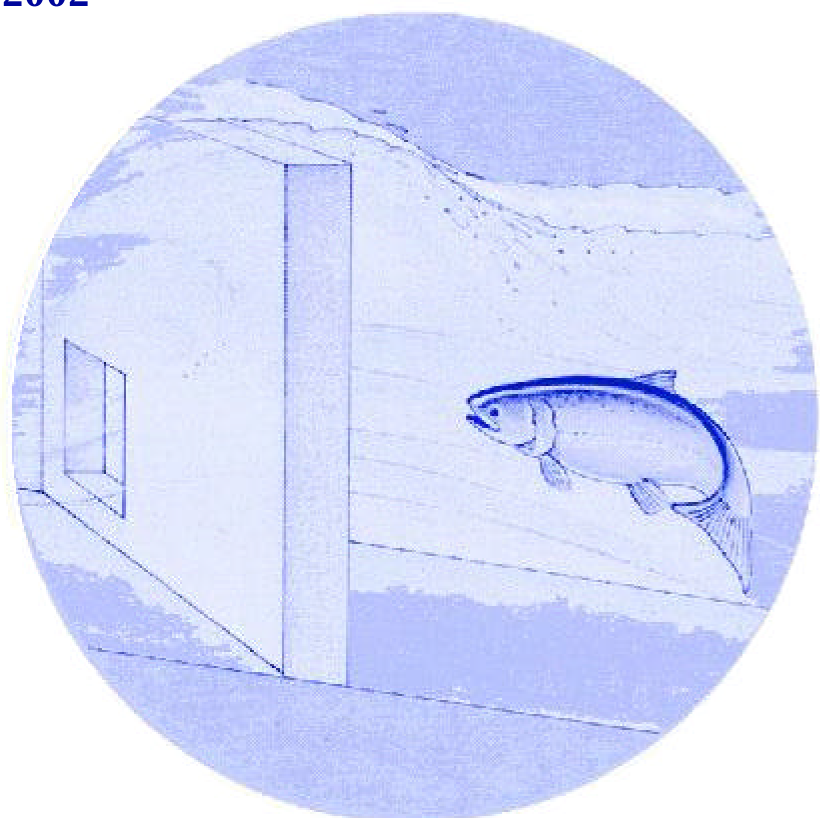
Yakima River Species Interactions Studies

Yakima/Klickitat Fisheries Project Monitoring and Evaluation

Annual Report
2002



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This report covers one of many topics under the Yakima/Klickitat Fisheries Project's Monitoring and Evaluation Program (YKFPME). The YKFPME is funded under two BPA contracts, one for the Yakama Nation and the other for the Washington Department of Fish and Wildlife (Contract number 00004666, Project Number 1995-064-24). A comprehensive summary report for all of the monitoring and evaluation topics will be submitted after all of the topical reports are completed. This approach to reporting enhances the ability of people to get the information they want, enhances timely reporting of results, and provides a condensed synthesis of the whole YKFPME. The current report was completed by the Washington Department of Fish and Wildlife.

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Annual Report 2002

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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 eleventh of a series of progress reports that address species interactions research and supplementation monitoring of fishes in the Yakima River basin associated with the Yakima/Klickitat Fisheries Project. Data have been collected before and during supplementation to characterize the ecology and demographics of non-target taxa (NTT) and target taxon, and to monitor interactions and supplementation success. Major topics of this report are associated with implementing NTT monitoring prescriptions for detecting potential impacts of hatchery supplementation, and monitoring fish predation indices. This report is organized into two 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, 2002 and December 31, 2002 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.

Release of large numbers of hatchery origin salmon has the potential to negatively impact other fish taxa (non-target taxa). To determine changes in the status of non-target taxa that could be related to hatchery smolt releases, we compared the abundance, size structure, and distribution of 16 non-target taxa before and four years after annual spring releases of about 1 million yearling salmon smolts (coho and chinook) in the Yakima River, Washington. We compared any observed changes in status to predetermined containment objectives that were judged to reflect acceptable levels of impact. We utilized detection strategies that would balance our ability to detect changes and the chances of falsely associating a change with supplementation. With the exception of steelhead and cutthroat trout size, all of the changes we observed were within the containment objectives established for the project. The mainstem Yakima River steelhead size index has significantly decreased through the post-supplementation period (-1%, $P<0.049$). The decreased size of cutthroat trout (-1%) was not significant ($P>0.37$), however, the power of our statistical test was low (Power=16% with alpha set at 0.10). Our analysis suggests that the depressed sizes of steelhead and cutthroat trout were not related to supplementation activities. For instance, tributary cutthroat trout and spring chinook salmon exhibited minimal overlap in distribution and had limited opportunity for interactions. In contrast, high overlap occurred between rainbow trout (an analog for steelhead) and spring chinook salmon in the upper Yakima River. However, we could not detect any differences in the sizes of rainbow trout between areas of high and low target taxa abundance. These results suggest that any impacts that might have been caused by releasing hatchery smolts into areas containing non-target taxa were balanced or exceeded by the benefits (e.g., ecological release) of reducing the progeny of naturally produced fish or by the increase in nutrients provided by the hatchery and returning adults. The reduction of naturally produced fish in the river was the result of removing fish that would have spawned in the river and culturing them in a hatchery. The interactions of non-target taxa monitored with a predation index, including fall chinook salmon, and Pacific lamprey, will be monitored with secondary impact detection strategies in the future and leopard dace and sandroller interactions will no longer be evaluated.

We estimated the number of salmonids that smallmouth bass ate during the spring of 2002 in the Yakima River. Predator surveys were conducted during the weeks of March 14 and March 28 and weekly from April 11 through June 21 in two sections of the lower Yakima River. Abundance was estimated using the relationship between catch per unit effort and population estimates that were calculated using maximum likelihood estimators of mark-recapture data from 1998 to 2000 and 2002. 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 2,942 on March 16 to a high of 36,463 on June 21. The increase in abundance was primarily due to immigration of fish from the Columbia River and partially from recruitment of smaller fish into the 150 mm and larger size range. Daily consumption of salmonids was relatively low until late April and sharply increased in early May. Consumption of salmonids sharply decreased in early June despite the fact that bass numbers remained high and water temperature increased. Smallmouth bass ate an estimated 175,712 salmonids during the spring. Only 2,570 of these were estimated to be spring chinook. The remainder was mostly fall chinook salmon. Salmonid consumption estimates for 2002 were most similar to estimates for 1999 with 171,031 salmonids of which 3,795 were spring chinook. We found a positive relationship between our estimates of fall chinook salmon consumption and estimates of fall chinook production. Sampling of smallmouth bass will not continue in 2003.

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).

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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 eleventh 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. 2001a, Pearsons et al. 2001b, Pearsons et al. 2002). 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 2002, Pearsons et al. in press). This progress report summarizes data collected between January 1, 2002 and December 31, 2002. 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 (Pearsons et al. 1994; Busack et al. 1997; Pearsons and Hopley 1999). 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 and coho 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 two chapters that represent major topics associated with monitoring stewardship, utilization, and strong interactor taxa. Chapter 1 reports the results of non-target taxa monitoring after the fourth release of hatchery salmon smolts in the upper

Yakima Basin. Chapter 2 describes predation on juvenile salmonids by smallmouth bass and channel catfish 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. 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. 2001a; Pearsons et al. 2001b; Pearsons et al. 2002).

Acknowledgments

We would like to thank Bonneville Power Administration, particularly David Byrnes, for financially supporting this work. In addition, we could not have completed this work without the help and support of many individuals during 2002. Most of these individuals are recognized on title pages or in acknowledgments of various chapters in this report.

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Chapter 1

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

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Abstract

Release of large numbers of hatchery origin salmon has the potential to negatively impact other fish taxa (non-target taxa). To determine changes in the status of non-target taxa that could be related to hatchery smolt releases, we compared the abundance, size structure, and distribution of 16 non-target taxa before and four years after annual spring releases of about 1 million yearling salmon smolts (coho and chinook) in the Yakima River, Washington. We compared any observed changes in status to predetermined containment objectives that were judged to reflect acceptable levels of impact. We utilized detection strategies that would balance our ability to detect changes and the chances of falsely associating a change with supplementation. With the exception of steelhead and cutthroat trout size, all of the changes we observed were within the containment objectives established for the project. The mainstem Yakima River steelhead size index has significantly decreased through the post-supplementation period (-1%, $P<0.049$). The decreased size of cutthroat trout (-1%) was not significant ($P>0.37$), however, the power of our statistical test was low (Power=16% with alpha set at 0.10). Our analysis suggests that the depressed sizes of steelhead and cutthroat trout were not related to supplementation activities. For instance, tributary cutthroat trout and spring chinook salmon exhibited minimal overlap in distribution and had limited opportunity for interactions. In contrast, high overlap occurred between rainbow trout (an analog for steelhead) and spring chinook salmon in the upper Yakima River. However, we could not detect any differences in the sizes of rainbow trout between areas of high and low target taxa abundance. These results suggest that any impacts that might have been caused by releasing hatchery smolts into areas containing non-target taxa were balanced or exceeded by the benefits (e.g., ecological release) of reducing the progeny of naturally produced fish or by the increase in nutrients provided by the hatchery and returning adults. The reduction of naturally produced fish in the river was the result of removing fish that would have spawned in the river and culturing them in a hatchery. The interactions of non-target taxa monitored with a predation index, including fall chinook salmon, and Pacific lamprey, will be monitored with secondary impact detection strategies in the future and leopard dace and sandroller interactions will no longer be evaluated.

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 (Pearsons 2002). This paper will address impacts that occur during the early stages of supplementation which have been termed the Broodstock and Building stages by Pearsons (2002). 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 (Pearsons 2002). 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. The next stage of supplementation, the Building stage, provides the greatest opportunity for interactions between hatchery fish, naturally produced offspring of hatchery fish, and NTT. Large numbers of hatchery smolts and the offspring from returning hatchery adults 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.

Hatchery yearling smolts released and the progeny from returning adult hatchery fish can interact with NTT. 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 (reduced interspecific competition), 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. Type II interactions occur between NTT and naturally produced offspring of hatchery fish (Pearsons and Hopley 1999). Type II interactions may be more natural than Type I interactions because the behaviors of the target fish are not altered in a hatchery environment. While Type I interactions occur during the Broodstock stage, both Type I and Type II interactions occur during the Building stage of supplementation. 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. However, increased natural production of the target taxa translates into potentially increased interactions in the freshwater rearing area.

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 initial stages of supplementation (Ham and Pearsons 2000; Ham and Pearsons 2001; Pearsons 2002). 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 and early Building stages 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 (Bonneville Power Administration 1996; Busack et al.1997). 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). Approximately one million salmon smolts have been released annually in the upper Yakima River from 1999 to 2002 (Table 1). 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, 2000, and 2001) and near Jack Creek on the North Fork of the Teanaway River (1999) and below Easton Dam (1999-2002). More detail about the study area and background of the supplementation project has been previously described (Busack et al. 1997; Pearsons and Hopley 1999; Ham and Pearsons 2000).

Table 1. Numbers and location of yearling salmon released in the upper Yakima River 1999-2002.

		Spring Chinook Salmon				Coho Salmon				
Brood year	Release year	Clark Flats	Easton	Jack Creek	Total	Easton	Jack Creek	Hatchery Slough	Total	Grand Total
1997	1999	229,290	156,758		386,048	48,000	240,000	210,000	498,000	884,048
1998	2000	221,460	230,860	137,363	589,683	247,153		247,523	494,676	1,084,359
1999	2001	232,563	269,502	256,724	758,789	233,076		233,388	466,464	1,225,253
2000	2002	285,954	263,061	285,270	834,285	314,450			314,450	1,148,735

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 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 2001). These newer measures include spatial overlap, analogs, predation indexing, and modeling (Table 5). Each of these measures can improve the detectability of changes in NTT status, 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 3 and 4. 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 2 of this report).

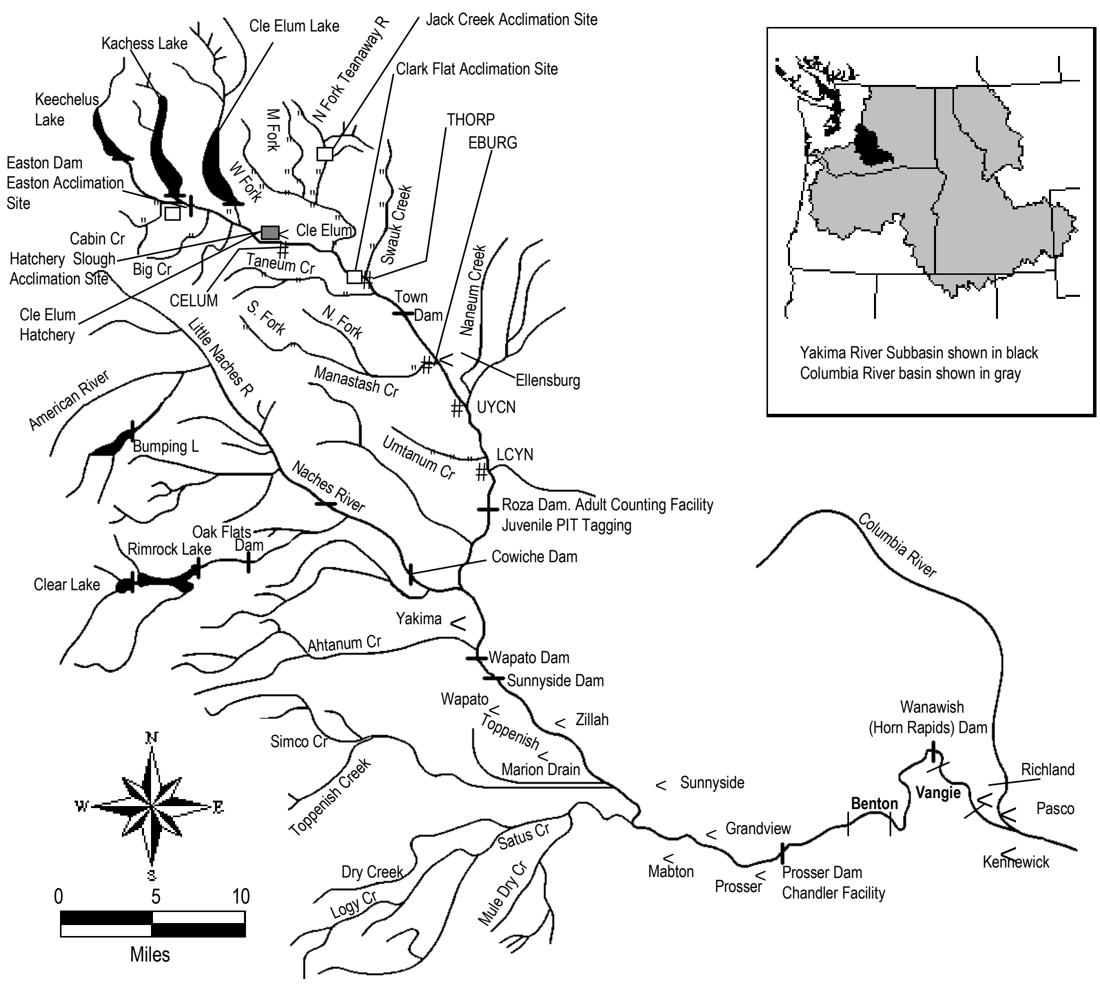

Figure 1. Yakima River Basin. Tributary survey sites ("), lower river mainstem survey sites (|~|), and major cities (<). Upper river mainstem survey sites (#) include Lower Canyon (LCYN), Upper Canyon (UCYN), Ellensburg (EBURG), Thorp (THORP), and Cle Elum (CELUM).

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 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 observed and estimate the length of all bull trout encountered.

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 5). A single electrofishing pass is performed and attempts are made to net all visible fish. Netted fish are held in perforated buckets 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 counted, grouped into age classes (adult, juvenile, age 0+), 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 for each site 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 measures are made. One type is generated from mark-recapture methods (rainbow trout) and the other is a visual estimate intended to index abundance (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 electrofishing pass is made to determine the proportion of marked and unmarked salmonids. 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 are 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 described in Chapter 2. 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 6). 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 5 and 6). These exceptions are included to provide a greater area in which to assess distributional changes.

Abundance estimates for residualized hatchery spring chinook salmon present in the Yakima River from mid September to mid October for release years 1999-2002 were calculated utilizing boat electrofishing recapture efficiencies. We calculated recapture efficiencies of similar sized rainbow trout utilizing mark-recapture methods in mainstem Yakima River electrofishing index sites. The rainbow trout recapture efficiencies were applied to the number of hatchery spring chinook netted during the mark runs in each index section. A final estimate of hatchery spring chinook residual abundance was expanded to the reach scale based on reach length (Table 2). Descriptions of mainstem study reaches are as follows: Lower Canyon (LCYN) extends upstream from Roza Dam to Umtanum Creek; Upper Canyon (UCYN) extends upstream from Umtanum Creek to the Ringer Road access; Ellensburg (EBURG) extends upstream from the Ringer Road access to the Ellensburg Dam; Thorp (THORP) extends upstream from the Ellensburg Dam to the Teanaway River; and Cle Elum (CELUM) extends upstream from the Teanaway River to the Cle Elum River.

Table 2. Estimated abundance of hatchery origin spring chinook salmon residuals in Upper Yakima River mainstem reaches.

	Yakima River Reach					
Year	LCYN	UCYN	EBURG	THORP	CELUM	Total
1999	87	127	98	69	0	381
2000	168	127	26	714	89	1,124
2001	6,581	1,594	736	1,665	0	10,576
2002	294	0	131	64	0	489
Avg.	1,783	462	248	628	22	3,143
SD	3,200	757	328	756	45	4,966

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 7, 8, and 9). 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 (StatSoft, Inc., 2001).

Results

Status monitoring of NTT, after four years of supplementation releases, indicated that most of the parameters we measure increased slightly and all, except steelhead and cutthroat trout size were within predetermined containment objectives (Table 10). Rainbow trout in the mainstem, which is also the analog for steelhead, increased in abundance, decreased slightly in size, and remained unchanged in distribution. The slight decrease in size (-1%) is outside of the containment objective for steelhead and is significant ($P<0.049$) but was within the containment objective for rainbow trout. However, comparisons of rainbow trout size in index areas that were stocked and those that were not stocked indicated that supplementation was not the cause of the decline in size (Figures 2 and 3). 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 primary impact detection strategy for bull trout and cutthroat trout is overlap in the distribution between these species and supplemented salmon (Table 5). There was no overlap of salmon and bull trout in our index sites, which indicated that supplementation activities did not negatively change the status of this species. However, cutthroat trout and supplemented spring chinook exhibited overlap in distribution in both tributary and mainstem Yakima River areas. The extent of the overlap in the mainstem Yakima River decreased with decreasing elevation (figure 4). The distributional overlap in tributary streams is low and represents less than 1% of the observed cutthroat trout distribution. The decreased size of tributary cutthroat trout was not significantly different from the baseline period ($P>0.37$), however, the power of our statistical test was low (Power=16% with alpha set at 0.10). The observed decline in cutthroat trout size was measured in tributary index monitoring sites which did not exhibit overlap in distribution with supplemented fish and was unlikely to be related to smolt releases. Speckled dace abundance remained below baseline levels ($P<0.011$), but was still well within our containment objectives. Finally, sculpin spp. abundance in tributary streams remained below baseline levels (-12%), although this difference was not statistically significant ($P>0.064$) and was within our predetermined containment objectives for this taxa.

The predation index used to monitor interactions with Pacific lamprey, fall chinook, leopard dace, and sandroller, will no longer be utilized (Chapter 2). The predation index calculated for these species indicates that the mechanism of predation that could be influenced by the supplementation of yearling smolts has not occurred. Additionally, the predation index indicates that these NTT have shown improvements during the post-supplementation years (i.e., predation rates have decreased). Lower Yakima River predatory fish predator/prey relationships and the status of the predatory fish monitoring program are discussed in detail in chapter 2 of this report.

Statistical tests of monitoring prescriptions before and after supplementation are presented in Tables 7, 8, and 9. Actual values (unmodelled and untransformed) are presented for abundance (Table 11), size (Table 12), and distribution (Table 13).

Table 3. 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 Ave.
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 River	MFT-2	Middle/West Fork Teanaway Rd. 5.1 km above junction with
	MFT-3	Middle/West Fork Teanaway Rd. 8.5 km above junction with
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	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	W. Fork Teanaway Rd. 5.6 km above junction with Teanaway Rd.
	WFT-3	400 m below West Fork Trailhead Rd.
		Upper Yakima Mainstem
Cle Elum	CELUM	Swift Water Campground to the Teanaway game ramp
Ellensburg	EBURG	Ellensburg KOA to Irene Reinhart ramp
Lower Canyon	LCYN	Road mile 11.7 on Highway 821 to 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	Benton	1.0 km below Chandler Pumping Station to 2.5 km above SR225
	Vangie	0.5 km below Grosscup Road to 0.5 km above VanGiesen Road

Table 4. 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 5. 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	Yes[1]
Steelhead	Status (Year 1 rainbow trout as analogs)/Electrofishing	CELUM, THORP, EBURG, UCYN, LCYN	Yes[4]
Fall chinook salmon	Predation index/Electrofishing	Benton, Vangie	Yes[1]
Leopard dace	Predation index with all dace as analogs/Electrofishing	Benton, Vangie	Yes[1]
Mountain sucker	Status: all suckers as analogs/ Visuals during Electrofishing	CELUM, THORP, EBURG, UCYN, LCYN	Yes[3]
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[4]
Spring chinook salmon	Status/Trapping	Chandler juvenile facility annual counts	No
Mountain whitefish	Status (subadult)/Visuals during Electrofishing	CELUM, THORP, EBURG, UCYN, LCYN	Yes[3]
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[3]
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 Visuals during Electrofishing	CELUM, THORP, EBURG, UCYN, LCYN	Yes[3]

[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 6. 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 7. Monitoring prescription abundance baseline mean, standard deviation, number of baseline survey years, post-supplementation average (n=4, 1999 - 2002 surveys), t statistic, 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 ± 0.00	--	1.000		
Cutthroat trout	2.02 ± 0.38	(9)	2.14 ± 0.56	-0.45	0.328		
Pacific lamprey	427,972	(1)	184,104 ± 30,911	7.06	0.003		
Steelhead	1.99 ± 0.11	(8)	2.17 ± 0.24	-1.78	0.052		
Fall chinook salmon	427,972	(1)	184,104 ± 30,911	7.06	0.003		
Leopard dace	52,017	(1)	46,307 ± 43,232	0.12	0.457		
Mountain sucker	2.00 ± 0.07	(6)	1.93 ± 0.07	1.58	0.076	44	60
Sand roller	6,702	(1)	3,176 ± 2,885	1.09	0.177		
Rainbow trout-main	1.99 ± 0.11	(8)	2.17 ± 0.24	-1.78	0.052		
Spring chinook salmon	5.14 ± 0.24	(16)	5.18 ± 0.36	-0.25	0.401		
Mountain whitefish	1.65 ± 0.11	(6)	1.79 ± 0.01	-2.48	0.019		
Rainbow trout – tribs.	2.44 ± 0.14	(9)	2.55 ± 0.09	-1.45	0.088		
Longnose dace	1.99 ± 0.10	(7)	2.03 ± 0.17	-0.47	0.324		
Sculpins	1.98 ± 0.20	(7)	1.83 ± 0.16	1.67	0.064	32	47
Speckled dace	1.98 ± 0.15	(6)	1.67 ± 0.20	2.86	0.011		
Suckers	2.00 ± 0.07	(6)	1.93 ± 0.07	1.58	0.075	44	60

Table 8. Monitoring prescription size baseline mean, standard deviation, number of baseline survey years, post-supplementation average (n=4, 1999 - 2002 surveys) t statistic, p-level, and power analysis where α is set to 0.05 or 0.10. Significant differences (P<0.05) are identified with an asterisk.

NTT	Baseline	(n)	Post	t	p	0.05	0.10
Bull Trout	2.00 ± 0.00	(3)	2.00 ± 0.00	--	1.000		
Cutthrout trout	1.87 ± 0.09	(9)	1.85 ± 0.07	0.33	0.373	09	16
Steelhead	2.08 ± 0.03	(9)	2.06 ± 0.02	1.80	0.049*		
Mountain sucker	1.64 ± 0.13	(6)	1.53 ± 0.14	1.29	0.115	35	51
Rainbow trout-main	2.08 ± 0.03	(9)	2.06 ± 0.02	1.80	0.049*		
Spring chinook salmon	1.78 ± 0.02	(8)	1.76 ± 0.08	0.72	0.242	40	56
Mountain whitefish	1.45 ± 0.27	(6)	1.32 ± 0.10	0.90	0.197	17	28
Rainbow trout – tribs.	2.43 ± 0.14	(9)	2.55 ± 0.09	-0.49	0.317		
Longnose dace	0.87 ± 0.09	(6)	1.00 ± 0.01	-2.81	0.011		
Sculpins	0.76 ± 0.05	(6)	0.90 ± 0.02	-4.72	0.001		
Speckled dace	0.53 ± 0.10	(6)	0.62 ± 0.05	-1.73	0.061		
Suckers	1.64 ± 0.13	(6)	1.53 ± 0.14	1.29	0.115	35	51

Table 9. Monitoring prescription distribution baseline mean, standard deviation, number of survey years, post-supplementation average (n=4, 1999-2002 surveys) t statistic, 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 ± 0.00	-	1.000		
Cutthroat trout	1.79 ± 0.00	(2)	1.88 ± 0.01	-0.94	0.200		
Rainbow trout-main	2.00 ± 0.00	(8)	2.00 ± 0.00	-	1.000		
Mountain whitefish	2.00 ± 0.00	(6)	2.00 ± 0.00	-	1.000		
Rainbow trout – tribs.	4.99 ± 0.02	(7)	4.99 ± 0.02	-0.90	0.195		
Longnose dace	1.89 ± 0.06	(7)	1.85 ± 0.08	1.10	0.150	30	45
Sculpins	1.96 ± 0.02	(6)	1.84 ± 0.11	2.43	0.020		
Speckled dace	1.94 ± 0.09	(6)	1.88 ± 0.00	1.28	0.118	24	37
Suckers	4.56 ± 0.06	(6)	4.53 ± 0.08	0.71	0.248	18	30

Table 10. Percent change in post supplementation NTT status relative to baseline for monitoring prescriptions. Values were calculated as a percentage for each year, rounded and the average taken. The minimum and maximum percent change for the post supplementation period is also listed. The containment objective (CO) is listed for each non-target taxa.

	Post Supplementation Change, (%)									
	CO	Abundance			Size			Distribution		
		Average	Min	Max	Average	Min	Max	Average	Min	Max
Bull trout	0	0	0	0	0	0	0	0	0	0
Cutthroat trout	0	6	-29	22	-1	-7	8	5	4	6
Pacific lamprey[1]	0	57	48	63						
Steelhead	0	9	0	27	-1	-2	-1	0	0	0
Fall chinook[1]	-5	57	48	63						
Leopard dace[1]	-5	11	-89	84						
Mtn. sucker	-5	-1	-8	6	31	-22	65	-1	-3	0
Sand roller[1]	-5	53	4	100						
Rainbow – main	-10	9	0	27	-1	-2	-1	0	0	0
Spring chinook	-10	2	-6	9	-1	-6	4			
Mtn. whitefish	-40	9	8	9	13	4	20	0	0	0
Rainbow – tribs	-40	5	1	9	0	-1	2	0	0	0
Longnose dace	-65	2	-7	13	16	14	17	-2	-8	2
Speckled dace	-85	-16	-25	-2	18	7	32	-3	-3	-3
Sculpins	-90	-12	-19	-9	18	14	22	-6	-13	0
Suckers	-90	-3	-8	0	31	-22	65	-1	-3	0

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

Table 11. Actual values for abundance (fish/km, unless otherwise indicated). Leopard dace, mountain sucker and sandroller are too rare for quantitation.

NTT	Baseline	(n)	Post Supplementation
Bull trout	22 ± 19[1]	(3)	18 ± 5 fish
Cutthroat trout	138 ± 90	(9)	205 ± 129 /km
Pacific lamprey	198 ± 241[2]	(6)	174 ± 106 migrants
Steelhead	63,247 ± 38,259[3]	(16)	36,975 ± 6,050 smolts
Fall chinook salmon	108,973 ± 102,976[3]	(16)	490,703 ± 794,564 smolts
Rainbow trout-main	147 ± 43	(8)	242 ± 130 age 1/km
Spring chinook salmon	158,355 ± 75,216[3]	(16)	192,573 ± 140,872 smolts
Mountain whitefish	116 ± 34	(6)	160 ± 24 subadult/km
Rainbow trout – tribs.	287 ± 89	(9)	359 ± 76 /km
Longnose dace	59 ± 22[4]	(7)	57 ± 14 /site
Sculpins	63 ± 27[4]	(7)	36 ± 6 /site
Speckled dace	104 ± 45[4]	(6)	55 ± 30 /site
Suckers	187 ± 43	(6)	161 ± 19 /km

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

Table 12. 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)	Post Supplementation
Bull trout	275 ± 134 mm	(3)	251 ± 32 mm
Cutthroat trout	155 ± 15 mm	(9)	152 ± 12 mm
Steelhead	166 ± 30 mm	(6)	169 ± 38 mm
Fall chinook salmon	83 ± 5 mm	(8)	86 ± 3 mm
Rainbow trout-main	201 ± 8 mm	(9)	194 ± 5 mm
Spring chinook salmon	128 ± 3 mm	(8)	125 ± 11 mm
Mountain whitefish	32 ± 15%	(6)	22 ± 4 % subadults
Rainbow trout – tribs.	133 ± 3 mm	(9)	135 ± 6 mm
Longnose dace	8 ± 2 g	(7)	10 ± 0 g
Sculpins	6 ± 1 g	(7)	8 ± 0 g
Speckled dace	3 ± 1 g	(6)	4 ± 1 g
Suckers	45 ± 13 %	(6)	35 ± 12 % adults

Table 13. Actual values for percent distribution.

NTT	(n)	Baseline	Post Supplementation
Bull trout	(3)	26 ± 17 %	28 ± 11 %
Cutthroat trout	(2)	66	76 ± 2 %
Rainbow trout-main	(8)	100 ± 0 %	100 ± 0 %
Rainbow trout – tribs.	(9)	95 ± 4 %	97 ± 3 %
Longnose dace	(7)	79 ± 10 %	71 ± 12 %
Sculpins	(7)	91 ± 5 %	72 ± 18 %
Speckled dace	(6)	89 ± 16 %	77 ± 0 %
Suckers	(6)	80 ± 11 %	73 ± 12 %

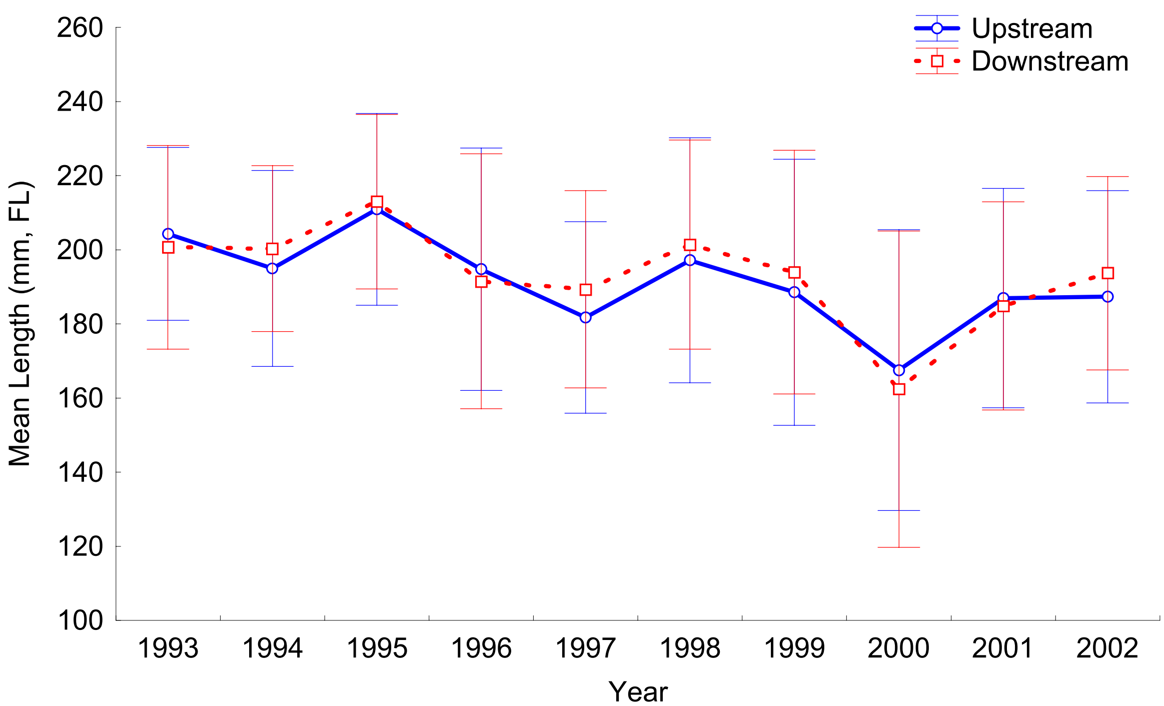

Figure 2. Mean fork length (FL) of Yakima River rainbow trout (<250mm) above and below the Clark Flats acclimation site discharge channel. Error bars represent 1 standard deviation.

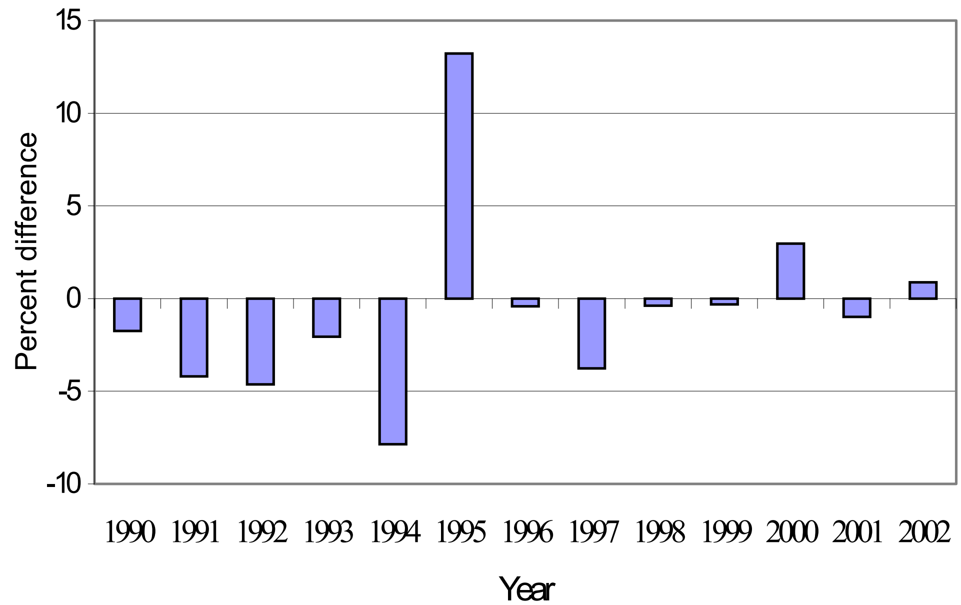

Figure 3. Difference in rainbow trout lengths between treatment and reference streams in the Teanaway Basin.

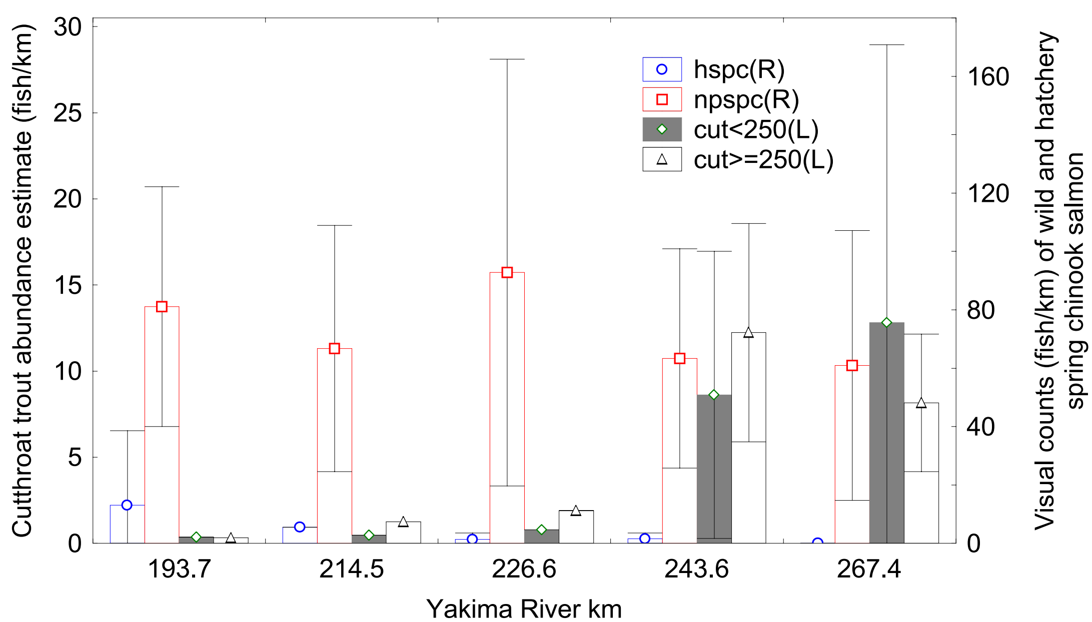

Figure 4. Cutthroat trout and spring chinook overlap in distribution in the mainstem Yakima River during the post-supplementation period, 1999-2002. River kilometers are measured to the middle of a sampling section. Error bars represent 1 standard deviation.

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 yearlings were balanced or exceeded by the benefits (e.g., ecological release) of reducing the progeny of naturally produced fish or increased nutrients provided by hatchery effluent or higher numbers of adult salmon; 3) benign interaction or density dependent benefits of higher numbers 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, tributary cutthroat trout, tributary rainbow trout, 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 trout 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 not observed upstream from the release site in the North Fork of the Teanaway River during 2002, but were observed upstream 2.5 km in 2000 and 1.4 km in 2001. However, none were observed in index areas containing bull trout and very few were observed in tributary index areas containing cutthroat trout. We assume that minimal or no spatial and temporal 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 or increased nutrients provided by hatchery effluent or higher numbers of adult salmon. The NTT that likely fit into this category are cutthroat trout and 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 and cutthroat trout, were within the containment objectives. The reduction of naturally produced target fish in the river was the result of taking fish that would have spawned in the river into the hatchery. The large return of wild fish in 2000 and the combination of supplementation and wild returns in 2001 produced progeny that had ample opportunity to interact with NTT. Thus, the proportion of the run that was taken for broodstock was relatively high in 1997, 1998, 1999, and low in 2000 and 2001. During years when high proportions of the run were taken for broodstock, more ecological release was likely to occur. We expected that impacts would be most noticeable during 2001 and 2002 because of the large numbers of salmon released (Type I interactions) and the increased natural production of supplementation origin salmon (Type II interactions).

Although we have observed decreases in the size of steelhead (rainbow trout as an analog) during the post-supplementation period, the decline is unlikely to have been caused by supplementation. If supplementation has changed the size structure or growth of the steelhead size index, we would expect to detect this change in areas with high densities of salmon. Rainbow trout located immediately downstream from the Clark Flats acclimation facility had the potential to interact with all upstream spring chinook and coho smolt releases as well as residual salmon that did not migrate to the ocean. Rainbow trout immediately upstream from the Clark Flats acclimation facility would primarily interact with smolt releases from Jack Creek and Easton acclimation facilities, the Cle Elum Hatchery slough coho releases, and lower numbers of residualized chinook salmon. We did not detect a reduction in the size of rainbow trout in the high-density areas of the target taxa below the Clark Flats acclimation site. In addition, we would expect that the size of rainbow trout below the release site in the North Fork Teanaway River would be smaller than those in comparable sites where target fish were not released. We did not however, detect any decreases in the size of rainbow trout in these high density areas suggesting that the decreased size is not related to supplementation. One potential explanation for the observed change is that density dependent mechanisms have altered the size of mainstem Yakima River rainbow trout. Preliminary analysis indicated that there is a negative relationship between the abundance and size of these fish. Additionally, the steelhead size index began to decline in the baseline period before hatchery fish were released. Finally, the length of steelhead smolts measured at the Chandler Juvenile facility have increased during the post-supplementation period, although these are mixed stock smolts from the Yakima and adjacent sub-basins that may not be representative of upper Yakima steelhead. This information leads us to believe that the decline in steelhead lengths is most likely the result of natural variation or some other factor.

Although our analysis suggests that the decline in the steelhead size index is not related to supplementation, we intend to conduct a more rigorous evaluation of the observed change. A statistical power analysis and sample size calculations will be used to determine the sample size necessary to detect impacts to the growth of rainbow trout in treatment and control areas in the Yakima River and in the Teanaway Basin. Evaluating the size index of the population utilizing individual fish should dramatically improve our ability to detect an impact if supplementation is affecting the size structure of the index. Two potential methods that might accomplish this while utilizing existing resources are anchor tagging individual rainbow trout, or utilizing scales to back calculate length at age for individual fish. We intend to implement the most statistically powerful strategy in 2003 because we can collect this information with little additional effort.

The observed decrease in the size of cutthroat trout in tributary index monitoring sites was not the result of supplementation activities because the index monitoring sites used to evaluate cutthroat trout status have not been within the distribution of spring chinook salmon. Therefore, the observed decrease in cutthroat trout size is most likely the result of natural variation or some other factor. Furthermore, less than 1% of tributary cutthroat trout were observed within the distribution of spring chinook. In 2002, the Yakama Nation counted the largest number of spring chinook redds on record for the North Fork Teanaway River. The progeny from these redds will be observed in 2003 and may help us to determine if the distribution of rearing salmon parr in the Teanaway Basin is likely to expand further into the range of cutthroat trout in the future. For this reason, we intend to evaluate cutthroat status in our established tributary index sites in 2003 as well as apportioning some additional effort to evaluate cutthroat trout in the distributional overlap area of the target taxon. If rearing salmon do not expand their distribution in the Teanaway system in 2003, we will likely streamline our sampling effort for tributary cutthroat trout in the future. However, we have identified a need to increase our emphasis on monitoring cutthroat trout status in the mainstem Yakima River in 2003.

Cutthroat trout in the mainstem Yakima River overlapped with both naturally produced and hatchery released salmon. The greatest overlap occurred at higher elevations and decreased with decreasing elevation. Large sized cutthroat trout in these areas could benefit from supplementation if they eat hatchery smolts, naturally produced salmon, or utilize food produced from returning hatchery adults. Large cutthroat trout have been shown to be piscivorous in other lotic systems in the Pacific Northwest (Lowry 1966). In contrast, smaller size classes of cutthroat trout may not benefit from an increased abundance of salmon. The smaller fish may not directly consume either hatchery produced or naturally produced salmon. In addition, smaller cutthroat trout may not have the competitive size advantage to compete for resources as well as the larger cutthroat trout.

The low abundance of cutthroat trout in mainstem index areas makes it difficult to evaluate their status. Furthermore, the cutthroat trout populations in the Yakima Basin have been shown to exhibit high amounts of natural variation in their status which complicates rapid and sensitive impact detection for this species (Ham and Pearsons 2000).

Large numbers of spring chinook salmon did not migrate to the ocean after release (residuals) and may have interacted with NTT (Table 2). Approximately 22% of the total spring chinook salmon production precocially matured and likely residualized in the river (Larson et al. in review). Residual fish have been 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. During 2001, precocials were more abundant and were more evenly distributed throughout the Yakima River and the North Fork Teanaway River than in previous years. Fewer residualized spring chinook salmon were observed in 2002 than in the two previous years. However, the observed residuals were larger than wild conspecifics and modal sized rainbow trout which could confer dominance status to hatchery origin salmon. 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 in or migrate through the lower Yakima River. This includes leopard dace, Pacific lamprey, fall chinook, sand roller, and spring chinook. The abundance index for these species is unlikely to be influenced by yearling salmon supplementation activities because the mechanisms of predation that could be influenced by supplementation were not observed. Yearling smolt releases were unlikely to have increased the frequency or magnitude of indirect predation on NTT. For example, we have estimated that smallmouth bass rarely consume yearling salmonids and thus, NTT are likely to be unaffected by yearling releases (Chapter 2). In addition, we did not observe an increase in the abundance of bass which would be expected if bass were consuming yearling smolts.

Since the predation index will be discontinued in future years, we recommend shifting our monitoring strategies for fall chinook and Pacific lamprey to secondary impact detection strategies that have been previously identified (Ham and Pearsons 1999). Briefly, simple status monitoring will replace interactions monitoring for these species. Lamprey abundance and fall chinook abundance and size are recorded by the Yakama Nation at the Chandler facility and will now be used as the primary monitoring strategy for these species. The liability in shifting our monitoring focus to secondary strategies is the resulting reduction in our impact detection ability for these NTT. Ham and Pearsons (1999) noted that the predation index provided large benefits in monitoring fall chinook interactions but only marginal improvements in detecting impacts to Pacific lamprey abundance. Therefore, discontinuing the predation index may inhibit our ability to detect impacts to fall chinook status but may not substantially reduce our monitoring ability for Pacific lamprey. Finally, we have no economically feasible alternative for monitoring the status of leopard dace and sandroller and have no plans to monitor their status in the future.

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.

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 (Pearsons 2002). 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. Only changes that are due to supplementation warrant risk containment action specific to the supplementation program. The only NTT that are outside of the containment objectives are steelhead and cutthroat trout. The declines in steelhead and tributary cutthroat trout size are unlikely to be due to supplementation and therefore do not require risk containment actions. The influence of supplementation on the size structure of mainstem Yakima River cutthroat is unknown and will receive particular attention in 2003. If substantive declines continue, then more refined methods of determining causation should be implemented. Monitoring prescriptions described in Table 5 appear to be working as they were designed and should continue to be implemented during 2003 with the exception of those related to the predation index. As previously described, monitoring prescriptions related to the predation index will not be implemented in future years. As a result, sandroller and leopard dace status will not be monitored while secondary impact detection strategies will be implemented for fall chinook salmon and Pacific lamprey. An additional monitoring prescription for mainstem cutthroat trout should be added. The monitoring prescriptions appear, thus far, to be relatively insensitive to impacts that were caused by factors other than supplementation. For example, bull trout abundance and size has decreased after the onset of supplementation in the Yakima Basin. However, because distributional overlap between bull trout and hatchery fish has not been observed, the decrease was not attributed to supplementation. Finally, the building stage of supplementation began in 2002. This stage is likely to be the one where the risk of impacts is the highest (Pearsons 2002).

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 and cutthroat trout. By reducing the number of these precociously mature salmon, both direct and indirect undesirable interactions with NTT will be reduced. We recommend implementation of feasable strategies to reduce the production and release of precociously mature salmon as soon as possible.

Acknowledgements

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Chapter 2

Lower Yakima River Predatory Fish Monitoring: Progress Report 2002, Bass and Catfish

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Abstract

We estimated the number of salmonids that smallmouth bass ate during the spring of 2002 in the Yakima River. Predator surveys were conducted during the weeks of March 14 and March 28 and weekly from April 11 through June 21 in two sections of the lower Yakima River. Abundance was estimated using the relationship between catch per unit effort and population estimates that were calculated using maximum likelihood estimators of mark-recapture data from 1998 to 2000 and 2002. 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 2,942 on March 16 to a high of 36,463 on June 21. The increase in abundance was primarily due to immigration of fish from the Columbia River and partially from recruitment of smaller fish into the 150 mm and larger size range. Daily consumption of salmonids was relatively low until late April and sharply increased in early May. Consumption of salmonids sharply decreased in early June despite the fact that bass numbers remained high and water temperature increased. Smallmouth bass ate an estimated 175,712 salmonids during the spring. Only 2,570 of these were estimated to be spring chinook. The remainder was mostly fall chinook salmon. Salmonid consumption estimates for 2002 were most similar to estimates for 1999 with 171,031 salmonids of which 3,795 were spring chinook. We found a positive relationship between our estimates of fall chinook salmon consumption and estimates of fall chinook production. Sampling of smallmouth bass will not continue in 2003.

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, 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 conducted 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. This chapter represents the work performed by the Washington Department of Fish and Wildlife and includes the two smallmouth bass reaches.

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. Between 1999 and 2002 we sampled weekly in order to obtain a more precise index of predation throughout the spring smolt emigration. We sampled a week later in 2002 than in 2001 to see if we were sampling the entire range of predation on fall chinook.

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 of the lower Yakima River. 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 is 8.0 km long, while the Benton section is 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" (Figure 1).

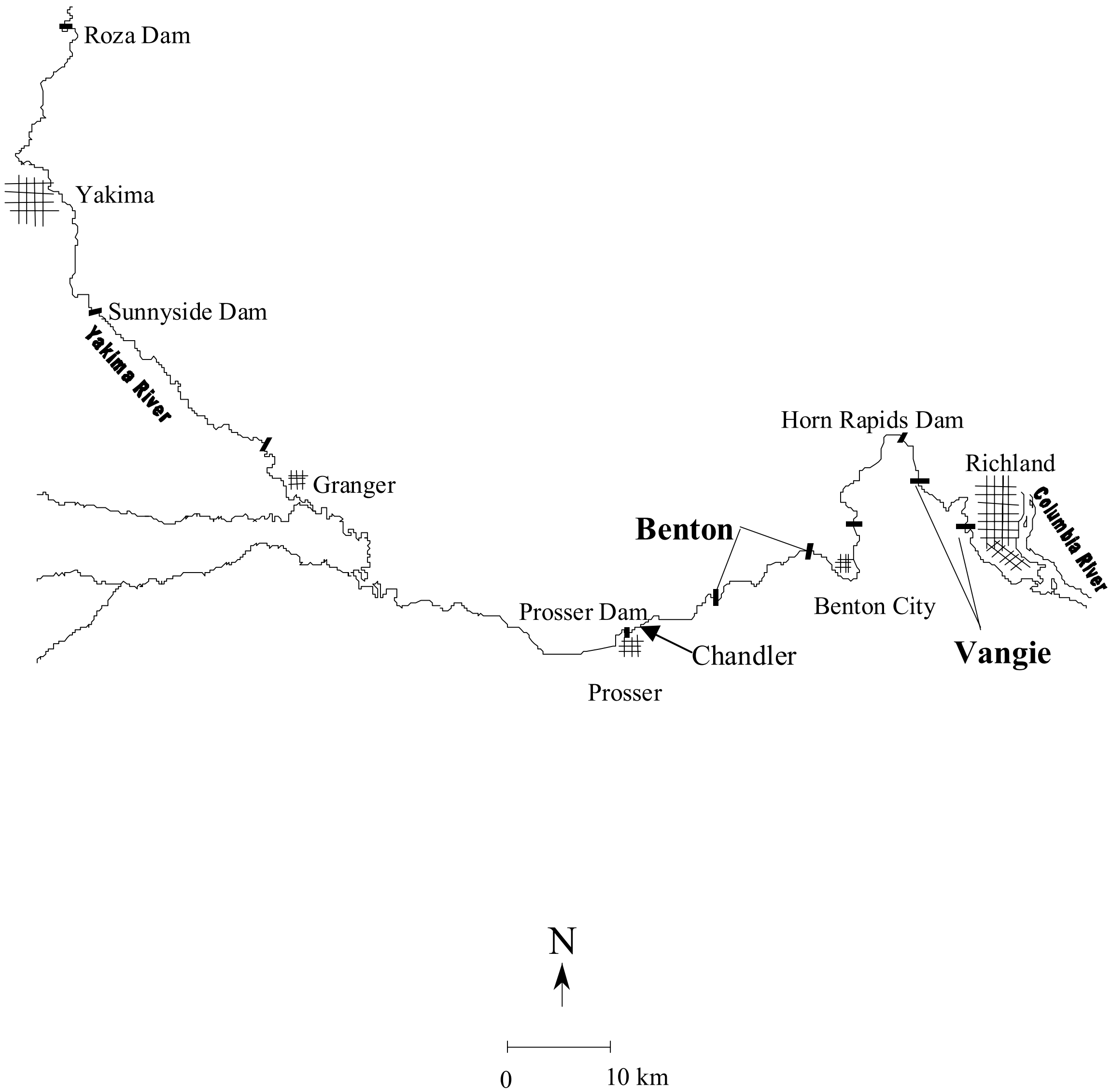

Figure 1. Map of the study area in the lower Yakima River showing index sections in bold type.

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 13 sample weeks between March 14 and June 21, 2002. In addition, mark-recapture population estimates were performed in the Benton and Vangie sections between April 23 and 26, 2002. Regression analysis was used to examine the relationship between population estimates and CPUE for 1998, 1999, 2000 and 2002 data combined (we were unable to get a valid population estimate during 2001). The regression equation was then applied to raw CPUE data to estimate population size for each of the 13 sample weeks in 2002.

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 fish 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 random subsample of all predatory fish ≥ 150 mm was examined for stomach contents except when CPUE of fish was low, then all predatory fish were examined.

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 (Light et al. 1983). Channel catfish samples were obtained by gastric lavage and by sacrificing some of the fish to check the efficacy of the lavage and when very large contents were encountered. All diet samples were placed in whirl-paks with 10 ml 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 of the USGS 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.

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, average temperatures for the 24-hour period prior to the mean time that samples containing single salmonid prey were eaten (11:00 AM) were used. 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:

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

Equation 2 was 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):

$$C = n(24/ET90) \qquad [3]$$

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

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:

$$SE = PExFxC \qquad [4]$$

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 3.

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:

$$S_{tot} = (PE / SL)xRLxFxC \qquad [5]$$

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

Production

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 376 in 1998, 662 in 1999, 984 in 2000, and 413 in 2001 (Watson and LaRiviere 1999; Watson and Cummins 2000; RickWatson 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 a reasonable approximation.

Results

Smallmouth Bass

Abundance Estimates

We used a relationship between mark-recapture population estimates performed in 1988, 1999, 2000, and 2002 and CPUE to estimate abundance of smallmouth bass for all weeks in 2002 (Figure 2).

Abundance of bass ≥150 mm increased during the spring from a low of 2,942 on March 16 to a high of 36,463 on June 21. Abundance estimates for 2002 were similar to all years (Figure 3) except for 2001, which had much lower estimates (Fritts et al. 2002). Population estimates from 1998 to 2002 showed a similar trend of increasing abundance throughout the spring (Figure 3).

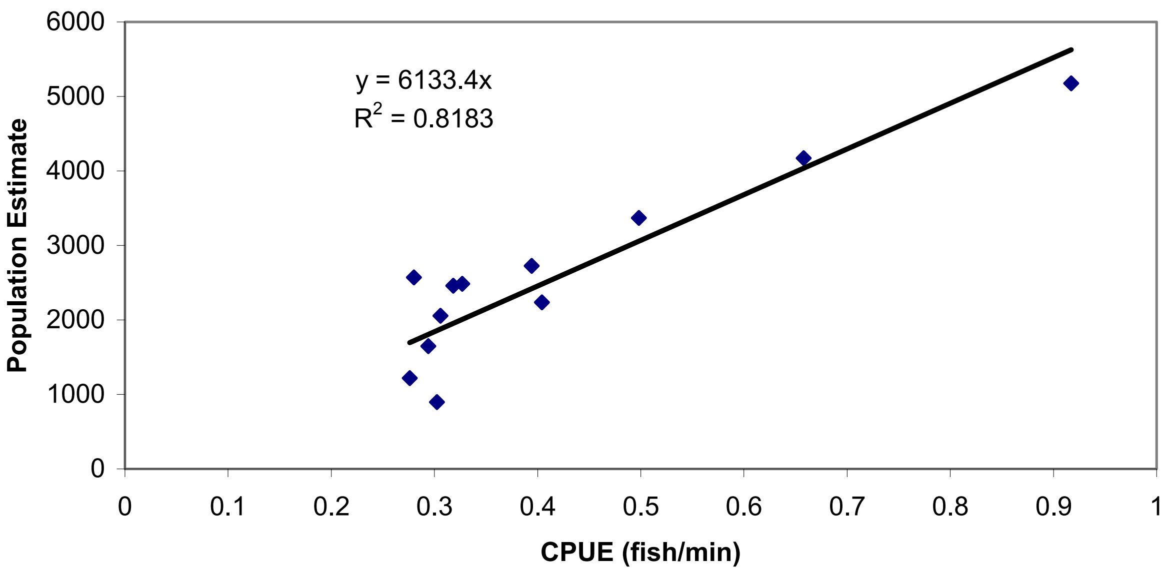

Figure 2. Relationship between CPUE and population estimates in the Benton and Vangie sections during 1998, 1999, 2000 and 2002.

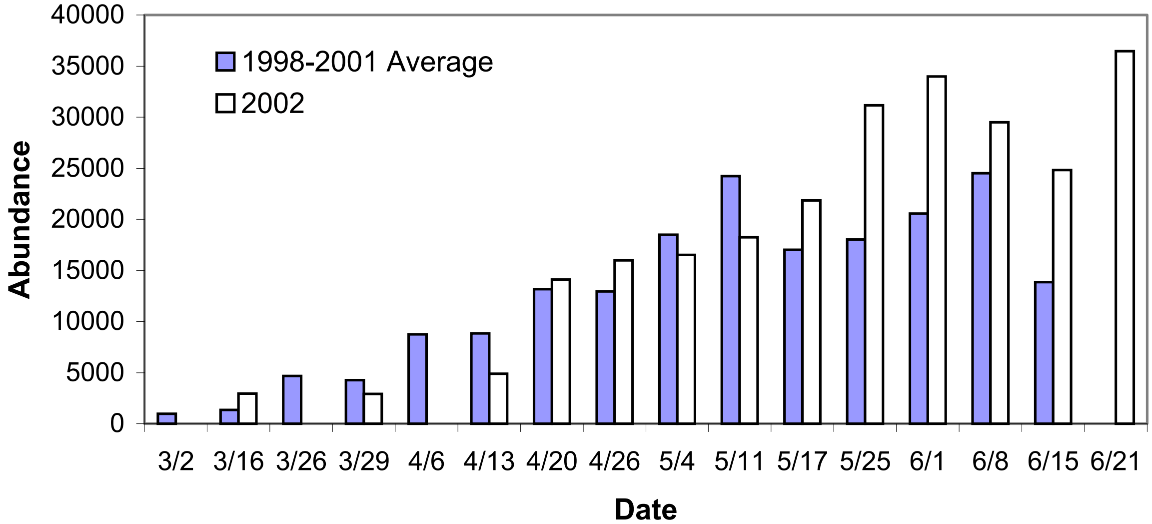

Figure 3. Average weekly estimated abundance of smallmouth bass ≥ 150 mm FL in the lower 68 km of the Yakima River 1998 to 2001 versus 2002.

The increase in abundance between March and June is attributed to immigration and recruitment of smaller fish into the 150 mm and larger size category. We believe smallmouth migrate from the Columbia River into the Yakima River and back because the trend of movement upstream in the spring and downstream in the summer continued in 2002 (Figure 4).

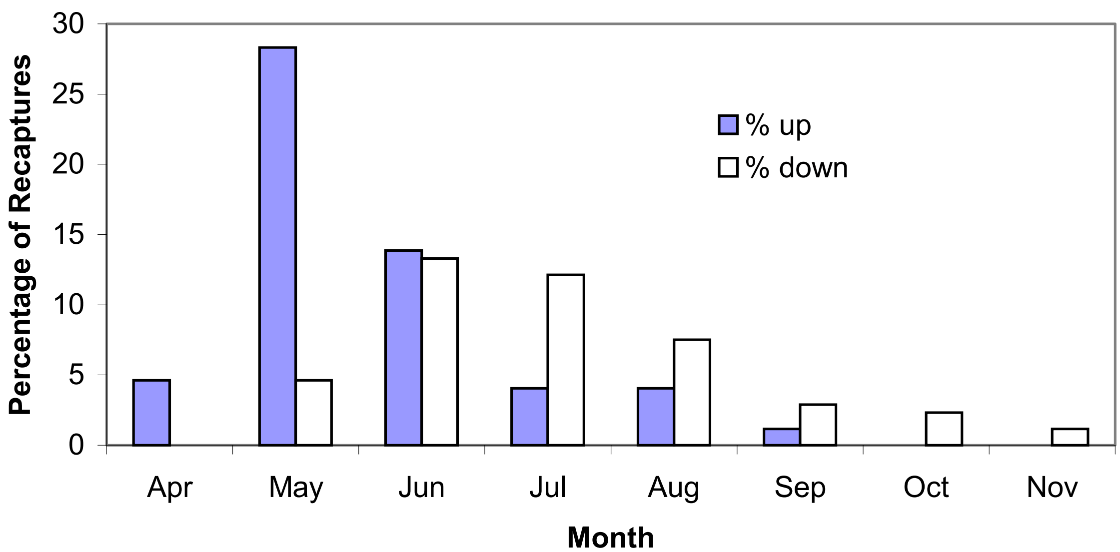

Figure 4. Movement of tagged smallmouth bass in the Yakima River based on electrofishing and angling recapture data from 1997 to 2002. Fish were only used if they moved more than 5 km and were at large less than 250 days.

Diet

Fall chinook salmon were found in the guts of smallmouth bass throughout the sampling period and peaked the week of May 20. This coincided with a release of over one million hatchery fall chinook at Chandler (Table 1). Spring chinook were rarely found in the guts. The percentage of stomachs that contained salmonids in the gut rose sharply in mid to late April and remained high until the beginning of June when it decreased considerably (Table 1). Thirteen fish taxa were identified in the guts of smallmouth bass (Table 2). As was seen in the other years of this study, fall chinook salmon were the dominant fish species consumed, making up 45.6 percent of the fish found in the guts (Table 2). Mountain whitefish and dace made up a relatively small proportion of the fish consumed in 2002 compared to previous years (Table 2). Channel catfish and smallmouth bass made up a relatively large proportion of the fish consumed in 2002 compared to previous years (Table 2).

Table 1. Summary results of diet analyses for smallmouth bass ($\geq$ 150 mm FL) sampled in the Benton and Vangie reaches from March 14 to June 21, 2002. The number of stomachs examined (N), the number of guts in each sample that were empty, 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	Salmonid	SPC
3/14	Benton	10	8	0	2	0	0
3/28	Benton	14	4	6	4	0	1
4/11	Benton	14	3	8	2	0	0
4/18	Benton	46	26	9	12	7	1
4/24	Benton	83	23	49	12	3	0
5/02	Benton	45	14	24	7	6	0
5/09	Benton	52	14	26	13	6	0
5/16	Benton	45	10	22	15	12	0
5/23	Benton	59	12	34	17	13	0
5/30	Benton	61	15	28	18	8	0
6/06	Benton	42	11	21	11	0	0
6/13	Benton	35	6	22	7	4	0
6/20	Benton	55	21	32	7	0	0
3/15	Vangie	7	6	1	0	0	0
3/29	Vangie	4	3	1	0	0	0
4/12	Vangie	22	16	4	2	1	0
4/19	Vangie	26	12	5	9	2	0
4/26	Vangie	77	36	34	8	3	0
5/03	Vangie	42	9	29	4	4	0
5/10	Vangie	34	8	22	4	2	0
5/17	Vangie	26	14	7	5	0	1
5/24	Vangie	20	6	11	5	2	0
5/31	Vangie	36	8	20	7	5	0
6/07	Vangie	45	13	29	2	0	0
6/14	Vangie	47	15	30	2	1	0
6/21	Vangie	42	9	31	2	0	0

Table 2. Species composition of fish found in smallmouth bass stomachs collected in the lower Yakima River March 14 through June 21, 2002. 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	CHM	COH	DAC	FAC	LAMP	MWF	NPM	NSA	SAL	SMB	SPC	SUC
3/14	Benton	2										1			1
3/28	Benton	4				1							2	1	
4/11	Benton	2		1									1		
4/18	Benton	15		3		1	7		1		1		1	1	
4/24	Benton	13		1			3						8		1
5/02	Benton	8					7								1
5/09	Benton	14	3			1	6		1		1		2		
5/16	Benton	18					15		1			2			
5/23	Benton	24	7			1	14				1				1
5/30	Benton	30	3				18		2	1	1	1	2		2
6/06	Benton	11	1	1		1			1		3	1	2		1
6/13	Benton	9	1			1	5				1		1		
6/20	Benton	8	4			2					2				
3/15	Vangie	0													
3/29	Vangie	0													
4/12	Vangie	2					1		1						
4/19	Vangie	10	1			1	2				2	1	3		
4/26	Vangie	10	2				3		3		1		1		
5/03	Vangie	6					6								
5/10	Vangie	5					3		2						
5/17	Vangie	6		1					2		1			1	1
5/24	Vangie	5	1				2				2				
5/31	Vangie	9	2				6				1				
6/07	Vangie	2							1				1		
6/14	Vangie	2				1	1								
6/21	Vangie	2	1								1				
Totals		217	26	7	0	10	99	0	15	1	18	6	24	3	8
Percent total			12.0	3.2	0.0	4.6	45.6	0.0	6.9	0.5	8.3	2.8	11.1	1.4	3.7

[a] CCF = channel catfish, CHM = chiselmouth, COH = coho salmon, 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

Smallmouth bass, suckers, fall chinook salmon, common carp, mountain whitefish, spring chinook salmon, and chiselmouth were the most abundant fishes that we observed in the lower Yakima River (Table 3, 4). The numbers of fish that we observed gradually increased during the sampling period. Fall chinook salmon were relatively rare until April 19 and spring chinook salmon were relatively rare after April 19, 2002 (Figure 5).

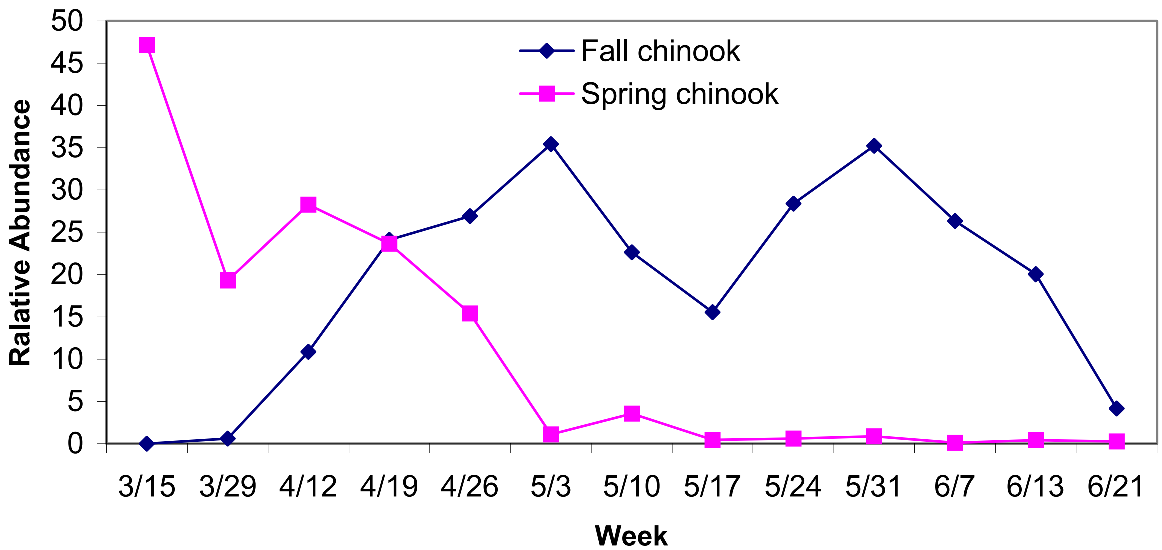

Figure 5. Relative abundance (percent of all prey-sized fish observed) of spring chinook salmon smolts and fall chinook parr and smolts in the Benton and Vangie sections of the lower Yakima River versus sample date, 2002.

Table 3. 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 14	March 28	April 11	April 18	April 24[c]	May 2	May 9
BBH	0.17	5.83	0.38	0.00	0.11	0.00	0.61
BRT	0.00	0.14	0.13	0.13	0.47	0.09	0.00
CCF[b]	0.00	0.00	0.00	0.00	0.11	0.00	0.09
CCP	6.29	2.84	6.90	4.70	3.11	7.07	1.66
CHM	1.75	0.14	6.13	4.97	0.95	2.72	1.13
COH	0.00	0.00	1.92	0.00	0.74	0.00	0.00
DAC	0.35	0.00	2.55	0.40	4.16	1.99	0.17
FAC	0.00	0.57	12.39	24.46	22.64	32.61	17.98
LMB	0.00	0.00	0.00	0.00	0.00	0.00	0.17
LMP	0.00	0.14	0.00	0.00	0.00	0.00	0.00
MWF	15.03	14.79	8.94	2.82	4.32	4.98	8.46
NPM	1.22	1.42	1.15	1.34	1.53	1.63	1.22
PMK	0.00	0.14	0.00	0.00	0.00	0.00	0.00
PMO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSS	0.00	0.14	0.00	0.00	0.00	0.36	0.00
SCU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SMB	18.37	37.72	21.45	29.33	34.95	29.62	53.76
SPC	42.83	25.32	23.37	15.86	17.80	0.27	5.24
SUK	13.99	10.53	13.67	15.32	8.79	18.21	9.42
WCR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSH	0.00	0.28	1.02	0.67	0.32	0.45	0.09
YLP	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	572	703	783	744	1899	1104	1146

[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), 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 3 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 16	May 23	May 30	June 6	June 13	June 20
BBH	0.41	0.00	0.14	0.46	0.33	0.44
BRT	0.14	0.00	0.00	0.00	0.17	0.00
CCF[b]	0.00	0.30	0.14	0.00	0.33	0.74
CCP	5.67	5.76	8.80	13.81	13.86	7.94
CHM	7.05	6.06	12.86	8.95	13.37	6.76
COH	0.00	0.00	0.27	0.00	0.00	0.00
DAC	7.47	6.21	0.00	6.98	3.96	17.06
FAC	18.12	20.61	18.94	13.81	13.20	4.12
LMB	0.14	0.00	0.00	0.00	0.00	0.00
LMP	0.00	0.00	0.00	0.00	0.00	0.00
MWF	3.60	3.94	3.25	1.97	0.50	0.88
NPM	1.38	1.52	4.19	1.67	0.66	1.18
PMK	0.00	0.00	0.00	0.00	0.00	0.00
PMO	0.00	0.00	0.00	0.00	0.00	0.00
RSS	0.00	0.00	0.00	0.00	0.00	0.00
SCU	0.00	0.00	0.00	0.00	0.00	0.00
SMB	38.73	34.24	23.66	25.64	31.84	32.94
SPC	1.11	1.82	1.22	0.61	0.33	0.44
SUK	16.18	19.39	26.39	26.10	21.45	27.50
WCR	0.00	0.15	0.00	0.00	0.00	0.00
WSH	0.00	0.00	0.14	0.00	0.00	0.00
YLP	0.00	0.00	0.00	0.00	0.00	0.00
Totals	723	660	739	659	606	680

[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), 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. 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 15	March 29	April 12	April 19	April 26[c]	May 3	May 10
BBH	0.71	0.41	0.14	0.26	0.49	0.24	0.64
BRT	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CCF[b]	0.00	0.00	0.00	0.13	0.00	0.12	0.00
CCP	15.91	13.95	20.68	14.78	10.86	14.88	6.55
CHM	0.00	0.00	1.51	3.69	4.06	2.80	0.80
COH	0.00	0.00	0.00	0.00	0.14	0.00	0.00
DAC	0.00	0.00	0.96	0.00	0.28	0.00	0.00
FAC	0.00	0.27	0.96	10.82	16.33	14.63	18.85
LMB	0.00	0.00	0.14	0.00	0.00	0.37	0.16
LMP	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MWF	26.13	35.57	15.21	2.24	7.92	11.10	6.23
NPM	0.00	0.00	0.14	0.40	1.89	1.71	1.12
PMK	0.00	0.00	0.00	0.00	0.07	0.24	0.32
PMO	0.00	0.00	0.00	0.13	0.00	0.00	0.00
RSS	0.00	0.14	0.00	0.66	0.07	0.12	0.00
SCU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SMB	13.30	20.52	15.60	22.70	32.80	29.15	51.44
SPC	7.13	2.33	11.92	18.73	6.66	1.46	0.32
SUK	36.10	26.54	32.74	25.20	18.29	23.17	13.42
WCR	0.24	0.00	0.00	0.00	0.00	0.00	0.00
WSH	0.48	0.27	0.00	0.13	0.14	0.00	0.16
YLP	0.00	0.00	0.00	0.13	0.00	0.00	0.00
Totals	421	731	730	758	1427	820	626

[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), 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 Vangie section (rkm 12.2 – 20.2). Total number of fish observed per day is listed for reference.

Species.[a]	May 17	May 24	May 31	June 7	June 14	June 21
BBH	1.40	0.46	0.00	0.00	0.00	1.86
BRT	0.00	0.00	0.00	0.00	0.00	0.00
CCF[b]	0.00	0.46	0.65	0.75	2.79	1.86
CCP	14.34	16.31	31.92	15.55	25.46	13.36
CHM	2.45	3.96	10.57	7.14	9.67	10.20
COH	0.00	0.00	0.00	0.00	0.00	0.00
DAC	1.75	0.00	0.00	0.00	0.00	0.00
FAC	1.57	15.40	10.89	13.42	2.42	0.37
LMB	0.17	0.00	0.11	0.00	0.00	0.00
LMP	0.00	0.00	0.00	0.00	0.00	0.00
MWF	9.44	2.29	0.11	0.64	1.49	1.11
NPM	2.45	0.61	1.31	1.06	4.09	5.57
PMK	0.00	0.46	0.00	0.00	0.19	0.00
PMO	0.70	0.30	0.00	0.00	0.00	0.00
RSS	0.00	0.15	0.00	0.00	0.00	0.00
SCU	0.00	0.00	0.00	0.00	0.00	0.00
SMB	27.80	25.30	15.03	24.27	36.42	30.97
SPC	0.17	0.15	0.00	0.00	0.00	0.00
SUK	37.76	34.15	29.41	37.17	17.47	34.51
WCR	0.00	0.00	0.00	0.00	0.00	0.19
WSH	0.00	0.00	0.00	0.00	0.00	0.00
YLP	0.00	0.00	0.00	0.00	0.00	0.00
Totals	572	656	918	939	538	539

[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), 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

Consumption of salmonids by smallmouth bass in 2002 followed the same general pattern as the four previous years (Figure 6). Between March and early May consumption was relatively low and gradually increased as bass abundance, available prey, and temperatures increased. Consumption then quickly rose to a peak in late May then began to decline through mid June despite high bass abundance and increasing temperatures. One possible explanation for this decrease is that availability of salmonids begins to decrease in June. An additional explanation is that bass are beginning to spawn at this time and have ceased to feed (Fritts et al. 2001). Between March 22 and June 16, 2002, we estimated that smallmouth bass consumed 175,712 salmonids of which 2,570 were spring chinook or coho. Between the same dates in 2001 we estimated 230,265 salmonids, 6,906 of which were spring chinook and coho, were consumed. In 2000 we estimated 202,722 salmonids of which 3,083 were spring chinook or coho, were consumed.

We found a positive relationship between fall chinook salmon redd counts and consumption by smallmouth bass for the years 1999 to 2002 (Figure 7). We were unable to include the 1998 consumption estimate due to the lack of a redd estimate for 1997.

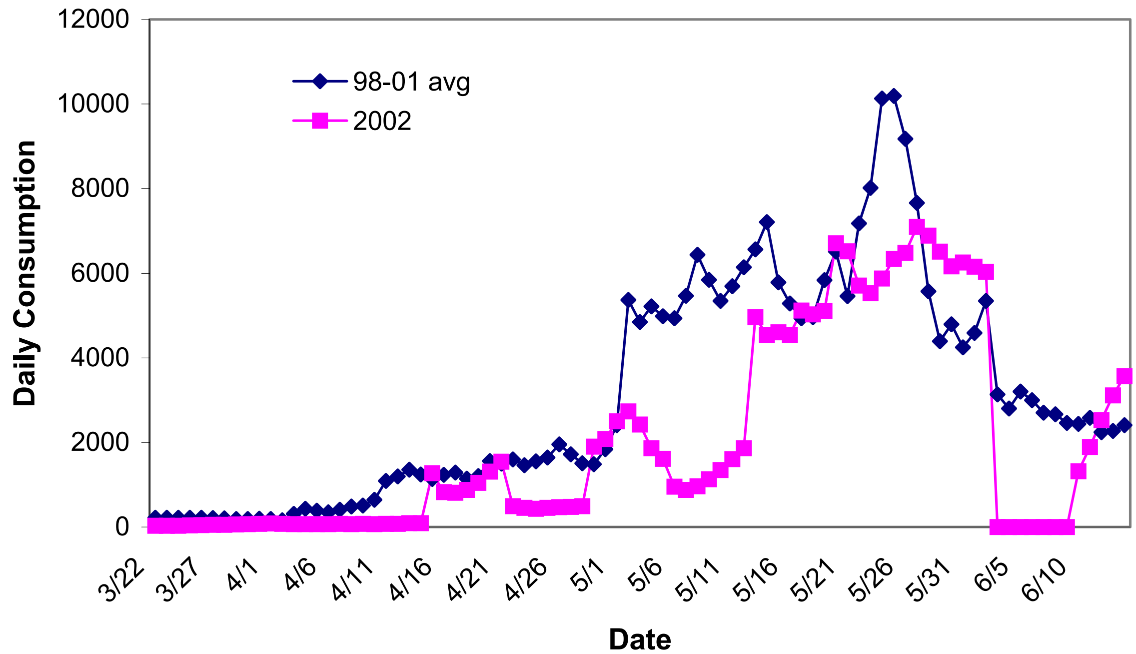

Figure 6. Estimates of average daily salmonid consumption by smallmouth bass from 1998 to 2001 versus 2002 in the Yakima River between Prosser Dam and the confluence of the Columbia River.

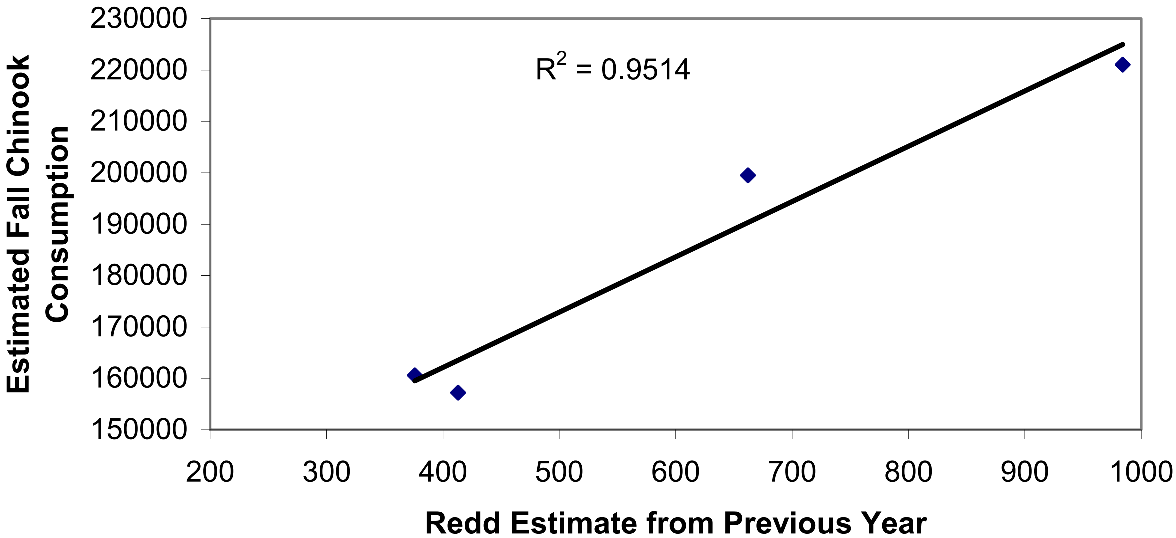

Figure 7. Estimated fall chinook consumption versus the estimated number of fall chinook salmon redds in the lower Yakima River below Prosser Dam from the previous year. Consumption estimates for the years 1999 to 2002 are covered.

Production

We estimated 188,000 naturally produced fall chinook fry emerged in 1999, 331,000 emerged in 2000, 492,000 emerged in 2001, and 206,500 emerged in 2002 below Prosser Dam. 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, 11% had passed by June 1 in 2000, 8% had passed by June 1, 2001, and 15% had passed by June 1, 2002 (a substantial number were trapped and hauled from Chandler and released near the mouth of the Yakima River in late May 2001 due to low flows) 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 River 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 8). We have found evidence that the impact of smallmouth bass on fall chinook salmon increases with decreased production of fall chinook (Figure 9).

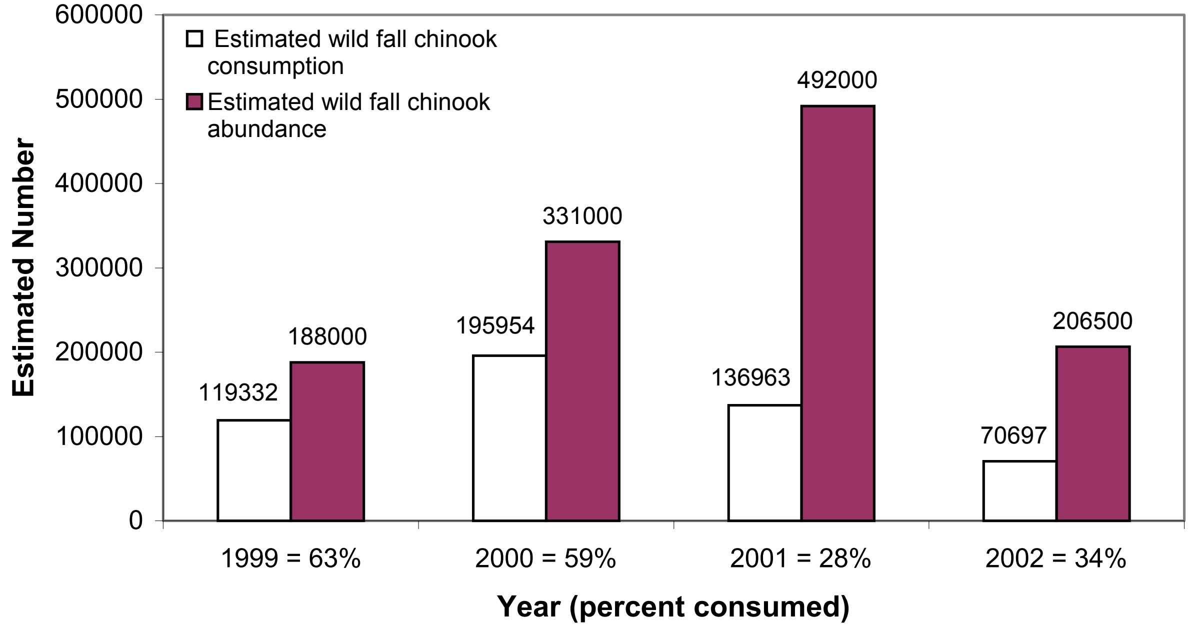

Figure 8. Estimated naturally produced fall chinook abundance below Prosser Dam and estimated consumption from March 22 to June 30 by smallmouth bass for 1999 to 2002 in the lower 68 km of the Yakima River. Listed in parentheses is the percent of natural production consumed by smallmouth.

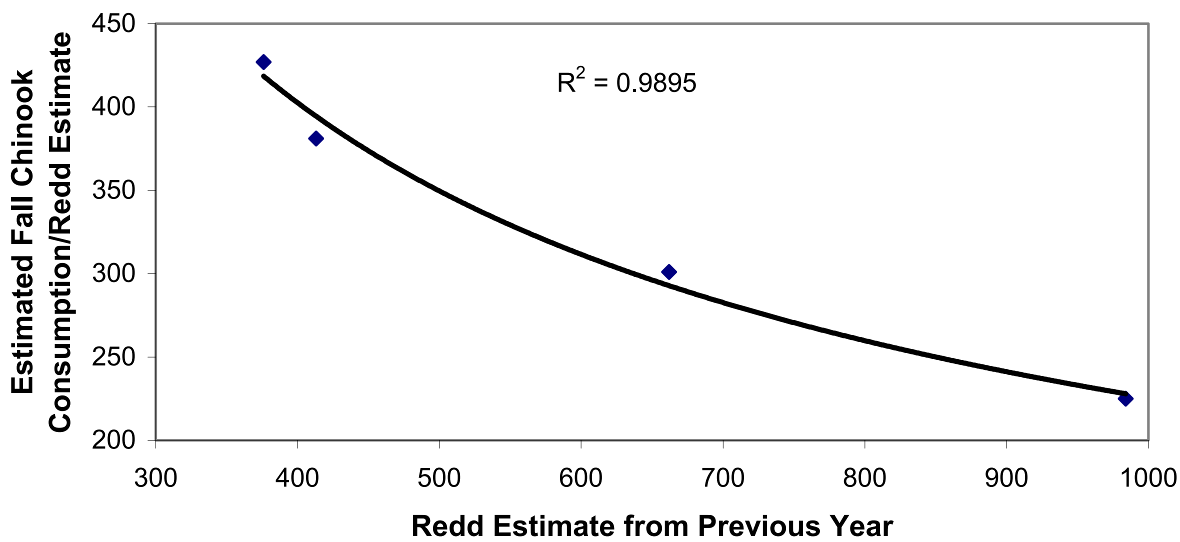

Figure 9. Estimated fall chinook salmon consumption divided by the redd estimate for the lower Yakima River below Prosser Dam from the previous year versus the redd estimate from the previous year. Consumption estimates for the years 1999 to 2002 are covered.

Percent of Population Consumed

We compared our estimated consumption to estimated numbers of juvenile salmonids above and below Prosser Dam to show the relative impact of smallmouth predation (Table 5). The most significant population impact was to wild fall chinook. However, during 2001, a higher percentage of yearling salmonids were consumed than were subyearling salmonids.

Table 5. Population size, estimated number consumed and percent of population consumed by smallmouth bass for salmonid species during March 1 to June 30, 1999 to 2002. Population sizes are from estimated passage at Chandler (YN data) and estimated fry production below Prosser for fall chinook.

		Species[a]				
		WFAC	HFAC	WSPC + WCOHO	HSPC + HCOHO	WSTH
1999	Population size	227,000	1,891,000	211,788	219,082[b]	32,868
	Number consumed	119,332	57,591	3,083	0	0
	Percent consumed	53	3	1	0	0
2000	Population size	529,000	2,012,135	94,352	390,064	42,696
	Number consumed	195,954	10,123	3,795	0	0
	Percent consumed	37	0.5	4	0	0
2001	Population size	2,169,500[c]	2,076,000	137,300	894,000	28,428
	Number consumed	136,963	135,410	10,833	2,037	0
	Percent consumed	6	7	8	0.2	0
2002	Population size	250,620	2,000,000	386,814	355,749	38,523
	Number consumed	94,611	78,532	2,597	0	0
	Percent consumed	38	4	0.7	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.
[C]Estimates of passage at Chandler may be inflated due to higher than average entrainment rates caused by extremely low discharges.

Channel Catfish

The diets of channel catfish in 2002 were similar to previous years base on samples obtained by electrofishing (Table 6). The low percentage of catfish containing salmonids the last four years of sampling suggests they may not be as serious a predator in our study area as was once thought, although our sample sizes are small due to the difficulty of capturing channel catfish by electrofishing (Table 7).

Of the 34 adult sized channel catfish we captured by electrofishing in 2001, 78 percent were captured in the Vangie section and 65 percent were captured in the month of June. This suggests the majority of catfish migrate into the Yakima River later in the spring than do smallmouth bass and possibly do not travel as far upstream as the bass.

Table 6. Composition of channel catfish stomachs collected during electrofishing in the lower Yakima River, April through June 1998, 1999, 2000, 2001, and 2002. 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 [a]	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	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)
2001	19	8	4	1	5	1	1	0	0
		(42.1)	(21.1)	(5.3)	(26.3)	(5.3)	(5.3)	(0.0)	(0.0)
2002	23	8	2	0	12	3	6	0	0
		(34.7)	(8.7)	(0.0)	(52.2)	(13.0)	(26.1)	(0.0)	(0.0)

[a]Results using channel catfish samples gathered by electrofishing, trapping and gillnetting during 1998.

Table 7. Species composition of fish found in channel catfish stomachs collected in the lower Yakima River April through June 1998, 1999, 2000, 2001, and 2002. 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 [b] (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 (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
2001 (N=4)													
0	0	0	0	0	1	1	1	0	0	0	0	1[c]	0
0.0	0.0	0.0	0.0	0.0	25.0	25.0	25.0	0.0	0.0	0.0	0.0	25.0	0.0
2002 (N=2)													
0	0	0	0	0	2	0	0	0	0	0	0	0	0
0.0	0.0	0.0	0.0	0.0	100	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 channel catfish samples gathered by electrofishing, trapping and gillnetting during 1998.
[c]Probably a coho based on diagnostic bone measurements versus length measurement in field.

Discussion

Predation by smallmouth bass has undoubtedly contributed substantially to the lowered survival of naturally produced fall chinook salmon in the lower Yakima River, but is 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 observed that smallmouth bass rarely ate yearling salmonids but readily consumed subyearlings (Poe et al. 1991; Tabor et al. 1993; Poe et al. 1994; Zimmerman 1999).

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). However, we found that wild fall chinook salmon were more susceptible to predation than hatchery fall chinook salmon. 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.

Because consumption increased in years of high natural production of fall chinook salmon (Figure 7), we believe this is another indicator that smallmouth bass are compensating for increased production by increasing their predation rate. This type of compensatory predation is a major concern if your objective is to have high numbers of naturally producing salmonids. Survival of fall chinook salmon will have to be increased in other life stages or geographic areas in order to exceed a threshold (maximum consumption) where predators will no longer be able to increase their predation rate to take advantage of the higher availability of salmonid prey. Although compensatory predation seems to be occurring, there is some evidence that smallmouth bass can be swamped by large numbers of fall chinook salmon so that their impact is reduced when fall chinook salmon densities are higher (Figure 9).

Consumption of spring chinook by smallmouth bass has been relatively small compared to consumption of fall chinook during the last four years we have sampled (2.1% of consumed salmonids are spring chinook). This is approximately 1.5% of hatchery produced or 2.2% of wild spring chinook smolts passing Prosser Dam from 1999 to 2002. 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 to 2002 has shown that smallmouth bass generally ate smaller fish such as fall chinook salmon and rarely ate fish over 100 mm in length (Figure 10). Based on data collected at the Chandler Juvenile Monitoring Facility, 100 mm is about the smallest spring chinook salmon that could be expected to emigrate through our study section in the spring.

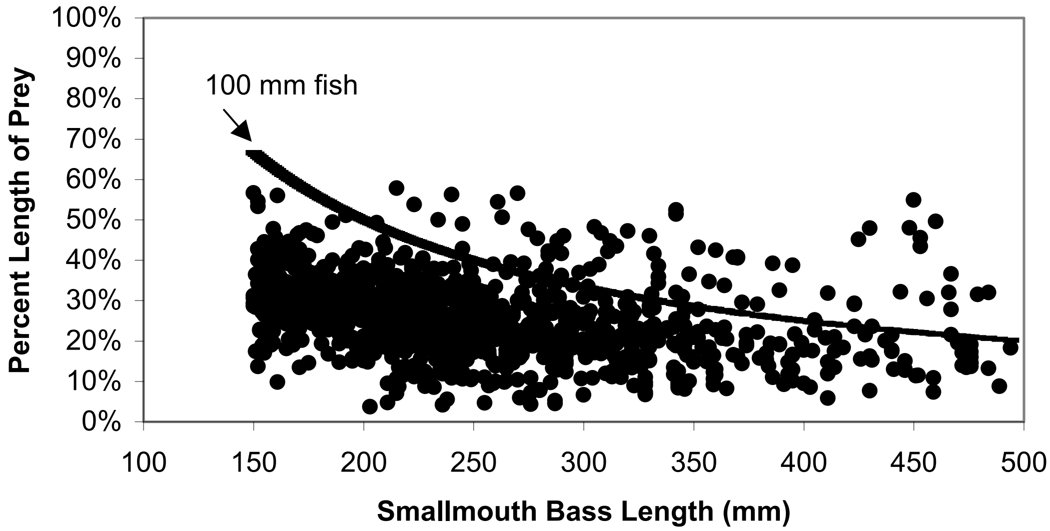

Figure 10. Percent lengths (FL) of fish found in smallmouth bass gut samples from 1998 to 2002. Included is the percent length of a 100 mm fish for each length of smallmouth.

The abundance (Figure 3) and consumption (Figure 6) estimates from 1998 to 2002 were somewhat different in magnitude but have maintained a similar pattern during all years. Starting in 2002, we had planned on monitoring the effects of a new regulation change for bass in the lower Yakima River by looking for changes in this pattern or changes in the size structure of the population (Fritts et al. 2002). The previous limit was five bass with no more than three over fifteen inches. The bass regulation in the lower Yakima River was changed on May 1, 2002 to no limit for bass less than twelve inches, a protected slot for bass twelve to seventeen inches, and only one bass greater than seventeen inches. This regulation is designed to increase angler exploitation on the smaller bass, which eat the most salmon in the Yakima River during spring. Washington Department of Fish and Wildlife performed angler surveys in 2002 to gauge the amount of angler exploitation on these smaller bass but found little evidence of increased exploitation due to the change (Hoffarth 2002). Due to funding constraints and lack of any appreciable increase in predation by smallmouth bass that could be related to yearling salmonid supplementation, we will not continue sampling in 2003.

Recommendations

In McMichael et al. 1999, a number of methods to reduce predation by smallmouth bass were discussed. Most of these have major shortcomings in terms of the feasibility of implementation or the likelihood of successfully reducing predation. If there is enough interest in reducing predation on fall chinook salmon by smallmouth bass, we recommend investigating the feasibility of removing upstream migrating bass at Horn Rapids (Wanawish) Dam. Smallmouth bass are undoubtedly using the fishways at this dam but may not be able to swim directly over the dam. Traps could be placed at the exits of the two fishways and smallmouth bass (and any other undesirable species) could be removed. This could produce substantial benefits to fall chinook salmon because it would isolate the smallmouth bass population upstream of the dam where we have found the highest incidence of predation occuring. With the smallmouth bass population upstream of the dam isolated from the lower Yakima River/Columbia River population, there is a much higher possibility that various removal methods could succesfully reduce their density and or change their size structure.

Acknowledgments

Gabriel Temple assisted in the field. The Yakama Nation Fisheries provided fish passage data collected at the Chandler Juvenile Monitoring Facility. 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.

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