December 2001

YAKIMA RIVER SPECIES INTERACTIONS STUDIES

Annual Report 2000

DOE/BP-00004666-1

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:

Pearsons, Todd N., Anthony L. Fritts, Gabriel M. Temple, Neal S. Burres, Michael R. Schmuck, Charles W. Hopley - Washington Department of Fish and Wildlife, 2001, Yakima River Species Interactions Studies Annual Report 2000, Report to Bonneville Power Administration, Contract No. 00004666, Project No. 199506424, 125 electronic pages (BPA Report DOE/BP-00004666-1)

This report and other BPA Fish and Wildlife Publications are available on the Internet at:

http://www.efw.bpa.gov/cgi-bin/efw/FW/publications.cgi

For other information on electronic documents or other printed media, contact or write to:

Bonneville Power Administration
Environment, Fish and Wildlife Division
P.O. Box 3621
905 N.E. 11th Avenue
Portland, OR 97208-3621

Please include title, author, and DOE/BP number in the request.

Yakima River Species Interactions Studies

Annual Report 2000

Prepared by:

Todd N. Pearsons
Anthony L. Fritts
Gabriel M. Temple
Neal S. Burres
Michael R. Schmuck
Charles W. Hopley

Contributors:

James L. Dunnigan (Yakama Nation)
Linda L. Lamebull (Yakama Nation)

Washington Department of Fish and Wildlife
600 Capitol Way North
Olympia, Washington 98501-1091

Prepared for:

U.S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, Oregon 97283-3621

Project Number 1995-064-24

December 2001

Executive Summary

Species interactions research and monitoring was initiated in 1989 to investigate ecological interactions among fish in response to proposed supplementation of salmon and steelhead in the upper Yakima River basin. This is the ninth of a series of progress reports that address species interactions research and supplementation monitoring of fishes in the Yakima River basin. Data have been collected prior to supplementation to characterize the ecology and demographics of non-target taxa (NTT) and target taxon, and develop methods to monitor interactions and supplementation success. Major topics of this report are associated with the chronology of ecological interactions that occur throughout a supplementation program, implementing NTT monitoring prescriptions for detecting potential impacts of hatchery supplementation, hatchery fish interactions, and monitoring fish predation indices. This report is organized into four chapters, with a general introduction preceding the first chapter. This annual report summarizes data collected primarily by the Washington Department of Fish and Wildlife (WDFW) between January 1, 2000 and December 31, 2000 in the Yakima basin, however these data were compared to data from previous years to identify preliminary trends and patterns. Summaries of each of the chapters included in this report are described below.

- A temporal context to assess and contain ecological risks associated with salmon supplementation is described in this paper. A successful supplementation program has at least four stages that are termed Baseline, Broodstock, Building, and Boundary. These stages can be characterized by the number of fish that spawn in the wild and hatchery. The type and strength of ecological interactions differ during the four stages of supplementation dynamics. During the Baseline stage, interactions between target and non-target species are likely to be relatively low because of the depressed abundance of the target species. During the Broodstock collection phase, interactions between naturally produced target species and non-target species are reduced but interactions between hatchery produced target species and non-target species are potentially high. Interactions with wild fish are likely to be highest during the Building stage because of the high abundance of hatchery smolts released and naturally produced supplemented fish. During the Boundary stage, only interactions between naturally produced fish occur, but these interactions are likely to be more frequent than during the Baseline stage particularly if the environmental capacity for non-target species has not been improved in concert with the target species. The temporal context described indicates that risk assessment and containment should address each of the stages of supplementation dynamics individually and collectively, the time-span of which could be between 10 and 40 years.

- Release of large numbers of hatchery origin salmon has the potential to negatively impact other taxa (non-target taxa, NTT). To determine changes in NTT status that could be related to hatchery smolt releases, we compared the abundance, size structure, and distribution of 16 non-target taxa before and 2 years after annual spring releases of about 1 million yearling salmon smolts (coho and chinook) in the Yakima River. Approximately 25% of chinook salmon released were precocial males which did not migrate to the ocean and reared in areas with many NTT. Relative to presupplementation conditions, most of the parameters that we measured increased slightly and all, except steelhead size (-4%), were within the predetermined containment objectives. With the exception of speckled dace and sculpins, all of the changes that we observed were lower than what we could detect statistically with a power of 90%. These results suggest that any impacts that might have been caused by releasing hatchery smolts were balanced or exceeded by the benefits (e.g., ecological release) of reducing the progeny of naturally produced fish. The reduction of naturally produced fish in the river was the result of taking fish that would have spawned in the river into the hatchery.

- We estimated the number of salmonids that smallmouth bass ate during the spring of 2000 in the Yakima River. Predator surveys were conducted during the weeks of March 2 and March 16 and weekly from March 30 through June 16 in two sections of the lower Yakima River and in small areas of hypothetically high predation, termed "hotspots". Abundance was estimated using a relationship between catch per unit effort and population estimates that were calculated using maximum likelihood estimators of mark and recapture data. Diet was determined by lavaging smallmouth bass and identifying consumed fish in the lab by examining diagnostic bones. Daily consumption was calculated by estimating the average number of salmonids that a bass ate per day and extrapolating that number to the number of bass in the lower 68 kilometers of the Yakima River. Daily estimates were then summed to yield total consumption during the spring. Abundance of bass >150 mm increased during the spring from a low of 985 on March 2 to a high of 28,145 on May 4. The increases in abundance were primarily due to immigration of fish from the Columbia River and partially from growth of smaller fish. Daily consumption of salmonids was relatively low until late April and sharply increased in early May. Consumption of salmonids gradually decreased throughout May and June to near zero by June 16 despite the fact that smallmouth bass numbers remained relatively high and temperature increased. This decrease is likely to be due to bass shifting their behaviors from feeding to spawning. Smallmouth bass ate an estimated 202,722 salmonids during the spring. Only 3,083 of these were estimated to be spring chinook. The remainder was mostly fall chinook salmon. Salmonid consumption estimates for 2000 were similar to estimates for 1999 (171,031 total salmonids and 3,795 spring chinook). Horn Rapids Dam (Wanawish) had only a fraction of the smallmouth congregated below it as it had in 1999 and may not be a hotspot during all years. Roza Dam had low densities of northern pikeminnow again in 2000.

- We conducted population estimates for northern pikeminnow *Ptychocheilus oregonensis* using mark recapture methodology during April, May and June in three sections of the Yakima River above Prosser Dam. However, we were only able to obtain valid population estimates for the Toppenish site (Rkm 145.6-153.4) due to low and variable numbers of recaptured fish at the other sites. The abundance of northern pikeminnow > 199 mm fork length/km in the Toppenish site ranged from 336.2 – 616.8 fish/km from April to June. Most recaptured northern pikeminnow (n = 151; 97.4%) were recaptured in the same section that they were originally tagged, suggesting limited northern pikeminnow movement during the period of this study. Salmonid consumption by northern pikeminnow was higher during the May and June sampling periods than the March and April periods at all sites. Throughout the salmonid outmigration season (March 15 – June 15, 2000) 10.4% of the northern pikeminnow sampled contained at least one salmonid. We classified most salmonids (96%) as yearling smolts (spring chinook *Oncorhynchus tshawytscha*, coho *O. kisutch*, and steelhead *O. mykiss*) based on predicted fork length from diagnostic bones. We relied on the presence of either a coded wire or PIT tag to identify hatchery origin spring chinook and coho salmon. Yearling salmon remains that were not accompanied with a coded wire or PIT tag were identified as unmarked yearling salmonids, and were likely a combination of hatchery and wild origin spring chinook and coho, since estimated fork length at time of ingestion, diagnostic bones, or presence of a coded wire or PIT tag were not reliable methods of determining species or hatchery/wild origin. We estimated a total of 759,315 salmonids were consumed by northern pikeminnow from Prosser Dam to Roza Dam from March 15 – June 15, 2000. We independently modeled consumption of hatchery coho, hatchery spring chinook, unmarked yearling salmon, sub-yearling salmonids, and steelhead, with seasonal consumption estimates of 235,878, 205,402, 308,128, 34,485, and 29,477 fish respectively. Development of a northern pikeminnow predation index in future years should continue to utilize weekly salmonid consumption estimates since this portion of the predation index is likely more variable throughout the outmigration period than predator abundance.

All findings in this report should be considered preliminary and subject to further revision unless they have been published in a peer-reviewed technical journal (i.e., see General Introduction).

Table of Contents

List of Figures

Chapter 4

List of Tables

Chapter 3

Chapter 4

General Introduction

This report is intended to satisfy two concurrent needs: 1) provide a contract deliverable from the Washington Department of Fish and Wildlife (WDFW) to the Bonneville Power Administration (BPA), with emphasis on identification of salient results of value to ongoing Yakima/Klickitat Fisheries Project (YKFP) planning, and 2) summarize results of research that have broader scientific relevance. This is the ninth of a series of progress reports that address species interactions research and supplementation monitoring of fishes in response to supplementation of salmon and steelhead in the upper Yakima River basin (Hindman et al. 1991; McMichael et al. 1992; Pearsons et al. 1993; Pearsons et al. 1994; Pearsons et al. 1996; Pearsons et al. 1998, Pearsons et al. 1999, Pearsons et al. 2001). Journal articles and book chapters have also been published from our work (McMichael 1993; Martin et al. 1995; McMichael et al. 1997; McMichael and Pearsons 1998; McMichael et al. 1998; Pearsons and Fritts 1999; McMichael et al. 1999; McMichael et al. 1999; Pearsons and Hopley 1999; Ham and Pearsons 2000; Ham and Pearsons 2001; Amaral et al. 2001; McMichael and Pearsons 2001; Pearsons et al. in press). This progress report summarizes data collected between January 1, 2000 and December 31, 2000. These data were compared to findings from previous years to identify general trends and make preliminary comparisons. Interactions between fish produced as part of the YKFP, termed target species or stocks, and other species or stocks (non-target taxa) may alter the population status of non-target species or stocks. This may occur through a variety of mechanisms, such as competition, predation, and interbreeding (reviewed in Pearsons et al. 1994; Busack et al. 1997). Furthermore, the success of a supplementation program may be limited by strong ecological interactions such as predation or competition (Busack et al. 1997).

Our work has adapted to new information needs as the YKFP has evolved. Initially, our work focused on interactions between anadromous steelhead and resident rainbow trout (for explanation see Pearsons et al. 1993), then interactions between spring chinook salmon and rainbow trout, and recently interactions between spring chinook salmon and highly valued non-target taxa (NTT; e.g., bull trout); and interactions between strong interactor taxa (e.g., those that may strongly influence the abundance of spring chinook salmon; e.g., smallmouth bass) and spring chinook salmon. The change in emphasis to spring chinook salmon has largely been influenced by the shift in the target species planned for supplementation (Bonneville Power Administration et al. 1996; Fast and Craig 1997). Originally, steelhead and spring chinook salmon were proposed to be supplemented simultaneously (Clune and Dauble 1991). However, due in part to the uncertainties associated with interactions between steelhead and rainbow trout, spring chinook salmon were supplemented before steelhead. This redirection in the species to be supplemented has prompted us to prioritize interactions between spring chinook and rainbow trout, while beginning to investigate other ecological interactions of concern. Pre-facility monitoring of variables such as rainbow trout density, distribution, and size structure was continued and monitoring of other NTT was initiated in 1997.

This report is organized into four chapters which represent major topics associated with monitoring stewardship, utilization, and strong interactor taxa. Chapter 1 describes the chronology of ecological interactions associated with the life-span of salmon supplementation programs. Chapter 2 reports the results of non-target taxa monitoring after the second release of hatchery salmon smolts in the upper Yakima Basin. Chapter 3 (smallmouth bass and channel catfish) and 4 (northern pikeminnow) describe predation on juvenile salmonids in the lower Yakima River.

The chapters in this report are in various stages of development and should be considered preliminary unless they have been published in a peer-reviewed journal. Chapter 1 has been submitted for publication in the journal “Fisheries”. Additional field work and/or analysis is in progress for topics covered in this report. Throughout this report, a premium was placed on presenting data in tables so that other interested parties could have access to the data. Readers are cautioned that any preliminary conclusions are subject to future revision as more data and analytical results become available.

Except where otherwise noted, the methods and general site descriptions are the same as described in previous reports (Hindman et al. 1991; McMichael et al. 1992; Pearsons et al. 1993; Pearsons et al. 1994; Pearsons et al. 1996; Pearsons et al. 1998; Pearsons et al. 1999; Pearsons et al. 2001).

Acknowledgments

We would like to thank Bonneville Power Administration for financially supporting this work. In addition, we could not have completed this work without the help and support of many individuals during 2000. Most of these individuals are recognized on title pages or in acknowledgments of various chapters in this report.

References

Amaral, S. V., F. C. Winchell, and T. N. Pearsons. 2001. Reaction of chinook salmon, northern pikeminnow, and smallmouth bass to behavioral guidance stimuli. Pages 125-144 in C. C. Coutant, editor. Behavioral technologies for fish guidance. American Fisheries Society, Symposium 26, Bethesda, Maryland.

Bonneville Power Administration, Washington Department of Fish and Wildlife and Yakama Indian Nation. 1996. Yakima Fisheries Project - Final Environmental Impact Statement. Bonneville Power Administration, Portland, Oregon. DOE/BP-2784.

Busack, C., B. Watson, T. Pearsons, C. Knudsen, S. Phelps, and M. Johnston. 1997. Yakima Fisheries Project Spring Chinook Supplementation Monitoring Plan. Bonneville Power Administration, Portland, Oregon. DOE/BP-64878-1.

Clune, T., and D. Dauble. 1991. The Yakima/Klickitat fisheries project: a strategy for supplementation of anadromous salmonids. Fisheries 16(5):28-34.

Fast, D. E., and C. Craig. 1997. Innovative hatchery project working to rebuild wild salmon populations. Hydro Review XVI:30-33.

Ham, K. D., and T. N. Pearsons. 2000. Can reduced salmonid population abundance be detected in time to limit management impacts? Canadian Journal of Fisheries and Aquatic Sciences 57:1-8.

Ham, K. D., and T. N. Pearsons. 2001. A practical approach for containing ecological risks associated with fish stocking programs. Fisheries 26(4):15-23.

Hindman, J. N., G. A. McMichael, J. P. Olson, and S. A. Leider. 1991. Yakima River Species Interactions Studies. Annual Report FY 1990 submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-01483-1. 75 pp.

Martin, S. W., J. A. Long, and T. N. Pearsons. 1995. Comparison of survival, gonad development, and growth between rainbow trout with and without surgically implanted dummy radio transmitters. North American Journal of Fisheries Management 15:494-498.

McMichael, G. A., J. P. Olson, E. L. Bartrand, M. Fischer, J. N. Hindman, and S. A. Leider. 1992. Yakima River Species Interactions Studies. Annual Report FY 1991 submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-01483-2. 177 pp.

McMichael, G. A. 1993. Examination of electrofishing injury and short-term mortality in hatchery rainbow trout. North American Journal of Fisheries Management 13:229-233.

McMichael, G. A., C. S. Sharpe, and T. N. Pearsons. 1997. Effects of residual hatchery-reared steelhead on growth of wild rainbow trout and spring chinook salmon. Transactions of the American Fisheries Society 126:230-239.

McMichael, G. A., and T. N. Pearsons. 1998. Effects of wild juvenile spring chinook salmon on growth and abundance of wild rainbow trout. Transactions of the American Fisheries Society 127:261-274.

McMichael, G. A., A. L. Fritts, and T. N. Pearsons. 1998. Electrofishing injury to stream salmonids; injury assessment at the sample, reach, and stream scales. North American Journal of Fisheries Management 18:894-904.

McMichael, G. A., T. N. Pearsons, and S. A. Leider. 1999. Minimizing ecological impacts of hatchery-reared juvenile steelhead on wild salmonids in a Yakima basin tributary. Pages 365-380 in Eric Knudson et al. editors. Sustainable fisheries management: Pacific salmon. CRC Press, Boca Raton, FL.

McMichael, G. A., T. N. Pearsons, and S. A. Leider. 1999. Behavioral interactions among hatchery-reared steelhead smolts and wild *Oncorhynchus mykiss* in natural streams. North American Journal of Fisheries Management 19:948-956.

McMichael, G. A. and T. N. Pearsons. 2001. Upstream movement of residual hatchery steelhead into areas containing bull trout and cutthroat trout. North American Journal of Fisheries Management 21:517-520.

Pearsons, T. N., G. A. McMichael, E. L. Bartrand, M. Fischer, J. T. Monahan, and S. A. Leider. 1993. Yakima Species Interactions Study. Annual Report FY 1992 submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-01483-3. 98 pp.

Pearsons, T. N., G. A. McMichael, S. W. Martin, E. L. Bartrand, M. Fischer, and S. A. Leider. 1994. Yakima River Species Interactions Studies. Annual Report FY 1993 submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-99852-2. 247 pp.

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 FY 1995-1997 submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-64878-6.

Pearsons, T. N., K. D. Ham, G. A. McMichael, E. L. Bartrand, A. L. Fritts, and C. W. Hopley. 1999. Yakima River Species Interactions Studies. Annual Report FY 1998 submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-64878-5.

Pearsons, T. N., and A. L. Fritts. 1999. Maximum size of chinook salmon consumed by juvenile coho salmon. North American Journal of Fisheries Management 19:165-170.

Pearsons, T. N., and C. W. Hopley. 1999. A practical approach for assessing ecological risks associated with fish stocking programs. Fisheries 24(9):16-23.

Pearsons, T. N., A. L. Fritts, K. D. Ham, G. A. McMichael, E. L. Bartrand, G. M. Temple, and C. W. Hopley. 2001. Yakima River Species Interactions Studies. Annual Report FY 1999 submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-64878-7.

Pearsons, T. N., S. R. Phelps, S. W. Martin, E. L. Bartrand, and G. A. McMichael. In press. Gene flow between resident and anadromous rainbow trout in the Yakima basin: ecological and genetic evidence. In P. Howell and D. Buchannan editors, proceedings of the inland rainbow trout workshop. Malheur Field Station, Oregon.

Chapter 1

Chronology of ecological interactions associated with the life-span of salmon supplementation programs

Todd N. Pearsons

Washington Department of Fish and Wildlife
600 Capitol Way North
Olympia, WA 98501-1091

Abstract

A temporal context to assess and contain ecological risks associated with salmon supplementation is described in this paper. A successful supplementation program has at least four stages that are termed Baseline, Broodstock, Building, and Boundary. These stages can be characterized by the number of fish that spawn in the wild and hatchery. The type and strength of ecological interactions differ during the four stages of supplementation dynamics. During the Baseline stage, interactions between target and non-target species are likely to be relatively low because of the depressed abundance of the target species. During the Broodstock collection phase, interactions between naturally produced target species and non-target species are reduced but interactions between hatchery produced target species and non-target species are potentially high. Interactions with wild fish are likely to be highest during the Building stage because of the high abundance of hatchery smolts released and naturally produced supplemented fish. During the Boundary stage, only interactions between naturally produced fish occur, but these interactions are likely to be more frequent than during the Baseline stage particularly if the environmental capacity for non-target species has not been improved in concert with the target species. The temporal context described indicates that risk assessment and containment should address each of the stages of supplementation dynamics individually and collectively, the time-span of which could be between 10 and 40 years.

Introduction

Intra- and interspecies interactions will occur as a result of supplementation programs, but whether those interactions are biologically significant, socially acceptable and whether the impacts of the interactions are statistically detectable depends upon the supplementation program and how that program is evaluated (Pearsons and Hopley 1999; Ham and Pearsons 2000; Ham and Pearsons 2001). The definition of supplementation that is widely utilized in the Columbia Basin, and that will be used in this paper, is: Athe use of artificial propagation in an attempt to maintain or increase natural production while maintaining the long term fitness of the target population, and keeping the ecological and genetic impacts on non-target populations within specified biological limits≅ (RASP 1992). This definition implies an increase in the number of natural origin recruits, not just an increase in the number of hatchery origin fish on the spawning grounds. The timing and strength of ecological interactions that occur throughout the life-span of a supplementation program is of critical importance to the planning and evaluation of a program. Misunderstanding the timing and strength of ecological interactions can result in false interpretations which can contribute towards improper balancing of costs and benefits (Ham and Pearsons 2001).

Ecological impacts to non-target taxa (NTT) and to the wild component of the target taxon has never been rigorously quantified throughout the duration of a salmon supplementation program. However many published studies indicate the potential for negative interactions to occur (McMichael et al. 1997; McMichael et al. 1999; Hawkins and Tipping 1999). Hatchery produced fish may compete with, prey upon, increase sickness to, alter predator consumption of, and alter behavior of wild conspecifics and nontarget species (Marnell 1986; Nickelson et al. 1986; Pearsons and Hopley 1999). Practical management questions that should be asked within the context of ecological interactions and supplementation dynamics include: How often and how long is it necessary to monitor ecological interactions to contain risks? Is it necessary to assess risks for different stages of supplementation or can it be assumed that the types and magnitudes of interactions are constant throughout a supplementation program? These questions are addressed in this paper.

In this paper, I describe the types of ecological interactions that are likely to occur during the life-span of a supplementation program that successfully increases natural production. Application to unsuccessful supplementation programs is also discussed. In addition, I discuss how approaches to risk assessment and monitoring can be influenced by viewing the chronology of ecological interactions associated with supplementation dynamics. Although genetic interactions also influence the success of a supplementation program, they will not be addressed in this paper.

Chronology of a successful supplementation program

In order to understand the ecological interactions that are likely to occur during a supplementation program, it is necessary to provide a template of supplementation dynamics. A successful supplementation program has at least four stages that are termed Baseline, Broodstock, Building, and Boundary (Figure 1). These stages can be characterized by the relative number of fish that spawn in the wild and hatchery (Table 1). The Baseline stage is typically a period of depressed abundance of the target taxon, since low abundance of the target taxon is one of the main reasons for initiating a supplementation program. The abundance of the target taxon may be depressed because of high density independent or density dependent mortality. It is important to recognize that low abundance may indicate low natural carrying capacity. Adding more fish to a system with a low natural carrying capacity is unlikely to result in increases in natural origin recruits. Exceptions may occur if depensatory mechanisms exist such as predator traps or threshold prey deficits (Peterman 1977; Peterman and Gatto 1978; and Walters and Kitchell 2001). After the decision has been made to begin a supplementation program, adult salmon are collected for broodstock. I assume that fish that are native to the supplemented population are used for broodstock. When broodstock are collected, they are eliminated from spawning in the wild. The lower number of naturally spawning fish will likely result in temporarily reduced numbers of juvenile fish in the wild unless strong density dependence was inhibiting survival. When adults from the hatchery return to spawn in the wild, then the building stage begins. The length of time before the number of adults spawning in the wild increases, depends upon the life-history and survival of the target taxon. Species that typically mature at an older age (e.g., stream type chinook salmon) will take longer to rebuild than species that mature early (e.g., pink salmon). The Building stage generally begins between 2-5 years after the initiation of broodstock collection. The Building stage is characterized by increasing numbers of naturally spawning fish of both hatchery and wild origin. This stage continues until carrying capacity is reached. The time between the initiation and completion of the Building stage is dependent upon the size of the supplementation program and the productivity of the hatchery (Busack and Knudsen, Washington Department of Fish and Wildlife, personal communication). The Boundary stage is characterized by a stable number of fish spawning in the wild that represents the carrying capacity of the environment. It may take 20-50 years to detect whether carrying capacity has been reached because of the large interannual variation in abundance of salmon (Busack et al. 1997). Once carrying capacity is reached, a decision to terminate hatchery supplementation can be made. For the purposes of this paper, I will assume that supplementation will be terminated when carrying capacity is reached. Again, it is important to note that supplementation is unlikely to increase the carrying capacity of the natural environment and habitat restoration will need to be implemented in order to sustain supplemented populations above baseline levels. However, when a hatchery is in operation, it can increase the total capacity (e.g., natural and artificial environments combined) of the system, not unlike a highly productive tributary stream.

Interactions chronology relative to a successful supplementation program

Ecological interactions between supplemented and unsupplemented taxa can be described relative to the four stages of supplementation dynamics. The type and strength of interactions are related to the number and type of fish that are propagated in the wild and the hatchery (Figure 1, Table 1). For discussion purposes, I will be referring to releases of smolts because the release of non-migrants is generally not done in the Pacific Northwest. During the Baseline stage, interactions between target and non-target taxa are likely to be relatively low because of the depressed abundance of the target species (e.g., ecological release, which is the relaxation of ecological interactions that depress a species). If it is assumed that density dependent interactions generally result in impacts that harm NTT, then abundances of NTT are likely to be larger when salmon populations are depressed. However, it is possible that NTT benefit from increased numbers of salmon (e.g., increase in nutrients or prey; Bilby et al. 1996; 1998) and the abundance of NTT may be restricted (e.g., ecological restriction, which is the reduction of ecological interactions that enhance a species). It is critical to know the relationship between abundance of salmon and NTT in order to know if ecological release or restriction is likely to be occurring.

During the Broodstock collection phase, interactions between naturally produced target species and NTT are reduced but interactions between hatchery produced target species and NTT are potentially high. In essence, rearing of fish in a hatchery is an ecological tradeoff between lower interactions with wild fish before the smolt stage, with higher interactions from the smolt to adult stages. A reduction in the interactions among naturally produced fish occurs because target species that would normally rear in the wild are reared in the hatchery. In contrast, the higher survival of fish reared in the hatchery translates into greater number of smolts than would have occurred naturally. Greater numbers of hatchery smolts increases interaction potentials between hatchery and wild fish in the freshwater migration corridor, freshwater rearing area (e.g., if hatchery fish residualize), estuary, and ocean. Type I interactions are those that occur between hatchery fish (e.g., smolt, residual, or adult) and wild fish (Pearsons and Hopley 1999). If Type I impacts are less than benefits produced from ecological release, then non-target species will benefit, the converse is also true. Type I interactions can be non-natural because humans artificially rear and release the fish. Hatchery fish are typically more numerous, more concentrated, larger and in some instances more aggressive than wild fish (Ruzzante 1994; White et al. 1995). These differences can confer dominance status to hatchery fish (McMichael et al. 1997; Rhodes and Quinn 1998; McMichael et al. 1999), decrease the size refuge of wild fish to predation by hatchery fish (Pearsons and Fritts 1999), and change the functional and numerical response of predators to mixed groups of hatchery and wild fish (Peterman and Gatto 1978; Wood 1987; Collis et al. 1995). If smolts actively migrate after release, then the interactions with NTT in the freshwater migration corridor are likely to be relatively low.

During the Building stage, Type I and Type II interactions occur. Type II interactions are those that occur between naturally produced offspring of hatchery fish and wild fish. Supplementation hatcheries inherently produce type II interactions because the goal is to increase natural production. Impacts to wild fish are likely to be highest during the building stage particularly if Type I interactions are strong.

During the Boundary stage, only interactions between naturally produced fish occur (e.g., Type II interactions). These interactions are likely to be more frequent than during the baseline stage particularly if the environmental capacity for non-target species has not been improved in concert with the target species.

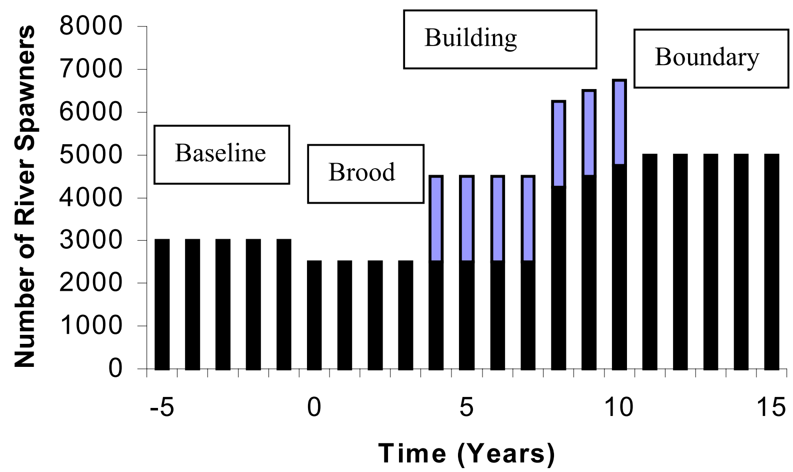

Figure 1. The total number of adult hatchery (upper stacked bar) and wild (lower stacked bar) origin target species naturally spawning over time from a hypothetically successful supplementation program in a semi-constant environment. Broodstock for supplementation are collected during year 0. Before supplementation starts, the target population is typically at depressed abundance.

Without knowing the relative importance of freshwater and post freshwater rearing to survival, the impact to NTT cannot be predicted. To clarify, freshwater rearing occurs prior to smolt emigration, and post freshwater rearing occurs from the smolt to adult stages. When the signs of the interactions are the same for both freshwater and post freshwater, predictions about impacts can be made (Table 2). For example, when interactions are negative in all environments, the abundance of NTT will decrease in the Building and Boundary stages. Furthermore, when interactions are negative for freshwater rearing and positive for the remainder of life, abundance of NTT will increase during the Broodstock stage. The converse is true when interactions are negative for freshwater rearing and positive for the remainder of life. NTT abundance will increase during the Building and Boundary stages when interactions are positive throughout freshwater rearing and elsewhere.

Table 1. Hypothetical numbers of spawners and smolts produced in a hatchery and river during four stages of supplementation.

Location and lifestage of fish	Baseline	Broodstock	Building	Boundary
River spawners	3,000	2,500	5,300	5,000
Hatchery spawners	0	500	500	0
Total spawners	3,000	3,000	5,800	5,000
River produced smolts	100,000	83,333	150,000	166,667
Hatchery smolts	0	810,000	810,000	0
Total smolts	100,000	893,333	960,000	166,667

Table 2. Interaction strength relative to ecological relationship between target and non-target species (negative or positive) and between historic and baseline target species abundance for four different scenarios. Freshwater rearing occurs prior to smolt emigration, and post freshwater rearing occurs from the smolt to adult stages. Baseline interaction strength is relative to historic interaction strength (abundant target species) and interaction strength of the other three stages is relative to baseline interaction strength. "Negative" (-) refers to interactions that decrease non-target species with increases in target taxa. "Positive" (+) is the converse. Interaction strength is qualitatively higher if two symbols (++) are used.

Direction of Interaction		Interaction strength							
		Baseline relative to historic		Broodstock relative to baseline		Building relative to baseline		Boundary relative to baseline	
Fresh	Post	Fresh	Post	Fresh	Post	Fresh	Post	Fresh	Post
-	-	+	+	++	- -	-	--	--	-
-	+	+	-	++	++	-	++	--	+
+	-	-	+	--	--	+	--	++	-
+	+	-	-	--	++	+	++	++	+

Implications

The chronology of ecological interactions associated with the life-span of salmon supplementation programs suggests that monitoring of interactions should occur during each of the stages – Baseline, Broodstock, Building, and Boundary. If the goal of a monitoring program is to detect impacts to NTT (e.g., Ham and Pearsons 2001), then it would be better to distribute monitoring effort throughout each stage than to concentrate all effort into one or two stages. For example, monitoring for five years immediately after the initiation of a supplementation program would likely provide a false impression of the impacts of the supplementation program. Positive or no impacts may be detected during the Broodstock stage if ecological release is significant.

The duration of monitoring to detect ecological interactions to NTT could be between 10 and 40 years (Busack et al. 1997; Ham and Pearsons 2000).

Risk assessments of supplementation programs should also be specific to the life span of the program. Pearsons and Hopley (1999) identified the need to assess risk for type I and II interactions. For example, risk assessments might be conducted for each of the Broodstock, Building, and Boundary stages. Ecological risks are likely to be quite different for each of the stages. Prior knowledge of 1) the relationship between abundance of hatchery and wild salmon and the abundance of non-target taxa, and 2) the relative importance of freshwater and post freshwater survival would allow predictions about ecological interactions to be made. Certainly, these would be fruitful areas for future investigation.

This paper addressed the interactions that could occur from a successful supplementation program, but many of the findings also apply to unsuccessful supplementation programs and harvest augmentation hatcheries as well. For example, ecological interactions resulting from an unsuccessful hatchery program might be similar to the Baseline, Broodstock, and parts of the Building stages for a successful supplementation program. Ecological interactions associated with harvest augmentation hatcheries might be confined primarily to the Baseline and Broodstock stages except when unintentional supplementation occurs. In this case, ecological interactions associated with Building and Boundary stages may also occur.

In conclusion, impacts of a supplementation program should be evaluated by considering the impacts within each of the four stages and summing across the life-span of a program. Negative impacts in one stage could be cancelled by positive impacts in another stage unless impacts do irreversible harm. Conversely, negative or positive impacts could be cumulative, which could result in large ecological benefits or costs.

Acknowledgments

I thank Craig Busack and Curt Knudsen whose modeling of supplementation dynamics triggered me to think about how ecological interactions might change throughout a supplementation program. Howard Fuss and Curt Knudsen provided helpful reviews. I thank Bonneville Power Administration who funded this work through the Washington Department of Fish and Wildlife's Yakima Species Interactions Studies.

References

Bilby, R. E., Fransen, B. R., and Bisson, P. A. 1996. Incorporation of nitrogen and carbon from spawning coho salmon into the trophic system of small streams: evidence from stable isotopes. Canadian Journal of Fisheries and Aquatic Sciences 53:164-173.

Bilby, R. E., Fransen, B. R., Bisson, P. A and J.K. Walter. 1998. Response of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead (*O. mykiss*) to the addition of salmon carcasses to two streams in southwestern Washington, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences 55:1909-1918.

Busack, C., B. Watson, T. Pearsons, C. Knudsen, S. Phelps, and M. Johnston. 1997. Yakima Fisheries Project Spring Chinook Supplementation Monitoring Plan. Bonneville Power Administration, Portland, Oregon. DOE/BP-64878-1

Collis, K., R. E. Beaty, and B. R. Crain. 1995. Changes in catch rate and diet of northern squawfish associated with the release of hatchery-reared juvenile salmonids in a Columbia River reservoir. North American Journal of Fisheries Management 15:346-357.

Ham, K. D., and T. N. Pearsons. 2000. Can reduced salmonid population abundance be detected in time to limit management impacts? Canadian Journal of Fisheries and Aquatic Sciences 57:17-24.

Ham, K. D., and T. N. Pearsons. 2001. A practical approach for containing ecological risks associated with fish stocking programs. Fisheries 25(4):15-23.

Hawkins, S. W., and J. M. Tipping. 1999. Predation by juvenile hatchery salmonids on wild fall chinook salmon fry in the Lewis River, Washington. California Fish and Game 85(3):124-129.

Marnell, L. F. 1986. Impacts of hatchery stocks on wild fish populations. Pages 339-347 in R. H. Stroud, editor. Fish culture in fisheries management. American Fisheries Society, Fish Culture Section and Fisheries Management Section, Bethesda, Maryland.

McMichael, G. A., C. S. Sharpe, and T. N. Pearsons. 1997. Effects of residual hatchery-reared steelhead on growth of wild rainbow trout and spring chinook salmon. Transactions of the American Fisheries Society 126:230-239.

McMichael, G. A., T. N. Pearsons, and S. A. Leider. 1999. Behavioral interactionsamong hatchery-reared steelhead smolts and wild *Oncorhynchus mykiss* in natural streams. North American Journal of Fisheries Management 19:948-956.

Nickelson, T. E., M. F. Solazzi, and S. L. Johnson. 1986. The use of hatchery coho salmon (*Oncorhynchus kisutch*) presmolts to rebuild wild populations in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences 43:2443-2449.

Pearsons, T. N., and A. L. Fritts. 1999. Maximum size of chinook salmon consumed byjuvenile coho salmon. North American Journal of Fisheries Management 19:165-170.

Pearsons, T. N., and C. W. Hopley. 1999. A practical approach for assessingecological risks associated with fish stocking programs. Fisheries 24(9):16-23.

Peterman, R. M. 1977. A simple mechanism that causes collapsing stability regions in exploited salmonid populations. Journal of the Fisheries Research Board of Canada 34:1130-1142.

Peterman, R. M., and M. Gatto. 1978. Estimation of functional responses of predators on juvenile salmon. Journal of the Fisheries Research Board of Canada 35:797-808.

Regional Assessment of Supplementation Project (RASP). 1992. Supplementation in the Columbia Basin. Final report. Bonneville Power Administration. Portland, Oregon. DOE/BP-01830-14.

Rhodes, J. S., and T. P. Quinn. 1998. Factors affecting the outcome of territorialcontests between hatchery and naturally reared coho salmon parr in the laboratory. Journal of Fish Biology 53:1220-1230.

Ruzzante, D. E. 1994. Domestication effects on aggressive and schooling behavior in fish. Aquaculture 120:1-24.

Walters, C., and J. F. Kitchell. Cultivation/depensation effects on juvenile survival and recruitment: implications for the theory of fishing. Canadian Journal of Fisheries and Aquatic Sciences 58:39-50.

White, R. J., J. R. Karr, and W. Nehlsen. 1995. Better roles for fish stocking in aquatic resource management. American Fisheries Society Symposium 15:527-550.

Wood, C. C. 1987. Predation of juvenile Pacific salmon by the common merganser (*Mergus merganser*) on eastern Vancouver Island. I: Predation during the seaward migration. Canadian Journal of Fisheries and Aquatic Sciences 44:941-949.

Chapter 2

Results of non-target taxa monitoring after the second release of hatchery salmon smolts in the upper Yakima Basin

Neal S. Burres

Todd N. Pearsons

and

Gabriel M. Temple

Washington Department of Fish and Wildlife
600 Capitol Way North
Olympia, Washington 98501-1091

Abstract

Release of large numbers of hatchery origin salmon has the potential to negatively impact other taxa (non-target taxa, NTT). To determine changes in NTT status that could be related to hatchery smolt releases, we compared the abundance, size structure, and distribution of 16 non-target taxa before and 2 years after annual spring releases of about 1 million yearling salmon smolts (coho and chinook) in the Yakima River. Approximately 25% of chinook salmon released were precocial males which did not migrate to the ocean and reared in areas with many NTT. Relative to presupplementation conditions, most of the parameters that we measured increased slightly and all, except steelhead size (-4%), were within the predetermined containment objectives. With the exception of speckled dace and sculpins, all of the changes that we observed were lower than what we could detect statistically with a power of 90%. These results suggest that any impacts that might have been caused by releasing hatchery smolts were balanced or exceeded by the benefits (e.g., ecological release) of reducing the progeny of naturally produced fish. The reduction of naturally produced fish in the river was the result of taking fish that would have spawned in the river into the hatchery.

Introduction

Despite the long history of stocking hatchery salmon into streams, few evaluations of impacts to non-target taxa (NTT) have been conducted. Many mechanisms of impacts have been documented (Marnell 1986; Nielsen 1994; Hawkins and Tipping 1999), but impacts to NTT population size, growth, or distribution generally have not been conclusively demonstrated at scales larger than experimental reaches (Fresh 1997). Exceptions include the relatively large-scale evaluations of stocking salmon before the smolt stage (Bjornn 1978; Nickelson et al. 1986). Although these studies are illuminating, most contemporary hatchery salmon programs release smolts. In order to evaluate impacts of contemporary programs, information about the impacts of smolt releases is needed.

Ecological interactions resulting from smolt releases should be evaluated throughout the life-span of a hatchery supplementation program because the type and strength of ecological interactions differ during stages of hatchery supplementation dynamics (Chapter 1). This paper will address impacts that occur during the initial stages of supplementation which has been termed the Broodstock stage by Pearsons (Chapter 1). When a supplementation program is initiated wild broodstock are collected, spawned, and then their progeny are released as smolts. During this initial stage, interactions between naturally produced target species and NTT are reduced but interactions between hatchery produced target species and NTT are potentially high (Chapter 1). "In essence, rearing of fish in a hatchery is an ecological tradeoff between lower interactions with wild fish before the smolt stage, with higher interactions from the smolt to adult stages. A reduction in the interactions among naturally produced fish occurs because target species that would normally rear in the wild are reared in the hatchery. In contrast, the higher survival of fish reared in the hatchery translates into greater number of smolts than would have occurred naturally. Greater numbers of hatchery smolts increases interaction potentials between hatchery and wild fish in the freshwater migration corridor, freshwater rearing area (e.g., if hatchery fish residualize), estuary, and ocean. Type I interactions are those that occur between hatchery fish (e.g., smolt, residual, or adult) and wild fish (Pearsons and Hopley 1999). If Type I impacts are less than benefits produced from ecological release, then non-target species will benefit, the converse is also true. Type I interactions can be non-natural because humans artificially rear and release the fish. Hatchery fish are typically more numerous, more concentrated, larger, and in some instances more aggressive than wild fish (Ruzzante 1994; White et al. 1995). These differences can confer dominance status to hatchery fish (McMichael et al. 1997; Rhodes and Quinn 1998; McMichael et al. 1999), decrease the size refuge of wild fish to predation by hatchery fish (Pearsons and Fritts 1999), and change the functional and numerical response of predators to mixed groups of hatchery and wild fish (Peterman and Gatto 1978; Wood 1987; Collis et al. 1995). If smolts actively migrate after release, then the interactions with NTT in the freshwater migration corridor are likely to be relatively low."

Hatchery smolts can interact with wild fish during downstream migration and during periods when they residualize in rearing environments. Ecological interactions that can occur during migration include competition, predation, behavioral anomalies, and pathogenic interactions (Pearsons and Hopley 1999). If competition occurs, it is likely to be intense but of short duration, because hatchery smolts generally move downstream and feed as they migrate or during brief "resting" periods. It is during the "resting" periods that competition might be most intense. Hatchery spring chinook smolts were observed to behaviorally dominate wild smolts and secure the most food and best habitat in laboratory experiments (Pearsons and Ham 2001). Predation by chinook and coho salmon smolts on naturally produced salmon has also been demonstrated (Sholes and Hallock 1979; Hawkins and Tipping 1999). As mentioned before, the release of large numbers of hatchery smolts can change the functional and numerical response of predators to mixed groups of hatchery and wild fish (Peterman and Gatto 1978; Wood 1987; Collis et al. 1995). Depending upon the predator response, the releases can either benefit or harm naturally produced species. Large numbers of hatchery fish can also alter the behavior of wild fish, which has the potential to influence susceptibility to predators or food acquisition (Hillman and Mullan 1989; McMichael et al. 1999). Finally, hatchery fish have the potential to transmit or increase the susceptibility of pathogens to wild fish (Goede 1986; Bucke 1993; McVicar 1997). The same aforementioned interactions can occur during the periods when "smolts" residualize. Although the intensity or manifestation of the interaction may differ. For example, competition is likely to be more potent locally when fish residualize because they remain in an area, as opposed to more temporal occupation of areas during downstream migration.

Impacts to NTT are difficult to detect because of high interannual variation of response variables and the low number of annual surveys available to isolate the impacts that occur during the Broodstock stage (Ham and Pearsons 2000; Ham and Pearsons 2001; Chapter 1 of this report). For example, prospective power analyses indicated that abundance impacts of <19% were not statistically detectable after 5 annual surveys (Ham and Pearsons 2000). The broodstock stage of a chinook salmon with a modal age of 4+ lasts only three to four years. Thus, impacts must be detected in three to four years. Based on these constraints, only large impacts will be statistically detectable.

In this paper, we examine the impacts to NTT during the Broodstock stage of a spring chinook supplementation program and the reintroduction of coho salmon in the Yakima Basin, Washington (Figure 1). Concerns about the possibility of hatchery fish having negative impacts on valued non-target taxa (NTT) in the Yakima basin prompted the development and implementation of a risk containment monitoring program. Spring chinook and coho salmon were released in the upper Yakima Basin for the first time during spring 1999 as part of the Yakima/Klickitat Fisheries Project (YKFP). The goal for both of these species is to increase natural production using artificial propagation (supplementation). A total of 386,048 (229,290 Clark Flats, 156,758 Easton) and 589,683 (221,460 Clark Flats, 230,860 Easton, 137,363 Jack Creek) were released during 1999 and 2000 respectively. Approximately 500,000 coho salmon smolts were released into the upper Yakima Basin during 1999 and 2000. Spring chinook salmon were volitionally released into the Yakima River from sites near the cities of Easton, Thorp, and near Jack Creek on the North Fork of the Teanaway River (Figure 1). Coho salmon were volitionally released into the Yakima River from sites near the city of Cle Elum (hatchery slough 1999 and 2000) and near Jack Creek on the North Fork of the Teanaway River (1999) and below Easton Dam (2000). More detail about the study area and background of the supplementation project has been previously described (Pearsons and Hopley 1999, Ham and Pearsons 2000).

Methods

We monitored the changes in status of 16 NTT that have the potential to be impacted by the supplementation of spring chinook salmon and coho salmon in the Yakima Basin. Status is defined as the abundance, distribution, and size structure of an NTT and change in status as a deviation from baseline conditions (prior to supplementation). A change in status does not indicate causation, but a significant decline in status must occur if supplementation did have a negative impact. Therefore, changes in status can be used to trigger further studies to identify the causes of changes in monitoring variables. In some cases, changes in status and whether a change occurred from supplementation can be determined simultaneously. This occurs when control sites are available and are currently monitored. Based upon baseline data, the most statistically powerful and economically feasible techniques were assembled into monitoring prescriptions.

Monitoring prescriptions were developed to maximize our sensitivity to detect changes. Previous work identified the difficulty in detecting changes using abundance monitoring alone (Ham and Pearsons 2000). Subsequent work identified improvements in detecting changes by using alternative measures (Ham and Pearsons in review). These newer measures include spatial overlap, analogs, predation indexing, and modeling (Table 3). Each of these measures can improve the detectability of changes, but each also has certain shortcomings. Spatial overlap is used for species that are located upstream of target species acclimation sites during the baseline period (e.g., bull trout and cutthroat trout). Increases in distribution of the target species can result in spatial overlap with NTT resulting in the potential for impacts. If overlap never occurs, then impacts are assumed to be negligible. However, if overlap does occur, then changes to status must be investigated. NTT that have similar ecological responses to interactions are used as analogs if they significantly improve the ability to detect changes. The use of analogs is particularly useful when NTT are rare and dispersed, and therefore difficult to sample. The potential liability of using analogs is that one must assume that impacts to the analog are the same as to an NTT. Monitoring a predation index is useful when predation is the primary interaction of concern. However, interpretation of how the predation index changes the status of the NTT may not be straightforward. Finally, modeling of flow can be used to reduce the amount of unexplained inter-annual variation in an NTT response variable. If the parameters used in the model are not actually causing the changes observed in the status of NTT (e.g., spurious correlations), then the model may give a false interpretation. We follow the risk containment approach for detecting and protecting NTT described by Ham and Pearsons (2001).

The wide range in life cycles of the NTT, river conditions and flow necessitate the use of sampling techniques ranging from snorkeling, backpack electrofishing, dam counts, and trapping to boat electrofishing. Abundance, size structure and distribution (status) are determined annually at the sites indicated in Figure 1 and Tables 1 and 2. Techniques have been previously described by Ham and Pearsons (2000), but are briefly described here for completeness. In addition, a separately described predation index was also used for monitoring (Chapter 3 of this report).

The spatial overlap between bull trout and supplemented salmon in the North Fork of the Teanaway River is inventoried by snorkeling. The entire rearing area of bull trout is snorkeled at

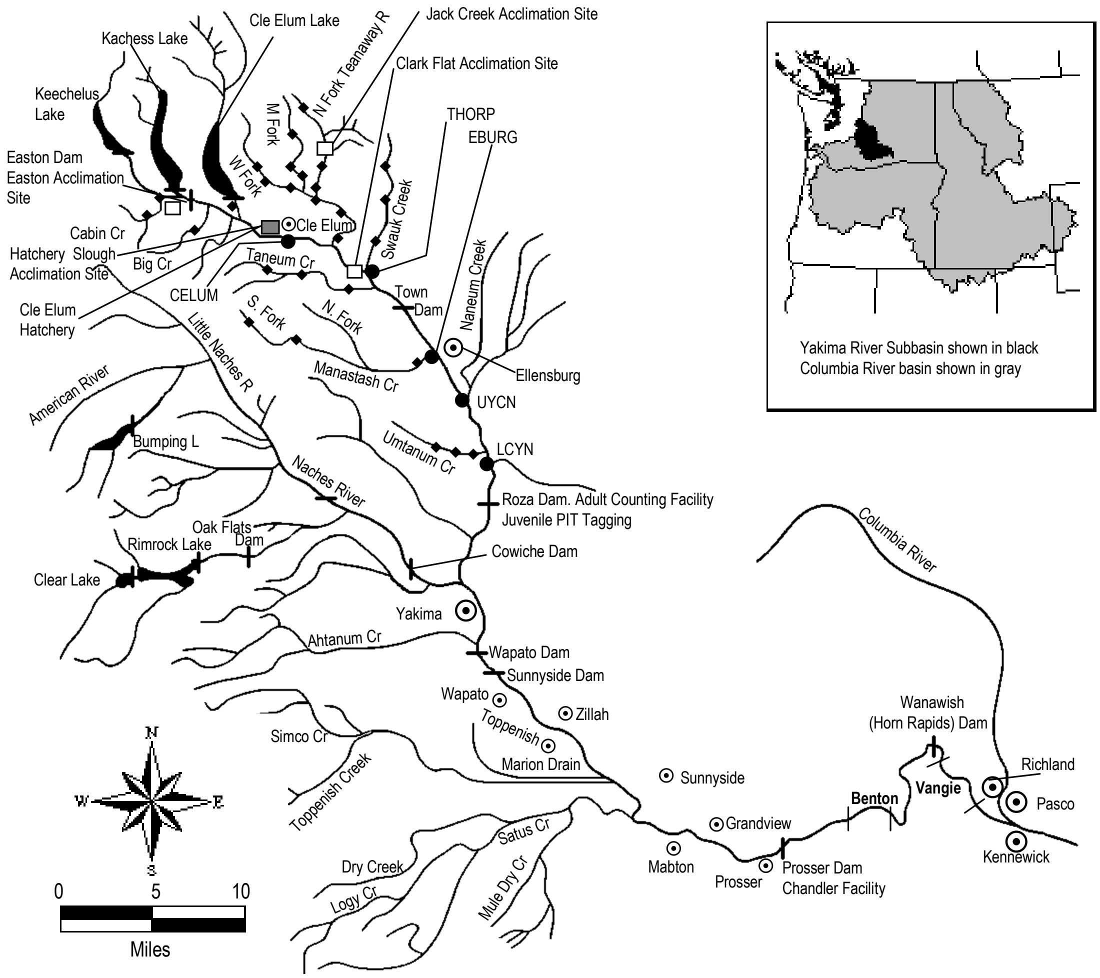

Figure 1. Yakima River Basin. Tributary (◆), upper river mainstem (●) and lower river mainstem (|~|) survey sites.

night to determine if any salmon are present. Night snorkeling is recommended as the best low impact sampling strategy for bull trout. During September two divers, equipped with underwater lights, move upstream and count all fish encountered and estimate the length of bull trout observed.

Population estimates in upper Yakima tributary sites are based on single pass backpack electrofishing. In tributary streams, a crew of three to six people electrofish 200-m long index sites during the day with a backpack electrofisher (Table 3). A single pass is made and all fish are netted and held in a perforated bucket in the stream. All fish are anesthetized, identified to species and the lengths and weights of salmonids are recorded. For other taxa, the fish are weighed as a group and an average weight calculated. An estimate of salmonid abundance is calculated by expanding the first pass count by the median capture ratio established during the baseline monitoring phase. The capture ratio is the number of fish captured on the first pass divided by a multiple-removal estimate of the number of fish in the site (Zippen 1958).

In the mainstem of the upper Yakima River, a crew of two people electrofish 4.2 –7.4 km long sites at night with a driftboat electrofisher. Two types of abundance estimates are made. One type is generated from mark-recapture methods (rainbow trout) and the other is a visual estimate (mountain whitefish, suckers). During the electrofishing passes all fish are identified visually and trout are netted. Trout are marked and released. One week later another pass is made to determine the proportion of marked and unmarked salmonids. Visual estimates during electrofishing are analogous to snorkel counts because the fish are only observed and never handled. An estimate of salmonid abundance is determined by maximum likelihood estimators using standard mark-recapture techniques (Mark-Recapture for Windows 1997, Version 5.0 Beta, Montana Fish, Wildlife, and Parks).

Spring chinook smolt counts are made at the Chandler facilities and provided by the Yakama Nation (Fast et al. 1991). Estimates of the total number of fish passing Prosser Dam are made by expanding the number of fish collected in the trap by a flow/entrainment relationship.

Predation indices for fall chinook salmon, leopard dace and sand roller, are calculated using methods previously described (Chapter 3). Predation estimates are based on boat electrofishing mark recapture estimates of the predator population, stomach contents to determine relative proportions of prey, and metabolic variables to estimate consumption. The predation index is expressed as the total number of an NTT that is eaten by smallmouth bass during the spring. The abundance of smallmouth bass predators in the lower Yakima River was determined by electrofishing. Diet samples are collected by gastric lavage and frozen for later analysis in the laboratory. Fish consumed are identified by counting, keying and measuring diagnostic bones. Fish lengths of prey are estimated from bone lengths using standard equations (Hansel et al. 1988). Estimated weights are calculated from lengths using our own equations or those of Vigg et al. (1991). Finally, consumption by each predator is calculated using a meal turnover time method.

Size structure of an NTT was quantified as the mean length (salmonids), weight (non-salmonids in tributaries), or percent of fish visually observed that are adults (mountain whitefish and suckers), of fish collected in sites used to describe abundance. All salmonids longer than 79 mm are measured. Non-salmonids in the tributaries are grouped into life-stages and weighed as separate groups.

Distribution of an NTT is quantified as the weighted area of index sites that contain a minimum number of an NTT (Table 4). Index sites are weighted based on the length of stream that they represent. Most of the sites that are used to determine distribution are the same as those used to describe abundance. However, some exceptions do occur (Tables 3 and 4). These exceptions are included to provide a greater area in which to assess distributional changes.

Analysis

Changes in NTT status or surrogate measures were detected with a one-tailed t-test and results were expressed as log percent changes from baseline (Tables 5, 6, and 7). The numerical values for abundance, size and distribution are also presented for interpretation of changes and comparison with historical values. The statistical power was calculated to determine the probability of committing a type II statistical error with the one-tailed t-test using the program Statistica (Statistica Power Analysis, StatSoft, Inc., 1999).

Results

Relative to presupplementation conditions, most of the parameters that we measured increased slightly and all, except steelhead size (-4%), were within the predetermined containment objectives (Table 8). There was no overlap of salmon and bull or cutthroat trout in our index sites, which indicates that the supplementation programs did not negatively change the status of these species. Rainbow trout in the mainstem, which is also the analog for steelhead, increased slightly in abundance, decreased slightly in size, and remained unchanged in distribution. The slight decrease in size is outside of the containment objective for steelhead but not for rainbow trout. The status of rainbow trout in the tributaries was similar to baseline conditions. This result is expected because the spatial overlap of salmon and trout was low in all of the tributaries except the North Fork of the Teanaway River. The status of mountain whitefish improved. Fall chinook salmon increased in abundance and spring chinook salmon status remained unchanged.

With the exception of speckled dace and sculpins, all of the changes that we observed were lower than what we could detect statistically with a power of 90% (Tables 5,6,7). The declines of speckled dace and sculpins are unlikely to be related to supplementation because the spatial overlap with salmon was low. Actual values (unmodelled and untransformed) are presented for abundance (Table 9), size (Table 10), and distribution (Table 11).

Table 1. Monitoring site names, abbreviations used in text and locations.

Site Name	Abb.	Location
		Upper Yakima Tributaries
Cabin Creek	CAB-1	4.4 km up Cabin Creek Rd. from junction with Railroad Av. (Easton)
Domerie Creek	DOM-A	0.9 rkm above Cle Elum River
Manastash Creek	MAN-3	Buck Meadows Campground at Old Quartz Mountain Trailhead
Middle Fork	MFT-1	Middle/West Fork Teanaway Rd. 1.6 km above junction with Teanaway Rd.
Teanaway River	MFT-2	Middle/West Fork Teanaway Rd. 5.1 km above junction with Teanaway Rd.
	MFT-3	Middle/West Fork Teanaway Rd. 8.5 km above junction with Teanaway Rd.
North Fork.	NFT-1	Teanaway Rd., km 13.5
Teanaway River	NFT-2	Teanaway Rd., km 19.3
	NFT-3	Teanaway Rd., km 33.1
	NFT-A	Bottom of site is 30 m below trail #1383 bridge
	NFT-B	350 m above Eldorado Creek (near Camp Wahoo)
Stafford Creek	STF-A	Bottom of site is 50 m above Standup Creek
	STF-B	Bottom of site is 200 m below confluence with Bear Creek
Swauk Creek	SWK-1	First bridge crossing on private road. at Milepost 95.6 on Highway 10
	SWK-2	Highway 97, Milepost 151.75
	SWK-3	Highway 97, Milepost 158
Taneum Creek	TAN-1	On West Taneum Rd. 1.9 km above Thorp Cemetery Rd.
	TAN-2	On West Taneum Rd. 11.9 km above Thorp Cemetery Rd.
	TAN-3	N. Fork Taneum Rd. 0.7 km above S. Fork Meadows junction
	TAN-A	10.2 road miles up West Taneum Road, 650 m below Forks
	TAN-B	10.2 road miles up West Taneum Road, 1550 m above Forks
Umtanum Creek	UMT-1	0.4 rkm above confluence with Yakima River
	UMT-1.5	3.4 rkm above confluence with Yakima River
	UMT-2	0.4 km downstream from Umtanum Creek/Durr Road crossing
West Fork	WFT-1	Confluence with Middle Fork Teanaway
Teanaway River	WFT-2	On West Fort Teanaway Rd. 5.6 km above junction with Teanaway Rd.
	WFT-3	400 km below West Fork Trailhead Rd.
		Upper Yakima Mainstem
Cle Elum	CELUM	Swift Water Campground to 300 m above the Teanaway game ramp
Ellensburg	EBURG	Top of the riffles below the Ellensburg KOA to 200 m above Reinhart ramp
Lower Canyon	LCYN	Road mile 11.7 on Highway 821 to 200 m upstream of the Slab takeout
Thorp	THORP	Anderson Homestead to 200 m above the Thorp highway bridge
Upper Canyon	UCYN	150 m above Wilson Creek to 150 m above Bighorn takeout
		Lower Yakima Mainstem
Fish Predation Sites	Benton	1.0 km below Chandler Pumping Station to 2.5 km above SR225 Bridge
	Vangie	0.5 km below Grosscup Road to 0.5 km above VanGiesen Road Bridge

Table 2. Latitude and longitude positions in degrees, minutes (DM) or decimal degrees (DD) of monitoring sites.

Site Name	Lat. (DM)	Long. (DM)	Lat. (DD)	Long. (DD)
CAB-1	-121 13.602	47 14.484	-121.2267	47.2414
DOM-A	-121 4.008	47 14.142	-121.0668	47.2357
MAN-3	-120 57.366	47 2.256	-120.9561	47.0376
MFT-1	-120 53.760	47 15.714	-120.8960	47.2619
MFT-2	-120 55.722	47 16.782	-120.9287	47.2797
MFT-3	-120 57.630	47 17.910	-120.9605	47.2985
NFT-1	-120 52.734	47 16.242	-120.8789	47.2707
NFT-2	-120 51.330	47 18.696	-120.8555	47.3116
NFT-3	-120 55.974	47 24.390	-120.9329	47.4065
NFT-A	-120 53.094	47 22.824	-120.8849	47.3804
NFT-B	-120 56.178	47 24.714	-120.9363	47.4119
STF-A	-120 49.938	47 21.264	-120.8323	47.3544
STF-B	-120 48.258	47 21.804	-120.8043	47.3634
SWK-1	-120 44.748	47 7.700	-120.7458	47.1295
SWK-2	-120 41.682	47 13.572	-120.6947	47.2262
SWK-3	-120 41.808	47 17.178	-120.6968	47.2863
TAN-1	-120 45.816	47 5.100	-120.7636	47.0850
TAN-2	-120 52.950	47 6.696	-120.8765	47.1116
TAN-3	-120 56.478	47 6.660	-120.9413	47.1110
TAN-A	-120 55.416	47 6.630	-120.9236	47.1105
TAN-B	-120 56.760	47 6.210	-120.9460	47.1035
UMT-1	-120 29.106	46 51.300	-120.4851	46.8550
UMT-1.5	-120 31.740	46 51.876	-120.5285	46.8646
UMT-2	-120 33.846	46 52.446	-120.5641	46.8741
WFT-1	-120 53.850	47 15.360	-120.8975	47.2560
WFT-2	-120 57.108	47 15.816	-120.9518	47.2636
WFT-3	-120 58.566	47 16.176	-120.9761	47.2696
Vangie-first site	-119 22.043	46 19.317	-119.3674	46.3220
Vangie-last site	-119 19.830	46 18.101	-119.3305	46.3020
Benton-first site	-119 34.485	46 16.270	-119.5731	46.2710
Benton-last site	-119 30.302	46 15.784	-119.5050	46 2631

Table 3. Primary monitoring detection strategy, sampling method, abundance and size structure index sites, and if environmental models were used to assess changes to NTT.

NTT	Detection Strategy/Method	Index Sites	Model[5]
Bull trout	Spring chinook salmon spatial overlap/Snorkeling	North Fork Teanaway River, river km 8.0 to 14.2 from the confluence of Jungle Creek	No
Cutthroat trout	Spring chinook salmon spatial overlap/Electrofishing	DOM-A, MAN-3, NFT-3, NFT-A, NFT-B, STF-A, STF-B, SWK-2, SWK-3, TAN-2, TAN-3, TAN-A, TAN-B, WIL-A	No
Pacific lamprey	Predation index (Fall chinook salmon as analog)/Electrofishing	Benton, Vangie	No
Steelhead	Status (Year 1 rainbow trout as analogs)/Electrofishing	CELUM, THORP, EBURG, UCYN, LCYN	No
Fall chinook salmon	Predation index/Electrofishing	Benton, Vangie	No
Leopard dace	Predation index with all dace as analogs/Electrofishing	Benton, Vangie	Yes[1]
Mountain sucker	Status: all subadult suckers as analogs/Visuals during Electrofishing	CELUM, THORP, EBURG, UCYN, LCYN	Yes[4]
Sand roller	Predation index (sand roller or chiselmouth <100 mm as analogs)/Electrofishing	Benton, Vangie	Yes[1]
Rainbow trout- mainstem	Status/Electrofishing	CELUM, THORP, EBURG, UCYN, LCYN	Yes[3]
Spring chinook salmon	Status/Trapping	Chandler juvenile facility annual counts	No
Mountain whitefish	Status (subadult)/Visuals during Electrofishing	CELUM, THORP, EBURG, UCYN, LCYN	Yes[4]
Rainbow trout – tributaries	Status/Electrofishing	MFT-1,2,3; NFT-1,2,3; SWK-1,2,3; TAN-1,2,3; and WFT-1,2,3	No
Longnose dace	Status/Electrofishing	MFT-1, MFT-2, NFT-1, SWK-2	Yes[2]
Speckled dace	Status/Electrofishing	SWK-1, UMT-1, UMT-1.5, UMT-2	Yes[4]
Sculpins	Status/Electrofishing	MFT-1,2,3; NFT-1,2,3; SWK-1,2,3; TAN-1,2,3; UMT-1,1.5,2; and WFT-1,2,3	No
Suckers	Status (subadult)/Visuals during Electrofishing	CELUM, THORP, EBURG, UCYN, LCYN	Yes[4]

[1]Calculated from bass population estimate, stomach contents, meal turnover times and water temperature.
Based on Bureau of Reclamation flow data from stations at the [2]Teanaway River near Cle Elum, Wa., [3]Yakima River near Umtanum, Wa. and [4]Yakima River near Cle Elum, Wa.
[5]Models are only applied to abundance estimates, not size or distribution.

Table 4. Index sites and threshold values for distribution monitoring of NTT.

NTT	Distribution Index Sites	Threshold for Use
Bull trout	North Fork Teanaway River, river km 8.0 to 14.2 from the confluence of Jungle Creek	≥ 1 fish/site
Cutthroat trout	NFT-3; TAN-3	≥ 10 fish/km
Steelhead	Year 1 rainbow trout in CELUM, THORP, EBURG, UCYN, LCYN	≥ 100 fish/km
Rainbow trout-mainstem	CELUM, THORP, EBURG, UCYN, LCYN	≥ 100 fish/km
Mountain whitefish	CELUM, THORP, EBURG, UCYN, LCYN	≥ 40 fish/km
Rainbow trout – tributaries	CAB-1; MFT-1,2,3; NFT-1,2,3; SWK-2,3; TAN-1,2,3; UMT-1,2 and WFT-1,2,3	≥ 25 fish/km
Longnose dace	CAB-1; MFT-1,2,3; NFT-1,2; SWK-2,3; WFT-1,2,3	≥ 30 fish/km
Speckled dace	MFT-1; SWK-1; UMT-1, 1.5, 2; WFT-1	≥ 60 fish/km
Sculpins	CAB-1; MFT-1,2,3; NFT-1,2,3; SWK-1,2,3; TAN-1,2,3; UMT-1,1.5,2 and WFT-1,2,3	≥ 100 fish/km
Suckers	CELUM, THORP, EBURG, UCYN, LCYN	≥ 40 fish/km
	SWK-1; UMT-1,1.5,2	≥ 10 fish/km

Table 5. Monitoring prescription abundance baseline mean, standard deviation, number of baseline survey years, post-supplementation average (n=2, 1999 and 2000 surveys) critical value of t, p-level and power analysis where α is set to 0.05 or 0.10.

NTT	Baseline	(n)	Post	t	p	0.05	0.10
Bull trout	2.00 ± 0.00	(3)	2.00				
Cutthroat trout	2.00 ± 0.00	(2)	2.00				
Pacific lamprey	427,972	(1)	170,330				
Steelhead	1.99 ± 0.11	(8)	2.04	-0.50	0.633		
Fall chinook salmon	427,972	(1)	170,330				
Leopard dace	52,017	(1)	39,182				
Mountain sucker	2.00 ± 0.07	(6)	2.14	-1.64	0.151		
Sand roller	6,702	(1)	5,507				
Rainbow trout-main	1.99 ± 0.11	(8)	2.04	-0.50	0.633		
Spring chinook salmon	5.14 ± 0.24	(16)	5.09	0.29	0.775	8	16
Mountain whitefish	1.98 ± 0.12	(6)	2.18	-1.97	0.095		
Rainbow trout – tribs.	2.44 ± 0.14	(9)	2.51	-0.69	0.507		
Longnose dace	1.99 ± 0.10	(7)	2.12	-1.28	0.240		
Sculpins	1.77 ± 0.17	(7)	1.51	1.98	0.089	53	69
Speckled dace	1.98 ± 0.15	(6)	1.52	4.21	0.006	95	99
Suckers	2.00 ± 0.07	(6)	2.14	-1.64	0.151		

Table 6. Monitoring prescription size baseline mean, standard deviation, number of baseline survey years, post-supplementation average (n=2, 1999 and 2000 surveys) critical value of t, p-level and power analysis where α is set to 0.05 or 0.10.

NTT	Baseline	(n)	Post	t	p	0.05	0.10
Bull Trout	2.00 ± 0.00	(3)	2.00				
Cutthrout trout	2.00	(2)	2.00				
Steelhead	2.23 ± 0.04	(9)	2.15	1.71	0.121	76	78
Mountain sucker	1.73 ± 0.11	(6)	1.85	-1.57	0.167		
Rainbow trout-main	2.23 ± 0.04	(9)	2.15	1.71	0.121	76	78
Spring chinook-salmon	1.78 ± 0.02	(8)	1.76	1.03	0.332	31	47
Mountain whitefish	1.83 ± 0.09	(6)	1.91	-1.22	0.268		
Rainbow trout – tribs.	2.13 ± 0.01	(9)	2.13	-0.98	0.352		
Longnose dace	0.87 ± 0.09	(6)	0.99	-1.74	0.130		
Sculpins	0.76 ± 0.05	(7)	0.88	-3.03	0.023		
Speckled dace	0.53 ± 0.10	(6)	0.59	-0.67	0.530		
Suckers	1.73 ± 0.11	(6)	1.85	-1.57	0.167		

Table 7. Monitoring prescription distribution baseline mean, standard deviation, number of survey years, post-supplementation average (n=2, 1999 and 2000 surveys) and power analysis where α is set to 0.05 or 0.10.

NTT	Baseline	(n)	Post	t	p	0.05	0.10
Bull trout	2.00 ± 0.00	(3)	2.00				
Cutthroat trout	2.00		2.00				
Rainbow trout-main	2.00 ± 0.00	(8)	2.00				
Mountain whitefish	2.00 ± 0.00	(6)	2.00				
Rainbow trout – tribs.	5.00 ± 0.02	(7)	4.99	-0.163	0.874	14	24
Longnose dace	1.89 ± 0.06	(7)	1.80	1.77	0.119	52	68
Sculpins	1.96 ± 0.02	(7)	1.75	7.43	0.001	100	100
Speckled dace	1.94 ± 0.09	(6)	1.88	0.88	0.414	18	30
Suckers	4.50 ± 0.07	(6)	4.57	-1.25	0.259		

Table 8. Percent change in 1999 (Y1) and 2000 (Y2) relative to baseline for NTT monitoring prescriptions. Values were calculated as a percentage for each year, rounded and the average taken

		Change, (%)								
		Abundance			Size			Distribution		
	CO	Y1	Y2	x	Y1	Y2	x	Y1	Y2	X
Bull trout	0	0	0	0	0	0	0	0	0	0
Cutthroat trout	0	0	0	0	0	0	0	0	0	0
Pacific lamprey	0	66	54	60						
Steelhead	0	0	5	3	1	-7	-4[2]	0	0	0
Fall chinook	-5	66	54	60						
Leopard dace	-5	74	-25	25						
Mtn. sucker	-5	0	14	7	8	5	7	1	2	2
Sand roller	-5	4	32	18						
Rainbow – main	-10	0	5	3	1	-7	-4[2]	0	0	0
Spring chinook	-10	6	-6	-1[2]	1	1	1			
Mtn. whitefish	-40	6	13	10	5	3	4	0	0	0
Rainbow – tribs	-40	1	5	3	0	1	0[2]	0	0	0
Longnose dace	-65	13	-1	6	14	14	14	-8	-2	-5
Speckled dace	-85	-25	-22	-23[2]	32	-9	11	-3	-3	-3
Sculpins	-90	-19	-11	-15	16	16	16	-13	-8	-11
Suckers	-90	0	14	7	8	6	7	1	2	2

[1]Abundance is related to predation index, size structure and distribution not determined

[2]Averages vary slightly (less than 1%), due to rounding errors from significant digits not shown

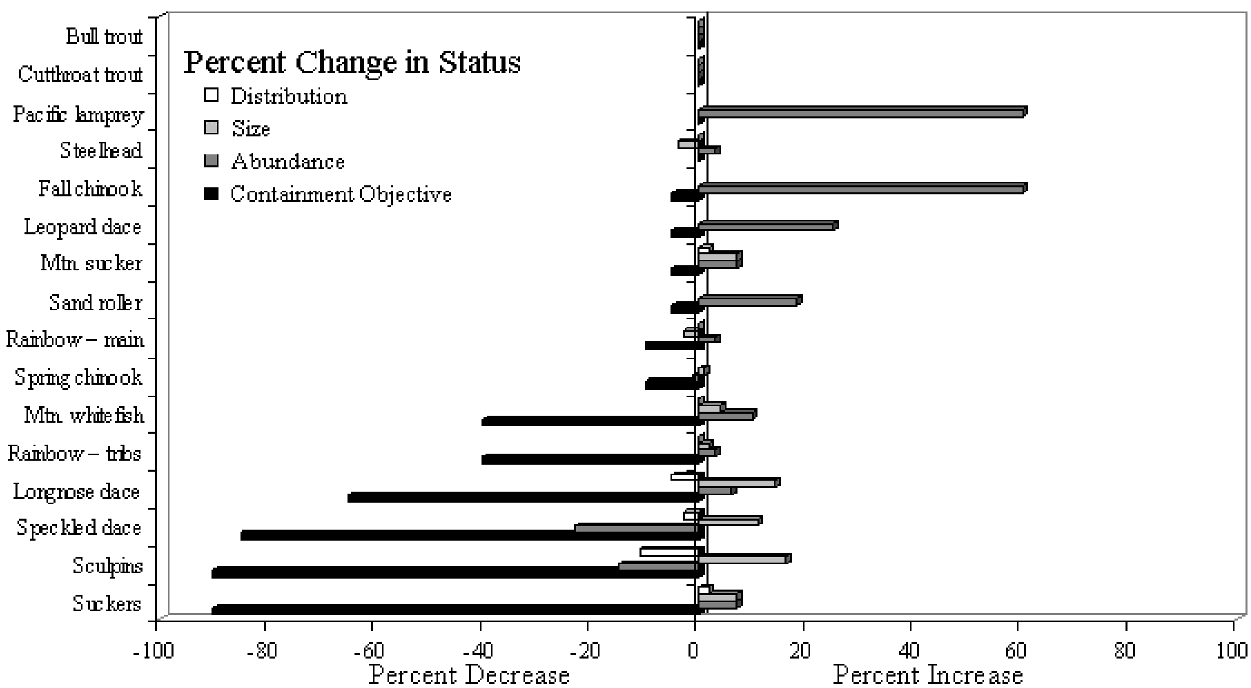

Figure 2. Percent change for distribution, size, abundance and containment objective for each of the 16 NTT (data shown in tabular format in Table 8).

Table 9. Actual values for abundance (fish/km, unless otherwise indicated). Leopard dace, mountain sucker and sandroller are to rare for quantitation.

NTT	Baseline	(n)	Year 1	Year 2
Bull trout	22 ± 19[1]	(3)	20 fish	13 fish
Cutthroat trout	138 ± 90	(9)	20/km	253/km
Pacific lamprey	198 ± 241[2]	(6)	196 migrants	102 migrants
Steelhead	63,247 ± 38,259[3]	(16)	38,266 smolts	42,696 smolts
Fall chinook salmon	108,973 ± 102,976[3]	(16)	45,702 smolts	198,002 smolts
Rainbow trout-main	147 ± 43	(8)	160 age 1/km	194 age 1/km
Spring chinook-salmon	158,355 ± 75,216[3]	(16)	245,019 smolts	61,513 smolts
Mountain whitefish	247 ± 73	(6)	364 subadult/km	383 subadult/km
Rainbow trout – tribs.	286 ± 89	(9)	288/km	364/km
Longnose dace	58 ± 22[4]	(7)	56/site	59/site
Sculpins	63 ± 27[4]	(7)	27/site	38/site
Speckled dace	104 ± 45[4]	(6)	27/site	32/site
Suckers	186 ± 43	(6)	189 subadult/km	315 subadult/km

[1]Number of fish, [2]Number of migrants, [3]Number of smolts, [4]Number/site

Table 10. Actual values for size. Leopard dace, mountain sucker and sandroller are too rare for quantitation. Size of Pacific lamprey is not determined.

NTT	Baseline	(n)	Year 1	Year 2
Bull trout	275 ± 134 mm	(3)	246 mm	267 mm
Cutthroat trout	153 ± 19 mm	(9)	115 mm	169 mm
Steelhead	166 ± 30 mm	(6)	174 mm	154 mm
Fall chinook salmon	83 ± 5 mm	(8)	88 mm	86 mm
Rainbow trout-main	249 ± 13 mm	(9)	256 mm	195 mm
Spring chinook-salmon	128 ± 4 mm	(8)	131 mm	118 mm
Mountain whitefish	31 ± 15%	(6)	86% subadult	78% subadult
Rainbow trout – tribs.	133 ± 4 mm	(9)	135 mm	137 mm
Longnose dace	8 ± 2 g	(7)	10 g	10 g
Sculpins	6 ± 1 g	(7)	8 g	9 g
Speckled dace	3 ± 1 g	(6)	5 g	3 g
Suckers	45 ± 13%	(6)	74% subadult	69% subadult

Table 11. Actual values for distribution.

NTT	(n)	Baseline	Year 1	Year 2
Bull trout	(3)	60 ± 35	80%	80%
Cutthroat trout	(2)	66	74%	74%
Rainbow trout-main	(8)	100 ± 0	100%	100%
Rainbow trout – tribs.	(9)	97 ± 4	97%	100%
Longnose dace	(7)	79 ± 10	55%	72%
Sculpins	(7)	91 ± 5	51%	63%
Speckled dace	(6)	89 ± 19	77%	77%
Suckers	(6)	100 ± 15	73%	91%

Discussion

The detection of few negative impacts to NTT status, that could be related to supplementation, is likely due to 1) the lack of spatial overlap between salmon and NTT, 2) the impacts of hatchery smolts balanced or exceeded the benefits (e.g., ecological release) of reducing the progeny of naturally produced fish, 3) benign interaction or density dependent benefits of higher number of smolts, and 4) the low statistical power of our tests. Six of 15 NTT had limited or no overlap with hatchery salmon (bull trout, cutthroat trout, rainbow trout in the tributaries, longnose dace, speckled dace, and sculpins). However the opportunity for overlap existed. For example, hatchery steelhead that were released in 1994 into the North Fork of the Teanaway River migrated upstream into areas containing bull and cutthroat trout (McMichael and Pearsons 2001). Steelhead were released into the river very close to the area where salmon were released. Hatchery spring chinook were observed up to 2.4 km above the release site in the North Fork of the Teanaway River during 2000. However, none were observed in index areas containing cutthroat or bull trout. We assume that a lack of overlap precludes significant ecological interactions.

In areas where overlap occurred, impacts that might have been caused by releasing hatchery smolts were balanced or exceeded by the benefits (e.g., ecological release) of reducing the progeny of naturally produced fish. The NTT that likely fit into this category are rainbow trout in the mainstem, steelhead, mountain whitefish, and suckers. Most of the NTT that spatially overlapped salmon showed positive or no changes in status and all of the NTT, except steelhead, were within the containment objectives. The decline in steelhead size (rainbow trout as analog) could be due to the supplementation program, because there was significant overlap between supplemented species and steelhead. However, we have insufficient information to attribute causation at this time. Nonetheless, other information suggest that interactions among salmon and NTT occurred.

Large numbers of spring chinook salmon did not migrate to the ocean after release (residuals) and may have interacted with NTT. Approximately 25% of the total spring chinook salmon production precocially matured and residualized in the river. These fish were concentrated below the Clark Flats acclimation site and some were observed below the Easton acclimation site during 1999 and 2000. Other high concentrations were observed below the acclimation site in the North Fork Teanaway River during 2000. Residuals were larger than wild conspecifics and modal sized rainbow trout which could confer dominance status. They also ate similar prey items, and food appeared to be limiting growth to rainbow trout and wild conspecifics (James et al. 1999; WDFW unpublished data). Previously, we found that residual hatchery spring chinook salmon negatively impacted the growth of wild spring chinook salmon in small enclosures in the Teanaway Basin (WDFW unpublished data).

Some of the interactions with NTT may have been benign or produced density dependent benefits because of the large number of smolts released. NTT that fit into this category include many of the species that rear or migrate through the lower Yakima River. This includes Pacific lamprey, fall chinook, sand roller, and spring chinook.

The discussion of impacts should be tempered by a realistic view of the natural variability of most indicators of impact. This variability limits the ability to detect impacts, even after 5 years of stocking (Ham and Pearsons 2000). The lack of impacts to NTT that spatially overlap salmon is, at this stage, insufficient evidence to draw conclusions about what interactions are or are not important.

Some declines occurred in the status of NTT but the monitoring prescriptions results suggest that the declines were not caused by activities related to the stocking of hatchery salmon. It is likely that the declines that we observed for some NTT were caused by biotic or abiotic factors unrelated to hatchery supplementation.

Management Implications

We are using the approach described by Ham and Pearsons (2001) to contain risks to NTT throughout the life span of salmon supplementation programs in the Yakima Basin (Chapter 1). According to this risk containment approach, if we detect a change in status that is greater than a containment objective, then we attempt to determine if the change was caused by the supplementation program. The only NTT that currently is cause for concern is steelhead. Results from 2001 will indicate whether we need to determine causation for the change in steelhead status. Currently, the change is too small and statistically unreliable to make changes to the monitoring program. Beginning in 2002 the Building stage will begin. This stage is likely to be the one where the risk of impacts is highest (Chapter 1). Monitoring prescriptions described in Table 3 appear to be working as they were designed and should continue to be implemented during 2001. They appear, thus far, to be relatively insensitive to impacts that were caused by factors other than supplementation.

Implementation of strategies to limit the number of precocially mature salmon entering the natural environment would decrease the risk of failing to meet containment objectives, including those for steelhead.

Acknowledgements

We are thankful to the many people on the Ecological Interactions Team who helped collect the data. Anthony Fritts, Michael Schmuck, Lynda Andrew, and Phillip Smith were instrumental in the collection of field data during 2000. We thank the Yakama Nation for supplying the status data for the anadromous fishes. We also thank David Byrnes, Bonneville Power Administration who was helpful in securing and administering funding for this work.

Literature Cited

Bjornn, T. C. 1978. Survival, production, yield of trout and chinook salmon in the Lemhi River, Idaho. University of Idaho, College of Forestry, Wildlife, and Range Sciences Bulletin Number 27. Moscow.

Bucke, D. 1993. The significance of diseases and anomalies in wild salmonids. Fisheries Research 17:209-217.

Collis, K., R. E. Beaty, and B. R. Crain. 1995. Changes in catch rate and diet of northern squawfish associated with the release of hatchery-reared juvenile salmonids in a Columbia River reservoir. North American Journal of Fisheries Management 15:346-357.

Fresh, K. L. 1997. The role of competition and predation in the decline of Pacific salmon and steelhead. Pages 245-275 in D. J. Stouder, P. A. Bisson, and R. J. Naiman, editors, Pacific salmon and their ecosystems: Status and future options. Chapman and Hall, New York, New York.

Ham, K. D., and T. N. Pearsons. 2000. Can reduced salmonid population abundance be detected in time to limit management impacts? Canadian Journal of Fisheries and Aquatic Sciences 57:17-24.

Ham, K. D., and T. N. Pearsons. Submitted. What level of ecological impact can be detected in salmonid populations? Canadian Journal of Fisheries and Aquatic Sciences.

Ham, K. D., and T. N. Pearsons. 2001. A practical approach for containing ecological risks associated with fish stocking programs. Fisheries 26(4):15-23.

Hillman, T. W., and J. W. Mullan. 1989. Effect of hatchery releases on the abundance and behavior of wild juvenile salmonids. Pages 265-285 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.

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

Goede, R. W. 1986. Management considerations in stocking of diseased or carrier fish. Pages 349-355 in R.H. Stroud, editor, Fish culture in fisheries management. American Fisheries Society, Bethesda, MD.

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.

Hawkins, S. W., and J. M. Tipping. 1999. Predation by juvenile hatchery salmonids on wild fall chinook salmon fry in the Lewis River, Washington. California Fish and Game 85(3):124-129.

James, B. B., T. N. Pearsons, and G. A. McMichael. 1999. Spring chinook salmon interactions indices and residual/precocial monitoring in the upper Yakima Basin. Annual Report FY 1998 submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-64878-4.

Marnell, L. F. 1986. Impacts of hatchery stocks on wild fish populations. Pages 339-347 in R. H. Stroud, editor. Fish culture in fisheries management. American Fisheries Society, Fish Culture Section and Fisheries Management Section, Bethesda, Maryland.

McMichael, G. A., C. S. Sharpe, and T. N. Pearsons. 1997. Effects of residual hatchery-reared steelhead on growth of wild rainbow trout and spring chinook salmon. Transactions of the American Fisheries Society 126:230-239.

McMichael, G. A., T. N. Pearsons, and S. A. Leider. 1999. Behavioral interactions among hatchery-reared steelhead smolts and wild *Oncorhynchus mykiss* in natural streams. North American Journal of Fisheries Management 19:948-956.

McMichael, G. A., and T. N. Pearsons. 2001. Upstream movement of residual hatchery steelhead into areas containing bull trout and cutthroat trout. North American Journal of Fisheries Management 21:517-520.

McVicar, A. H. 1997. Disease and parasite implications of the coexistence of wild and cultured Atlantic salmon populations. ICES J. Mar. Sci. 54:1093-1103.

Nickelson, T. E., M. F. Solazzi, and S. L. Johnson. 1986. The use of hatchery coho salmon (*Oncorhynchus kisutch*) presmolts to rebuild wild populations in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences 43:2443-2449.

Nielsen, J. L. 1994. Invasive cohorts: impacts of hatchery-reared coho salmon on the trophic, developmental, and genetic ecology of wild stocks. Pages 361-385 In D. J. Stouder, K. L. Fresh, and R. J. Feller eds. Theory and Application in Fish Feeding Ecology. The Belle W. Baruch Library in Marine Science Number 18, University of Southern Carolina Press.

Pearsons, T. N., and A. L. Fritts. 1999. Maximum size of chinook salmon consumed by juvenile coho salmon. North American Journal of Fisheries Management 19:165-170.

Pearsons, T. N., and K. D. Ham. 2001. Behavioral dominance and predator avoidance in juvenile spring chinook salmon reared under different hatchery conditions. Pages 16-27 in Pearsons, T. N., A. L. Fritts, K. D. Ham, G. A. McMichael, E. L. Bartrand, G. M. Temple, and C. W. Hopley. 2001. Yakima River Species Interactions Studies. Annual Report FY 1999 submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-64878-7.

Pearsons, T. N., and C. W. Hopley. 1999. A practical approach for assessing ecological risks associated with fish stocking programs. Fisheries 24(9):16-23.

Peterman, R. M., and M. Gatto. 1978. Estimation of functional responses of predators on juvenile salmon. Journal of the Fisheries Research Board of Canada 35:797-808.

Regional Assessment of Supplementation Project (RASP). 1992. Supplementation in the Columbia Basin. Final report. Bonneville Power Administration. Portland, Oregon. DOE/BP-01830-14.

Rhodes, J. S., and T. P. Quinn. 1998. Factors affecting the outcome of territorial contests between hatchery and naturally reared coho salmon parr in the laboratory. Journal of Fish Biology 53:1220-1230.

Ruzzante, D. E. 1994. Domestication effects on aggressive and schooling behavior in fish. Aquaculture 120:1-24.

Sholes, W. H., and R. J. Hallock. 1979. An evaluation of rearing fall-run chinook salmon *Oncorhynchus tshawytscha*, to yearlings at Feather River Hatchery, with a comparison of returns from hatchery and downstream releases. California Fish and Game 64:239-255.

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, R. J., J. R. Karr, and W. Nehlsen. 1995. Better roles for fish stocking in aquatic resource management. American Fisheries Society Symposium 15:527-550.

Wood, C. C. 1987. Predation of juvenile Pacific salmon by the common merganser (*Mergus merganser*) on eastern Vancouver Island. I: Predation during the seaward migration. Canadian Journal of Fisheries and Aquatic Sciences 44:941-949.

Zippen, C. 1958. The removal method of population estimation. Journal of Wildlife Management 22:82-90.

Chapter 3

Lower Yakima River Predatory Fish Monitoring: Progress Report 2000, Bass and Catfish

Anthony L. Fritts

Todd N. Pearsons

Gabriel M. Temple

and

Michael R. Schmuck

Washington Department of Fish and Wildlife
600 Capitol Way North
Olympia, Washington 98501-1091

Abstract

We estimated the number of salmonids that smallmouth bass ate during the spring of 2000 in the Yakima River. Predator surveys were conducted during the weeks of March 2 and March 16 and weekly from March 30 through June 16 in two sections of the lower Yakima River and in small areas of hypothetically high predation, termed “hotspots”. Abundance was estimated using a relationship between catch per unit effort and population estimates that were calculated using maximum likelihood estimators of mark and recapture data. Diet was determined by lavaging smallmouth bass and identifying consumed fish in the lab by examining diagnostic bones. Daily consumption was calculated by estimating the average number of salmonids that a bass ate per day and extrapolating that number to the number of bass in the lower 68 kilometers of the Yakima River. Daily estimates were then summed to yield total consumption during the spring. Abundance of bass >150 mm increased during the spring from a low of 985 on March 2 to a high of 28,145 on May 4. The increases in abundance were primarily due to immigration of fish from the Columbia River and partially from growth of smaller fish. Daily consumption of salmonids was relatively low until late April and sharply increased in early May. Consumption of salmonids gradually decreased throughout May and June to near zero by June 16 despite the fact that smallmouth bass numbers remained relatively high and temperature increased. This decrease is likely to be due to bass shifting their behaviors from feeding to spawning. Smallmouth bass ate an estimated 202,722 salmonids during the spring. Only 3,083 of these were estimated to be spring chinook. The remainder was mostly fall chinook salmon. Salmonid consumption estimates for 2000 were similar to estimates for 1999 (171,031 total salmonids and 3,795 spring chinook). Horn Rapids Dam (Wanawish) had only a fraction of the smallmouth congregated below it as it had in 1999 and may not be a hotspot during all years. Roza Dam had low densities of northern pikeminnow again in 2000.

Introduction

Predation by nonnative introduced species in the Columbia River Basin has been suggested as a contributing factor for the declines of the native pacific salmon *Oncorhynchus spp*. (Li et. al 1987; Bennett et. al 1991; Poe et. al 1991; Rieman et. al 1991; Tabor et. al 1993; Poe et. al 1994; Zimmerman and Parker 1995; Zimmerman 1999). In the late nineteenth century, very little was known about the affects of introduced species on the native fish faunas of the Northwest. This is evidenced by the following statements taken from Lampman (1946); the bass would "prove himself, if given the opportunity, the best friend of our salmon and trout" and "One salmon trout that follows the salmon up from the ocean and clear to their furthest spawning grounds, and then like a hungry wolf tears the spawn from the mother salmon while she is complying with nature's decree, will do the salmon more real harm than a thousand bass of either species." Even David Starr Jordan, a noted early ichthyologist, approved of the introduction of bass in Oregon believing they would confine their diets to minnows, suckers, and chubs.

By the late 1800's, the abundance of the native trout and salmon were already declining in localized areas and settlers arriving to the Pacific Northwest wanted to be able to fish for species they grew up with in the East such as black bass. Smallmouth bass *Micropterus dolomieui* are a top predator native to the Eastern and Midwest United States and Southeast Canada (Wydoski and Whitney 1979). One of the earliest introductions of smallmouth bass in Washington State occurred in 1925 when 5000 juvenile fish were planted in the Yakima River by state game protector N. E. Palmer and again in 1934 (Lampman 1946). By the early 1940's, smallmouth were reported to be plentiful in the lower 68 km of the Yakima River and also in the adjacent Columbia River and up into the Snake River (Lampman 1946). Some researchers have theorized that the introduction of smallmouth bass to Northwest rivers has caused a shift in the trophic dynamics of the riverine systems (Poe et al. 1994). Where northern pikeminnow *Ptychocheilus oregonensis* was once the keystone predator of the system, smallmouth bass may have displaced them by competition or direct predation (Fletcher 1991; Shrader and Gray 1999). In areas where smallmouth bass are abundant, anecdotal evidence suggests that pikeminnow have shifted from their usual diets containing a high percentage of sculpins and crayfish to a diet containing a higher percentage of salmonids (Poe et al. 1994; Zimmerman 1999). Smallmouth may be competing with pikeminnow for nonsalmonid prey or displacing pikeminnow from near shore littoral habitat where the usual nonsalmonid prey are abundant to areas where emigrating salmonids are the dominant prey.

Although smallmouth bass can feed heavily on other fishes (Poe et al. 1991; Zimmerman 1999), there have been mixed reports of smallmouth preying on salmonids in lotic environments of the Northwest. Shrader and Gray (1999) and Summers and Daily (2001) reported no predation on salmonids in the John Day River, Oregon and very low predation on salmonids in the Willamette River, Oregon respectively. The John Day River study was in areas where there are no salmonids rearing and salmonids are only available during their spring outmigration when discharge and turbidity are high and water temperatures are low. The Willamette study was done in a reach were there is thought to be few salmonid spawners and salmonids are for the most part only available during their outmigration. Poe et al. (1991) reported that smallmouth bass diets in the John Day Reservoir of the Columbia River were composed of only 4% salmonids by weight from April to August increasing from almost no salmonids in April to 6% by weight in August.

This increase over time was attributed to the increase in spatial overlap of subyearling chinook salmon with smallmouth bass. Tabor et al. (1993) found that salmonids consisted of 59% of smallmouth diets by weight and were present in 65% of the samples in the Columbia River at the interface of the Hanford Reach and the McNary Pool near Richland. The high rates of predation were attributed to smallmouth consumption on subyearling chinook from the Hanford Reach population that rear in large numbers in the same habitat preferred by smallmouth bass, are a suitable size for forage fish, and are available to the smallmouth bass for a longer time period because they emerge and rear in areas where smallmouth are present and slowly emigrate down the river later in the summer. In all these studies, smallmouth bass were shown to predominantly consume subyearling salmonids over yearling salmonid smolts such as spring chinook, coho *O. kisutch* and steelhead *O. mykiss*. These yearling smolts were emigrating past the smallmouth during a short time period in the spring, and were much larger than the subyearlings.

Of the aforementioned studies that were done in river sections that are not inundated by a dam (reservoir), none conducted rigorous estimates of predator abundance so estimates of salmonid consumption could not be calculated. In our study on the Yakima River, we have the ability to conduct reliable mark/recapture estimates of smallmouth bass abundance in an important tributary to the Columbia River with relatively healthy runs of chinook salmon. With these estimates, we are able to calculate total consumption of salmonids by smallmouth bass during the spring smolt emigration period that can be used to monitor trends in the impact of smallmouth on salmonids in a free-flowing river environment.

Predatory fish surveys were initiated in 1997 as part of an effort to develop and monitor a predation impact index relative to spring chinook salmon (Busack et al. 1997; McMichael et al. 1998; Pearsons et al. 1998; McMichael et al. 1999). After the 1998 field season, we determined that the Horn Rapids index section was redundant information and that we needed to reapportion more effort to studying northern pikeminnow. This resulted in allocating two reaches for studying northern pikeminnow and two reaches for studying bass and catfish. The Yakama Nation works on the pikeminnow reaches and the Sunnyside Dam hotspot and their results are presented in chapter 4. This chapter represents the work performed by the Washington Department of Fish and Wildlife and includes the two smallmouth bass reaches, Roza and Horn Rapids hotspots.

Data from 1998 indicated that smallmouth bass were capable of consuming a substantial number of age-0 fall chinook salmon, but that they did not consume large numbers of yearling spring chinook salmon (McMichael et al. 1999). Findings from 1997 to 1999 indicated that a substantial number of smallmouth bass migrate up the Yakima River from the Columbia River during the smolt emigration period. As was described in the monitoring plan (Busack et al. 1997), we sampled during the estimated peak and last quartile of spring chinook salmon smolt migration during 1998. As in 1999, we sampled weekly in order to obtain a more precise index of predation throughout the spring smolt emigration, however there were a few minor changes in 2000. We started earlier in the month of March because we found a spring chinook ingested by a smallmouth on the first sample of 1999. We also extended our sampling one week later into June in order to include more of the fall chinook predation as well as the latter part of spring chinook emigration.

Busack et al. (1997) outlined the specific need for determining the abundance of predators and their consumption rates of spring chinook salmon smolts in the spring chinook salmon monitoring plan for the Yakima Fisheries Project. The overall goal of our study was to continue to calculate predation indices for the main predatory fish species during the majority of the spring smolt emigration period in the lower Yakima River. This report supercedes all of our previous reports on smallmouth bass predation in the lower Yakima River and should be considered preliminary until more data are collected and analyses are performed.

Methods

Study Area

The study area and fish fauna was previously described by McMichael et al. (1999). Population estimates were conducted by boat electrofishing in two sections and catch per unit effort estimates were conducted in three presumptive hot spots. The two sections sampled by electrofishing drift boat were; 1. the end of Grosscup Road to Van Giesen Road bridge (Vangie), and 2. Chandler Power House to Benton City (Benton). The Vangie section was 8.0 km long, while the Benton section was 7.8 km long. These sections were used to extrapolate to their larger corresponding reaches. The Benton reach is 39.9 km long and is located between Prosser Dam and Horn Rapids Dam. The Vangie reach is 28.1 km long and is located between Horn Rapids Dam and the mouth of the Yakima River. In this report, we refer to the sampled area as the "section" and the area it represents as the "reach". A northern pikeminnow hot spot was sampled by angling immediately below Roza Dam (rkm 180) and a smallmouth bass hot spot was sampled by angling immediately below Horn Rapids (Wanawish) Dam (rkm 28.1)(Figure 1).

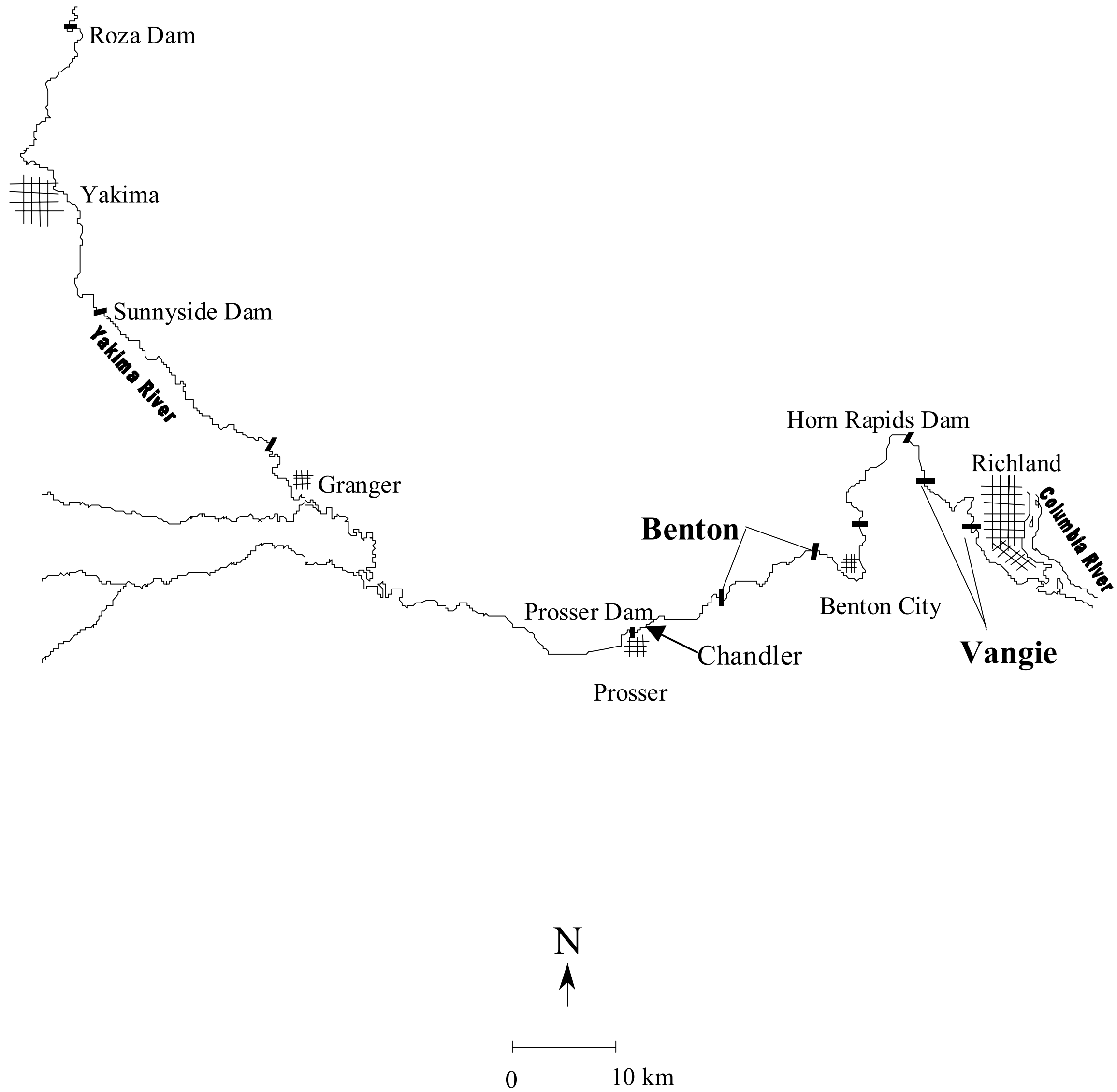

Figure 1. Map of the study area in the lower Yakima River showing index sections in bold type.

Abundance Estimates

Abundance estimates were conducted on smallmouth bass captured by boat electrofishing. We used catch per unit effort (CPUE; smallmouth bass ≥ 150mm FL/min) as an indicator of abundance in both sample sections during 12 sample weeks between March 2 and June 16, 2000. In addition, mark-recapture population estimates were done in each sample section between April 25 and 28, 2000 and between May 16 and 19, 2000. Regression analysis was used to examine the relationship between population estimates and CPUE for 1998, 1999 and 2000 data combined. The regression equation was then applied to raw CPUE data to estimate population size for each of the 14 sample weeks in 2000.

Electrofisher settings were about 400 V pulsed DC (PDC; Coffelt's CPS setting) at between 2 and 5 Amps during spring sampling. All predatory fish over 100 mm FL were netted and fishes ≥ 200 mm were marked with a serially numbered anchor tag. During mark-recapture population estimates the recapture runs followed 1 day after the marking runs and all predatory fish ≥ 100 mm were fin clipped on the marking runs. The electrofishing runs were generally along the banks, especially during high flows. The numbers of each species of fishes that were electrofished were visually assessed and recorded by the person netting.

Fish were processed every kilometer during all electrofishing runs. Length (mm), weight (g), and condition of fish, i.e. bird scars, hook scars, and visible electrofishing injuries were recorded for all fish. A subsample of all predatory fish ≥ 150 mm was examined for stomach contents.

Hot Spots

The Roza Dam "hot spot" was sampled on April 10 and 11 by two anglers beginning 1 hour before sunrise and continuing until either the catch dropped to 2 fish per hour or until noon, whichever came first. Pikeminnow were held in plastic totes until 5 to 10 were accumulated and then length (mm), weight (g), and condition of fish was recorded. All fish on the 10th were marked with a fin clip and a serially numbered anchor tag and released All fish on the 11th were examined for marks and then sacrificed and stomach samples containing fish were immediately frozen for later examination in the lab. CPUE was calculated for the sampling dates.

The Horn Rapids Dam "hot spot" was sampled seven times between March 29 and June 14 by two anglers for either one hour per day or until a half of an hour had elapsed between captures. Smallmouth bass were held in large plastic tubs until sampling was completed. Length (mm), weight (g), and condition of fish was recorded and all fish ≥ 200 mm were anchor tagged. A subsample of fish was examined for stomach contents by gastric lavage (Light et al. 1983) and samples were immediately frozen for later examination in the lab. CPUE was calculated for the seven sample dates.

Diet Samples

Diet samples were collected from smallmouth bass, channel catfish, and northern pikeminnow that were captured by electrofishing. Diet samples for smallmouth bass were obtained by gastric lavage and channel catfish and northern pikeminnow samples were obtained by sacrificing the fish. All diet samples were placed in whirl-paks with 10 cc of buffered solution and tagged with date, stomach number, species, length, weight, and the section where the fish was captured and then placed on dry ice. Samples were kept frozen until they were ready to be examined in the laboratory (1 to 3 months).

In the lab, the diet samples were weighed to the nearest 0.1 g, then transferred into a pancreatin solution to digest soft tissues, revealing only bones, and finally placed in various size glass and nalgene containers. The analysis of the contents consisted of placing the contents of a single sample into a petri dish and counting and identifying fish to the lowest possible taxonomic classification based on diagnostic bones. For bone identification, a series of keys and sketches produced and provided by the Biological Resources Division station located in Cook, Washington, were used. Standard equations presented by Hansel et al. (1988), as well as some equations that we developed were used to calculate estimated length of fish in the stomach samples based on dimensions of bones measured to the nearest 0.05 mm with an ocular micrometer. Length-weight regressions based on live fish we collected concurrently with the predatory fishes, as well as equations presented by Vigg et al. (1991), were then used to calculate estimated weight of each prey fish at the time of ingestion.

Prey preference for smallmouth bass was examined by subtracting the percentage of a given prey species observed while electrofishing (availability) from the percentage of that species observed in smallmouth bass guts (use).

Temperature (T) was obtained from thermographs placed in each section and set to record the water temperature each hour. Using an equation derived from Rogers and Burley (1991) we back-calculated the average time since ingestion of salmonid prey by smallmouth bass (*DT*).

$$DT = -200\ln(-E^{0.513}S^{-0.513} + 1)S^{0.29}e^{-0.15T}W^{-0.23} \qquad [1]$$

E = amount of prey evacuated (g)[back-calculated weight at time of ingestion – weight of stomach contents sampled],
S = prey meal weight [back-calculated weight at time of ingestion](g),
T = water temperature (C)[24 hour mean from midnight to midnight for sampling day], and
W = predator weight (g)

Digestion time was used to reveal the time(s) of day that predators were eating salmonid prey items and the length of time they were in the gut before we sampled them. Based on those results we then elected to use the average temperature for the 24-hour period prior to the mean time that samples containing single salmonid prey were eaten (11:00 AM). This new temperature variable will be called *T2* and is used in our consumption equations.

Consumption

We used the equation presented by Tabor et al. (1993) to calculate evacuation time (*ET90*; days) for smallmouth bass and modified it to solve for *ET90* in hours. This is the number of hours for a given meal to be 90 percent evacuated at a given temperature and predator weight:

$$ET90 = (24.542S^{0.29}e^{-0.15T2}W^{-0.23})x(24) \quad [2]$$

For northern pikeminnow, we used the equation presented by Beyer et al. (1988) to calculate evacuation time (*ET90*; hours). This is also the number of hours for a given meal to be 90 percent evacuated at a given temperature and predator weight:

$$ET90 = 1147S^{0.61}T2^{-1.60}W^{-0.27} \quad [3]$$

For channel catfish, we calculated evacuation time by the following equation (derived from data presented by Schrable et. al. (1969)). This equation only uses temperature as a variable. In the future, we hope to find an equation that uses meal size and predator weight.

$$ET90 = -4.93525 + e^{3.91943-0.02289T2} \quad [4]$$

Equations 2-4 were used to obtain average daily evacuation times by using daily *T2* data and the *S* and *W* values obtained by our weekly sample. For example, the *S* and *W* we get on our Friday sample is used to calculate Friday through Thursday's daily evacuation times along with the actual *T2* for each day.

To calculate estimated consumption rate *C* (salmonids per predator per day) we used the equation presented by Ward et al. (1995):

$$C = n(24 / ET90) \quad [5]$$

n = mean number of salmonids observed in predator gut samples per day, and
ET90 = mean daily evacuation time for a salmonid meal (hours) from equations 2-4.

Extrapolations

Weekly population estimates of smallmouth bass $\geq$ 150 mm FL (the minimum size found to consistently contain salmonids) were generated by the regression equation based on the relationship between mark-recapture population estimates and CPUE for the Benton and Vangie study sections. To estimate the daily number of salmonids eaten within each study section by smallmouth bass (*SE*) we used the following equation:

$$SE = PExFxC \qquad [6]$$

PE = weekly population estimate of smallmouth bass $\geq$ 150 mm FL within the study section,
F = fraction of smallmouth bass stomachs examined that contained at least one salmonid, and
C = estimated daily consumption rate per predator from equation 5.

To estimate the number of salmonids consumed daily by smallmouth bass in the lower 68 km of the Yakima River (the range of high bass densities) (S_{tot}), we added the number of salmonids consumed in the Benton and Vangie reaches. We used the following equation to estimate consumption in each of the reaches:

$$S_{tot} = (PE / SL)xRLxFxC \qquad [7]$$

SL = length of the study section (km), and
RL = length of reach being extrapolated to (km).

Selectivity

To estimate the number of fall chinook produced naturally below Prosser Dam we used the following equation:

$$N = NRxEFxSE$$

NF = estimated number of redds,
EF = estimated fecundity, and
SE = estimated survival to emergence.

Estimates of redds below Prosser Dam were 662 in 1999 and 984 in 2000 (Rick Watson pers. com.). We used 5000 eggs/female based on the fecundity of fall chinook above Prosser Dam in 1997 which was 4994 eggs/female (Yakama Nation unpublished data). For estimated survival to emergence we used 10 percent. Although we do not have data to support this survival, Healey 1991 reported survival from egg to emergence from several published estimates was 30 percent or less under natural conditions. Because the Yakima River below Prosser contains a high percentage of fine sediments and has accumulated contaminants from agricultural runoff and municipal sources, we believe our estimated survival is close to the true number.

Maximum Consumption

Maximum daily consumption of fall chinook by smallmouth bass was calculated for 1999 and 2000 using data collected during our predatory surveys and bioenergetic functions presented by Hanson et. al. 1997. Weekly catches of smallmouth $\geq$ 150 mm were ran through the equation for each day of the week using daily average temperatures. The proportion of maximum consumption was set as one to simulate feeding at a maximum rate for their specific weight and the water temperature. The average grams consumed daily was then extrapolated over the population estimate of the section and the reach for that week to get total grams consumed in the section and the reach. The total grams consumed were then divided by the average weight of fall chinook in the Lower Yakima for that month to get total maximum daily consumption of fall chinook.

Results

Smallmouth Bass

Abundance Estimates

As in 1998 and 1999, we found a positively correlated relationship between our population estimates and CPUE (Figure 2). We used this relationship to extrapolate our CPUE in weeks when no mark-recapture estimates were performed.

Abundance of bass ≥150 mm increased during the spring from a low of 985 on March 2 to a high of 28,145 on May 4 (Figure 3). Estimates fluctuated after May 4 around an average of 25,500 and slowly declined although not significantly. Population estimates during 1998 and 1999 also showed a similar trend of increasing throughout the spring period. Mark-recapture population estimate statistics for smallmouth bass in the Benton and Vangie sections are presented in Table 1.

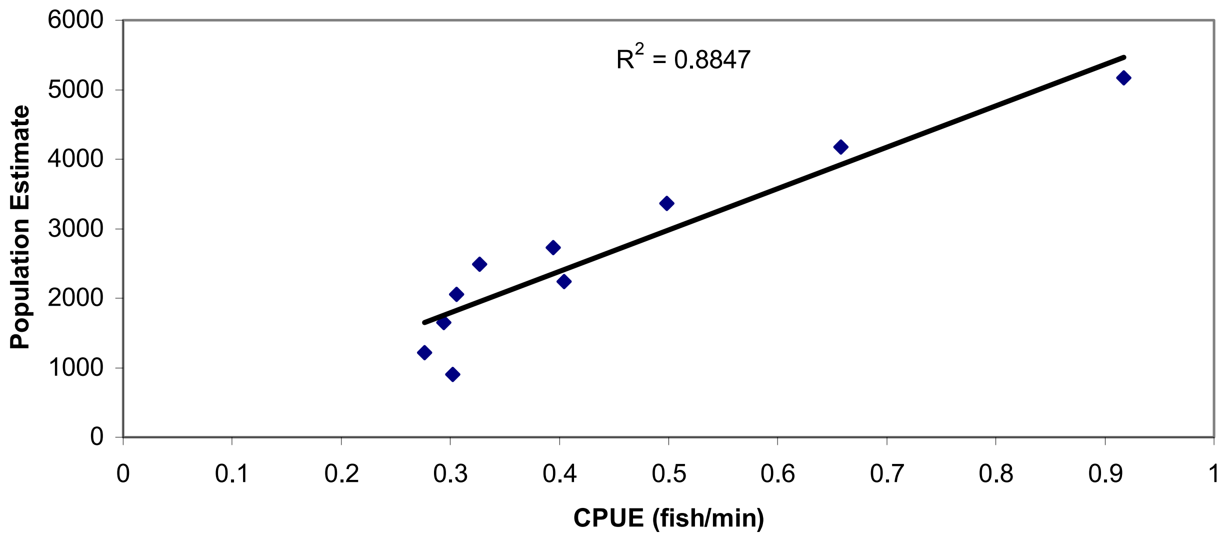

Figure 2. Relationship between CPUE and population estimates in the Benton and Vangie sections during 1998, 1999 and 2000.

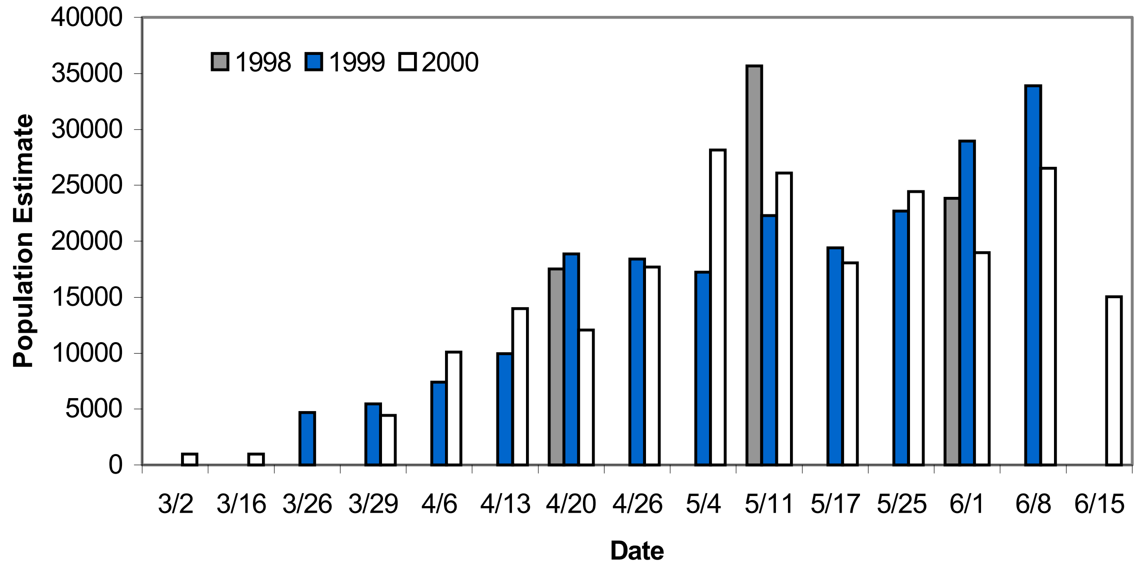

Figure 3. Estimated population size of smallmouth bass ≥ 150 mm FL in the lower 68 km of the Yakima River versus date in 1998, 1999 and 2000.

Table 1. Unexpanded population estimate data for smallmouth bass (SMB) in two sections of the Yakima River. Dates (2000), species/size class (mm FL), estimate, standard deviations (SD), capture efficiency (Effic.), and validity of the estimate are shown for each river section/date.

Dates	Species/size	Section	Estimate	SD	Effic.	Valid
4/25-26	SMB/≥100	Benton	2622	458.3	9.6%	Yes
4/25-26	SMB/≥150	Benton	899	197.3	14.6%	Yes
4/25-26	SMB/≥200	Benton	297	75.9	20.5%	Yes
4/27-28	SMB/≥100	Vangie	5959	1155.9	5.0%	Yes
4/27-28	SMB/≥150	Vangie	2724	944.8	6.1%	Yes
4/27-28	SMB/≥200	Vangie	2050	860.8	4.7%	Yes
5/16-17	SMB/≥100	Benton	5591	1620.9	5.0%	Yes
5/16-17	SMB/≥150	Benton	2055	858.2	6.0%	Yes
5/16-17	SMB/≥200	Benton	NA	NA	NA	NA
5/18-19	SMB/≥100	Vangie	2563	427.4	10.5%	Yes
5/18-19	SMB/≥150	Vangie	1221	232.2	12.6%	Yes
5/18-19	SMB/≥200	Vangie	649	144.5	13.2%	Yes

The increase in abundance between March 2 and June 8 is attributed to immigration and recruitment of smaller fish into the 150 mm and larger category. The trend of movement upstream in the spring and downstream in the summer continued in 2000 (Figure 4). We believe smallmouth migrate from the Columbia River into the Yakima River and back. This year we saw a greater increase in bass 150 to 249 mm than we have in the past compared to fish greater than 249 mm (Figure 5) This is thought to be due to a strong year class of age two fish that average 170 mm with a large proportion in the 150 to 160 mm range. Our recapture data suggests that these age two fish do not move around much, which suggests that recruitment played a larger role in the increase in 2000 than in previous years.

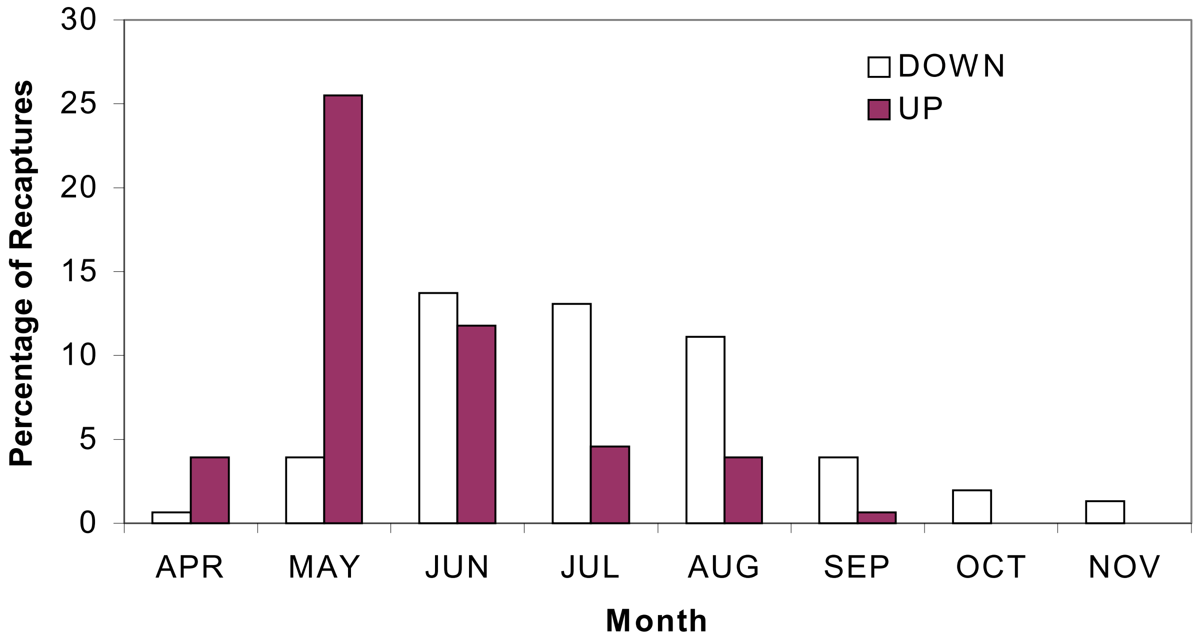

Figure 4. Movement of tagged smallmouth bass in the Yakima River based on electrofishing and angling recapture data from 1997 to 2000. Fish were only used if they moved more than 5 km and were at large less than 250 days.

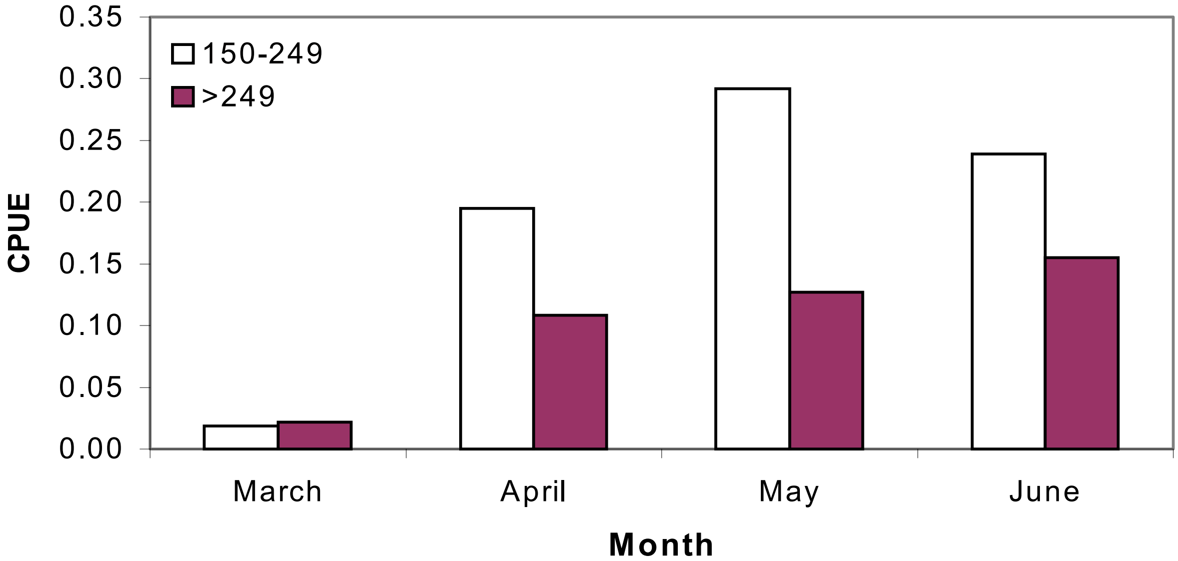

Figure 5. Catch per unit effort (fish per minute) by month of smallmouth bass 150 to 249 mm and greater than 249 mm captured during electrofishing in 2000.

Diet

Fall chinook were found in the guts of smallmouth bass on the first sampling day of March 2 but were not common until around mid April (Table 2). Spring chinook were rarely found in the gut and only in the Vangie section. The percentage of stomachs that had fish and salmonids in the gut rose sharply in early April and remained high until the beginning of June where it decreased considerably (Table 2). Ten fish taxa were identified in the guts of smallmouth bass (Table 3). Fall chinook and dace were the dominant fish species found in the guts, making up 60% of the fish in the gut (Table 3).

Table 2. Summary results of diet analyses for smallmouth bass (≥ 150 mm FL) sampled in the Benton and Vangie reaches from March 2 to June 16, 2000. The number of stomachs examined (N), the number (percent) of fish=s guts in each sample that were empty, or contained invertebrates, fish, anadromous salmonids, and/or spring chinook salmon (SPC). The fish category includes salmonids. The salmonid category does not include SPC

Date	Section	N	Empty	Invert	Fish	Salmonids	SPC
3/2	Benton	5	40.0	20.0	40.0	20.0	0.0
3/16	Benton	5	40.0	40.0	20.0	0.0	0.0
3/30	Benton	18	22.2	66.6	16.6	0.0	0.0
4/6	Benton	37	51.4	21.6	27.0	8.1	0.0
4/13	Benton	39	25.6	51.3	25.6	17.9	0.0
4/20	Benton	37	18.9	51.4	32.4	16.2	0.0
4/26	Benton	68	48.5	36.8	17.6	10.3	0.0
5/4	Benton	37	16.2	75.7	40.5	21.6	0.0
5/11	Benton	36	8.3	75.0	38.9	30.6	0.0
5/17	Benton	91	7.7	83.5	20.9	7.7	0.0
5/25	Benton	36	13.9	61.1	38.9	16.7	0.0
6/1	Benton	37	21.6	56.8	27.0	8.1	0.0
6/8	Benton	35	22.9	65.7	25.7	5.7	0.0
6/15	Benton	19	15.8	68.4	21.1	0.0	0.0
3/3	Vangie	0	0.0	0.0	0.0	0.0	0.0
3/17	Vangie	1	0.0	100.0	0.0	0.0	0.0
3/31	Vangie	13	92.3	7.7	0.0	0.0	0.0
4/7	Vangie	21	42.9	38.1	28.6	14.3	0.0
4/14	Vangie	36	30.6	50.0	33.3	27.8	2.8
4/21	Vangie	36	33.3	52.8	30.6	16.7	0.0
4/28	Vangie	128	50.0	35.2	17.2	10.9	0.8
5/5	Vangie	34	38.2	50.0	32.4	23.5	0.0
5/12	Vangie	29	17.2	48.3	34.5	17.2	0.0
5/19	Vangie	52	34.6	50.0	28.8	17.3	1.9
5/26	Vangie	52	30.8	55.8	17.3	3.8	0.0
6/2	Vangie	44	23.1	54.5	22.7	18.2	0.0
6/9	Vangie	44	52.3	34.1	25.0	9.1	2.3
6/16	Vangie	37	32.4	56.8	10.8	2.7	0.0

Table 3. Species composition of fish found in smallmouth bass stomachs collected in the lower Yakima River March 2 through June 16, 2000. Total number of prey fish in sample (N), and number of each prey species are presented for each date in each section.

		Prey Species[a]													
Date	Section	N	CCF	CCP	CHM	DAC	FAC	LAMP	MWF	NPM	NSA	SAL	SMB	SPC	SUC
3/2	Benton	2					1						1		
3/16	Benton	1													1
3/30	Benton	5	1						1				2		1
4/6	Benton	11			1	1	2		1		3	1	2		
4/13	Benton	14				2	6		4			1	1		
4/20	Benton	14	1			1	6		1			1	4		
4/26	Benton	16					11		1		2		2		
5/4	Benton	21				2	8			2	2				7
5/11	Benton	15				2	12						1		
5/17	Benton	25				7	8		7		2		1		
5/25	Benton	19			1	7	8		2		1				
6/1	Benton	11				7	3		1						
6/8	Benton	12				2	3				5				2
6/15	Benton	4				4									
3/3	Vangie	0													
3/17	Vangie	0													
3/31	Vangie	0													
4/7	Vangie	9					5				2	1	1		
4/14	Vangie	20				1	15		2	1				1	
4/21	Vangie	13					6	1	2		4				
4/28	Vangie	25	1		1	3	14		2		2		1	1	
5/5	Vangie	12					8		1	1	2				
5/12	Vangie	10					5	1	1		1		1		1
5/19	Vangie	18			1	3	8				5			1	
5/26	Vangie	10			1	1	2	1	2		2				1
6/2	Vangie	12					8		1		3				
6/9	Vangie	11				1	3		1		4		1	1	
6/16	Vangie	4				1	1				2				
Totals		314	3		5	45	143	3	30	4	42	4	18	4	13
Percent total			0.9		1.6	14.3	45.5	0.9	9.6	1.3	13.4	1.3	5.7	1.3	4.1

[a] CCF = channel catfish, CCP = common carp, CHM = chiselmouth, DAC = dace spp., FAC = fall chinook salmon, LAMP = unidentified lamprey, MWF = mountain whitefish, NPM = northern pikeminnow, NSA = unidentified non-salmonid, SAL = unidentified salmonid, SMB = smallmouth bass, SPC = spring chinook salmon, SUC = sucker spp.

Availability

Suckers, smallmouth bass, chinook salmon, common carp, chiselmouth, and dace were the most abundant fishes that we observed in the lower Yakima River (Table 4, 5). The numbers of fish that we observed gradually increased during the sampling period. Fall chinook salmon were relatively rare until April 20th and spring chinook salmon were fairly common until the third week of April (Figure 6).

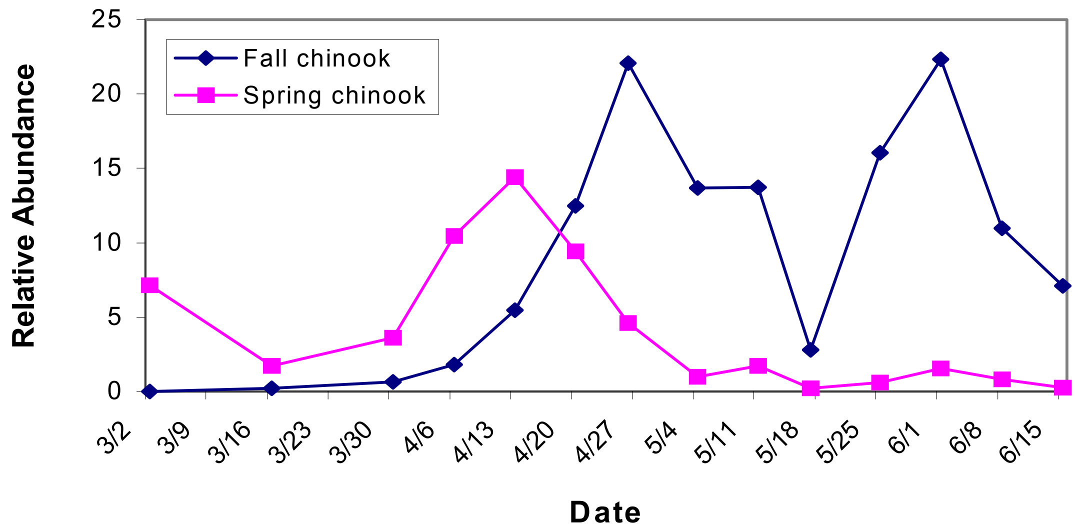

Figure 6. Relative abundance (percent of all fish observed) of spring chinook salmon smolts and fall chinook parr and smolts in the Benton and Vangie sections of the lower Yakima River versus sample date, 2000.

Table 4. Visually estimated percent composition of species in the Benton section (rkm 49.3 – 57.1). Total number of fish observed per day is listed for reference.

Species.[a]	March 2	March 16	March 30	April 6	April 13	April 20	April 26[c]
BBH							1
BRT							
CCF[b]							
CCP	13.7	15.3	7.2	10.9	14.4	19.4	6.3
CHM	0.3	1.8	3.1	9.3	3.8	1.4	3.0
COH	1.2	2.1	4.1	1.4	0.3	1.1	0.2
DAC	2.1		0.4	1.8	3.0	8.7	3.8
FAC		0.3	1.2	1.4	6.4	0.2	28.6
LMB							
LMP							
MWF	10.6	15.9	10.7	4.3	4.1	5.0	4.9
NPM			0.8	0.7	0.3		0.4
PMK							0.03
PMO							
RSS		0.6		0.7		0.2	0.2
SCU							
SMB	11.6	10.5	29.2	26.8	22.5	13.3	24.3
SND							
SPC	15.8	1.8	8.2	10.9	24.2	15.8	7.7
SUK	41.0	49.5	31.1	24.9	19.6	33.4	17.8
WCR							
WSH	3.6	2.1	4.1	7.0	1.3	91.6	2.7
YLP							
Totals	329	333	514	441	1020	563	2528

[a] BBH (brown bullhead), BRT (brown trout), CCF (channel catfish), CCP (common carp), CHM (chiselmouth), COH (coho salmon), DAC (dace spp.), FAC (fall chinook), LMB (largemouth bass), LMP (lamprey spp.), MWF (mountain whitefish), NPM (northern pikeminnow), PMK (pumpkinseed), PMO (peamouth), RSS (redside shiner), SCU (prickly sculpin), SMB (smallmouth bass), SND (sandroller), SPC (spring chinook), SUK (sucker spp.), WCR (white crappie), WSH (wild steelhead), YLP (yellow perch).

[b]Channel catfish are relatively unsusceptible to capture by electrofishing, therefore, they represent a larger but unknown proportion of the total fish community than is represented by these data.

[c] Mark-recapture run using 2 boats and combining visual data.

Table 4 continued. Visually estimated percent composition of species in the Benton section (rkm 49.3 – 57.1). Total number of fish observed per day is listed for reference.

Species.[a]	May 4	May 11	May 17[c]	May 25	June 1	June 8	June 15
BBH		0.2	0.1				
BRT							0.1
CCF[b]	0	0	0	0	0.1	0	0
CCP	11.0	7.8	31.1	11.4	11.4	15.7	17.2
CHM	7.2	1.8	11.8	11.7	9.3	11.3	19.5
COH	0.2	0.8	0	0	0.8	0.1	0
DAC	8.1	4.9	5.5	11.8	9.3	11.2	9.5
FAC	16.0	17.6	3.9	16.7	12.3	11.9	6.2
LMB							
LMP							
MWF	4.9	1.2	2.3	2.0	9.3	2.1	2.1
NPM	0.3	0.9	0.7	0.6	0.1	0.4	1.6
PMK							
PMO						0.2	
RSS	1.3	0.5	0.1	0	0	0	0
SCU							
SMB	30.2	31.4	23.7	20.1	21.8	18.7	12.9
SND							
SPC	1.9	2.6	0.6	1.3	4.3	1.1	0.3
SUK	17.9	28.0	19.8	24.3	21.1	27.3	30.6
WCR	0.1						
WSH	0.9	2.3	0.5	0.1	0	0	0
YLP							
Totals	913	653	2688	897	717	941	728

[a] BBH (brown bullhead), BRT (brown trout), CCF (channel catfish), CCP (common carp), CHM (chiselmouth), COH (coho salmon), DAC (dace spp.), FAC (fall chinook), LMB (largemouth bass), LMP (lamprey spp.), MWF (mountain whitefish), NPM (northern pikeminnow), PMK (pumpkinseed), PMO (peamouth), RSS (redside shiner), SCU (prickly sculpin), SMB (smallmouth bass), SND (sandroller), SPC (spring chinook), SUK (sucker spp.), WCR (white crappie), WSH (wild steelhead), YLP (yellow perch).
[b] Channel catfish are relatively unsusceptible to capture by electrofishing, therefore, they represent a larger but unknown proportion of the total fish community than is represented by these data.
[c] Mark-recapture run using 2 boats and combining visual data.

Table 5. Visually estimated percent composition of species in the Vangie section (rkm 12.2 – 20.2). Total number of fish observed per day is listed for reference.

Species.[a]	March 3	March 17	March 31	April 7	April 14	April 21	April 28[c]
BBH		0.2					0.2
BRT							
CCF[b]	0	0	0	0	0	0	0.1
CCP	32.3	32.6	34.8	15.6	31.8	17.8	16.4
CHM	0.2	0	0.1	4.4	5.3	2.8	1.5
COH	0	0.2	0.3	0.4	0.2	0	0
DAC	0.2	0.2	1.3	0.5	0.3	0.4	2.8
FAC	0	0.2	0.3	2.2	4.4	15.6	14.9
LMB							0.1
LMP							
MWF	13.4	16.0	13.1		4.3	1.6	4.3
NPM	0	0.3	0	0	0.1	0	0.8
PMK							
PMO						0.1	
RSS	4.8	0.5	3.3	0.5	0.4	1.6	0.9
SCU							
SMB	5.2	6.5	14.9	12.1	23.7	13.4	31.6
SND							
SPC	1.9	1.7	0.5	10.1	3.8	4.4	2.0
SUK	40.3	41.7	30.8	53.7	25.2	41.8	24.1
WCR							
WSH	1.9	0	0.5	0.5	0.4	0.3	0.4
YLP							
Totals	539	599	753	546	906	679	2323

[a] BBH (brown bullhead), BRT (brown trout), CCF (channel catfish), CCP (common carp), CHM (chiselmouth), COH (coho salmon), DAC (dace spp.), FAC (fall chinook), LMB (largemouth bass), LMP (lamprey spp.), MWF (mountain whitefish), NPM (northern pikeminnow), PMK (pumpkinseed), PMO (peamouth), RSS (redside shiner), SCU (prickly sculpin), SMB (smallmouth bass), SND (sandroller), SPC (spring chinook), SUK (sucker spp.), WCR (white crappie), WSH (wild steelhead), YLP (yellow perch).

[b]Channel catfish are relatively unsusceptible to capture by electrofishing, therefore, they represent a larger but unknown proportion of the total fish community than is represented by these data.

[c] Mark-recapture run using 2 boats and combining visual data.

Table 5 continued. Visually estimated percent composition of species in the Vangie section (rkm 12.2 – 20.2). Total number of fish observed per day is listed for reference.

Species.[a]	May 5	May 12	May 19[c]	May 26	June 2	June 9	June 16
BBH	0.1		0.03	0.1	0.1		
BRT							
CCF[b]	0.1	0.3	0.2	0.1	0.3	0.8	1.8
CCP	27.5	27.0	26.0	22.9	19.0	22.3	19.0
CHM	4.5	3.1	17.4	8.6	11.5	11.6	18.6
COH	0	0	0	0.1	0.2	0	0
DAC	0.5	1.7	0.8	1.5	0	1.5	0.7
FAC	11.4	9.7	1.9	15.4	29.0	10.0	8.0
LMB	0.1		0.1				
LMP			0.2				
MWF	1.4	1.3	1.8	7.2	2.7	3.2	4.2
NPM	0.3	0.6	1.0	0	1.2	0.2	0.3
PMK				0.1			
PMO	0.1		0.03	0.1		0.1	
RSS	0.2	1.4	0.7	0	0	0	
SCU			0.03	0.2			
SMB	26.8	28.0	15.7	17.8	14.4	20.9	12.8
SND							
SPC	0.4	0.9	0.2	0.2	0	0.9	0.5
SUK	26.4	25.6	33.9	25.6	21.6	28.5	34.1
WCR							
WSH	0	0.2	0.1	0.1	0	0	0
YLP							
Totals	919	636	3155	978	1087	888	763

[a] BBH (brown bullhead), BRT (brown trout), CCF (channel catfish), CCP (common carp), CHM (chiselmouth), COH (coho salmon), DAC (dace spp.), FAC (fall chinook), LMB (largemouth bass), LMP (lamprey spp.), MWF (mountain whitefish), NPM (northern pikeminnow), PMK (pumpkinseed), PMO (peamouth), RSS (redside shiner), SCU (prickly sculpin), SMB (smallmouth bass), SND (sandroller), SPC (spring chinook), SUK (sucker spp.), WCR (white crappie), WSH (wild steelhead), YLP (yellow perch).

[b]Channel catfish are relatively unsusceptible to capture by electrofishing, therefore, they represent a larger but unknown proportion of the total fish community than is represented by these data.

[c] Mark-recapture run using 2 boats and combining visual data.

Consumption

In contrast to 1999, daily consumption of salmonids by smallmouth bass in 2000 was more evenly distributed with a less pronounced peak. Salmonid consumption decreased in the latter part of the sampling period despite an abundant population of bass and warmer water temperatures but was not nearly as pronounced as in 1998 and 1999 (Figure 7). Between March 2 and June 16, 2000, we estimated that smallmouth bass consumed 202,722 salmonids of which 3,083 were spring chinook. Between the same dates in 1999 our estimate was 171,031 salmonids of which 3,795 were spring chinook

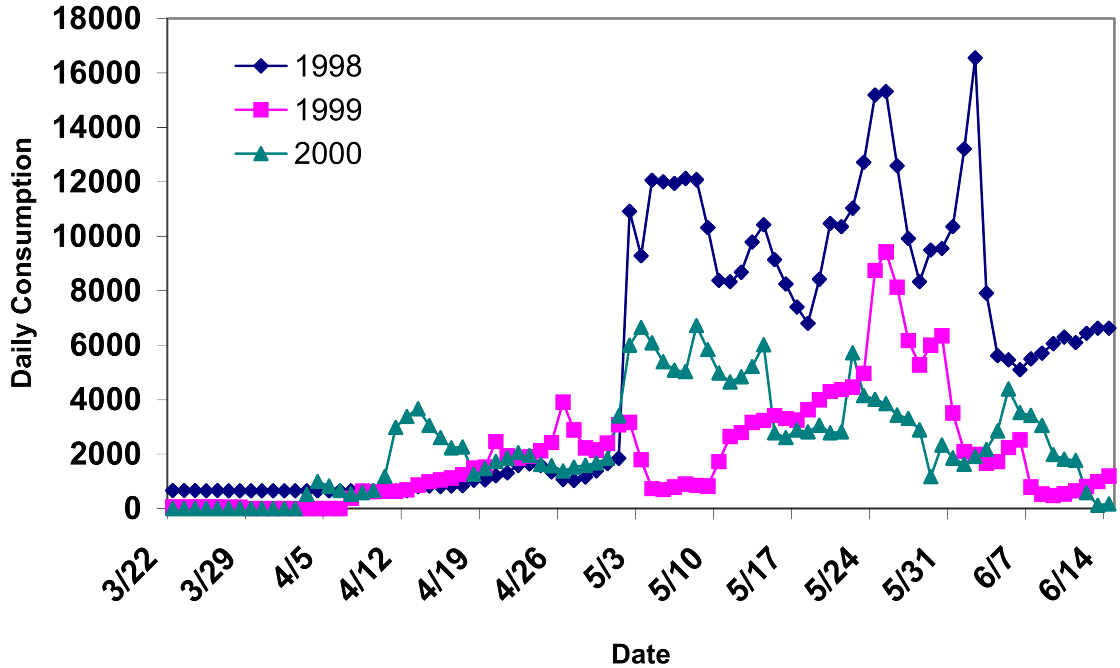

Figure 7. Estimates of daily salmonid consumption by smallmouth bass during 1998, 1999 and 2000 in the Yakima River between Prosser Dam and the confluence of the Columbia River.

Selectivity

Smallmouth bass seem to prefer smaller sized prey such as naturally produced fall chinook (Figure 8). In 2000 the mean size of hatchery fall chinook released was greater than in 1999 (Table 6). In 1999, we considered fall chinook in guts ≥55mm hatchery fall chinook and in 2000 we considered fall chinook ≥65mm to reflect the difference in size between the two years. It is interesting to note that smallmouth bass ate less hatchery fall chinook in 2000 despite the fact that the numbers released were essentially the same (about 2 million) and smallmouth ate more fall chinook overall in 2000 than in 1999. This may be related to the fact that hatchery fall chinook were larger at release on average in 2000 than in 1999. In addition, because there were more naturally produced fall chinook in 2000, they may have acted as a shield for hatchery fall chinook.

Table 6. Mean lengths of hatchery fall chinook released and minimum length of chinook in gut considered hatchery origin (>99% of releases were equal to or greater than this length) in 1999 and 2000.

Year	Mean length of hatchery fall chinook		Minimum length considered hatchery fall chinook in gut	
	April 20 release	May 26 release	April 20 release	May 26 release
1999	84mm	69mm	65mm	55mm
2000	83mm	91mm	65mm	70mm

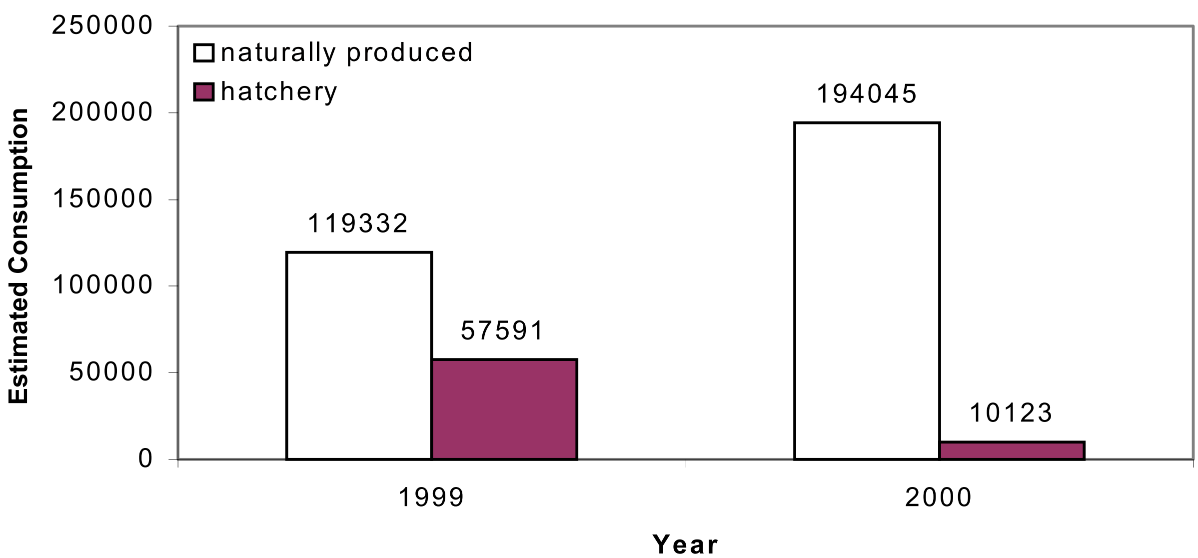

Figure 8. Estimated consumption of naturally produced and hatchery fall chinook in 1999 and 2000 based on lengths of chinook found in guts.

We estimated 331,000 naturally produced fry emerged in 1999 and 492,000 emerged in 2000. These fry are believed to make up the majority of naturally produced fry consumed by smallmouth bass for the following reasons. Only 35% of the upriver (spawned upstream of Prosser Dam) naturally produced fry passed Prosser Dam by June 1, 1999 and only 11% had passed by June 1 in 2000 based on estimates at the Chandler Trap. These migrating fish are generally larger than the fish that we are calling naturally produced in the smallmouth guts based on lengths taken at Chandler. These actively migrating fish are also spending more time offshore and are probably not spending much time in the Lower Yakima so they are available to the smallmouth for a shorter amount of time. If we assume that our estimates of naturally produced fry are somewhere within an order of magnitude of the actual number produced, smallmouth could be a limiting factor on natural production, especially in years with low production (Figure 9).

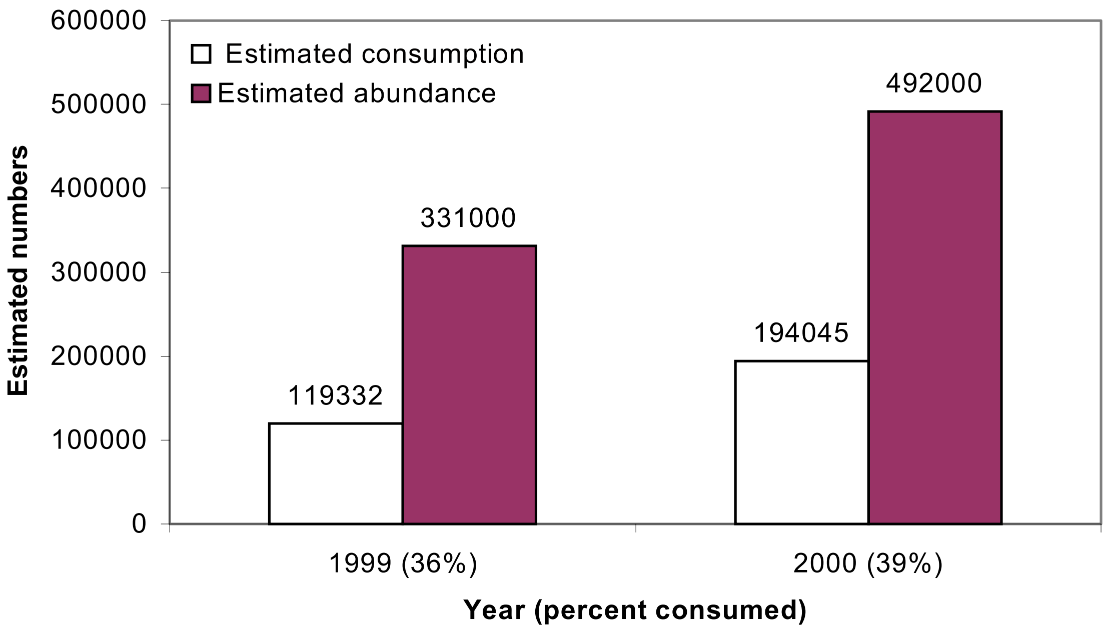

Figure 9. Estimated naturally produced fall chinook abundance and estimated consumption by smallmouth bass for 1999 and 2000 in the lower 68 km of the Yakima River. Listed in parentheses is the percent of natural production consumed by smallmouth.

Percent of Population Consumed

We compared our estimated consumption to estimated numbers of juvenile salmonids to show the relative impact of smallmouth predation (Table 7).

Table 7. Population size, estimated number consumed and percent of population consumed by smallmouth bass for salmonid species in 1999 and 2000. Population sizes are from estimated passage at Chandler (YN data) and estimated fry production below Prosser for fall chinook.

	1999			2000		
Species[a]	Population size	Number consumed	Percent consumed	Population size	Number consumed	Percent consumed
WFAC	370,453	119,332	32	690,002	194,045	28
HFAC	1,891,000	57,591	3	2,012,135	10,123	0.5
WSPC + WCOHO	211,788	3,083	1	94,352	3,795	4
HSPC + HCOHO	219,082[b]	0	0	390,064	0	0
WSTH	32,868	0	0	42,696	0	0

[a]WFAC-wild fall chinook, HFAC-hatchery fall chinook, WSPC-wild spring chinook, WCOHO-wild coho, HSPC-hatchery spring chinook, HCOHO-hatchery coho, WSTH-wild steelhead.
[b]All coho passing Chandler in 1999 assumed to be hatchery origin.

Maximum Consumption

From 1998 to 2000 our estimated consumption averaged 31 percent of our calculated maximum consumption (Figure 10). If we use estimated wild fall chinook passage at the Chandler Trap (Prosser Dam) as an indicator of the relative abundance of fall chinook below Prosser Dam between years we see that consumption was higher in years of more abundant fall chinook and that smallmouth bass ate fall chinook at a higher percentage of their maximum consumption.

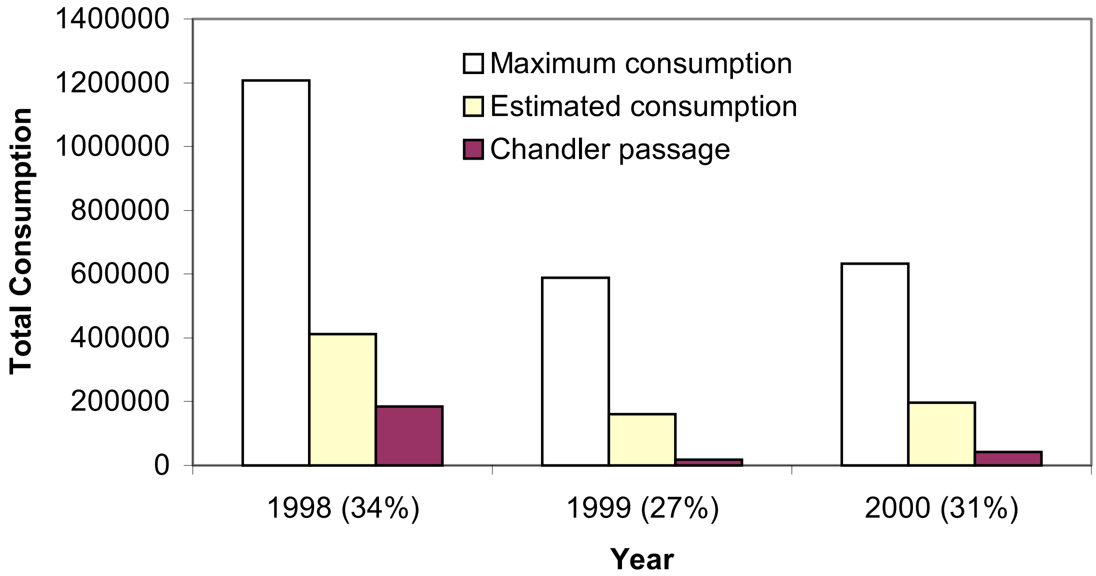

Figure 10. Estimated maximum consumption, estimated total consumption and estimated passage at Chandler (Prosser Dam) of wild fall chinook salmon between March 22 and June 10 1998-2000. Numbers in parentheses are the percent of estimated consumption to maximum consumption.

Channel Catfish

The diets of channel catfish in 2000 were more similar to the diets of 1999 than to 1998 and could be related to sample size and collection methods. Samples from 1998 were collected by a combination of electrofishing, trapping, gill netting and angling whereas samples in 1999 and 2000 were collected by electrofishing only. A higher percentage of channel catfish were empty compared to 1999 and a lower percentage ate fish during 2000 (Table 8). When only the catfish collected by electrofishing were analyzed, the diets from 1998 to 2000 were similar (Table 8). In contrast to 1998 and 1999, no salmonids were found in the guts in 2000 (Table 9). The low percentage of catfish containing salmonids the last three years of sampling suggests they may not be as serious a predator in our study area as was once thought.

Adult-sized channel catfish were either not abundant or difficult to capture by electrofishing during the spring period. Of the 33 catfish captured in 2000, 64 percent were captured in the month of June after the majority of salmonids had emigrated.

Table 8. Composition of channel catfish stomachs collected in the lower Yakima River, April through June 1998, 1999 and 2000. Total number of stomachs in sample (N), and number of times (with percentage below) each category was found in a stomach is presented. Anadromous salmonids are included in the fish category. The invertebrate (Invert.) category includes crayfish.

		Food Category							
Year	N	Empty	Fish	Salmonid	Invert.	Crayfish	Seeds	Bird	Rodent
1998	137	70	26	4	43	31	21	3	2
		(51.0)	(19.0)	(2.9)	(31.3)	(22.6)	(15.3)	(2.2)	(1.5)
1998[a]	10	3	2	0	4	0	1	0	0
		(30.0)	(20.0)	(0.0)	(40.0)	(0.0)	(10.0)	(0.0)	(0.0)
1999	24	6	5	1	16	1	1	0	0
		(25.0)	(20.8)	(4.2)	(66.7)	(4.2)	(4.2)	(0.0)	(0.0)
2000	26	9	3	0	13	1	1	0	1
		(34.6)	(11.5)	(0.0)	(50.0)	(3.8)	(3.8)	(0.0)	(3.8)

[a]Results using only channel catfish samples gathered by electrofishing during 1998.

Table 9. Species composition of fish found in channel catfish stomachs collected in the lower Yakima River April through June 1998, 1999 and 2000. Total number of fish in stomachs (N), and number (with percentage below) of prey species is presented.

Prey Species[a]													
CCF	CCP	CHM	DAC	FAC	SUC	MWF	NSA	NPM	SAL	SCU	SMB	SPC	WSH
1998 (N=21)													
8	3	2	1	77	8	3	7	2	2	1	6	0	1
6.6	2.5	1.7	0.8	63.6	6.6	2.5	5.8	1.7	1.7	0.8	5.0	0.0	0.8
1998[b] (N=2)													
1	0	0	0	0	0	0	1	0	0	0	0	0	0
50.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0
1999 (N=7)													
0	0	1	1	0	2	1	0	0	0	0	1	1	0
0.0	0.0	14.3	14.3	0.0	28.5	14.3	0.0	0.0	0.0	0.0	14.3	14.3	0.0
2000 (N=5)													
1	0	2	0	0	2	0	0	0	0	0	0	0	0
20.0	0.0	40.0	0.0	0.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]CCF = channel catfish, CCP = common carp, CHM = chiselmouth, DAC = dace spp., FAC = fall chinook salmon, SUC = sucker spp., MWF = mountain whitefish, NSA = non-salmonid spp., NPM = northern pikeminnow, SAL = salmonid spp., SCU = sculpin spp., SMB = smallmouth bass, SPC = spring chinook, WSH = wild steelhead.
[b]Results using only channel catfish samples gathered by electrofishing during 1998.

Hot Spot Sampling

Suspected "hotspots" of predation were again sampled in 2000. Sampling at Roza Dam yielded few northern pikeminnow, similar to previous years (CPUE was 0.042 fish/min compared to 0.029 in 1999) but this time three fish (27%) contained spring chinook and 36% contained mountain whitefish, dace, and sculpins. Mean length of pikeminnow captured in April 10 and 11 was 383 mm (range 290-515 mm). We did not get any recaptures so were unable to generate a population estimate.

Sampling at Wanawish Dam was not nearly as "hot" in 2000 as it was in 1999 (mean CPUE was 0.07 and 0.31 fish/min respectively) possibly because we hit it at the peak in 1999 or lower flows in 2000 allowed unimpeded passage for smallmouth bass. Smallmouth bass collected below Wanawish in 2000 were primarily empty as in 1999 (Table 10).

Table 10. Composition of smallmouth bass guts collected by angling below Wanawish Dam April 19 to June 14, 2000. Number of smallmouth bass pumped (N) and number of each prey category is presented with percentages below in parentheses.

N	Empty	Fish	Salmonid	Invert.	Crayfish
			1999		
70	57	6	2	6	2
	(81)	(9)	(3)	(9)	(3)
			2000		
49	36	7	0	4	1
	(73)	(14)	(0)	(8)	(2)

Discussion

Predation by smallmouth bass has undoubtedly contributed substantially to lowered survival of the offspring of naturally spawning fall chinook salmon in the lower Yakima River, but unlikely to have contributed substantially to declines in survival of offspring of wild and hatchery spring chinook salmon, hatchery coho salmon, and wild steelhead. Smallmouth bass primarily ate the smallest salmon available, and the smallest salmon were offspring of naturally spawning fall chinook salmon. Others have also observed that smallmouth bass rarely take yearling salmonids but will readily consume subyearlings (Poe et al. 1991; Tabor et al. 1993; Poe et al. 1994; Zimmerman 1999).

We found that wild fall chinook salmon were more susceptible to predation than hatchery fall chinook salmon. Hatchery fish are typically thought to be more susceptible to predators because of maladaptive behavior and inappropriate coloration (Maynard et al. 1995; White et al. 1995). Fish size appeared to be more influential than behavior or coloration in determining susceptibility of chinook salmon in the lower Yakima River. Hillman and Mullan (1989) also found that smaller sized wild salmon were more susceptible to rainbow trout predators than larger hatchery fish.

For the years 1998 to 2000 we calculated that smallmouth bass consumed fall chinook at an average of 31 percent of their maximum possible consumption (Figure 10). Because the percent of maximum consumption (total overall consumption of fall chinook) increased in years of high natural production of fall chinook, we believe there is a possibility of smallmouth bass compensating for increased production by increasing their predation rate.

Smallmouth bass ate slightly more salmonids in 2000 than in 1999. We believe the most likely explanation for the similarities between 1999 and 2000, besides similar estimates of smallmouth abundance, are that water temperature and discharge were relatively similar in 1999 and 2000 relative to 1998. Water temperature averaged less than one degree Celsius higher in the spring period during 2000 than in 1999 and discharge averaged 48 CMS lower in 2000 compared to 1999.

Daily fall chinook consumption was high for a more prolonged period without a large peak, which was evident in 1999. During the sampling period of 2000, there were more than twice as many wild fall chinook from above Prosser Dam migrating through our sampling sections than there were in 1999, based on passage estimates from the Chandler Juvenile Monitoring Facility. This may be an indicator of the abundance of naturally produced fall chinook below Prosser Dam and could account for our higher estimates. It could also account for the fact that consumption was higher for a prolonged period because there were more resident (non-migrating) fall chinook that were available to the smallmouth for a longer period of time.

Consumption of spring chinook by smallmouth bass has been relatively small compared to consumption of fall chinook during the three years we have sampled (1.4% of consumed salmonids are spring chinook). This comes to only about 1.6% of hatchery produced and 1.9% of wild produced spring chinook smolts passing Prosser Dam. Our data is similar to data from Columbia River studies (Poe et al. 1991; Tabor et al. 1993; Poe et al. 1994; Zimmerman 1999) that found smallmouth consume mostly subyearling (fall) chinook, most likely because of temporal and spatial overlap and size. Our data for 1998, 1999, and 2000 has shown that smallmouth bass generally eat smaller fish such as fall chinook and rarely eat fish over 100 mm in length (Figure 11) which is about the smallest size for a spring chinook emigrating through our study sites based on data collected at the Chandler Trap.

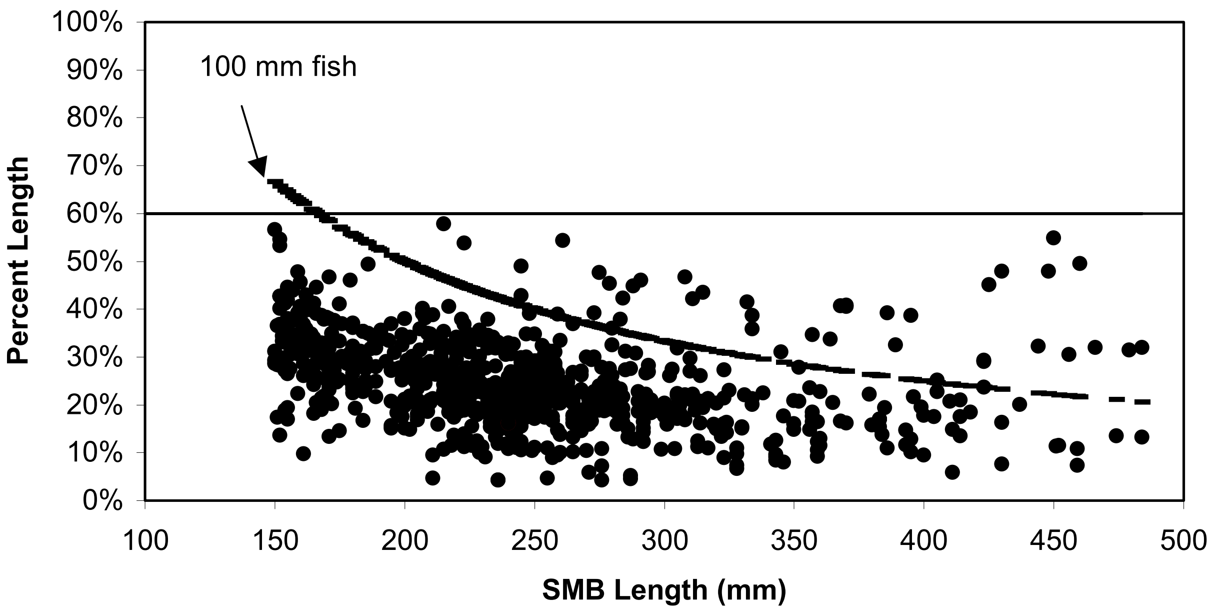

Figure 11. Percent lengths (FL) of fish prey found in smallmouth bass gut samples during 1998, 1999, and 2000. Included is the percent length of a 100 mm fish for each length of smallmouth.

Due to the high consumption of fall chinook by smallmouth bass and particularly the apparent preference for, and higher vulnerability of naturally produced fall chinook, managers are becoming interested in ways to reduce predation. There are many potential methods to reduce the impact of smallmouth bass on fall chinook salmon (and other non-target species) but they all have their faults and potentials for failure. All or most of the potential strategies would involve a continued effort, as the benefits would quickly dissipate when the efforts were ceased. Some of the methods that have been considered are; lifting of angling regulations, a bounty program, returning to a more natural hydrograph and or reducing water temperatures, disruption of smallmouth bass spawning, predator swamping, and direct removal by electrofishing. With any removal of a portion of a population, there is always the potential of compensatory survival where the survival of the remainder of the population increases because of the decreased density and makes up for the additional mortality of the management action. Therefore, all of the above-mentioned strategies share this potential problem except for possibly the natural hydrograph/temperature reduction and should always be considered before any management action is adopted.

Changing the current angling regulations on smallmouth bass in the Yakima River from five fish per day and no more than three over 15 inches to no limit would be the easiest management action to do fiscally because it basically costs nothing to change and enforce. Some problems with this are that many of the anglers that fish for smallmouth bass (who consequently are the most successful at catching bass) are dedicated to their targeted species and release all fish they catch. These anglers are also very organized and would likely oppose any change in regulations that they think would harm the smallmouth bass fishery. Of the anglers that report catching a tagged smallmouth (who admittedly may be skewed towards the catch and release anglers), 43% say they release all the bass they catch and that amounts to 50% of the smallmouth caught. Another potential problem is that anglers often keep the largest fish they catch and release the smaller fish that eat the most salmonids. If this method were undertaken, a slot limit designed to reduce the number of smaller, more predatory fish may be better suited to both reduce predation and reduce angler opposition.

A bounty program on northern pikeminnow in the Columbia River has been reported to reduce their numbers by 9-16% annually (Beamesderfer et al. 1996). This would be promising except that once again there would undoubtedly be high angler and public opposition, possible low participation, and it would also be very expensive to implement. Many of the fish would be removed after the spring smolt migration eliminating much of the reduction in predation for that year. Also, the benefits would cease soon after the bounty program was lifted.

Reduction of water temperatures would entail returning the river to a more natural hydrograph of a large spring freshet and sustained high water throughout much of the spring by changing the management configuration of the irrigation system and/or cooling and filtering the irrigation return water by routing it underground. Vaccaro (1986) projected a 2 to 3 C decrease in water temperature in April and May of 1981 for unregulated flow conditions (102 to 181 m^3/s) versus regulated flow (42 to 57 m^3/s). We calculated that a 3 C decrease in water temperature during April and May of 2000 could have reduced consumption of fall chinook by smallmouth bass by 36% during that time period by affecting the metabolic rates of smallmouth bass. The reduction in temperature could also hamper spawning efforts by smallmouth bass and make the Yakima River less attractive as a place to spawn, rear, and feed. This method would also be beneficial to other native fishes and adult migrating salmonids by providing temperatures and or flows that they are adapted to. This method obviously has some drawbacks. The management of water in the Yakima Basin is already complex due to a limited amount of water and a variety of uses and therefore this could probably only be implemented in years of higher than average water supplies when the benefits to salmonids and other non-target taxa would be less pronounced.

Disruption of smallmouth bass spawning seems somewhat promising. It is reported that male smallmouth bass guard their nests from egg predators and guard the newly hatched fry (Carlander 1977; Winemiller and Taylor 1982). Lukas and Orth (1995) reported that increased water velocity at nest sites caused by increased discharge accounted for 85% of nest failures. Henderson and Foster (1956) reported that all twelve nests observed in a slough in the Hanford Reach of the Columbia River had been deserted and the eggs were covered with fungus after the increased flows caused cold water to enter the slough. Some drawbacks associated with this are 1) surplus water would have to be available to increase flows and decrease temperatures 2) accurate information of smallmouth spawning would need to be available for each year to time the water pulses and 3) smallmouth bass are capable of a prolonged period of spawning so more than one release of water may be needed to be effective. Some smallmouth would certainly successfully spawn and their offspring could have very high survival (compensatory) and excellent growth rates.

Predator swamping would be achieved by releasing a large number of hatchery produced salmonids so that the smallmouth would be satiated, thereby increasing the odds of more naturally produced and hatchery fish making it out of the Yakima River. We believe that to be successful, fish would have to be released near the same size as naturally produced fish. Otherwise smallmouth may pay little attention to the larger hatchery fish and continue to focus on the naturally produced fish. There is a possibility that swamping may just cause smallmouth to switch from other prey and eat primarily fall chinook causing no savings to fall chinook. Growth and survival of smallmouth may also be increased by the extra prey causing higher predation within a year or two.

Removal by electrofishing could have some success in that we estimate we can remove 25 to 30% of the estimated smallmouth population in our sections yearly by maintaining our same rate of effort as in 1999 and 2000. Although electrofishing is biased towards larger fish, we would still be able to remove a large range of sizes (age classes), albeit not at a representative rate for each age class. Once again, a drawback of this method is that it will only produce positive results as long as we maintain our effort. Injury to non-target taxa, mainly adult salmonids is also a major concern although during our sampling in 2000 we only shocked an estimated 0.2% of the returning adult spring chinook and we quickly shut off the current when they were encountered

Recommendations

We recommend a new study in one of our index sections to ascertain the effects of a smallmouth bass removal program. We could use the same sampling effort and methods as in previous years, calculating our regular predation index, and the only difference will be that we will remove all smallmouth that we capture in our Benton section. This removal would be done for approximately five years and during this time abundance, size structure and growth will be monitored and compared to our Vangie section to see if smallmouth survival is able to compensate for our effort of removal. We will also monitor to see if there is a change in smallmouth diet or a change in relative abundance of other species, particularly northern pikeminnow. We believe this study is essential to answer critical uncertainties before any large-scale removal program is initiated.

Acknowledgments

Eric Bartrand, Phillip Smith, and Jason Allen assisted with the field work. Many anglers provided valuable tagged fish recapture data. This work was funded by the Bonneville Power Administration as part of the Yakima/Klickitat Fisheries Project.

References

Beamesderfer, R. C. P., D. L. Ward, and A. A. Nigro. 1996. Evaluation of the biological basis for a predator control program on northern squawfish (*Ptychocheilus oregonensis*) in the Columbia and Snake rivers. Canadian Journal of Fisheries and Aquatic Sciences 53:2898-2908.

Bennett, D. H., J. A. Chandler, and L. K. Dunsmoor. 1991. Smallmouth bass in the Pacific Northwest: benefit or liability. Pages 126-135 *in* D. C. Jackson, editor, The first international smallmouth bass symposium. Mississippi State University, Mississippi State, Mississippi.

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.

Busack, C., and five coauthors. 1997. Yakima fisheries project: spring chinook supplementation monitoring plan. Bonneville Power Administration, Portland, Oregon. DOE/BP-64878-1.

Carlander, K. 1977. Handbook of freshwater fisheries biology, volume 2. Iowa State University Press, Ames. 431 Pages.

Fletcher, D. H. 1991. Interspecific impacts of smallmouth bass in the Northwestern United States. Pages 104-109 *in* D. C. Jackson, editor, The first international smallmouth bass symposium. Mississippi State University, Mississippi State, Mississippi.

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.

Hanson, P. C., T. B. Johnson, D. E. Schindler, and J. F. Kitchell. 1997. Bioenergetics model 3.0 for Windows. University of Wisconsin, Sea Grant Institute, Technical Report WISCU-T-97-001, Madison.

Healy, M. C. 1991 Life history of chinook salmon (*Oncorhynchus tshawytscha*). Pages 313-393 *in* C. Groot and L. Margolis, editors. Pacific salmon life histories. University of British Columbia Press, Vancouver.

Henderson, C., and R. F. Foster. 1956. Studies of smallmouth black bass (*Micropterus dolomieu*) in the Columbia River near Richland, Washington. Transactions of the American Fisheries Society 36:112-127.

Hillman, T. W., and J. W. Mullan. 1989. Effect of hatchery releases on the abundance and behavior of wild juvenile salmonids. Pages 266-285 *in* Summer and winter ecology of juvenile chinook salmon and steelhead trout in the Wenatchee River, Washington. Don Chapman Consultants, Inc. Boise, Idaho.

Lampman, B. H. 1946. The coming of the pond fishes. Metropolitan Press, Portland, Oregon.

Li, H. W., C. B. Schreck, C. E. Bond, and E. Rexstad. 1987. Factors influencing changes in fish assemblages of Pacific Northwest streams. Pages 193-202 *in* W. J. Matthews and D. C. Heins, editors. Community and evolutionary ecology of North American stream fishes. University of Oklahoma Press, Norman.

Light, R. W., P. H. Alder, and D. E. Arnold. 1983. Evaluation of gastric lavage for stomach analyses. North American Journal of Fisheries Management 3:81-85.

Lukas, J. A., and D. J. Orth. 1995. Factors affecting nesting success of smallmouth bass in a regulated Virginia stream. Transactions of the American Fisheries Society 124:726-735.

Maynard, D. J., T. A. Flagg, and C. V. W. Mahnken. 1995. A review of seminatural culture strategies for enhancing the postrelease survival of anadromous salmonids. American Fisheries Society Symposium 15:307-314.

McMichael, G. A., A. L. Fritts, and J. L. Dunnigan. 1998. Lower Yakima River predatory fish census: feasibility study 1997. Pages 229-254 *in* Pearsons, T. N, and five coauthors. 1998. Yakima River species interactions studies, progress report 1995-1997. Bonneville Power Administration, Portland, Oregon.

McMichael, G. A., A. L. Fritts, and J. L. Dunnigan. 1999. Lower Yakima River predatory fish monitoring: progress report 1998. Pages 93-127 *in* ODFW and NMFS. 1999. Management implications of co-occurring native and non-native introduced fishes: Proceedings of the workshop. October 27-28, 1998, Portland, Oregon. Available from NMFS, 525 NE Oregon St., suite 510, Portland, OR 97232.

Pearsons, T. N., and five coauthors. 1998. Yakima River species interactions studies, progress report 1995-1997. Bonneville Power Administration, Portland, Oregon.

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.

Poe, T. P., R. S. Shively, and R. A. Tabor. 1994. Ecological consequences of introduced piscivorous fishes in the lower Columbia and Snake rivers. Pages 347-360 *in* D. J. Stouder, K. L. Fresh, and R. J. Feller, editors. Theory and application in fish feeding ecology. University of South Carolina Press, Columbia.

Rieman, B. E., R. C. Beamesderfer, S. Vigg, and T. P. Poe. 1991. Estimated loss of juvenile salmonids to predation by northern swuawfish, 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.

Schrader, T., and M. E. Gray. 1999. Biology and management of John Day river smallmouth bass. Information report number 99-1, Oregon Department of Fish and Wildlife, Portland.

Shrable, J. B., O. W. Tiemeier, and C. W. Deyoe. 1969. Effects of temperature on rate of digestion by channel catfish. The Progressive Fish Culturist 13:131-138.

Summers, J., and K. Daily. 2001. Willamette river bass diet study-spring 2000. Information report number 2001-04, Oregon Department of Fish and Wildlife, Portland.

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.

Vaccaro, J. J. 1986. Simulation of streamflow temperatures in the Yakima River asin, Washington, April-October, 1981. U. S. Geological Survey Water Resource Investigations report 85-4232. Tacoma, Washington. 91 pages.

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.

Ward, D. L., J. H. Petersen, and J. J. Loch. 1995. Index of predation on juvenile salmonids by northern squawfish in the lower and middle Columbia River and in the lower Snake River. Transactions of the American Fisheries Society 124:321-334.

White, R. J., J. R. Karr, and W. Nehlsen. 1995. Better roles for fish stocking in aquatic resource management. American Fisheries Society Symposium 15:527-547.

Winemiller, K. O., and D. H. Taylor. 1982. Smallmouth bass nesting behavior and nest site selection in a small Ohio stream. Ohio Journal of Science 82:266-273.

Wydoski, R. S., and R. R. Whitney. 1979. Inland fishes of Washington. University of Washington Press, Seattle.

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

Zimmerman, M. P., and R. M. Parker. 1995. Relative density and distribution of smallmouth bass, channel catfish, and walleye in the lower Columbia and Snake rivers. Northwest Science 69:19-28.

Chapter 4

Lower Yakima River Predation Indexing: Northern Pikeminnow

James L. Dunnigan

and

Linda L. Lamebull

Yakama Nation
Department of Fisheries
P.O. Box 151
Toppenish, Washington 98943

Abstract

We conducted population estimates for northern pikeminnow *Ptychocheilus oregonensis* using mark recapture methodology during April, May and June in three sections of the Yakima River above Prosser Dam. However, we were only able to obtain valid population estimates for the Toppenish site (Rkm 145.6-153.4) due to low and variable numbers of recaptured fish at the other sites. The abundance of northern pikeminnow > 199 mm fork length/km in the Toppenish site ranged from 336.2 – 616.8 fish/km from April to June. Most recaptured northern pikeminnow (n = 151; 97.4%) were recaptured in the same section that they were originally tagged, suggesting limited northern pikeminnow movement during the period of this study. Salmonid consumption by northern pikeminnow was higher during the May and June sampling periods than the March and April periods at all sites. Throughout the salmonid outmigration season (March 15 – June 15, 2000) 10.4% of the northern pikeminnow sampled contained at least one salmonid. We classified most salmonids (96%) as yearling smolts (spring chinook *Oncorhynchus tshawytscha*, coho *O. kisutch*, and steelhead *O. mykiss*) based on predicted fork length from diagnostic bones. We relied on the presence of either a coded wire or PIT tag to identify hatchery origin spring chinook and coho salmon. Yearling salmon remains that were not accompanied with a coded wire or PIT tag were identified as unmarked yearling salmonids, and were likely a combination of hatchery and wild origin spring chinook and coho, since estimated fork length at time of ingestion, diagnostic bones, or presence of a coded wire or PIT tag were not reliable methods of determining species or hatchery/wild origin. We estimated a total of 759,315 salmonids were consumed by northern pikeminnow from Prosser Dam to Roza Dam from March 15 – June 15, 2000. We independently modeled consumption of hatchery coho, hatchery spring chinook, unmarked yearling salmon, sub-yearling salmonids, and steelhead, with seasonal consumption estimates of 235,878, 205,402, 308,128, 34,485, and 29,477 fish respectively. Development of a northern pikeminnow predation index in future years should continue to utilize weekly salmonid consumption estimates since this portion of the predation index is likely more variable throughout the outmigration period than predator abundance.

Introduction

The Yakima/Klickitat Fisheries Project (YKFP) is an aggressive and proactive management attempt to increase natural production of anadromous salmonids within the Yakima River Basin and provide valuable information about supplementation efforts to the rest of the Columbia River Basin. An extensive monitoring plan for spring chinook *Oncorhynchus tshawytscha* (Busack et. al 1997) was developed by an interdisciplinary team of scientists, and is an integral portion of the YKFP. Several types of ecological interactions which may impact the dynamics within the Yakima River Basin and the success of the spring chinook supplementation program have been proposed for monitoring (Busack et. al 1997), including the impact of piscivorous fish. Several species of piscivorous fish are known to exist within the Yakima River system, including channel catfish *Ictalurus punctatus*, smallmouth bass *Micropterus dolomieui*, northern pikeminnow *Ptychocheilus oregonensis*, and largemouth bass *M. salmoides*. Previous work (McMichael et. al 1998) confirmed earlier observations (Patten et. al 1970) that the spatial distribution of piscivorous fishes within the Yakima River can roughly be described along a longitudinal profile. Channel catfish are most abundant in the Yakima River near Richland. Smallmouth bass are relatively the most abundant predatory species below Prosser Dam, and upstream of Prosser Dam the abundance of smallmouth bass decreases and northern pikeminnow becomes the most abundant predatory fish. Dunnigan (1997) suggested that the observed longitudinal profile of species may in part be described by differences in water temperature, and to a lesser degree, ecological interactions between species in the lower Yakima River.

Northern pikeminnow predation on migrating salmonid smolts in the Columbia and Snake rivers has been shown to be substantial, and often highest directly below large hydroelectric dams where smolts are often concentrated and disoriented (Ward et. al 1995; Tabor et al. 1993; Beamesderfer and Rieman 1991; Vigg et. al 1991). Throughout the history of this project, we have found that during the spring and early summer months of some years northern pikeminnow relative abundance below several of the irrigation diversion dams located on the Yakima River is higher than other sections of the Yakima River from Prosser Dam to Roza Dam (Dunnigan and Lamebull 2000; McMichael et. al 1998; Dunnigan 1997). The mechanism for northern pikeminnow congregation below irrigation diversion dams along the Yakima River is not entirely understood. Yakima River diversion dams may function as constriction points for northern pikeminnow moving upstream in search of spawning locations. Alternative mechanisms could focus on northern pikeminnow foraging behavior. Specifically, the attraction of predatory fishes to the fish bypass structures located at irrigation diversion dams. Vigg et. al (1991) suggest that many factors affect the dynamics of predation including: metabolic requirements, predator distribution, prey availability, predator size, and spawning behavior, but that temperature is probably the single most important variable which influences predation rates.

Field data collected in 2000 represented the fourth year of predator work in the Yakima River. Efforts above Prosser Dam in 1997 were largely feasibility work to establish monitoring sites and determine if predator abundance was high enough to warrant further investigation. In 1998, field activities were expanded to include estimates of predator abundance and smolt consumption, with the ultimate goal being the development of a spring chinook predation index for northern pikeminnow above Prosser Dam. However, development of a smolt predation index was somewhat limited by our ability to perform population estimates within the selected sampling sites (McMichael et. al 1998). The spring outmigration of 1999 represented the first YKFP release of hatchery spring chinook in the Yakima Basin. Dunnigan and Lamebull (2000) estimated that 60,583 yearling salmonids were consumed by northern pikeminnow from Prosser Dam to Roza Dam from April 12 – June 21, 1999, and concluded that the estimates of consumption were likely the most variable portion of the predation index. As was described in the monitoring plan (Busack et al. 1997), during the 1998 and 1999 field seasons we sampled during the estimated peak and last quartile of spring chinook salmon smolt migration. We decided to change our sampling strategy in 2000 to weekly sampling due to our inability to consistently sample during the precise peak and last quartile of spring chinook migration, and the high temporal variation in diet contents of northern pikeminnow. This report summarizes field and laboratory efforts conducted in 2000 for the improvement and continual refinement of a smolt predation index in the Yakima River above Prosser Dam.

Methods

Study Area

The lower Yakima River flows through irrigated farmland in an otherwise arid area in central Washington State. During the late spring and summer, much of the water in the lower Yakima River is utilized for irrigation and then returned to the river. Summer water levels can be extremely low below Sunnyside Dam, with summer water temperatures in this section of the Yakima River often approaching the upper lethal limits for salmonids (> 25^{o} C; Bidgood and Berst 1969). Non-native warm and cool water species such as smallmouth bass, channel catfish, pumpkinseed *Lepomis gibbosus,* bluegill *L. macrochirus*, yellow perch *Perca flavescens*, walleye *Stizostedion vitreum,* largemouth bass, black crappie *Pomoxis nigromaculatus*, brown bullhead *I. nebulosus,* common carp *Cyprinus carpio*, and goldfish *Carassius auratus* are present in the lower Yakima River. Many of the native species previously found in this lower reach, such as sandroller *Percopsis transmontana* and Pacific lamprey *Lampetra tridentata* (Patten et. al 1970), are now very rare.

Population estimates for predatory fishes were conducted by jetboat electrofishing in three sections (Figure 1): 1. Granger Site - from approximately 2.1 km upstream of the Granger boat ramp to a point 2.0 km downstream of the boat ramp (Rkm 130-134.1), 2. Toppenish Site - from Rkm 145.6 upstream to Rkm 153.4, and 3. Sunnyside Dam site - an area 0.18 km long immediately below Sunnyside Dam (Sunnyside; Rkm 167.0). Northern pikeminnow stomach samples were collected by electrofishing at all three sites listed above in addition to areas approximately 1.6 km above and below the Granger and Toppenish sites.

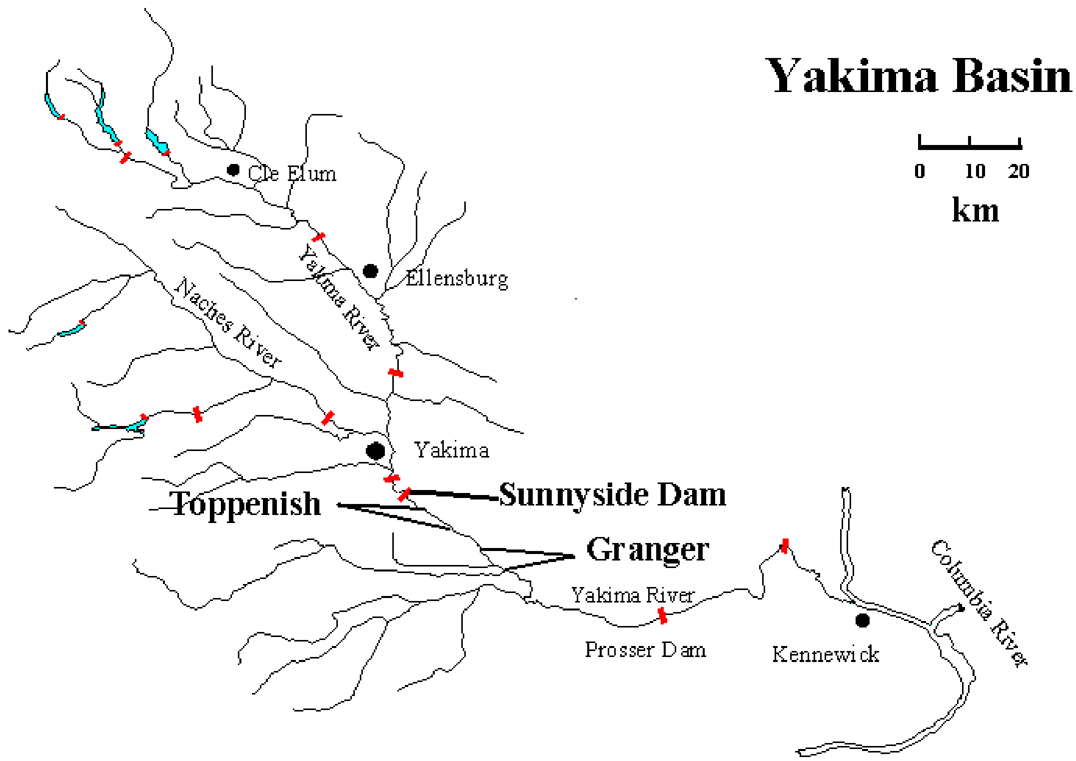

Figure 1. Map of the lower Yakima River. Sample locations are in bold type.

Predator Population Estimates/Movement

We collected piscivorous fish using daytime electrofishing by jetsled using a Coffelt model Mark 22 electrofishing unit, operating with an electrical output ranging from 200-350 volts at 5-8 amps. We recorded total time (minutes) electrical current was exposed to the water as a measure of effort. We measured fork length (FL, mm), weighed (g), and released all piscivorous fish captured on the same bank of the river within 1.0 km of the site of capture. All captured fish greater than 199 mm FL were marked with individually numbered Floy anchor tags and a fin clip. All captured fish 100-199 mm FL were marked with a fin clip, and fish less than 100 mm FL were released unmarked. Electrofishing at all sites was conducted during April, May and June.

We estimated absolute abundance of piscivorous fish at the three transects using a mark-recapture population estimate technique which assumes populations of piscivorous fish are "closed", suggesting no births, deaths or migrations occurred during sampling periods (Ricker 1958). Additional assumptions were that marked and unmarked fish have equal mortality rates, marked fish were randomly distributed throughout the transect, marks were not lost, and all marked fish captured were recognized and counted (Lagler 1956). In order to tag sufficient numbers of fish to perform valid population estimates, we generally performed 2 consecutive marking periods (days) and a single recapture period at Sunnyside and Granger and 2-3 consecutive marking and recapture periods (days) at Toppenish. The period of time between the first marking period and the last recapture period never exceeded 5 days.

We used a computer software program called Mark/Recapture (version 5.0) that uses a log-likelihood estimator to estimate absolute abundance of northern pikeminnow at the three transects.

Diet sampling

Diet samples were collected from predator fish that were captured via jet boat electrofishing during recapture periods conducted once per month for population estimates, and during weekly sampling efforts intended solely to estimate consumption during the period of March 21 to June 15. Sampling for purposes of the latter was conducted up to 13 km above and/or below the Granger and Toppenish sites. Diet sampling at the Sunnyside Dam site was restricted to that site only.

Digestive tracts were excised from predator fish > 199 mm, and all stomach contents were placed in whirl-pak bags and tagged with date, stomach number, species, length, weight, and the section where the fish was captured and then placed on dry ice. Samples were kept frozen until lab analyses were conducted 1 to 5 months later.

In the laboratory, any fish remains that were found in the predators were digested using a digestive enzyme (Taylor and Van Dyke 1985), stained (Cailliet et al. 1986), and identified to the lowest possible taxon with the use of diagnostic bones (Hansel et al. 1988). Yearly chinook or coho (based on estimated length) were classified as hatchery origin if a coded wire tag, PIT (passive integrated transponder) tag or elastomer mark was also present in the gut with diagnostic salmonid bones. Standard equations were used to calculate estimated FL of each prey fish based on dimensions of diagnostic bones (Hansel et al. 1988). We used estimated fork length to classify salmonid remains that were not accompanied by a hatchery mark as either yearling or sub-yearling salmonids. Length-weight regressions, based on live fish we collected concurrently with the predatory fishes, as well as equations presented by Vigg et al. (1991), were then used to estimate weight of each prey fish at the time of ingestion.

We estimated the digestion time (DT; hours) to 90% digestion of northern pikeminnow prey items using the equation presented by Beyer et al. (1988) and modified by Rieman et al. (1991):

$$DT = 1{,}147 \cdot M_i^{0.61} \cdot T_i^{-1.60} \cdot W^{-0.27} \qquad [1]$$

Where M_i = meal size (g) at time of ingestion of salmonid prey item i,
T_i = water temperature {C}, and
W = predator weight (g).

We estimated mean daily water temperature using an Onset Hobo Temp that recorded river temperature every 80 minutes in the river study section. We used mean daily water temperature (from the period 00:01-24:00) to estimate digestion time, since mean daily water temperatures varied little during the sections and time period of this study (approximately 0.8 degrees C variance within a day). We used the 90% digestion time for all prey items rather than the 100% digestion time to avoid the problem of lengthy estimates of digestion time due to indigestible prey items that remain in the gut for long time periods. We calculated meal turn-over (Windell 1978; Rieman et al. 1991) to estimate consumption rate (C; salmonids per predator per day) for each predator fish containing salmonids using the following formula:

$$C = n(24/DT) \qquad [2]$$

Where n = number of salmonids observed in the predator's gut.

Predation Index (Extrapolation)

We estimated the total number of northern pikeminnow >199 mm FL using mark-recapture techniques within the three sampling sections above Prosser Dam during the period March 15-June 15, 2000 (period of salmonid emigration), and conducted weekly sampling to estimate salmonid consumption (see above). We estimated the total daily number of salmonids consumed (SC) by northern pikeminnow within each study section using the following formula:

$$SC = N \cdot F \cdot C \qquad [3]$$

Where N = population estimate,
F = fraction of predators containing at least one salmonid in the gut, and

C = estimated daily salmonid consumption per predator from equation 2.

To estimate the total number of salmonids consumed by northern pikeminnow from Prosser Dam (Rkm 75.6) to Roza Dam (Rkm 205.8) we stratified this section of river into two strata based on similar characteristics within each strata. The lower stratum was from Prosser Dam to Rkm 136.7, and the upper stratum was from Rkm 136.7 to Roza Dam. We used monthly predator abundance and weekly salmonid consumption estimates to extrapolate total salmonid consumption. We had intended to use abundance and consumption data from the Granger and Toppenish sites to extrapolate to the lower and upper strata respectively. However, we were unable to estimate northern pikeminnow abundance within the Granger site in 2000 (Table 2). Therefore, we used estimates of abundance (fish/km) from the Toppenish sites collected in April, May and June to extrapolate to both the lower and upper strata. We used weekly consumption estimates from the Granger and Toppenish sites to extrapolate to the lower and upper strata respectively. We used the following formula to estimate the total number of salmonids consumed by northern pikeminnow >199 FL within a strata:

$$S_{ij} = \left(\frac{N_{ij} \cdot RL \cdot F_{ij} \cdot C_{ij}}{SL} \right) \cdot D_j \qquad [4]$$

Where S_{ij} = total number of salmonids consumed in stratum i over period j,
SL = the length (km) of the study section i,
RL = length of river (km) being extrapolated to,
N_{ij} = population estimate for stratum i in period j,
F_{ij} = the fraction of northern pikeminnow containing at least one salmonid in stratum i for period j,
C_{ij} = estimated daily salmonid consumption per predator in stratum i for period j, and
D_j = total number of days in period j.

Extrapolations were performed in a similar manner to estimate the number of hatchery origin spring chinook, hatchery origin coho, steelhead, sub-yearling salmonids, and non-marked salmonids by substituting appropriate values in equations 1-4. Estimates of total consumption from the Sunnyside Dam site were not extrapolated to any other portions of the Yakima River.

Results

Predator Population Estimates/Movement

Population estimates of northern pikeminnow (>199 mm FL) in the Toppenish site from mid-April to early June ranged from 2622 to 4811 (Table 1). Low catch rates and lack of recaptures for northern pikeminnow precluded estimating valid population estimates for this species at the Granger and Sunnyside sites (Table 1). Capture efficiency for northern pikeminnow <200 mm FL was low for the 2000 smolt emigration, and subsequently we were unable to perform population estimates for the smaller size classes of northern pikeminnow. During the 2000 sampling season only 8.8% of the northern pikeminnow captured using electrofishing techniques were less than 200 mm FL (Figure 2), although the relative proportion of northern pikeminnow <200 mm FL increased as the sampling season progressed. The proportions of northern pikeminnow <200 mm FL during the March, April, May and June sampling periods for all three sites were 0, 4.2, 7.7 and 20.2% respectively (Figure 3).

Few large or smallmouth bass were captured above Prosser Dam in 2000. For the sampling season (March 22 – June 16, 2000) a total of 8 largemouth and 11 smallmouth bass were captured above Prosser Dam in a total of 6155 minutes of electrofishing effort. Most large- and smallmouth bass were captured in the Granger site (7 and 7 respectively). We did not capture any bass at the Sunnyside Dam site. We weren't able to calculate population estimates for either large or smallmouth bass at any of our three sampling sites.

Table 1. Population estimate data for northern pikeminnow (NPM) in three sections of the Yakima River, 2000. Sample dates, species size class (mm fork length), population estimate, and results of a validity test (yes/no) for the estimate. Numbers in parentheses following the population estimate and confidence interval are number of fish per km.

Date	Section	Species	Estimate	Valid
4/10-12	Sunnyside	NPM >199 mm	No Est.	
5/1-3	Sunnyside	NPM >199 mm	258 (1433.3)	No
6/5-7	Sunnyside	NPM >199 mm	No Est.	
4/10-14	Toppenish	NPM >199 mm	2787 (357.3)	Yes
5/1-5	Toppenish	NPM >199 mm	2622 (336.2)	Yes
6/5-8	Toppenish	NPM >199 mm	4811 (616.8)	Yes
4/17-20	Granger	NPM >199 mm	1993 (486.1)	No
5/8-11	Granger	NPM >199 mm	282 (68.8)	No
6/13-16	Granger	NPM >199 mm	346 (84.4)	No

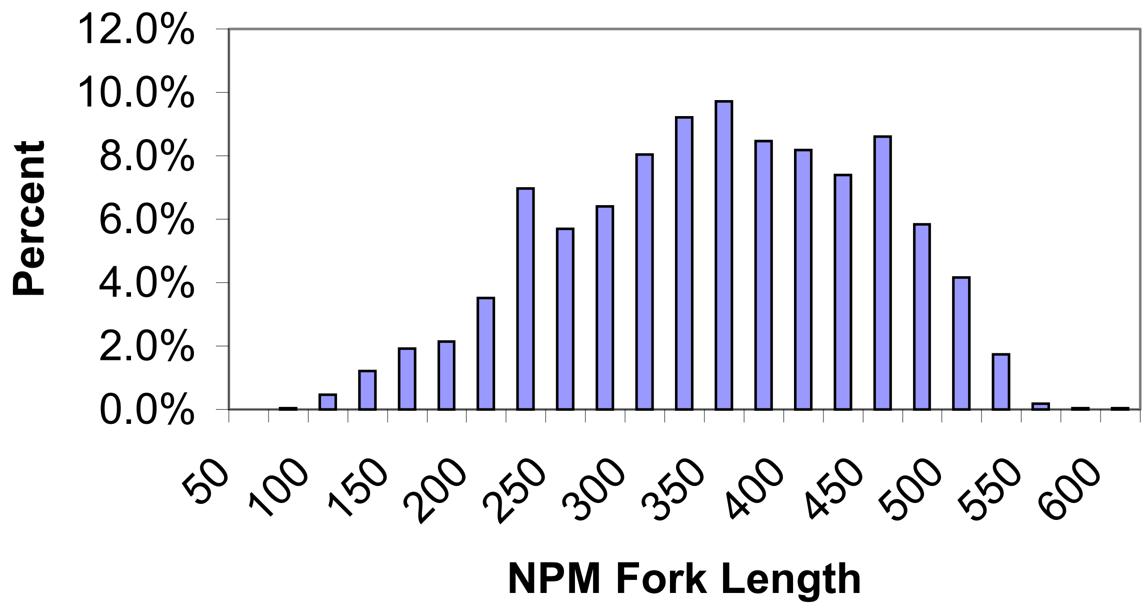

Figure 2. Length frequency for northern pikeminnow captured by boat electrofishing in the lower Yakima River between March, 21 and June 16, 2000, total sample size was 2,139.

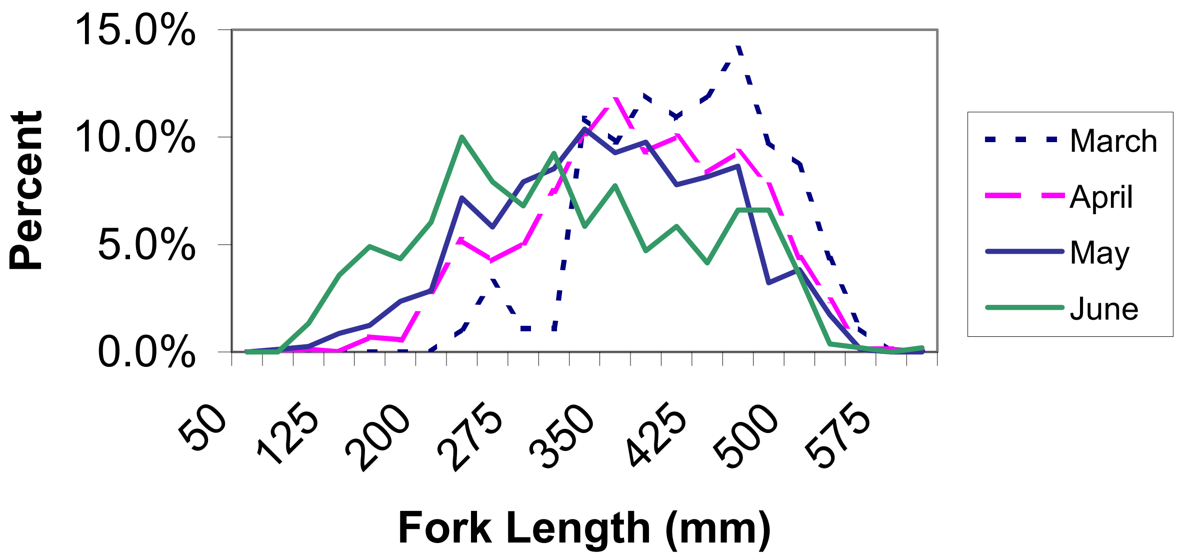

Figure 3. Monthly length distribution (mm) of northern pikeminnow March 21 – June 16, 2000, captured by boat electrofishing.

We found little evidence that northern pikeminnow moved significantly between sites, although only approximately 22% of our electrofishing effort for the season occurred outside the sections of river that most of the northern pikeminnow were tagged. During the 2000 field season, we recaptured 155 northern pikeminnows originally tagged in 1997 through 2000 ranging from 1- 1,039 days after they were tagged. In 2000 most northern pikeminnows were recaptured in the Toppenish site. Most northern pikeminnows (n=151; 97.4%) were recaptured in the same site that they were originally tagged. The average number of days between marking and recapture was 146.8 days. We caught 4 fish that were captured out of the site that they were originally tagged in. Three of the four fish caught out of the site they were originally tagged in had moved upstream 357, 49 and 309 days after originally tagged. The single fish that had moved downstream was captured the day after being originally tagged and released. All fish had moved less than 20 miles. Anglers reported capturing 3 tagged northern pikeminnow in 2000. Two of the three fish were reported captured within 2 km of the original site of release. The third fish was tagged at Sunnyside Dam on 8/20/97, and reported captured in the sport reward program on the Columbia River at Rkm 595.5 on 6/24/00.

While conducting electrofishing mark-recapture population estimates for northern pikeminnow at the Sunnyside Dam, Toppenish, and Granger sites, we observed a total of eight, thirteen and twelve different species respectively (Table 2). The 3 most abundant species in the Sunnyside Dam and Granger sections (in decending order of abundance) were sucker spp. (largescale *Catostomus macrocheilus* and bridgelip C. *columbianus* combined), mountain whitefish (*Prosopium williamsoni*) and chiselmouth (*Acrocheilus alutaceus*), but in the

Toppenish section mountain whitefish were the most abundant followed by suckers and chiselmouth. Our visual counts indicated that mountain whitefish abundance decreases from the Sunnyside to Granger sites (Table 2).

Table 2. Visually estimated fish species composition. Values in order include total season number, percent composition of seasonal total [in parentheses], and the mean number per km for season total (in parentheses) in the Yakima River at the Sunnyside Dam, Toppenish, and Granger sample sites, 2000, data was collected by boat electrofishing.

Species	**Sunnyside Dam Rkm 167.0**	**Toppenish Rkm 145.6-153.4**	**Granger Rkm 130-134.1**
CCF	0 [0%] (0)	2 [0.00%] (0.02)	0 [0%] (0)
CCP	27 [0.6%] (12.5)	1701 [3.4%] (15.58)	1344 [6.6] (30.55)
CHM	520 [12.4%] (240.74)	6489 [13.1%] (59.42)	2932 [14.4] (66.64)
COH	40 [1.0%] (18.52)	245 [0.5%] (2.24)	14 [0.1%] (3.43)
DAC	0 [0%] (0)	149 [0.3%] (1.36)	29 [0.1%] (0.66)
FCH	6 [0.1%] (2.78)	97 [0.2%[(0.89)	151 [0.74] (3.43)
LGM	0 [0%] (0)	2 [0.00%] (0.02)	5 [0.02%] (0.11)
MWF	1386 [33.1%] (641.7)	18418 [37.2%] (168.66)	5217 [25.6%] (118.57)
NPM	82 [2.0%] (37.96)	834 [1.7%] (7.62)	218 [1.1%] (4.95)
RBT	2 [0.05%] (0.93)	12 [0.02%] (0.11)	4 [0.02%] (0.09)
RSS	0 [0%] (0)	2311 [4.7%] (21.16)	1708 [8.4%] (38.82)
SCK	269 [6.4%] (124.54)	1917 [3.9%] (17.55)	840 [4.12] (19.09)
SMB	0 [0%] (0)	1 [0.00%] (0.01)	4 [0.02%] (0.09)
STH	8 [0.2%] (3.70)	31 [0.06%] (0.28)	4 [0.02%] (0.09)
SUC	1848 [44.1%] (855.56)	17259 [34.9%] (158.05)	7931 [38.9%] (180.25)

CCF (channel catfish), CCP (common carp), CHM (chiselmouth), COH (coho salmon), DAC (dace spp.), FCH (fall chinook), LGM (largemouth bass), MWF (mountain whitefish), NPM (northern pikeminnow), RBT (rainbow trout), RSS (redside shiner), SCK (spring chinook), SMB (smallmouth bass), STH (steelhead), and SUC (sucker spp.)

Diet Sampling

Out of 983 northern pikeminnow >199 mm examined, 104 (10.6%) contained remains of salmonids (Table 3). Of the 104 northern pikeminnow containing salmonids, each piscivorous fish contained an average of 1.52 salmon per predator. Salmonid consumption by northern pikeminnow increased sharply through mid-May and June at all sites (Table 3). Differences in the proportion of salmonids per predator between sites within the sampling season were not apparent. Based on the predicted fork length of salmonids from regression relationships of diagnostic bones, we classified most (n = 98; 96.1%) salmonids observed in the northern pikeminnow as yearling smolts (spring chinook, coho or steelhead smolts). We were not able to confidently distinguish between coho and spring chinook based on diagnostic bones.

We found a total of 60 coded wire tags (CWT) in the stomach contents of 46 northern pikeminnow, which allowed us to determine hatchery treatment group (Table 4). We found an additional 6 passive integrated transponder (PIT) tags in the stomach contents of 6 northern pikeminnow. Three of the PIT tags were from hatchery spring chinook and 3 were from hatchery coho salmon. Although we used the presence of a CWT or PIT tag to indicate hatchery origin, the absence of a CWT or PIT tag does not definitively categorize the fish as wild origin. All hatchery spring chinook and coho salmon released in the Yakima basin in 2000 were marked with length and a half CWT (1.65 by 1.1 mm). All coho (~1 million) and a portion of spring chinook that were PIT tagged (approximately 40,000) were also marked with a single snout CWT. The remainder of the spring chinook production (~560,000) was tagged with 2 CWT in various body locations. We found a total of 17 single spring chinook CWT in the guts of northern pikeminnow indicating that either the accompanying PIT or paired CWT had been lost. Additionally, only two of the six PIT tags found in the guts of northern pikeminnow were accompanied by a CWT. We therefore concluded that due to the unknown frequency of CWT or PIT tag loss or retention rate of various tags in the guts of a northern pikeminnow, the presence of a tag could be used to indicate hatchery origin, but the absence of a tag could not be used reliably to establish hatchery/wild origin. Estimated fork length at time of ingestion was also not a reliable method of differentiating between unmarked hatchery spring chinook or coho. Although mean fork length of hatchery spring chinook, coho, and wild spring chinook were all statistically different from each other ($p < 0.05$), differences were not relatively large and significant overlap between the three groups existed (Figure 4), making differentiation between groups based on estimated length difficult.

Fish was a relatively common prey item for the 983 northern pikeminnow we examined, with 30.5% (n = 300) containing fish (all species) prey items. Salmonids (*Oncorhynchus* spp.) represented the most abundant fish prey item in our study, with 10.6% (n = 104) of the northern pikeminnow >199 mm containing at least one salmonid. Crayfish and other invertebrates were also important types of prey items for northern pikeminnow, constituting a combined proportion of approximately 37.6% of the total prey items (Table 3). We did not evaluate the relative caloric or biomass contribution of each type of prey item to the diets of northern pikeminnow. We identified 13 separate species of prey fish consumed by northern pikeminnow (Table 5). The five most abundant prey species/genus consumed by northern pikeminnow were salmon *Oncorhynchus* spp., cottids *Cottus* spp., sucker *Catostomus* spp., mountain whitefish, and redside shiner *Richardsonius balteatus* (respectively; Table 5).

Table 3. Summary of the diet analyses for northern pikeminnow (>199 mm fork length) sampled in the Sunnyside, Toppenish, and Granger sites from March 21 to June 15, 2000. The number of stomachs examined (N), the number and percent (in parenthesis) of the fish's guts in each sample that were empty, or contained invertebrates (Invert.), fish eggs, vegetation (Veg.), crayfish, rodent, fish (all species including salmonids), unknown items (Unk), and salmonids (Sal.; not including mountain whitefish) are presented. Row totals may exceed the sample number (N) due to single predator fish consuming multiple prey items.

Site	Date	N	Empty (%)	Invert. (%)	Fish Eggs (%)	Veg. (%)	Crayfish (%)	Rodent (%)	Fish (%)	Unk. (%)	Sal. (%)
Granger	3/22	36	15 (41.6%)	15 (41.6%)	--	--	2 (5.55%)	--	5 (13.9%)	1 (2.94%)	1 (2.78)
Above Granger	4/4	25	5 (20.0%)	12 (48.0%)	1 (4.0%)	6 (24.0%)	4 (16.0%)	--	8 (32.0%)	1 (4.0%)	2 (8.0%)
Granger and Below	4/19-20	100	49 (49.0%)	29 (29.0%)	--	3 (3.0%)	4 (4.0%)	--	18 (18.0%)	--	6 (6.0%)
Above and Below Granger	4/25	26	13 (50.0%)	5 (19.2%)	--	5 (19.2%)	1 (3.84%)	--	6 (23.1%)	1 (3.84%)	1 (3.84%)
Granger	5/11	13	4 (30.7%)	5 (38.4%)	--	1 (7.69%)	3 (23.0%)	--	3 (23.1%)	--	1 (7.69%)
Above Granger	5/16	38	12 (31.5%)	18 (47.3%)	--	6 (15.7%)	5 (13.1%)	--	5 (13.2%)	1 (2.63%)	1 (2.63%)
Above Granger	5/24	28	9 (32.1%)	4 (14.2%)	--	1 (3.5%)	6 (21.4%)	--	9 (32.1%)	1 (3.5%)	6 (21.0%)
Above and Below Granger	5/31	18	14 (77.7%)	2 (11.1%)	--	--	--	--	1 (5.6%)	--	1 (5.55%)
Granger	6/15	15	6 (40.0%)	4 (26.6%)	--	5 (33.3%)	1 (6.66%)	--	4 (26.6%)	--	--
Sunnyside	3/21	15	3 (20.0%)	3 (20.0%)	--	--	--	--	--	--	--
Sunnyside	4/3	12	--	3 (25.0%)	--	--	1 (8.33%)	--	9 (75.0%)	--	--
Sunnyside	4/12	6	3 (50.0%)	2 (33.3%)	--	--	--	--	1 (16.6%)	--	--
Sunnyside	5/3	20	10 (50.0%)	6 (30.0%)	--	1 (5.00%)	3 (15.0%)	--	2 (10.0%)	1 (5.00%)	--

Table 3. (Cont.) Summary of the diet analyses for northern pikeminnow (>199 mm fork length) sampled in the Sunnyside, Toppenish, and Granger sites from March 21 to June 15, 2000. The number of stomachs examined (N), the number and percent (in parenthesis) of the fish's guts in each sample that were empty, or contained invertebrates (Invert.), fish eggs, vegetation (Veg.), crayfish, rodent, fish (all species including salmonids), unknown items (Unk), and salmonids (Sal.; not including mountain whitefish) are presented. Row totals may exceed the sample number (N) due to single predator fish consuming multiple prey items.

Site	Date	N	Empty (%)	Invert. (%)	Fish Eggs (%)	Veg. (%)	Crayfish (%)	Rodent (%)	Fish (%)	Unk. (%)	Sal. (%)
Sunnyside	5/22	8	1 (12.5%)	--	--	--	1 (12.5%)	--	6 (75.0%)	--	5 (62.5%)
Sunnyside	6/7	10	1 (10.0%)	1 (10.0%)	--	--	--	--	9 (90.0%)	--	5 (50.0%)
Below Toppenish	3/21	41	11 (26.8%)	27 (65.8%)	--	2 (4.87%)	1 (2.43%)	--	5 (12.2%)	1 (2.43%)	1 (2.43%)
Above Toppenish	4/3	93	14 (15.%)	37 39.7%)	--	4 (4.30%)	6 (6.45%)	--	38 (40.9%)	2 (2.15%)	4 (4.3%)
Toppenish	4/13-14	60	20 (33.3%)	21 (35.0%)	--	1 (1.66%)	1 (1.66%)	--	33 (55.0%)	1 (1.66%)	3 (5.0%)
Above Toppenish	4/24	83	29 (34.9%)	34 (40.9%)	1 (1.20%)	3 (3.61%)	2 (2.46%)	--	19 (22.9%)	1 (1.20%)	7 (8.43%)
Toppenish	5/4-5	94	26 (27.6%)	39 (41.4%)	--	19 (20.2%)	4 (4.25%)	--	17 (18.1%)	2 (2.12%)	6 (6.38%)
Above and Below Toppenish	5/15	66	14 (21.2%)	6 (9.09%)	--	1 (1.50%)	5 (7.57%)	--	30 (45.5%)	--	9 (13.6%)
Above Toppenish	5/22-24	46	9 (19.5%)	11 (23.9%)	--	4 (8.69%)	8 (17.9%)	1 (2.17%)	21 (45.7%)	--	18 (39.1%)
Above and Below Toppenish	5/30-31	69	24 (34.7%)	14 (20.2%)	--	1 (1.44%)	4 (15.9%)	--	25 (36.2%)	1 (1.44%)	10 (14.4%)
Toppenish	6/7	39	12 (30.7%)	5 (12.8%)	--	--	2 (5.12%)	--	24 (61.5%)	2 (5.12%)	17 (42.5%)

Table 3. (Cont.) Summary of the diet analyses for northern pikeminnow (>199 mm fork length) sampled in the Sunnyside, Toppenish, and Granger sites from March 21 to June 15, 2000. The number of stomachs examined (N), the number and percent (in parenthesis) of the fish's guts in each sample that were empty, or contained invertebrates (Invert.), fish eggs, vegetation (Veg.), crayfish, rodent, fish (all species including salmonids), unknown items (Unk), and salmonids (Sal.; not including mountain whitefish) are presented. Row totals may exceed the sample number (N) due to single predator fish consuming multiple prey items.

Site	Date	N	Empty (%)	Invert. (%)	Fish Eggs (%)	Veg. (%)	Crayfish (%)	Rodent (%)	Fish (%)	Unk. (%)	Sal. (%)
Total		983	307 (31.2)	305 (31.0)	1 (0.1)	63 (6.4)	65 (6.6)	1 (0.1)	300 (30.5%)	16 (1.6)	104 (10.6)

Table 4. Total number of coded wire tags (CWT) recovered from stomach contents of 46 northern pikeminnow out of 983 collected by electrofishing in 2000.

	Spring Chinook Treatment Groups		Coho Treatment Groups	
Spring Chinook Acclimation Sites	OCT	SNT	Early (May 7)	Late (May 31)
Clark Flats	3	7		
Easton	3	1		
Jack Creek	1	8		
Coho Acclimation Sites				
Cle Elum			5	1
Easton			4	6
Lost Creek			10	5
Stiles			0	6
Total	7	16	19	18

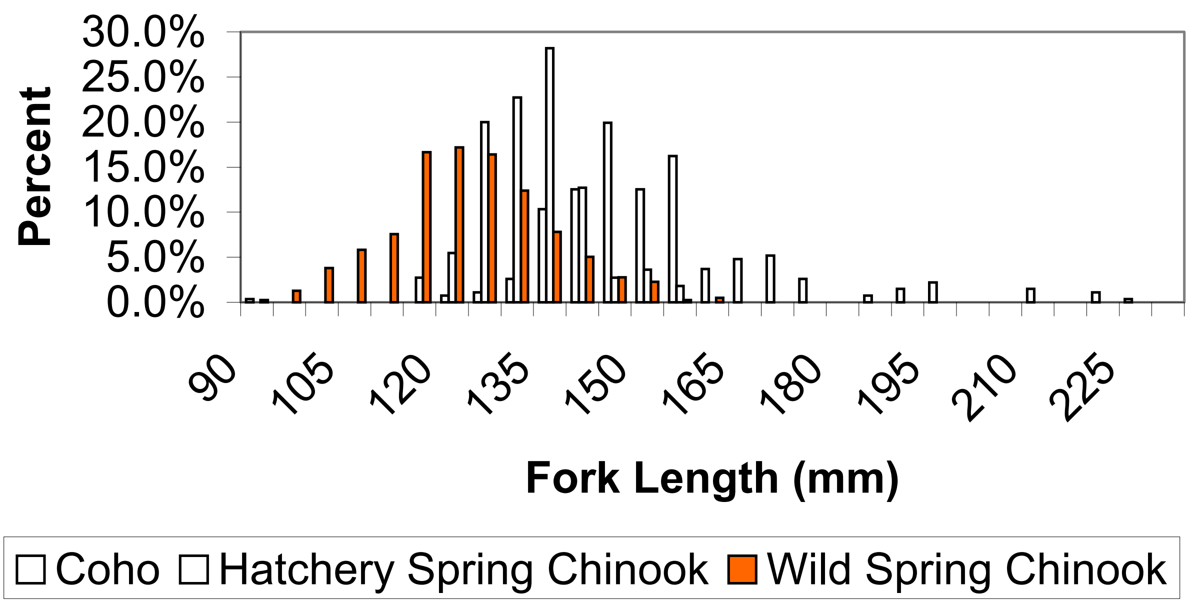

Figure 4. Length frequency distribution of coho (mean FL = 150.4), hatchery spring chinook (mean FL = 130.4 mm), and wild spring chinook (mean FL = 120.3 mm) collected at Chandler Juvenile Monitoring Facility, 2000.

Table 5. Species composition of fish found in northern pikeminnow collected in the Granger, Toppenish, and Sunnyside sites April – June, 2000. Total number of fish in the sample (N), and the number of each prey species, followed by the percent of the number of the fish in the sample in parentheses. Totals represent the total number of prey species present. Row totals may exceed the sample number (N) due to single predator fish consuming multiple prey species.

			Species														
Site	Date	N	CCP	CHM	CHN	COH	COT	DAC	LMP	MWF	NPM	PSS	RSS	SAL	STH	SUC	NSA	Total
Sunnyside	4/3	12		1 (8.3)			2 (16.7)	1 (8.3)		3 (25)	1 (8.3)					1 (8.3)	1 (8.3)	10
Sunnyside	4/12	21					1 (4.8)											1
Sunnyside	5/3	20						1 (5)										1
Sunnyside	5/22	8			1 (12.5)	2 (25.0)					1 (12.5)			3 (37.5)	1 (12.5)			8
Sunnyside	6/7	10				2 (20)		1 (10)	1 (10)	2 (20)				5 (50)				11
Granger	3/22	36					3 (8.3)		1 (2.8)				3 (8.3)	1 (2.8)		2 (5.6)		10
Above Granger	4/4	25								2 (8)	1 (4)		1 (4)	2 (8)		1 (4)	2 (8)	9
Granger	4/19	100		1 (1)	2 (2)		2 (2)		1 (1)		3 (3)		4 (4)	4 (4)		4 (4)	1 (1)	22
Above Granger	4/25	26					1 (3.8)		1 (3.8)					1 (3.8)		2 (7.7)	1 (3.8)	6
Granger	5/11	13		1 (7.7)	1 (7.7)												1 (7.7)	3
Above Granger	5/16	38					1 (2.6)						1 (2.6)	1 (2.6)		1 (2.6)	1 (2.6)	5
Above Granger	5/24	28				2 (7.1)		1 (3.8)			1 (3.8)			3 (10.7)	1 (3.8)	2 (7.1)		10
Above Granger	5/31	18												1 (5.6)				1
Granger	6/15	15	1 (6.7)					1 (6.7)					1 (6.7)			1 (6.7)	1 (6.7)	5
Below Toppenish	3/21	41					1 (2.4)				3 (7.3)		2 (4.9)	1 (2.4)		1 (2.4)		8

Table 5. (Cont.) Species composition of fish found in northern pikeminnow collected in the Granger, Toppenish, and Sunnyside sites April – June, 2000. Total number of fish in the sample (N), and the number of each prey species, followed by the percent of the number of the fish in the sample in parentheses. Totals represent the total number of prey species present. Row totals may exceed the sample number (N) due to single predator fish consuming multiple prey species.

			Species															
Site	Date	N	CCP	CHM	CHN	COH	COT	DAC	LMP	MWF	NPM	PSS	RSS	SAL	STH	SUC	NSA	Total
Above Toppenish	4/3	93		6 (6.5)	1 (1.1)		8 (8.6)	3 (3.2)	3 (3.2)	3 (3.2)	2 (2.2)		6 (6.5)	3 (3.2)		5 (5.4)	4 (4.4)	37
Toppenish	4/13-14	60		4 (6.7)	2 (2.4)	1 (1.7)	12 (20)			7 (11.7)	1 (1.7)		1 (1.7)			7 (11.7)	3 (5)	38
Above Toppenish	4/24	83			3 (3.6)		3 (3.6)	1 (1.2)		1 (1.2)	1 (1.2)			5 (6)	1 (1.2)	3 (3.6)	6 (7.2)	24
Toppenish	5/4-5	94			1 (1.1)		4 (4.4)	2 (2.2)	1 (1.1)	3 (3.3)				3 (3.3)	3 (3.3)	1 (1.1)	1 (1.1)	19
Above Toppenish	5/15	66		1 (1.5)		2 (3)	1 (1.5)	5 (7.6)		2 (3)	4 (6.1)		5 (7.6)	8 (12.1)		3 (4.5)	3 (1.5)	34
Above Toppenish	5/22	46			1 (2.2)	6 (13)		1 (2.2)		2 (4.4)				12 (26.1)	1 (2.2)	1 (2.2)	1 (2.2)	25
Above Toppenish	5/31	69		2 (2.9)	4 (5.8)	2 (2.9)	4 (5.8)	3 (4.3)	2 (2.9)	1 (1.4)	2 (2.9)	1 (1.4)	2 (2.9)	6 (8.7)			1 (1.4)	24
Toppenish	6/7	40		2 (5)	5 (12.5)	13 (32.5)					1 (2.5)			5 (12.5)	1 (2.5)	4 (10)	2 (5)	33
Total	all	983	1 (0.1)	18 (1.8)	21 (2.1)	30 (3.1)	43 (4.4)	20 (2.0)	10 (1.0)	26 (2.6)	21 (2.1)	1 (0.1)	26 (2.6)	64 (6.5)	8 (0.8)	39 (4.0)	29 (3.0)	357

CCP = common carp, CHM = chiselmouth, CHN = hatchery chinook, COH = hatchery coho, COT = cottus spp., DAC = dace sppl, LMP = lamprey, MWF = mountain whitefish, NPM = northern pikeminnow, RSS = redside shiner, SAL = salmonid spp. (unmarked salmon, not including MWF), STH = steelhead/rainbow trout, SUC = sucker spp., and NSA = non-salmonid spp.

Few bass were collected for stomach analyses. We examined the stomach contents from 7 smallmouth bass (>199 mm FL) collected from the vicinity of the Granger site between 3/22 and 5/24, and found that none contained salmonids. Two of the smallmouth bass contained fish prey items, including redside shiner and northern pikeminnow. Similarly, the single largemouth bass collected within the Granger site contained no salmonid prey items.

Predation Index (Extrapolation)

We estimated a total of 759,315 salmonids were consumed by northern pikeminnow from Prosser Dam to Roza Dam from March 15 to June 15, for an average of approximately 8,165 salmon consumed per day (Figure 5). We used the Granger and Toppenish consumption data to extrapolate consumption from Prosser Dam to Rkm 136.7, and from Rkm 136.7 to Roza Dam respectively (Table 6; Figure 5), and the Toppenish abundance data to extrapolate northern pikeminnow abundance since northern pikeminnow abundance estimates were not available for the Granger site. Estimates of consumption for all salmonids were highest for the reach from Rkm 136.7 to Roza Dam due to a higher proportion of northern pikeminnow containing salmonids throughout the sampling season at the Toppenish site (Table 6).

We used the presence of either a CWT or PIT tag to identify hatchery salmon in the stomach of northern pikeminnows. Based on diagnostic bones and the presence of a tag, we estimated a total of 235,878 hatchery coho and 205,402 hatchery spring chinook (Figure 5) were consumed by northern pikeminnow from Prosser Dam to Roza Dam from March 15 to June 15 (31.1 and 27.1% of all salmonids, respectively). These estimates represent minimum estimates due to an unknown rate of tag loss of hatchery fish prior to and after consumption by northern pikeminnow. All yearling salmonid (non-steelhead) remains found in the digestive tracts of northern pikeminnow that were not accompanied with either a CWT or PIT tag were classified as unmarked salmonids, and daily and season consumption estimates were performed. We estimated a season total of 308,128 unmarked yearling salmonids were consumed over the outmigration period from Prosser to Roza dams (Figure 5).

We used estimated fork length (mm) at time of ingestion to distinguish yearling salmonids from sub-yearling salmonids. We estimated a total of 34,485 sub-yearling salmonids were consumed by northern pikeminnows during the outmigration period from Prosser to Roza dams (Figure 6). Although we were able to differentiate between yearling and sub-yearling salmonids based on estimated length based on dimensions of diagnostic bones, were not able to differentiate between species. Since both sub-yearling fall chinook and coho reside within the study reaches, the estimate of sub-yearlings consumption likely consists of a combination of sub-yearling chinook and coho.

Although we were not able to confidently distinguish between chinook and coho salmon diagnostic bones, we were able to differentiate steelhead from the other two, and therefore estimate daily and season consumption estimates for steelhead. We estimated a total of 29,477 steelhead were consumed by northern pikeminnow during the 2000 spring outmigration (Figure 6).

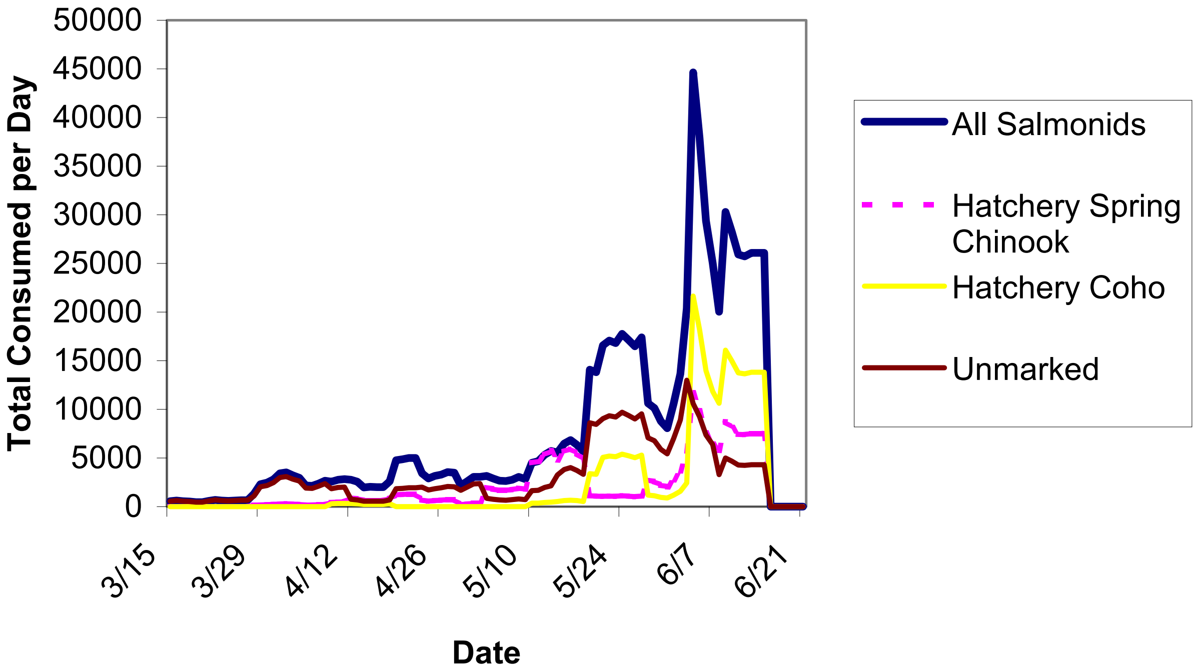

Figure 5. Estimated daily consumption of all salmonids, hatchery spring chinook, hatchery coho, and unmarked yearling salmon from Prosser Dam to Roza Dam between March 15 and June 15, 2000. Hatchery determination was based on the presence of a coded wire or PIT tag. Unmarked salmon represent either wild salmonids, or hatchery salmon that lost either the PIT or coded wire tag.

Table 6. Mean daily salmonid consumption per salmonid piscivorous predator per day (Daily Consumpt. Rate), mean daily salmonid consumption within each section, and total extrapolated salmonid consumption for each river section the data was extrapolated over (Extrapolation Range), using the northern pikeminnow population estimate (Pop. Est.), percent of the northern pikeminnow containing salmonids (%w/ salmon) during the sample date. All consumption estimates were calculated using the estimated original weight at time of consumption for all prey items (Beyer et al. 1988; Rieman et al. 1991).

Sample Date	**Extra-polation Dates**	**N**	**Extra-polation Range (Rkm)**	**Section**	**%w/ salmon**	**Daily Consumpt. Rate**	**Mean Daily Consumpt. (Section)**	**Total Consumption (Extrapolated)**
3/21	3/15-27	41	136.8-205.8	Below Toppenish	2.43	3.62	0.27	2,180
3/21	3/15-27	15	165.8	Sunnyside	0	0	0	0
3/22	3/15-28	36	75.6-136.8	Granger	2.8	9.69	0.69	5,464
4/3	3/28-4/8	93	136.8-205.8	Above Toppenish	4.3	12.83	1.07	12,476
4/3	3/28-4/8	12	165.8	Sunnyside	0	0	0	0
4/4	3/29-4/11	25	75.6-136.8	Granger	8.0	13.24	0.94	24,800
4/13-14	4/9-18	60	136.8-205.8	Toppenish and Above Toppenish	5.0	5.44	0.54	26,821
4/12	4/9-18	21	165.8	Sunnyside	0	0	0	0
4/19-20	4/12-22	100	75.6-136.8	Granger and Below Granger	6.0	15.29	1.39	20,058
4/24	4/19-28	83	136.8-205.8	Above Toppenish	8.4	11.87	1.18	22,687
4/25	4/23-5/2	26	75.6-136.8	Above Granger and Below Granger	3.8	13.67	1.36	11,493
5/4-5	4/29-5/9	94	136.8-205.8	Toppenish	6.4	10.07	0.91	14,922
5/3	4/29-5/9	20	165.8	Sunnyside	0	0	0	0
5/11	5/3-13	13	75.6-136.8	Granger	7.7	10.6	0.96	15,249
5/15	5/10-18	66	136.8-205.8	Above Toppenish and Below Toppenish	13.6	12.94	1.43	40,936
5/16	5/14-20	38	75.6-136.8	Above Granger	2.6	10.6	1.51	5,739
5/22	5/13-30	8	165.8	Sunnyside	62.5	23.73	1.31	1483
5/22-24	5/19-27	46	136.8-205.8	Above Toppenish	39.1	12.82	1.42	116,371
5/24	5/21-27	28	75.6-136.8	Above Granger	21.4	9.94	1.42	29,216
5/30-31	5/28-6/3	69	136.8-205.8	Above Toppenish and Below Toppenish	14.5	9.97	1.41	62,231

Table 6. (Cont.) Mean daily salmonid consumption per salmonid piscivorous predator per day (Daily Consumpt. Rate), mean daily salmonid consumption within each section, and total extrapolated salmonid consumption for each river section the data was extrapolated over (Extrapolation Range), using the northern pikeminnow population estimate (Pop. Est.), percent of the northern pikeminnow containing salmonids (%w/ salmon) during the sample date. All consumption estimates were calculated using the estimated original weight at time of consumption for all prey items (Beyer et al. 1988; Rieman et al. 1991).

Sample Date	**Extra-polation Dates**	**N**	**Extra-polation Range (Rkm)**	**Section**	**%w/ salmon**	**Daily Consumpt. Rate**	**Mean Daily Consumpt. (Section)**	**Total Consumption (Extrapolated)**
5/31	5/28-6/7	18	75.6-136.8	Above Granger and Below Granger	5.6	16.3	1.48	34,169
6/7	5/31-6/15	10	165.8	Sunnyside	62.5	18.53	1.15	1112
6/7	6/4-15	40	136.8-205.8	Toppenish	42.5	18.36	1.53	332,195
6/15	6/4-15	15	75.6-136.8	Granger	0	0	0	0
Total		983						759,315

Population Estimates for Granger were not available, in order to calculate salmonid consumption levels during these periods, we applied the abundance (fish/km) from the Toppenish site.
Population estimates for Sunnyside Dam were not available, consumption values are represented as numbers of salmonids consumed per 100 northern pikeminnow.

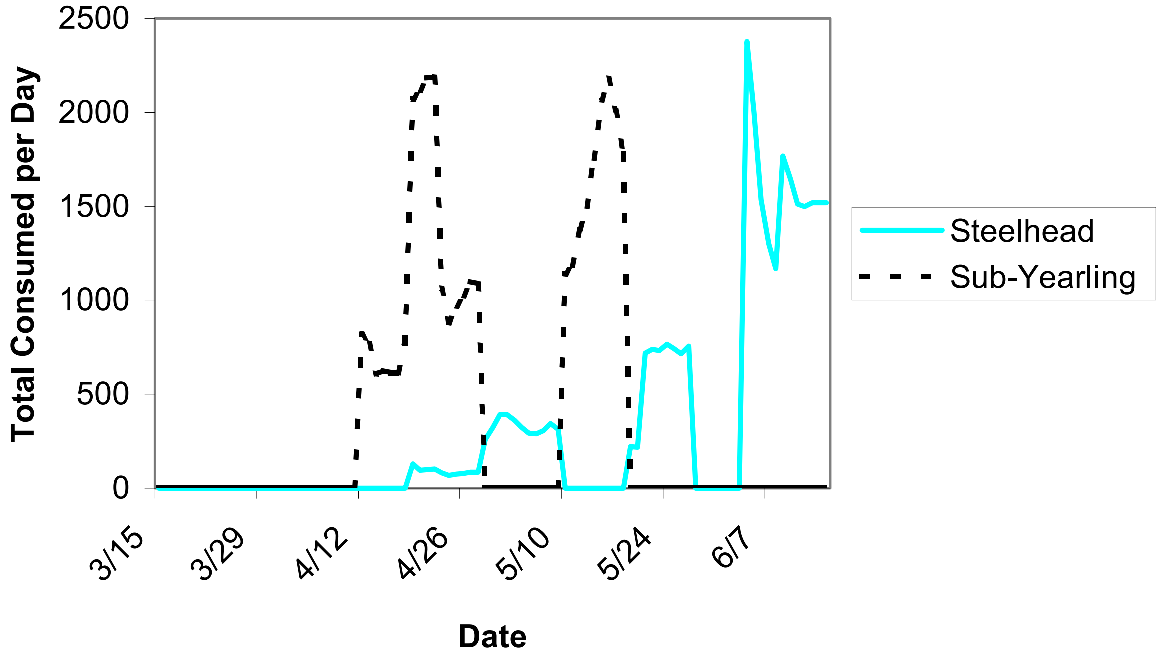

Figure 6. Estimated daily consumption of steelhead and sub-yearling salmonids from Prosser Dam to Roza Dam between March 15 and June 15, 2000. Sub-yearling salmonid determination was based on estimated fork length at time of ingestion.

We were not able to estimate absolute consumption estimates for the Sunnyside Dam site due to difficulties in estimating abundance of northern pikeminnow at this site. However, we were able to estimate relative consumption expressed as the number of salmonids consumed per 100 northern pikeminnow. For the outmigration period (March 15-June 15) we estimated a total of 2,596 salmonids (all), 1,359 unmarked salmonids, 841 hatchery coho, 214 hatchery spring chinook (Figure 7), 321 steelhead, and 74 sub-yearling salmonids (Figure 8) were consumed per 100 northern pikeminnow present at Sunnyside Dam in 2000. Estimates of consumption for the Sunnyside Dam site were not extrapolated to any other sections of the Yakima River.

Although we were unable to differentiate between coho and spring chinook using diagnostic bones recovered from northern pikeminnows, we can assess the likelihood of a given sample being either spring chinook or coho based on sample date. Approximately 1 million hatchery coho were released in the Yakima sub-basin in 2000, with approximately 500,000 released on May 7 and the remaining fish released on May 31. The YKFP released approximately 579,000 hatchery spring chinook beginning March 15, 2000. Smolt passage at the Chandler Juvenile Fish Monitoring Facility (CJMF) also suggests that the majority of the hatchery salmonids in the river prior to May 7, were spring chinook (Figure 9). Thus, most unmarked salmonids observed in the northern pikeminnow guts prior to May 7 were likely spring chinook. Prior to May 7, we estimated that 27,927 hatchery spring chinook, 2,731 hatchery coho and 76,639 unmarked yearling salmonids were consumed by northern pikeminnow. Assuming all unmarked yearling salmonids in the northern pikeminnow prior to May 7 were spring chinook, then as many as 104,566 juvenile spring chinook may have been consumed during this period. Therefore it is likely that most unmarked yearling salmonids consumed during this period were a combination of both hatchery and wild origin spring chinook. Estimates of unmarked salmonid consumption by northern pikeminnow from May 8 – June 15 (231,489 smolts) represent a combination of both hatchery coho and hatchery and wild origin spring chinook since sample date, diagnostic bones, length frequency distribution, nor experimental marks were reliable methods of identification during this period.

Low stomach sample numbers of both small- and largemouth bass reduced our ability to detect predation on salmonids by either of these species (see above section). Therefore, we did not calculate estimates of salmonid consumption for either large- or smallmouth bass.

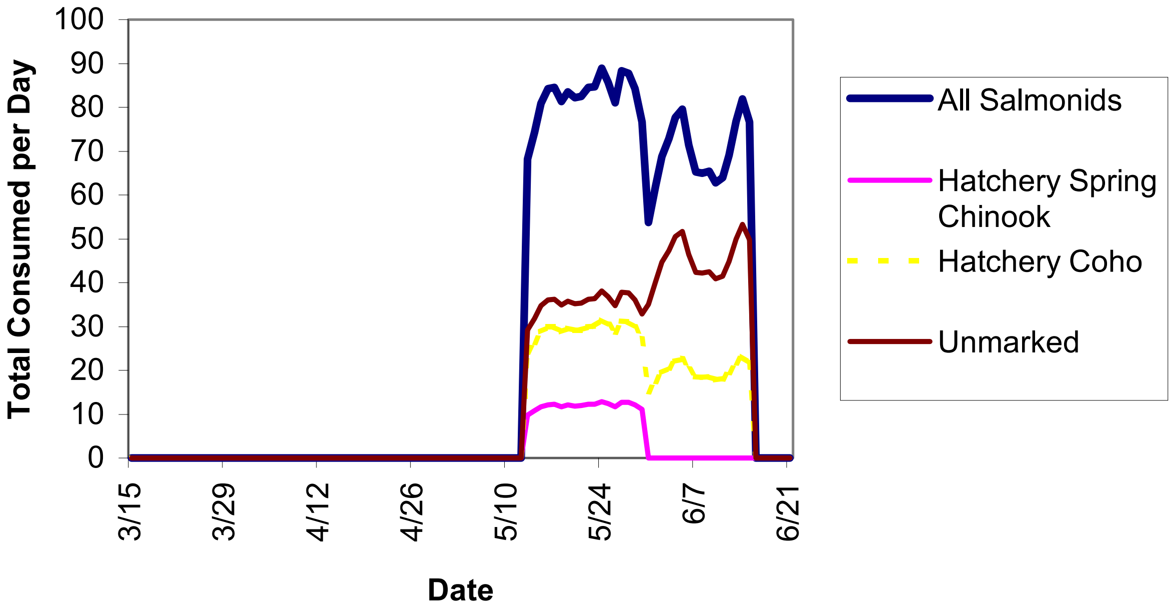

Figure 7. Estimated daily consumption (per 100 northern pikeminnow) of all salmonids, hatchery spring chinook, hatchery coho, and unmarked yearling salmon at Sunnyside Dam between March 15 and June 15, 2000. Hatchery determination was based on the presence of a coded wire or PIT tag. Unmarked salmon represent either wild salmonids, or hatchery salmon that lost either the PIT or coded wire tag.

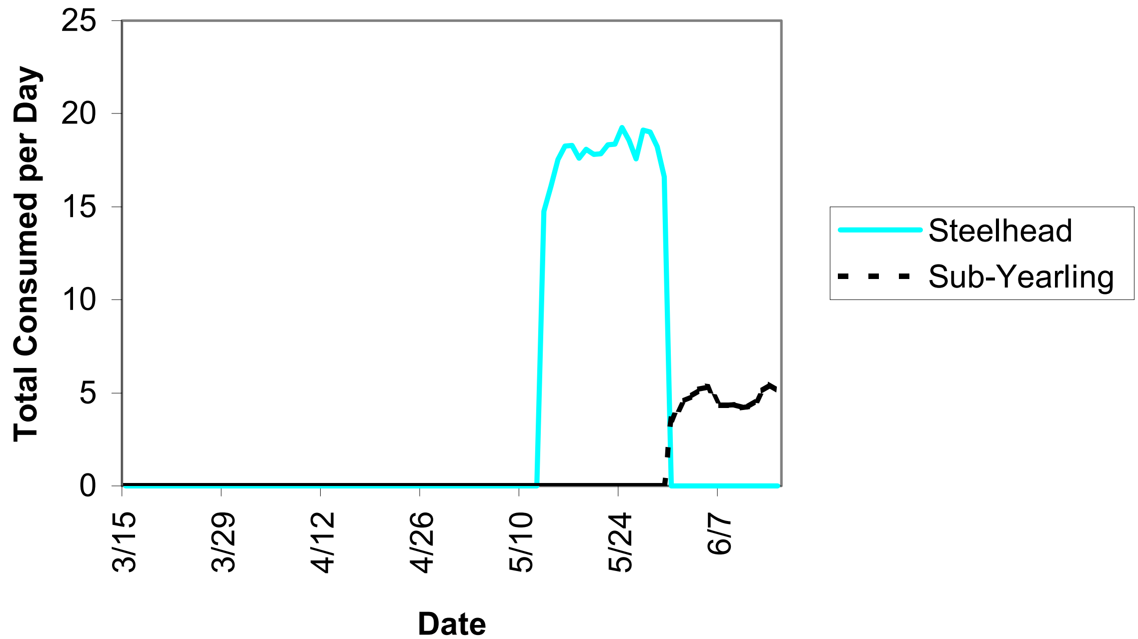

Figure 8. Estimated daily consumption (per 100 northern pikeminnow) of steelhead and sub-yearling salmonids at Sunnyside Dam between March 15 and June 15, 2000. Sub-yearling salmonid determination was based on estimated fork length at time of ingestion.

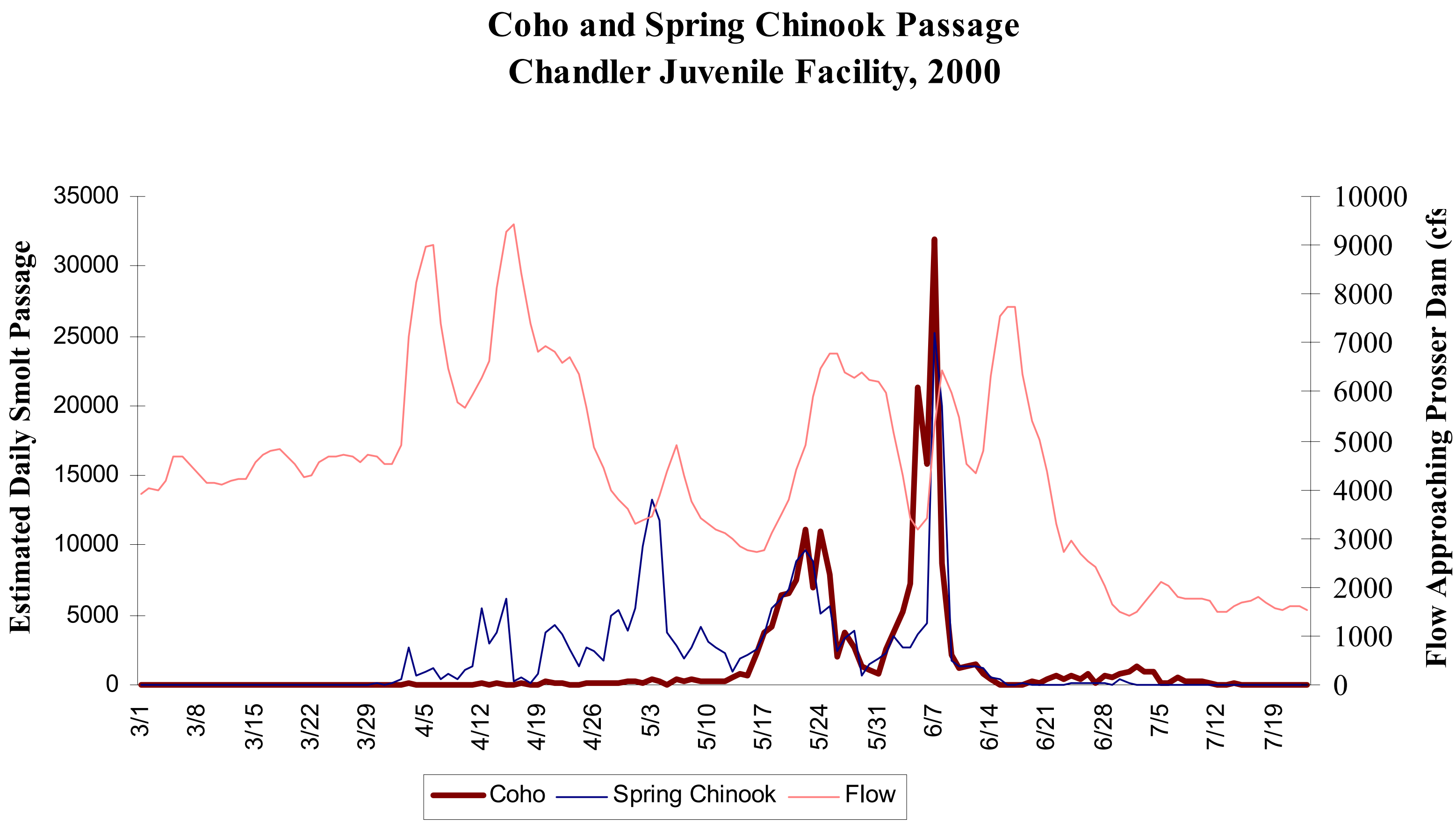

Figure 9. Spring chinook and coho smolt passage at Chandler Juvenile Fish Monitoring Facility (CJMF), 2000.

Discussion

Our results indicate that northern pikeminnow predation on salmonids during the 2000 emigration season was relatively high. We estimated that a total of 759,315 salmonids were consumed from Prosser to Roza dams during the period March 15 – June 15. In order to put the total losses into perspective of a proportion of hatchery spring chinook and coho production lost to northern pikeminnow predation, we must make some assumptions. It is likely that unmarked yearling salmon remains recovered from northern pikeminnow stomachs prior to May 7 were either wild or hatchery origin spring chinook, based on the date of release for hatchery coho. If this assumption is true, then a minimum spring chinook consumption estimate for the season is 282,041 spring chinook (unmarked salmon prior to May 7 plus hatchery spring chinook March 15-June 15). Alternatively, if we assume that all unmarked yearling salmon were spring chinook, then as many as 513,530 spring chinook salmon may have been consumed by northern pikeminnow. The latter is almost certainly an overestimate since the unmarked salmon likely contained an unknown portion of hatchery coho that lost either the coded wire or PIT tag. Nevertheless, based on our estimates of consumption, a minimum of 35.5% of the hatchery spring chinook production in 2000 was consumed by northern pikeminnows. This estimates rises to 88.7% if we assume that all unmarked salmon were hatchery spring chinook. If on the other hand, we assume that all unmarked salmon after May 7 were hatchery coho, then as many as 467,360 coho may have been consumed. Thus, between 23.5 to 46.7% of the hatchery coho production may have been lost to northern pikeminnow predation. Although the ambiguity of not being able to positively identify the unmarked salmon adds a level of uncertainty to the seasonal consumption estimates, we are confident that our estimates are reasonably close to the true losses. We base this statement on two independent observations. Peaks in estimated salmonid consumption (Figure 5) closely correlates to prey abundance (as indexed by estimated passage at CJMF; Figure 9). Secondly, Neeley (2000) estimated a mean survival index of 0.351 and 0.207 for hatchery spring chinook and coho (respectively) from release to McNary Dam, suggesting that approximately 376,000 hatchery spring chinook and 793,000 hatchery coho died prior to reaching McNary Dam. Our results suggest that northern pikeminnow predation may have accounted for approximately 64% of the losses of hatchery spring chinook and coho from release to McNary Dam, assuming that all the unmarked yearling salmonids were hatchery origin.

The estimated salmonid consumption by northern pikeminnows during the 2000 outmigration was over an order of magnitude higher than the estimated consumption for the 1999 outmigration. Dunnigan and Lamebull (2000) estimated a total of 60,583 yearling salmonids were consumed by northern pikeminnow from Prosser Dam to Roza Dam from April 12 – June 21, 1999. We believe that several factors help explain the differences observed between the 1999 and 2000 seasons. Sampling to estimate consumption during the 1999 outmigration season was limited to the historic peak and last quartile of the historic spring chinook outmigration, in addition to the first week of June. Dunnigan and Lamebull (2000) concluded that more frequent sampling was needed to ensure a more precise estimate of consumption throughout the spring chinook outmigration period. Thus, estimates of consumption obtained in 2000 were probably more precise than those collected in 1999 due to an increased frequency of sampling during the 2000 outmigration. Estimates of hatchery spring chinook and coho survival from release to McNary Dam were higher in 1999 than 2000. Survival indices for hatchery coho released in the Yakima River decreased from 40.2% in 1999 to 20.0% in 2000 (Dunnigan 2000). Survival indices for hatchery spring chinook also decreased from 1999 to 2000, from survival indices in 1999 ranging from 48.6 – 63.5% to a mean survival index of 35.2% in 2000 (Neeley 2000).

Differences in estimates of northern pikeminnow abundance between years also help explain annual differences in estimated salmonid consumption. The abundance of northern pikeminnow > 199 mm fork length was higher in 2000 than 1999. For example, estimates of the number of northern pikeminnow > 199 mm in the Toppenish section in 2000 ranged from 336 - 616 fish/km from April through June, with abundance estimates obtained in 1999 ranging from 120-221 fish/km in the same section (Dunnigan and Lamebull 2000). Not only was seasonal abundance of northern pikeminnow in the lower Yakima River higher in 2000, but per capita consumption of salmonids was also higher in 2000. During the 2000 season, we estimated that 10.6% of the northern pikeminnow contained at least one salmonid. This was more than twice as high than the estimate of 4.1% obtained in 1999. This discrepancy was even higher during the period when most predation occurred during both years (May and June), with 17.0% of the northern pikeminnow in May and June of 2000 containing at least one salmonid compared to 5% in 1999 (Dunnigan and Lamebull 2000). Thus, despite differences in methodology to estimate consumption between years, it is likely that absolute salmonid consumption by northern pikeminnow was higher in 2000 than 1999.

Environmental conditions in the Yakima River during the 1999 smolt outmigration period were also consistent with lower estimated salmonid consumption than compared to the 2000 outmigration. The 1999 smolt outmigration period had cooler water temperatures and higher discharge than occurred in 2000. The mean daily water temperature during the period April 1 – June 15 at Prosser Dam during the 2000 outmigration was 1.7° C higher ($p = 0.000003$) than 1999 with differences greater later in the outmigration (Figure 10). The higher water temperatures in 2000 likely resulted in an increased metabolic rate for northern pikeminnow during that period (Brown and Moyle 1981; Vigg et al. 1991), and an associated higher meal turnover time. Yakima River discharge above Prosser Dam was also higher during the 1999 outmigration period than compared to 2000. Mean daily discharge approaching Prosser Dam during the period April 1 – June 15 was significantly higher ($p = 0.0008$) in 1999 than 2000 (mean daily discharge 6480 and 5256 cfs respectively; Figure 11). Although conditions in the lower Yakima River were somewhat dissimilar in 1999 and 2000, conditions in 2000 may more closely typify average conditions during most years. Mean daily temperatures (April 1 – June 15) during 2000 were very similar ($p = 0.610$) to average conditions during from 1988-1999 (mean temperatures 13.9 and 13.7 respectively; Figure 10). Mean daily discharge (April 1 – June 15) above Prosser Dam during 2000 was higher ($p = 0.0002$) than the annual average during the period 1981-1999 (5256 and 4510 cfs, respectively; Figure 11). Therefore, the level of predation observed in 2000 may be considered a typical level of impact during most years in the Yakima Basin, given similar migration timing and hatchery and natural origin production levels.

Low recapture rates during the 2000 sampling season prohibited us from calculating valid northern pikeminnow population estimates for the Granger site. In order to estimate seasonal consumption from Prosser Dam to Rkm 136.7, we used estimates of abundance obtained from the Toppenish site throughout the season. Population estimates of northern pikeminnow in prior years have been difficult to obtain in the Granger section (McMichael et al. 1998; Dunnigan and LameBull 2000). Since few valid estimates of the absolute abundance of northern pikeminnow have been obtained in the Granger section, we had little evidence to suggest that abundance differs between the two sections. The extrapolated total number of salmonids consumed between Prosser Dam and Rkm 136.7 (146,478) was lower than the extrapolated total from Rkm 136.7 to Roza Dam (612,837; Table 6). Differences in estimated salmonid consumption were due solely to a lower incidence of predation for northern pikeminnow collected in Yakima River downstream of Rkm 136.7. The estimated proportion of northern pikeminnow containing at least one salmonid from the Toppenish section was approximately twice as high as those collected from the Granger section (12.69 and 6.35%, respectively). Differences in the proportion of northern pikeminnow containing at least one salmonid may be due to differences in the physical habitat upstream and downstream of Rkm 136.7 (Dunnigan and Lamebull 2000) and associated differences in northern pikeminnow foraging behavior.

Although we were unable to estimate consumption of salmonids by northern pikeminnow at Sunnyside Dam, we believe that per capita predation at this location is likely higher than other areas of the free flowing Yakima River. Low capture efficiency also prevented us from performing valid population estimates at the Sunnyside Dam site, but relative abundance (expressed as number seen/km; Table 1) was nearly 5 and 7.7 times higher than either the Toppenish and Granger sites, respectively. The proportion of northern pikeminnows containing at least one salmonid at the Sunnyside Dam site was also higher than either the Toppenish or Granger sites. For the entire outmigration period (March 15 – June 15) the average proportion of northern pikeminnow containing salmonids at the Sunnyside Dam site was 14.08%, which was higher than either the Toppenish (12.69%) or the Granger (6.35%) sites. These differences are even more disparate later during the season when most spring chinook and coho are migrating. The average proportion of northern pikeminnow containing salmonids from May –June 15 for the Sunnyside Dam, Toppenish, and Grangers sites are 26.3, 19.1, and 8.03% respectively. Thus, we believe that given the likely higher abundance of northern pikeminnow and incidence of predation at the Sunnyside Dam site, that predation associated at this locale is higher than free flowing sections of the Yakima River.

We estimated a total of 34,485 sub-yearling salmonids were consumed by northern pikeminnow in 2000, with approximately 3.9% of all salmonids consumed by northern pikeminnow being sub-yearling salmonids. In contrast, in 1998, approximately 50% of all salmonids consumed by northern pikeminnow in the Granger site (the Toppenish site was not sampled in 1998) were classified as sub-yearling (McMichael et al. 1998), yet in 1999 none of the 492 northern pikeminnow examined contained sub-yearling salmonids (Dunnigan and Lamebull 2000). Our consumption estimate of 34,485 sub-yearling salmonids may be an underestimate of the total seasonal consumption based on sampling dates. Since this project is primarily intended to estimate yearling salmonid consumption (specifically spring chinook), our sampling period concluded with the tail end of the yearling smolt outmigration (early June; Figure 9), and concluded well before the peak in the sub-yearling chinook migration at CJMF (Figure 12). During the June-July period water temperatures are elevated relative to April and May, and likely result in an increased metabolic rate for northern pikeminnow (Brown and Moyle 1981; Vigg et al. 1991), thus potentially increasing predation during the period after our sampling concluded.

Although our sampling period (March 15-June 15) adequately overlapped with the migration period for steelhead (Figure 12), our sampling locations were located upriver of the center of gravity for steelhead production in the Yakima Basin. Hockersmith et al. (1995) found that 48% of adult steelhead radio tagged at Prosser Dam from 1989-1992 spawned in Satus Creek. All of our sampling locations are located upriver of Satus Creek. Therefore, our 2000 northern pikeminnow consumption estimate of 29,477 steelhead likely represented steelhead produced in Toppenish Creek, the Naches or upper Yakima sub-basins, and likely substantially underestimated total predation on steelhead based on the juxtaposition of sampling locations and steelhead production within the Yakima Basin.

Recommendations

Based on the relatively high levels of estimated salmonid predation by northern pikeminnow, we recommend that an additional objective be added to this project. Future work should include field and modeling activities to investigate the feasibility of predation control efforts for northern pikeminnow above Prosser Dam. Additional information regarding the age structure, life history and reproductive ecology of northern pikeminnow in the Yakima River may prove to be useful information in formulating a northern pikeminnow predation control program in this basin.

The change in sampling protocol from 1999 to 2000 that increased the periodicity of consumption sampling to weekly intervals substantially increased the precision of the predation index, and therefore should continue. However, we should continue to monitor length frequency and age structure within the study reaches in order to retain our ability to determine whether or not differences in the predation index through time are attributable to a shifted northern pikeminnow age structure. We currently believe that the most limiting factor to achieving reliable estimates of salmonid consumption by northern pikeminnow in the lower Yakima River is our ability to consistently perform valid population estimates, especially at the Granger and Sunnyside Dam sites. We therefore recommend attempting slightly different sampling methodologies and/or techniques at these sites in an attempt to achieve higher capture numbers and ultimately valid population estimates. For example, adjusting the number of mark and/or recapture days during the population estimate period may provide better results.

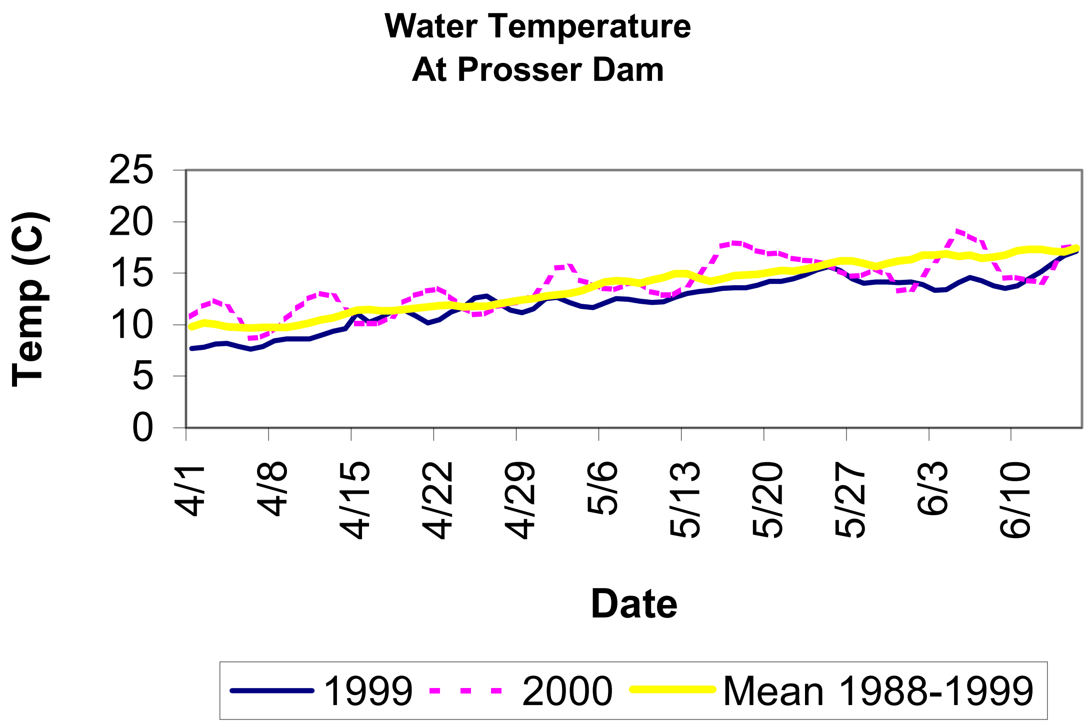

Figure 10. Mean daily water temperature at Prosser Dam, during 1999, 2000, and mean 1988-1999.

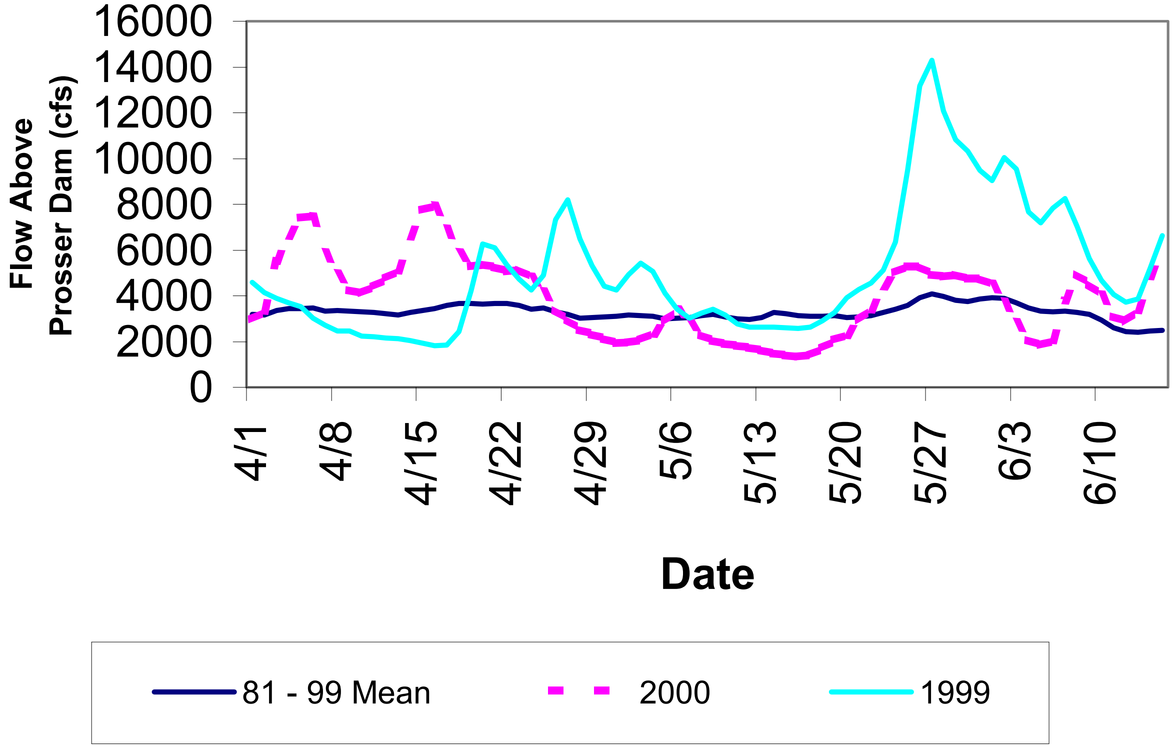

Figure 11. Mean daily discharge in cubic feet per second (cfs) approaching Prosser Dam during 1999, 2000, and 1981-1999 (mean).

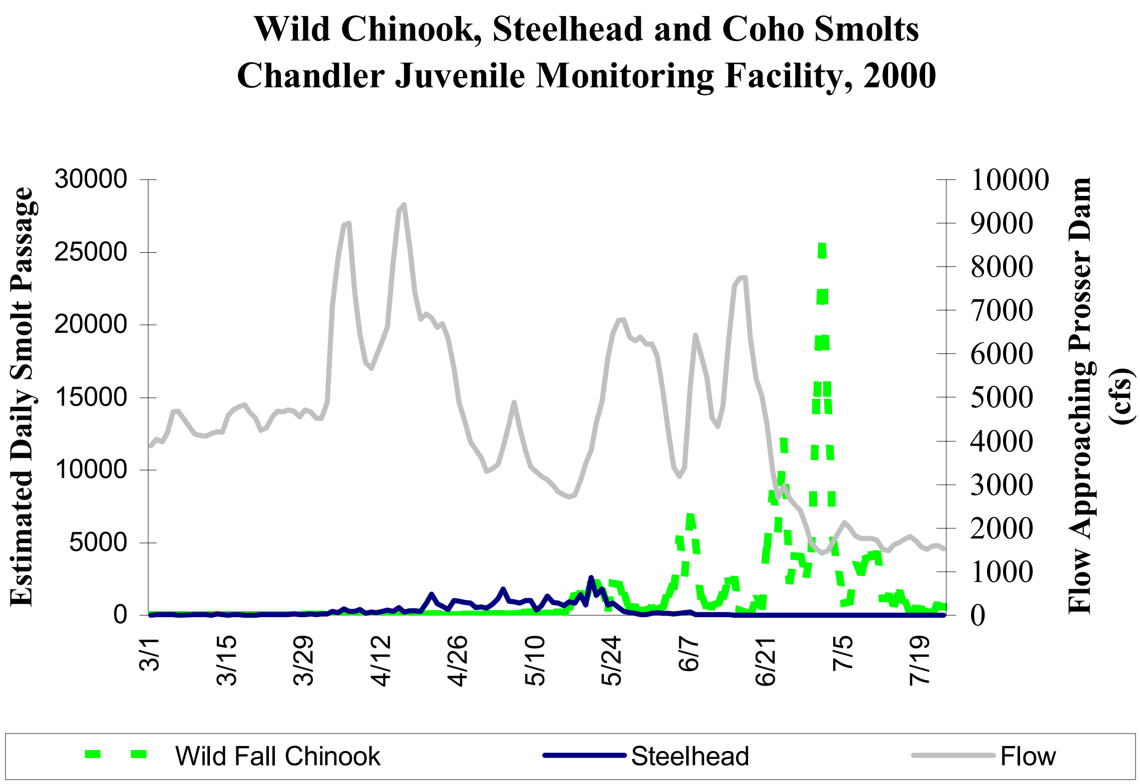

Figure 12. Seasonal estimated daily passage of wild fall chinook and steelhead juveniles at the Chandler Juvenile Monitoring Facility (CJMF), 2000.

Acknowledgements

We are thankful to the many people that helped make this project a reality. Joe Jay Pinkham, Jason Allen and Jerald Reed aided in the collection of field data. Melvin Sampson provided administrative support. David Fast, Todd Pearsons, and Anthony Fritts reviewed this manuscript. David Byrnes administered funding. This work was funded by the Bonneville Power Administration, under the Yakima Klickitat Fisheries Project.

References

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.

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

Bigood, B.F., and A.H. Berst. 1969. Lethal temperatures for Great Lakes rainbow trout. Journal of the Fisheries Research Board of Canada 26:456-459.

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.

Busack, C., B. Watson, T. Pearsons, C. Knudsen, S. Phelps, and M. Johnston. 1997. Yakima Fisheries Project: Spring Chinook supplementation Monitoring Plan. Internal Yakama Indian Nation Report. Yakama Indian Nation, Toppenish, Washington.

Cailliet, G.M., M. S. Love, and A.W. Ebeling. 1986. Fishes - A field and laboratory manual on their structure, identification and natural history. Waveland Press, Incorporated. Prospect Heights, Illinois.

Dunnigan, J.L. 1997. Predator fish abundance in the lower Yakima River. Yakama Nation internal report. Toppenish, Washington.

Dunnigan, J.L. 2000. Yakima coho monitoring and evaluation 1999 annual report. Bonneville Power Administration annual project report. Portland OR.

Dunnigan, J.L., and L.L. Lamebull. 2000. Lower Yakima River predation indexing: northern pikeminnow, 2000 annual report. In, Pearsons, T. N., and six coauthors. 1999. Yakima River species interactions studies. Annual report 1999. Project number 95-064-02. Bonneville Power Administration, Portland, Oregon.

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.

Hockersmith, E., J. Vella, L. Stuehrenber, R. Iwamota, and G. Swan. 1995. Yakima River radio-telemetry study: steelhead, 1989-1993. BPA Annual Report. Project number 89-

089. Lagler, K.F. 1956. Freshwater fishery biology. Wm. C. Brown Company, Dubuque, Iowa.

McMichael, G.A., A. Fritts, and J.L. Dunnigan. 1998. Lower Yakima River predatory fish census: feasibility study 1997. Bonneville Power Administration annual project report. Portland OR.

Neeley, D. 2000. Annual report: outmigration year 2000. Part 1. Supplemented fish survival to McNary Dam. Yakama Nation, unpublished report, Toppenish, Washington.

Patten, B.H., R.B. Thompson, and W.D. Gronlund. 1970. Distribution and abundance of fish in the Yakima River, Washington, April 1957 to May 1958. U.S. Department of the Interior Fish and Wildlife Service. Fish Bulletin No. 603.

Ricker, W.E. 1958. Handbook of computations for biological statistics of fish populations. Fisheries Research Board of Canada, Bulletin 119.

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.

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

Taylor, W.R., and G.C. Van Dyke. 1985. Revised procedures for staining and clearing small fishes and other vertebrates for bone and cartilage study. Cybium 9:107-119.

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.

Ward, D.L., J.H. Petersen, J.J. Loch. 1995. Index of predation on juvenile salmonids by Northern squawfish in the lower and middle Columbia River and in the lower Snake River. Transactions of the American Fisheries Society 124:321-334.

Windell, J.T. 1978. Estimating food consumption rates of fish populations. Pages 227-254 *in* T. Bagenal, editor. Methods for assessment of fish production in fresh waters. Blackwell Scientific Publications, London.