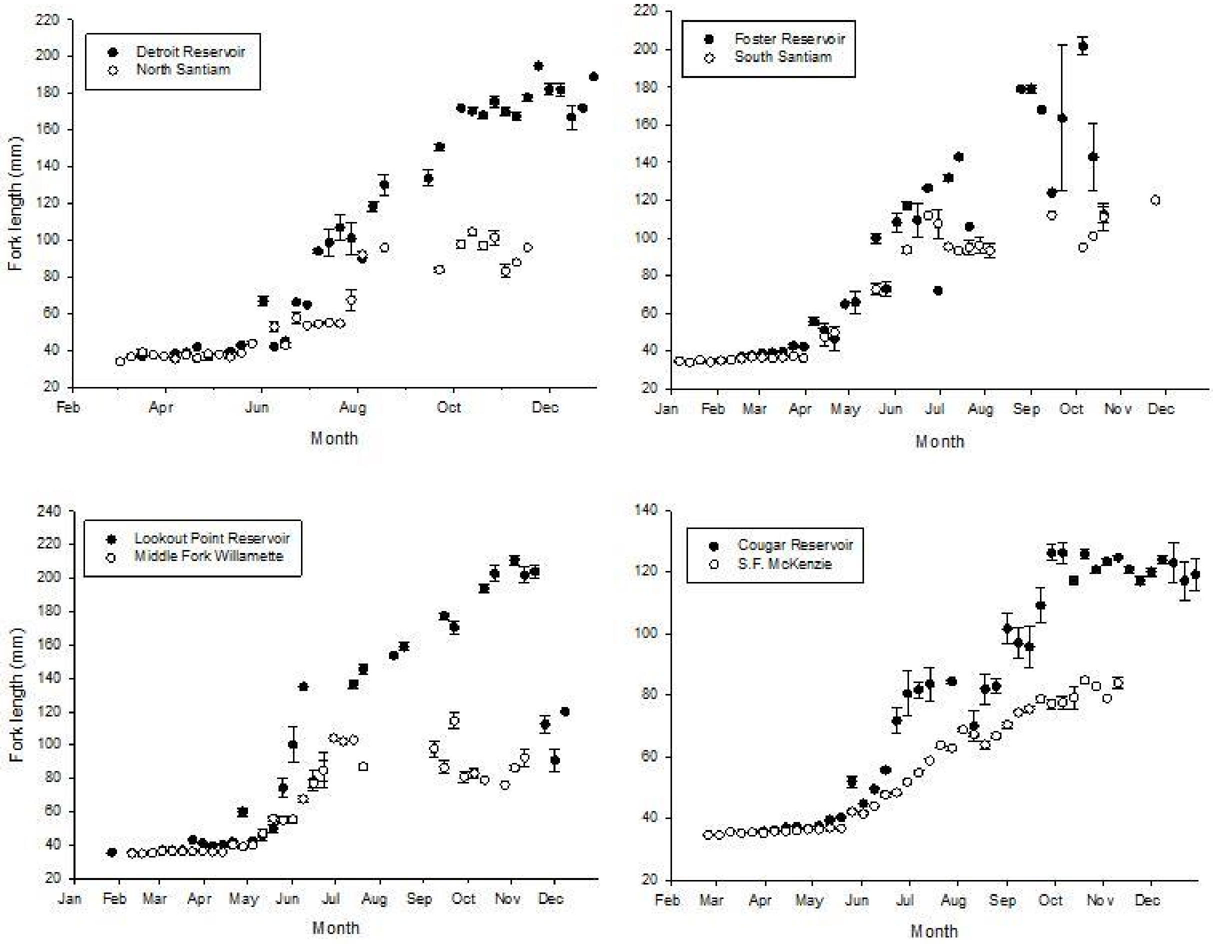

Figure 2-1. Fork lengths of subyearling Chinook salmon captured in WVP reservoirs and streams above reservoirs, 2013. Error bars are standard error.

Differences in subyearling size among reservoirs were consistent with results from 2012 (Appendix Figure A-7). Subyearlings in Fall Creek Reservoir were the largest, averaging 220 mm FL by fall (Figure 2-2) but not significantly different from Foster and Lookout Point subyearlings (Kruskal-Wallis one-way ANOVA on ranks; $P>0.05$). Subyearlings in Detroit were intermediate in size and subyearlings in Cougar Reservoir were the smallest. Both Detroit and Cougar reservoir subyearlings were significantly smaller than fish in other reservoirs and from each other (Kruskal-Wallis one-way ANOVA on ranks; $P<0.05$).

In general, the reservoirs with the largest subyearlings also had the earliest fry entrance timing and warmer summer surface temperatures, two factors that could influence growth. Fish size and temperature were significantly related (Simple linear regression; $P<0.05$) (Figure 2.3). Reservoir temperature and median fry entrance date were negatively correlated (Pearson r = -0.79). Previous sampling above Fall Creek Reservoir showed peak fry entrance around early March, similar to Foster Reservoir (Keefer et al 2011; Romer et al 2013). Peak entrance timing into Lookout Point reservoir is approximately early April, whereas timing into Detroit and Cougar reservoirs peak around early May. The growth advantage of earlier entrance timing and warmer temperatures was clear when considering the size of fish in May. Subyearlings in Fall Creek Reservoir were already >100 mm FL by May when most fry (<40 mm FL) were still entering Cougar and Detroit reservoirs.

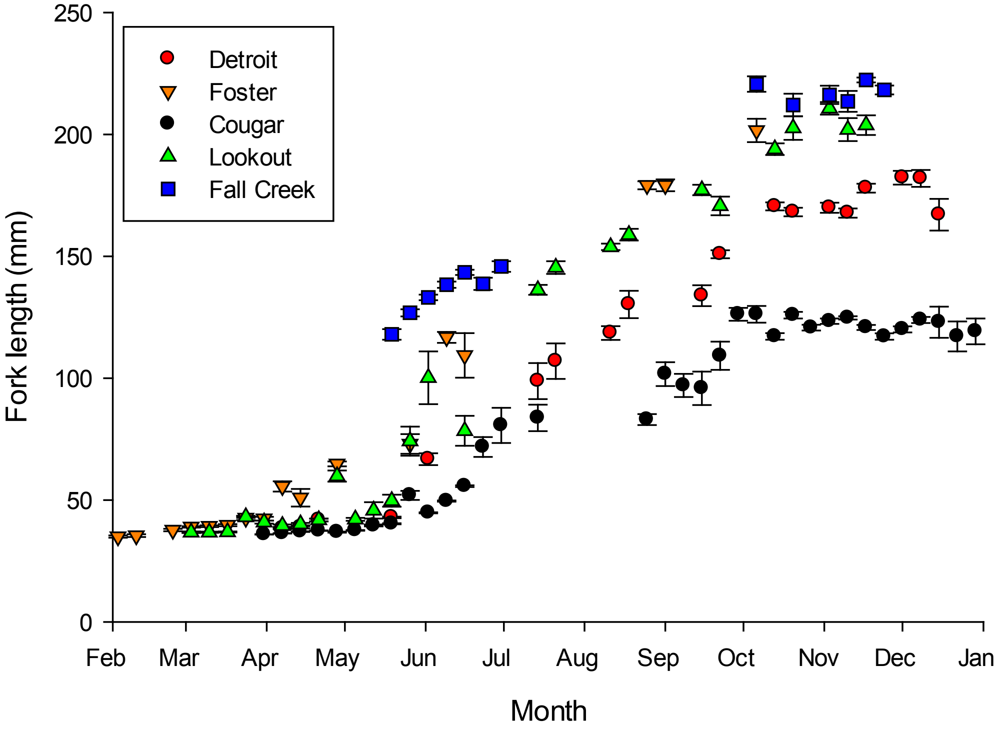

Figure 2-2. Mean fork length by week of natural-origin subyearling Chinook salmon in WVP reservoirs, 2013. Detroit Reservoir included unmarked hatchery subyearlings released as fry in May. Error bars are the standard error.

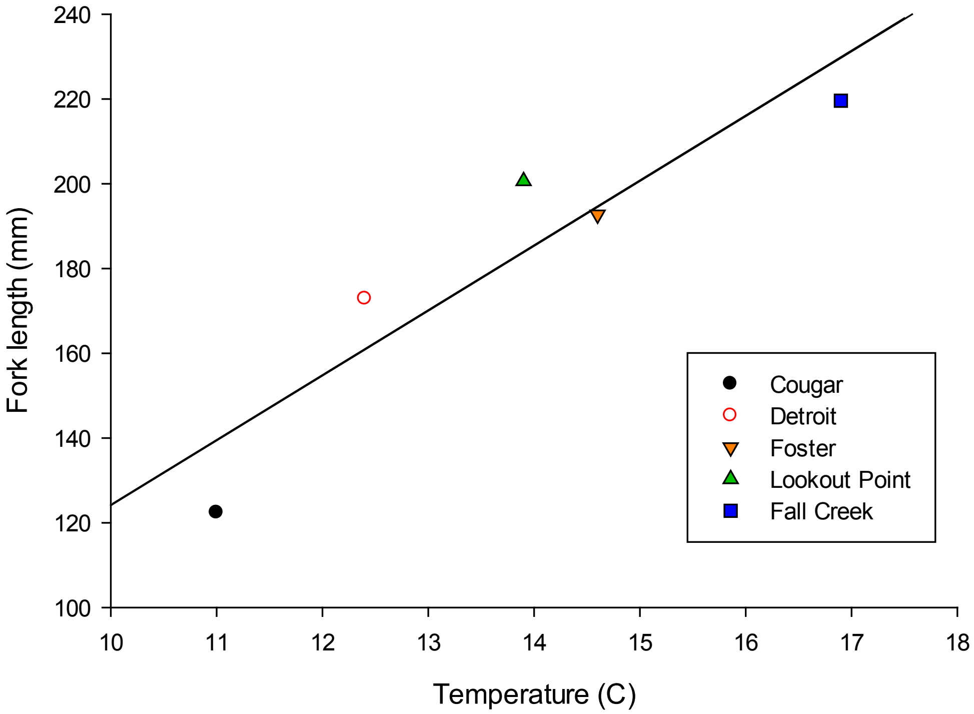

Figure 2-3. Mean size of subyearling Chinook salmon in the fall (Oct-Dec) in relation to reservoir temperature for five WVP reservoirs. Temperature was the average of hourly temperatures measured on 1 June 2013 at 3-m depth. Simple linear regression significant at *P*=0.026.

Growth Rates – We estimated subyearling growth rates among reservoirs to determine the influence on size differences observed. We PIT tagged and recaptured 12 subyearling Chinook salmon that reared in Cougar Reservoir. Mean growth rate was 0.43 ±0.02 mm/d (SE). Most fish were tagged in the summer at the screw trap above the reservoir and presumably entered the reservoir soon thereafter. Additionally, most recaptures were in November below the dam. As such, growth rate may be underestimated because it did not include the spring growth period and includes the late fall period when growth would be slower. We estimated a growth rate of 0.52 mm/d based on difference in mean fish size between May and October. This later estimate accounted for growth occurring in the spring and did not include the slow growth period in late fall.

In Lookout Point Reservoir, only three PIT-tagged subyearlings were recaptured to calculate growth rate. These fish were tagged in the spring and recaptured before October. Based on these three fish, mean growth rate was 1.09 ± 0.03 mm/d (SE). Growth rate based on mean fish size in May and October was 0.94 mm/d.

Growth rates for subyearlings in other WVP reservoirs were calculated from mean fork lengths in May and October and ranged from 0.65-0.84 mm/d (Table 2-1). Growth rate in Cougar Reservoir was consistently lower than other reservoirs over the last three years

(Table 2-1). Growth rate in Detroit Reservoir was comparable to Foster Reservoir. Fall Creek Reservoir growth rate was less than other reservoirs with the exception of Cougar Reservoir; however, there may exist some bias in this estimate: the growth rate estimate for Fall Creek Reservoir relied on fish collected at the evaluator below Fall Creek Dam in May that were already over 100 mm FL, so the estimate did not incorporate the early fry growth period. Assuming an average fork length for fry of 34 mm and a median reservoir entrance date of March 15 (Keefer et al. 2011), growth rate from March through October would be 0.84 mm/d, similar to Foster and Detroit reservoirs. We could not detect a relationship between growth rate and reservoir water temperature (simple linear regression; $P>0.05$), although power was low due to the small sample size (n = 5).

Table 2-1. Growth rate of subyearlings in WVP reservoirs calculated from mean fork length in May and October, 2013.

Reservoir	Growth rate (mm/d)		
	2011	2012	2013
Detroit	0.73	0.78[a]	0.84
Foster	n/a	n/a	0.80
Cougar	0.52	0.55	0.52
Lookout Point	0.71	0.97	0.94
Fall Creek			0.65[b]

[a] Mean length in May estimated from screw trap above reservoir.

[b] Mean length in May estimated from fish passing the dam and caught in the fish evaluator. Growth rate may be underestimated because it does not include fry to parr growth period.

Discussion

Greater growth of subyearling Chinook salmon rearing in reservoirs compared to streams was evident again this year and was likely attributable to the greater primary and secondary productivity in reservoirs and temperature regimes that allowed for optimal growth. Additionally, vertical distribution results (see Section 1) showed that Chinook salmon seasonally changed position in the water column corresponding to optimal rearing temperatures throughout the year, an option not available to stream-rearing fish.

The differences among reservoirs in the size subyearlings reached by the end of the growing season was consistent with 2012 results. Subyearlings in Fall Creek, Lookout Point, and Foster reservoir were the largest by fall and Cougar Reservoir subyearlings were the smallest. Detroit subyearlings were intermediate in size.

Several factors appear to influence subyearling size including duration of time rearing in reservoirs (i.e., fry entrance timing), reservoir water temperatures, and growth rate. Although some of these factors are likely interrelated, reservoir temperature was the one factor that we could detect a positive relationship with subyearling size. Generally, reservoirs with the warmest spring temperatures also had the earliest fry entry dates. These reservoirs would reach optimal rearing conditions of 12.2 to14.8ºC (Hicks 2000) sooner than other reservoirs, allowing for more growth to occur. Growth rates did not differ greatly among reservoirs, with the exception of Cougar Reservoir that had the slowest growth rate and the coolest temperatures. Interestingly, Fall Creek Reservoir did not have a greater subyearling growth rate compared to other reservoirs, but it was the warmest and had early fry entrance timing.

Other factors may also influence the size fish reach by fall. Very few fry were produced above Detroit Reservoir compared to Cougar Reservoir in 2013 (Romer et al. 2014), so presumably there would be little intraspecific competition in Detroit Reservoir. Additionally, growth rates in Cougar Reservoir were slower than the other WVP reservoirs for the last three years. Catch per unit effort in Cougar Reservoir was consistently higher each year compared to other reservoirs, suggesting greater fish densities. The slower growth rate observed may be the result of density-dependent compensation. Interannual variation in growth rate may occur in a reservoir with changes in juvenile fish densities.

The most rapid growth rate estimated this year was approximately 1 mm/d for subyearlings in Lookout Point Reservoir. 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). Our growth rate estimates for Lookout Point could be biased high if differential mortality due to predation on smaller individuals occurred.

SECTION 3: PARASITIC COPEPOD INFECTION PREVALENCE AND INTENSITY

Background

In recent years, several researchers working in WVP reservoirs noted higher than usual infection levels by the parasitic copepod *Salmincola californiensis* on juvenile Chinook salmon and this prompted interest in monitoring infection levels. The copepod 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.

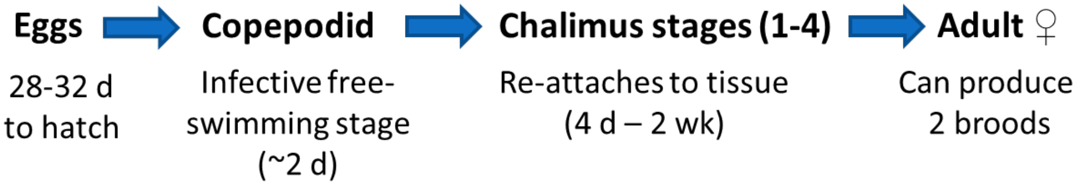

Figure 3-1. Life cycle of female *Salmincola californiensis.*

Suitable copepodid attachment sites consist of solid subdermal structures, including fin rays, gill filament rods, scales, 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). In previous assessments, we observed attachment to the gill to be more common for reservoir-rearing Chinook salmon (Monzyk et al. 2013).

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). We observed a positive correlation between copepod prevalence and juvenile Chinook salmon fork length for fish rearing in reservoirs (Monzyk et. al 2012). However, larger fish were likely in reservoirs for a longer period of time and therefore experienced extended exposure to parasites. The highest infection prevalence and intensity among subyearlings was in late fall (Monzyk et al. 2013). We observed significantly higher infection prevalence and intensity for juvenile Chinook salmon rearing reservoirs compared to streams, with some reservoir juveniles infected with >20 copepods on the gills.

Low-level infections observed in stream-rearing fish are generally not believed to be lethal, especially if the parasites are not attached to gill lamellae. However, the high intensity infections on the gills of reservoir-rearing fish can cause gill tissue destruction (Kabata and

Cousens 1977; Sutherland and Wittrock 1985) resulting in anemia and high mortality during saltwater transition (Sutherland and Wittrock 1985; Pawaputanon 1980). In 2012, we observed high intensity infection levels in Fall Creek Reservoir Chinook salmon (i.e., >20 copepods on gills) that could potentially cause high mortality during saltwater transition. Anecdotal information suggests Chinook salmon in Hills Creek Reservoir are also highly infected. In this report, we describe the prevalence and intensity of copepod infection through time for reservoir- and stream-rearing juvenile Chinook salmon and other salmonids species. We also compare infection trends from previous years.

Methods

In 2013 (April-December), we assessed infection by *S. californiensis* among *Oncorhynchus* spp. 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 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.

We assessed both the prevalence and intensity of copepod infection. Prevalence was defined as the percentage of fish infected with at least one copepod. We compared prevalence between reservoir- and stream-rearing subyearlings collected between October-November (z-test; α=0.05), the time period when sample sizes are generally the largest for both groups. Hatchery fish may differ from natural-origin fish in size and duration of rearing in reservoirs; therefore we analyzed hatchery fish separately when they were distinguishable from naturally-produced fish. Intensity was defined as the number of copepods per infected fish. We only analyzed copepod intensity on the gills because of the potential detrimental effects this attachment location has on fish during saltwater transition. We compared copepod intensity between reservoir- and stream-rearing subyearling Chinook salmon with the Mann-Whitney Rank Sum test (α=0.05). We also compared intensity between yearlings and subyearling when collected during similar time periods.

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 of 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. Age-class of juvenile Chinook salmon was determined by length-frequency analysis (see Section 2).

Results

We macroscopically examined 11,903 salmonids for infection by *S. californiensis* on gills and fins. Copepods were more common on the gills of salmonids rearing in reservoirs (Table 3-1). For instance, 79% of the copepods on reservoir-rearing Chinook salmon were attached to gills, compared to 24% for stream-rearing Chinook salmon. This was similar to the proportions observed in 2012 between reservoir- and stream-rearing Chinook salmon (81 and 30%, respectively). The difference in attachment location could partly be attributable to the larger size of salmonids in reservoirs.

Table 3-1. Percent of *Salmincola californiensis* attached to the gills and fins of infected Pacific salmonids by rearing location in the Willamette basin, 2013.

			Copepods		
			Gills		Fins
Rearing location/ Species	Number of fish	Mean fork length (mm)	Number adult ♀	Percent of total	Number adult ♀
Reservoir	**9,692**	**140.9**	**12,405**	**81.4**	**2,834**
Chinook	5,403	124.0	8,664	78.8	2,328
Hat. Chinook	1,698	168.4	3,217	92.4	264
Rainbow/Steelhead[a]	1,231	150.4	316	71.5	126
Hat. Rainbow	236	214.4	189	63.6	108
Cutthroat	42	140.4	3	42.9	4
Kokanee	1,082	155.2	16	80.0	4
Stream	**2,211**	**74.7**	**17**	**23.9**	**54**
Chinook	1,471	69.3	14	24.6	43
Hat Chinook	17	106.2	0	--	0
Rainbow/Steelhead[a]	1	78	0	--	0
Cutthroat	25	142.6	1	25.0	3
Kokanee	1	100	0	--	0

[a] *O. mykiss from the South Santiam River were likely juvenile steelhead.*

Prevalence

Copepod infection prevalence was greater for subyearling Chinook salmon rearing in reservoirs compared to streams (z-test P<0.05; Table 3-2). Prevalence for stream-rearing subyearlings was < 10% during in the fall but >59% in reservoirs. Within reservoirs, prevalence increased each month (Figure 3-2). Infection prevalence in the spring was generally low (<10%) in most WVP reservoirs, but was 43.8% in Fall Creek Reservoir (n=32). Subyearlings in Fall Creek Reservoir also had the highest prevalence in the fall with a 98.7% infection rate in November (n=158) and were also the largest in size (see Section 2).

Table 3-2. Copepod prevalence between reservoir- and stream-rearing subyearling Chinook salmon, October-November 2013.

	Reservoir		Stream		
Location	Prevalence	n	Prevalence	n	*P* (z-test)
Cougar / South Fork McKenzie	0.87	1,916	0.07	42	<0.001
Detroit / North Santiam	0.93	281	0.06	71	<0.001
Foster / South Santiam	0.59	32	0.00	5	0.047
Lookout Point / MF Willamette	0.64	335	0.09	22	<0.001

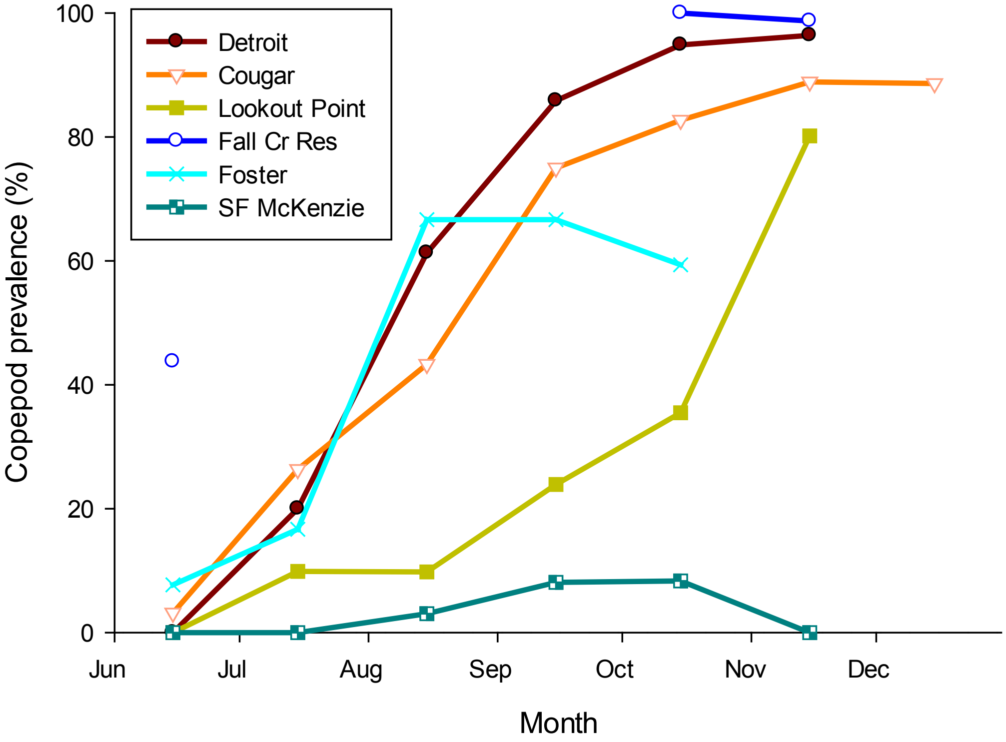

Figure 3-2. Proportion of subyearling Chinook salmon with copepods present by month for WVP reservoirs and the South Fork McKenzie River, 2013.

Susceptibility to infection differed among salmonid species in reservoirs. We did not observe increasing prevalence over time for salmonids other than Chinook salmon. This was most evident in Detroit Reservoir where prevalence among unclipped rainbow trout was relatively constant from July through November (range: 19-36%); however, monthly prevalence among subyearling Chinook salmon increased from 25 to 91% (Figure 3.3).

Kokanee were the least infected by parasitic copepods with a mean prevalence of <1% in both Detroit (n=962) and Foster (n=121) reservoirs. Cutthroat trout also had low infection prevalence with only 2 of 42 infected among all reservoir collections.

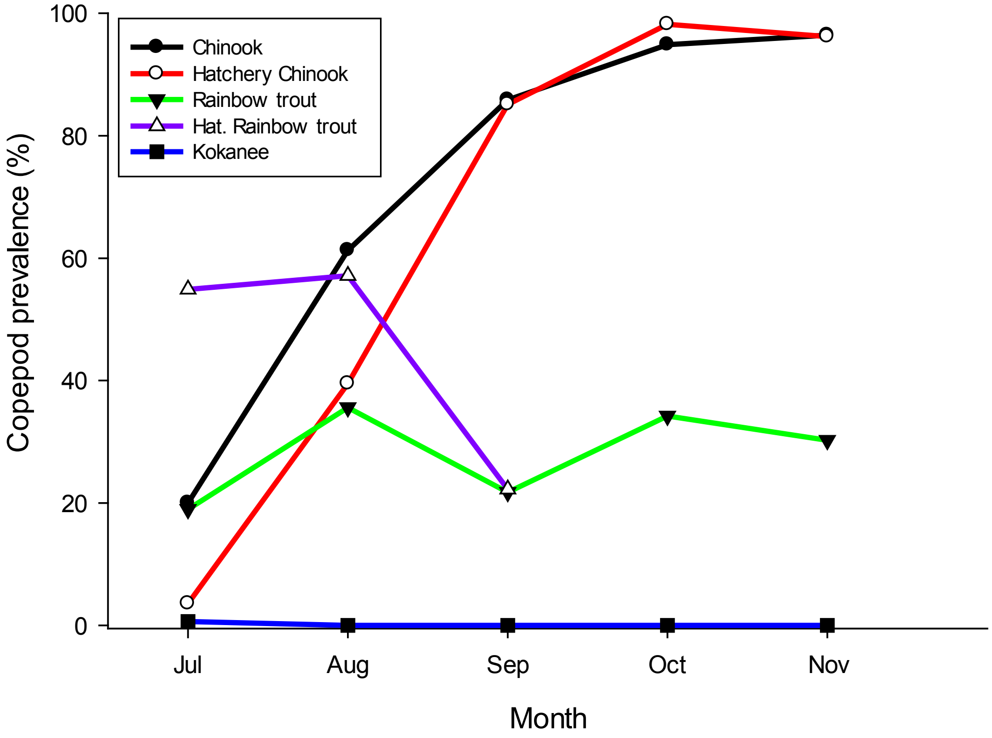

Figure 3-3. Monthly copepod prevalence for salmonid species in Detroit Reservoir, 2013.

Copepod prevalence in November was not significantly different between AD-clipped and unclipped Chinook salmon in Detroit Reservoir (z-test, *P*>0.05) (Figure 3-3). Mean fork length was similar between groups (unclipped=172 mm; AD-clipped=175 mm) However, hatchery Chinook in Lookout Point reservoir had greater prevalence in November (z-test, *P*<0.01) and were larger than unclipped fish (unclipped prevalence=80%, mean FL=208 mm; Ad-clipped prevalence=95%, mean FL=225 mm).

Intensity

As with prevalence, infection intensity was greater for subyearling Chinook salmon in reservoirs (Figure 3-4). The majority of infected stream-rearing subyearlings (94%) had just one copepod, generally attached to a fin, while most reservoir-rearing fish had multiple parasites that were usually attached to the gills.

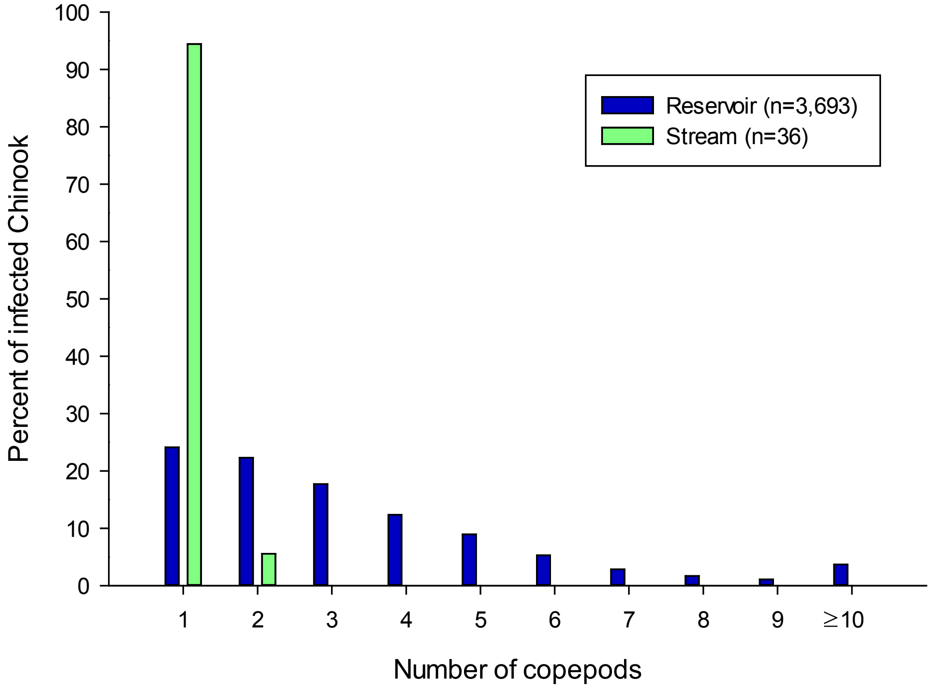

Figure 3-4. Copepod intensity among reservoir- and stream-rearing subyearling Chinook salmon, 2013. Copepod attachment location includes both gills and fins.

Infection intensity on the gills of reservoir-rearing subyearling Chinook salmon increased from late spring through fall (Figure 3-5). In Cougar Reservoir, copepods were first observed in June with an intensity of one copepod on the gills. The maximum intensity observed was 30 copepods in October on a 180 mm FL subyearling. Several fish >170 mm FL (n=4) that we designated as subyearlings in the fall (based on length-frequency analysis) had >15 copepods on gills. These fish may have actually been small yearlings (see appendix Figure A-6). Despite this possible misidentification of age-class, yearlings in Cougar Reservoir had significantly greater infection than subyearlings during October-December (Mann-Whitney Rank Sum test, P>0.001) (Figure 3.6), suggesting infection intensity continues to increase for fish that remain in the reservoir an additional year.

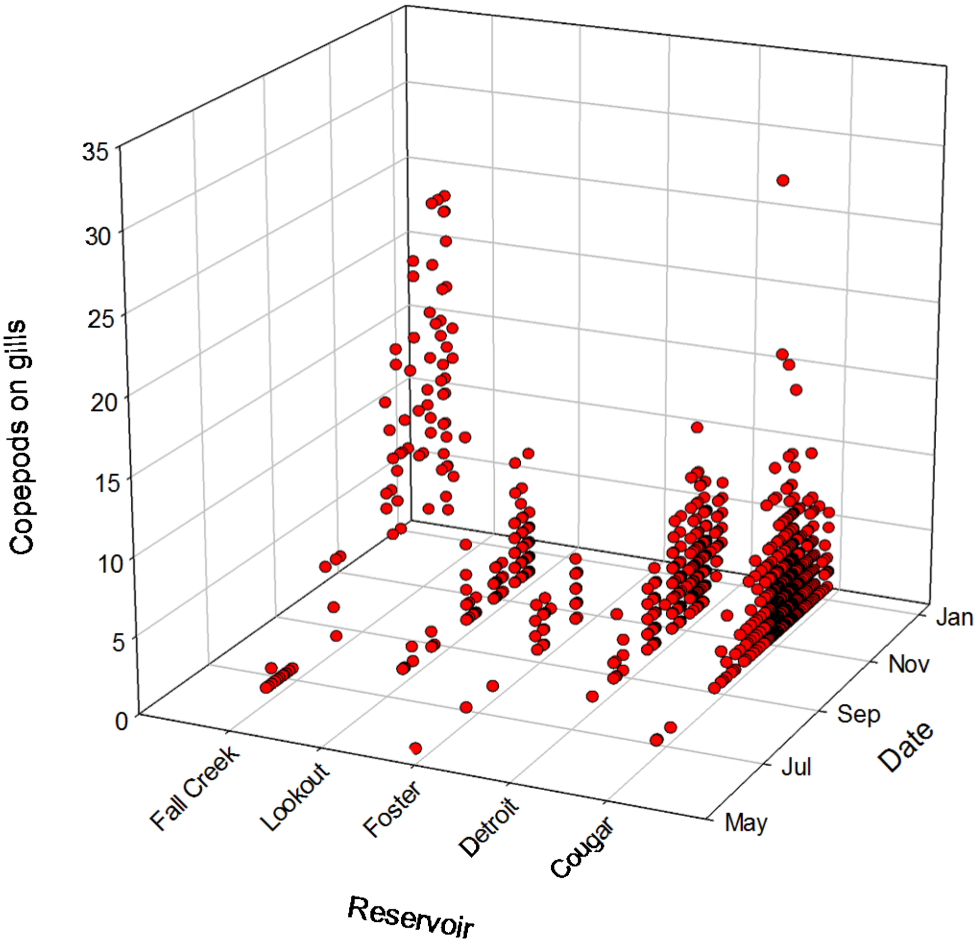

Figure 3-5. Number of parasitic copepods observed on gills of subyearling Chinook salmon examined in WVP reservoirs, 2013. Chinook from Cougar and Fall Creek reservoirs were primarily sampled via traps below dams. Lookout Point and Detroit reservoir sampling was performed primarily with gill nets.

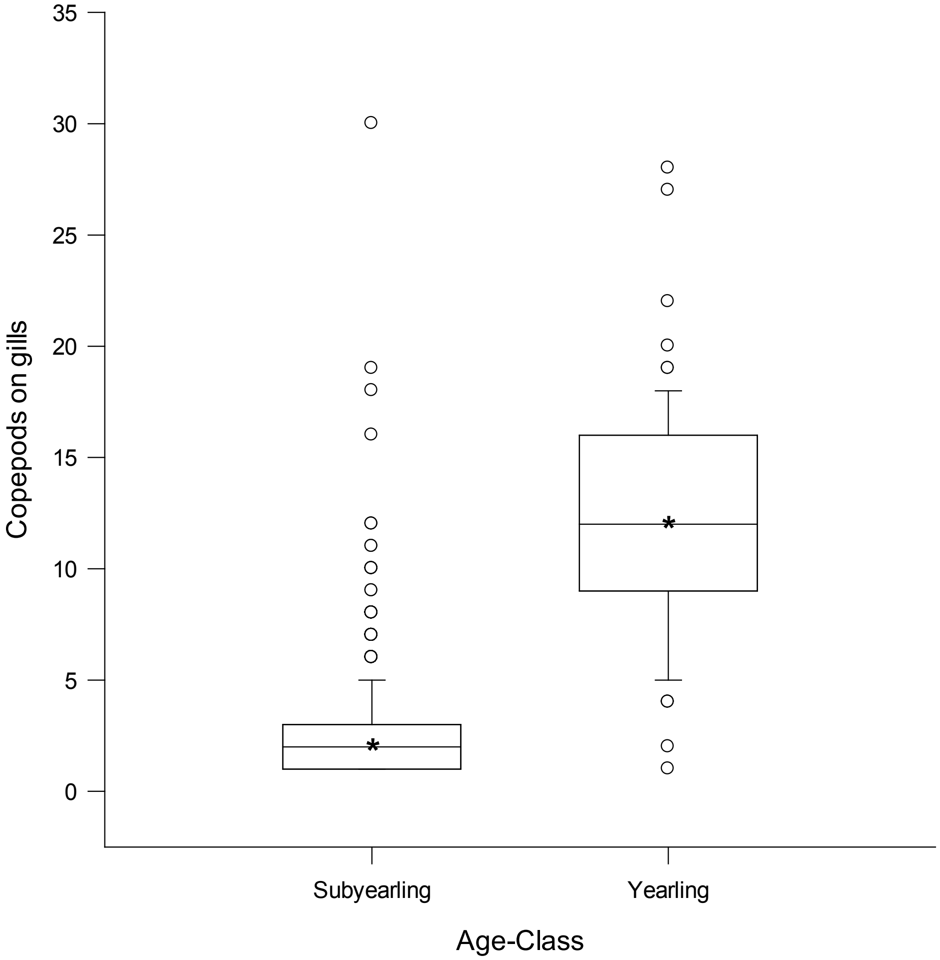

Figure 3-6. Number of copepods on gills of infected subyearling and yearling Chinook salmon in Cougar Reservoir, October-December 2013. Asterisks denote the median, the box represents 25th-75th percentiles, whiskers are the 10th -90th percentile and open circles are outliers.

Among all WVP reservoirs, subyearlings from Fall Creek Reservoir exhibited the greatest infection intensity (Figure 3-7). By late fall (November-December), the median number of gill copepods was 13. Approximately 16% of Fall Creek fish were infected with ≥20 copepods on their gills (Figure 3-7). Fall Creek Reservoir subyearlings were also larger than those rearing in other WVP reservoirs, averaging 217 mm FL (SE=1.5) by late fall. Gill infection of ≥20 copepods were observed in other reservoirs as well. Approximately 5.5% of infected fall-migrating yearlings in Cougar Reservoir and 25% of Chinook salmon of unknown age in Hills Creek Reservoir had ≥ 20 copepods on their gills. The highly infected fish from Hills Creek Reservoir were all >200 mm FL and collected below the dam in the fall (USACE data).

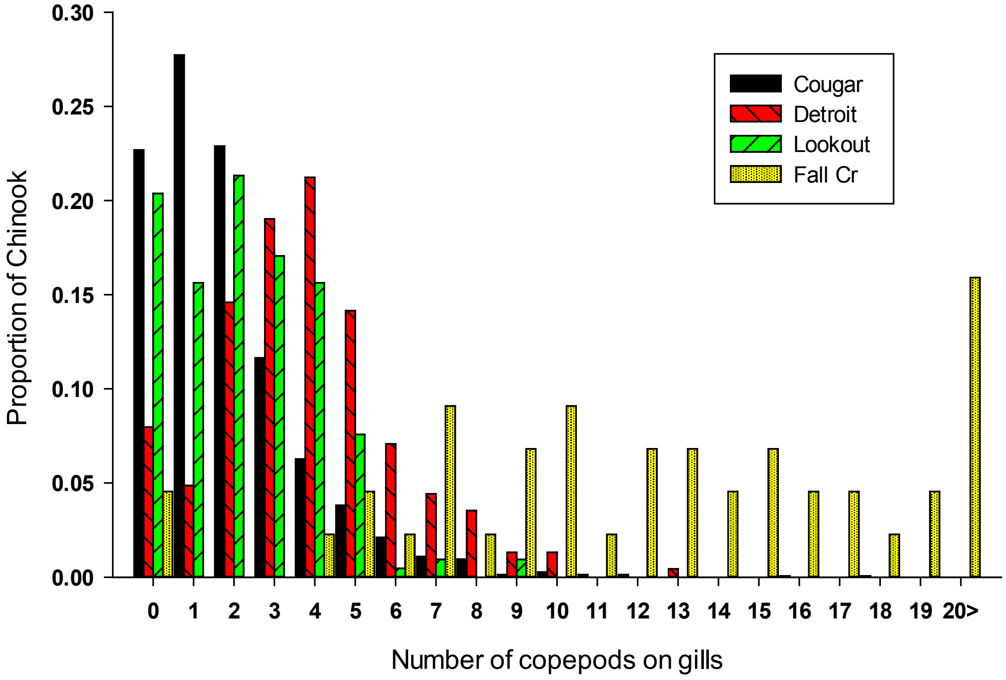

Figure 3-7. Copepod intensity on the gills of subyearling Chinook salmon in four WVP reservoirs, November-December 2013. Chinook salmon from Detroit and Lookout Point (LOP) were collected primarily from gill nets in the reservoirs. Cougar and Fall Creek samples were from screw traps below dams. Fall Creek data courtesy of USACE.

Discussion

The results observed in 2013 were very similar to those in 2012 (Monzyk et al. 2013), suggesting little interannual variation in copepod infection prevalence and intensity among reservoirs. 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 of fish 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. Evidence of the importance of host size rather than exposure time can be found 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 in size and also had the highest copepod infection prevalence and intensity by late fall. These fish were already >100 mm FL by June and had an infection prevalence of 43.8%, whereas prevalence by June among subyearlings in other reservoirs was <10%.

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) who reported that gills were the preferred attachment location on larger fish. In addition to the larger size of fish, the higher infection prevalence and intensity in reservoirs may be related to low water flows. 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 flow environments has also been noted in wild salmon (Friend 1941). During the copepodid stage, the copepod crawls along the host body in search of a suitable attachment location (Kabata and Cousens 1973). Lack of water currents in reservoirs may provide better conditions for copepods to seek out the gills for attachment.

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. The seasonal increase was specific to Chinook salmon compared to other salmonid species in reservoirs. There are several possible reasons for the greater infection prevalence and intensity for subyearling Chinook salmon compared to rainbow trout and kokanee such as: habitat overlap between parasite and host; schooling behavior of a 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 (0-5 m), Chinook salmon were generally 14-23 m deep, and kokanee were at ~27 m (see Section 1: Juvenile Chinook Salmon Distribution in Reservoirs). Although the vertical distribution of copepodids in reservoirs is currently unknown, 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. Copepodids sink when not actively swimming and contact with the substrate immediately elicits a swimming response towards the surface (Kabata and Cousens1973). 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 were more surface-oriented but Chinook salmon had a much greater infection rate, despite their smaller size. Feeding behavior differences between the species may explain the observed differences. Budy et al. (2005) demonstrated that rainbow trout in reservoirs select prey items ≥ 1 mm in length which suggests they may not target 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 copepodid length. If juvenile Chinook salmon feed on copepodids, this could explain the increasing infection rate through time. High infection levels of hatchery rainbow trout in Blue River Reservoir were reported in the summer of 2013 (Christina Murphy, OSU, personal communication), but it is unclear whether infection of these fish began at the hatchery prior to release or in the reservoir.

This was the second year we observed very high levels of infection for Chinook salmon in Fall Creek Reservoir. It appears copepods are able to 'reseed' the reservoir after winter drawdowns flush out most reservoir water. It is possible that infected trout may remain in the stream or isolated pools above the dam and infect the subyearling Chinook salmon cohort that enters the reservoir the following spring. Another possibility is that infected adult steelhead and Chinook salmon transported above the dam may seed the reservoir with copepodids while holding in the stream above the reservoir.

Over the last two years, 16-20% of Chinook salmon from Fall Creek Reservoir exceeded infection levels reported to cause increased mortality during saltwater transition. Catch data below Hills Creek Reservoir indicated about 25% of the fall migrants had similarly high infection intensity as well as 5.5% of fall-migrating yearlings in Cougar Reservoir. Pawaputanon (1980) demonstrated that juvenile sockeye salmon *O. nerka* with mean gill infection level of 23 copepods experienced 90% mortality during salinity tolerance tests compared to 10% mortality for non-infected control fish (an 80% mortality rate). If similar mortality rates can be expected for juvenile Chinook salmon, then about 13-16% of Fall Creek Chinook would not survive their transition to seawater due to infection by *S. californiensis*. Similarly, around 20% of Hills Creek fall migrants do not survive ocean entrance. No studies have been conducted on smolt survival at intermediate infection levels, but this too could be a source of mortality. The effects of varying infection levels on juvenile Chinook salmon survival during saltwater transition is not currently known but merits further investigation. If high infection intensity is shown to cause mortality to smolts, then measures can be taken to reduce infection. One possible management option would be prophylactic treatment of infected adults with hydrogen peroxide before transporting above dams to reduce the potential for infection of juveniles.

SECTION 4: SPECIES COMPOSITION AND PREDATION ON SALMONIDS IN FOSTER RESERVOIR

Background

Predation in reservoirs may impart a greater mortality rate for juvenile Chinook salmon and steelhead than would otherwise occur if WVP dams did not exist. Studies in Columbia River reservoirs have shown that predation rates on juvenile Chinook salmon by smallmouth bass *Micropterus dolomieu* and northern pikeminnow *Ptychocheilus oregonensis* 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 salmonids depends on predator abundance, water temperature, predator size and mouth gape, spatial and temporal overlap, and size of juvenile salmonids.

Previously, we concluded that juvenile salmonids in Lookout Point Reservoir were at greater risk of predation than Detroit and Cougar reservoirs based on predator species composition and relative abundance (Monzyk et al. 2012, 2013). Piscivorous species collected in Lookout Point Reservoir included largemouth bass *M. salmoides*, northern pikeminnow, crappie *Poxomis* spp., and walleye *Sander vitreus*. Northern pikeminnow, largemouth bass, and walleye had the highest occurrence of prey fish in their diet. Although walleye had the greatest overall consumption rate on juvenile Chinook salmon, northern pikeminnow were more abundant in Lookout Point Reservoir and likely present the greatest predation risk. Predation on subyearling Chinook salmon was greatest in the spring (Monzyk et al. 2013). In Detroit Reservoir, only one large (>300 mm FL) rainbow trout *O. mykiss* was found to have preyed on juvenile Chinook salmon (Monzyk et al 2012). Rainbow trout become increasingly piscivorous after reaching a threshold size of about 250-300 mm FL (Larkin and Smith 1954; Parkinson et al. 1989).

The Oregon Department of Fish and Wildlife (ODFW) conducted several fish surveys in Foster Reservoir over the past few decades to assess the fishery. Potential predators of juvenile Chinook salmon in the reservoir include northern pikeminnow, largemouth bass, smallmouth bass, crappie, and yellow perch *Perca flavescens*, bullhead *Ameiurus* spp., and rainbow trout (ODFW, unpublished data). It appears from these surveys that the largemouth bass population has been largely supplanted by smallmouth bass in recent decades. In a 1995 survey report, Kin Daily (ODFW fish biologist) wrote "….it's pretty obvious that there are less largemouth and more smallmouth bass than there used to be." In a 2006 survey, no largemouth bass were captured in a limited gill net survey.

In 2013, we conducted surveys in Foster Reservoir to assess overall species composition and relative abundance and distribution of piscivorous fish in the reservoir. We collected diet samples from piscivorous fish to determine diet composition and species-specific consumption rates on juvenile salmonids.

Methods

Species Composition

We assessed fish species composition in Foster Reservoir in 2013 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 composition information from any incidental bycatch with gear types used primarily for juvenile Chinook salmon and steelhead collections (i.e., fry floating box traps, small and large Oneida Lake traps, and small-mesh gill nets). Methods used for these gear types can be found in other sections of this report. We also included capture data from our screw trap located in the tailrace below Foster Reservoir (Romer et al. 2013). Sampling in the reservoir followed a stratified random sampling design. The reservoir was stratified into lower, middle and upper thirds with the upper third subdivided into the South Santiam and Middle Santiam arms (Figure 4-1).

Boat electrofishing was conducted at least once each month from April through October. Both day and night electrofishing was conducted in April, May, and October. Electrofishing in June was day only and night only from July-September. The electrofisher settings were 850-1000 V, 2-2.5 amps with a pulse width of 5 ms, and a frequency of 120 DC. For each session, sampling occurred in each reservoir section along areas chosen based on habitat potential for predatory fish. Each shoreline area was sampled for 15 minutes shock time.

We also deployed large-mesh experimental-type gill nets during spring and summer at sites selected on habitat potential for predatory fish. We did not sample in late summer and fall to avoid accidental capture of spring Chinook salmon adults that may have fallen back into the reservoir after outplanting. 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 for larger predatory fish species. Gill nets were set perpendicular to shore on the bottom and fished for approximately 24 h over a period of 1 – 5 d each month from April through August, except during June when we did not set gill nets.

We summarized the species composition of all fish collected with our sampling. In addition, we summarized the composition and distribution of potentially piscivorous species ≥150 mm FL. Predation studies on salmonids in the Columbia River basin typically collect diet information for piscivorous fish ≥ 200 mm FL (Vigg et al. 1991; Tabor et al. 1993). We selected a minimum size of 150 mm FL because smaller piscivorous fish were likely able to prey on the small salmonid fry available in the reservoir. Distributions of predators were summarized as catch per unit effort (CPUE) in the lower and middle reservoir sections and the two arms of the upper section (Figure 4-1).

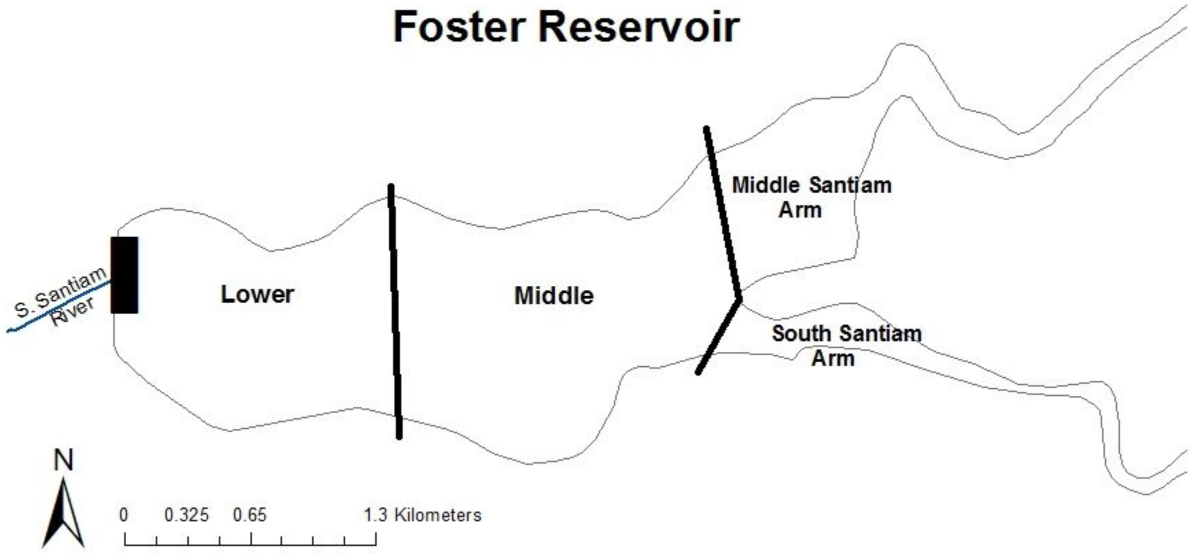

Figure 4-1. Foster Reservoir sections used for sampling fish in 2013. The upper reservoir section was divided into the Middle Santiam and South Santiam arms.

Predatory Fish Diet Analysis

Only predators ≥ 150 mm FL sampled from gill nets or by 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. 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 euthanized with 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® on ice in the field and then frozen until processing.

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 diet categories present, resulting in a sum of prey taxonomic categories > 100%. Therefore, we scaled frequency of occurrence results to 100%.

Consumption Rates

We estimated consumption rates of juvenile Chinook salmon and *O. mykiss* by 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 a salmonid species (fish/d), n = number of juvenile salmonids consumed, and N = number of predators sampled, including those with empty stomachs.

Consumption rates were calculated for each prey species. However, not all salmonids in diet samples were identifiable to species, so we assigned unknown salmonids to species based on relative abundance of known salmonids found in diet samples.

Based on observed water temperatures and size of predators and prey, we predicted that a portion of salmonid 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 predator 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 and *O. mykiss* prey, average size of predators sampled, and water temperatures for each season. Average size of available Chinook salmon and *O. mykiss* prey was estimated from length information in Section 2 of this report and weights (g) calculated from length-weight relationship of Vigg et al. (1991). We used the evacuation model developed by Beyer et al. (1988) for northern pikeminnow. For smallmouth bass, we used the evacuation model developed by Rogers and Burley (1991). This model required smallmouth bass weights (g) that we estimated from a length-weight relationship developed by Kolander et al. (1993), with fork length converted to total length using the formula by Carlander (1977). 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 or *O. mykiss* consumed per day.

Results

Species Composition

Sampling included 11.8 h of boat electrofishing, 25 large-mesh gill net sets, 25 small-mesh gill net sets, and 12 large Oneida Lake trap sets in addition to nearshore trapping in Foster Reservoir (see Section 1) and screw trapping below the dam. We captured a total of 17 fish species, seven of which were non-native (Table 4-1). Several thousand young-of-year northern pikeminnow and bluegill *Lepomis macrochirus* were caught during October in nearshore traps. Excluding these fish, yellow perch were the most numerically dominant species collected in in our sampling. However, most (70%) yellow perch were collected in the screw trap below the dam.

Among piscivorous fish species ≥150 mm FL, smallmouth bass were the most numerous (n=142); rainbow trout (n=121), yellow perch (n=101), and northern pikeminnow (n=98) were also relatively abundant. Largemouth bass were rare (n=6) and no large crappie were collected. Smallmouth bass CPUE during boat electrofishing was higher in the lower reservoir and the Middle Santiam arm. The greatest northern pikeminnow CPUE occurred in the South Santiam arm. Gill net CPUE for pikeminnow was also greatest in the South Santiam arm. Northern pikeminnow were the largest piscivorous species in size with some individuals over 500 mm FL (Figure 4.2). We did not sample many smallmouth bass or yellow perch over 250 mm FL and most rainbow trout were less than 200 mm FL (Figure 4-2).

Predatory Fish Diet Analysis

We collected diet samples from smallmouth bass, northern pikeminnow, yellow perch, rainbow trout and yellow bullhead ≥150 mm FL in Foster Reservoir. A total of 196 samples were collected in the spring, 76 in summer, and 18 in fall. Most samples came from smallmouth bass and northern pikeminnow during spring and summer (Table 4-2). Fewer samples were collected in the fall mainly because of reduced CPUE during fall electrofishing. Bullheads were the only potentially piscivorous species in which we did not find fish in stomach samples (Table 4-3). Smallmouth bass and northern pikeminnow had fish as the dominant prey item and were the only species that contained juvenile salmonids in their stomachs.

Table 4-1. Number and size of fish species collected in Foster Reservoir, 2013. Data does not include young-of-year northern pikeminnow and bluegill caught in the fall. Fish were captured using floating box traps (236 sets), small Oneida traps (61 sets), large Oneida traps (12 sets), boat electrofishing (11.8 hours), gill netting (25 large-mesh, 25 small-mesh sets), and a screw trap in the Foster Dam tailrace. Asterisks denote non-native species.

Species	Number captured	Mean fork length (mm)	Fork length range (mm)
Cutthroat trout *(O. clarkii)*	4	126	86 -169
Rainbow trout/steelhead *(O. mykiss)*	653	114	50-500
Hatchery rainbow trout *(O. mykiss)*	121	229	110-336
Chinook salmon (*O. tshawytscha*)	631	66	31-385
Kokanee *(O. nerka)*	181	143	24-375
Northern pikeminnow *(P. oregonensis)*	413[b]	160	23-525
Yellow Perch *(Perca flavescens)**	1,080	104	34-290
Sculpin *(Cottus* spp.*)*	57	64	23-94
Largemouth bass *(M. salmoides)**	9	193	35-440
Smallmouth bass (*M.dolomieu)**	386	144	38-371
White crappie *(Pomoxis annularis)**	7	113	99-148
Bluegill *(Lepomis macrochirus)**	233[b]	103	16-183
Brown bullhead *(Ameiurus nebulosus)**	14	85	32-305
Yellow bullhead *(A. natalis)**	69	79	32-240
Redside shiner *(Richardsonius balteatus)*	162	47	25-85
Dace *(Rhinichthys* spp.*)*	61	41	24-95
Largescale sucker *(Catostomus macrocheilus)*	219	57	34-495
Brook lamprey *(Lampetra richardsoni)*	20	199	158-210

[b] Young-of-year northern pikeminnow (n=5,639) and bluegill (n=5,356) were also caught in October.

Table 4-2. Total number of diet samples collected and percent empty by predator species in Foster Reservoir, 2013.

			Spring		Summer		Fall	
Species	Total samples	% empty	N	% empty	N	% empty	N	% empty
Rainbow trout[a]	11	9.1%	6	16.7%	0	0.0%	5	0.0%
Yellow bullhead	6	33.3%	4	25.0%	2	50.0%	0	0.0%
Yellow Perch	66	48.5%	58	48.3%	6	66.7%	2	0.0%
N. pikeminnow	93	62.4%	61	63.9%	26	65.4%	6	33.3%
Smallmouth bass	114	15.8%	67	17.9%	42	7.1%	5	60.0%

[a] Includes both naturally-produced (N = 2) and hatchery rainbow trout (N = 9).

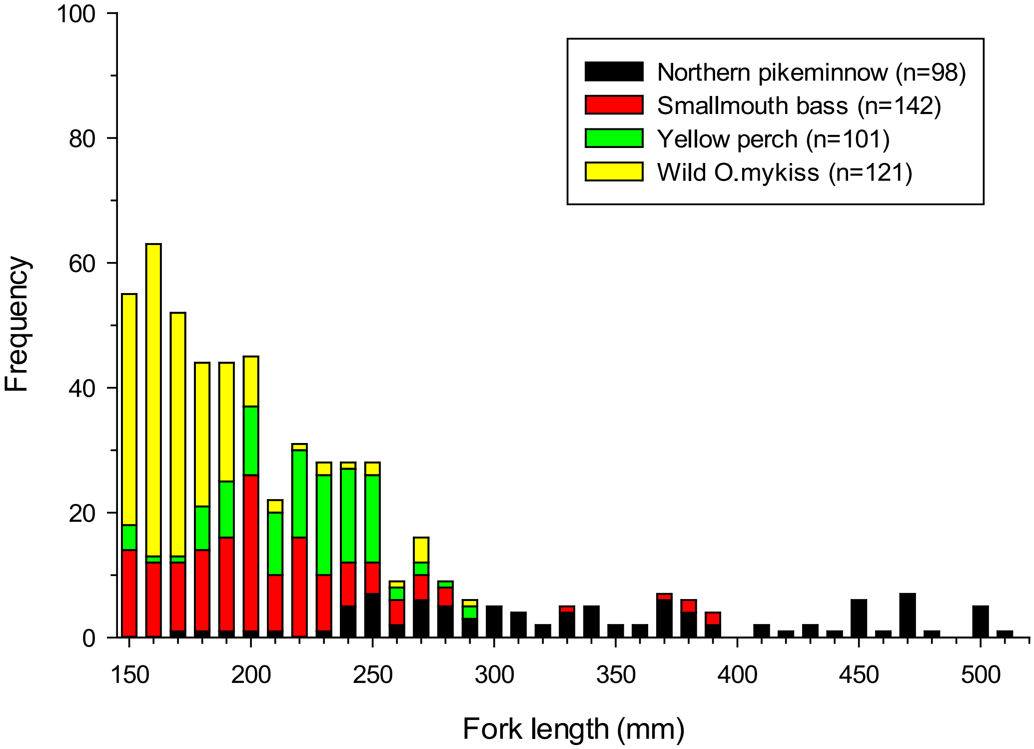

Figure 4-2. Length frequency of the most common piscivorous fish over 150 mm fork length collected in Foster Reservoir, 2013.

Table 4-3. Mean fork length and range of predatory species collected for diet sampling and size of fish that consumed juvenile Chinook salmon (CHS), *O. mykiss* (RbT), or unknown salmonids (Unk) in Foster Reservoir, 2013.

Species	Mean fork length (mm)	Minimum predator size (mm) with fish in diet	Fork lengths (mm) of predators with CHS, RbT, or Unk prey
Rainbow trout	269 (188 – 336)	248	
Yellow bullhead	191 (167 – 240)	none	
Yellow perch	219 (155 – 290)	177	
Northern pikeminnow	347 (168 – 525)	177	RbT: 325,430, 500 Unk: 366
Smallmouth bass	209 (110 – 390)	150	CHS:(182-215) RbT:(222-255)

Smallmouth Bass- A total of 114 smallmouth bass were sampled, with 96 containing non-empty stomachs. Smallmouth bass had the highest occurrence frequency of fish (55%) in their stomachs (Figure 4-3). Crayfish was also a prevalent prey item (35%) during the spring and summer (Figure 4-3). In the fall, fish were the only prey item found in stomachs, but only three smallmouth bass were sampled. For the year, we found 102 individual fish consumed by 64 smallmouth bass. Sculpin (n=26) comprised most of these prey fish. Fifteen prey fish were salmonids: seven Chinook salmon, six *O. mykiss*, and two unidentifiable salmonids (Table 4-4). All salmonid consumption occurred in the spring.

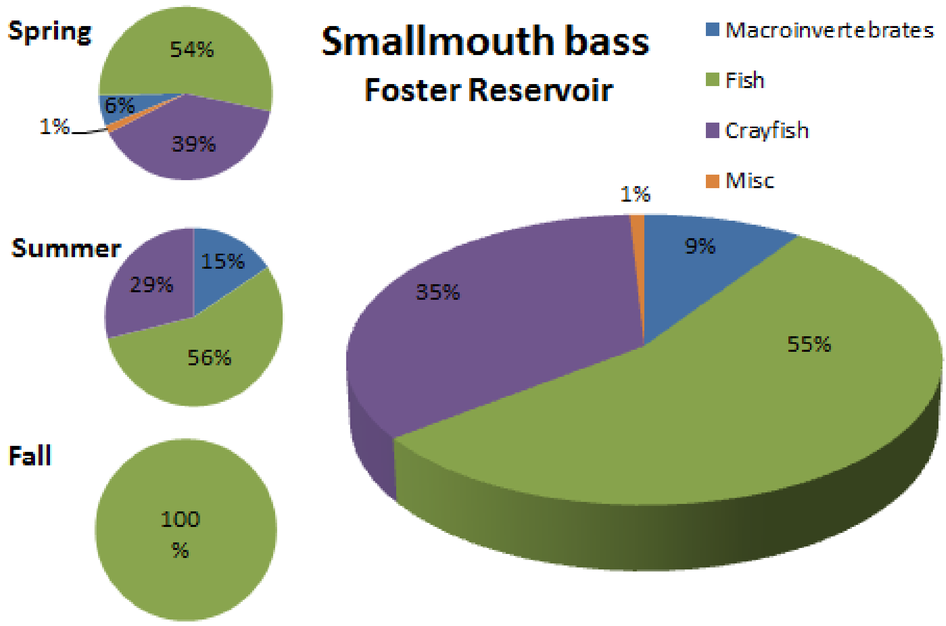

Figure 4-3. Occurrence frequency of prey taxon in smallmouth bass diets in Foster Reservoir, 2013. Frequencies were scaled to 100%.

Table 4-4. The number of prey fish by species/group found in the diet samples of piscivorous fish in Foster Reservoir, 2013. Numbers in parentheses are non-empty stomachs sampled.

	Piscivorous species			
Prey species	Rainbow trout (10)	Yellow perch (34)	Smallmouth bass (96)	Northern pikeminnow (35)
Chinook	0	0	7	0
O. mykiss	0	0	6	4
Unknown salmonid spp.	0	0	2	1
Sucker	0	1	8	0
Sculpin	1	1	26	1
Bullhead spp.	0	0	0	1
Yellow perch	0	0	15	3
Bluegill	0	2	16	3
Smallmouth bass	0	0	3	3
Unk centrarchid spp.	0	1	12	11
N. pikeminnow	0	0	1	0
Brook lamprey	0	0	0	1
Unkown fish spp.	0	3	6	7[a]
Total	1	8	102	35

[a] one of the unknown fish spp. was an unknown non- salmonid

Northern Pikeminnow- A total of 93 northern pikeminnow were sampled with only 35 containing non-empty digestive tracts. This was the lowest rate of non-empty samples among piscivorous species and likely attributable to the more rapid digestion rate for this species. Northern pikeminnow had a greater diet diversity compared to smallmouth bass, but fish were the most frequently occurring prey item (54%) (Figure 4-4). We found a higher frequency of fish in stomach samples during spring and fall compared to the summer when macroinvertebrates and mollusks occurred more frequently (Figure 4-4). However, fall results are based on only four fish.

Centrarchids were the most prevalent prey fish (49%) found in northern pikeminnow samples (Table 4-4). Five salmonids were consumed; four *O. mykiss* and one unidentifiable salmonid. The four pikeminnow that consumed salmonids ranged in size from 325 – 500 mm FL (Table 4-3) and were all captured in mid-May with gill nets. One pikeminnow consumed a western brook lamprey.

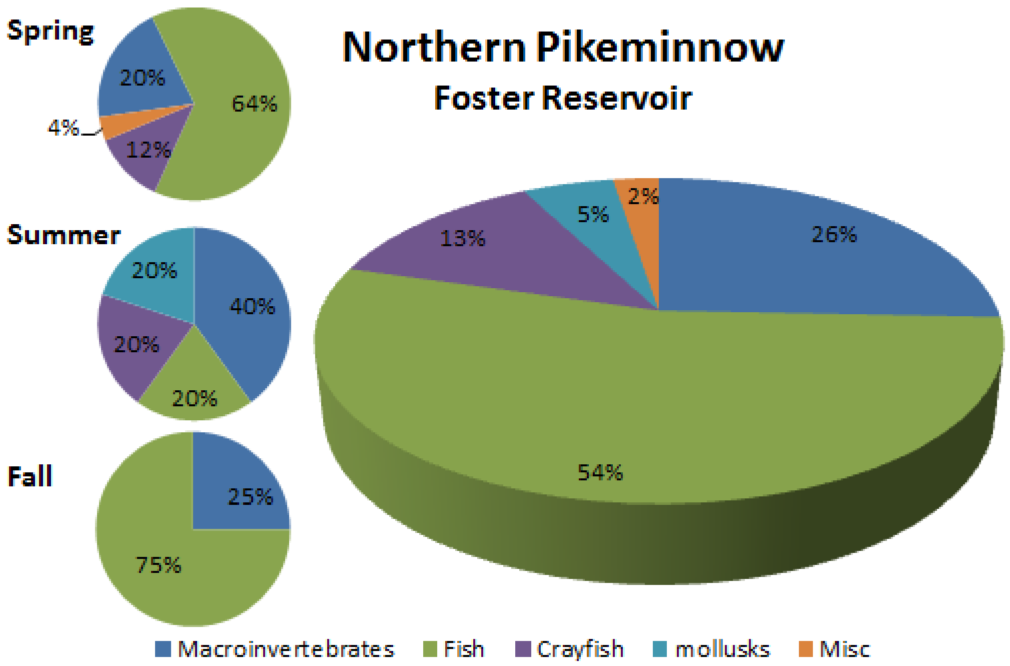

Figure 4-4. Occurrence frequency of prey taxon in northern pikeminnow diets in Foster Reservoir, 2013. Frequencies were scaled to 100%.

Yellow Perch – A total of 66 yellow perch were samples with 34 containing non-empty stomachs. Over half of the prey items found in yellow perch diet samples were mollusks and fish comprised only 19% (Figure 4-5). Mollusks and crayfish comprised most of the prey found in spring and summer samples suggesting a benthic feeding niche, especially in the summer (Figure 4-5). Fish were present in both spring (16%) and fall (67%) samples; however, only two yellow perch were collected for diet sample analysis in the fall. None of the eight prey fish found in yellow perch stomachs were salmonids, but there were three fish that were not assignable to family. The other five prey fish were a combination of largescale suckers, sculpin, bluegill, and an unidentifiable centrarchid (Table 4-4).

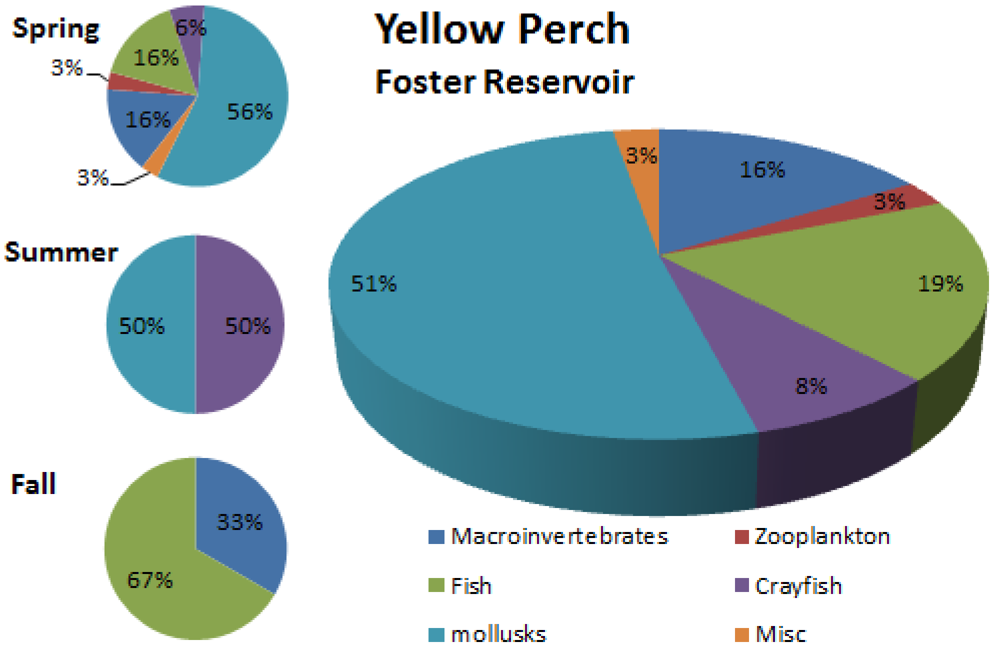

Figure 4-5. Occurrence frequency of prey taxon in yellow perch stomachs sampled in Foster Reservoir, 2013. Frequencies were scaled to 100%.

Rainbow trout- Rainbow trout comprised a small number (n=11) of predators sampled. Nine of these rainbows were of hatchery origin. We intentionally did not sample wild *O. mykiss* <150 mm FL because they could potentially be steelhead. Rainbow trout were largely insectivorous. One sculpin was identified in a stomach of a 248 mm FL hatchery rainbow trout in the spring. Due to the small sample size of rainbow trout, this one sculpin resulted in fish comprising 15% of prey in spring rainbow trout diet samples (Figure 4-6). By fall, rainbow trout were exclusively insectivorous based on the five trout sampled.

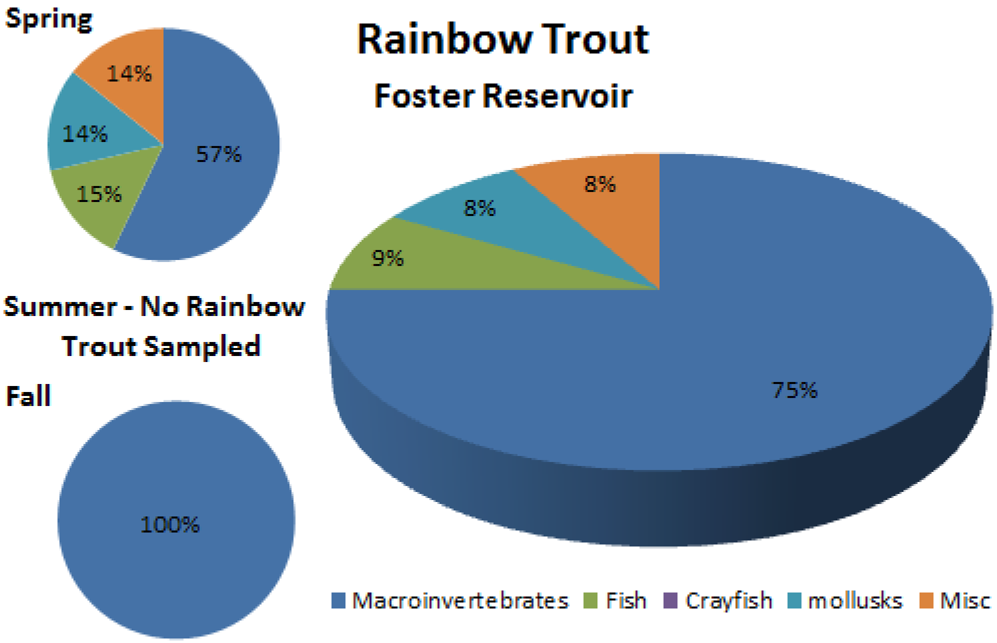

Figure 4-6. Occurrence frequency of prey taxon in rainbow trout diets in Foster Reservoir, 2013. Frequencies were scaled to 100%.

Bullheads- All six bullheads sampled in 2013 were yellow bullhead. We collected the samples in late spring (n=4) and early summer (n=2), but the stomach samples contained no fish (Table 4-3). Four bullhead diet samples contained crayfish, and two were empty (Table 4-2). Bullheads are opportunistic piscivores that are typically nocturnal in their feeding activity and benthic oriented. We did not capture any bullheads greater than 150 mm FL for diet sampling during the fall.

Consumption Rates

We estimated consumption rates for smallmouth bass and northern pikeminnow on juvenile salmonids in the spring. Chinook salmon and *O. mykiss* were the only identifiable salmonids in diet samples (Table 4-4). There were three unidentifiable salmonids (two in smallmouth bass; one in a pikeminnow). We assigned a species designation to the unknown salmonids based on the relative abundance of known salmonids found in diet samples for each predator species. Juvenile Chinook salmon and *O. mykiss* were found in relatively equal proportion in smallmouth bass stomachs so the two unknown salmonids were split between these two prey species. Only *O. mykiss* were found in northern pikeminnow samples so the one unknown salmonid was designated as *O. mykiss*. We did not assign kokanee to any of the unknown salmonid prey items because of their low relative abundance in the reservoir and our diet analysis found no identifiable kokanee prey items.

Calculation of evacuation rates showed that only northern pikeminnow were likely to completely evacuate salmonid prey in less than 24 h after consumption. The average-sized Chinook salmon (70 mm FL, 3.5 g @ T=16º C) and *O. mykiss* (113 mm, 12g @ T=16º C) available as prey in spring were estimated to be completely evacuated within 6.3 h and 13.3 h, respectively for an average-sized northern pikeminnow (347 mm FL, 434 g). Therefore consumption rates for northern pikeminnow were multiplied by a factor of 3.8 for Chinook and 1.8 for *O. mykiss* to provide daily consumption rates (salmonids/d).

We found no evidence of consumption on juvenile Chinook salmon by northern pikeminnow but consumption on juvenile *O. mykiss* was 0.148 fish/d. Smallmouth bass consumed 0.119 juvenile Chinook/d and 0.104 *O. mykiss*/d during the spring (Table 4-5). Non-salmonid fish consumption during the spring was four to six times greater than that of salmonid consumption (Table 4-5). Most of these non-salmonid prey fish were sculpin, yellow perch, or centrarchids and were equivalent in size to available salmonid prey.

Table 4-5. Daily consumption rates (fish/d) of juvenile Chinook salmon and *O. mykiss* by predator species during spring in Foster Reservoir, 2013. Consumption rates with unidentified salmonids not assigned to species are given in parentheses.

Predator species	Prey species		
	Chinook	*O. mykiss*	Non – Salmonid[b]
Northern pikeminnow	0.000 (0.000)	0.148[a] (0.118)	0.707
Smallmouth bass	0.119 (0.104)	0.104 (0.090)	0.597

[a] The consumption rate uncorrected for evacuation rate was 0.082 (0.066) fish/d.

[b] Includes unknown non-salmonid prey species and assumes similar evacuation rates as *O. mykiss*.

Discussion

We collected 17 fish species in Foster Reservoir in 2013 including seven non-native species. Among the large predator species capable of preying on juvenile Chinook salmon and steelhead, smallmouth bass and northern pikeminnow were the only ones that consumed salmonids and therefore present the greatest risk. Yellow perch and rainbow trout were also common but did not consume juvenile salmonids. Largemouth bass were rare, confirming previous observations that smallmouth bass have largely supplanted largemouth bass in the reservoir over the last few decades.

Smallmouth bass and northern pikeminnow tended to be distributed in different areas of the reservoir. Smallmouth were more common in the lower reservoir along the rip-rap shoreline and dam face as well as the Middle Santiam arm where submerged tree stumps were common. Smallmouth bass prefer rocky structures, logs, and piers (Etnier and Starnes 1993) and will seek out rock ledges and crevices to hibernate (Keating 1970). Northern pikeminnow were most common in the South Santiam arm of the upper reservoir. We also observed greater abundance of northern pikeminnow in the upper end of Lookout Point Reservoir (see Section 5 of this report). It is unclear whether pikeminnow congregate in the

South Santiam arm because of prey availability or in preparation for spawning. Northern pikeminnow are broadcast spawners that gather in large aggregations to deposit eggs over clean, rocky substrate in slow moving water (Beamesderfer 1992). In John Day Reservoir, Vigg et al. (1991) noted consumption rates for northern pikeminnow were greater in the upper reservoir whereas smallmouth bass consumption rates were highest in the middle and lower reservoir.

Prey fish comprised the majority of items consumed by smallmouth bass and northern pikeminnow, whereas yellow perch and rainbow trout consumed fish at a much lower frequency. Rainbow trout become increasingly piscivorous after reaching a threshold size of about 250-300 mm FL (Larkin and Smith 1954; Parkinson et al. 1989) but there were few trout of this size in Foster Reservoir. Therefore, it is not likely that rainbow trout have a large impact on juvenile salmonids.

Smallmouth bass predation on Chinook salmon and *O. mykiss* in Foster Reservoir is likely driven by habitat overlap and migration timing. 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). Most juvenile Chinook found in smallmouth bass stomachs were from collections in the lower and middle sections of the reservoir, though several samples were obtained from bass in the Middle Santiam arm. Subyearling Chinook were more abundant in the lower and middle sections of the reservoir (Section 1 of this report). The majority of smallmouth bass we sampled were less than 200 mm FL and salmonid consumption occurred in the spring. Moyle (2002) found that smallmouth bass prey consists mainly of fish and crayfish once they reach a size of 100 – 150 mm FL. Pflug and Pauley (1984) noted that crayfish are a large part of smallmouth diet, but that salmon become the major diet component when salmon are migrating during the spring.

The relative small size of smallmouth bass and the rapid growth of juvenile Chinook salmon suggest that Chinook salmon would only be vulnerable in the spring. Subyearling steelhead enter the reservoir in summer and fall and would theoretically be vulnerable to predation during this time. We were unable to collect many stomach samples from predators in the fall to accurately describe predation. However, the availability of young-of-year bluegill and northern pikeminnow in the fall may lessen the risk to subyearling steelhead.

We did not observe consumption of juvenile Chinook by northern pikeminnow. This could be a function of apparent limited spatial overlap, with northern pikeminnow more abundant in the upper reservoir and juvenile Chinook more abundant in the lower reservoir. However, caution should be taken in interpreting our results since sample size was limited (n=35 non-empty stomachs). Most diet studies are conducted over several years with larger sample sizes than we were able to collect for this study. We did detect consumption of *O. mykiss* by northern pikeminnow. A portion of the prey fish could be hatchery rainbow trout since several thousand hatchery rainbow trout were stocked into the upper reservoir in the spring. Most hatchery trout are >195 mm FL and therefore likely only vulnerable to the larger northern pikeminnow. Consumption rates on juvenile *O. mykiss* by northern pikeminnow and smallmouth bass were similar. We estimated both predators would each consume an *O. mykiss* approximately once every 10 days on average in the spring. We estimated similar consumption on juvenile Chinook salmon by smallmouth bass in the spring. The consumption rates are comparable to estimates for northern pikeminnow in Lookout Point Reservoir (Monzyk et al. 2013). The impact of predators on the juvenile salmonid survival in Foster Reservoir depends in large part on the population sizes of predators. We currently do not have population estimates of predator species in Foster Reservoir.

The small size of juvenile Chinook salmon during spring and juvenile steelhead in late summer complicated our analysis of diet habits of predators in Foster Reservoir due to the rapid digestion rate of smaller prey and because they are more likely to be missed during sample processing. 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, $P = 0.936$, $z = 0.081$). 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 is a conservative estimate.

SECTION 5: ABUNDANCE OF PISCIVOROUS SPECIES IN LOOKOUT POINT RESERVOIR

Background

A diverse assemblage of piscivorous fish species reside in Lookout Point Reservoir including crappie, walleye, northern pikeminnow, and largemouth bass. All these species are known to prey on Chinook salmon in the reservoir (Monzyk et al. 2013). 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). In Lookout Point Reservoir, northern pikeminnow, largemouth bass, and walleye had the highest occurrence of fish in their diet. Although walleye had the greatest overall consumption rate of juvenile Chinook salmon, northern pikeminnow were more abundant and likely present the greatest predation risk to Chinook salmon. We concluded that juvenile salmonids in Lookout Point Reservoir were at greater risk of predation compared to Detroit and Cougar reservoirs based on predator species composition and relative abundance (Monzyk et al. 2012, 2013).

A deep drawdown operation of Lookout Point Reservoir has been considered by managers to improve conditions for juvenile fish passage and reduce predator populations (USACE 2012). To assess the impact of a drawdown on predator populations, information is needed on current population levels. A standardized approach is important to provide consistent and measurable fish community metrics that can be repeated over time to detect changes in the predator species community (IDFG 2012). Our objective this year was to conduct systematic, standardized sampling in the reservoir pre-drawdown to develop relative abundance indices for predators that can be compared to indices after operational changes. We also assessed the distribution of predators in the reservoir.

In 2011 and 2012 we collected diet samples from northern pikeminnow and calculated daily consumption rates of juvenile Chinook salmon. To relate this metric to the number of fish consumed, an abundance estimate of northern pikeminnow is needed. Therefore, our final objective was to conduct additional sampling to estimate northern pikeminnow abundance in Lookout Point Reservoir.

Methods

Predator Relative Abundance Indices

Boat electrofishing, gill netting, and Oneida Lake traps were used for standardized sampling to reduce potential species vulnerability bias with any one gear type. We used a stratified random sampling design with the reservoir divided into upper, middle, and lower sections and areas within each section randomly selected for sampling.

Electrofishing- Boat electrofishing was conducted both day and night in May and June. Each unit of electrofishing effort consisted of 900 seconds (15 minutes) of shocking time along a randomly selected shoreline area approximately 800 m (0.5 mile) in length. The generator powered pulsator (GPP) was set to 1,000 V with a pulse width of 5 ms and a frequency of 120 DC. Equal electrofishing effort occurred in each reservoir section (lower, middle, upper) per week. All predator species netted were enumerated and measured for fork length (nearest mm). We also recorded the number of each predator species that we were unable to net into the boat. For each unit of effort, we recorded surface water temperature and GPS coordinates for the beginning and ending locations.

Gill netting- Standardized gill netting was conducted in the reservoir in May and June. Gill nets were experimental type nets that consist of four 7.6 m x 3.0 m panels of different mesh size (7.6-cm, 6.4-cm, 5.1-cm, 3.8-cm square mesh). A sinking and floating net were set in pairs and fished at a site for 24 hours. Nets were deployed perpendicular to shore with the smallest mesh closest to the bank. The number and size of all fish species in each net were recorded (nearest mm). Fish caught in the floating and sinking nets were recorded separately.

Oneida Lake trapping- We set Oneida Lake traps in the reservoir in May and June. An Oneida Lake trap consisted of a 0.64 cm mesh holding box (2.4 m x 2.4 m x 2.4 m) with a lead net (34.1 m x 3.0 m) extending from shore to the box and two wings (7.2 m x 3.0 m) set at 45° angles leading into the box. Oneida traps were a passive capture gear type designed to intercept fish moving within 34.1 m along the shoreline and in the upper 3.0 m of the water column. Traps were fished for approximately 24 h. All fish caught were enumerated and fork length recorded on all piscivorous species.

For each gear type, we compared catch per unit effort (CPUE) among species captured with Kruskal-Wallis one-way ANOVA tests ($\alpha=0.05$). We also compared differences in size for each species among reservoir sections with Kruskal-Wallis one-way ANOVA tests ($\alpha=0.05$).

Northern Pikeminnow Population Size

All northern pikeminnow ≥150 mm FL captured with Oneida Lake traps or by standardized electrofishing were PIT-tagged in the dorsal sinus and the left ventral fin was removed as a secondary mark. We conducted additional electrofishing to maximize capture and tagging of northern pikeminnow. For this effort, areas were selected (non-randomly) that potentially had high CPUE based on habitat characteristics or previous sampling. There were no limits on the amount of shocking time or shoreline length sampled. Areas within each reservoir section were sampled but effort was not equal among sections. Sampling occurred from mid-April to early-July. We recorded the number and size of all species collected and the number observed but not netted. The number of seconds shocked was recorded along with starting and ending coordinates of the shoreline sampled. All northern pikeminnow captured were examined for previous marks and if not marked, given a PIT tag and left ventral fin clip.

To determine whether a closed capture population model was appropriate, we first used a Cormack-Jolly-Seber estimator (open population estimator) to estimate survival between weekly sampling intervals and over the course of our 10-week season. This allowed us to determine whether pikeminnow were removed from the sampling area through natural mortality or passage through Lookout Point Dam.

We used the Huggins closed-capture model in program MARK (White and Burnham 1999) to estimate northern pikeminnow abundance, with ten consecutive encounter occasions. This model requires a minimum of three sampling occasions to estimate capture probabilities and can include covariates that are known to affect capture probabilities [e.g., fish size, temperature, reservoir zone (Peterson and Paukert 2009)]. The Huggins model does not directly estimate abundance, but rather abundance (N) is derived using the following formula:

$$N = M_t / (1 - [(1-p_1)(1-p_2)(1-p_3)(1-p_4)(1-p_5)(1-p_6)(1-p_7)(1-p_8)(1-p_9)(1-p_{10})]),$$

where M_t is the total number of marks in the population, p_1 is the probability of capture for occasion one, p_2 is the probability of capture for occasion two, p_3 is the probability of capture for occasion three, etc.

We calculated 95% confidence intervals for this estimate according to Chao (1987) and calculated 95% confidence intervals for the estimate obtained from the Ricker model using a Poisson approximation (Ricker 1975).

To evaluate which of the independent variables in our Huggins closed-capture model (sampling occasion, effort, sampling protocol, fork length, or zone of capture) had a greater effect on the dependent variable (capture probability), we examined the parameter estimates for the best approximating capture probability model. The parameter estimates were on a logit scale, so to facilitate interpretation of the parameters we calculated the odds ratios by exponentiating the parameter estimates (Hosmer and Lemeshow 2000). Odds ratios are an estimate of the odds of an event occurring (here, capture of a fish) in response to increasing the predictor variable one unit or the relative differences between two groups. An odds ratio of one is interpreted as no effect on the response or no differences between groups. An odds ratio estimate greater than one is interpreted as a positive effect. An odds ratio estimate less than one is interpreted as a negative effect. For example, if the odds ratio is 0.322 for sampling occasion 1 vs. 2, then fish are approximately 3 times (1/0.322) less likely to be captured on occasion 2 compared to occasion 1.

To account for the fact that all fish are not always available for capture (in a reservoir section other than the one currently being sampled), we created a variable that indicated whether the sampling was being conducted in the section where the fish was caught and tagged the first time. We also added covariates for recapture effect, fork length, electrofishing effort, average temperature, indicator variables (0,1) for: standard day sampling effort, standard night electrofishing effort, and ‘other methods’ (Oneida trap, hook and line, gillnet combined) . We created a capture history and fit all possible subsets of the covariates listed above then selected the best model using Akaike’s Information Criteria with small sample bias adjustment (AICc; Burnham and Anderson 2002).

Distribution

We evaluated distribution of piscivorous species by plotting CPUE during electrofishing to shoreline distance to the dam. We used the combined electrofishing effort from standardized sampling and non-standardized sampling conducted for northern pikeminnow population estimates with CPUE calculated as fish caught per 15 m of shock time. We also compared CPUE among reservoir sections for other gear types if sufficient fish numbers were collected.

Results

We collected 364 piscivorous fish in Lookout Point Reservoir during standardized sampling (Table 5-1). An additional 1,155 fish were collected via electrofishing as part of the pikeminnow population estimate. Several hundred young-of-year crappie were also collected during June electrofishing but not included in the analysis. We initially conducted daytime electrofishing but catch rates for northern pikeminnow and walleye were low, so nighttime electrofishing was conducted to improve capture efficiency. Only nighttime electrofishing results during standardized sampling were used for developing abundance indices.

Table 5-1. Number of piscivorous fish caught by gear type in Lookout Point Reservoir, 2013.

	Species					
Gear-type	Crappie	Northern pikeminnow	Largemouth bass	Walleye	Bullhead	Gear Total
Oneida Lake trap	6	13	0	0	1	**20**
Gillnet -Floating	3	30	0	0	2	**35**
Gillnet -Sinking	78	26	7	9	11	**131**
Boat electofishing (standardized)	13	70	67	20	8	**178**
Boat electrofishing (non-standarized)	47	835	131	63	79	**1,155**
Species total	**147**	**974**	**205**	**92**	**101**	**1,519**

Predator Abundance Indices

We conducted 9.1 h of standardized night electrofishing, 12 Oneida Lake trap sets, and 21 gill net sets (both floating and sinking) from 28 May to 27 June, 2013. Additionally, we used the total of fish netted and observed during electrofishing when calculating CPUE. Few black crappie *Pomoxis nigromaculatus* were captured (n=4) and were combined with white crappie for analysis. Similarly, brown bullhead *Ameiurus nebulosus* (n=2) were combined with yellow bullhead for analysis.

Northern pikeminnow had the highest CPUE for all gear types with the exception of crappie in sinking gill nets (Figure 5-1). Northern pikeminnow CPUE was significantly higher than other species collected with boat electrofishing and floating gillnets (Kruskal-Wallis ANOVA on ranks, *P*<0.05). There was no significant difference in CPUE between crappie and northern pikeminnow captured in Oneida Lake traps and sinking gillnets. Overall, sample sizes were small for Oneida Lake traps (n=12 sets) which resulted in lower power to detect differences with this gear type.

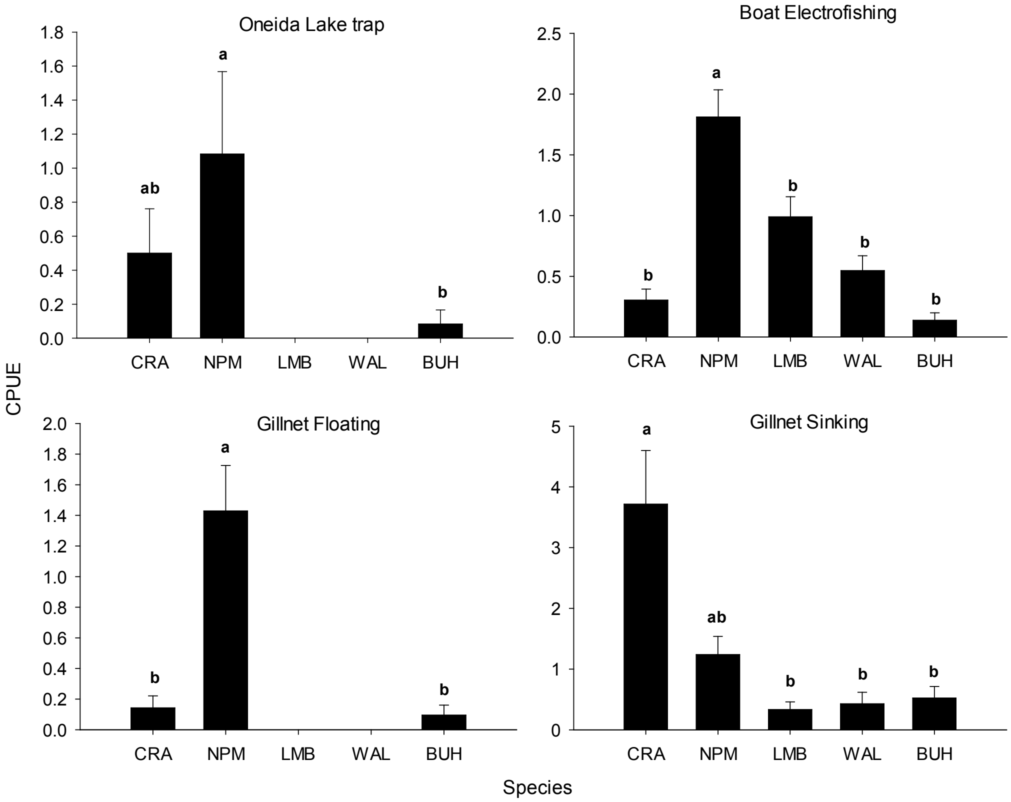

Figure 5-1. Mean catch per unit effort (CPUE) of piscivorous fish species in Lookout Point Reservoir by gear type, 2013. Species codes are as follows: CRA=crappie spp.; NPM=northern pikeminnow; LMB=largemouth bass; WAL=walleye; BUH=bullhead spp. Within a panel, bars not having a letter in common are significantly different. Error bars are the standard error.

Northern Pikeminnow Population Size

We tagged 844 pikeminnow ≥150 m FL over the course of 10 weeks and recaptured 58 tagged fish with a total shocking effort of 69 h (Table 5-2). Only six of the recapture events occurred in a reservoir section other than the section where the fish was initially tagged. Reservoir pool elevation ranged from 277.4 m above sea level on April 24 to 275.2 m on July 2, 2013.

Table 5-2. Number of northern pikeminnow (NPM) tagged, recaptured, and the associated electrofishing effort summarized by reservoir zone in Lookout Point Reservoir, 2013.

Section	NPM Tagged	NPM Recaptured	Effort (h)
Lower	112	9	13.6
Middle	216	21	20.7
Upper	516	28	34.5
Total	844	58	68.8

The best model included: Fork length, sampling not in the zone where marked, electrofishing effort, average temperature, standardized day sampling protocol, standardized night electrofishing protocol, and ‘other methods’. The AIC model weights indicate that there was no support for any other model. All parameters in the full model were statistically significant ($\alpha = 0.05$) except for fork length.

Weekly survival probability (between sampling intervals) was 99.3% and over the course of 10 weeks the survival probability was 93.2%. This indicated that tagged northern pikeminnow were not being removed (dying or leaving) from the population between sampling intervals. In addition, to verify that tagged pikeminnow were not exiting Lookout Point Reservoir, we scanned all northern pikeminnow captured just downstream of Lookout Point Dam in Dexter Reservoir during a northern pikeminnow derby held on July 27-28, 2013, after all tagging was completed. We scanned 2,059 pikeminnow from Dexter Reservoir and no tagged fish from Lookout Point Reservoir were detected.

The estimate of large northern pikeminnow (≥150 mm FL) present in the littoral zone of Lookout Point Reservoir in 2013 was 7,067 (95% CI 5,466 – 9,224). We believe this is an underestimate due to the large zones (low spatial resolution) used in the model for estimating abundance, along with very low capture probabilities. The c-hat for this model was 5.9, exceeding acceptable values of 1. This indicates that we have overdispersion in our dataset. Stated differently, there was variation in the data set that could not be accounted for by our model.

Distribution

The highest electrofishing CPUE for northern pikeminnow and crappie was in the upper end of the reservoir (Figure 5-2). Crappie were rarely captured during electrofishing but our three highest catches occurred in the upper end of the reservoir. For both species, catch tended to be highest near the head of the reservoir from the township of Hampton upstream to the Hampton boat ramp. Electrofishing capture may have been aided by shallower water in this area, but gillnet captures of northern pikeminnow were also significantly higher in the upper reservoir section (Kruskal-Wallis ANOVA on ranks, $P<0.05$). For crappie, gillnet catch in the upper and middle sections of the reservoir were similar and significantly greater than in the lower section. Largemouth bass and walleye were more abundance in the lower half of the reservoir based on electrofishing CPUE (Figure 5-2). Too few fish of these species were captured with other gear-types to corroborate electrofishing results.

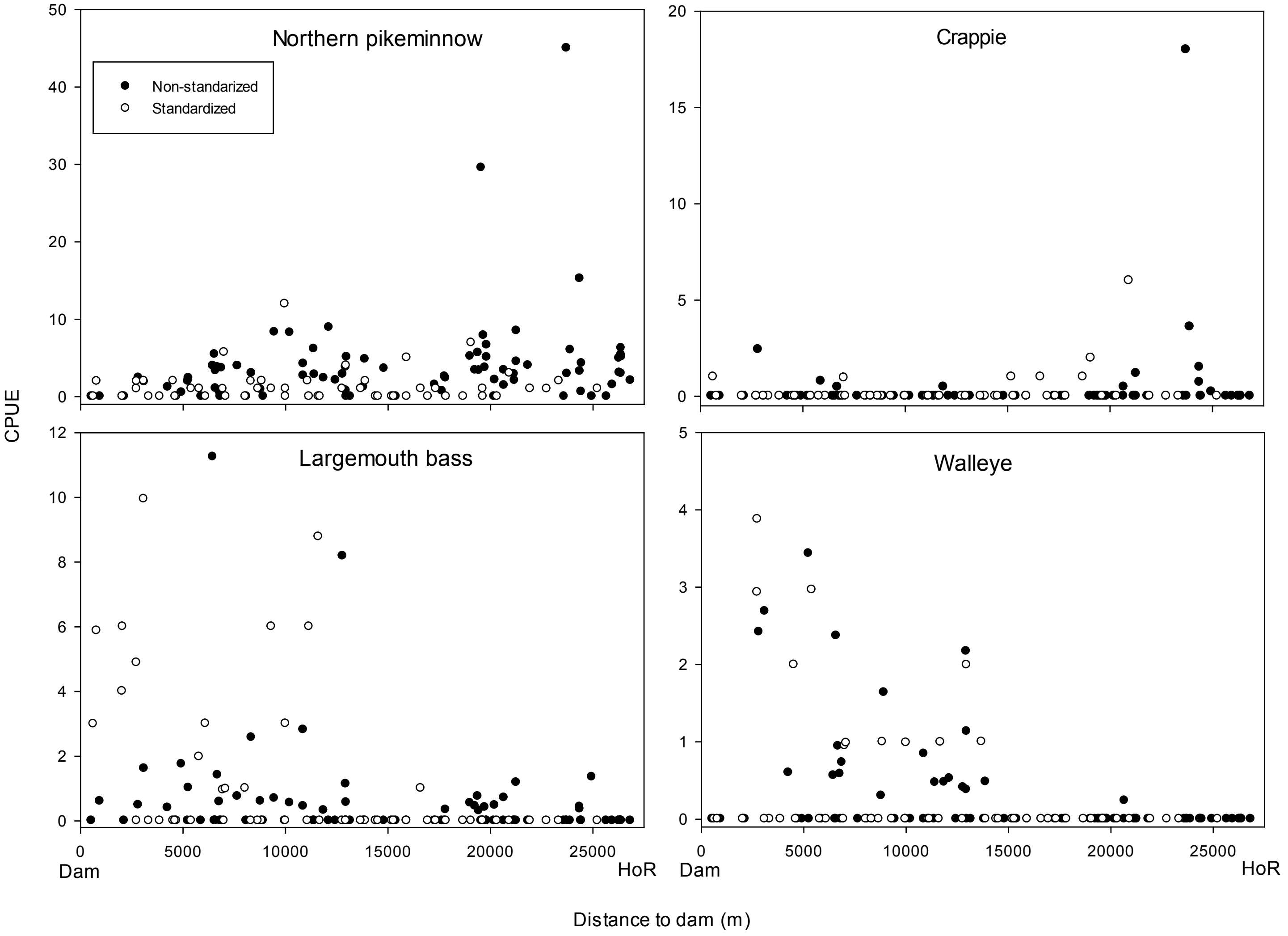

Figure 5-2. Catch per unit effort (CPUE) in relation to shoreline distance for piscivorous fish species caught during electrofishing in Lookout Point Reservoir, 2013. Standardized electrofishing was 900 s shock time at randomly chosen areas and non-standardized involved sampling in just those areas expected to provide good northern pikeminnow habitat. All effort was stratified by reservoir section.

Size- With the exception of crappie, larger individuals of each species were generally found in the upper end of the reservoir (Table 5-3). A length-frequency graph for northern pikeminnow showed a bimodal distribution with larger northern pikeminnow (>300 mm FL) predominately found in the upper reservoir (Figure 5-3).

Northern pikeminnow are a long-lived species that can live up to age 19 (Wydoski and Whitney 2003). Assuming the size-at-age information reported in Wydoski and Whitney (2003) for northern pikeminnow in the Columbia River applies to Lookout Point Reservoir, then northern pikeminnow between 325-500 mm FL were likely age 7-16. Most of the northern pikeminnow we collected were between 220-260 mm FL and were likely age 4 or 5. The reason for the bimodal length-frequency distribution is likely a result of a weak 2007 cohort (age-6 fish).

Table 5-3. Median size of piscivorous fish collected for all gear types by reservoir section in Lookout Point Reservoir, 2013. For each species, fork length values without a letter in common are significantly different.

	Northern pikeminnow			Largemouth bass			Walleye			Crappie		
Reservoir section	n	Median FL (mm)		n	Median FL (mm)		n	Median FL (mm)		n	Median FL (mm)	
Upper	587	258	a	11	350	a	8	483	a	57	300	a
Middle	281	240	b	11	330	a	23	240	b	35	300	a
Lower	102	230.5	b	19	204	b	27	240	b	7	295	a

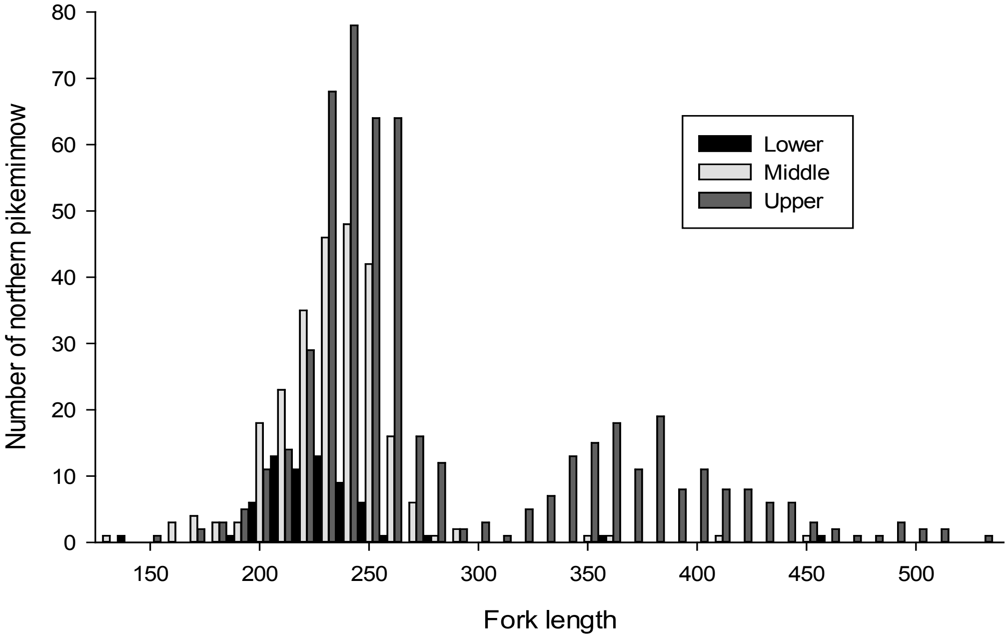

Figure 5-3. Length frequency distribution for northern pikeminnow tagged in Lookout Point Reservoir, 2013.

Discussion

Northern pikeminnow were the most numerically abundant predator species collected during standardized sampling in Lookout Point Reservoir. Northern pikeminnow are native to the Willamette River, and those present in Lookout Point Reservoir are likely a remnant population from the Middle Fork Willamette River prior to the completion of Lookout Point Dam in 1954. Numerous northern pikeminnow were collected in the reservoir by Hasselman and Garrison (1957) soon after completion of Lookout Point Dam. In 2013, most of the northern pikeminnow we captured were in the upper section of the reservoir with few large individuals captured in the lower reservoir sections. The highest capture rates during electrofishing occurred in areas near where the Middle Fork Willamette River enters the reservoir. Most were caught in shallow backwater areas in water temperatures ranging from 19.0-23.5 C. According to Wydoski and Whitney (2003), northern pikeminnow move to shallow areas or near the surface in pelagic portions of lakes to seek out specific temperatures and our results are consistent with findings from Brown and Moyle (1981) stating that northern pikeminnow prefer a temperature range of 16-22°C. Greater abundance in the upper end of the reservoir was also consistent with results in Foster Reservoir that showed greater catch in the upper arm of that reservoir (see Section 4).

Northern pikeminnow spawning in the Columbia River occurs in June – July when water temperatures reach at least 13.9°C (Wydoski and Whitney 2003). This minimum spawning temperature for northern pikeminnow was exceeded in the upper reservoir section of Lookout Point Reservoir by May 1, 2013 and may help explain why fish were congregated in the upper reservoir section. Northern pikeminnow are broadcast spawners that gather in large aggregations to deposit eggs over clean, rocky substrate in slow moving water at a wide range of depths in littoral areas (Beamesderfer 1992). Northern pikeminnow reach sexual maturity between 200 – 350 mm, at ages ranging from 3-8 years with males typically maturing sooner than females (Beamesderfer 1992; Parker et al. 1995). In our study, the larger pikeminnow (>300 mm FL) were almost exclusively captured in the upper end of the reservoir. Pikeminnow can reach a maximum fork length of 600 mm and can live up to 16 years in the Columbia River (Rieman and Beamesderfer 1990; Parker et al. 1995).

Considerable spatial overlap exists between northern pikeminnow predators and juvenile Chinook salmon prey in Lookout Point Reservoir. Chinook salmon subyearlings begin entering the head of the reservoir in January with a peak in movement from February – June (Romer et al. 2012). The mean fork length of subyearlings entering Lookout Point Reservoir during May 2013 was 48 mm (SD = 12.8 mm) and were more abundant near the head of the reservoir (Monzyk et al. 2012). We estimated 7,083 large northern pikeminnow resided in Lookout Point Reservoir in 2013. Consumption rates of juvenile Chinook salmon by northern pikeminnow >150 mm FL in the spring (0.160 fish/d) estimated from previous diet studies in Lookout Point Reservoir (Monzyk et al. 2013) results in an estimated 101,995 juvenile Chinook consumed from April -June. It is possible that the northern pikeminnow population in Dexter Reservoir is much larger than in Lookout Point Reservoir. Over 2,000 northern pikeminnow were caught by anglers in one weekend during a fishing derby held there in July 2013. Mark-recapture efforts during previous derbies resulted in estimates of >20,000 northern pikeminnow (Jeff Ziller, ODFW, personal communication).

Northern pikemionnnow were the most abundant predator collected in surface-oriented gear set in Lookout Point Reservoir whereas both northern pikeminnow and crappie were abundant in bottom-oriented gear, especially in the middle and upper sections of the reservoir. Crappie prefer 4-5 m depth along steeply sloping banks with tree stumps (Markham et al. 1991) and this type of habitat is abundant in Lookout Point and other WVP reservoirs. We did not catch many crappie during electrofishing but the effective range of our boat electrofishing unit was only 2-3 m judging by the depth at which we were able to effectively shock largescale suckers *Catostomus macrocheilus*, which were generally holding close to the substrate.

While northern pikeminnow were more abundant in the upper end of the reservoir, largemouth bass and walleye were caught at higher rates in the lower half of the reservoir. However, the larger individuals of these predator species tended to be in the upper reservoir. We sampled during the spawning season for all these species and the larger individuals may have been in the upper reservoir to spawn. There is a greater diversity of depths, substrate types, and flows in the upper reservoir section that may provide better spawning habitat for predator species. Information on the spawn timing and locations for predator species would be useful to determine if reservoir elevations could be altered to reduce or disrupt spawning activities of predators in the reservoir.

The standardized sampling we conducted could be used to address the impact of altered reservoir operations on spawning success or relative abundance of predator species. One issue that could complicate an analysis is the annual variability in year-class strength for a species that may mask the effect of the reservoir operation. Walleye in the Columbia River are known to have highly variable year-class strengths with occasional dominant years (Rieman and Beamesderfer 1990, Friesen and Ward 2000). In 2011 and 2012, < 9% of the walleye caught were ≤ 250 mm FL but in 2013 the majority (52%) were of this size, suggesting a stronger recruitment in recent years. For northern pikeminnow, age-6 fish (the 2007 cohort) were rare in Lookout Point Reservoir. In 2007, Lookout Point Reservoir never reached full pool and was drawn down beginning in early May. It is possible that the unusual reservoir operation disrupted successful spawning of northern pikeminnow in 2007. Operations in 2010 were similar but drawdown began a month later (6 June). Future predator sampling should shed light on the success of 2010 cohort as they will be large enough to effectively sample with our gear in 2014.

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. The one benefit of reservoir rearing is the rapid growth compared to stream-rearing fish and the survival advantage to adulthood this growth would likely impart. Unfortunately, several factors work against reservoir-rearing fish that may cancel out this benefit. For instance, juvenile Chinook, salmon in reservoirs are more heavily infected with parasitic copepods on the gills that likely results in mortality as they transition to saltwater.

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 more concentrated in the upper end of the reservoirs and slowly dispersed along nearshore habitat towards the dam over the course of the spring. Only a very small proportion of fry-sized Chinook salmon (<60 mm FL) reached the dams by spring. The exception to this was subyearlings in Foster Reservoir. 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 with parasitic copepods and the intensity varied between individuals and reservoirs. We did not quantify the impact of gill tissue damage from infection on juvenile Chinook fitness but strongly suggest this be investigated. The limited studies conducted on the effect of heavy copepod infection suggest that a large portion of reservoir-rearing Chinook salmon will not survive ocean entrance. If this is the case, management strategies need to be implemented to reduce the risk of infection. One possible management action could be the prophylactic treatment of adult salmonids transported above dams, as these fish may be a key source of copepods in the reservoir systems.

We evaluated predation risk to juvenile Chinook salmon by piscivorous fish species in Lookout Point and Foster reservoirs. This was our first year of sampling in Foster Reservoir and sampling was limited. Most diet studies are carried out over several years to provide large enough sample sizes to draw meaningful conclusions. We recommend a second year of predator diet sampling in Foster Reservoir to refine our consumption rate information. In Lookout Point Reservoir, we showed that northern pikeminnow were the most numerically abundant predator species and estimated they consume >100,000 juvenile Chinook in the spring. Based on predation potential, both Foster and Lookout Point reservoirs appear to have a greater predation risk to juvenile salmonids than other reservoirs we studied (Cougar and Detroit). Reservoir operations could be altered to reduce predation risks, but more information on northern pikeminnow spawn timing and behavior would be needed

Despite the risks that parasitic copepods and predation impart on juvenile Chinook rearing in reservoirs, the greatest current risk is mortality associated with dam passage.

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. 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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References

Amundsen, P.-A., R. Kristoffersen, R. Knudsen, and A. Klemetsen. 1997. Infection of *Salmincola edwardsii* (Copepoda: Lernaeopodidae) in an age-structured population of Arctic charr—a long-term study. Journal of Fish Biology 51:1033–1040.

Barndt, S. and J. Stone. 2003. Infestation of *Salmincola californiensis* (Copepoda: Lernaeopodidae) in wild coho salmon, steelhead, and coastal cutthroat trout juveniles in a small Columbia River tributary. Transactions of the American Fisheries Society, 132:1027-1032.

Beamesderfer, R. C., and B. E. Rieman. 1991. Abundance and distribution of northern squawfish, walleyes, and smallmouth bass in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:439-447.

Beamesderfer, R.C. 1992. Reproduction and early life history of northern squawfish, *Ptychocheilus oregonensis*, in Idaho's St. Joe River. Environmental Biology of Fishes 35:231.241.

Beeman, J. W., H. C. Hansel, A. C. Hansen, P. V. Haner, J. M. Sprando, C. D. Smith, S. D. Evans, and T. W. Halton. 2013. Behavior and dam passage of juvenile Chinook salmon at Cougar Reservoir and dam, Oregon, March 2011–February 2012. Report to U.S. Army Corps of Engineers, Portland, Oregon.

Beyer, J. M., G. Lucchetti, and G. Gray. 1988. Digestive tract evacuation in northern squawfish (*Ptychocheilus oregonensis*). Canadian Journal of Fisheries and Aquatic Sciences 45:548-553.

Black, G. A., 1982. Gills as an attachment site for *Salmincola edwardsii* (Copepoda: Lernaeopodiae). The Journal of Parasitology 68:1172-1173.

Brown, L. R., and P. B. Moyle. 1981. The impact of squawfish on salmonid populations: a review. North American Journal of Fisheries Management 1:104-111.

Budy P., Haddix, T., and R. Schneidervin. 2005. Zooplankton size selection relative to gill raker spacing in rainbow trout. Transactions of the American Fisheries Society 134: 1228-1235.

Bureau of Commercial Fisheries. 1960. Downstream Migrant Studies South Fork McKenzie River 1957, 1959, 1960. Department of Interior Bureau of Commercial Fisheries, Portland, Oregon.

Carlander, K.D. 1977. Handbook of freshwater fishery biology. Volume 2. Iowa State University Press, Ames.

Chao, A. 1987. Estimating the population size for capture-recapture data with unequal catchability. Biometrics 43:783-791.

Connor, W. P., and H. L. Burge. 2003. Growth of wild subyearling fall Chinook salmon in the Snake River. North American Journal of Fisheries Management 23:594-599.

Dauble, D. D., T. L. Page, and R. W. Hanf, Jr. 1989. Spatial distributions of juvenile salmonids in the Hanford Reach, Columbia River. Fishery Bulletin 87:775-790.

Duncan, J. P., 2011. Characterization of fish passage conditions through a Francis turbine and regulating outlet at Cougar Dam, Oregon, using sensor fish, 2009-2010: Pacific Northwest Laboratory report PNNL-20408, 172 p.

Etnier, D., and W. Starnes. 1993. The fishes of Tennessee. Knoxville, TN: University of Tennessee Press.

Foote, C. J., K. Moore, K. Stenberg, K. J. Craig, J. K. Wenburg, and C. C. Wood. 1999. Genetic differentiation in gill raker number and length in sympatric anadromous and nonanadromous morphs of sockey salmon, *Oncorhynchus nerka.* Environmental Biology of Fishes 54:263-274.

Friend, G. F. 1941. The life-history and ecology of the gill-maggot *Salmincola salmonea* (L.) (copepod crustacean). Transaction of the Royal Society of Edinburgh 60:503-541.

Friesen, T. A., and D. L. Ward. 2000. Biological characteristics of Columbia River walleye in relation to northern pikeminnow management. Information Reports number 2000-05. Oregon Department of Fish and Wildlife, Salem.

Friesen, T. A., J. S. Vile, and A. L. Pribyl. 2007. Outmigration of juvenile Chinook salmon in the lower Willamette River, Oregon. Northwest Science 81:173-190.

Friesen, T. A., M. A. Johnson, S. E. Savoie and R. K. Schroeder. *In prep*. Migration, survival, growth, and fate of hatchery juvenile Chinook salmon released above and below dams in the Willamette River Basin. Annual report to the U.S. Army Corps of Engineers, Task Order W9127N-10-2-0008 -0009. Oregon Department of Fish and Wildlife, Corvallis.

Fritts, A. L., and T. N. Pearsons. 2004. Smallmouth bass predation on hatchery and wild salmonids in the Yakima River, Washington. Transactions of the American Fisheries Society 133:880-895.

Frost, C. N. 2000. A key for identifying preyfish in the Columbia River based on diagnostic bones. U.S. Geological Survey, Cook, WA.

Gray, G. A., and D. W. Rondorf. 1986. Predation of juvenile salmonids in Columbia basin reservoirs. Pages 178-185 *in* G.E. Hall and M.J. VanDenAvyle, editors. Reservoir Fisheries Management: Strategies for the 80s. American Fisheries Society, Southern Division, Reservoir Committee, Bethesda, Maryland.

Hansel, H. C., S. D. Duke, P. T. Lofy, and G. A. Gray. 1988. Use of diagnostic bones to identify and estimate original lengths of ingested prey fishes. Transactions of the American Fisheries Society 117:55-62.

Hasselman, R., and R. Garrison. 1957. Studies on the squawfish *Ptychocheilus oregonensis* in Lookout Point and Dexter reservoirs, 1957. U.S. Fish and Wildlife Service report. 41 p.

Hicks, M. 2000. Evaluating standards for protecting aquatic life in Washington's surface water quality standards. Draft discussion paper and literature summary. Revised 2002. Washington State Department of Ecology, Olympia, WA.

Hosmer, D.W., Jr., and S. Lemeshow. 2000. Applied Logistic Regression. Wiley, New York.

Independent Science Group (ISG). Return to the River Report. 1996. Document number 96-6, Northwest Power Planning Council Independent Scientific Advisory Board, Portland, OR.

Independent Scientific Review Panel (ISRP). 2011-26. Review of the Research, Monitoring, and Evaluation Plan and Proposals for the Willamette Valley Project. Northwest Power and Conservation Council, Portland, Oregon. http://www.nwcouncil.org/library/report.asp?d=648.

Ingram P., and L. Korn. 1969. Evaluation of fish passage facilities at Cougar Dam on the South Fork McKenzie River in Oregon. Fish Commission of Oregon, Research Division, Portland.

Kabata, Z., and B. Cousens. 1973. Life cycle of *Salmincola californiensis* (Dana 1852) (Copepoda: Lernaeopodidae). Journal of the Fisheries Research Board Canada 30: 881-903.

Kabata, Z., and B. Cousens. 1977. Host-parasite relationships between Sockeye salmon, *Oncorhyncus nerka*, and *Salmincola californiensis* (Copepoda: Lernaeopodiae). Journal of the Fisheries Research Board Canada 34:191-202.

Keating, J.F., Jr. 1970. Growth rates and food habits of smallmouth bass in the Snake, Clearwater and Salmon rivers, Idaho 1965-1967. MSc., University of Idaho Graduate School. 40 p.

Keefer, M. L., G. A. Taylor, D. F. Garletts, C. K. Helms, G. A. Gauthier, T. M. Pierce, and C. C. Caudill. 2011. Reservoir entrapment and dam passage mortality of juvenile

Chinook salmon in the Middle Fork Willamette River. Ecology of Freshwater Fish 21:222-234.

Keefer, M. L., G. A. Taylor, D. F. Garletts, C. K. Helms, G. A. Gauthier, T. M. Pierce, and C. C. Caudill. 2012. High-head dams affect downstream fish passage timing and survival in the Middle Fork Willamette River. River Research and Applications: online publication DOI: 10,1002/rra.1613.

Kolander, T. D., D.A. Willis, and B.R. Murphy. 1993. Proposed revision of the standard weight (W_s) equation for smallmouth bass. North American Journal of Fisheries Management 13:398-400.

Korn, L. and E. M. Smith. 1971. Rearing Juvenile Salmon in Columbia River Basin Storage Reservoirs. Pages 287-298 in G. E. Hall, editor. Reservoir fisheries and limnology. American Fisheries Society, Special Publication 8, Bethesda, Maryland.

Larkin, P. A., and S. B. Smith. 1954. Some effects of introduction of redside shiner on the Kamloops trout in Paul Lake British Columbia. Transactions of the American Fisheries Society 83:161-175.

Lister, D. B., and H. S. Genoe. 1970. Stream habitat utilization by cohabitating underyearlings of chinook (*Oncorynchus tshawytscha*) and coho (*O. kisutch*) in the Big Qualicum River, British Columbia. Journal of the Fisheries Research Board of Canada 27:1215-1224.

Mattson, C. R. 1962. Early life history of Willamette River spring Chinook salmon. Fish Commission of Oregon Report, Portland, Oregon.

McGladdery, S. E., and C. E. Johnston. 1988. Egg development and control of the gill parasite, *Salmincola salmoneus*, on Atlantic salmon kelts (*Salmo salar*) exposed to four different regimes of temperature and photoperiod. Aquaculture 68:193-202.

Miller, S. A., and T. A. Friesen. 2012. An assessment of operational approaches to reduce predation on upper Willamette River Chinook salmon and steelhead and improve juvenile passage in Willamette Valley Project reservoirs. Oregon Department of Fish and Wildlife (ODFW) report to U.S. Army Corps of Engineers, Portland, Oregon.

Monzyk, F. R., J. D. Romer, R. Emig, and T. A. Friesen. 2011a. Pilot head-of-reservoir juvenile salmonid monitoring. Annual Report of Oregon Department of Fish and Wildlife (ODFW) to U.S. Army Corps of Engineers, Portland, Oregon.

Monzyk, F. R., J. D. Romer, R. Emig, and T. A. Friesen. 2011b. Life-history characteristics of juvenile spring Chinook salmon rearing in Willamette Valley reservoirs. Annual Report of Oregon Department of Fish and Wildlife (ODFW) to U.S. Army Corps of Engineers, Portland, Oregon.

Monzyk, F. R., J. D. Romer, R. Emig, and T. A. Friesen. 2012. Life-History Characteristics of Juvenile Spring Chinook Salmon Rearing in Willamette Valley Reservoirs. Annual Report to U.S. Army Corps of Engineers, Portland, Oregon. Task Order W9127N-10-2-0008-0007. Oregon Department of Fish and Wildlife, Corvallis.

Monzyk, F. R., J. D. Romer, R. Emig, and T. A. Friesen. 2013. Life-History Characteristics of Juvenile Spring Chinook Salmon Rearing in Willamette Valley Reservoirs. Annual Report to U.S. Army Corps of Engineers, Portland, Oregon. Task Order W9127N-10-2-0008-0007. Oregon Department of Fish and Wildlife, Corvallis.

Nagasawa, K, and S. Urawa. 2002. Infection of *Salmincola californiensis* (Copepoda: Lernaeopodidae) on juvenile Masu salmon (*Oncorhynchus masou*) from a stream in Hokkaido. Bulletin of the National Salmon Resources Center 5:7-12.

Normandeau Associates, Inc. 2010. Estimates of direct survival and injury of juvenile Chinook salmon (*Oncorhynchus tshawytscha*), passing a regulating outlet and turbine at Cougar Dam, Oregon. Draft Report to U.S. Army Corps of Engineers, Portland, Oregon. Contract Number W912EF-08-D-0005, Task Order DT01. Normandeau Associaties Inc, Stevenson, WA.

NMFS. 2008. 2008-2023 Willamette River Basin Project Biological Opinion. NOAA's National Marine Fisheries Service, Northwest Region, Seattle, WA. F/NWR/2000/02117.

Parker, R.M., M. P. Zimmerman, and D. L. Ward. 1995. Variability in biological characteristics of northern squawfish in the lower Columbia and Snake rivers. Transactions of the American Fisheries Society 124:335-346.

Parkinson, E. A., J. M. B. Hume, and R. Dolighan. 1989. Size Selective Predation by Rainbow trout on two lacustrine *Oncorhynchus nerka* populations. Fisheries Management Report No. 94, 14p. British Columbia Fisheries Branch.

Parrish, J. K., K. Haapa-aho, W. Walker, M. Stratton, J. Walsh, and H. Ziel. 2006. Small-bodied and Juvenile Fishes of the Mid-Columbia Region Including Keys to Diagnostic Otoliths and Cranial Bones. Draft Version, March 2006. University of Washington, Seattle.

Pawaputanon, K. 1980. Effects of a parasitic copepod, *Salmincola californiensis* (dana, 1852) on juvenile sockeye salmon, *Oncorhynchus nerka*. Dissertation. The University of British Columbia. Vancouver.

Peterson, J. T., and C. P. Paukert. 2009. Converting nonstandard fish sampling data to standardized data. Pages 195-214 in: S. A. Bonar, D. W. Willis, and W. A. Hubert, editors. Standardized Sampling Methods in North America. American Fisheries Society, Bethesda, Maryland.

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

Poulin, R., M. A. Curtis, and M. E. Rau. 1990. Response of the fish ectoparasite Salmincola edwardsii (Copepoda) to stimulation, and their implication for host-finding. Oikos 61:169-174.

Poulin, R., M. A. Curtis, and M. E. Rau. 1991. Size, behaviour, and acquisition of ectoparasitic copepods by brook trout, *Salvelinus fontinalis*. Oikos 61:169-174.

Richter A., and S. A. Kolmes. 2005. Maximum temperature limits for Chinook, coho, and chum salmon, and steelhead trout in the Pacific Northwest. Reviews in Fisheries Science 13:23-49.

Reimers, P. E. 1989. Management of wild and hatchery coho salmon in the Tenmile Lakes system. Oregon Department of Fish and Wildlife, Information Report 89-5, Portland.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada, Bulletin 191, Ottawa, Ontario.

Rieman, B.E., and Beamesderfer, R.C. 1990. Dynamics of a northern squawfish population and the potential to reduce predation on juvenile salmonids in a Columbia River reservoir. North American Journal of Fisheries Management 10:228-241.

Rieman, B. E., R. C. Beamesderfer, S. Vigg, and T. P. Poe. 1991. Estimated loss of juvenile salmonids to predation by northern squawfish, walleyes, and smallmouth bass in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:448–458.

Rogers, J. B. and C. C. Burley. 1991. A sigmoid model to predict gastric evacuation rates of smallmouth bass (*Micropterus dolomieui*) fed juvenile salmon. Canadian Journal of Fisheries and Aquatic Sciences 48:933-937.

Romer, J. D., F. R. Monzyk, R. Emig, and T. A. Friesen. 2012. Juvenile salmonid outmigration monitoring at Willamette Valley Project reservoirs. Annual Report of Oregon Department of Fish and Wildlife (ODFW) to U.S. Army Corps of Engineers, Portland, Oregon.

Romer, J. D., F. R. Monzyk, R. Emig, and T. A. Friesen. 2013. Juvenile salmonid outmigration monitoring at Willamette Valley Project reservoirs. Annual Report of Oregon Department of Fish and Wildlife (ODFW) to U.S. Army Corps of Engineers, Portland, Oregon.

Romer, J. D., F. R. Monzyk, R. Emig, and T. A. Friesen. 2014. Juvenile salmonid outmigration monitoring at Willamette Valley Project reservoirs. Annual Report of

Oregon Department of Fish and Wildlife (ODFW) to U.S. Army Corps of Engineers, Portland, Oregon.

Rondorf, D. W., G. A. Gray, and R. B. Fairley. 1990. Feeding ecology of subyearling Chinook salmon in riverine and reservoir habitats of the Columbia River. Transactions of the American Fisheries Society 119:16-24.

Schroeder, R. K., K. R. Kenaston, and L. K. McLaughlin. 2007. Spring Chinook salmon in the Willamette and Sandy rivers. Oregon Department of Fish and Wildlife Progress Reports 2006-2007, Project Number F-163-R-11/12, Fish Division, Salem.

Schroeder, R. K., L. D. Whitman, and B. J. Cannon 2013. Spring Chinook salmon in the Willamette River. Oregon Department of Fish and Wildlife, Fish Research Report F-163-R-13, Annual Progress Report, Portland.

Sharpe, C. S., B. Cannon, T. A. Friesen, D. Hewlett, and P. Olmsted. *In review*. Work completed for compliance with the 2008 Willamette Project Biological Opinion, USACE funding: 2012 hatchery baseline monitoring. Annual Report to U.S. Army Corps of Engineers, Portland, Oregon. Task Order: W9127N-12-2-0004-0009. Oregon Department of Fish and Wildlife, Corvallis.

Skalski, J. R., D. Mathur, and P. G. Heisey. 2002. Effects of turbine operating efficiency on smolt passage survival. North American Journal of Fisheries Management 22:1193-1200.

Sutherland, D. R., and D. D. Wittrock. 1985. The effects of *Salmincola californiensis* (Copepoda: Lernaeopodiae) on the gills of farm-raised rainbow trout, *Salmo gairdneri*. Canadian Journal of Zoology 63:2893-2901.

Sutton, T. M., M. J. Cyterski, J. J. Ney and M. C. Duval. 2004. Determination of factors influencing stomach content retention by striped bass captured using gillnets. Journal of Fish Biology 64:903–910.

Tabor, R. A., R. S. Shively, and T. P. Poe. 1993. Predation on juvenile salmonids by smallmouth bass and northern squawfish in the Columbia River near Richland, Washington. North American Journal of Fisheries Management 13:831-838.

Tabor, R. A., B. A. Footen, K. L. Fresh, M. T. Celedonia, F. Mejia, D. L. Low, and L. Park. 2007. Smallmouth bass and largemouth bass predation on juvenile Chinook salmon and other salmonids in the Lake Washington Basin. North American Journal of Fisheries Management 27:1174-1188.

Tabor, R. A., K. L. Fresh, R. M. Piaskowski, H. A. Gearns, and D. B. Hayes. 2011. Habitat use by juvenile Chinook salmon in the nearshore areas of Lake Washington: effects of depth, lakeshore development, substrate, and vegetation. North American Journal of Fisheries Management 31:700-713.

Taylor, G. 2000. Monitoring of Downstream Fish Passage at Cougar Dam in the South Fork McKenzie River, Oregon 1998-00 Final Report, Oregon Department of Fish and Wildlife, Springfield OR. pp.1-9.

Townsend, L. D. 1944. Variation in the number of pyloric caeca and other numerical characters in Chinook salmon and in trout. Copeia 1944:52-54.

Treasurer, J. W. 1988. Measurement of regurgitation in feeding studies of predatory fishes. Journal of Fish Biology 33:267–271.

U.S. Army Corps of Engineers. 2012. Willamette River Basin Operational Measures Evaluation Report. U.S. Army Corps of Engineers, Portland District, Portland, OR.

Vigg, S., T. P. Poe, L. A Prendergast, and H. C. Hansel. 1991. Rates of consumption of juvenile salmonids and alternative prey fish by northern squawfish, walleyes, smallmouth bass, and channel catfish in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:421-438.

White, G.C. and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46 Supplement: 120-138.

Wydoski, R. S., and R. L. Whitney. 2003. Inland fishes of Washington, 2nd edition. University of Washington Press, Seattle, WA.

Zakel, J. C., and D. W. Reed. 1984. Downstream migration of fish at Leaburg Dam, McKenzie River, Oregon, 1980 to 1983. Oregon Department of Fish and Wildlife Information Reports 84-13. Fish Division, Research and Development Section, Corvallis.

Zimmerman, M. P. 1999. Food habits of smallmouth bass, walleye, and northern pikeminnow in the lower Columbia River Basin during outmigration of juvenile anadromous salmonids. Transactions of the American Fisheries Society 128:1036-1054.

Zymonas, N. D., J. V. Tranquilli, and M. Hogansen. 2012 (*In review*). Monitoring and evaluation of impacts to bull trout (*Salvelinus confluentus*) and spring Chinook salmon (*Oncorhynchus tshawytscha*) in the South Fork McKenzie River from construction of water temperature control facilities at Cougar Dam, Oregon. Final Report to U.S. Army Corps of Engineers, Portland, Oregon. Oregon Department of Fish and Wildlife, Corvallis.

Appendix

Table A-1. Species composition collected in nearshore traps in four WVP reservoirs, 2013.

Species/rear	Cougar	Detroit	Foster	Lookout Point
Chinook subyearlings *(O. tshawytscha)*	14,395	234	398	1,893
Hatchery Chinook *(O. tshawytscha)*	5	0	0	3
Dace *(Rhinichthys spp.)*	26,518	7,298	47	92
Rainbow trout *(O. mykiss)*	50	68	296	27
Hatchery rainbow trout *(O. mykiss)*	0	4	6	0
Cutthroat trout *(O. clarkii)*	12	0	1	10
Sculpin *(Cottus spp.)*	3	0	40	191
Northern pikeminnow *(P. oregonensis)*	0	0	5,948	43
Redside shiner *(Richardsonius balteatus)*	0	0	161	334
Unknown Cyprinid	0	0	1	0
Brown bullhead *(Ameiurus nebulosus)*	0	92	11	6
Yellow bullhead *(A. natalis)*	0	0	54	1
Bass spp. *(Micropterus spp.)*	8	0	108	5
White Crappie *(Pomoxis annularis)*	0	0	1	5
Bluegill *(Lepomis macrochirus)*	0	120	5,495	3
PumpkinSeed *(Lepomis gibbosus)*	0	3,228	0	0
Unknown Centrarchid	0	0	5	1
Yellow perch *(Perca flavescens)*	0	0	191	0
Mountain whitefish *(Prosopium williamsoni)*	4	0		2
Suckers *(Catostomus spp.)*	0	0	100	12
Rough-skinned newt *(Taricha granulosa)*	148	1,043	574	526

Table A-2. Dimensions of select Willamette Valley Project reservoirs at full and low conservation pool.

Reservoir	Year completed[a]	Dam height (m)[a]	Elevation above sea level (m)	Depth (m)		Length (km)	
				Full pool[a]	Low pool	Full pool	Low pool
Foster	1967	38.4	214	37.5	~30	7.4	5.6
Fall Creek	1965	62.5	256	55.2	~23	9.2	4.1
Lookout Point	1953	84.1	287	73.8	~43	21.0	10.9
Detroit	1953	141.1	481	110.9	~79	14.4	10.3
Cougar	1964	158.2	518	142.3	~94	9.7	5.2
Hills Creek	1962	103.9	472	96.6	~68	12.2	7.1

[a] Data from National Performance of Dams Program (Stanford University)

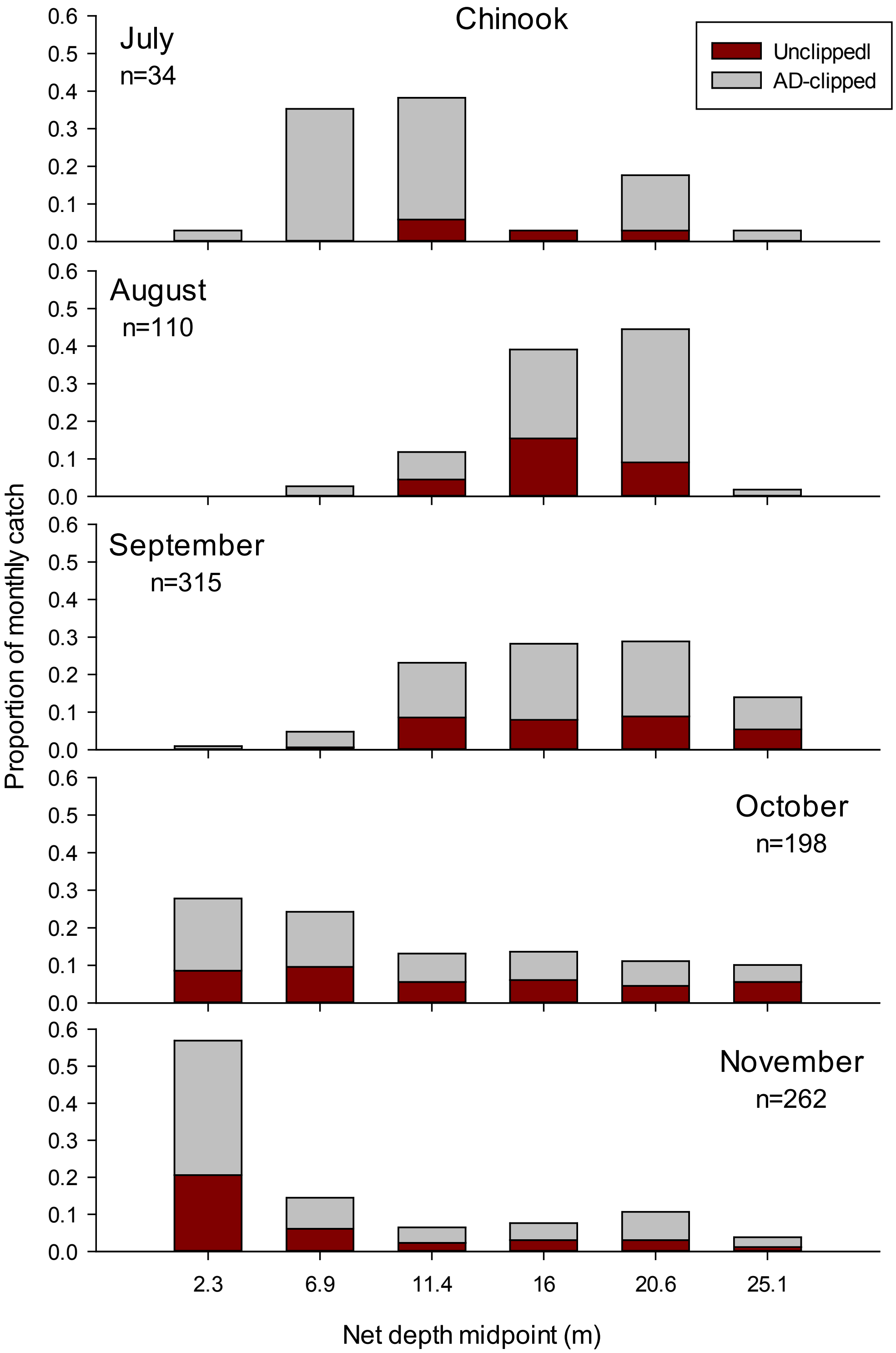

Figure A-1. Proportion of subyearling Chinook salmon caught at specific depth intervals in Detroit Reservoir from July to November 2013. An unknown proportion of the unclipped Chinook were of hatchery origin.

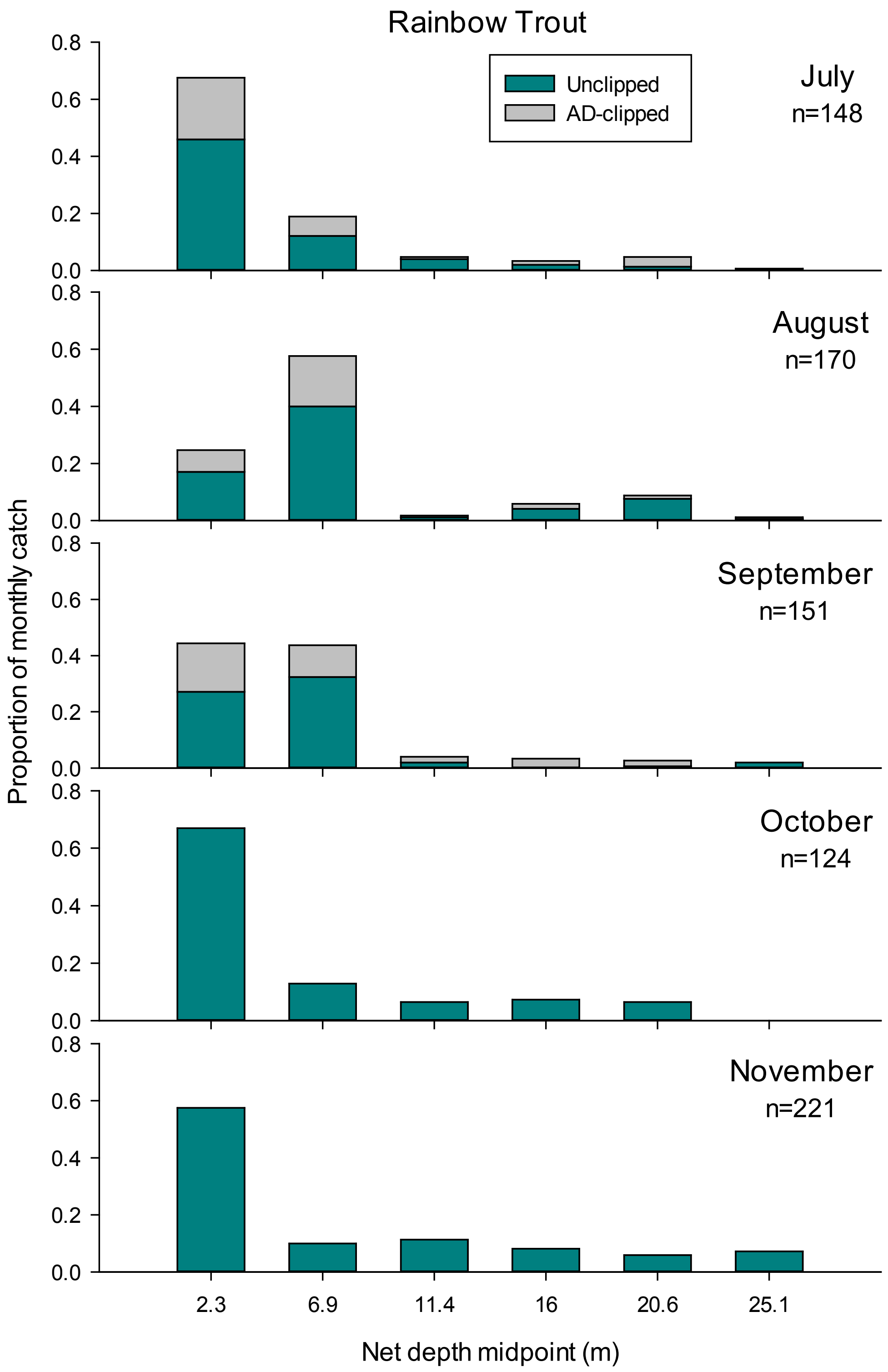

Figure A-2. Proportion of rainbow trout caught at specific depth intervals in Detroit Reservoir from July to November, 2013. An unknown proportion of unclipped trout caught were of hatchery origin.

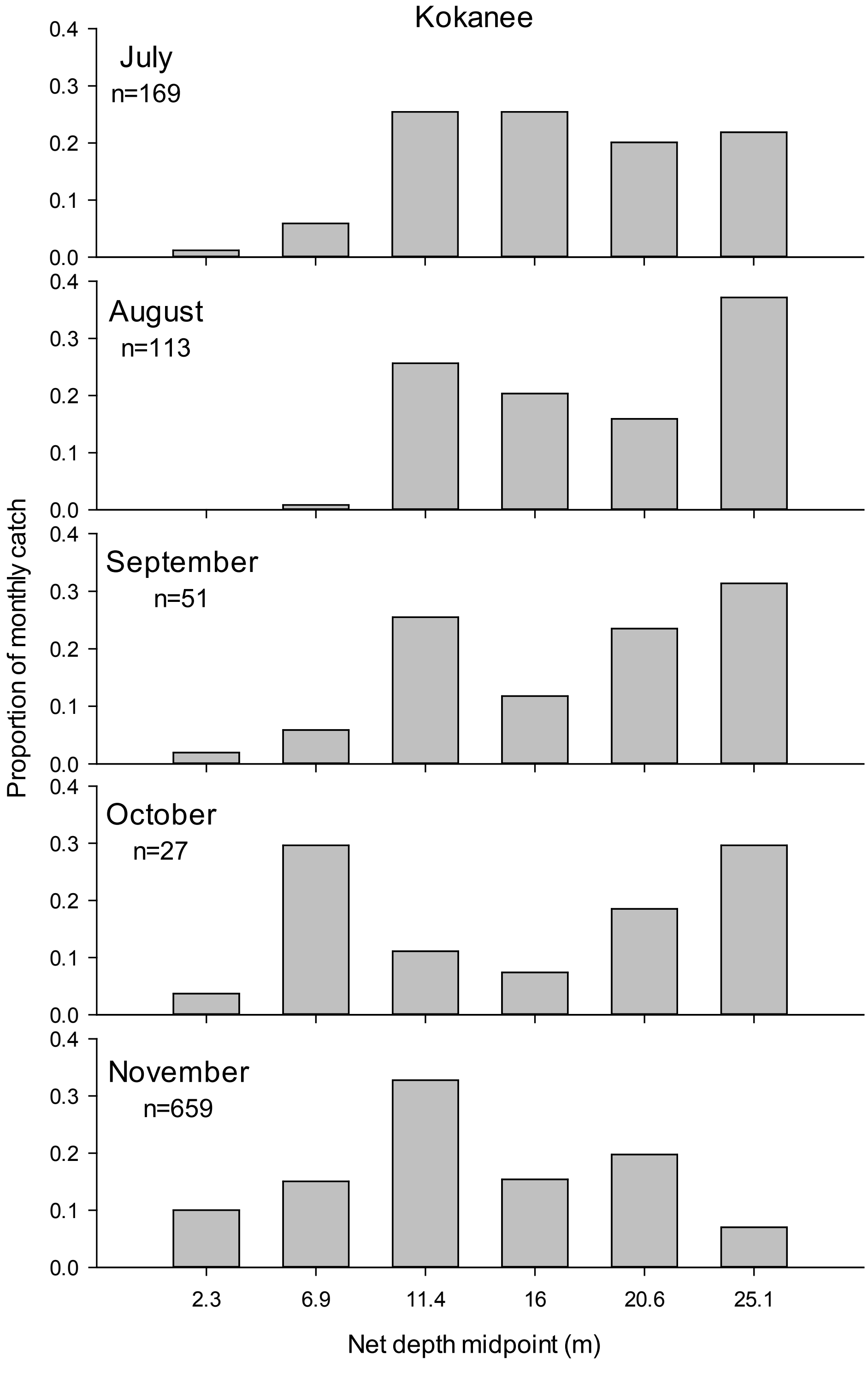

Figure A-3. Proportion of kokanee caught at specific depth intervals in Detroit Reservoir from July to November, 2013.

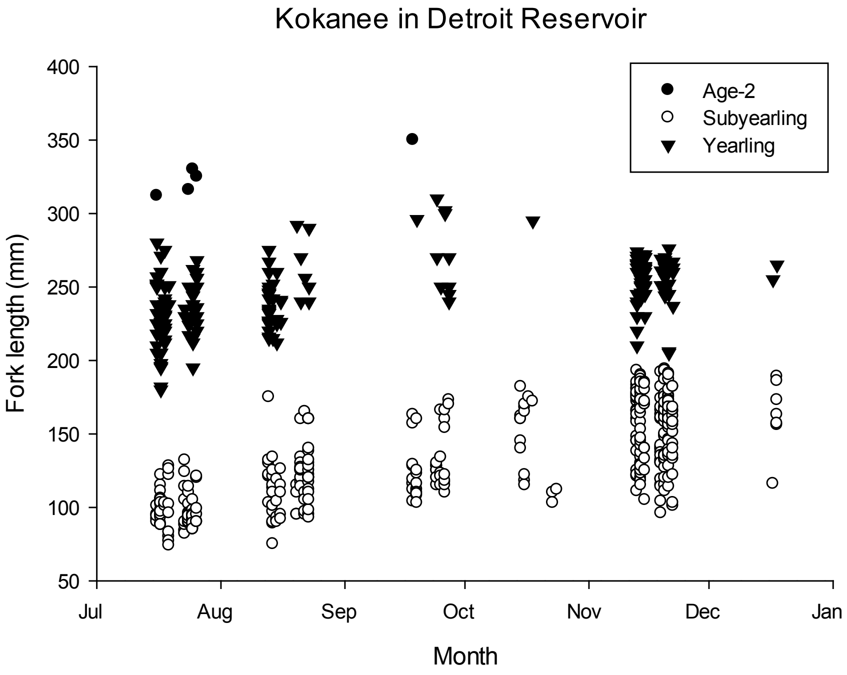

Figure A-4. Fork lengths of kokanee collected from gill nets in Detroit Reservoir, 2013. Age determination based on length-frequency analysis.

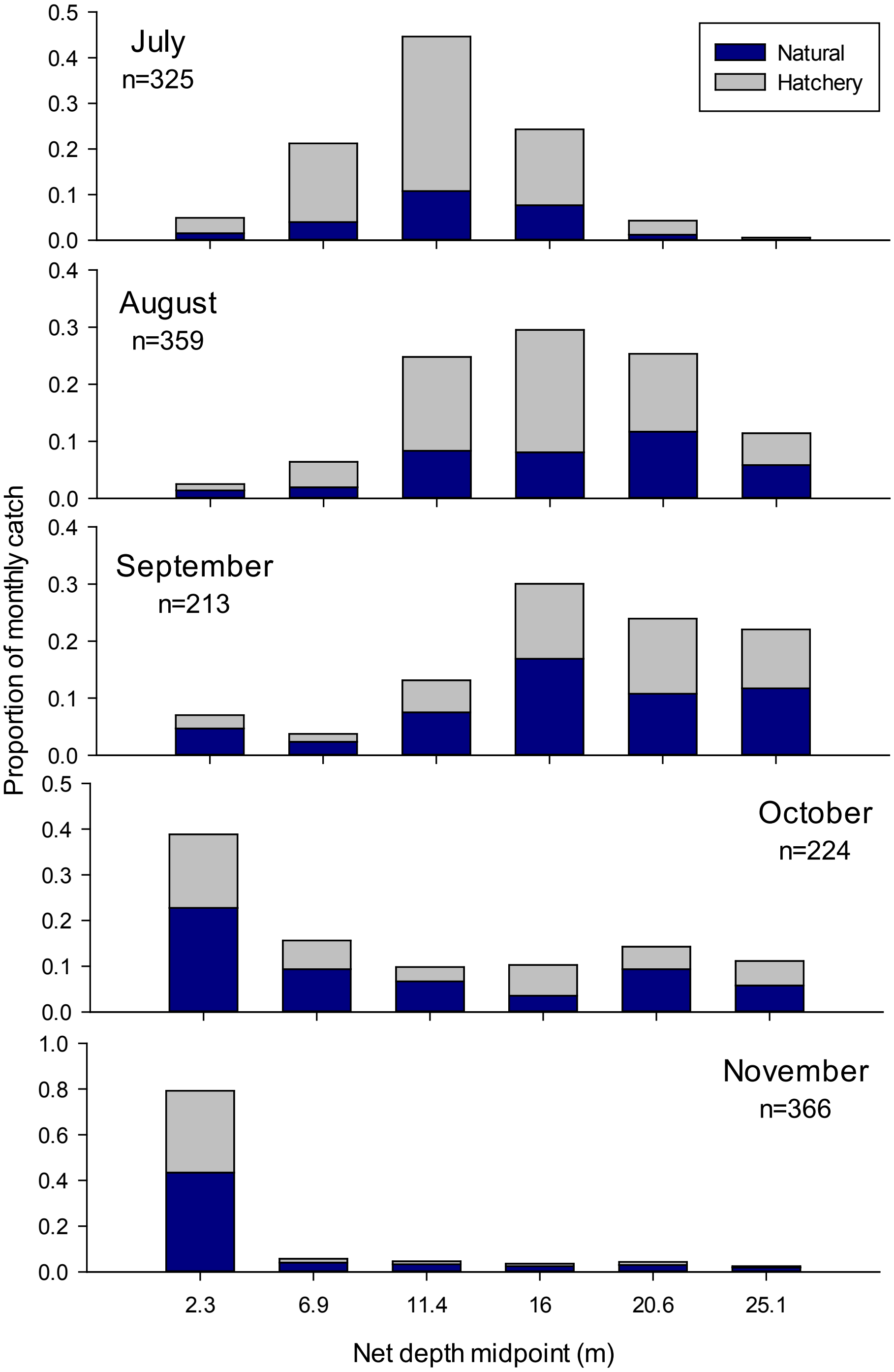

Figure A-5. Proportion of hatchery and natural-origin juvenile Chinook salmon caught at specific depth intervals in Lookout Point Reservoir from July to November, 2013.

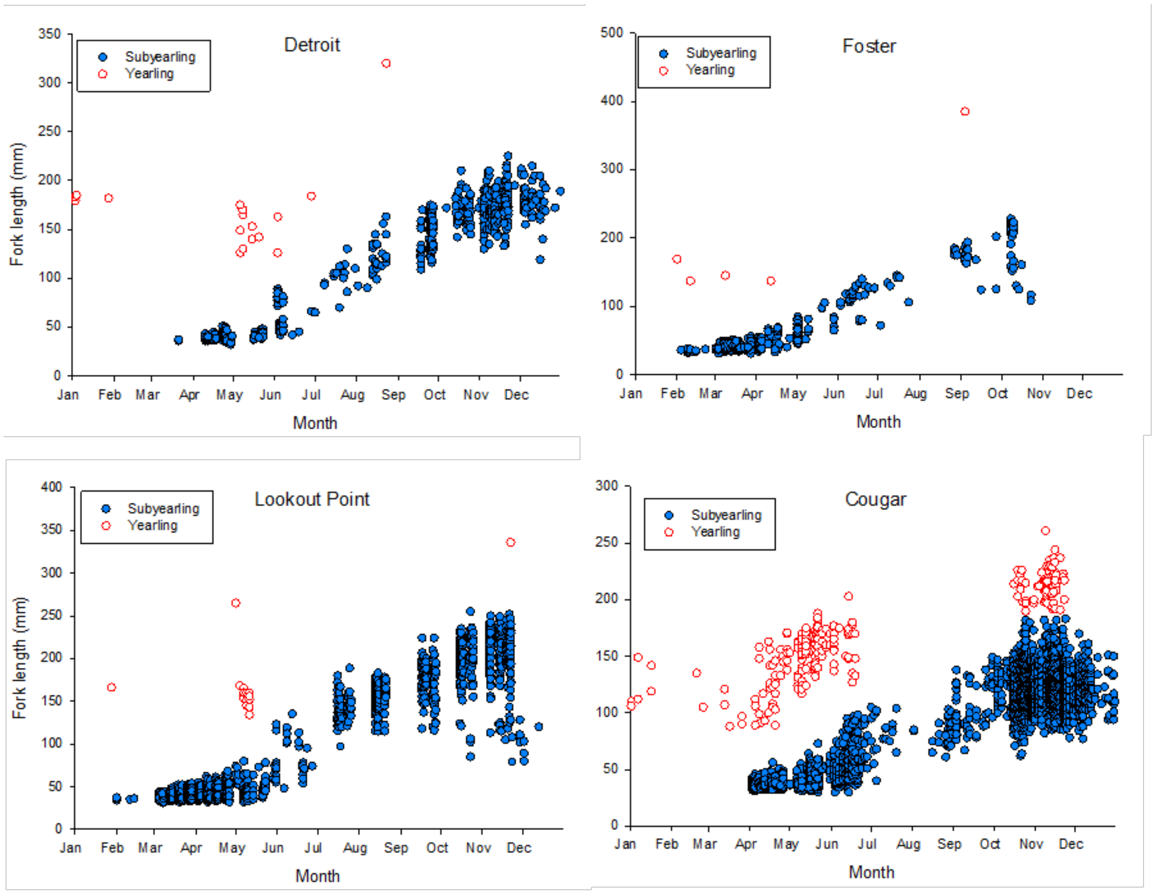

Figure A-6. Fork lengths of juvenile Chinook salmon caught in Willamette Valley Project reservoirs, 2013. Age determination based in length-frequency analysis.

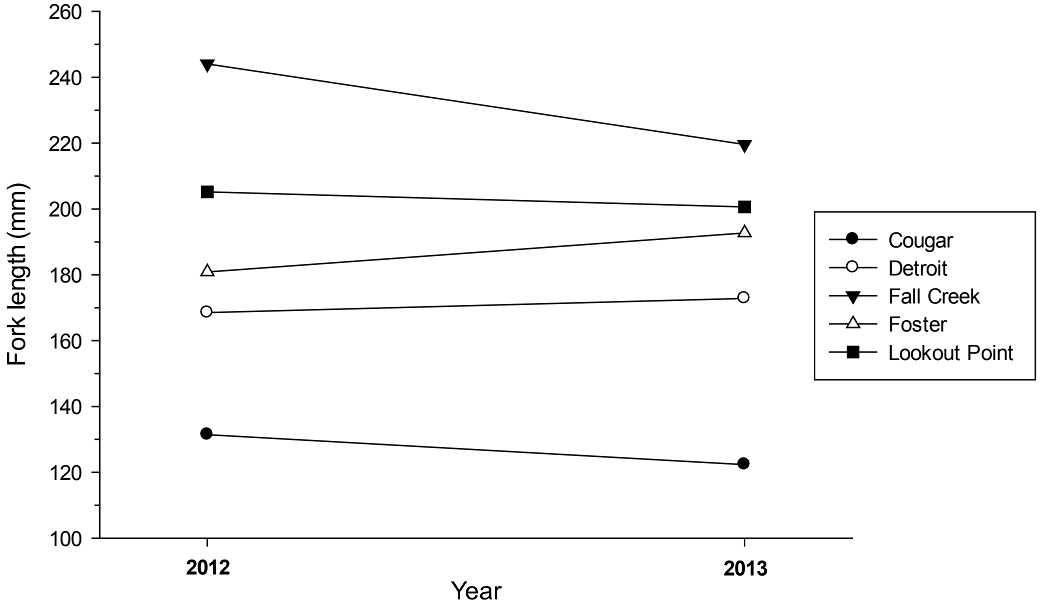

Figure A-7. Mean fork length of reservoir-rearing subyearlings in the fall (Oct-Dec), 2012 and 2013.