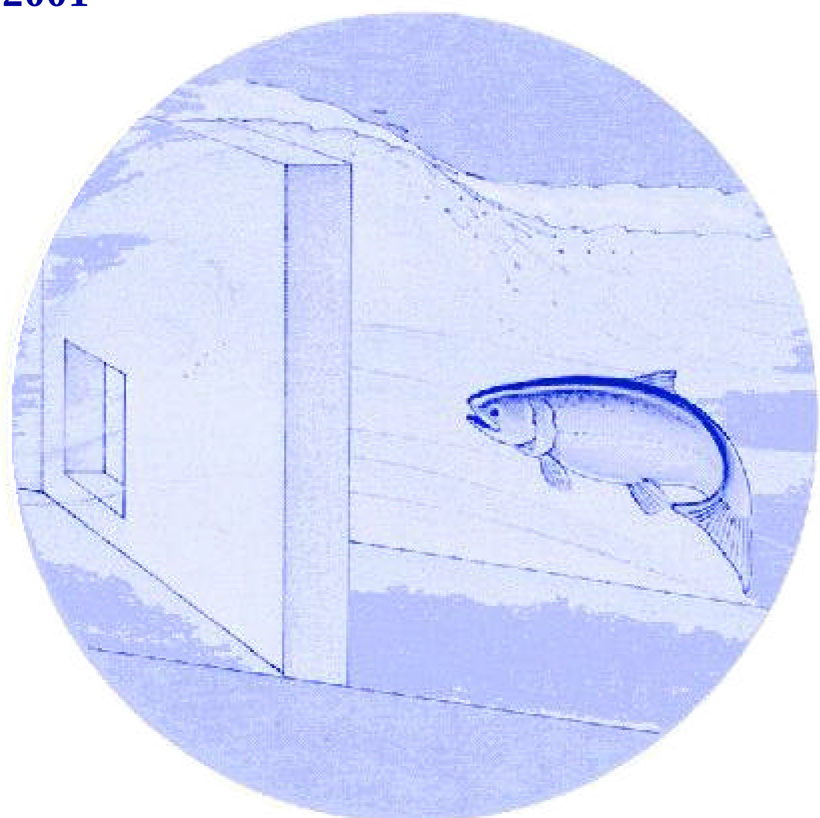
Yakima River Species Interactions Studies

Yakima/Klickitat Fisheries Project Monitoring and Evaluation

Annual Report
2001



DOE/BP-00004666-9

May 2002

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

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.

Yakima River Species Interactions Studies

Annual Report 2001

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Project Number 1995-064-24

May 2002

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 tenth of a series of progress reports that address species interactions research and supplementation monitoring of fishes in the Yakima River basin. Data have been collected 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, 2001 and December 31, 2001 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 taxa (non-target taxa, NTT). To determine changes in NTT status that could be related to hatchery smolt releases, we compared the abundance, size structure, and distribution of 16 non-target taxa before and 3 years after annual spring releases of about 1 million yearling salmon smolts (coho and chinook) in the Yakima River. Approximately 20% of the chinook salmon released were precocial males which did not migrate to the ocean and reared in the freshwater environment along with many NTT. Relative to presupplementation conditions, most of the parameters that we measured increased slightly or did not change, and all, except steelhead size (-1%) and leopard dace abundance (-13%), were within the predetermined containment objectives. Neither of the two status indicators that were outside of the containment objectives were significantly different from pre-supplementation conditions ($P>0.05$). The lack of statistically significant tests for steelhead and leopard dace could be the marginal power of the statistical tests (Power=56% for steelhead and Power=16% for leopard dace with an alpha of 0.10). However, comparisons of the steelhead 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. The decrease in the leopard dace abundance index was also unlikely to have been caused by supplementation activities because the mechanisms of predation that could be influenced by yearling salmon releases were not observed. These results suggest that risk containment actions are not necessary at this time. However, future risks could be reduced by minimizing the production and release of precocially mature salmon.

- We estimated the number of salmonids that smallmouth bass ate during the spring of 2001 in the Yakima River. Predator surveys were conducted during the weeks of March 15 and March 29 and weekly from April 12 through June 15 in two sections of the lower Yakima River and spot sampling in an area of hypothetically high predation, termed a"hotspot".

Abundance was estimated using the relationship between catch per unit effort and population estimates that were calculated using maximum likelihood estimators of mark and recapture data from 1998 to 2000. We were unable to obtain valid mark-recapture estimates in 2001. 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 1,685 on March 16 to a high of 13,104 on May 17. 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 temperature increased. This decrease is likely to be due to bass shifting their behaviors from feeding to spawning. Smallmouth bass ate an estimated 230,265 salmonids during the spring. Only 6,906 of these were estimated to be spring chinook. The remainder was mostly fall chinook salmon. Salmonid consumption estimates for 2001 were similar to estimates for 2000 (202,722 total salmonids and 3,083 spring chinook) despite the lower abundance of bass in 2001. Horn Rapids Dam (Wanawish) again had only a fraction of the smallmouth congregated below it as it had in 1999 and may not be a hotspot during all years.

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 tenth 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). Journal articles and book chapters have also been published from our work (McMichael 1993; Martin et al. 1995; McMichael et al. 1997; McMichael and Pearsons 1998; McMichael et al. 1998; Pearsons and Fritts 1999; McMichael et al. 1999; McMichael et al. 1999; Pearsons and Hopley 1999; Ham and Pearsons 2000; Ham and Pearsons 2001; Amaral et al. 2001; McMichael and Pearsons 2001; Pearsons et al. in press). This progress report summarizes data collected between January 1, 2001 and December 31, 2001. These data were compared to findings from previous years to identify general trends and make preliminary comparisons. Interactions between fish produced as part of the YKFP, termed target species or stocks, and other species or stocks (non-target taxa) may alter the population status of non-target species or stocks. This may occur through a variety of mechanisms, such as competition, predation, and interbreeding (reviewed in Pearsons et al. 1994; Busack et al. 1997). Furthermore, the success of a supplementation program may be limited by strong ecological interactions such as predation or competition (Busack et al. 1997).

Our work has adapted to new information needs as the YKFP has evolved. Initially, our work focused on interactions between anadromous steelhead and resident rainbow trout (for explanation see Pearsons et al. 1993), then interactions between spring chinook salmon and rainbow trout, and recently interactions between spring chinook salmon and highly valued non-target taxa (NTT; e.g., bull trout); and interactions between strong interactor taxa (e.g., those that may strongly influence the abundance of spring chinook salmon; e.g., smallmouth bass) and spring chinook salmon. The change in emphasis to spring chinook salmon has largely been influenced by the shift in the target species planned for supplementation (Bonneville Power Administration et al. 1996; Fast and Craig 1997). Originally, steelhead and spring chinook salmon were proposed to be supplemented simultaneously (Clune and Dauble 1991). However, due in part to the uncertainties associated with interactions between steelhead and rainbow trout, spring chinook 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 which represent major topics associated with monitoring stewardship, utilization, and strong interactor taxa. Chapter 1 reports the results of non-target taxa monitoring after the third 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).

Acknowledgments

We would like to thank Bonneville Power Administration for financially supporting this work. In addition, we could not have completed this work without the help and support of many individuals during 2001. 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 third 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 taxa (non-target taxa, NTT). To determine changes in NTT status that could be related to hatchery smolt releases, we compared the abundance, size structure, and distribution of 16 non-target taxa before and 3 years after annual spring releases of about 1 million yearling salmon smolts (coho and chinook) in the Yakima River. Approximately 20% of the chinook salmon released were precocial males which did not migrate to the ocean and reared in the freshwater environment along with many NTT. Relative to presupplementation conditions, most of the parameters that we measured increased slightly or did not change, and all, except steelhead size (-1%) and leopard dace abundance (-13%), were within the predetermined containment objectives. Neither of the two status indicators that were outside of the containment objectives were significantly different from pre-supplementation conditions ($P>0.05$). The lack of statistically significant tests for steelhead and leopard dace could be the marginal power of the statistical tests (Power=56% for steelhead and Power=16% for leopard dace with an alpha of 0.10). However, comparisons of the steelhead 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. The decrease in the leopard dace abundance index was also unlikely to have been caused by supplementation activities because the mechanisms of predation that could be influenced by yearling salmon releases were not observed. These results suggest that risk containment actions are not necessary at this time. However, future risks could be reduced by minimizing the production and release of precocially mature salmon.

Introduction

Despite the long history of stocking hatchery salmon into streams, few evaluations of impacts to non-target taxa (NTT) have been conducted. Impacts to NTT population size, growth, or distribution generally have not been conclusively demonstrated at scales larger than experimental reaches (Fresh 1997), but many mechanisms of impacts have been documented (Marnell 1986; Nielsen 1994; Hawkins and Tipping 1999). 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 2001). This paper will address impacts that occur during the initial stages of supplementation which has been termed the Broodstock stage by Pearsons (2001). 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 2001). 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 a greater number of smolts than would have occurred naturally. Greater numbers of hatchery smolts increases interaction potentials between hatchery and wild fish in the freshwater migration corridor, freshwater rearing area (e.g., if hatchery fish residualize), estuary, and ocean. Type I interactions are those that occur between hatchery fish (e.g., smolt, residual, or adult) and wild fish (Pearsons and Hopley 1999). If Type I impacts are less than the benefits produced from ecological release, then non-target species will benefit, and the converse is also true. Type I interactions can be non-natural because humans artificially rear and release the fish. Hatchery fish are typically more numerous, more concentrated, larger, and in some instances more aggressive than wild fish (Ruzzante 1994; White et al. 1995). These differences can confer dominance status to hatchery fish (McMichael et al. 1997; Rhodes and Quinn 1998; McMichael et al. 1999), decrease the size refuge of wild fish to predation by hatchery fish (Pearsons and Fritts 1999), and change the functional and numerical response of predators to mixed groups of hatchery and wild fish (Peterman and Gatto 1978; Wood 1987; Collis et al. 1995). If smolts actively migrate after release, then the interactions with NTT in the freshwater migration corridor are likely to be relatively low.

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

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

In this paper, we examine the impacts to NTT during the Broodstock stage of a spring chinook supplementation program and the reintroduction of coho salmon in the Yakima Basin, Washington (Figure 1). Concerns about the possibility of hatchery fish having negative impacts on valued non-target taxa (NTT) in the Yakima basin prompted the development and implementation of a risk containment monitoring program. Spring chinook and coho salmon were released in the upper Yakima Basin for the first time during spring 1999 as part of the Yakima/Klickitat Fisheries Project (YKFP). The goal for both of these species is to increase natural production using artificial propagation (supplementation). A total of 386,048 (229,290 Clark Flats, 156,758 Easton), 589,683 (221,460 Clark Flats, 230,860 Easton, 137,363 Jack Creek), and 738,466 (246,515 Clark Flats, 239,862 Easton, 252,089 Jack Creek) were released during 1999, 2000, and 2001 respectively. Approximately 500,000 coho salmon smolts were released into the upper Yakima Basin during 1999,2000, and 2001. 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 (2000 and 2001). More detail about the study area and background of the supplementation project has been previously described (Pearsons and Hopley 1999; Ham and Pearsons 2000).

Methods

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

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

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

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

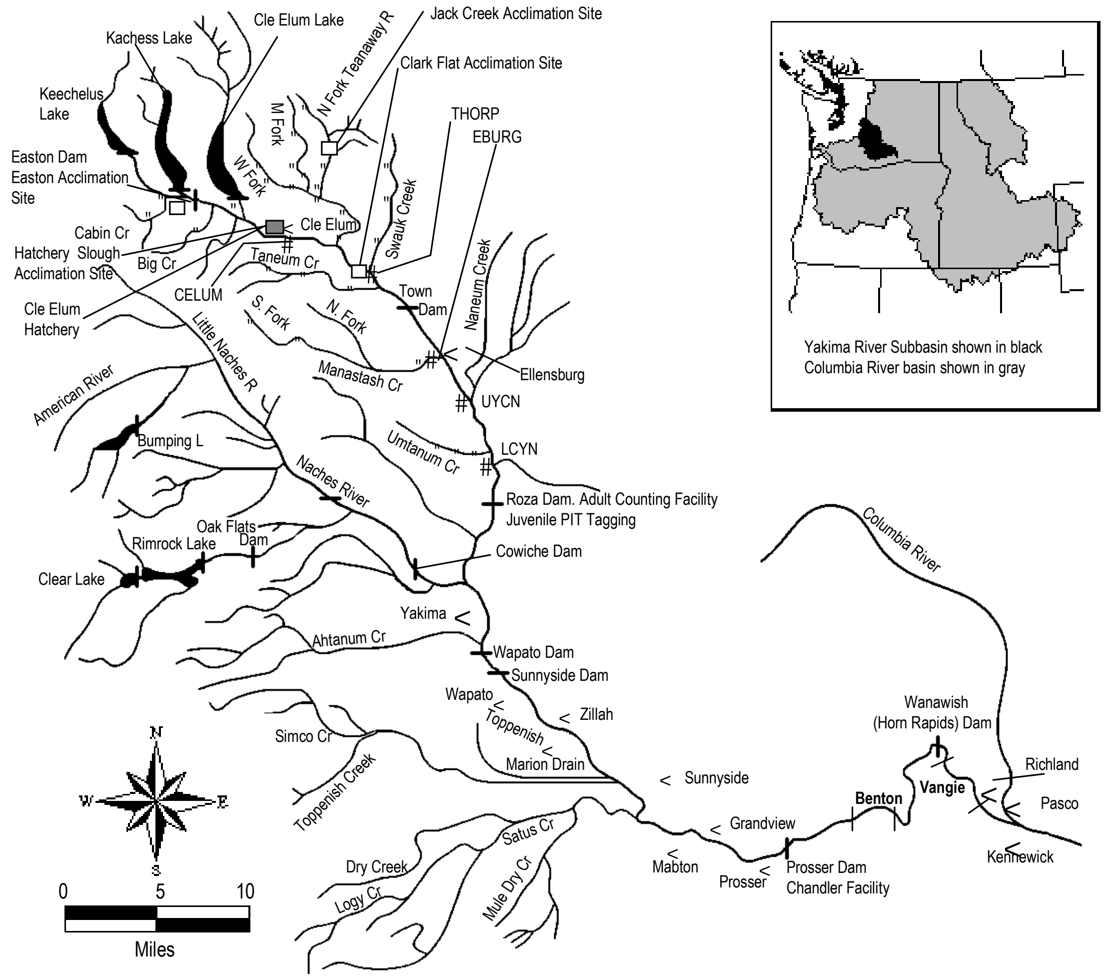

Figure 1. Yakima River Basin. Tributary ("), upper river mainstem (#) and lower river mainstem (|~|) survey sites.

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

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

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

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

Predation indices for fall chinook salmon, leopard dace and sand roller, are calculated using methods described in Chapter 2 of this report. Predation estimates are based on boat electrofishing mark recapture estimates of the predator population, stomach contents to determine relative proportions of prey, and metabolic variables to estimate consumption. The predation index is expressed as the total number of an NTT that is eaten by smallmouth bass during the spring. The abundance of smallmouth bass predators in the lower Yakima River was determined by electrofishing. Diet samples are collected by gastric lavage and frozen for later analysis in the laboratory. Fish consumed are identified by counting, keying and measuring diagnostic bones. Fish lengths of prey are estimated from bone lengths using standard equations (Hansel et al. 1988). Estimated weights are calculated from lengths using our own equations or those of Vigg et al. (1991). Finally, consumption by each predator is calculated using a meal turnover time method.

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

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

Analysis

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

Results

Relative to presupplementation conditions, most of the parameters that we measured increased slightly and all, except steelhead size (-1%) and leopard dace abundance (-13%), were within the predetermined containment objectives (Table 8). There was no overlap of salmon and bull or cutthroat trout in our index sites, which indicates that the supplementation programs did not negatively change the status of these species. Rainbow trout in the mainstem, which is also the analog for steelhead, increased in abundance, decreased slightly in size, and remained unchanged in distribution. The slight decrease in size is outside of the containment objective for steelhead but not for rainbow trout. The status of rainbow trout in the tributaries was similar to baseline conditions. This result is expected because the spatial overlap of salmon and trout was low in all of the tributaries except the North Fork of the Teanaway River. The abundance index of fall chinook salmon increased and spring chinook salmon status remained relatively unchanged. The abundance index for leopard dace was not significantly lower than the baseline value ($P>0.45$; Table 5) and the size index for steelhead was not significantly lower than the baseline size ($P>0.069$; Table 6). The lack of statistically significant tests for steelhead and leopard dace could be the marginal power of the statistical tests (Power=56% for steelhead and Power=16% for leopard dace with an alpha of 0.10). However, comparisons of the 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).

Comparisons of monitoring prescriptions before and after supplementation are presented in Tables 5,6, and 7. Actual values (unmodelled and untransformed) are presented for abundance (Table 9), size (Table 10), and distribution (Table 11).

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

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

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

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

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

NTT	Detection Strategy/Method	Index Sites	Model[5]
Bull trout	Spring chinook salmon spatial overlap/Snorkeling	North Fork Teanaway River, river km 8.0 to 14.2 from the confluence of Jungle Creek	No
Cutthroat trout	Spring chinook salmon spatial overlap/Electrofishing	DOM-A, MAN-3, NFT-3, NFT-A, NFT-B, STF-A, STF-B, SWK-2, SWK-3, TAN-2, TAN-3, TAN-A, TAN-B, WIL-A	No
Pacific lamprey	Predation index (Fall chinook salmon as analog)/Electrofishing	Benton, Vangie	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. [2,3,4]Based on Bureau of Reclamation flow data from stations at the:
[2]Teanaway River near Cle Elum, Wa., [3]Yakima River near Umtanum, Wa., and
[4]Yakima River near Cle Elum, Wa.
[5]Models are only applied to abundance estimates, not size or distribution.

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

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

Table 5. Monitoring prescription for NTT abundance before and during supplementation. The baseline mean, standard deviation, number of baseline survey years, post-supplementation average (n=3, 1999 - 2001 surveys), t statistic, p-level and power analysis where α is set to 0.05 or 0.10 are presented.

NTT	Baseline	(n)	Post	t	p	0.05	0.10
Bull trout	2.00 ± 0.00	(3)	2.00 ± 0.00				
Cutthroat trout	2.00 ± 0.00	(2)	2.00 ± 0.00				
Pacific lamprey	427,972	(1)	193,062 ± 30,851	6.59	0.011		
Steelhead	1.99 ± 0.11	(8)	2.20 ± 0.28	-1.84	0.050		
Fall chinook salmon	427,972	(1)	193,062 ± 30,851	6.59	0.011		
Leopard dace	52,017	(1)	58,957 ± 42,936	-0.14	0.45	8	16
Mountain sucker	2.00 ± 0.07	(6)	1.92 ± 0.09	1.43	0.098	41	57
Sand roller	6,702	(1)	3671 ± 3318	0.79	0.256		
Rainbow trout-main	1.99 ± 0.11	(8)	2.20 ± 0.28	-1.84	0.050		
Spring chinook salmon	5.14 ± 0.24	(16)	5.05 ± 0.31	0.58	0.286	14	24
Mountain whitefish	1.98 ± 0.12	(6)	2.16 ± 0.08	-2.18	0.033		
Rainbow trout – tribs.	2.44 ± 0.14	(9)	2.56 ± 0.10	-1.41	0.095		
Longnose dace	1.99 ± 0.10	(7)	2.09 ± 0.14	-1.26	0.119		
Sculpins	1.98 ± 0.20	(7)	1.82 ± 0.20	1.53	0.082	30	45
Speckled dace	1.98 ± 0.15	(6)	1.58 ± 0.10	4.24	0.002	97	99
Suckers	2.00 ± 0.07	(6)	1.92 ± 0.09	1.43	0.098	41	57

Table 6. Monitoring prescription for NTT size before and during supplementation. The baseline mean, standard deviation, number of baseline survey years, post-supplementation average (n=3, 1999 - 2001 surveys) t statistic, p-level and power analysis where α is set to 0.05 or 0.10 are presented.

NTT	Baseline	(n)	Post	t	p	0.05	0.10
Bull Trout	2.00 ± 0.00	(3)	2.00 ± 0.00				
Cutthrout trout	2.00 ± 0.00	(2)	2.00 ± 0.00				
Steelhead	2.10 ± 0.03	(9)	2.07 ± 0.01	1.61	0.069	41	56
Mountain sucker	1.64 ± 0.13	(6)	1.56 ± 0.16	0.83	0.217	20	33
Rainbow trout-main	2.10 ± 0.03	(9)	2.07 ± 0.01	1.61	0.069	41	56
Spring chinook-salmon	1.78 ± 0.02	(8)	1.79 ± 0.07	-0.21	0.419		
Mountain whitefish	1.43 ± 0.27	(6)	1.29 ± 0.14	0.77	0.233	15	26
Rainbow trout – tribs.	2.13 ± 0.01	(9)	2.13 ± 0.02	-0.73	0.240		
Longnose dace	0.87 ± 0.09	(6)	1.01 ± 0.01	-2.43	0.023		
Sculpins	0.76 ± 0.05	(6)	0.91 ± 0.02	-4.44	0.002		
Speckled dace	0.53 ± 0.10	(6)	0.64 ± 0.05	-1.86	0.053		
Suckers	1.64 ± 0.13	(6)	1.56 ± 0.16	0.83	0.217	20	33

Table 7. Monitoring prescription for NTT distribution before and during supplementation. The baseline mean, standard deviation, number of survey years, post-supplementation average (n=3, 1999-2001 surveys) t statistic, p-value and power analysis where α is set to 0.05 or 0.10 are presented.

NTT	Baseline	(n)	Post	t	p	0.05	0.10
Bull trout	2.00 ± 0.00	(3)	2.00 ± 0.00				
Cutthroat trout	2.00 ± 0.00	(2)	2.00 ± 0.00				
Rainbow trout-main	2.00 ± 0.00	(8)	2.00 ± 0.00				
Mountain whitefish	2.00 ± 0.00	(6)	2.00 ± 0.00				
Rainbow trout – tribs.	4.99 ± 0.02	(7)	4.99 ± 0.02	-0.44	0.335		
Longnose dace	1.89 ± 0.06	(7)	1.84 ± 0.09	1.03	0.166	29	44
Sculpins	1.96 ± 0.02	(6)	1.82 ± 0.13	2.65	0.017	100	100
Speckled dace	1.94 ± 0.09	(6)	1.88 ± 0.00	1.10	0.155	40	57
Suckers	4.56 ± 0.06	(6)	4.52 ± 0.09	0.75	0.238	20	33

Table 8. 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.

		Post Supplementation Change, (%)								
		Abundance			Size			Distribution		
	CO	Average	Min	Max	Average	Min	Max	Average	Min	Max
Bull trout	0	0	0	0	0	0	0	0	0	0
Cutthroat trout	0	0	0	0	0	0	0	0	0	0
Pacific lamprey[1]	0	55	48	62						
Steelhead	0	10	0	27	-1	-2	-1	0	0	0
Fall chinook[1]	-5	55	48	62						
Leopard dace[1]	-5	-13	-89	74						
Mtn. sucker	-5	0	-8	6	22	-22	65	-1	-3	0
Sand roller[1]	-5	45	4	100						
Rainbow – main	-10	10	0	27	-1	-2	-1	0	0	0
Spring chinook	-10	-1	-6	6	0	-4	4			
Mtn. whitefish	-40	9	6	13	25	4	54	0	0	0
Rainbow – tribs	-40	5	1	9	0	-1	2	0	0	0
Longnose dace	-65	5	-1	13	16	14	17	-3	-8	2
Speckled dace	-85	-20	-25	-15	22	16	32	-3	-3	-3
Sculpins	-90	-13	-19	-10	19	16	22	-7	-13	0
Suckers	-90	-4	-8	0	22	-22	65	-1	-3	0

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

Table 9. The actual values for abundance of NTT (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)	19 ± 6 fish
Cutthroat trout	138 ± 90	(9)	197 ± 157 /km
Pacific lamprey	198 ± 241[2]	(6)	127 ± 61 migrants
Steelhead	63,247 ± 38,259[3]	(16)	36,463 ± 7,303 smolts
Fall chinook salmon	108,973 ± 102,976[3]	(16)	640,414 ± 901,397 smolts
Rainbow trout-main	147 ± 43	(8)	264 ± 150 age 1/km
Spring chinook-salmon	158,355 ± 75,216[3]	(16)	134,428 ± 97,379 smolts
Mountain whitefish	247 ± 73	(6)	375 ± 10 subadult/km
Rainbow trout – tribs.	286 ± 89	(9)	372 ± 88 /km
Longnose dace	58 ± 22[4]	(7)	63 ± 10 /site
Sculpins	63 ± 27[4]	(7)	35 ± 7 /site
Speckled dace	104 ± 45[4]	(6)	44 ± 26 /site
Suckers	186 ± 43	(6)	164 ± 23 /km

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

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

NTT	Baseline	(n)	Post Supplementation
Bull trout	275 ± 134 mm	(3)	242 ± 32 mm
Cutthroat trout	153 ± 19 mm	(9)	143 ± 27 mm
Steelhead	166 ± 30 mm	(6)	184 ± 27 mm
Fall chinook salmon	83 ± 5 mm	(8)	87 ± 1 mm
Rainbow trout-main	249 ± 13 mm	(9)	198 ± 3 mm
Spring chinook-salmon	128 ± 4 mm	(8)	129 ± 10 mm
Mountain whitefish	31 ± 15% subadults	(6)	21 ± 6 % subadults
Rainbow trout – tribs.	133 ± 4 mm	(9)	136 ± 8 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 ± 0 g
Suckers	45 ± 13 % adults	(6)	38 ± 14 % adults

Table 11. The actual values for percent spatial distribution of NTT.

NTT	(n)	Baseline	Post Supplementation
Bull trout	(3)	26 ± 17 %	33 ± 0 %
Cutthroat trout	(2)	66 %	75 ± 2 %
Rainbow trout-main	(8)	100 ± 0 %	100 ± 0 %
Rainbow trout - tribs.	(9)	95 ± 4 %	96 ± 4 %
Longnose dace	(7)	79 ± 10 %	71 ± 15 %
Sculpins	(7)	91 ± 5 %	69 ± 21 %
Speckled dace	(6)	89 ± 16 %	77 ± 0 %
Suckers	(6)	80 ± 11 %	72 ± 15 %

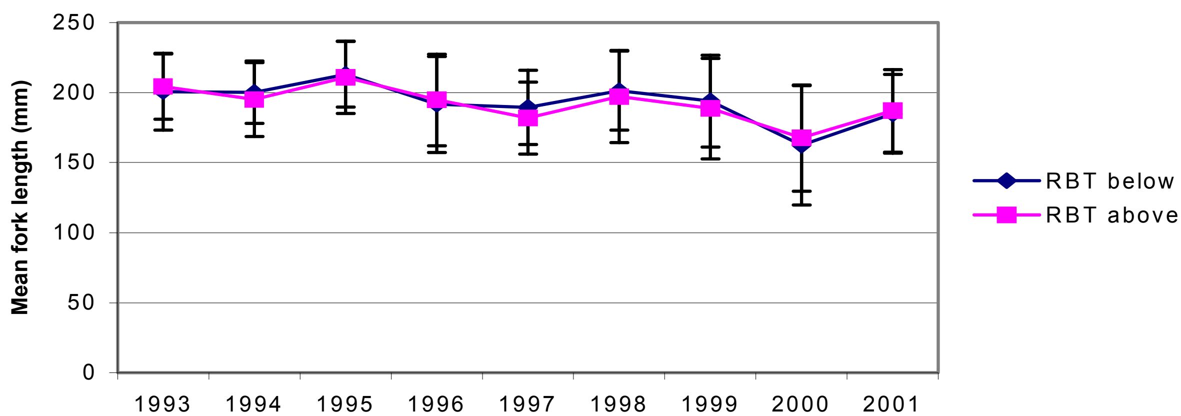

Figure 2. Mean fork length of Yakima River rainbow trout (<250mm) above and below the Clark Flats acclimation site discharge channel. Error bars represent 1 standard deviation.

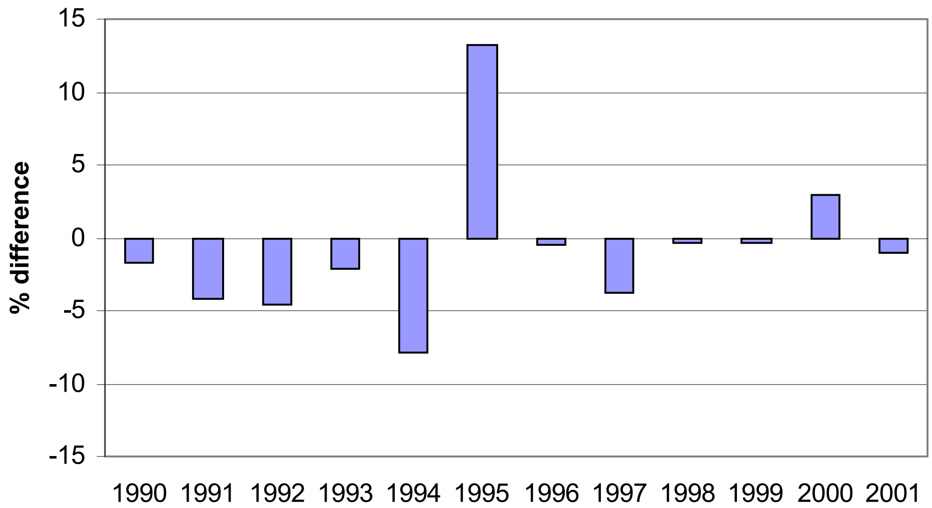

Figure 3. Difference in rainbow trout lengths between treatment and reference streams in the Teanaway Basin.

Discussion

The detection of few negative impacts to NTT status that could be related to supplementation is likely due to 1) the lack of spatial overlap between salmon and NTT, 2) the impacts of hatchery smolts 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, cutthroat trout, rainbow trout in the tributaries, longnose dace, speckled dace, and sculpins). However the opportunity for overlap existed. For example, steelhead were released into the North Fork of the Teanaway River very close to the area where salmon were released, and steelhead migrated upstream into areas containing bull and cutthroat trout (McMichael and Pearsons 2001). Hatchery spring chinook were observed up to 2.4 km above the release site in the North Fork of the Teanaway River during 2000. However, none were observed in index areas containing cutthroat or bull trout. We assume that a lack of overlap precludes significant ecological interactions.

In areas where overlap occurred, negative 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 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 leopard dace, 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. However, the abnormally high survival of progeny of fish that spawned in 1996 produced the largest adult return on record in 2000 and the progeny of these fish had ample opportunity to interact with NTT. Thus, the proportion of the run that was used for hatchery broodstock was relatively high in 1997, 1998, and 1999, and low in 2000. During years when high proportions of the run were taken for broodstock, more ecological release was likely to occur. We expected impacts to be most noticeable during 2001 because the largest number of salmon were released (Type I interactions) and the naturally produced progeny came from the largest number of natural spawners.

Although we observed decreases in the size index of steelhead, the decreases are unlikely to be caused by salmon supplementation. If supplementation decreased the growth of the steelhead index, then we would expect that the size of fish below the Clark Flats acclimation site would have been smaller than the fish above the 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. Neither of these scenarios were observed which suggests that the decrease in steelhead size was not due to supplementation activities. Furthermore, steelhead lengths began to decline during the baseline period before hatchery fish were released. This leads us to conclude that the decline in steelhead lengths is most likely the result of natural variation.

Large numbers of spring chinook salmon did not migrate to the ocean after release (residuals) and may have interacted with NTT. Approximately 20% of the total spring chinook salmon production precocially matured (Don Larson, NMFS, pers. com.) and likely residualized in the river. These fish were concentrated below the Clark Flats acclimation site and some were observed below the Easton acclimation site during 1999 and 2000. Other high concentrations were observed below the acclimation site in the North Fork Teanaway River during 2000. During 2001, precocials were more evenly distributed throughout the Yakima River and the North Fork Teanaway River than in previous years. Hatchery origin residuals were larger than wild conspecifics and modal sized rainbow trout which could confer dominance status to hatchery fish. They also ate similar prey items, and food appeared to be limiting growth to rainbow trout and wild conspecifics (James et al. 1999; WDFW unpublished data). Previously, we found that residual hatchery spring chinook salmon negatively impacted the growth of wild spring chinook salmon in small enclosures in the Teanaway Basin (WDFW unpublished data).

Some of the interactions with NTT may have been benign or produced density dependent benefits because of the large number of smolts released. NTT that fit into this category include many of the species that rear or migrate through the lower Yakima River. This includes leopard dace, Pacific lamprey, fall chinook salmon, sand roller, and spring chinook. The decrease in the leopard dace abundance index was unlikely to have been caused 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 abundance of bass during 2001 which would be expected if the bass were eating yearling smolts and their abundance, survival, and growth benefitted from hatchery releases. Leopard dace are likely to be affected more by subyearling (fall chinook) than yearling releases because bass consume over 150,000 fall chinook annually (Chapter 2). Predators that eat yearling salmonids, such as northern pikeminnow, may be a better indicator of indirect predation impacts of yearling salmonid programs on leopard dace and other NTT.

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 2001). According to this risk containment approach, if we detect a change in status that is greater than a containment objective, we will then 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 leopard dace. The declines in these NTT are unlikely to be due to supplementation and therefore do not require risk containment actions. If substantive declines continue, then more refined methods of determining causation should be implemented. Beginning in 2002 the Building stage will begin. This stage is likely to be the one where the risk of impacts is highest (Pearsons 2001). Monitoring prescriptions described in Table 3 appear to be working as they were designed and should continue to be implemented during 2002. However, the species of predator that is currently used to generate predation indices should be changed to a species that is influenced by yearling programs (e.g., northern pikeminnow). 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 have been depressed 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.

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. By reducing the abundance of these precocially mature salmon, both direct and indirect undesirable interactions with NTT will be reduced. We recommend implementation of feasible strategies to reduce the production and release of precocially mature salmon as soon as possible.

Acknowledgements

We are thankful to the many people on the Ecological Interactions Team who helped collect the data. Anthony Fritts, Germaine Hart, Christopher Johnson, Keith Pitts, Michael Schmuck, and Timothy Webster were instrumental in the collection of field data during 2001 . We thank the Yakama Nation for supplying the status data for the anadromous fishes. We also thank David Byrnes, Bonneville Power Administration who was helpful in securing and administering funding for this work.

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Chapter 2

Lower Yakima River Predatory Fish Monitoring: Progress Report 2001, Bass and Catfish

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Abstract

We estimated the number of salmonids that smallmouth bass ate during the spring of 2001 in the Yakima River. Predator surveys were conducted during the weeks of March 15 and March 29 and weekly from April 12 through June 15 in two sections of the lower Yakima River and spot sampling in an area of hypothetically high predation, termed a"hotspot". Abundance was estimated using the relationship between catch per unit effort and population estimates that were calculated using maximum likelihood estimators of mark and recapture data from 1998 to 2000. We were unable to obtain valid mark-recapture estimates in 2001. 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 1,685 on March 16 to a high of 13,104 on May 17. 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 temperature increased. This decrease is likely to be due to bass shifting their behaviors from feeding to spawning. Smallmouth bass ate an estimated 230,265 salmonids during the spring. Only 6,906 of these were estimated to be spring chinook. The remainder was mostly fall chinook salmon. Salmonid consumption estimates for 2001 were similar to estimates for 2000 (202,722 total salmonids and 3,083 spring chinook) despite the lower abundance of bass in 2001. Horn Rapids Dam (Wanawish) again had only a fraction of the smallmouth congregated below it as it had in 1999 and may not be a hotspot during all years.

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 5,000 juvenile fish were planted in the Yakima River by state game protector N. E. Palmer and again in 1934 (Lampman 1946). By the early 1940's, smallmouth were reported to be plentiful in the lower 68 km of the Yakima River and also in the adjacent Columbia River and up into the Snake River (Lampman 1946). Some researchers have hypothesized that the introduction of smallmouth bass to Northwest rivers has caused a shift in the trophic dynamics of the riverine systems (Li et al. 1987; Poe et al. 1994). Northern pikeminnow *Ptychocheilus oregonensis* was once the keystone predator of the system, but smallmouth bass now occupy areas that pikeminnow formerly inhabited (Li et al. 1987; Fletcher 1991; Shrader and Gray 1999). Smallmouth bass may have displaced pikeminnow through mechanisms of competition or predation. 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 compete with pikeminnow for nonsalmonid prey or displace pikeminnow from near shore littoral habitat, where the usual nonsalmonid prey are abundant, to areas where emigrating salmonids are the dominant prey.

Although smallmouth bass can feed heavily on other fishes (Poe et al. 1991; Zimmerman 1999), there have been mixed reports of smallmouth preying on salmonids in lotic environments of the Northwest. Shrader and Gray (1999) and Summers and Daily (2001) reported no predation on salmonids in the John Day River, Oregon and very low predation on salmonids in the Willamette River, Oregon respectively. The John Day River study was in areas where there are few salmonids rearing and salmonids are only available during the spring outmigration when discharge and turbidity are high and water temperatures are low. The Willamette study was done in a reach where 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 emigrated 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 relatively large runs of spring and fall 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 supplementation (Busack et al. 1997; McMichael et al. 1998; Pearsons et al. 1998; McMichael et al. 1999; Fritts et al. 2001a,b). 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, and the Horn Rapids hotspot.

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

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

Methods

Study Area

The study area and fish fauna was previously described by McMichael et al. (1999). Population estimates were conducted by boat electrofishing in two river sections and catch-per-unit-effort estimates were conducted in a presumptive hot spot. The boundaries of 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". A smallmouth bass hot spot was sampled by angling immediately below Horn Rapids (Wanawish) Dam (rkm 28.1)(Figure 1).

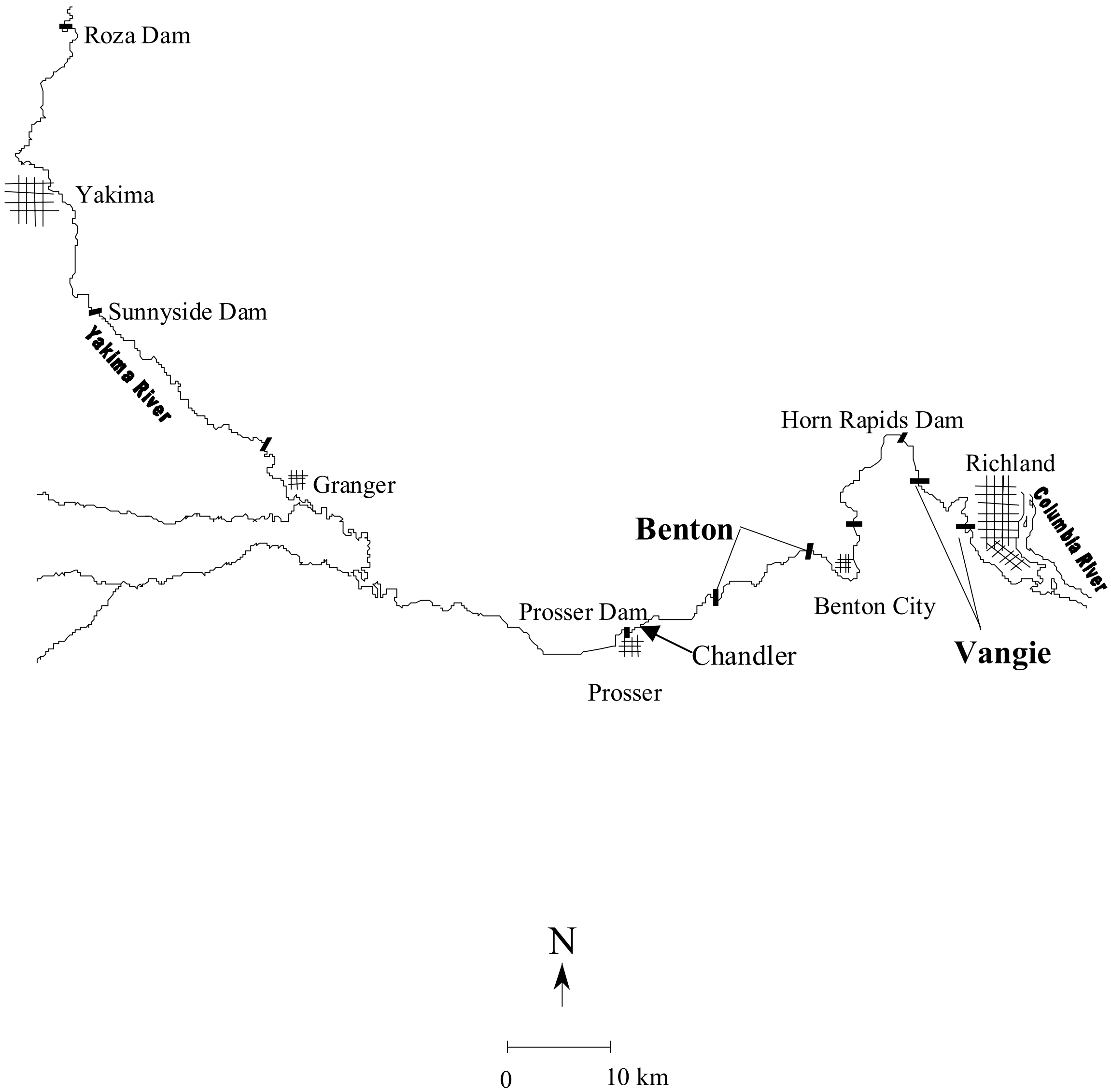

Figure 1. Map of the study area in the lower Yakima River showing index sections in bold type.

Abundance Estimates

Abundance estimates were conducted on smallmouth bass captured by boat electrofishing. We used catch-per-unit-effort (CPUE; smallmouth bass ≥ 150mm FL/min) as an indicator of abundance in both sample sections during 12 sample weeks between March 15 and June 15, 2001. In addition, mark-recapture population estimates were done in the Benton section between May 16 and 17, 2001. Regression analysis was used to examine the relationship between population estimates and CPUE for 1998, 1999 and 2000 data combined. The regression equation was then applied to raw CPUE data to estimate population size for each of the 12 sample weeks in 2001.

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

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

Hot Spots

The Horn Rapids Dam "hot spot" was sampled twice in May by two anglers for one hour. Smallmouth bass were held in large plastic tubs until sampling was completed. Length (mm), weight (g), and condition of fish was recorded and all fish ≥ 200 mm were anchor tagged. A subsample of fish was examined for stomach contents by gastric lavage (Light et al. 1983) and samples were immediately frozen for later examination in the lab. CPUE was calculated for the sample date.

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

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

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

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

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

Consumption

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

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

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

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

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

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

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

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

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

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

Extrapolations

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

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

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

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

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

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

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,and 984 in 2000 (Watson and LaRiviere 1999; Watson and Cummins 2000; RickWatson, WDFW, pers. com.). We used 5000 eggs/female based on the fecundity of fall chinook above Prosser Dam in 1997, which was 4994 eggs/female (Yakama Nation, unpublished data). For estimated survival to emergence we used 10 percent. Although we do not have data to support this survival, Healey

(1991) reported survival from egg to emergence from several published estimates was 30 percent or less under natural conditions. Because the Yakima River below Prosser contains a high percentage of fine sediments and has accumulated contaminants from agricultural runoff and municipal sources, we believe our estimated survival is close to the true number.

Maximum Consumption

Maximum daily consumption of fall chinook by smallmouth bass was calculated for 1999 and 2001 using data collected during our predatory surveys and bioenergetic functions presented by Hanson et al. 1997. Weekly catches of smallmouth ≥ 150 mm were run through the equation for each day of the week using daily average temperatures. The proportion of maximum consumption was set to one in order to simulate feeding at a maximum rate for their specific weight and the water temperature. The average grams consumed daily was then extrapolated over the population estimate of the section and the reach for that week to get total grams consumed in the section and the reach. The total grams consumed were then divided by the average weight of fall chinook in the Lower Yakima for that month to get total maximum daily consumption of fall chinook.

Results

Smallmouth Bass

Abundance Estimates

We were unable to generate a valid population estimate in 2001 apparently due to low numbers of bass. Therefore, we used the relationship between CPUE and mark-recapture estimates that was generated using data from 1998 to 2000 to estimate abundance for all weeks in 2001 (Figure 2).

Abundance of bass ≥150 mm increased during the spring from a low of 1,685 on March 16 to a high of 13,104 on May 17. Estimates declined after May 17 and then rebounded in early June to near peak for the rest of the spring. Abundance estimates were much lower in 2001 compared to 1998 to 2000 (Figure 3). Population estimates from 1998 to 2001 showed a similar trend of increasing abundance throughout the spring (Figure 4).

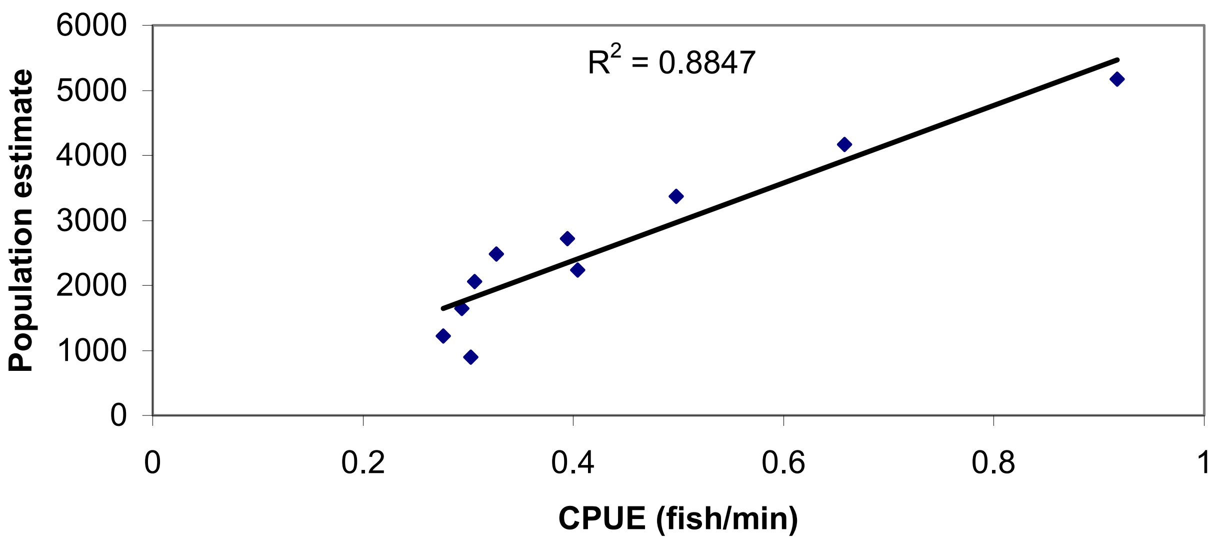

Figure 2. Relationship between CPUE and population estimates in the Benton and Vangie sections during 1998, 1999 and 2000.

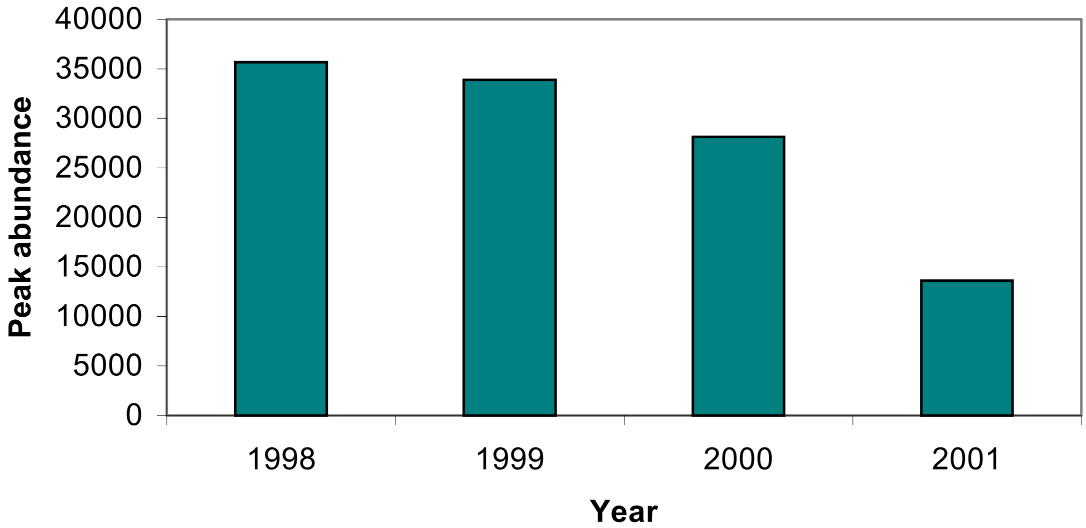

Figure 3. Yearly peak abundance of smallmouth bass for 1998 to 2001.

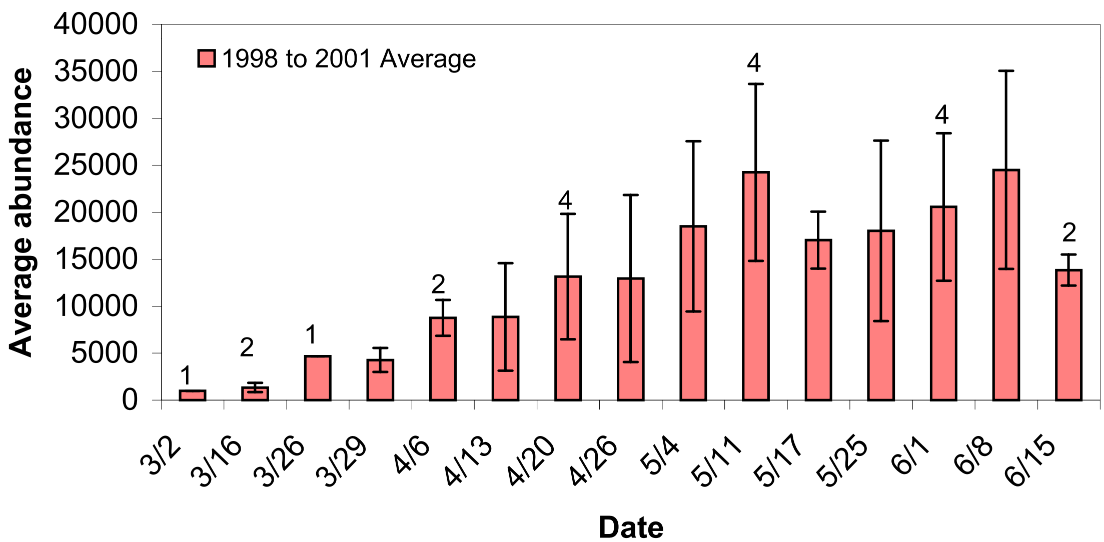

Figure 4. Average weekly estimated abundance of smallmouth bass $\geq$ 150 mm FL in the lower 68 km of the Yakima River 1998 to 2001 with plus and minus one standard deviation. All are based on a sample size of three unless inticated above the bar.

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 2001 (Figure 5). As with last year, we saw a greater increase in bass 150 to 249 mm than we have in the past compared to fish greater than 249 mm (Figure 6). The majority of that increase is fish in the 200 to 249 mm range which are generally three year old fish based on scale aging data. This supports our report of a strong age two year class in 2000 which had a large effect on our abundance estimates (Fritts et al. 2001b). Based on preliminary data, we believe these fish are also migrating in from the Columbia River although our tag recaptures do not support large-scale migrations of bass in this size range however, about 10 percent of tagged fish 200 to 249 mm moved farther than 5 kilometers.

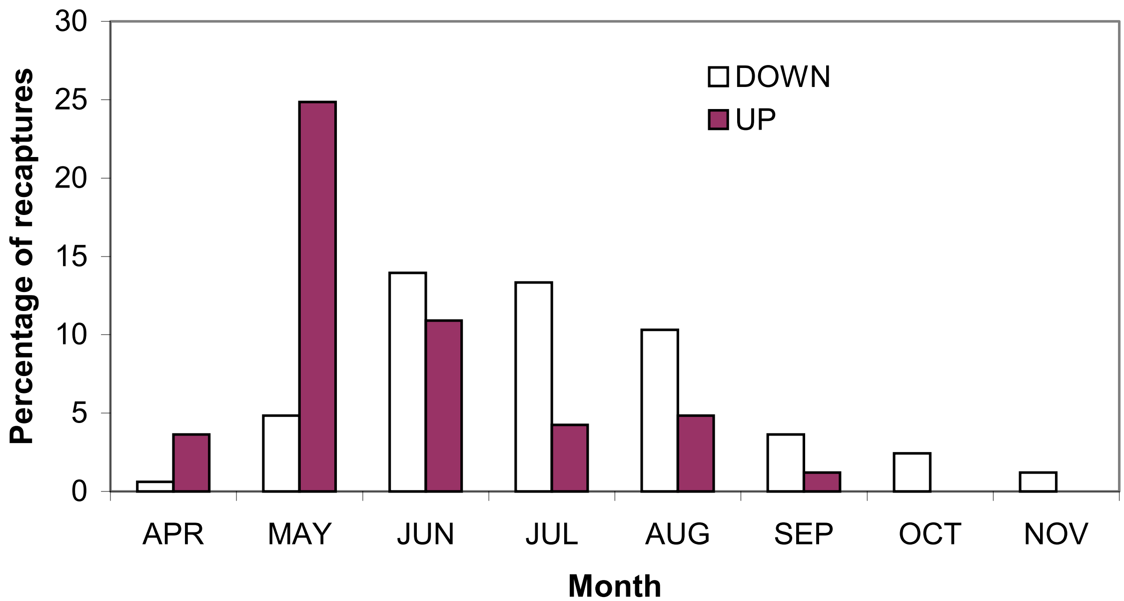

Figure 5. Movement of tagged smallmouth bass in the Yakima River based on electrofishing and angling recapture data from 1997 to 2001. Fish were only used if they moved more than 5 km and were at large less than 250 days.

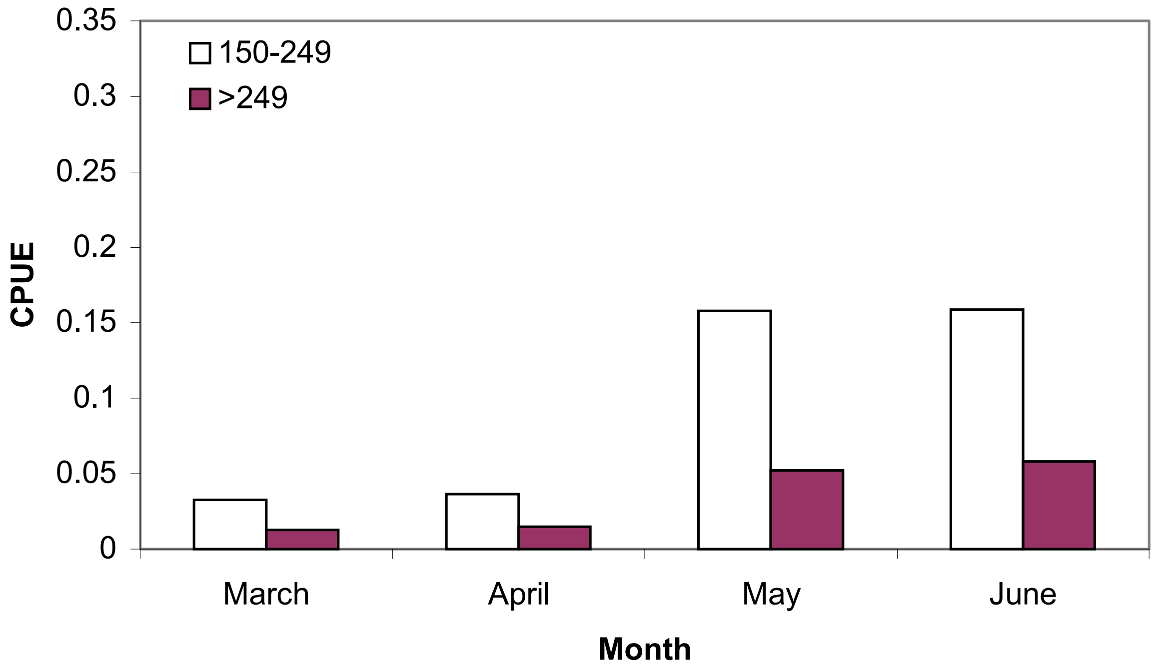

Figure 6. Catch per unit effort (fish per minute) by month of smallmouth bass 150 to 249 mm and greater than 249 mm captured during electrofishing in 2001.

Diet

Fall chinook were found in the guts of smallmouth bass throughout the sampling period and peaked the week of May 18. This coincided with a release of over one million hatchery fall chinook at Chandler (Table 1). Spring chinook were rarely found in the guts and the majority of them were consumed in June. The percentage of stomachs that had fish and 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). Eleven fish taxa were identified in the guts of smallmouth bass (Table 2). Fall chinook, mountain whitefish and dace were the dominant fish species consumed, making up 92 percent of the fish found in the guts (Table 2).

Table 1. Summary results of diet analyses for smallmouth bass (≥ 150 mm FL) sampled in the Benton and Vangie reaches from March 15 to June 15, 2001. The number of stomachs examined (N), the number (percent) of fish=s guts in each sample that were empty, or contained invertebrates, fish, anadromous salmonids, and/or spring chinook salmon (SPC). The fish category includes salmonids. The salmonid category does not include SPC

Date	Section	N	Empty	Invert	Fish	Salmonid	SPC
3/15	Benton	7	1	5	1	0	0
3/29	Benton	10	3	5	4	1	0
4/12	Benton	9	4	5	0	0	0
4/19	Benton	11	0	8	6	5	0
4/26	Benton	5	1	1	4	2	0
5/03	Benton	51	6	30	16	7	1
5/10	Benton	22	3	16	14	6	0
5/17	Benton	39	4	21	22	18	0
5/24	Benton	15	2	6	8	3	0
5/31	Benton	21	2	15	4	0	0
6/07	Benton	28	7	17	4	0	1
6/14	Benton	28	1	22	5	2	1
3/16	Vangie	6	4	0	2	2	0
3/30	Vangie	11	4	4	3	0	0
4/13	Vangie	10	4	5	3	1	0
4/20	Vangie	20	10	5	5	1	0
4/27	Vangie	9	2	1	7	2	0
5/04	Vangie	18	3	7	8	4	0
5/11	Vangie	20	1	7	16	7	0
5/18	Vangie	39	13	11	17	12	0
5/25	Vangie	9	0	4	6	5	0
6/01	Vangie	9	2	3	3	2	0
6/08	Vangie	21	8	9	5	2	1
6/15	Vangie	16	2	12	2	1	0

Table 2. Species composition of fish found in smallmouth bass stomachs collected in the lower Yakima River March 15 through June 15, 2001. 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
3/15	Benton	1	0	0	0	0	0	0	0	0	0	0	1	0	0
3/29	Benton	4	0	0	0	1	1	0	1	0	0	0	1	0	0
4/12	Benton	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/19	Benton	19	0	0	0	0	6	0	13	0	0	0	0	0	0
4/26	Benton	8	0	0	0	2	2	0	4	0	0	0	0	0	0
5/03	Benton	23	1	0	0	8	10	0	2	0	1	0	0	1	0
5/10	Benton	20	1	0	0	8	9	0	1	0	1	0	0	0	0
5/17	Benton	41	0	0	0	3	35	0	1	0	1	0	0	0	1
5/24	Benton	12	0	0	0	2	3	0	7	0	0	0	0	0	0
5/31	Benton	5	0	0	0	5	0	0	0	0	0	0	0	0	0
6/07	Benton	4	0	0	0	3	0	0	0	0	0	0	0	1	0
6/14	Benton	5	0	0	0	2	2	0	0	0	0	0	0	1	0
3/16	Vangie	30	0	0	0	0	30	0	0	0	0	0	0	0	0
3/30	Vangie	3	0	0	0	2	0	0	0	0	1	0	0	0	0
4/13	Vangie	4	0	0	0	0	1	0	3	0	0	0	0	0	0
4/20	Vangie	9	0	0	0	3	1	0	5	0	0	0	0	0	0
4/27	Vangie	9	0	0	0	0	2	2	5	0	0	0	0	0	0
5/04	Vangie	10	0	0	0	0	4	0	6	0	0	0	0	0	0
5/11	Vangie	23	0	0	0	0	7	0	14	0	2	0	0	0	0
5/18	Vangie	18	2	1	0	2	13	0	0	0	0	0	0	0	0
5/25	Vangie	12	0	0	0	1	10	0	1	0	0	0	0	0	0
6/01	Vangie	3	0	0	0	0	2	0	1	0	0	0	0	0	0
6/08	Vangie	6	0	1	1	1	2	0	1	0	0	0	0	0	0
6/15	Vangie	3	1	0	0	1	1	0	0	0	0	0	0	0	0
Totals		272	5	2	1	44	141	2	65	0	6	0	2	3	1
Percent total			1.8	0.7	0.4	16.2	51.8	0.7	23.9	0	2.2	0	0.7	1.1	0.4

[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, common carp, mountain whitefish, 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 19th and spring chinook salmon were relatively rare throughout the spring (Figure 7).

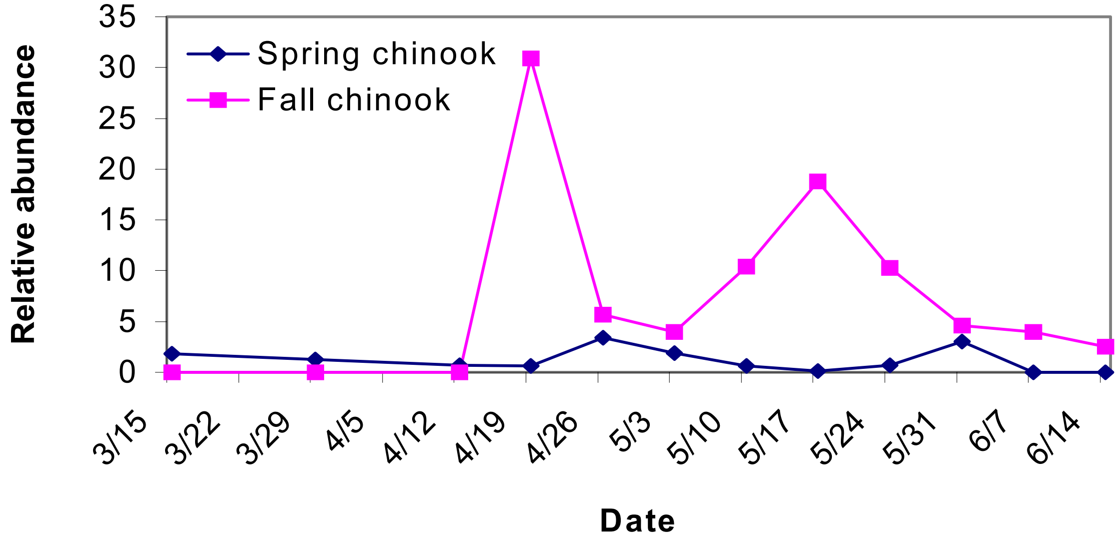

Figure 7. Relative abundance (percent of all fish observed) of spring chinook salmon smolts and fall chinook parr and smolts in the Benton and Vangie sections of the lower Yakima River versus sample date, 2001. Hatchery fall chinook were released from Prosser on April 19, May 7, and May 16.

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 15	March 29	April 12	April 19	April 26	May 3	May 10
BBH	0.0	0.0	0.0	0.0	0.3	0.0	0.0
BRT	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCF[b]	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCP	14.6	1.1	0.7	7.3	41.4	7.4	18.7
CHM	1.3	5.9	18.2	17.9	0.6	2.7	2.9
COH	0.0	1.1	0.0	0.0	0.0	0.3	0.0
DAC	0.9	11.8	0.0	0.0	0.3	2.5	5.0
FAC	0.0	0.0	0.0	21.8	0.0	3.3	5.0
LMB	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LMP	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MWF	8.8	10.2	5.0	12.0	3.9	0.8	1.9
NPM	15.0	18.2	43.9	0.0	3.6	1.9	0.5
PMK	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PMO	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RSS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SCU	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SMB	41.2	27.8	20.4	12.8	5.8	61.7	16.1
SND	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SPC	1.3	0.5	0.4	1.7	0.0	2.5	1.4
SUK	15.5	23.0	11.1	26.5	44.0	16.7	48.4
WCR	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSH	1.3	0.5	0.4	0.0	0.0	0.3	0.0
YLP	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Totals	226	187	280	234	309	366	417

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

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

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

Table 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 17[c]	May 24	May 31	June 7	June 14
BBH	0.0	0.0	0.7	0.0	0.0
BRT	0.0	0.0	0.0	0.0	0.0
CCF[b]	0.0	0.2	0.4	0.0	0.0
CCP	8.8	12.9	13.6	11.7	4.6
CHM	2.1	7.2	8.2	9.7	11.9
COH	0.0	0.2	0.0	0.0	0.0
DAC	4.1	15.9	5.7	9.7	8.2
FAC	18.9	0.0	0.0	0.6	0.5
LMB	0.0	0.0	0.0	0.0	0.0
LMP	0.0	0.2	0.0	0.0	0.0
MWF	3.6	7.8	0.0	1.9	6.5
NPM	0.1	0.4	0.4	0.0	0.2
PMK	0.0	0.0	0.0	0.0	0.0
PMO	0.0	0.0	0.0	0.0	0.0
RSS	0.0	0.0	0.0	0.0	0.0
SCU	0.0	0.0	0.0	0.0	0.0
SMB	38.5	9.4	29.7	30.8	50.6
SND	0.0	0.0	0.0	0.0	0.0
SPC	0.3	0.8	2.5	0.0	0.0
SUK	23.4	45.0	38.7	35.1	16.7
WCR	0.0	0.0	0.0	0.0	0.0
WSH	0.1	0.0	0.0	0.3	0.7
YLP	0.0	0.0	0.0	0.0	0.0
Totals	748	511	279	308	413

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

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

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

Table 4. 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 16	March 30	April 13	April 20	April 27	May 4	May 11
BBH	0.0	0.0	0.0	0.0	0.6	1.0	0.0
BRT	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CCF[b]	0.0	0.4	1.0	0.6	0.0	0.0	0.5
CCP	22.2	16.8	5.2	24.9	78.1	21.6	30.0
CHM	0.0	1.4	0.0	0.0	0.0	0.5	5.3
COH	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DAC	0.0	0.0	0.0	1.2	0.6	0.5	0.0
FAC	0.0	0.0	0.0	0.0	1.5	1.5	2.8
LMB	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LMP	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MWF	35.9	25.4	29.9	18.5	4.4	5.9	9.1
NPM	0.0	0.0	0.0	0.6	0.6	0.0	0.3
PMK	0.0	0.4	0.0	0.0	0.0	0.0	0.0
PMO	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RSS	0.0	0.7	0.0	0.0	0.0	0.5	0.0
SCU	0.0	0.0	0.0	0.0	0.3	0.5	0.8
SMB	9.1	32.6	41.2	32.4	4.7	41.2	23.2
SND	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SPC	0.5	1.1	1.0	0.0	0.9	2.5	1.3
SUK	32.3	21.1	21.6	22.0	8.5	24.5	27.0
WCR	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSH	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YLP	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Totals	198	279	97	173	342	204	397

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

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

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

Table 4 continued. Visually estimated percent composition of species in the Vangie section (rkm 12.2 – 20.2). Total number of fish observed per day is listed for reference.

Species.[a]	May 18[c]	May 25	June 1	June 8	June 15
BBH	0.2	0.0	0.3	0.0	0.0
BRT	0.0	0.0	0.0	0.0	0.0
CCF[b]	0.6	8.3	1.1	4.4	2.7
CCP	9.0	24.4	55.3	23.2	3.4
CHM	4.2	12.9	3.7	0.0	1.9
COH	0.0	1.1	0.0	0.0	0.0
DAC	0.3	6.0	0.9	0.6	0.0
FAC	11.3	8.6	1.7	2.8	3.0
LMB	0.2	0.0	0.0	0.0	0.0
LMP	0.0	0.3	0.0	0.0	0.0
MWF	16.9	14.3	3.2	1.1	17.0
NPM	0.8	0.0	1.7	0.0	1.5
PMK	0.0	0.0	0.3	0.0	0.0
PMO	0.2	0.0	0.0	0.0	0.0
RSS	0.0	0.0	0.0	0.0	0.0
SCU	0.2	0.6	0.0	0.6	0.0
SMB	36.3	10.9	22.3	45.9	52.3
SND	0.0	0.0	0.0	0.0	0.0
SPC	0.9	0.3	1.1	0.0	0.0
SUK	19.0	12.3	8.0	21.5	18.2
WCR	0.0	0.0	0.0	0.0	0.0
WSH	0.2	0.0	0.3	0.0	0.0
YLP	0.0	0.0	0.0	0.0	0.0
Totals	664	349	349	181	264

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

Consumption

Consumption of salmonids by smallmouth bass in 2001 followed the same general trend as the three previous years (Figure 8). Between March and early May consumption was relatively low and gradually increased as bass abundance, available prey, and temperatures increased. In early May, consumption quickly rose to a peak in late May and 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 is decreasing in June, but this is not supported by passage estimates of fall chinook at Chandler and the fact that consumption of all other fish is also decreasing in a similar fashion. The most likely explanation remains that bass are beginning to spawn at this time and have ceased to feed (Fritts et al. 2001a). Between March 22 and June 16, 2001, we estimated that smallmouth bass consumed 230,265 salmonids of which 6,906 were spring chinook. Between the same dates in 2000 our estimate was 202,722 salmonids of which 3,083 were spring chinook

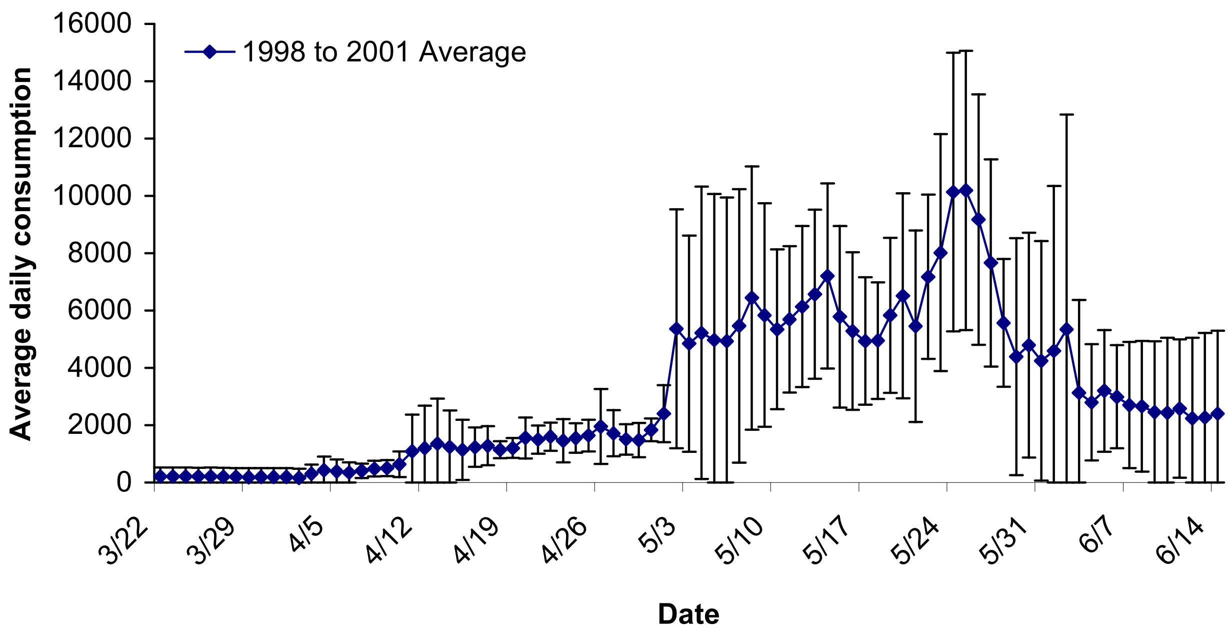

Figure 8. Estimates of average daily salmonid consumption by smallmouth bass from 1998 to 2001 showing plus and minus one standard deviation in the Yakima River between Prosser Dam and the confluence of the Columbia River.

Production

We estimated 188,000 naturally produced fall chinook fry emerged in 1999, 331,000 emerged in 2000, and 492,000 emerged in 2001 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, and 8% had passed by June 1, 2001 (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 naturally produced fish that are observed in the smallmouth guts based on lengths taken at Chandler. These actively migrating fish are also probably spending more time offshore and are probably not spending much time in the lower Yakima so they are available to the smallmouth for a shorter length of time. If we assume that our estimates of naturally produced fry are somewhere within an order of magnitude of the actual number produced, smallmouth could be a limiting factor on natural production, especially in years with low production (Figure 9).

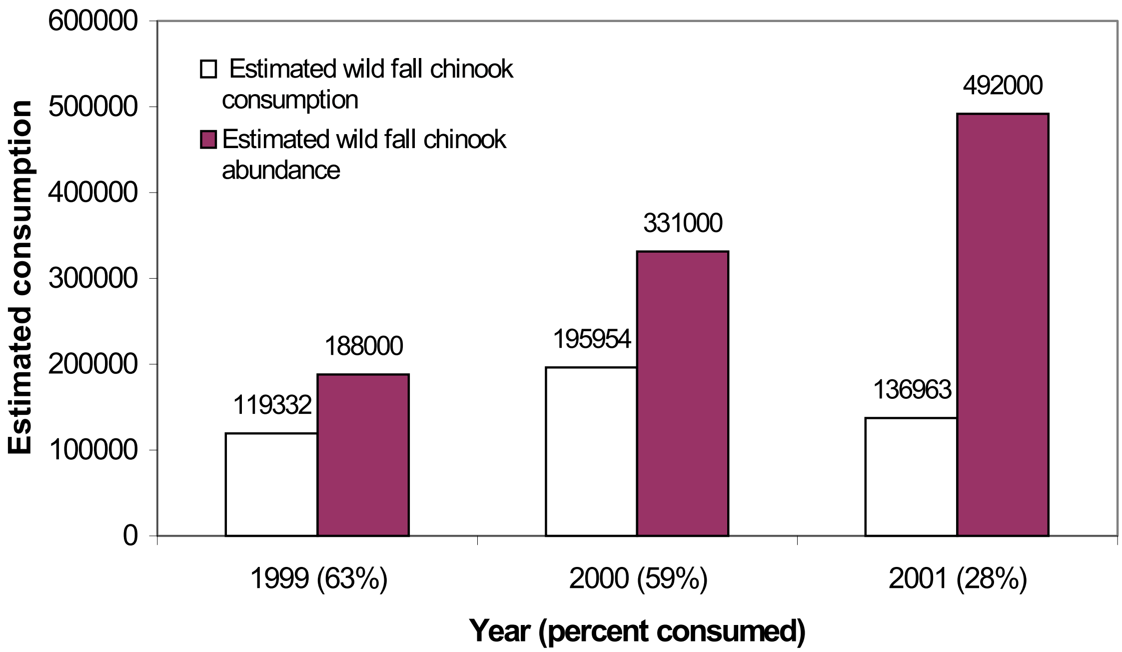

Figure 9. Estimated naturally produced fall chinook abundance below Prosser Dam and estimated consumption from March 22 to June 30 by smallmouth bass for 1999, 2000, and 2001 in the lower 68 km of the Yakima River. Listed in parentheses is the percent of natural production consumed by smallmouth.

Percent of Population Consumed

We compared our estimated consumption to estimated numbers of juvenile salmonids above and below Prosser Dam to show the relative impact of smallmouth predation (Table 5).

Table 5. Population size, estimated number consumed and percent of population consumed by smallmouth bass for salmonid species in 1999, 2000, and 2001. 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

[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.

Maximum Consumption

From 1998 to 2001 our estimated consumption averaged 32 percent of our calculated maximum consumption (Figure 10). Note that we had to use the date range of March 22 to June 16 in order to compare 1998 to 2001. If we use estimated wild fall chinook passage at the Chandler Trap (Prosser Dam) as an index of the relative abundance of fall chinook below Prosser Dam between years we see that the consumption rate was higher in years of more abundant fall chinook (Table 6).

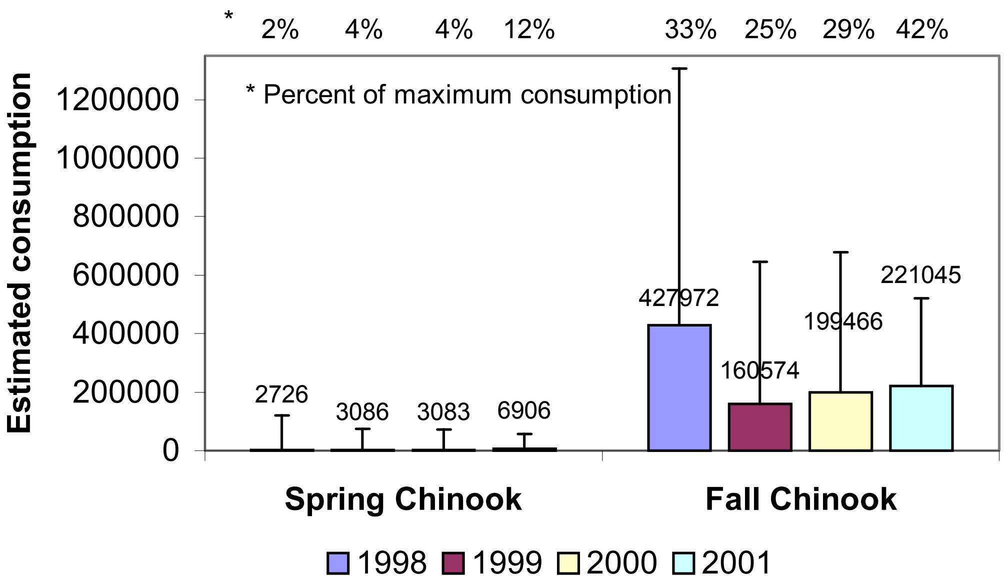

Figure 10. Estimated consumption, estimated maximum consumption and percent of maximum consumption (Cmax) consumed by smallmouth bass for spring chinook and fall chinook salmon between March 22 and June 16, 1998-2001.

Table 6. Passage of naturally produced fall chinook at Chandler (Prosser Dam) March through July, 1998 to 2001 and rates of salmonid consumption March 22 to June 16, 1998 to 2001.

	1998	1999	2000	2001
Chandler passage	486,537	39,453	198,002	1,677,537
Salmonids consumed per smallmouth	12.5	8	10.5	30.5

Channel Catfish

The diets of channel catfish in 2001 were similar to previous years based on our small sample sizes obtained by electrofishing (Table 7). One of the catfish in 2001 contained a yearling sized smolt that we identified as a coho based on coho regressions from bone measurements. 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 (Table 8).

Of the 30 adult sized channel catfish we captured by electrofishing in 2001, 90 percent were captured in the Vangie section and 40 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 7. Composition of channel catfish stomachs collected in the lower Yakima River, April through June 1998, 1999, 2000, and 2001. Total number of stomachs in sample (N), and number of times (with percentage below) each category was found in a stomach is presented. Anadromous salmonids are included in the fish category. The invertebrate (Invert.) category includes crayfish.

		Food Category							
Year	N	Empty	Fish	Salmonid	Invert.	Crayfish	Seeds	Bird	Rodent
1998	137	70 (51.0)	26 (19.0)	4 (2.9)	43 (31.3)	31 (22.6)	21 (15.3)	3 (2.2)	2 (1.5)
1998[a]	10	3 (30.0)	2 (20.0)	0 (0.0)	4 (40.0)	0 (0.0)	1 (10.0)	0 (0.0)	0 (0.0)
1999	24	6 (25.0)	5 (20.8)	1 (4.2)	16 (66.7)	1 (4.2)	1 (4.2)	0 (0.0)	0 (0.0)
2000	26	9 (34.6)	3 (11.5)	0 (0.0)	13 (50.0)	1 (3.8)	1 (3.8)	0 (0.0)	1 (3.8)
2001	19	8 (42.1)	4 (21.1)	1 (5.3)	5 (26.3)	1 (5.3)	1 (5.3)	0 (0.0)	0 (0.0)

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

Table 8. Species composition of fish found in channel catfish stomachs collected in the lower Yakima River April through June 1998, 1999, 2000, and 2001. Total number of fish in stomachs (N), and number (with percentage below) of prey species is presented.

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

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

Hot Spot Sampling

The suspected “hotspot” of predation below Wanawish Dam was sampled twice in 2001. Catch per unit effort was very low (0.03 fish per minute) corresponding to low abundance of bass and possibly sampling at a time when bass were not moving over the dam. It may be that smallmouth move in large pods or certain discharges delay passage over the dam causing us to have a high catch rate one week and low catch rate the next week.

Discussion

Predation by smallmouth bass has undoubtedly contributed substantially to 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. In addition, larger hatchery fish generally survive better than smaller ones and this pattern is thought to be due to size selective predation.

We originally hypothesized that the low CPUE's of smallmouth bass in 2001 were caused by the low, clear water conditions. This could have been caused by smallmouth bass occupying habitat away from the streambank where we sample because of the low water and slower velocities. Smallmouth may also have been better able to avoid the electroshocker because of clearer water conditions that allowed them to see a greater distance.

Contrary to our hypothesis the low CPUE's were likely due to low numbers of bass. If we assume that the majority of fish tagged the previous year went back to the Columbia River in the summer and fall and would have to migrate back into the Yakima River in the spring in order for us to catch them, we can assume that a lower rate of recaptures of the previous years tags reflects either lower numbers of fish returning to the Yakima or higher mortality during the summer and winter. We took the average number of tags applied in 1998 to 2001 and divided by the number applied in the previous year for 1998 to 2001. We multiplied those numbers by the quotient of the number of previous year's tags that we recaptured by the total number of previous year's tags applied. This multiplier was used to account for the varying number of fish tagged each year. The resulting recapture rates were very similar to our estimates of peak abundance (Figure 11) and give us some assurance that our low CPUE's in 2001 are accurate and not just a result of differential efficiency caused by environmental differences among years.

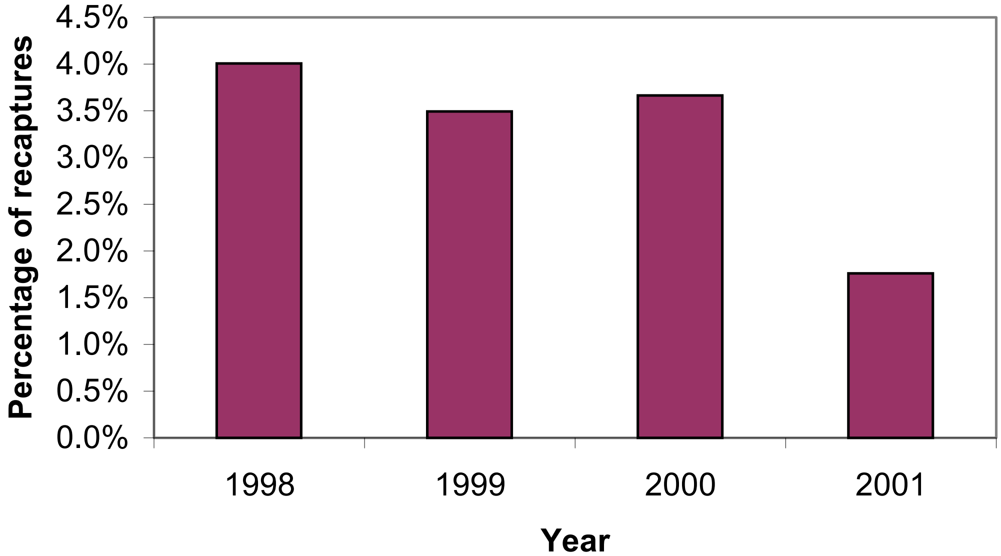

Figure 11. Percentage of tags from the previous year recaptured during electrofishing in 1998 to 2001.

Even though smallmouth bass were much less abundant in the Yakima River than in previous years they ate slightly more salmonids in 2001 than in 1999 and 2000 because of a higher consumption rate per bass. Smallmouth bass may increase their rate of predation on fall chinook when fall chinook are abundant. Smallmouth bass had the highest rate of estimated consumption in 2001, and 2001 had the highest estimated fall chinook production. In addition smallmouth bass had the second highest rate of estimated consumption in 1998 and 1998 had the second highest estimated production of fall chinook. Lower abundance of bass could explain higher predation rates in 2001 due to less intraspecific competition, but we believe this is unlikely. The year with the second highest rate of smallmough bass predation, 1998, had the highest estimated abundance of bass in the last four years. For the years 1998 to 2001, we calculated that smallmouth bass consumed fall chinook at an average of 32 percent of their maximum possible consumption (Figure 10). We believe this is another indicator that smallmouth bass are compensating for increased production by increasing their predation rate because the percent of maximum consumption increased in years of high natural production of fall chinook. This type of compensatory predation is a major concern if the 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 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.

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 (2.2% of consumed salmonids are spring chinook). This is approximately 2.6% of hatchery produced or 5.3% of wild spring chinook smolts passing Prosser Dam from 1999 to 2001. This is most likely due to the differnce in temporal and spatial overlap and the difference in size. Yearling salmonids use the lower Yakima River as a migration corridor and therefore spend a short amount of time overlapping spatially with smallmouth bass. In contrast, fall chinook both rear and migrate in the lower Yakima River. Our data for 1998 to 2001 has shown that smallmouth bass generally ate smaller fish such as fall chinook and rarely ate fish over 100 mm in length (Figure 12) which is about the smallest size for a spring chinook emigrating through our study sites based on data collected at the Chandler Trap.

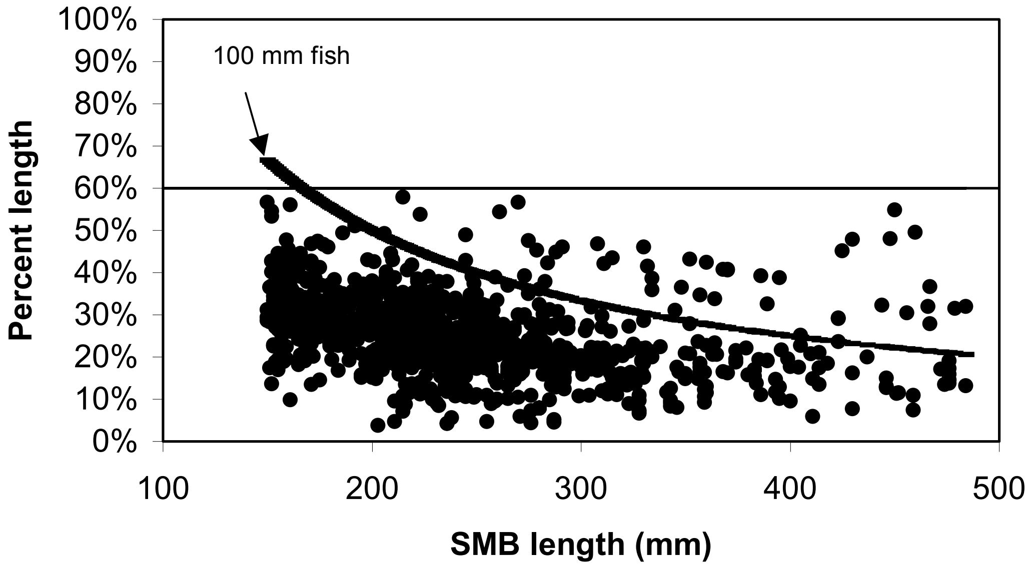

Figure 12. Percent lengths (FL) of fish found in smallmouth bass gut samples from 1998 to 2001. Included is the percent length of a 100 mm fish for each length of smallmouth.

Instead of doing an experimental removal of bass as we had planned last year (Fritts et al. 2001b), fish managers decided to change the angling regulation for smallmouth bass in the Yakima River. This regulation is designed to increase angler exploitation of the smaller bass, which eat the most salmon in the Yakima River during the spring. The previous limit was five bass with no more than three over fifteen inches. Effective May 1 2001, the regulation was changed 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. Washington Department of Fish and Wildlife will perform angler surveys to guage the amount of angler exploitation on these smaller bass for a period of three years and then re-evaluate the regulation. We will continue our monitoring in an attempt to determine if the regulation change reduces smallmouth bass predation on salmonids. Detecting changes in consumption due to management actions may not be possible simply by looking for differences in total consumption or bass abundance because of high natural year-to-year variation but it may be possible by looking for changes in the patterns within a year. The abundance (Figure 4) and consumption (Figure 9) estimates from 1998 to 2001 were different in magnitude but have maintained a similar trend during all years.

Recommendations

We recommend evaluating methods to reduce our monitoring effort in the future. Because trends have been fairly consistent for all sampling years under a wide range of environmental conditions, it might be possible to find ways to sample less without sacrificing a great deal of precision in our consumption estimates. For example, we may be able to sample every other week instead of every week or sample one section instead of two, cutting our effort in half.

Acknowledgments

Gabriel Temple and Christopher Johnson assisted in the field. 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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