December 1999

SPRING CHINOOK SALMON INTERACTIONS INDICES AND RESIDUAL/PRECOCIAL MONITORING IN THE UPPER YAKIMA BASIN

Annual Report 1998

DOE/BP-64878-4

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views of this report are the author's and do not necessarily represent the views of BPA.

This document should be cited as follows:

James, Brenda B., Todd N. Pearsons, Geoffrey A. McMichael - Washington Department of Fish and Wildlife, Spring Chinook Salmon Interactions Indices and Residual/Precocial Monitoring in the Upper Yakima Basin, Annual Report 1998, Report to Bonneville Power Administration, Contract No. 1995BI64878, Project No. 9506409, 44 electronic pages (BPA Report DOE/BP-64878-4)

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Spring Chinook Salmon Interactions Indices and Residual/Precocial Monitoring in the Upper Yakima Basin

Annual Report 1998

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Project # 1995-064-09
Contract # 1995BI64878

December 1999

Executive Summary

Select ecological interactions and spring chinook salmon residual/precocial abundance were monitored in 1998 as part of the Yakima/Klickitat Fisheries Project's supplementation monitoring program. Monitoring these variables is part of an effort to help evaluate the factors that contribute to, or limit supplementation success. The ecological interactions that were monitored were prey consumption, competition for food, and competition for space. The abundance of spring chinook salmon life-history forms that have the potential to be influenced by supplementation and that have important ecological and genetic roles were monitored (residuals and precocials). Residual spring chinook salmon do not migrate to the ocean during the normal emigration period and continue to rear in freshwater. Precocials are those salmon that precocially mature in freshwater. The purpose of sampling during 1998 was to collect baseline data one year prior to the release of hatchery spring chinook salmon which occurred during the spring of 1999. All sampling that we report on here was conducted in upper Yakima River during summer and fall 1998.

- The stomach fullness of juvenile spring chinook salmon during the summer and fall averaged 12%. The food competition index suggested that mountain whitefish (0.59), rainbow trout (0.55), and redside shiner (0.55) were competing for food with spring chinook salmon. The space competition index suggested that rainbow trout (0.31) and redside shiner (0.39) were competing for space with spring chinook salmon but mountain whitefish (0.05) were not.

- Age-0 spring chinook salmon selected a fairly narrow range of microhabitat parameters in the summer and fall relative to what was available. Mean focal depths and velocities for age 0 spring chinook salmon during the summer were 0.5 m $\pm$ 0.2 m and 0.26 m/s $\pm$ 0.19 m/s, and during the fall 0.5 m $\pm$ 0.2 m and 0.24 m/s $\pm$ 0.18 m/s. Among potential competitors, age 1+ rainbow trout exhibited the greatest degree of microhabitat overlap with spring chinook salmon.

- Abundance of naturally occurring spring chinook salmon residuals (age 1+ during the summer) was low (< 0.007/m), representing less than 2% of the naturally produced spring chinook salmon (age 0+ and age 1+ during the summer). Abundance of naturally occurring spring chinook salmon that complete their life cycle in freshwater was high relative to anadromous adults. We observed an average of 9.5 precocially mature spring chinook salmon on redds with anadromous adults. In addition, 87% of the redds with anadromous adults present also had precocial males attending.

All findings in this report should be considered preliminary and subject to further revision as more data and analytical results become available.

Table of Contents

List of Figures

List of Tables

Chapter 3

General Introduction

This report examines some of the factors that can influence the success of supplementation, which is currently being tested in the Yakima basin using upper Yakima stock of spring chinook salmon. Supplementation success in the Yakima basin is defined relative to four topic areas: natural production, genetics, ecological interactions, and harvest (Busack et al. 1997). The success of spring chinook salmon supplementation in the Yakima basin is dependent, in part, upon fish culture practices and favorable physical and biological conditions in the natural environment (Busack et al. 1997). Shortfalls in either of these two topics (i.e., failure in culturing many fish that have high long-term fitness or environmental conditions that constrain spring chinook salmon production) will cause supplementation success to be limited. For example, inadvertent selection or propagation of spring chinook that residualize or precocially mature may hinder supplementation success. For instance, spring chinook salmon that residualize (do not migrate during the normal migration period) may have lower survival rates than migrants and, additionally, may ecologically interact with wild fish and cause unacceptable impacts to non-target taxa. Large numbers of precocials (nonanadromous spawners) may increase competition for females and significantly skew ratios of offspring sired by nonanadromous males, which could result in more nonanadromous spring chinook in future generations. Conditions in the natural environment may also limit the success of spring chinook supplementation. For example, intra or interspecific competition may constrain spring chinook salmon production. Spring chinook salmon juveniles may compete with each other for food or space or compete with other species that have similar ecological requirements. Monitoring of spring chinook salmon residuals, precocials, prey abundance, carrying capacity, and competition will help researchers interpret why supplementation is working or not (Busack et al. 1997). Monitoring ecological interactions will be accomplished using interactions indices. Interactions indices will be used to index the availability of prey and competition for food and space.

The tasks described below represent various subject areas of juvenile spring chinook salmon monitoring but are treated together because they can be accomplished using similar methods and are therefore more cost efficient than if treated separately. Three areas of investigation we pursued in this work were: 1) strong interactor monitoring (competition index and prey index), 2) carrying capacity monitoring (microhabitat monitoring); 3) residual and precocial salmon monitoring (abundance). This report is organized into three chapter to represent these three areas of investigation. Data were collected during the summer and fall, 1998 in index sections of the upper Yakima basin (Figure 1). Data collected during 1998 was the last opportunity to collect data prior to stocking of hatchery reared spring chinook salmon which were first released during the spring of 1999. The monitoring plan for the Yakima/Klickitat Fisheries Project calls for the continued monitoring of the variables covered in this report. All findings in this report should be considered preliminary and subject to further revision as more data and analytical results become available.

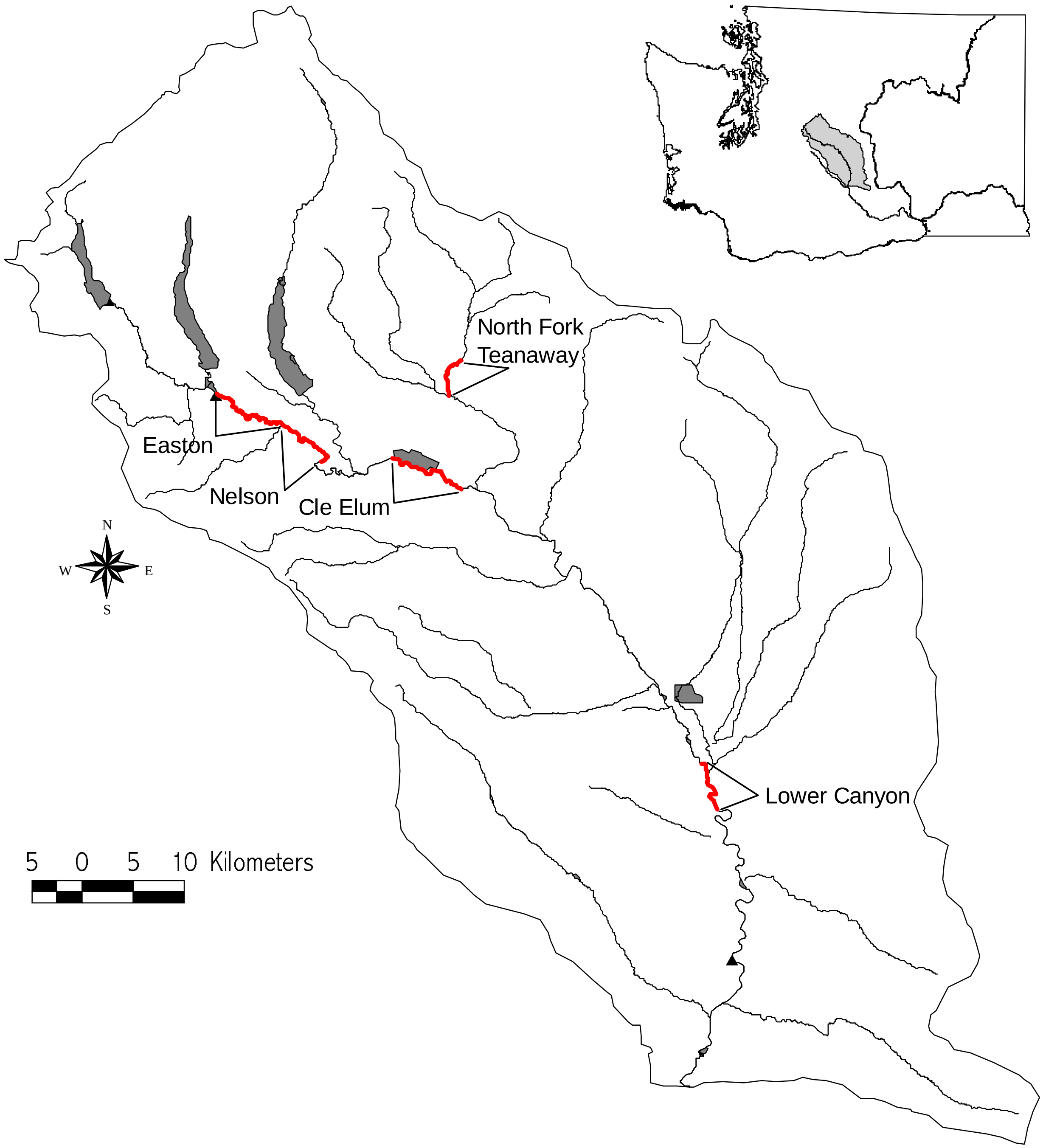

Figure 1. Locations of the study sections in the upper Yakima basin, Washington. Study sections are identified as thickened sections of the river.

Acknowledgments

We are thankful to the many people that helped make this report a reality. Dave Burgess, and Matt Polacek were instrumental in field collection of data and entering data into the computer. Kenneth Ham made the study area map from StreamNet data sources and reviewed the draft document. Jim Dunnigan provided a very helpful review of the report which resulted in some changes in the way the data was analyzed. Bill Hopley provided administrative support. David Byrnes administered funding. This work was funded by the Bonneville Power Administration as part of the implementation of the Yakima/Klickitat Fisheries Project's monitoring plan.

Literature Cited

Busack, C., B., Watson, Pearsons, T., C., Knudsen, S., Phelps, and M. Johnston. 1997. Yakima fisheries project spring chinook supplementation monitoring plan. Bonneville Power Administration, Portland, OR. DOE/BP-64878-1.

Chapter 1

Prey and Competition Indices of Juvenile Spring Chinook Salmon

Introduction

Supplementation is being implemented in the Yakima basin to increase natural production of spring chinook salmon, but certain factors extrinsic to hatchery culture, such as the abundance of prey or influence of competitors, may limit supplementation success (Busack et al. 1997). A change in the numbers or interaction strength of competitors has the potential to lower spring chinook salmon productivity relative to current levels. Competition for resources occur if a species utilizes a common resource that is in short supply (exploitative competition) or if a species limits access to a critical resource (interference competition) (Birch 1957). Two resources that are frequently competed for, in many communities, are space and food (Connell 1983, Schoener 1983). Mountain whitefish (*Prosopium williamsoni*), redside shiner (*Richardsonius balteatus*), and rainbow trout (*Oncorhynchus mykiss*) are the most likely candidates to compete for food and/or space with spring chinook salmon and limit spring chinook salmon productivity in the upper Yakima basin (Busack 1997; Pearsons 1998). Redside shiners have been shown to displace spring chinook salmon from preferred habitat (Hillman 1989) and are competitively superior to another cold-water salmonid, steelhead trout, at temperatures above 18^{o}C (Reeves et al 1987). Spring chinook salmon parr in the upper Yakima River are frequently observed in close association with redside shiners, and interspecific interactions have been observed between these two species (Pearsons et al. 1996). Rainbow trout are also commonly associated with spring chinook salmon in the upper Yakima River and their interactions sometimes result in displacement of spring chinook salmon parr (Pearsons et al. 1996). In contrast, mountain whitefish are rarely associated with spring chinook salmon but they may exploit food resources because they are very abundant and eat similar prey items as spring chinook salmon (Daily 1971; Pearsons et al. 1996). Because these competitors have the potential to have strong impacts to spring chinook salmon, we intend to monitor the strength of competition to see if it could explain variation in the abundance and size of spring chinook salmon.

Monitoring an indirect interaction such as competition is very challenging. Controlled field experiments are the best way to test competition, but logistically impractical when considering multiple species in a large river during many years. Historically, resource overlap has been used as an indication or demonstration of competition (Colwell and Futuyma 1971). However, without additional information, such as resource availability or behavioral interactions, overlap indices can be ambiguous (Colwell and Futuyma 1971; Sale 1974; Ross 1986). For example, high resource overlap between sympatric species is a good indication of competition only if resources are relatively scarce and important to the well being of the organisms. Conversely, low resource overlap is a good indication that significant competition is not occurring only when it can be demonstrated that the lack of overlap is due to innate differences in preferences and not interactive segregation. Accordingly, we will index the severity of competition using past observations of agonistic interactions and a combination of two metrics: resource overlap and resource availability (Busack et al 1997).

Prey availability can have a strong influence on the abundance and growth of spring chinook salmon irrespective of interspecific competition. Alteration of natural stream flow patterns, as frequently occurs in the Yakima River, can significantly affect prey abundance. The abundance of prey may limit the number of spring chinook salmon juveniles that can be produced in the upper Yakima basin. For example, spring chinook salmon may compete with one another for a limited amount of food, which may result in density dependent survival. Long-term monitoring of prey availability in a large river system is challenging because traditional methods of sampling stream invertebrates may not reflect the amount of prey that is actually available to fish. For instance, invertebrates that hide under rocks or that become active at night may not be available to spring chinook salmon that feed primarily during the day, but they would still be counted if traditional sampling methods were used. To eliminate this potential confound and to keep field expenses low, we chose to monitor the availability of prey by examining the stomach fullness of spring chinook salmon parr during the primary growing periods (Busack et al. 1997). Full stomachs will suggest that plenty of food is available and that it is not currently limiting spring chinook salmon production. Chinook salmon rearing in streams prey primarily on larval and adult insects and feed during the day (Healy 1991; Sagar and Glova 1988).

The purposes of this work are to 1) calculate baseline (before supplementation) indices of prey abundance and 2) calculate baseline indices of competition.

Methods

Prey Index

To determine baseline prey indices for juvenile spring chinook salmon we looked at several aspects of their diet including prey type and gut fullness. Three main stem sections and one tributary section of the upper Yakima River were used to collect data to determine baseline prey indices for juvenile spring chinook salmon. The main stem sections included; Nelson, a 7.2 km section of river below Easton Dam between the WDFW access ramp (river km 314.6) and the I-90 bridge (river km 307.4), Cle Elum (CE) an 8.8 km section of river that flows past Cle Elum from river km 294.5 (South Cle Elum Bridge) to river km 285.7 (WDFW access ramp near the Teanaway River confluence), and Upper Canyon (UCAN) a 4.8 km section of river south of Ellensburg from Ringer road access (river km 238.2) to Bighorn (river km 233.4). Data in the Cle Elum section was taken from the side-channels only due to high flows and dangerous conditions in the main stem. The fourth section was a 5 km section of the lower North Fork Teanaway River (NFT) between the mouth of Dickey Creek and the confluence of the North Fork and main stem Teanaway River. Sampling dates are summarized in Table 1.

Table 1. Summary of sampling dates and methods used to gather data for determining gut fullness of spring chinook salmon and diet and spatial overlap of spring chinook salmon and competitor species. ES=electroshocking, HL=hook and line.

	Section	Dates	Methods
Gut Fullness/ Diet Overlap	Easton	Jul 27-28	ES
	Nelson	Jul 21,23,30; Aug 27; Sep 14; Oct 20	ES, HL
	Cle Elum	Jul 30,31; Sep 2,3,23,24; Oct 14	ES, HL
	N. Fork Teanaway	Aug 3-5,13,20,24	ES, HL
	Upper Canyon	Sep 9,29; Oct 13,21,22	ES, HL
Spatial Overlap	Nelson	Jul 21; Aug 6,10,25-27; Sep 15,17	Snorkeling
	Cle Elum	Aug 18,19,31; Sep 1-3, 22	Snorkeling
	N. Fork Teanaway	Aug 11,12	Snorkeling
	Upper Canyon	Sep 8,10	Snorkeling

To describe their diet and determine gut fullness, age-0 spring chinook salmon were collected using several methods. Most fish were collected with a backpack electrofisher, however, when conditions did not favor electrofishing, an underwater hook and line method was used by floating live bait past the targeted species. Upon capture, the fish were anaesthetized with clove oil (Anderson et al. 1997), weighed (g), measured (mm), and when possible stomachs were flushed using a modified gastric lavage technique (Giles 1980). After collection, the stomach contents were preserved in alcohol and invertebrates were identified to order and counted. Contents from each stomach were then dried at 80^0 C for 48 hours and weighed to the nearest 0.0001g. Non-nutritious items, such as caddisfly cases, sticks, and stones, were removed from the sample prior to weighing. Analysis of variance (ANOVA) was used to compare the gut fullness of spring chinook salmon between sections. A student's t-test was used to compare the gut fullness of spring chinook salmon between seasons. A student's t-test was also used to compare gut content dry weight between the fish collected by hook/line and those collected by electroshocking to determine if collection methods affected gut fullness. Prior to testing, percentages were arc-sin transformed to normalize the data.

Food Competition Index

To determine the competition indices between age-0 spring chinook salmon and competitor species, diet overlap and gut fullness were determined for spring chinook salmon, rainbow trout, mountain whitefish, and redside shiners (Busack et al. 1997). Stomach content removal methods for rainbow trout were identical to those used for spring chinook salmon, however, mountain whitefish and redside shiners were preserved and gut contents were removed in the lab via dissection due to the inadequacy of gastric lavage techniques on these fish. Mountain whitefish were primarily captured in the Cle Elum section at night with a drift boat electrofishing unit because of difficulty capturing these fish during the day. Prey items were identified to order using a dissecting microscope. Diet overlap (O_{jk}) was determined using Schoener's (1970) index,

$$O_{jk} = 100 \text{ x } [1 - (1/2 \text{ x } \Sigma |p_{ij} - p_{ik}|)]$$

where p_{ij} is the proportion of resource *i* (food item) found in species *j* and p_{ik} is the proportion of resource *i* (food item) found in species *k*. The maximum dry weights of stomachs observed from the spring chinook salmon collected in 1998 were considered to be 100% full and were used as the reference point for gut fullness (Herbold 1986). Gut fullness was determined by plotting the log of the stomach content dry weights against the fish length and fitting a line through three of the maximum stomach dry weights representing a range of fish lengths (Figure 1). The equation of the line was then used to determine the maximum stomach fullness for each size class of fish. The stomach fullness was then calculated by dividing the observed fullness by the maximum fullness. The food competition index was then calculated by multiplying the diet overlap index by (1- stomach fullness index).

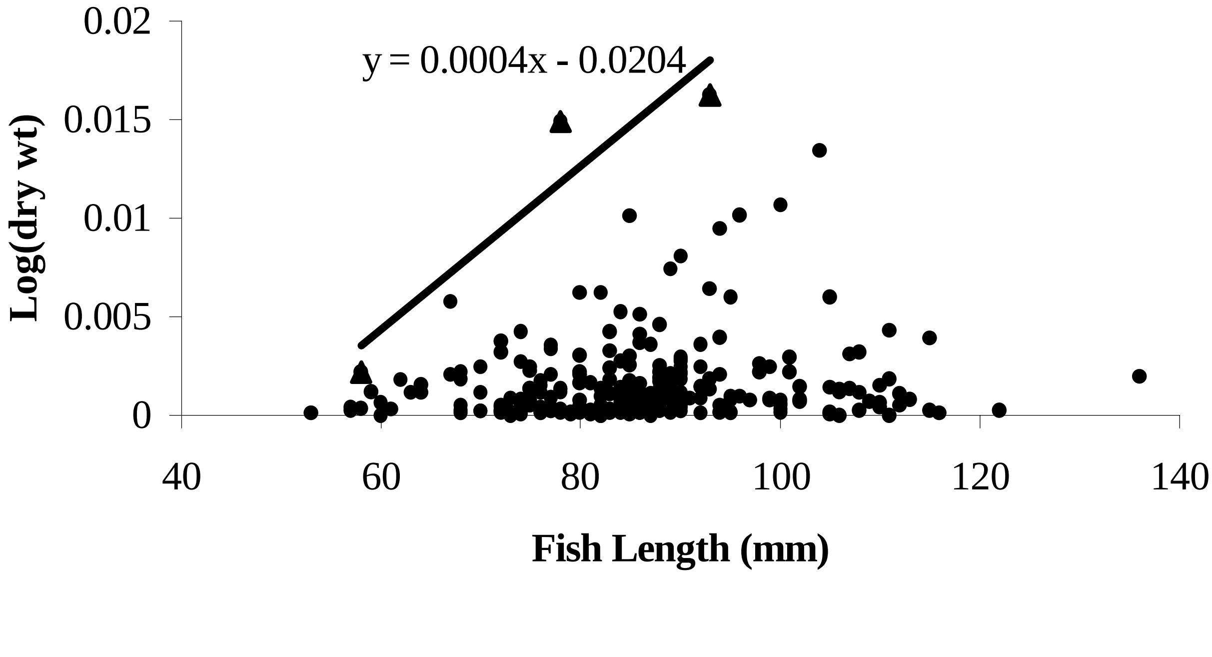

Figure 1. Log of stomach content dry weights of spring chinook salmon plotted against fork length. The triangular points are the maximum weights used to generate the equation used to determine maximum stomach fullness.

Space Competition Index

Spatial overlap and competitor abundance was determined using underwater observations. Spring chinook salmon and competitors were counted and age classes were determined (age 0+, age 1+, or adult). All observations were made when water temperatures were at or above 14^{o} C. Observations were made by having two snorkelers simultaneously snorkel each bank of a section. When conditions allowed, (i.e. shallow water or slow flows) snorkeling was conducted moving upstream, otherwise, observations were made while snorkeling downstream. Groups of fish that included spring chinook salmon and were within 30 cm of another were considered a pod and were assumed to interact (Pearsons et al. 1996). Any spring chinook salmon that was more than 30 cm from another fish was counted as a single fish. Data was recorded on a PVC cuff fitted around the snorkelers arm. Fish densities were calculated per linear meter.

A spatial competition index was calculated by combining spatial overlap data and competitor abundance data using a matrix described by Busack et al. (1997). The spatial overlap was expressed as the percent of spring chinook salmon pods that have at least one competitor present. The competitor abundance was calculated as the ratio of competitor abundance/spring chinook salmon abundance when fish are found within the same pod. The spatial and abundance indices were multiplied together resulting in the spatial competition index.

Results

Prey Index

A total of 266 age-0 spring chinook salmon stomachs were sampled for diet characteristics. Spring chinook salmon tended to be generalist feeders, exploiting representative species of several orders of macroinvertebrates. Figure 2 shows the frequency of occurrence and percent composition of each order found in the stomachs of spring chinook salmon.

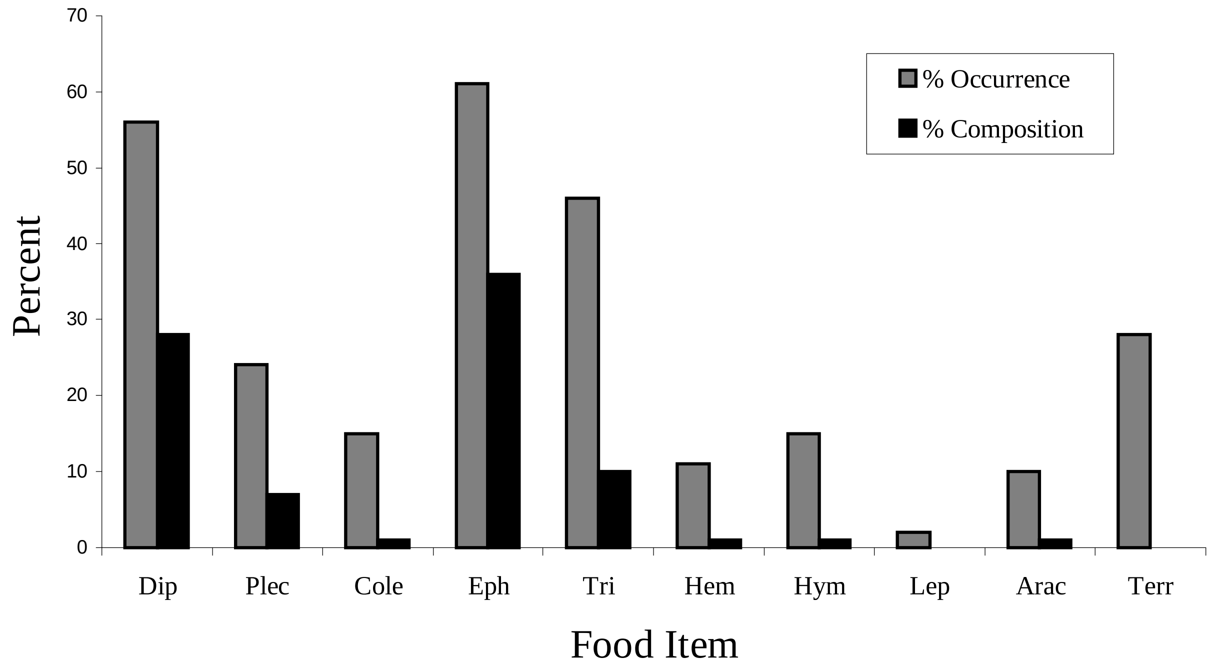

Figure 2. Frequency of occurrence and percent composition of food items found in age-0 spring chinook salmon. Dip=Diptera, Plec=Plecoptera, Cole=Coleoptera, Eph=Ephemeroptera, Tri=Trichoptera, Hem=Hemiptera, Hym=Hymenoptera, Lep=Lepidoptera, Arac=Arachnid, Terr=Terrestrial

The mean gut fullness of spring chinook salmon was relatively low (Table 2). Furthermore, although the mean dry weight of the stomach contents was identical between the summer and fall, there was a significant decrease in the mean gut fullness in the fall sample (t=2.04, p=0.04) because fish were longer and had larger potential maximum fullnesses. There was no difference in gut fullness between sections (F=1.88, p=0.11). The mean gut fullness of competitor species is also shown in Table 2 for comparison with spring chinook salmon. The fish collected using the hook/line method had higher stomach fullnesses than those collected by electrofishing (t=2.28, p=0.024).

Table 2. Stomach fullness for age-0 spring chinook salmon. Maximum and observed fullness are reported as mean dry weight (g).

	Maximum Fullness	Observed Fullness	St. Dev. Observed	Mean % Full
SPC	0.033	0.004	0.005	12.4
Summer	0.029	0.004	0.005	14.0
Fall	0.040	0.004	0.005	9.4
Mt. Whitefish	0.079	0.025	0.027	32.0
Rainbow Trout	0.237	0.023	0.047	9.7
Redside Shiner	0.020	0.002	0.004	10.0

Food Competition Index

The competition index calculated for age-0 spring chinook salmon suggests that there was significant competition for food (Table 3). Overall, the competition index suggests high competition between spring chinook salmon and all three competitors, however, competition with mountain whitefish was highest. When compared by season, food competition occurred most prominently during the fall sampling period. When compared by section, spring chinook salmon consistently showed high competition with all competitors with the exception of redside shiners in the Easton section.

Space Competition Index

Space competition indices were high for rainbow trout and redside shiners and low for mountain whitefish (Table 4). High indices for rainbow trout are primarily due to high spatial overlap, whereas high indices for redside shiner are primarily due to localized high abundance (Table 4). Competition for space appears to be lowest in the Cle Elum section and during the fall relative to summer.

Table 3. Food competition indices between age-0 spring chinook salmon and competitor species.

Species	Diet Overlap	1 - Fullness	Food Competition Index
		Easton	
Rainbow Trout	0.61	0.75	0.46
Redside Shiner	0.12	0.75	0.09
		Nelson	
Rainbow Trout	0.63	0.85	0.54
Redside Shiner	0.31	0.85	0.26
		Cle Elum	
Mountain Whitefish	0.63	0.91	0.57
Rainbow Trout	0.62	0.91	0.56
Redside Shiner	0.35	0.91	0.32
		NFT	
Mountain Whitefish	0.45	0.90	0.41
Rainbow Trout	0.71	0.90	0.64
Redside Shiner	0.67	0.90	0.60
		UCAN	
Rainbow Trout	0.78	0.89	0.69
		Summer	
Mountain Whitefish	0.53	0.85	0.45
Rainbow Trout	0.56	0.85	0.48
Redside Shiners	0.61	0.85	0.52
		Fall	
Mountain Whitefish	0.78	0.91	0.71
Rainbow Trout	0.77	0.91	0.70
		Total	
Mountain Whitefish	0.67	0.88	0.59
Rainbow Trout	0.63	0.88	0.55
Redside Shiners	0.63	0.88	0.55

Table 4. Space competition indices between age-0 spring chinook salmon and competitor species.

Species	Spatial Overlap	Competitor Abundance	Space Competition Index
		Nelson	
Mountain Whitefish	0.06	0.70	0.04
Rainbow Trout	0.28	0.81	0.23
Redside Shiners	0.05	7.41	0.37
		Cle Elum	
Mountain Whitefish	0.05	0.19	0.01
Rainbow Trout	0.20	0.69	0.14
Redside Shiners	0.11	0.83	0.09
		NFT	
Mountain Whitefish	0.22	0.86	0.19
Rainbow Trout	0.63	2.04	1.29
Redside Shiners	0.07	0.86	0.06
		Ucan	
Mountain Whitefish	0.06	1.17	0.07
Rainbow Trout	0.31	0.78	0.24
Redside Shiners	0.16	4.06	0.65
		Summer	
Mountain Whitefish	0.07	0.61	0.04
Rainbow Trout	0.27	1.19	0.32
Redside Shiners	0.05	5.26	0.26
		Fall	
Mountain Whitefish	0.07	0.84	0.06
Rainbow Trout	0.38	0.77	0.31
Redside Shiners	0.17	1.85	0.05
		Total	
Mountain Whitefish	0.07	0.72	0.05
Rainbow Trout	0.32	0.98	0.31
Redside Shiners	0.11	3.55	0.39

A total of 3,289 meters were snorkeled to calculate an overall spring chinook salmon lineal density of 0.17 fish per linear meter. The density of spring chinook salmon in the summer and fall was 0.20 per linear meter and 0.13 per linear meter, respectively (Table 5). The overall densities of spring chinook differed between sections. Spring chinook densities were highest in the Cle Elum section with 0.25 fish per linear meter, and lowest in the upper canyon section with 0.06 fish per linear meter.

Table 5. Summary of spring chinook salmon abundances and densities.

	Meters Sampled	# Spring Chinook Salmon	Number per Linear Meter
Summer	2234	439	0.20
Fall	1055	132	0.13
Cle Elum	1114	277	0.25
Nelson	700	127	0.18
N.F. Teanaway	600	43	0.07
Upper Canyon	875	52	0.06

Discussion

Gut fullness of spring chinook salmon was unexpectedly low during the summer and fall which may have been due to intra- and interspecific competition. Space competition indices were sufficiently high for rainbow trout and redside shiner to consider that competition for rearing space is probable. This is not surprising because unnaturally high flows, caused by releases of water from upstream dams, forces small salmonids to use a small fraction of the available habitat along the stream banks (Pearsons et al. 1996) and invertebrate production may be low because of substrate movement. In previous work, we observed rainbow trout, redside shiner, and spring chinook salmon interacting agonistically when they were in close proximity (Pearsons et al. 1996). Agonistic interactions frequently resulted in displacement from preferred feeding and holding areas. Thus, competitors such as rainbow trout and redside shiner are probably denying some spring chinook salmon access to food through behavioral mechanisms. In addition, food is being exploited by rainbow trout, redside shiner, and mountain whitefish as suggested by the food competition index. All competitor species that we studied had high prey overlaps with spring chinook salmon. Mountain whitefish is likely to be the strongest exploiter of food because they are very abundant and have a large average size. The biomass of mountain whitefish is at least 10 times the biomass of rainbow trout and redside shiner combined (WDFW unpublished data) and the stomach fullness of mountain whitefish was much higher than any of the other species we studied. Furthermore, the abundance of mountain whitefish and spring chinook observed in the fall (1993-1998) was also inversely related to the length of spring chinook salmon suggesting that intra- and interspecific competition affected the growth of spring chinook salmon (WDFW unpublished data).

The low stomach fullnesses that we calculated may have been influenced by the equation that we used to estimate the maximum fullness. We expect that the equation will change and become more robust as we increase our sample size in future years. The methods we used to collect fish for stomach sampling may have influenced stomach fullnesses we observed. Fish collected with hook and line had higher fullnesses than those collected by electrofishing. This could be due to the collection of fish that were actively feeding or collection of dominant fish that were most successful at acquiring food.

The indices that have been used in this study seem to be suitable for long-term monitoring of ecological interactions. The indices can be used in combination with spring chinook salmon response variables, such as growth or survival, to understand the dynamics of spring chinook salmon status. However, additional work may be necessary to determine if food is limiting spring chinook salmon growth. In 1999, we recommend that spring chinook salmon be collected throughout the day and night to determine if our low stomach fullnesses might be attributed to sampling time. In addition, we recommend that food availability be experimentally increased to determine if fish would feed more if more food were available. Finally, any residualized hatchery spring chinook or coho salmon should also be sampled during 1999 to determine the potential for competition for these animals. Due to their large abundance, a small sample of suckers should also be sampled to investigate the potential for food competition and whether further sampling is necessary.

References

Anderson, W. G., R. S., McKinley, and M. Colavecchia. 1997. The use of clove oil as an anesthetic for rainbow trout and its effects on swimming performance. North American Journal of Fisheries Management 17:301-307.

Birch, L. C. 1957. The meanings of competition. American Naturalist 91:5-18.

Busack, C., B., Watson, Pearsons, T., C., Knudsen, S., Phelps, and M. Johnston. 1997. Yakima fisheries project spring chinook supplementation monitoring plan. Bonneville Power Administration, Portland, OR. DOE/BP-64878-1.

Colwell, R. K., and D. J. Futuyma. 1971. On the measurement of niche breadth and overlap. Ecology 52:567-576.

Connell, J. H. 1983. On the prevalence and relative importance of interspecific competition: evidence from field experiments. American Naturalist 122:661-696.

Daily, M. K. 1971. The mountain whitefish: a literature review. Forest, Wildlife and Range Experiment Station, University of Idaho - station paper number 8. Moscow, Idaho.

Giles, N. 1980. A stomach sampler for use on live fish. Journal of Fish Biology 16:441-444.

Healey, M. C. 1991. Life history of chinook salmon (*Oncorhynchus tshawytscha*). Pages 312-393, In Pacific Salmon Life Histories, Groot, C. And L. Margolis editors. UBC Press, Vancouver, British Columbia.

Herbold, B. 1986. An alternative to the fullness index. Pages 319-320 in Contemporary studies on fish feeding: the proceedings of gutshop "84.

Hillman, T. W. 1989. Spatial interaction of juvenile chinook salmon and the redside shiner. Pages 209-247 in Don Chapman Consultants Inc., Summer and winter ecology of juvenile chinook salmon and steelhead trout in the Wenatchee River, Washington. Final report submitted to Chelan County Public Utility District, Washington.

Pearsons, T. N., G. A. McMichael, S. W. Martin, E. L. Bartrand, J. A. Long, and S. A. Leider. 1996. Yakima River Species Interactions Studies. Annual Report FY 1994 submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-99852-3. 150 pp.

Pearsons, T. N., G. A. McMichael, K. D. Ham, E. L. Bartrand, A. L. Fritts, and C. W. Hopley. 1998. Yakima River species interactions studies. Progress report 1995-1997, submitted to Bonneville Power Administration, Portland, Oregon.

Reeves, G. H., F. H. Everest, and J. D. Hall. 1987. Interactions between the redside shiner (*Richardsonius balteatus*) and the steelhead trout (*Salmo gairdneri*) in western Oregon:

the influence of water temperature. Canadian Journal of Fisheries and Aquatic Sciences 44:1603-1613.

Ross, S. T. 1986. Resource partitioning in fish assemblages: A review of field studies. Copeia 1986(2):352-388.

Sagar, P. M., and G. J. Glova. 1988. Diel feeding periodicity, daily ration and prey selection of a riverine population of juvenile chinook salmon, *Oncorhynchus tshawytscha* (Walbaum). Journal of Fish Biology 33:643-653.

Sale, P. G. 1974. Overlap in resource use, and interspecific competition. Oecologia 17:245-256.

Schoener, T. W. 1970. Nonsynchronous spatial overlap of lizards in patchy habitats. Ecology 51:408-418.

Schoener, T. W. 1983. Field experiments on interspecific competition. American Naturalist 122:240-285.

Chapter 2

Microhabitat Utilization of Spring Chinook Salmon

Introduction

The carrying capacity of the Yakima basin can limit the number of naturally produced spring chinook salmon *Oncorhynchus tshawytscha* even when supplementation mechanics are operating perfectly (Busack et al. 1997). For example, supplementing a stock that is near carrying capacity will not produce a large increase in naturally produced fish. Carrying capacity is defined as the maximum number of fish at their most demanding life-stage that can be supported by the available habitat. It is important to know what carrying capacity is in order to know whether supplementation mechanics are flawed or whether carrying capacity of the environment is limiting increased numbers of naturally produced fish.

Unfortunately, carrying capacity is very difficult to measure due to different requirements for each life stage as well as biotic and abiotic variability between years (Neitzel and Johnson 1996). Busack et al. (1997) described seven measures to index carrying capacity. One of these measures is an alteration of the patterns in microhabitat used by early spring chinook salmon parr, which is the topic of this chapter.

Different species and life stages of fishes show different preferences for specific microhabitat parameters (Lister and Genoe 1970; Hearn and Kynard 1986; Roper et al. 1994). The variation of microhabitats utilized by a species and life stage of fish is typically positively related to the density of that species/life stage as well as the density of competitor species (Allee 1982; Ross 1986; Grant and Kramer 1990; Robertson 1996). The microhabitat use of naturally produced juvenile spring chinook salmon, which are currently at low densities in the upper Yakima River basin, could serve as a baseline data set and indicate the preferred microhabitat as well as the range or variation of habitats used. Microhabitat use following supplementation might change in response to an increase in the number of naturally produced spring chinook salmon if supplementation is successful. For example, under excessive population densities, many parr might be forced to use faster and/or deeper water with less structural complexity than would parr at lower densities (below carrying capacity; Busack et al. 1997). The magnitude of the difference between microhabitat values at higher salmon densities might be expected to be greater than they would at lower densities if carrying capacity is exceeded at the higher density. For example, the coefficient of variation (CV) would be expected to be greater for focal point velocity measures for age-0 spring chinook salmon when salmon densities were greater. This may be due to some fish being forced to use less optimal microhabitats as the number of fish increases in a limited environment. This approach must assume that preferred microhabitat locations are limited.

This aspect of our study focused on obtaining a baseline set of core microhabitat values for age-0 spring chinook salmon and other species and life-stages of fishes that occupy similar habitats in four areas in the upper Yakima basin. In addition, we wanted to develop a way to monitor the range of microhabitats used within schools or pods of these fish by comparing the microhabitat values of the purported dominant fish within a pod and the fish that was furthest downstream within the pod (the purported most subordinate fish) as well as the difference in values for the fish at each outer edge of the pod. We expect that when densities are lower, the differences between these values would be less than when densities are higher.

Methods

To adequately characterize the microhabitat use of age-0 spring chinook salmon and associated species, we measured multiple variables surrounding fish that we observed by snorkeling in three sections of the Yakima River and in the North Fork of the Teanaway River (Table 1). The Nelson section of the Yakima River was sampled between the Washington Department of Fish and Wildlife (WDFW) access at the west end of Golf Course Road (about 300 m downstream of the mouth of Big Creek) and the low wooden bridge in the Elk Meadows subdivision. Side channels in the Cle Elum section of the Yakima River were sampled between the South Cle Elum Bridge and the WDFW access near the junction of highways 10 and 970. The Upper Canyon section of the Yakima River was sampled between the WDFW Ringer Road access and the mouth of Cherry Creek. The North Fork of the Teanaway River was sampled between the mouth Dickey Creek and the confluence of the North Fork and main stem of the Teanaway River. Microhabitat measurements were made during the months of July, August, and September, 1998 (Table 2). In each pod (defined in previous chapter) of fish, spring chinook salmon were counted and positions were recorded; which included head, tail, left, right, and average fish position. These positions within a pod were marked with painted washers placed where the fish were first observed. The average position was considered the general area where the majority of the fish were located. Fish lengths were estimated and focal depth and activity were recorded for the fish that held the head, tail, left, and right positions. Other fish within 30 cm of a spring chinook salmon were counted as part of the pod. Fish located more than 30 cm from a spring chinook salmon but likely associated with the pod were marked and measured separately.

Table 1. Microhabitat variables measured for spring chinook salmon, rainbow trout, redside shiners and mountain whitefish observed by snorkeling in the upper Yakima River basin in 1998.

Variable	Description
Position	Head, tail, left, right and average per pod
Length	Underwater visual fork length estimation (mm)
*Total Depth	(m)
*Focal Depth	Reported as % of water column in relation to total depth
*Surface Velocity	(m/s)
*60% Velocity	(m/s)
*Focal Velocity	Velocity measured at the fish focal point (m/s)
Activity	Feeding, swimming, holding, interacting, resting
Substrate	Dominant and subdominant recorded using the Wentworth scale (Cummins 1962)
Habitat Type	Deep pool, shallow, pool, deep run, shallow run, run, low gradient riffle, pocket pool (Frissell 1986)
Overhead Cover	Visual estimation of percent cover and distance to cover (m)
Instream Cover	Distance to marker (m) and cover type; wood, rock, aquatic vegetation, overhanging vegetation, undercut bank, water depth, and turbulence
Distance to Bank	(m)

*Core microhabitat variables prioritized for analyses

Table 2. Summary of dates and range of water temperatures (^{o} C) measured during data collection for 1998 baseline microhabitat data collection on spring chinook salmon in four study sections in the upper Yakima River basin. The season each sample was assigned to is also shown.

Section	Dates	Water Temperature (^{o} C)	Season
Nelson	July 21	14.5 – 16.0	Summer
Nelson	August 6	16.5 – 18.0	Summer
Nelson	August 10	16.0 – 19.0	Summer
Nelson	August 25-27	15.0 – 18.5	Summer
Nelson	September 15-17	16.0 – 17.0	Fall
Cle Elum	August 18-19	16.5 – 18.5	Summer
Cle Elum	August 31-Sept. 3	17.0 – 19.5	Summer
Cle Elum	Sept. 22	14.0	Fall
Upper Canyon	Sept. 8-10	15.0 – 19.0	Summer
N. Fork Teanaway	August 11-12	15.0 – 22.0	Summer

Various physical parameters were measured for each fish location. A wide array of habitat variables were assessed (Table 1), then a 'core group' of variables were selected from the larger group based on; 1) previous data collection efforts in the basin (Payne and Associates 1995, WDFW unpublished data) to enable use of a larger 'pre-supplementation' baseline data set, and 2) the descriptive value and statistical power of each variable to detect changes (i.e., shifts in microhabitat use, possibly due to increased population density). Total water depth was measured and dominant and sub-dominant substrates were classified using a modified Wentworth particle scale (Cummins 1962). Habitat type was noted for each marker and included; deep pool, shallow pool, deep run, run, low gradient riffle, and pocket pool (Frissell 1986). The distance to overhead cover was measured up to 1 m above the water surface and percent overhead cover was estimated for each marker placed. Instream cover type was noted and distance to each marker was measured. Instream cover was refuge the fish sought when spooked and was categorized as wood, rock, aquatic vegetation, overhanging vegetation, undercut bank, turbulence or depth. Current velocities were measured for each marker with a Marsh-McBirney or Swoffer flow meter at three points in the water column; the surface, 60% of the water column, and at the fishes' focal point. The distance to the nearest bank was also measured for each fish location.

Microhabitat use of age-1+ spring chinook salmon, rainbow trout, and mountain whitefish were also characterized. In the summer of 1998, we observed only three redside shiners; therefore, they were omitted from the microhabitat analyses.

In the interest of long term monitoring, the microhabitat data were grouped and analyzed by river section and season. By using these index sections, we hope to detect potential changes that may occur as supplementation proceeds. Grouping by season is necessary to detect differences in spring chinook salmon microhabitat as flows fluctuate due to changes in season and irrigation practices.

Basic descriptive analyses were used for measured variables. Analysis of variance (ANOVA) was used to compare summer microhabitat of age-0 spring chinook salmon between sections. Student-Newman-Keuls test (SNK) was used as the multiple range test. Students t-tests were used for comparing microhabitat variables between summer and fall for age-0 spring chinook salmon. Students t-tests were also used for making basic comparisons between age-0 spring chinook salmon and age-1+ rainbow trout, which was the most closely associated species in terms of microhabitat overlap.

Results

Age-0 spring chinook salmon were found in a relatively small portion of the available habitat and exhibited preference for specific microhabitat criteria. General summer microhabitat use by spring chinook salmon is summarized in Table 3. In the summer, spring chinook salmon most commonly utilized cobble/gravel as the dominant/subdominant substrate. The most commonly used summer habitat type for age-0 spring chinook salmon was river runs. Woody debris was found to be the most common instream cover type associated with age-0 spring chinook salmon in the summer. Summer microhabitat use by age-0 spring chinook salmon was consistent between sites.

Table 3. Summary of summer and fall microhabitats used by age-0 spring chinook salmon in 1998 in the upper Yakima River basin (all sites pooled). Depths were measured in meters (m). Velocities are reported as meters/second (m/s).

Variable	N	Mean	Std Dev	Std Error	Min	Max	Coefficient of Variation
			Summer				
Total Depth	501	0.72	0.27	0.01	0.21	1.80	0.38
Focal Depth	461	0.50	0.20	0.01	0.00	1.44	0.40
Surface Velocity	490	0.39	0.29	0.01	0.00	1.45	0.74
60% Velocity	485	0.31	0.23	0.01	0.00	1.08	0.74
Focal Velocity	450	0.26	0.19	0.01	0.00	1.06	0.73
			Fall				
Total Depth	86	0.77	0.26	0.03	0.24	1.50	0.34
Focal Depth	75	0.54	0.19	0.02	0.20	1.04	0.35
Surface Velocity	85	0.30	0.22	0.02	0.00	1.10	0.73
60% Velocity	86	0.25	0.20	0.02	0.00	1.10	0.80
Focal Velocity	74	0.24	0.18	0.02	0.01	0.97	0.75

A summary of summer microhabitat for each section is shown in Table 4. Single factor ANOVA's were used to determine if differences exist between sections with respect to summer microhabitat variables (Table 5). Summer total depth of age-0 spring chinook salmon in the Nelson section was greater than in the Cle Elum and NFT sections, however, Cle Elum and NFT sections showed no differences. Summer surface velocity varied among all sections. Although the Cle Elum and Nelson sections were similar when comparing 60% and focal velocities, both showed greater velocities than the NFT section. The distance that age-0 spring chinook salmon were found from the bank was similar in the Cle Elum and NFT sections, but was greater in the Nelson section.

Table 4. Summary of microhabitat parameters used by age-0 spring chinook salmon during summer 1998 in each study section in the upper Yakima River basin. Depths were measured in meters (m). Velocities are reported as meters/second (m/s).

Variable	N	Mean	Std Dev	Std Error	Min	Max	Coefficient of Variation
			Nelson				
Total Depth	171	0.87	0.31	0.02	0.29	1.80	0.35
Focal Depth	171	0.51	0.29	0.02	0.00	1.44	0.56
Surface Velocity	163	0.47	0.31	0.02	0.04	1.45	0.66
60% Velocity	163	0.32	0.23	0.02	0.00	1.06	0.71
Focal Velocity	148	0.28	0.21	0.02	0.00	1.06	0.74
			Cle Elum				
Total Depth	185	0.63	0.22	0.02	0.21	1.50	0.36
Focal Depth	185	0.41	0.20	0.01	0.00	1.22	0.49
Surface Velocity	183	0.38	0.25	0.02	0.00	1.10	0.67
60% Velocity	181	0.34	0.22	0.02	0.00	1.08	0.64
Focal Velocity	167	0.27	0.17	0.01	0.01	0.88	0.63
			North Fork Teanaway				
Total Depth	82	0.64	0.16	0.02	0.29	0.96	0.25
Focal Depth	83	0.45	0.17	0.02	0.00	0.74	0.38
Surface Velocity	83	0.15	0.16	0.02	0.00	0.59	1.00
60% Velocity	80	0.14	0.14	0.02	0.00	0.60	1.01
Focal Velocity	77	0.12	0.12	0.01	0.00	0.49	1.01

Table 5. Results of ANOVA test comparing summer microhabitat variables between study sections for age-0 spring chinook salmon in the upper Yakima River basin in 1998. Depths were measured in meters (m). Velocities are reported as meters/second (m/s).

Variable	*df*	**F**	*P*
Total Depth	434	48.55	<0.0001
Focal Depth	435	9.62	<0.0001
Surface Velocity	426	40.27	<0.0001
60% Velocity	421	28.36	<0.0001
Focal Velocity	389	25.10	<0.0001
Distance to Bank	435	9.62	<0.0001

Summer microhabitat used by age-1+ spring chinook salmon, rainbow trout, and mountain whitefish are summarized in Table 6. All species except mountain whitefish were most commonly found over a combination of cobble/gravel substrate using woody debris as instream cover. Age-0 mountain whitefish were most commonly associated with a bedrock substrate using turbulence as cover. The substrate use by age-0 mountain whitefish may be explained by the fact that most data for mountain whitefish were taken from the NFT section, which is predominantly a bedrock substrate. River runs were the most common habitat type utilized in the summer by all species with the exception of age-1+ rainbow trout, which were found in deep pools.

Student's t-tests were used to determine if differences exist between summer and fall with respect to microhabitat variables for age-0 spring chinook salmon (Table 7). Fall microhabitat for age-0 spring chinook salmon was similar to that utilized in the summer with the exception of velocities. As can be expected due to regulated flow reduction, fall surface and 60% velocities were significantly less than the summer velocities. Interestingly, focal velocities remained constant between summer (0.26 m/s) and fall (0.24 m/s). The most common substrate and habitat type remained unchanged between summer and fall for age-0 spring chinook salmon. The most common instream cover type associated with age-0 spring chinook salmon shifted from woody debris in the summer to water turbulence in the fall. Although fall microhabitat sampling was conducted in 1998, spring chinook salmon increased use of instream cover as temperatures dropped and became increasingly difficult to observe underwater.

Table 6. Summary of microhabitat used by age-1+ spring chinook salmon, age-0 and age-1+ rainbow trout, and mountain whitefish in the upper Yakima River basin during summer 1998 (all sections pooled). Depths were measured in meters (m). Velocities are reported as meters/second (m/s).

Variable	N	Mean	Std Dev	Std Error	Min	Max	Coefficient of Variation
Age-1+ Spring Chinook Salmon							
Total Depth	14	0.86	0.31	0.08	0.47	1.60	0.36
Focal Depth	14	0.24	0.16	0.04	0.06	0.53	0.67
Surface Velocity	13	0.79	0.48	0.13	0.06	1.65	0.61
60% Velocity	13	0.52	0.26	0.07	0.11	1.04	0.50
Focal Velocity	13	0.43	0.23	0.07	0.04	0.83	0.53
Age-0 Rainbow Trout							
Total Depth	27	0.43	0.13	0.03	0.29	0.68	0.30
Focal Depth	27	0.10	0.07	0.01	0.03	0.27	0.70
Surface Velocity	27	0.35	0.16	0.03	0.04	0.74	0.46
60% Velocity	27	0.28	0.15	0.03	0.03	0.58	0.54
Focal Velocity	27	0.21	0.12	0.02	0.01	0.40	0.57
Age-1+ Rainbow Trout							
Total Depth	26	0.71	0.31	0.06	0.31	1.45	0.44
Focal Depth	26	0.12	0.09	0.02	0.03	0.33	0.75
Surface Velocity	25	0.42	0.36	0.07	0.00	1.27	0.86
60% Velocity	25	0.29	0.26	0.05	0.00	0.92	0.90
Focal Velocity	25	0.22	0.21	0.04	0.00	0.79	0.95
Age-0 Mountain Whitefish							
Total Depth	8	0.67	0.21	0.08	0.45	1.00	0.31
Focal Depth	8	0.03	0.05	0.02	0.00	0.10	1.67
Surface Velocity	8	0.38	0.12	0.04	0.15	0.53	0.32
60% Velocity	8	0.45	0.20	0.07	0.28	0.80	0.44
Focal Velocity	8	0.27	0.20	0.07	0.11	0.67	0.74

Table 7. Results of student's t-tests comparing microhabitat variables between summer and fall for age-0 spring chinook salmon in the upper Yakima River basin in 1998 (sections pooled). Depths were measured in meters (m). Velocities are reported as meters/second (m/s).

Variable	*df*	*t*	*P*
Total Depth	585	-1.63	0.104
Focal Depth	100	-1.35	0.179
Surface Velocity	139	3.33	0.001
60% Velocity	569	2.32	0.021
Focal Velocity	522	0.78	0.434
Distance to Bank	586	-1.17	0.243

Table 8 shows the mean absolute differences between the head (most upstream in the pod) and tail (most downstream in the pod) and between left and right positions for five different microhabitat parameters measured in all sites and both seasons. These data illustrate relatively small and consistent differences.

Table 8. Mean absolute differences between head/tail (H/T) microhabitat positions and between left/right (L/R) positions held by age-0 spring chinook salmon in the upper Yakima River basin in 1998.

Positions	N	Total Depth	Focal Depth	Surface Velocity	60% Velocity	Focal Velocity
			Summer			
H/T	78	0.09	0.12	0.10	0.10	0.11
L/R	77	0.14	0.14	0.20	0.17	0.16
			Fall			
H/T	12	0.09	0.11	0.10	0.05	0.07
L/R	10	0.14	0.11	0.19	0.22	0.17
			Cle Elum – Summer			
H/T	29	0.04	0.09	0.12	0.11	0.13
L/R	29	0.10	0.14	0.18	0.17	0.13
			Nelson – Summer			
H/T	28	0.17	0.17	0.17	0.09	0.13
L/R	26	0.21	0.17	0.28	0.22	0.24
			North Fork Teanaway – Summer			
H/T	12	0.04	0.05	0.03	0.07	0.03
L/R	13	0.11	0.14	0.05	0.06	0.05
			Upper Canyon – Summer			
H/T	9	0.06	0.12	0.10	0.11	0.10
L/R	6	0.08	0.06	0.25	0.19	0.15

Age-1+ rainbow trout exhibited the greatest degree of microhabitat overlap with age-0 spring chinook salmon. When compared between age-1+ rainbow trout and age-0 spring chinook salmon, the means of the total depth, distance to bank and water velocities showed no significant differences. There was, however, a significant difference between the focal depths of the two fishes (P=0.01) with the mean focal depths of rainbow trout and age-0 spring chinook salmon at 83% and 66% of the water column, respectively. There was an overlap in instream cover use between rainbow trout juveniles and age-0 spring chinook salmon for both seasons. Both species most commonly utilized woody debris as cover in the summer, shifting to water turbulence in the fall.

Discussion

Age-0 spring chinook salmon in the upper Yakima River selected a fairly narrow range of microhabitat parameters in the study sites we examined during the summer and fall of 1998. The microhabitat values we report are similar to those presented by Payne & Associates (1995) for data they collected on age-0 spring chinook salmon in the Yakima basin in the summer of 1990 as well as those presented by Hillman et al. (1989) for data they collected in the Wenatchee River system during the summers (July and August) of 1986 and 1987.

If supplementation activities succeed in increasing the density of age-0 spring chinook salmon and the resulting population exceeds the carrying capacity of the habitat, we should see an increase in the variation of the microhabitats used. If we do not see an increase in the variation of microhabitats used by spring chinook salmon, it will not necessarily indicate that carrying capacity has not been reached/exceeded. Carrying capacity has two major components; space and food. Even if the availability of microhabitat is not limited with respect to the density of fish present, the carrying capacity with respect to food could be exceeded. The diet work in the first chapter of this section of the report should be able to detect whether future changes in density result in approaching or exceeding the overall carrying capacity of the upper Yakima River basin for age-0 spring chinook salmon. Furthermore, carrying capacity constraints may occur during periods when we are not measuring microhabitat such as during the winter.

We are making the assumption that if resources are limited, and supplementation increases fish density, the range and variability in microhabitat use will increase. To monitor the microhabitat use by age-0 spring chinook salmon subsequent to supplementation, baseline data were necessary for comparison. The coefficient of variation (CV) was calculated for specific descriptive variables and is shown in Table 3. By using the CV, we should be able to detect changes in the range of microhabitats used over time. Also, by calculating the mean absolute differences in variables between spring chinook salmon positions within a pod, we can obtain a range of variation in microhabitat use that may be useful in detecting changes in habitat use. If fish density increases substantially and we do not detect an increase in the variation (CV) of microhabitats used and in the mean absolute difference between positions within pods by age-0 spring chinook salmon, then we will conclude that the carrying capacity of the microhabitat has not been reached (i.e., the habitat is not limiting for this species/life stage).

Future monitoring of age-0 spring chinook salmon microhabitat use should focus on the summer period (July 15 – September 15). The variables that should be measured for each solitary spring chinook salmon are; total depth (m), focal depth (m), surface velocity (m/s), 60% velocity (m/s), focal point velocity (m/s), and water temperature (C). All sampling should be conducted when water temperature is 14 C or higher. The same data should also be collected on the head, tail, left, and right age-0 spring chinook salmon within each pod as well as the average position within the center of the pod. A minimum of 150 sets of microhabitat parameters should be measured within each of three locations; 1) the Nelson and 2) Cle Elum sections of the main stem Yakima River, and 3) within the lower 10 km of the North Fork of the Teanaway River.

References

Allee, B. A. 1982. The role of interspecific competition in the distribution of salmonids in streams. Pages 111-122 *in* E. L. Brannon and E. O. Salo, editors. Salmon and trout migratory behavior symposium. University of Washington Press. Seattle, Washington.

Cummins, K. W. 1962. An evaluation of some techniques for the collection and analysis of benthic samples with special emphasis on lotic waters. American Midland Naturalist 67:477-504.

Frissell, C. A., W. J. Liss, C. E. Warren, and M. D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. Environmental Management 10:199-214.

Grant, J. W., and D. L. Kramer. 1990. Territory size as a predictor of the upper limit to population density of juvenile salmonids in streams. Canadian Journal of Fisheries and Aquatic Sciences 47:1724-1737.

Hearn, W. E., and B. E. Kynard. 1986. Habitat utilization and behavioral interaction of juvenile Atlantic salmon (*Salmo salar*) and rainbow trout (*S. gairdneri*) in tributaries of the White River of Vermont. Canadian Journal of Fisheries and Aquatic Sciences 43:1988-1998.

Hillman, T. W., D. W. Chapman, and J. S. Griffith. 1989. Seasonal habitat use and behavioral interaction of juvenile chinook salmon and steelhead. I: daytime habitat selection. Pages 42-82 *in* Don Chapman Consultants, inc. Summer and winter ecology of juvenile chinook salmon and steelhead trout in the Wenatchee River, Washington. Final report submitted to the Chelan County Public Utility District, Washington.

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

Neitzel, D. A., and G. E. Johnson. 1996. Evaluation of carrying capacity: measure 7.1A of the Northwest Power Planning Council's 1994 fish and wildlife program. Report 1 of 4, final report. Bonneville Power Administration, Portland, Oregon. DOE/BP-62611-6.

Robertson, D. R. 1996. Interspecific competition controls abundance and habitat use of territorial Caribbean damselfishes. Ecology 77:885-899.

Roper, B. B., D. L. Scarnecchia, and T. J. LaMarr. 1994. Summer distribution of and habitat use by chinook salmon and steelhead within a major basin of the South Umpqua River, Oregon. Transactions of the American Fisheries Society 123:298-308.

Ross, S. T. 1986. Resource partitioning in fish assemblages: a review of field studies. Copeia 1986:352-388.

Thomas R. Payne & Associates. 1995. Development of fry and juvenile spring chinook habitat use criteria in the Yakima River Basin, Washington. Report prepared for the Yakima River Basin Defense Coalition. Yakima, Washington.

Chapter 3

Abundance of Residual and Precocial Spring Chinook Salmon

Introduction

Hatcheries have the potential to significantly alter the abundance of spring chinook salmon parr that do not migrate to the ocean during the spring of their release (termed residuals) and precocially mature in freshwater (termed precocials) (Mullan et al. 1992). The incidence of precocialism in chinook salmon has been documented in both hatchery (Mullan et al. 1992; Robertson 1957) and wild populations (Flain 1970; Gebhards 1960). The occurrence of precocialism in salmon has been credited to genetic factors and environmental and physiological cues (Bohlin et al. 1990; Thorpe 1987). Supplementation programs that have well developed broodstock guidelines and innovative rearing strategies may also produce residuals and precocials. Inadvertent propagation of hatchery spring chinook salmon that residualize or precocially mature may affect supplementation success in the Yakima basin (Busack et al. 1997). Four measures of supplementation success that could be influenced by the prevalence of residuals or precocials are attainment of ecological interactions, genetic, natural production, and harvest objectives (Busack et al. 1997). For instance, spring chinook salmon that residualize will not contribute to the number of anadromous fish produced during that brood, and additionally, may ecologically interact with wild fish. In addition, spring chinook salmon that mature in freshwater before migrating to the ocean and mate with anadromous females may contribute traits to progeny that differ from those contributed by anadromous males which may influence survival. We make a distinction between residuals and precocials because they can produce different ecological and genetic consequences and the fish are not necessarily equal. Although many residual fish may precocially mature, some may not, and some fish that do not residualize (e.g., age 0+ wild fish) may become precocially mature. Precocial spring chinook salmon are currently not collected for broodstock in the Yakima Klickitat Fisheries Program.

Preliminary snorkeling observations in the upper Yakima basin, which occurred prior to supplementation, indicated that natural abundance of residual and precocial spring chinook salmon was higher than previously thought. In 1996, precocial spring chinook salmon were observed on four of 12 (33%) spring chinook salmon redds with anadromous spring chinook salmon present. Residual spring chinook salmon were also typically larger, and more aggressive than age 0 spring chinook salmon. Fish that residualize often dominated behavioral interactions because of their large size which resulted in displacement of smaller fish from preferred locations (Pearsons et al. 1996). The purpose of this chapter is to describe results of baseline monitoring of residual and precocial spring chinook in the upper Yakima basin during 1998. During the spring of 1999 the first spring chinook smolts were released from the Easton and Clark Flats acclimation sites, so 1998 represented the last opportunity to look at natural densities of residuals and precocials in the upper Yakima basin.

Methods

Precocial and residual spring chinook salmon were studied in four Yakima River main stem sections and one Yakima River tributary section (see map in general introduction). These sections were selected because they are intensively utilized by spring chinook salmon for spawning and rearing and/or they were located near hatchery acclimation sites. The main stem sections sampled for residual spring chinook salmon included; Nelson, a 7.2 km section of river below Easton Dam from the WDFW ramp (river km 314.6) to the I-90 bridge at river km 307.4, Cle Elum (CE) an 8.8 km section of river that flows past Cle Elum from river km 294.5 to river km 285.7, and Upper Canyon (Ucan) a 4.8 km section of river south of Ellensburg from Ringer road access (river km 238.2) to Bighorn (river km 233.4). A 5 km section of the North Fork Teanaway River (NFT) between the mouth of Dickey Creek and the confluence of the North Fork and main stem Teanaway River was also sampled. Precocial data was also taken from the main stem Yakima River between Easton Dam (river km 325.9) and the top of the Nelson section (river km 314.6). We called this section "Easton". The sampling period for precocial and residual spring chinook salmon ranged from July 21, 1998 to October 22, 1998.

The baseline abundance of residual spring chinook salmon was determined by counting fish while snorkeling. Observations were conducted in the Nelson, Cle Elum, NFT, and Upper Canyon sections during the months of July and August (Summer) and September (Fall) when water temperatures were at or above 14 ^{o} C (Table 1). Both banks of the section being sampled were snorkeled simultaneously. Observations were made by having two snorkelers snorkel each bank of a section. When conditions allowed, (i.e. shallow water or slow flows) snorkeling was conducted moving upstream, otherwise, observations were made while snorkeling downstream. Most of the snorkeling in the main channel occurred while moving downstream, whereas side channels were generally snorkeled while moving upstream. Only side channels were snorkeled in the Cle Elum section because of the dangerous conditions in the main channel. All spring chinook salmon encountered were enumerated. Size was visually estimated underwater. Fish with a length greater than 120 mm (FL) were considered age-1+ residuals based on size and growth rate data collected previously (WDFW, unpublished data).

Observations were conducted in September and October to determine the presence and abundance of precocial spring chinook salmon. Sampling occurred in the Easton, Nelson, and Cle Elum sections of the upper Yakima River where high salmon redd densities have been observed in the past (Fast et al. 1991). Underwater observations were made between September 29 and October 12, 1998, during the time of spring chinook salmon spawning (Table 1). Each section was floated one or more times with an inflatable raft and salmon redds were flagged and numbered. Upon reaching a salmon redd we determined the presence or absence of anadromous salmon. A snorkeler would then begin 5-10 meters downstream of the redd and snorkel upstream, counting and enumerating all spring chinook encountered. Fish were categorized as either being on the redd (in the bowl), or associated with the redd (within 5 meters). In cases where a redd was snorkeled more than once, the observation with the highest precocial count was used for analysis.

Table 1. Summary of sections, dates and temperatures of residual and precocial observations.

Sections	Dates	Temperature °C
	Residual Observations	
Nelson	Jul 21; Aug 6, 10, 25-27; Sep 17	14.5-19.0
Cle Elum	Aug 31; Sep 1-3	17.0-19.5
Upper Canyon	Sep 8	18.5-19.0
	Precocial Observations	
Easton	Oct 1	13.0
Nelson	Sep 29, 30; Oct 5	14.0-15.5
Cle Elum	Oct 6, 12	10.5-11.0

We tried a variety of methods to collect precocial spring chinook so that we could confirm that they were mature, determine their age, and determine what they were eating. Although many precocial spring chinook salmon were taken incidentally by methods such as backpack and boat shocking, the primary and most successful method used was hook and line. A small hook baited with a live invertebrate was drifted downstream in front of the precocial fish. All fish collected were anesthetized with clove oil (Anderson et al. 1997) and fork lengths (mm) and weights (g) were obtained. Stomach contents were obtained by gastric lavage (see Chapter 1). Upon recovery from the anesthetic, fish were released where they were captured. Forty-four precocial spring chinook salmon were preserved for age and gonad analyses in the lab.

Results

Although 34 residual spring chinook salmon were observed between July 21 and September 17, only those observed on dates when snorkeled sections were measured were used in calculating fish per linear meter (Table 2). The Cle Elum section had the highest density of residual spring chinook salmon per linear meter. Nelson and Upper Canyon sections had similar densities of residual spring chinook salmon per linear meter. Residual spring chinook salmon accounted for 1.5% of the spring chinook salmon observed in the summer (Table 3). The Cle Elum section had the highest ratio of residuals to age-0 spring chinook salmon. Although the number of residual spring chinook salmon observed in late September and early October increased greatly, they were considered precocial fish and were not included in the density calculations.

Table 2. Density of residual spring chinook salmon per linear meter, summer 1998.

Section	# Residuals	Meters Sampled	#Fish/Linear meter
Nelson	1	700	0.001
Cle Elum	7	1114	0.006
N.F. Teanaway	0	600	0
U. Can	1	875	0.001

Table 3. Density of residual spring chinook salmon per age-0 spring chinook salmon (SPCY), summer 1998.

Section	# Residuals	# SPCY	% Residuals
Nelson	20	1275	1.6
Cle Elum	10	547	1.8
N.F. Teanaway	0	102	0
U. Can	1	88	1.1
Total	31	2012	1.5

Sixty-four spring chinook salmon redds were surveyed one or more times for a total of 98 observations between September 29 and October 12, 1998. Of the 64 redds surveyed, 36% were occupied (in the bowl) by at least one precocial spring chinook salmon and 41% had at least one precocial spring chinook salmon associated within 5 m of the redd (termed “associated”). Of the precocials found on redds, age-0 spring chinook salmon were nearly twice as abundant as age-1+ spring chinook salmon. Based on 64 observations, the mean number of precocial spring chinook salmon observed per redd was 2.7 (Table 4). The average number of precocial spring chinook salmon per active redd was 9.5. Additionally, the average number of precocials on or associated within 5 m of an active redd was 12.5 and the highest number of precocials on or associated with a redd was 48. Precocial spring chinook salmon were present 87% of the time that adult spring chinook salmon were present.

The average length of the spring chinook salmon precocials sampled was 138 mm. The most frequent length was 110 mm, which corresponds to age-0 fish. Sixty four percent of the precocials observed on the redds were age 0 and 36% were age 1+. The lengths of the smallest and largest precocial spring chinook salmon were 83 mm and 202 mm, respectively. Scales were taken from 26 precocial spring chinook salmon for aging purposes. Of these, 73% were age-1+ and 27% were age-0. However, this ratio is not representative of the population as the larger fish were targeted for capture.

Table 4. Summary of precocial spring chinook salmon activity on redds. Per redd refers to those with and without attending adult. Per active redd refers to those attended by at least one adult.

	Mean	Range	Std Dev	Percent
		Activity per Redd		
Precocials	2.7	0-23	5.2	36*
Age-0	1.7	0-19	3.6	34
Age-1+	1.0	0-9	2.0	27
		Activity per Active Redd		
Precocials	9.5	0-23	6.5	87*
Age-0	5.9	0-19	5.2	87
Age-1+	3.6	0-9	2.6	80

* Percentage of redds with precocial spring chinook on the redds.

Discussion

Precocial spring chinook salmon in the upper Yakima River were observed on 87% of active redds in 1998, almost three times as much as we observed in 1996 (33%; WDFW unpublished data). This difference in precocial use between years may be partially explained by the difference in numbers of redds counted in 1996 and 1998. During 1996, 814 redds were counted in the upper Yakima River, and during 1998, 148 were counted (Jim Dunnigan, Yakama Nation). Thus, more precocials would have been necessary to achieve the percentages observed in 1998 than in 1996.Although the 1998 survey was more thorough than that of 1996, only 23% of the 1998 redds we surveyed were active. Many of the redds that we sampled in 1998 had already been abandoned by anadromous adults and possibly precocial spring chinook salmon before our observations were made. The presence of a female on a redd had a large influence on how many precocial spring chinook salmon were observed. Almost all of the redds with a female present had precocials present, but when a female was not present precocials were generally absent. We observed this same pattern in 1996 and 1997 (WDFW unpublished data). For instance, during 1997 we sampled redds shortly after spawning was complete and found a very low incidence of precocials/redd. We recommend that future monitoring of precocials be done exclusively on active redds. This will reduce the annual variation in precocial abundance that is associated with sample timing.

The number of residual spring chinook salmon in our index sections was small (<2%) relative to the number of age 0 spring chinook, however we cannot eliminate the possibility that residual spring chinook salmon were more abundant in areas below our index sections, such as in the Yakima Canyon. It is interesting to note that few if any of the spring chinook salmon smolts that have been aged at the Chandler Juvenile Fish Facility have been older than 1 + (Bruce Watson, personal communication, YIN), suggesting that most of the residualized salmon die prior to migration or do not migrate to the ocean. Our counts of residuals decreased dramatically during the fall, presumably because they were attracted to adult females that were in cover and therefore made our efficiency of counting residuals low. Previous observations suggest that as spawning nears in the fall precocials tend to congregate near the anadromous females in the system. Therefore, we recommend that monitoring of residuals be restricted to the month of August to minimize error due to low snorkeling efficiency and confounding problems with precocial spawning movements during the fall.

References

Anderson, W. G., McKinley, R. S. and M. Colavecchia. 1997. The use of clove oil as an anesthetic for rainbow trout and its effects on swimming performance. North American Journal of Fisheries Management 17:301-307.

Busack, C., B., Watson, Pearsons, T., C., Knudsen, S., Phelps, and M. Johnston. 1997. Yakima fisheries project spring chinook supplementation monitoring plan. Bonneville Power Administration, Portland, OR. DOE/BP-64878-1.

Bohlin, T., Dellefors, C. and U. Faremo. 1990. Large or small at maturity – theories on the choice of alternative male strategies in anadromous salmonids. Ann. Zool. Fennici 27:139-147.

Fast, D. J. Hubble, M. Kohn, and B. Watson. 1991. Yakima River spring chinook enhancement study. Final report submitted to Bonneville Power Administration, Portland OR. DOE/BP-39461-9.

Flain, M. 1970. Precocious male Quinnat salmon *Oncorhynchus tshawytscha* (Walbaum) in New Zealand (Note). N.Z. Journal of Marine and Freshwater Research4:217-222.

Gebhards, S. V. 1960. Biological notes on precocious male chinook salmon parr in the Salmon river drainage, Idaho. The Progressive Fish-Culturist 22:121-123.

Mullan, J. W., Rockhold, A. and C. R. Chrisman. 1992. Life histories and precocity of chinook salmon in the Mid-Columbia river. The Progressive Fish Culturist 54:25-28.

Pearsons, T. N., G. A. McMichael, S. W. Martin, E. L. Bartrand, J. A. Long, and S. A. Leider. 1996. Yakima River Species Interactions Studies. Annual Report FY 1994 submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-99852-3. 150 pp.

Robertson, O. H. 1957. Survival of precociously mature king salmon male parr (*Oncorhynchus tshawytscha juv*.) after spawning. California Fish and Game 43(1):119-130.

Thorpe, J. E. 1987. Smolting versus residency: developmental conflict in salmonids. American Fisheries Society Symposium 1:244-252.