DEVELOPMENT OF A SYSTEM-WIDE PREDATOR CONTROL PROGRAM: STEPWISE IMPLEMENTATION OF A PREDATION INDEX, PREDATOR CONTROL FISHERIES, AND EVALUATION PLAN IN THE COLUMBIA RIVER BASIN

2005 ANNUAL REPORT

Prepared by:

Russell Porter
Pacific States Marine Fisheries Commission

In Cooperation with:

Oregon Department of Fish and Wildlife
Washington Department of Fish and Wildlife

Prepared for:

U.S. Department of Energy
Bonneville Power Administration
Environment, Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-3621

Project Number 199007700
Contract Number 00022819

TABLE OF CONTENTS

2005 EXECUTIVE SUMMARY

by
Russell G. Porter

This report presents results for year thirteen in a basin-wide program to harvest northern pikeminnow[1] (Ptychocheilus oregonensis). This program was started in an effort to reduce predation by northern pikeminnow on juvenile salmonids during their emigration from natal streams to the ocean. Earlier work in the Columbia River Basin suggested predation by northern pikeminnow on juvenile salmonids might account for most of the 10-20% mortality juvenile salmonids experience in each of eight Columbia River and Snake River reservoirs. Modeling simulations based on work in John Day Reservoir from 1982 through 1988 indicated that, if predator-size northern pikeminnow were exploited at a 10-20% rate, the resulting restructuring of their population could reduce their predation on juvenile salmonids by 50%.

To test this hypothesis, we implemented a sport-reward angling fishery and a commercial longline fishery in the John Day Pool in 1990. We also conducted an angling fishery in areas inaccessible to the public at four dams on the mainstem Columbia River and at Ice Harbor Dam on the Snake River. Based on the success of these limited efforts, we implemented three test fisheries on a system-wide scale in 1991—a tribal longline fishery above Bonneville Dam, a sport-reward fishery, and a dam-angling fishery. Low catch of target fish and high cost of implementation resulted in discontinuation of the tribal longline fishery. However, the sport-reward and dam-angling fisheries were continued in 1992 and 1993. In 1992, we investigated the feasibility of implementing a commercial longline fishery in the Columbia River below Bonneville Dam and found that implementation of this fishery was also infeasible.

Estimates of combined annual exploitation rates resulting from the sport-reward and dam-angling fisheries remained at the low end of our target range of 10-20%. This suggested the need for additional effective harvest techniques. During 1991 and 1992, we developed and tested a modified (small-sized) Merwin trapnet. We found this floating trapnet to be very effective in catching northern pikeminnow at specific sites. Consequently, in 1993 we examined a system-wide fishery using floating trapnets, but found this fishery to be ineffective at harvesting large numbers of northern pikeminnow on a system-wide scale.

In 1994, we investigated the use of trap nets and gillnets at specific locations where concentrations of northern pikeminnow were known or suspected to occur during the

---

[1] The common name of the northern squawfish was recently changed by the American Fisheries Society to northern pikeminnow at the request of the Confederated Tribes and Bands of the Yakama Indian Reservation.

spring season (*i.e.*, March through early June). In addition, we initiated a concerted effort to increase public participation in the sport-reward fishery through a series of promotional and incentive activities.

In 1995, 1996, and 1997, promotional activities and incentives were further improved based on the favorable response in 1994. Results of these efforts are subjects of this annual report.

Evaluation of the success of test fisheries in achieving our target goal of a 10-20% annual exploitation rate on northern pikeminnow is presented in Report C of this report. Overall program success in terms of altering the size and age composition of the northern pikeminnow population and in terms of potential reductions in loss of juvenile salmonids to northern pikeminnow predation is also discussed in Report C.

Program cooperators include the Pacific States Marine Fisheries Commission (PSMFC), Oregon Department of Fish and Wildlife (ODFW), and Washington Department of Fish and Wildlife (WDFW). The PSMFC was responsible for coordination and administration of the program; PSMFC subcontracted various tasks and activities to ODFW and WDFW based on the expertise each brought to the tasks involved in implementing the program. Objectives of each cooperator were as follows.

1. **WDFW (Report A)**: Implement a system-wide (*i.e.* Columbia River below Priest Rapids Dam and Snake River below Hells Canyon Dam) sport-reward fishery and operate a system for collecting and disposing of harvested northern pikeminnow.

2. **PSMFC (Report B)**: Provide technical, contractual, fiscal and administrative oversight for the program. In addition, PSMFC processes and provides accounting for the reward payments to participants in the sport-reward fishery.

3. **ODFW (Report C)**: Evaluate exploitation rate and size composition of northern pikeminnow harvested in the various fisheries implemented under the program together with an assessment of incidental catch of other fishes. Estimate reductions in predation on juvenile salmonids resulting from northern pikeminnow harvest and update information on year-class strength of northern pikeminnow.

Background and rationale for the Northern Pikeminnow Management Program can be found in Report A of our 1990 annual report (Vigg et al. 1990). Highlights of results of our work in 2005 by report are as follows:

Report A

Implementation of the Northern Pikeminnow Sport-Reward Fishery in the Columbia and Snake Rivers

1. Objectives for 2004 were to: (1) implement a recreational fishery that rewards anglers who harvest northern pikeminnow ≥ 228 mm (9 inches) total length, (2) collect, compile, and report data on angler participation, catch and harvest of northern pikeminnow and other fish species, and success rates of participating anglers during the season, (3) examine collected northern pikeminnow for the presence of external tags, PIT tags, and signs of tag loss, (4) collect biological data on northern pikeminnow and other fish species returned to registration stations, (5) scan northern pikeminnow for the presence of consumed salmonids containing PIT tags, and (6) Survey non-returning fishery participants who were targeting northern pikeminnow to obtain catch and harvest data on all fish species caught.

2. The NPSRF was conducted from May 2 through September 26, 2004 from the Dalles dam downstream and from May 16 through September 25, 2004 from the Dalles dam upstream. Nineteen registration stations were operated throughout the lower Snake and Columbia rivers.

3. A total of 241,357 northern pikeminnow ≥ 9 inches in total length were harvested during the 2004 season with 35,325 angler days spent harvesting these fish. Catch-per-angler-day for all anglers during the season was 6.83 fish.

4. Anglers submitted 171 northern pikeminnow with external tags, and an additional 93 with possible tag wounds and/or fin-clips, but without spaghetti or PIT tags. A total of 168 salmonid PIT tags from consumed juvenile salmonids were detected from scanned pikeminnows at the registrations stations and the codes recorded for transmittal to the PITAGIS database.

Report B

Northern Pikeminnow Sport-Reward Fishery Payments

1. For 2005 the rewards paid to anglers were $4, $5, and $8 per fish for the three payment tiers (the first 100 fish was $4 per fish, the reward for fish in the 101-400 fish range was $5 per fish and for all fish caught above 400 it was $8 per fish). The reward for a tagged fish was $500 per fish.

2. During 2005, excluding tagged fish, rewards paid totaled $1,460,724 for 239,172 fish.

3. A total of 171 tagged fish vouchers were paid. The total season tag rewards paid totaled $85,500.

4. A total of 1,724 separate successful anglers received payments during the season. This is less than the actual number of successful anglers, as some anglers with a voucher for one or a few fish do not send in their vouchers for payments. The actual number of successful anglers as reported in Report A was 2,164.

5. The total for all payments for non-tagged and tagged pikeminnows in 2005 was $1,546,224

6. The top angler earned $39,620 for the five month fishing season.

Report C

Development of a Systemwide Predator Control Program: Indexing and Fisheries Evaluation

1. Objectives in 2005 were to: (1) evaluate the efficiency of the northern pikeminnow fishery by analyzing exploitation rates; (2) estimate reductions in northern pikeminnow predation on juvenile salmonids since program implementation; (3) estimate tag loss for spaghetti tags; (4) validate aging methods for northern pikeminnow; (5) estimate abundance, consumption, and predation indices for predator fishes within the study area, and (6) explore hook and line angling for northern pikeminnow.

2. We tagged and released 901 northern pikeminnow ≥ 200 mm fork length in 2005 to assess exploitation. System-wide exploitation of northern pikeminnow ≥ 200 mm fork length was 16.3%, which incorporated a tag loss of 8.1%. System-wide exploitation of northern pikeminnow ≥ 250 mm fork length was 19%, the highest rate estimated since the program was fully implemented in 1991.

3. Northern pikeminnow abundance index values in Bonneville Reservoir were the lowest observed since 1991. However, spring consumption indices for northern pikeminnow in Bonneville Dam tailrace were greater than 2004, and were the highest observed to date in The Dalles Dam tailrace. The summer consumption index value below Bonneville Dam for rkm 114-121 was the highest since 1995. Northern pikeminnow summer consumption and predation indices were zero for Bonneville Dam forebay. However, predation indices more than doubled between spring (2.8) and summer (6.8) for the Bonneville Dam tailrace boat restricted zone

(BRZ). Smallmouth bass relative densities in 2005 were similar in most areas to 2004; consumption and predation rates varied among areas.

4. A total of 549 scale and 254 opercle samples were aged from tagged, indexed, and recaptured northern pikeminnow in 2005. Complete agreement (i.e., zero discrepancy) on ages assigned by the three readers was 72.1% for scales, and 2.8-18.7% for opercles. When aging northern pikeminnow > 8-9 years of age, we aged opercles consistently older than their corresponding scale age. The largest age discrepancy between corresponding scales and opercles for northern pikeminnow ≥ 350 mm was 11 years. We observed oxytetracycline (OTC) mark failure was significantly ($P < 0.05$) related to mark year; 75% of the failed OTC marked fish came from 2005.

5. Northern pikeminnow year-class analysis downstream of Bonneville Dam showed considerable variation from year to year in the percentage of age 3 and 4 fish. The percentage of age 5 northern pikeminnow has been relatively stable since 1993, accounting for 15-17% of the total. Smallmouth bass year-class analysis downstream of Bonneville Dam indicated a growing proportion of the population was composed of age 4fish.

6. The 2005 northern pikeminnow proportional stock density (PSD) value for below Bonneville Dam was 29% greater than all previous years. Smallmouth bass relative stock density of preferred length fish (RSD-P) and PSD values below Bonneville Dam were the lowest to date. Median relative weight (W_r) was significantly higher ($P< 0.01$) for male and female northern pikeminnow in 1993, 1994, 1999, 2004 and 2005 than in other years. Smallmouth bass had significantly ($P < 0.01$) higher W_r in 2005 than in 1990, 1996, and 1999 in all areas. When solely considering PSD, RSD-P and W_r data, a system-wide compensatory response by smallmouth bass and northern pikeminnow does not seem apparent.

7. We were unable to completely assess angling as a means to capture and tag additional northern pikeminnow. Because tagging effort must occur non-randomly (the same sampling effort is expended in each river mile), we concluded that successful angling would likely require additional boats and personnel.

Report A

Implementation of the Northern Pikeminnow Sport-Reward Fishery in the Columbia and Snake Rivers

2005 Annual Report

Prepared by:

Richard C. Bruce
Eric C. Winther
John D. Hone
Paul V. Dunlap

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

February, 2006

ACKNOWLEDGEMENTS

This project is funded by the Bonneville Power Administration (BPA), William Maslen, Project Manager and John Skidmore, COTR (Contract DE-BI719-94BI24514). We thank Carlene Stenehjem at BPA-Public Affairs; Tom Friesen and his staff at the Oregon Department of Fish and Wildlife (ODFW); and Russell Porter and his staff at the Pacific States Marine Fisheries Commission (PSMFC) for their coordination.

We are grateful to the City of Rainier for the use of the Rainier boat ramp; The City of Richland for the use of Columbia point Park; the Cowlitz County Parks and Recreation Department for the use of the Willow Grove boat ramp; The Port of Camas/Washougal for the use of the Camas/Washougal boat ramp; the Port of Cathlamet for the use of the Cathlamet Marina; the Port of Kalama for the use of the Kalama Marina; the Port of The Dalles for the use of The Dalles Boat Basin; the Portland Regional Parks Department for the use of the M.J. Gleason Boat Ramp and Chinook Landing; the U.S. Army Corps of Engineers for the use of Giles French Park, and the Greenbelt Boat Ramp; the U.S. Forest Service for the use of Bonneville Trailhead; the Washington Department of Transportation for the use of the Vernita Bridge Rest Area; Rod and Sharon Bailey for the use of Lyon's Ferry Marina; Dave and Linda Petersen for the use of Boyer Park; and Sheila Cannon and Ken Beer for the use of The Fishery at Coverts Landing.

We appreciate the efforts of Beverly Buitenbos, Dick Buitenbos, Melissa Dexheimer, Paul Dunlap, Bill Fleenor, Leif Fox, Lisa Goldschmidt, Travis Harwood, Josh Hede, Maria Holmes, Jeff Lesselyoung, Leslie Limardo, Darrin Mayer, Derrick Meaghers, Eric Meyer, Linda Moore, Sabrina Peters, Cole Shelton, Tracy Sobelman, Mark Thompson, Bob Warrington, Alyce Wells, Dennis Werlau, and Sarah Wilkinson for operating the sport-reward fishery registration stations.

We also recognize Diana Murillo for her excellent work in computer data entry and document verification, Fella Tanaka for her numerous phone survey interviews, Kathleen Moyer for serving as the lead technician for the PIT tag recovery portion of the program, as well as Julie Memarian and Paul Dunlap for producing our weekly field activity reports, overseeing the Sport-Reward hotline, and helping to keep the program operating smoothly throughout the season.

In memory of Mark D. Thompson, 1961-2005.

ABSTRACT

We are reporting on the progress of the Northern Pikeminnow *ptychocheilus oregonensis* Sport-Reward Fishery (NPSRF) implemented by the Washington Department of Fish and Wildlife (WDFW) on the Columbia and Snake Rivers from May 2 through September 25, 2005. The objectives of this project were to (1) implement a recreational fishery that rewards anglers who harvest northern pikeminnow ≥ 228mm (9 inches) total length, (2) collect, compile, and report data on angler participation, catch and harvest of northern pikeminnow and other fish species, and success rates of participating anglers during the season, (3) examine collected northern pikeminnow for the presence of external tags, fin clips, and signs of tag loss, (4) collect biological data on northern pikeminnow and other fish species returned to registration stations, (5) scan northern pikeminnow for the presence of consumed salmonids containing Passive Integrated Transponder (PIT) tags, and (6) obtain catch and harvest data on fish species caught by non-returning fishery participants who were targeting northern pikeminnow.

A total of 241,357 northern pikeminnow ≥ 228 mm and 5,117 pikeminnow < 228 mm were harvested during the 2005 season. There were a total of 5,385 different anglers who spent 35,325 angler days participating in the fishery. Catch per unit effort for combined returning and non-returning anglers was 6.83 fish/angler day. The Oregon Department of Fish and Wildlife (ODFW) reported that the overall exploitation rate for the 2005 NPSRF was 19%.

Anglers submitted 170 northern pikeminnow with external spaghetti tags, of which there were 146 with both spaghetti and PIT tags, and 93 with possible tag wounds and/or fin clips, but without spaghetti or PIT tags. A total of 168 PIT tags from consumed juvenile salmonids were detected and interrogated from northern pikeminnow received during the 2005 NPSRF.

Peamouth *Mylocheilus caurinus*, smallmouth bass *Micropterus dolomieue*, white sturgeon *Acipenser transmontanus*, and channel catfish *Ictalurus punctatus* were the fish species most frequently harvested by NPSRF anglers targeting northern pikeminnow. The incidental catch of salmonids *Oncorhynchus spp*, by participating anglers targeting northern pikeminnow remained below established limits for the Northern Pikeminnow Management Program.

INTRODUCTION

Mortality of juvenile salmonids *oncorhynchus spp.* migrating through the Columbia River system is a major concern of the Columbia Basin Fish and Wildlife Program, and predation is an important component of mortality (NPPC 1987a). Northern pikeminnow *Ptychocheilus oregonensis*, formerly known as northern squawfish (Nelson et al. 1998), are the primary piscine predator of juvenile salmonids in the Lower Columbia and Snake River Systems (Rieman et al. 1991). Rieman and Beamesderfer (1990) predicted that predation on juvenile salmonids could be reduced by up to 50% with a sustained exploitation rate of 10-20% on northern pikeminnow > 275 mm fork length (FL) (11 inches total length). The Northern Pikeminnow Management Program (NPMP) was founded in 1990, with the goal of implementing fisheries which achieve the recommended 10-20% annual exploitation on northern pikeminnow >275 mm FL within the program area (Vigg and Burley 1989). In 2000, NPMP administrators reduced the minimum size for eligible (reward size) northern pikeminnow to 228 mm FL (9 inches total length) in response to recommendations contained in a review of NPMP justification, performance, and cost-effectivenesss (Hankin and Richards 2000). Beginning in 1991, the Washington Department of Fish and Wildlife (WDFW) was contracted to conduct the Sport-Reward Fishery component of the NPMP (Burley et al. 1992). The NPSRF enlists recreational anglers to harvest reward sized (≥9" total length) northern pikeminnow from within program boundaries on the Columbia and Snake Rivers by using monetary reward system. Since 1991, anglers participating in the NPSRF have harvested more than 2.6 million reward sized northern pikeminnow and spent more than 603,000 angler days of effort in becoming the NPMP's most successful component for achieving the annual 10-20% exploitation rate on northern pikeminnow within the program boundaries (Klaybor et al. 1993; Friesen and Ward 1999).

The 2005 NPSRF continued to provide a tiered reward system Hisata et al. 1995) which paid anglers a higher amount per fish based on achieving designated harvest levels and a separate bonus reward for returning northern pikeminnow that were spaghetti tagged by the Oregon Department of Fish and Wildlife (ODFW) as part of the NPSRF's biological evaluation. Catch and harvest data were collected from returning anglers, and non-returning anglers in order to monitor the effect of the NPSRF on other fish species.

The objectives of the 2005 NPSRF were to (1) implement a recreational fishery that rewards anglers who harvest northern pikeminnow ≥ 228 mm (9 inches) total length, (2) collect, compile, and report data on angler participation, catch and harvest of northern pikeminnow and other fish species, and success rates of participating anglers during the season, (3) examine collected northern pikeminnow for the presence of external tags, fin-clips, and signs of tag loss, (4) collect biological data on northern pikeminnow and other fish species returned to registration stations, (5) scan northern pikeminnow for the presence of consumed salmonids containing PIT tags, and (6) survey non-returning fishery participants who were targeting northern pikeminnow to obtain catch and harvest data on all fish species caught.

METHODS OF OPERATION

FISHERY OPERATION

BOUNDARIES AND SEASON

The NPSRF was conducted on the Columbia River from the mouth to the boat-restricted zone below Priest Rapids Dam, and on the Snake River from the mouth to the boat-restricted zone below Hells Canyon Dam (Figure 1). In addition, anglers were allowed to harvest (and submit for payment) northern pikeminnow caught in backwaters, sloughs, and up to 400 feet from the mouth of tributaries within this area.

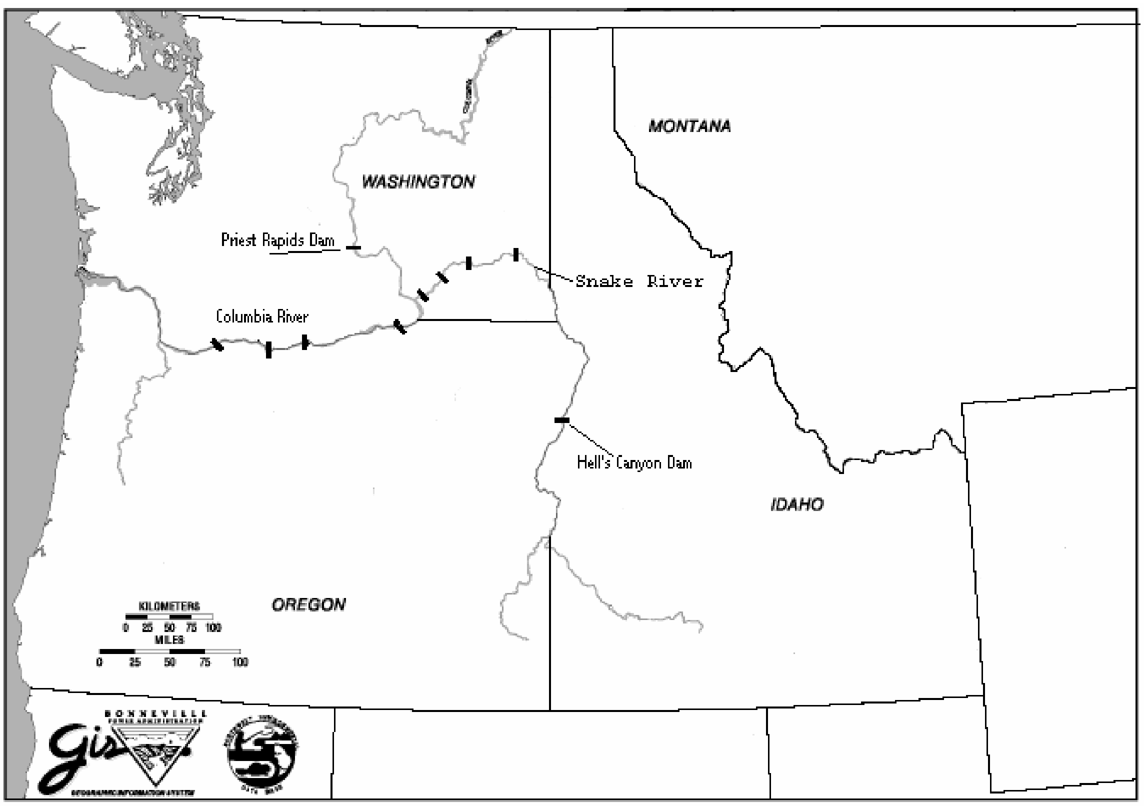


Figure 1. Northern Pikeminnow Sport-Reward Fishery Program Area

The NPSRF was fully implemented from May 16 through September 25, 2005. In addition, twelve stations below the John Day Dam conducted a two week long "pre-season" beginning on May 2, 2005 in order to take advantage of favorable river conditions that provided anglers with an earlier opportunity to begin harvesting northern pikeminnow.

REGISTRATION STATIONS

Sixteen registration stations (Figure 2) were located on the Columbia and Snake Rivers to provide anglers with access to the Sport-Reward Fishery. WDFW technicians set up

1. Cathlamet Marina (12-4 pm)
2. Willow Grove Boat Ramp (5-8 pm)
3. Rainier Marina (4-8 pm)
4. Kalama Marina (11:30am-3 pm)
5. M. James Gleason Boat Ramp (12-8 pm)
6. Chinook Landing (7:30-10 am)
7. Washougal Boat Ramp (12-8 pm)
8. The Fishery (4-8:30 pm)
9. Bonneville Trail Head (11am-4:00 pm)
10. The Dalles Boat Basin(12-8 pm)
11. Giles French (12-8 pm)
12. Columbia Point Park (11am-5:30 pm)
13. Vernita Bridge (3:30-7:30 pm)
14. Lyon's Ferry (9:30am-1 pm)
15. Boyer Park (11:30 am -2:30 pm)
16. Greenbelt (3:30-7:30 pm)

Figure 2. 2005 Northern Pikeminnow Sport Reward Fishery Registration Stations

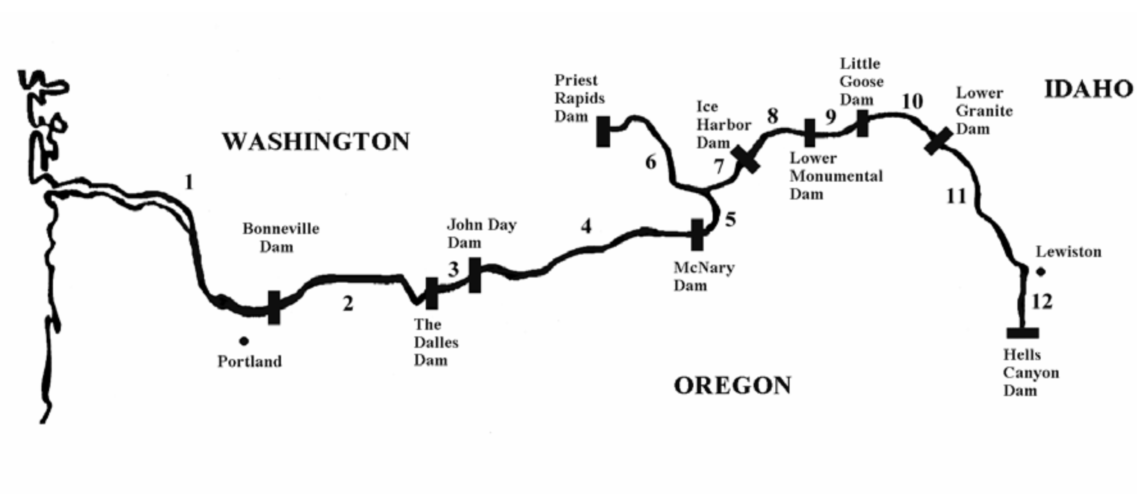
daily (seven days a week) registration stations at designated locations (normally public boat ramps or parks) which were available to anglers between two and eight hours per day during the season. Technicians registered anglers to participate in the NPSRF, collected creel information, issued pay vouchers to anglers returning with eligible northern pikeminnow, recorded biological data, scanned northern pikeminnow for the presence of PIT tags, and provided Sport-Reward Fishery information to the public. Self-registration boxes were located at each station so anglers could self register when WDFW technicians were not present.

REWARD SYSTEM

The 2005 NPSRF rewarded anglers for harvesting northern pikeminnow $\geq$ 228mm (9 inches) total length (TL). The 2005 NPSRF continued to use a tiered reward system developed in 1995 (Hisata et al. 1995) that paid anglers a higher reward per fish once they had reached designated harvest levels over the course of the season. To receive payment, anglers returned their catch (daily) to the location where they had registered. Station technicians identified the angler's fish and issued a payment voucher for the total number of eligible northern pikeminnow. Anglers mailed payment vouchers to the Pacific States Marine Fisheries Commission (PSMFC) for redemption. Anglers returning with northern pikeminnow that were spaghetti-tagged by ODFW as part of the biological evaluation of the fishery (Vigg et al. 1990), were issued a separate tag payment voucher that was mailed to ODFW for tag verification before payment was made by PSMFC. During the 2005 season, the NPSRF paid anglers $4 each for their first 100 northern pikeminnow, $5 each for numbers 101-400, and $6 each for all fish over 400. Anglers received $500 each for returning eligible spaghetti-tagged northern pikeminnow.

ANGLER SAMPLING

Angler data and creel data for the NPSRF were compiled from angler registration forms. One registration form represented one angler day. Angler data consisted of name, date, fishing license number, phone number, and city, state, zip code of participating angler. Creel data recorded by WDFW technicians included fishing location (Figure 3), and primary species targeted (Appendix B). Anglers were asked if they specifically fished for northern pikeminnow at any time during their fishing trip. A "No" response ended the



Fishing Locations:

1. Below Bonneville Dam
2. Bonneville Reservoir
3. The Dalles Reservoir
4. John Day Reservoir
5. McNary Reservoir to the Mouth of the Snake River
6. Mouth of the Snake River to Priest Rapids Dam
7. Mouth of the Snake River to Ice Harbor Dam
8. McNary Reservoir
9. Lower Monumental Reservoir
10. Little Goose Reservoir
11. Lower Granite Reservoir to the Mouth of the Clearwater River
12. Mouth of Clearwater River to Hell's Canyon Dam

Figure 3. Fishing location codes used for the Northern Pikeminnow Sport-Reward Fishery

exit interview. A "Yes" response prompted the technician to ask the angler, and record data on how many of each species of fish were caught, harvested or released while targeting northern pikeminnow. A fish was considered "caught" when the angler touched the fish, whether it was released or harvested. Fish returned to the water alive were defined as "released". Fish that were retained by the angler or not returned to the water alive were considered "harvested".

RETURNING ANGLERS

Technicians interviewed all returning anglers at each registration station to obtain any missing angler data, and to record creel data from each participant's angling day. Creel data from caught and released fishes were recorded from angler recollection. Creel data from all harvested fish species were recorded from visual observation.

NON-RETURNING ANGLERS

Non-returning angler data was compiled from the pool of anglers who had registered for the NPSRF and targeted northern pikeminnow, but did not return to a registration station to participate in an exit interview. WDFW technicians attempted to survey 20% of the NPSRF's non-returning anglers by telephone in order to obtain creel data from that segment of the NPSRF's participants. To obtain the 20% sample, non-returning anglers were randomly selected from each registration station for each week. A technician called anglers from each random sample until the 20% sample was attained. Non-returning anglers were surveyed with the same exit interview questions used for returning anglers. Anglers were asked: "did you specifically fish for northern pikeminnow at any time during your fishing trip?" With a "Yes" response, anglers were asked to report the number and species of adult and/or juvenile salmonids and the number of reward size northern pikeminnow that were caught and harvested/released while they targeted northern pikeminnow. Angler catch and harvest data were not collected from anglers who did not target northern pikeminnow on their fishing trip. Non-returning angler catch data for non-salmonid species was last obtained in 2000. At that time it was recommended that the procedure be repeated in 2005 to determine if trends in catch had changed. In response, non-returning anglers in 2005 were also asked the above questions as they pertain to non-salmonid species.

NORTHERN PIKEMINNOW HANDLING PROCEDURES

BIOLOGICAL SAMPLING

Technicians examined all fishes returned to registration stations and recorded species as well as number of fish per species. Technicians examined all northern pikeminnow for the presence of external tags (spaghetti or dart), fin-clip marks, and signs of tag loss. Fork lengths and sex (determined by evisceration) of northern pikeminnow as well as fork lengths for any other harvested fish species were recorded whenever possible. All spaghetti tagged northern pikeminnow were scanned for PIT tags, measured for fork length, eviscerated to determine sex, and scale and opercle samples were taken. Data from tags, fin-clip marks or signs of tag loss were recorded on data forms and on a tag envelope. The tag was placed in the envelope, stapled to the tag payment voucher and given to the angler to submit to ODFW for verification.

PIT TAG DETECTION

Northern pikeminnow harvested by anglers participating in the NPSRF have been found to ingest juvenile salmonids carrying passive integrated transponder (PIT) tags (Glaser et al. 2000). PIT tags were also used for the first time as a secondary mark in all northern pikeminnow that were fitted with spaghetti tags as part of the 2003 NPMP's biological evaluation activities. The use of PIT tags rather than fin clips as a secondary mark in northern pikeminnow has improved the NPSRF's estimate of tag loss, and resulted in a more accurate estimate of exploitation for the NPSRF. WDFW technicians scanned 100% of all northern pikeminnow returned to registration stations for PIT tags using two types of PIT tag "readers". Northern Pikeminnow were scanned using primarily Destron Fearing portable transceiver systems (model #FS2001F) to record information from PIT tag detections for submission to the Columbia Basin PIT tag information System (PTAGIS). The NPSRF also used Allflex ISO Compatible RF/ID Portable Readers (model #RS601) to scan northern pikeminnow and assist in recovery of initial PIT tag data when the Dextrons were not available. Scanning began on the first day of the NPSRF pre-season and continued throughout the rest of the year. Technicians individually scanned all reward sized northern pikeminnow for PIT tag presence and complete biological data were recorded from pikeminnow with positive readings. All PIT tagged northern pikeminnow were labeled and preserved for later dissection and tag recovery. All data were verified after recovery of PIT tags and all PIT tag readers were downloaded regularly to a central laptop computer from which detection information was forwarded to PTAGIS via electronic mail.

NORTHERN PIKEMINNOW PROCESSING

During biological sampling, all northern pikeminnow were eviscerated (to determine sex), or caudal clipped as an anti-fraud measure to eliminate the possibility of previously processed northern pikeminnow being resubmitted for payment. In 2005, most northern pikeminnow were caudal clipped rather than eviscerated in order to facilitate accurate scanning for PIT tags. Sampled northern pikeminnow were iced and transported to cold storage facilities from which they were ultimately delivered to rendering facilities for final disposal.

RESULTS AND DISCUSSION

NORTHERN PIKEMINNOW HARVEST

The NPSRF harvested a total of 241,357 reward size northern pikeminnow ($\geq$ 228 mm TL) during the 2005 season and achieved the NPSRF's highest ever exploitation rate at 19% (ODFW, personal communication). Although the 2005 harvest was 10% lower (26,057 fish) than the record harvest from 2004, it was still the NPSRF's second highest harvest to date and was 42% higher than the mean 1991-2004 season harvest. The 2005 NPSRF continued the trend toward higher than average harvest seen in the five most recent NPSRF seasons (Figure 4). The upswing in harvest coincides with aggressive

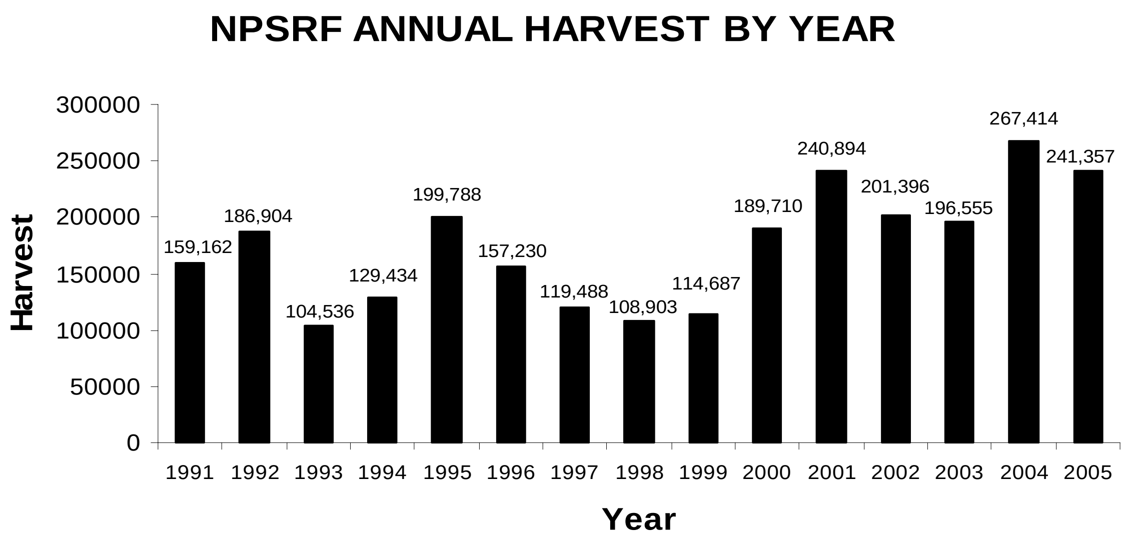


Figure 4. Annual Harvest Totals for the Northern Pikeminnow Sport Reward Fishery

actions taken by the NPMP to improve program effectiveness following recommendations contained in the Hankin and Richards Independent Review of NPMP Justification, Performance, and Cost Effectiveness (2000). These actions include lowering the minimum size northern pikeminnow eligible for reward payment from 11" to 9" in 2000, and boosting angler rewards in the 2001, 2004, and 2005 seasons. In addition to reward size northern pikeminnow, the 2005 NPSRF also harvested 5,117 northern pikeminnow <228 mm TL

The weekly harvest totals for the 2005 NPSRF followed a pattern very similar to the pattern from the 2004 NPSRF (Figure 5). Early, and late season harvest totals were comparable, but weekly harvest levels for the heart of the season in 2005 never reached

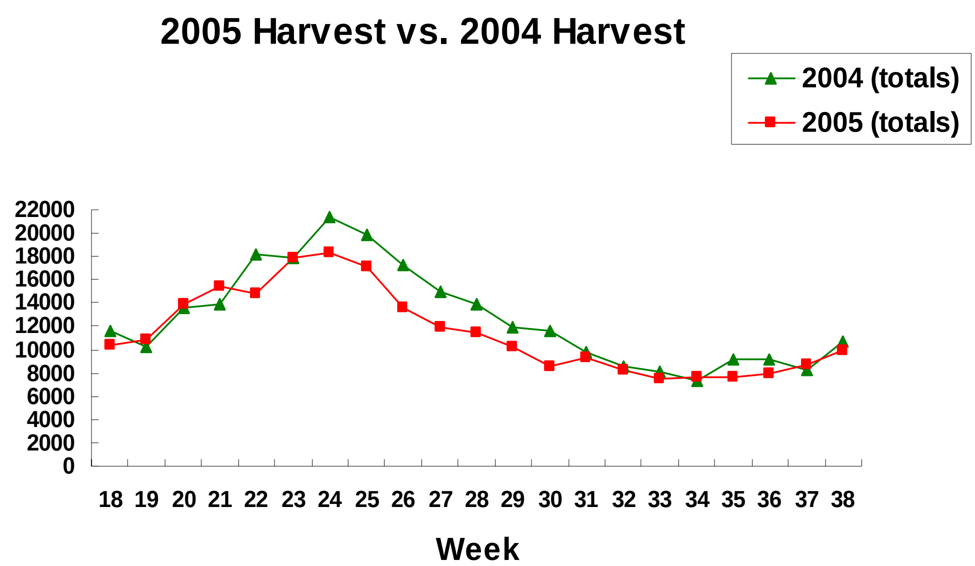


Figure 5. 2005 Weekly NPSRF Harvest vs. 2004 Weekly Harvest.

the record setting levels of the 2004 NPSRF. Mean weekly harvest was 11,493 in 2005 versus 12,734 in 2004, and ranged from a peak of 18,298 in week 24 (June 13-19) to 7,530 in week 33 (August 15-21) (Figure 6). Peak harvest in week 24 occurred during

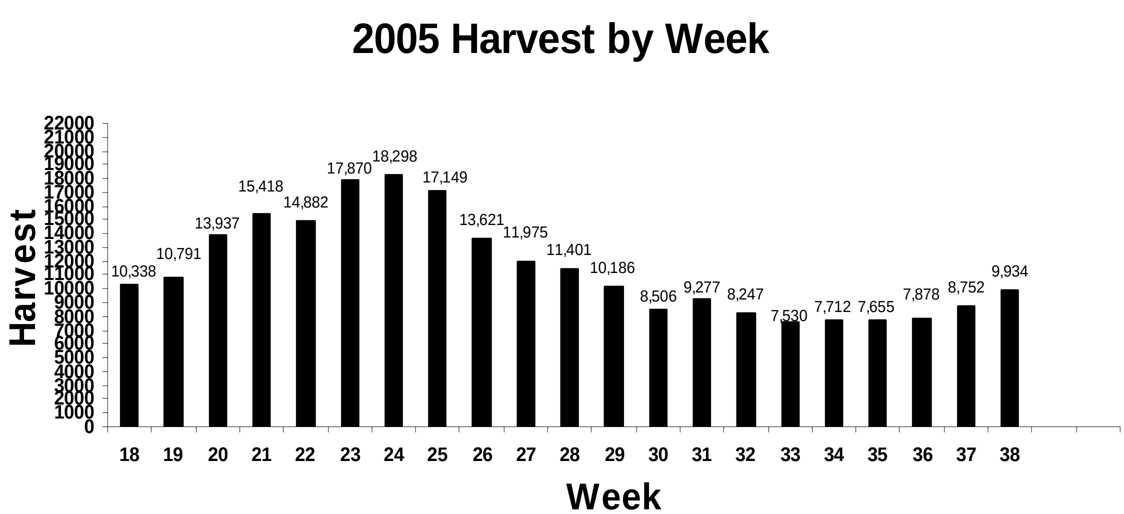


Figure 6. Northern Pikeminnow Sport-Reward Fishery Harvest by Week.

the same week as in 2004, but was lower by 3,162 fish. Even though weekly harvest totals for the 2005 NPSRF were down from 2004, they were consistently higher than the mean weekly harvest totals for 1991-2004 (Figure 7). Weekly harvest for the 2005

NPSRF followed the same weekly pattern seen to date, although peak harvest occurred two weeks earlier than the NPSRF's historical peak in week 26 (Fox et al. 1999).

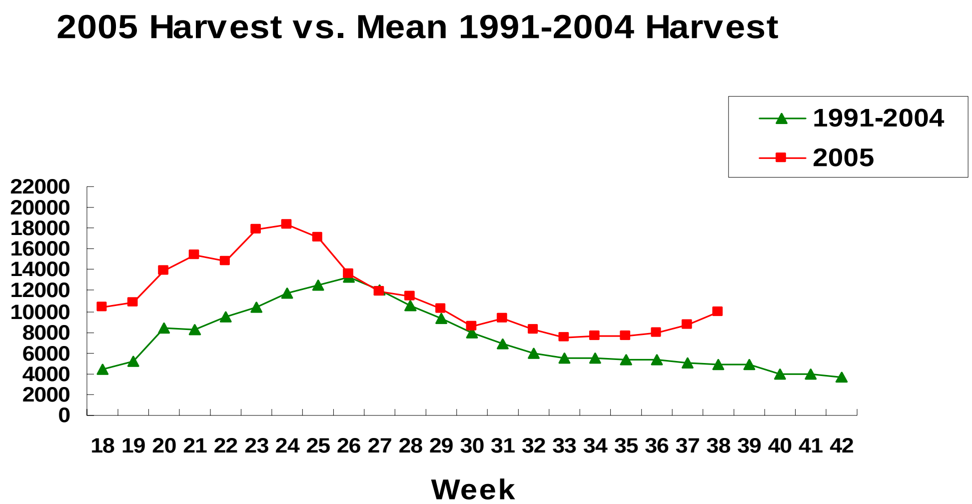


Figure 7. Comparison of 2005 Mean NPSRF Weekly Harvest to 1991-2004 Mean Weekly Harvest.

2005 Harvest by Fishing Location

The mean harvest by fishing location was 20,113 northern pikeminnow and ranged from 87,575 reward size northern pikeminnow in fishing location 01 (downstream of Bonneville Dam) to 131 northern pikeminnow from fishing location 05 (McNary Dam to mouth of the Snake River) (Figure 8). Harvest from Fishing Location 01 (the Columbia river below Bonneville Dam) accounted for 37% of total harvest and was the NPSRF's highest producing area as it has been for each year since 1991. NPSRF anglers once again harvested an unusually high number of northern pikeminnow from Bonneville Pool (Fishing location 02) as was first documented during the 2004 NPSRF (Hone et al. 2004). Harvest in this fishing location has traditionally been concentrated in and around the tailrace area of The Dalles Dam and during the past two seasons, NPSRF staff have recorded consistently larger than usual catches from anglers fishing exclusively in this area. The increase in harvest of northern pikeminnow from this area during the 2004, and 2005 NPSRF has coincided with the installation of a concrete water diversion wall in the tailrace of the Dalles Dam during the winter of 2003 (Normandeau Associates, Inc. and J. R. Skalski. 2005).

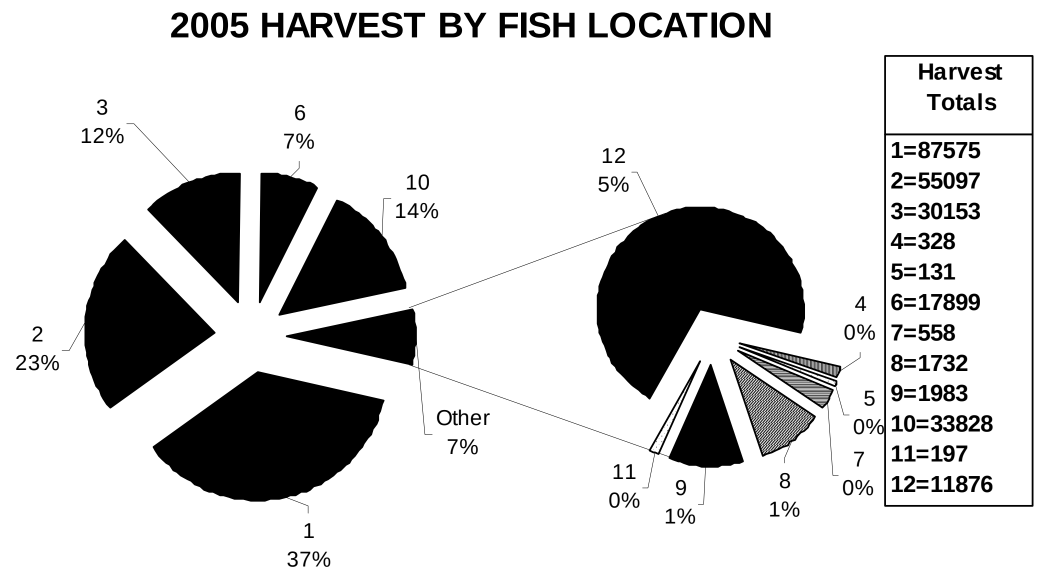


Figure 8. 2005 Northern Pikeminnow Sport-Reward Fishery Harvest by Fishing Location

2005 Harvest by Registration Station

The mean harvest per registration station was 15,085 reward size northern pikeminnow and ranged from 47,183 northern pikeminnow at The Dalles station (20% of the total NPSRF harvest) to 1,942 northern pikeminnow at the Lyon's Ferry station (Figure 9). These numbers are similar to the numbers for 2004.

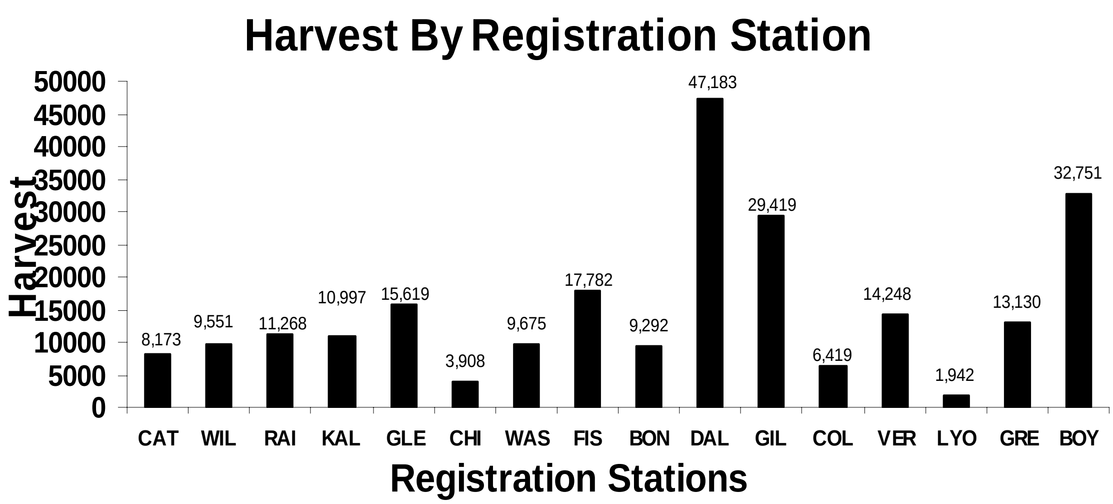


Figure 9. 2005 Northern Pikeminnow Sport-Reward Fishery Harvest by Registration Station. CAT-Cathlamet, WIL-Willow Grove, RAI-Rainier, KAL-Kalama, GLE-Gleason, CHI-Chinook, WAS-Washougal, FIS-The Fishery, BON-Bonneville Trailhead, DAL-TheDalles, GIL-Giles French, COL-Columbia Point, VER-Vernita, LYO-Lyon's Ferry, GRE-Greenbelt, BOY-Boyer Park.

Incidental Catch/Harvest by Species

Returning anglers

As expected, returning anglers targeting northern pikeminnow during the 2005 NPSRF, most often caught and harvested northern pikeminnow. Other fish species incidentally caught by these anglers were mostly peamouth, smallmouth bass, white sturgeon, and channel catfish as has been the case in each year that the NPSRF has been implemented since 1991 (Table 1).

Table 1. Catch and Harvest Totals of non-salmonids by Returning Anglers Targeting Northern Pikeminnow During the 2005 Northern Pikeminnow Sport-Reward Fishery.

Non-Salmonid Species	Caught	Harvest	Harvest Percent
Northern Pikeminnow >228mm	241,381	241,357	99.99%
Peamouth	51,880	5,960	11.49%
Northern Pikeminnow <228mm	49,833	5,117	10.27%
Smallmouth Bass	19,368	1,557	8.04%
White Sturgeon	6,933	155	2.24%
Channel Catfish	6,573	1,239	18.85%
Sucker (unknown)	2,849	216	7.58%
Sculpin (unknown)	2,543	287	11.29%
Walleye	1,332	794	59.61%
American Shad	735	192	26.12%
Yellow Perch	724	135	18.65%
Starry Flounder	713	40	5.61%
Chiselmouth	521	99	19.00%
Carp	518	48	9.27%
Bullhead (unknown)	400	34	8.50%
Catfish (unknown)	116	32	27.59%
Crappie (unknown)	81	24	29.63%
Bluegill	74	7	9.46%
Redside Shiner	63	7	11.11%
Whitefish	34	7	20.59%
Largemouth Bass	21	1	4.76%
Pumpkinseed	19	3	15.79%
Sandroller	15	1	6.67%

In addition to these species, anglers also reported that they caught the salmonids listed in Table 2 during the 2005 NPSRF. Incidental salmonid catch by NPSRF anglers consisted mostly of juvenile steelhead and adult chinook. Anglers reported that all juvenile salmonids were released, and all juvenile steelhead not specifically reported as missing the adipose fin were recorded as “wild”. Harvested adult salmonids (hatchery chinook and steelhead) were taken incidentally and only retained during a legal salmonid fishery. Instances where anglers reported harvesting “trout” are likely residualized hatchery steelhead smolts from the Snake River that are caught and kept by anglers during a legal fishery, and misidentified as trout. Salmonids recorded as "unknown" are recorded that way based solely on angler recollection (since they were caught and released) rather than identification by WDFW technicians. Any anglers who report illegally harvesting salmonids (whether juvenile or adult salmonids), are immediately reported to the appropriate enforcement entity.

Table 2. Salmonid Catch and Harvest totals by Returning Anglers Targeting Northern Pikeminnow during the 2005 NPSRF.

Salmon

Species	Caught	Harvest	Harvest Percent
Chinook (Adult)	45	17	37.78%
Chinook (Jack)	18	8	44.44%
Chinook (Juvenile)	34	0	0.00%
Coho (Adult)	1	0	0.00%
Coho (Juvenile)	15	0	0.00%
Cutthroat (unknown)	21	4	19.05%
Salmon Pacific (unknown)	1	0	0.00%
Steelhead Adult (Hatchery)	31	4	12.90%
Steelhead Adult (Wild)	48	0	0.00%
Steelhead Juvenile (Hatchery)	40	0	0.00%
Steelhead Juvenile (Wild)	96	0	0.00%
Trout (Unknown)	289	30	10.38%

Non-returning Anglers Catch and Harvest Estimates

We surveyed 2,169 non-returning anglers (18% of all non-returning anglers) to record their catch and/or harvest of northern pikeminnow, salmonid species, and non-salmonid species. Surveyed non-returning anglers targeting northern pikeminnow reported that they caught and/or harvested the species listed in column 1 of Table 3 during the 2005 NPSRF. A simple estimator was applied to the catch and harvest totals obtained from the surveyed anglers to obtain a total catch and harvest estimate for all non-returning anglers. Estimated total catch and harvest of northern pikeminnow and incidentally caught species for all non-returning anglers participating in the 2005 NPSRF is listed in columns 4 and 5 of Table 3.

Table 3. 2005 NPSRF Catch and Harvest for surveyed Non-returning Anglers and Estimated non-return totals.

Species	Caught	Harvested	%Harvested	Estimated Total Catch	Estimated Total Harvest
Northern Pikeminnow ≥ 228 mm	97	74	76.29%	539	411
Northern Pikeminnow < 228 mm	606	123	20.30%	3366	683
Peamouth	1299	184	14.16%	7214	1022
Smallmouth Bass	859	99	11.53%	4771	550
White Sturgeon	449	4	0.89%	2494	22
Sculpin (combined species)	108	4	3.70%	600	22
Channel Catfish	104	40	38.46%	578	222
Sucker (combined species)	87	12	13.79%	483	67

Table 3. Continued.

Species	Caught	Harvested	%Harvested	Estimated Total Catch	Estimated Total Harvest
Bullhead (combined species)	78	11	14.10%	433	61
Starry Flounder	54	5	9.26%	300	28
American Shad	48	18	37.50%	267	100
Walleye	39	19	48.72%	217	106
Yellow Perch	34	3	8.82%	189	17
Carp	30	12	40.00%	167	67
Bluegill	21	10	47.62%	117	56
Chiselmouth	17	3	17.65%	94	17
Largemouth Bass	8	8	100%	44	44
Crappie (combined species)	1	0	0%	6	0
Blue Catfish	1	0	0%	6	0
Mountain Whitefish	1	0	0%	6	0
Rock Bass	1	0	0%	6	0
Trout, unknown	21	0	0%	117	0
Steelhead (juvenile - Adipose absent)	3	0	0%	17	0
Coho (juvenile)	3	0	0%	17	0
Chinook (Jack)	3	0	0%	17	0
Steelhead Adult (Adipose absent)	2	1	50%	12	6
Steelhead Adult (Adipose present)	1	0	0%	6	0
Coho (adult)	1	0	0%	6	0
Chinook (Juvenile)	1	0	0%	6	0
Trout, Cutthroat	1	0	0%	6	0

N=12,046 n=2,169

Fork Length Data

A total of 88,183 northern pikeminnow ≥ 200 mm (36.6% of all northern pikeminnow returned to registration stations) were sampled for fork length in 2005. Of these, 85,486 had a fork length > 209 mm. The mean fork length for northern pikeminnow ≥ 200 mm was 293.9 mm with a standard deviation of 66.5 mm. The length frequency distribution of northern pikeminnow ≥ 200 mm is presented in Figure 10.

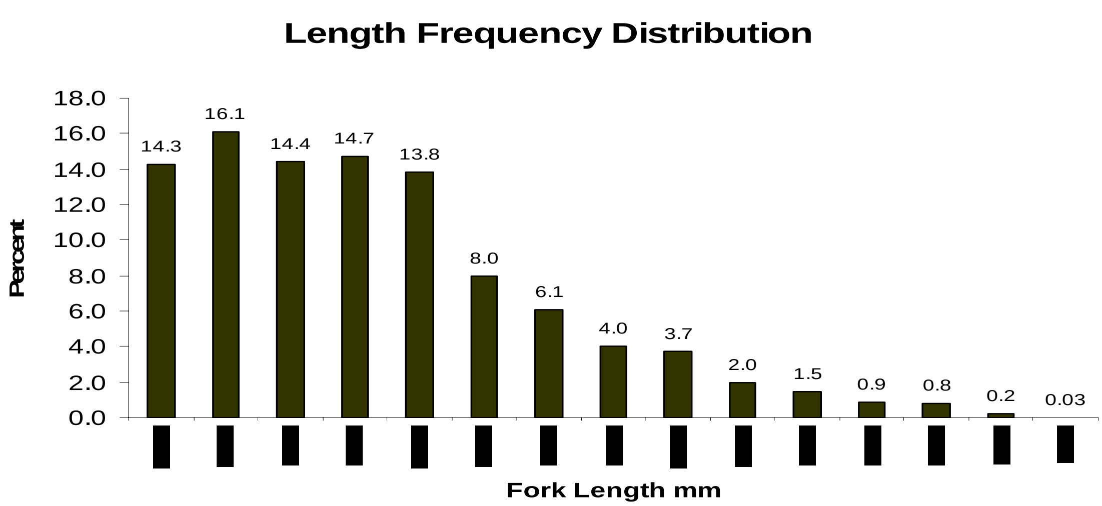


Figure 10. Length frequency distribution of northern pikeminnow ≥ 200 mm FL sampled in 2005.

Angler Effort

The NPSRF recorded total effort of 35,323 angler days spent during the 2005 season. This was nearly identical to the 2004 total of 35,211 angler days. Weekly effort ranged from 957 in week 35 (August 29-September 4) to 2,506 during week 25 (June 20-26) (Figure 11). Effort peaked during week 25, which was one week later than this year's peak harvest. When total effort is divided into returning and non-returning angler days, 23,196 angler days (66%) were recorded by returning anglers. The percentage of returning anglers is the same as the 2004 NPSRF, and continues the trend toward a higher percentage of participants being recorded as returning anglers as seen in recent years. In addition, 88% of total effort (20,387 angler days), was attributed to successful anglers who harvested NPM.

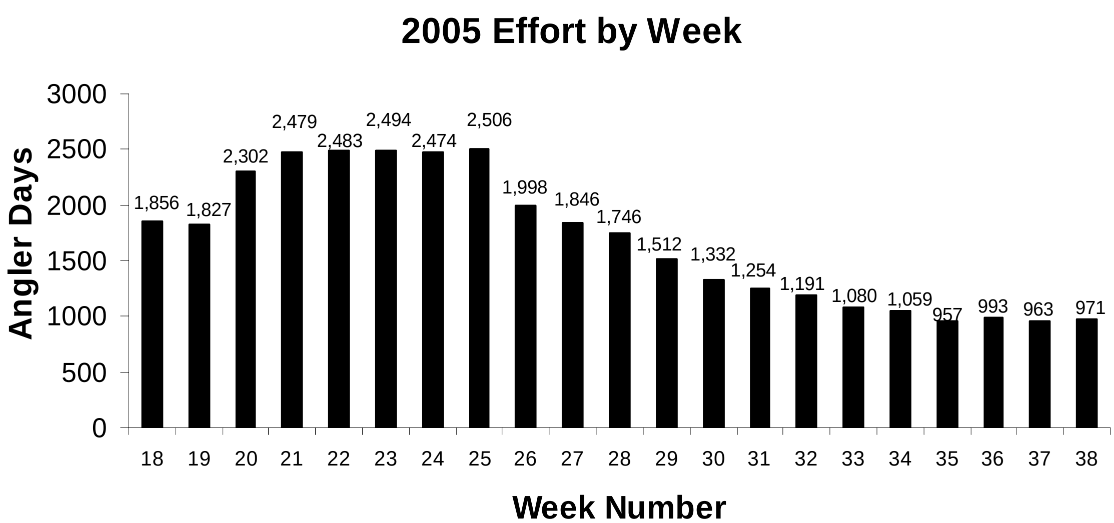


Figure 11. 2005 Northern Pikeminnow Sport-Reward Fishery Effort by Week.

At 1,682 angler days, mean weekly effort for the 2005 NPSRF was also nearly identical to the 2004 mean (1,677). Although total effort and mean weekly effort was nearly the same between years, the seasonal pattern of how the effort was expended was different as seen in Figure 12. The 2004 season followed the typical pattern for the NPSRF, building from the start to a peak at week 24 and then trailing off to the end of the season with a smaller upturn in late August/ early September. The 2005 NPSRF had a better early season with a more prolonged 5 week period of peak effort before tailing off below 2004 without much of a late season bump.

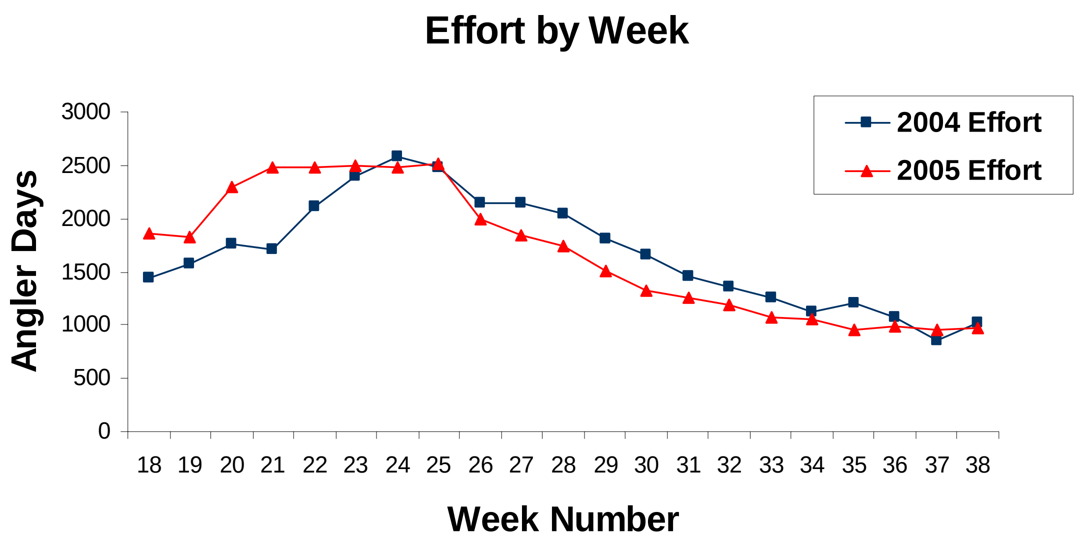


Figure 12. 2005 Weekly Northern Pikeminnow Sport-Reward Fishery Effort vs. 2004 Weekly Effort.

Other than the first and last weeks of the season, overall, 2005 NPSRF effort continued to track below mean 1991-2004 effort levels (Figure 13), and followed the same pattern that the NPSRF has recorded since the program's inception. The effort peak during week 25, was slightly earlier than the NPSRF's traditional peak effort period seen from 1991-2004 (Figure 13).

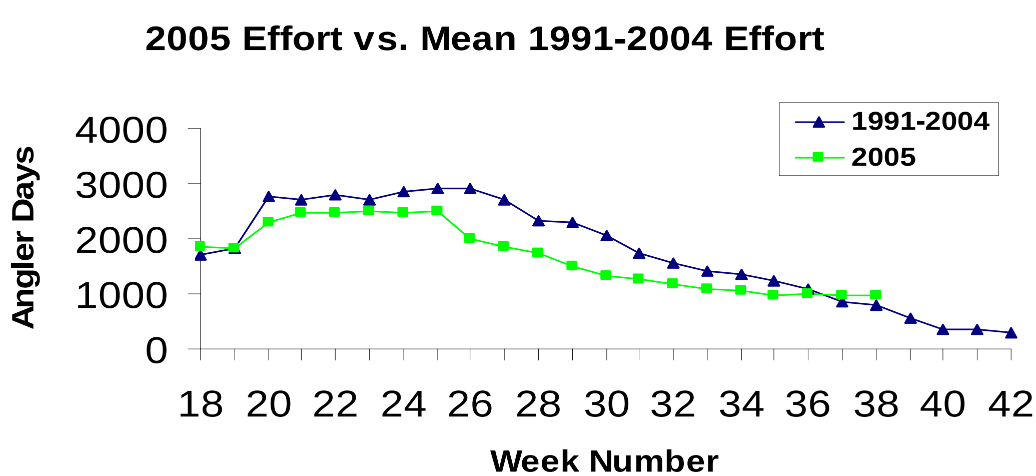


Figure 13. 2005 NPSRF Weekly Effort vs. Mean 1991-2004 Effort.

Mean annual effort (returning anglers only) by fishing location was 1,699 angler days and ranged from 9,104 (45% of NPSRF total) in fishing location 01 (below Bonneville Dam) to 13 in fishing location 05 (McNary Dam to mouth of Snake River) (Figure 14).

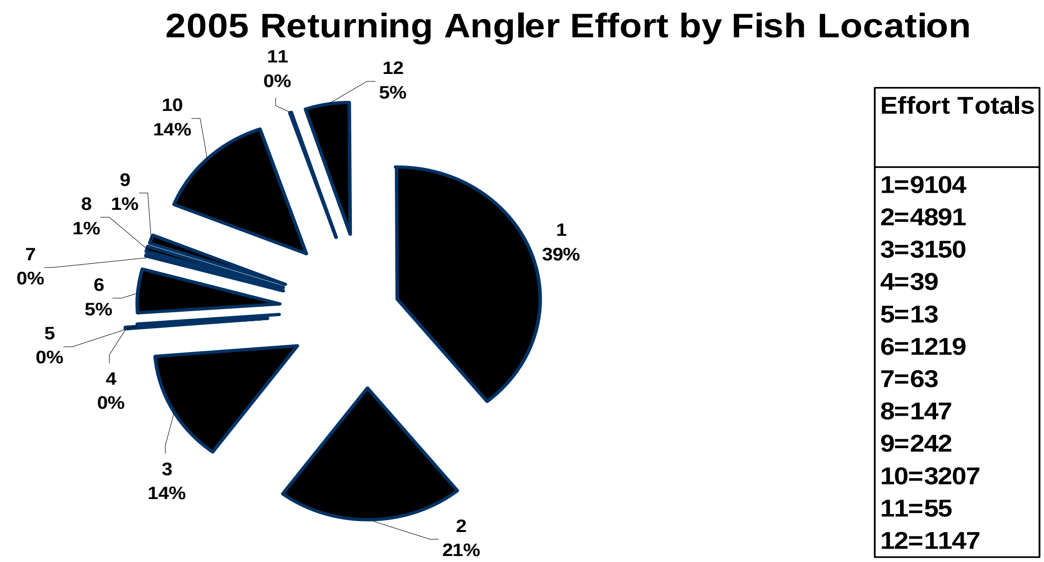


Figure 14. 2005 NPSRF Angler Effort by Fishing Location (returning anglers only).

Mean effort per registration station was 2,208 angler days and ranged from 6,804 angler days at The Dalles to 526 angler days at Lyons Ferry (Figure 15).

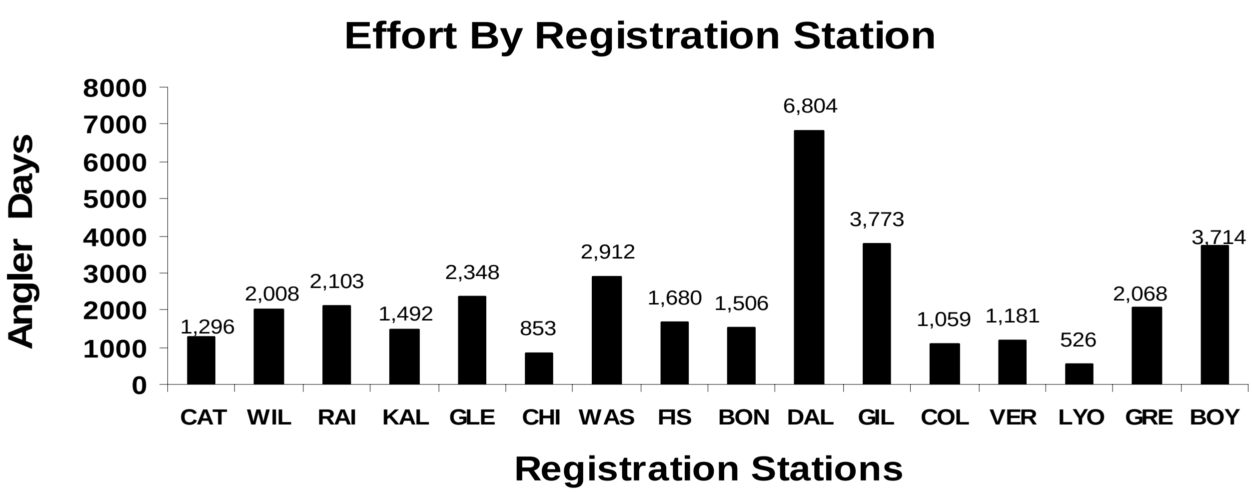


Figure 15. Northern Pikeminnow Sport-Reward Fishery Angler Effort by Registration Station. CAT-Cathlamet, WIL-Willow Grove, RAI-Rainier, KAL-Kalama, GLE-Gleason, CHI-Chinook, WAS-Washougal, FIS-The Fishery, BON-Bonneville Trailhead, DAL-TheDalles, GIL-Giles French, COL-Columbia Point, VER-Vernita, LYO-Lyon's Ferry, GRE-Greenbelt, BOY-Boyer Park.

CATCH PER ANGLER DAY

The NPSRF recorded an overall catch per unit of effort (CPUE) of 6.83 northern pikeminnow harvested per angler day (returning + non-returning anglers) during the 2005 season. This catch rate was down slightly from 7.59 recorded in 2004. Overall, there has been a fairly steady increase in CPUE from 1991-2005 (Figure 16). Returning angler CPUE was 11.84 northern pikeminnow per angler day. We estimated CPUE for non-returning anglers to be 0.04 using our harvest estimates of northern pikeminnow by this group of anglers from Table 3. Clearly (as has been the case since 1991), returning anglers are considerably more skillful at harvesting reward size northern pikeminnow than are non-returning anglers.

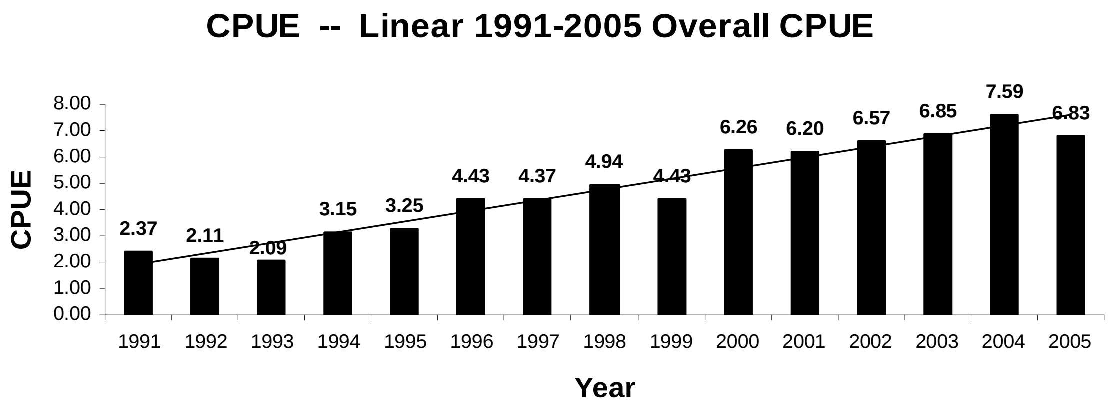


Figure 16. Annual CPUE Totals (returning + non-returning anglers) for the NPSRF 1991-2005.

Mean weekly CPUE was 6.83 and ranged from 5.57 in week 18 (May 2-8) to a peak of 10.23 in week 38 (September 19-25) (Figure 17).

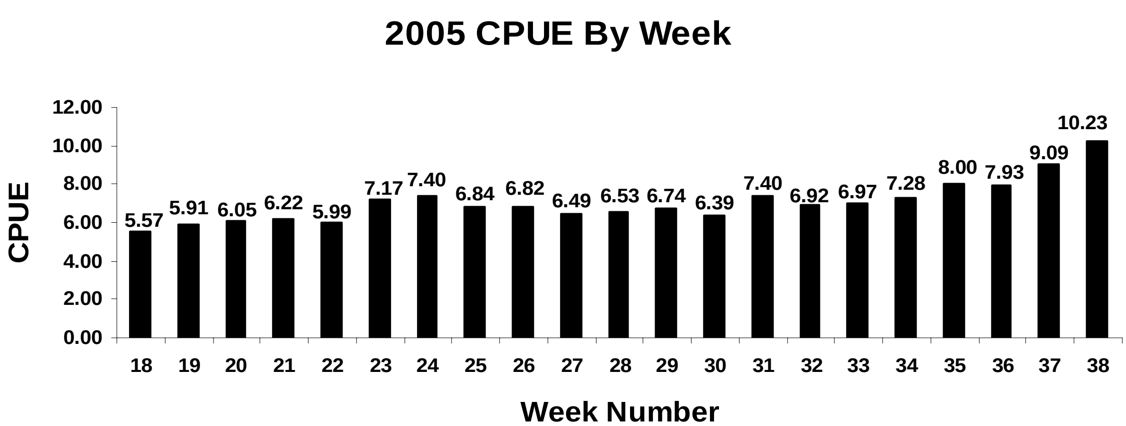


Figure 17. 2005 Northern Pikeminnow Sport-Reward Fishery Angler CPUE by Week.

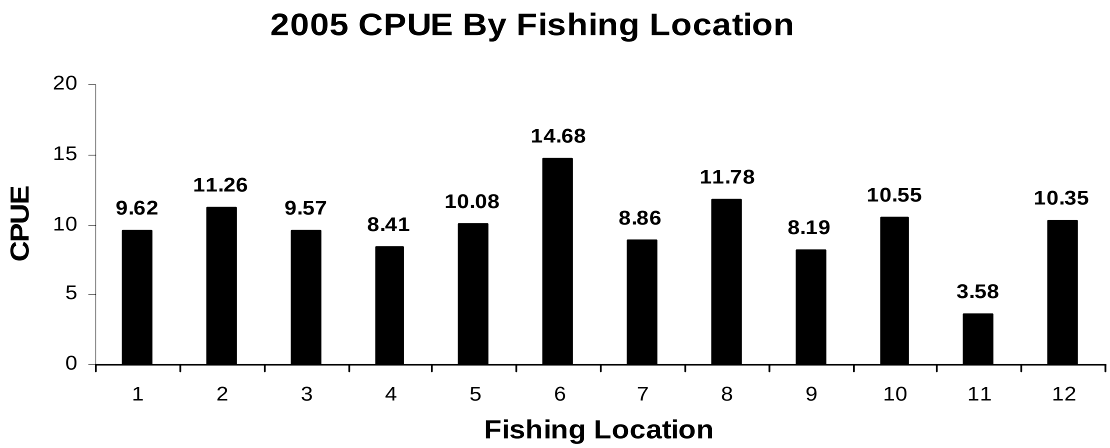


Figure 18. 2005 Northern Pikeminnow Sport-Reward Fishery Angler CPUE by Fishing Location.

The CPUE by fishing location during the 2005 NPSRF ranged from 14.68 northern pikeminnow per day in fishing location 6 (Mouth of the Snake River to Priest Rapids Dam) to 3.58 in fishing location 11 (Lower Granite Reservoir to the mouth of the Clearwater River) (Figure 18).

The registration Station that recorded the highest CPUE from the 2005 NPSRF was Vernita with 12.06 northern pikeminnow per angler day (Figure 19). The registration station with the lowest CPUE was Washougal with 3.32 northern pikeminnow per angler day. For the most part, changes in registration station CPUE were subtle for the 2005 NPSRF. Gleason illustrated the largest change in CPUE with an increase from 4.46 in 2004 to 6.65 in 2005.

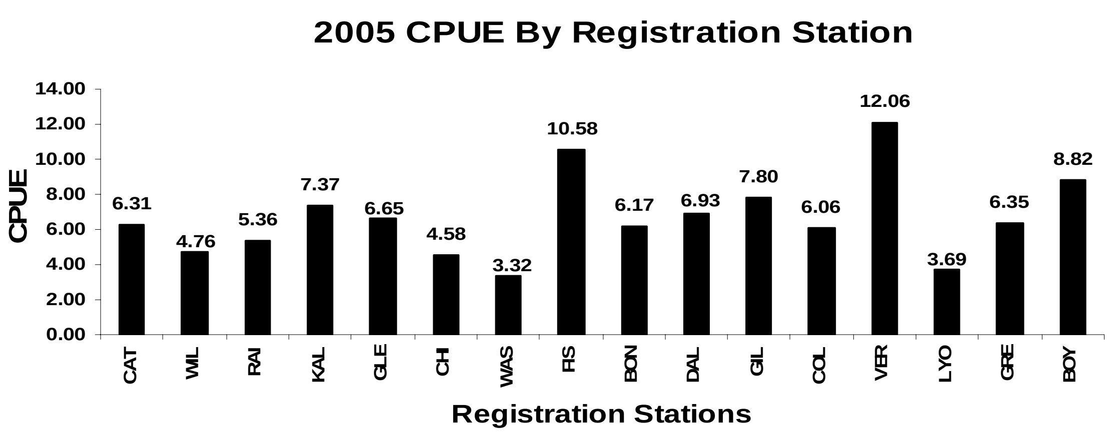


Figure 19. 2005 Northern Pikeminnow Sport-Reward Fishery Angler CPUE by Registration Station. CAT-Cathlamet, WIL-Willow Grove, RAI-Rainier, KAL-Kalama, GLE-Gleason, CHI-Chinook, WAS-Washougal, FIS-The Fishery, BON-Bonneville Trailhead, DAL-TheDalles, GIL-Giles French, COL-Columbia Point, VER-Vernita, LYO-Lyon's Ferry, GRE-Greenbelt, BOY-Boyer Park.

ANGLER TOTALS

There were 5,385 separate anglers who participated in the 2005 NPSRF. Two thousand, one hundred and sixty four of these anglers (40%) were classified as successful since they harvested at least one northern pikeminnow during the 2005 season. The average annual harvest of reward size northern pikeminnow per successful angler was 112 northern pikeminnow per season. When we break down the 2,164 successful anglers by tier, 82% (1,784 anglers) harvested fewer than 100 northern pikeminnow (Tier 1) during the 2005 season (Figure 20), with an average harvest of 14. Ten percent (209 anglers) harvested between 101 and 400 northern pikeminnow (Tier 2) with an average harvest of 200 NPM. Eight percent (168 anglers) caught more than 400 northern pikeminnow (Tier 3) averaging 1,043 NPM.

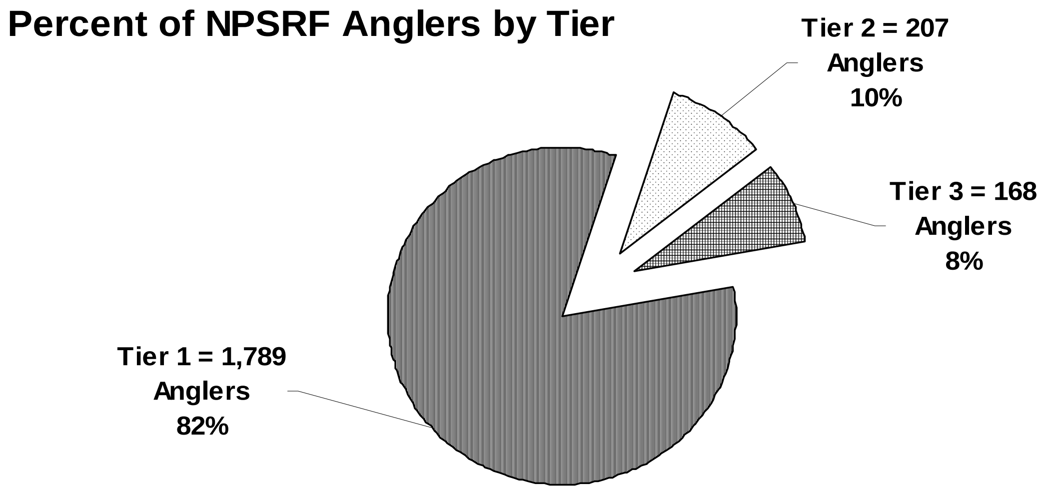


Figure 20. 2005 NPSRF Percentage of Anglers (returning) by tier (based on fish harvested.

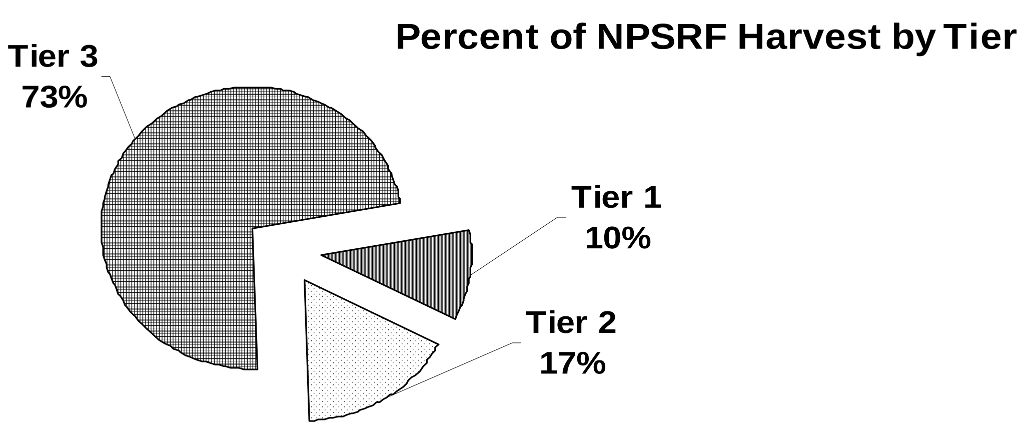


Figure 21. Percentage of total 2005 NPSRF Harvest by Angler Tier (Tier 1 = <100, Tier 2 =101-400, Tier 3 = > 400).

The average angler spent more effort pursuing northern pikeminnow during in the 2005 NPSRF than in 2004. Tier 1 anglers spent an average of 7 days fishing (up from an average of 6 days in 2004) during the 2005 season (Figure 22). Tier 2 anglers spent an average of 32 days fishing (up from 29 days in 2004), while Tier 3 anglers spent an average of 72 days fishing (up from 61 days in 2004) during the 2005 NPSRF. This is the first year that the NPSRF has noted much change in angler effort totals (by tier level) from levels first reported in the 2000 NPSRF Annual Report (Glaser et al 2000).

Cumulative 2005 NPSRF harvest by angler tier was as follows: Of the total 2005 NPSRF harvest, Tier 1 anglers caught 10% (25,458 northern pikeminnow), Tier 2 anglers caught 17% (41,704 northern pikeminnow), and Tier 3 anglers caught 73% (175,263 northern pikeminnow) (Figure 21). Compared to 2004, harvest decreased 2% for Tiers 1 and 2 anglers and increased 4% for Tier 3 anglers.

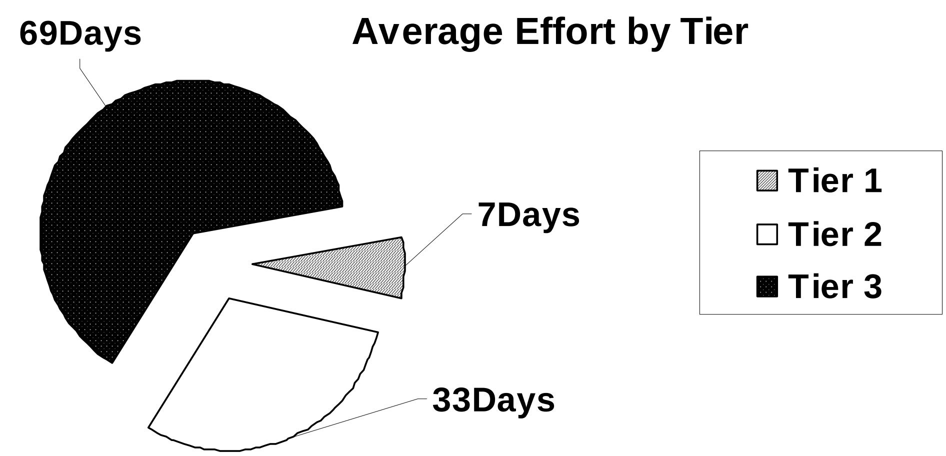


Figure 22. Average Effort of 2005 NPSRF Anglers by Tier (Tier 1 = <100, Tier 2 =101-400, Tier 3 = > 400) .

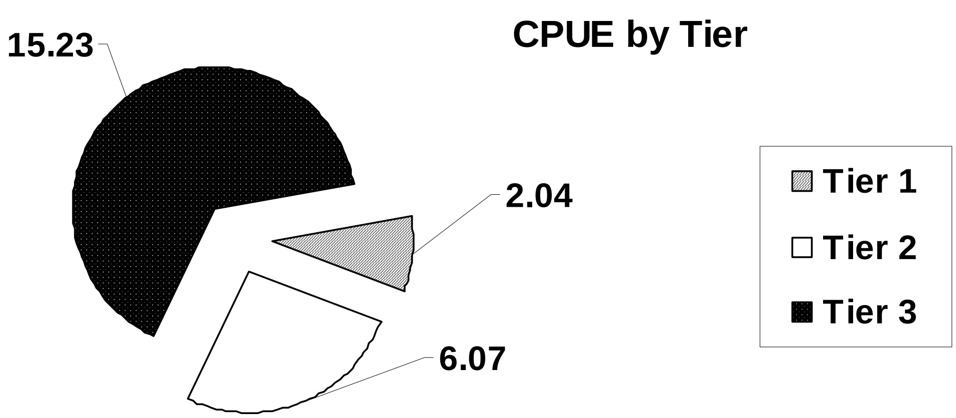


Figure 23. Average CPUE of 2005 NPSRF Anglers by Tier (Tier 1 = <100, Tier 2 =101-400, Tier 3 = > 400).

CPUE decreased from 2004 across all three tier levels (Figure 23). The CPUE for Tier 1 anglers was 2.10 northern pikeminnow per registered angling trip during the 2005

NPSRF (down from 2.44). The CPUE for Tier 2 anglers was 6.12 northern pikeminnow per trip (down from 6.94), while Tier 3 angler CPUE was 15.22 northern pikeminnow per trip (down from 17.52 in 2004) during the 2005 NPSRF.

The top angler for the 2005 NPSRF harvested 4,800 NPM, which was 60 more fish than the number two angler harvested, and 136 more fish than last years top angler who harvested 4,664 northern pikeminnow. The CPUE for this year's top angler was 47.1 northern pikeminnow (compared to the 2004 top angler's CPUE of 40.6), and he spent 102 angler days of effort during the 2005 season (versus 115 days by the top angler in 2004). By comparison, the two anglers who participated the most, fished 144 days each and harvested 2,452 northern pikeminnow and 1,649 northern pikeminnow respectively.

TAG RECOVERY

Returning anglers recovered and turned in 170 northern pikeminnow tagged with external spaghetti tags during the 2005 NPSRF compared to 174 spaghetti tags in 2004 (Hone et al., 2004). WDFW technicians identified 146 spaghetti tagged northern pikeminnow that had been PIT tagged by ODFW as a secondary mark. Technicians recorded an additional 93 northern pikeminnow with a fin-clip marks and/or wounds consistent with having lost an ODFW spaghetti tag. The recovered tags and potential tag loss data was estimated by ODFW to equal a 19% exploitation rate for the 2005 NPSRF (ODFW, personal communication, NPMP Coordination Meeting 1/10/06).

A total of 241,357 northern pikeminnow were individually scanned for the presence of PIT tags. This represents 100% of the total harvest of reward-size fish for the 2005 NPSRF (northern pikeminnow not qualifying for rewards were also scanned whenever possible). We recovered a total of 168 PIT tags from consumed smolts that had been ingested by northern pikeminnow harvested during the 2005 NPSRF. This compares to the 2004 NPSRF when 154 PIT tags were recovered from consumed smolts (Hone et al., 2004). The 2005 NPSRF recorded the first PIT tag recovery of the season on May 2nd and continued to collect recoveries throughout the season until August 28th (Figure 24).

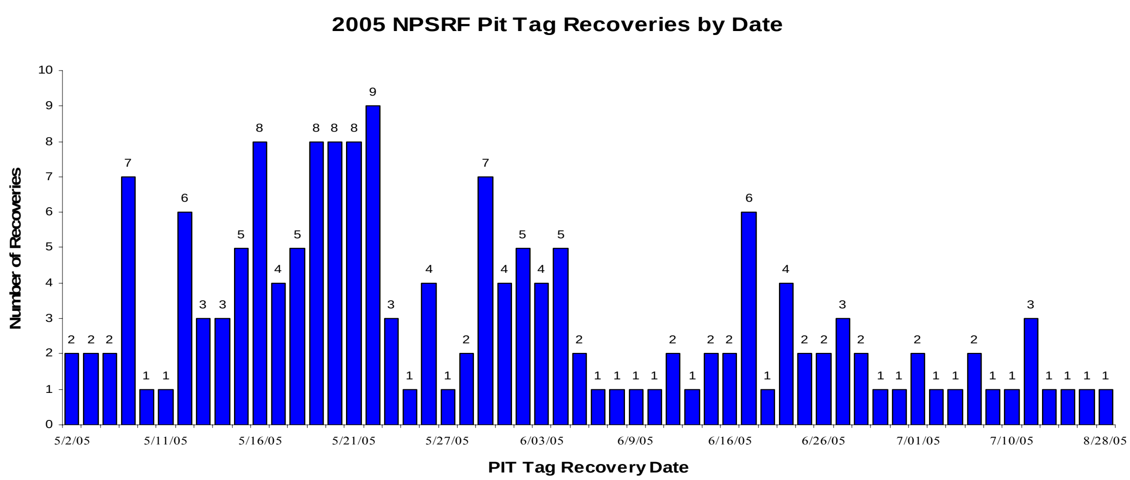


Figure 24. 2005 NPSRF PIT Tag Recoveries by Date.

PIT tag recoveries peaked on May 22nd, which was slightly later than the May 18th peak for the past two NPSRF seasons. Although the single day total number of PIT tags recovered from ingested smolts was not as high in 2005, there was a more prolonged period of higher PIT tag recoveries spread out before and after the peak. Recoveries of PIT tags also lasted later into the year with the last recovery recorded nearly a month later than in 2004 (8/1/04).

Pit tag recoveries by fishing location once again showed that northern pikeminnow harvested from the Bonneville Pool (fishing location 02), and The Dalles Pool (fishing location 03) had ingested the largest number of salmon and steelhead smolts containing PIT tags (Figure 25). This corresponds with ODFW findings which indicate that northern pikeminnow predation on juvenile salmonids is greatest in lower Columbia River areas.

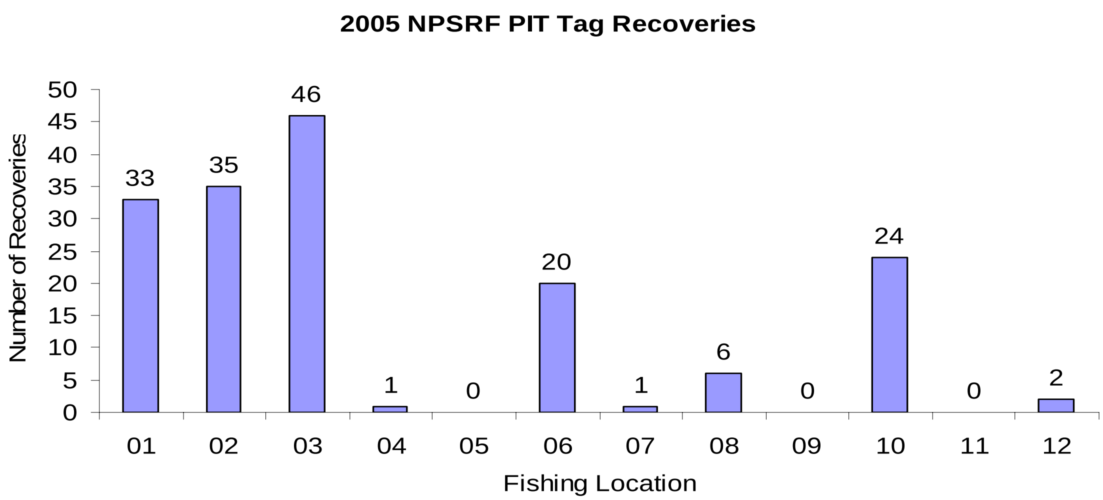


Figure 25. 2005 NPSRF PIT Tag Recoveries by Fishing Location

All 168 PIT tag recoveries from ingested smolts were queried through the PTAGIS database and those queries yielded the following results. Fork lengths of smolts at release from PTAGIS were compared to fork lengths of northern pikeminnow from which the pit tag was recovered (Figure 26). Mean fork length for consumed smolts was 100.17 mm, while mean fork length for the "consuming" northern pikeminnow was 359.6 mm. Both means were smaller than the same means from 2004. Also, as was the case last year, the mean fork length of northern pikeminnow found to have consumed PIT tagged smolts was much larger than the overall mean fork length for all reward-size northern pikeminnow from the 2005 NPSRF (293.9 mm).

Species composition of PIT tagged smolts recovered from northern pikeminnow harvested in the 2005 NPSRF indicated that 119 (70.83%) of the PIT tags were from chinook smolts, 34 (20.24%) were from steelhead smolts, 6 (3.57%) were from coho smolts, and 2 (1.19%) were from PIT tagged sockeye smolts. We also recovered 7 PIT tags listed as "unknown species" in PTAGIS which accounted for the remaining 4.17%. PIT tag queries of PTAGIS for the chinook smolts indicated that 16 of them (13.45%)

were of wild origin. PTAGIS queries also indicated that 3 of the PIT tagged steelhead (8.82%) were of wild origin.

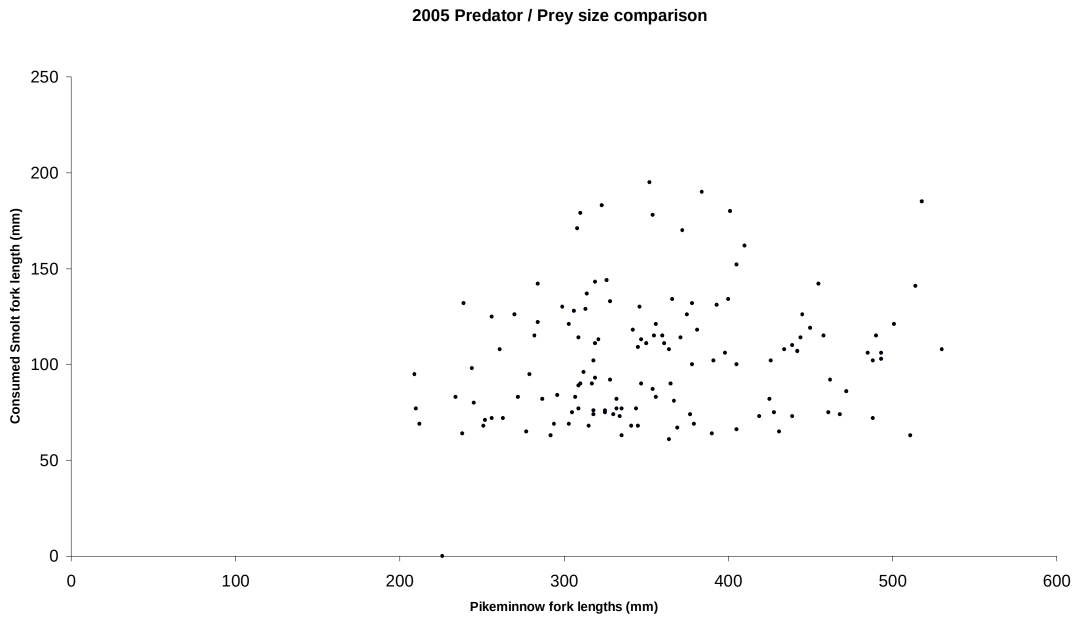


Figure 26. 2005 NPSRF Predator Prey Size Comparison (N=133).

Analysis of PIT tag recovery dates from the 2005 NPSRF continues to document northern pikeminnow predation on downstream migrating juvenile salmonids, primarily spring chinook. Our PIT tag recovery data also shows that northern pikeminnow consume smolts (including Snake River fish) most heavily during the smolts peak migration month of May. Full implementation of the NPSRF throughout the month of May would be useful for capturing and documenting northern pikeminnow predation on these fish. Further data collection and analysis of PIT tag recoveries from juvenile salmonids consumed by northern pikeminnow harvested in the NPSRF may lead to a better understanding of northern pikeminnow predation on salmonid smolts and the factors affecting the vulnerability of smolts to predation while migrating through the Columbia River System.

SUMMARY

The 2005 NPSRF succeeded in reaching the NPMP's 10-20% exploitation goal for the eighth consecutive year, achieving the NPSRF's highest ever exploitation rate at 19%. Even though harvest declined by 10% from the previous year, it was still the second best harvest in NPMP history, trailing only the record setting harvest from the 2004 NPSRF. Angler CPUE was also slightly down from 2004 and was consistently down across all tier levels indicating that fishing conditions were less favorable throughout the NPSRF program area. Overall effort remained constant between years (even though there were fewer participating anglers), due to the fact that participants at each angler tier level spent more angler days fishing in 2005 than in 2004. Despite lower harvest and CPUE levels for the 2005 NPSRF, this did not have a negative effect on overall program success as indicated by the NPMP's increased exploitation rate.

The increased reward level at did encourage anglers at all three tiers to increase their participation as seen in the increased average number of days spent fishing, however the number of anglers at tiers 1 and 2 declined nearly 21%, and even Tier 3 anglers declined 2.4% from the 2004 NPSRF. The increased effort expended by anglers, (especially Tier 3 anglers), compensated for less favorable river conditions to produce the record exploitation rate achieved by the 2005 NPSRF. While it is good to stimulate effort across all tier levels through the use of increased angler rewards, the NPSRF must also continue to find ways to recruit new anglers to the program in order to compensate for inevitable angler attrition over the years. Retention of reward levels similar to current levels for future NPSRF seasons will help retain our most effective and efficient anglers and may also help recruit new anglers to the program.

Detection of PIT tags from juvenile salmonids (retained in the gut of northern pikeminnow when they have been consumed), continues to show promise as a way to obtain additional data on northern pikeminnow predation on outmigrating smolts. Peak PIT tag recoveries from juvenile salmonids consumed by northern pikeminnow continued to coincide with peak downstream smolt migration in May, peaking on May 22nd in 2005 and much less pronounced than either 2004 or 2003. Species composition of PIT tag recoveries from ingested juvenile salmonids showed that while the majority of predation was on hatchery fish, there were also significant numbers of wild chinook and steelhead (including Snake River fish) being consumed by northern pikeminnow. PIT tags were once again used by ODFW as a secondary mark in spaghetti tagged northern pikeminnow during 2005 as a way to eliminate uncertainties associated with tag loss in order to achieve a more accurate estimate of pikeminnow exploitation by the NPSRF. PIT tag recoveries continued to be monitored to identify and document angler fraud from northern pikeminnow tagged outside NPSRF boundaries.

RECOMMENDATIONS FOR THE 2006 SEASON

1.) Begin implementation of the 2006 NPSRF for all registration stations below the John Day Dam on May 1st and the remaining stations on May 15th in response to expected above average river flow (especially in the Snake River), which typically creates river conditions in the upstream areas which are less conducive to harvesting northern pikeminnow.

2.) Maintain emphasis by WDFW technicians on standardized application of angler pre-registration procedures as required by NPMP mandates.

3.) Review NPSRF Rules of participation as needed, adjusting to the dynamics of the fishery and fishery participants, in order to maintain NPSRF integrity.

4.) Develop angler education materials designed to recruit new anglers to NPSRF, and to improve the angling efficiency of current participants in order to achieve the NPMP's 10-20% exploitation goal.

5.) Consider adding additional registration station coverage in areas such as John Day pool if logistically and economically feasible.

6.) Retain the option to extend the NPSRF season on a site-specific basis if warranted by high harvest, angler effort, and/or CPUE levels.

7.) Continue to scan all northern pikeminnow for PIT tags in order to recover tags and record data from juvenile salmonids ingested by northern pikeminnow, and from northern pikeminnow tagged by ODFW as part of the biological evaluation of the NPMP.

8.) Continue to develop additional measures to identify potential angler fraud and to deter anglers from fraudulently submitting northern pikeminnow to the NPMP for payment.

9.) Survey 20% of non-returning anglers to record total non-returning angler catch of all salmonids to estimate total non-returning angler catch and harvest per NPMP protocol.

10.) Investigate additional incentives for anglers to harvest northern pikeminnow from within program boundaries, i.e., spaghetti tagged fish.

REFERENCES

Burley, C.C., D.C. Klaybor, G.W. Short, and G.J. Hueckel. 1992. Evaluation of the northern squawfish sport-reward fishery in the Columbia and Snake Rivers. Report B *in* C.F. Willis and A.A. Nigro, editors. Development of a system-wide predator control program: stepwise implementation of a predator index, predator control fisheries, and evaluation plan in the Columbia River Basin (Northern Pikeminnow Management Program). 1991 Annual Report. Contract DE-B179 -90-BP07084, Bonneville Power Administration, Portland, Oregon.

Fox, L.G., J.J. Amren, B.G. Glaser, M.L. Wachtel, and E.C. Winther. 1999. Implementation of the northern pikeminnow sport-reward fishery in the Columbia and Snake Rivers. *In* Development of a system-wide predator control program: stepwise implementation of a predator index, predator control fisheries, and evaluation plan in the Columbia River Basin (Northern Pikeminnow Management Program). 1999 Annual Report, project number 90-007. Bonneville Power Administration, Portland, Oregon.

Friesen, T.A., and D.L. Ward 1999. Management of northern pikeminnow and implications for juvenile salmonid survival in lower Columbia and Snake Rivers. North American Journal of Fisheries Management 19:406-420.

Glaser, B.G., J.J. Amren, L.G. Fox., M.L. Wachtel, and E.C. Winther. 2000. Implementation of the northern pikeminnow sport-reward fishery in the Columbia and Snake Rivers. *In* Development of a system-wide predator control program: stepwise implementation of a predator index, predator control fisheries, and evaluation plan in the Columbia River Basin (Northern Pikeminnow Management Program). 2000 Annual Report, project number 90-077. Bonneville Power Administration, Portland, Oregon.

Hankin, D.G., and J. Richards. 2000. The northern pikeminnow management program: an independent review of program justification, performance, and cost effectiveness. Report to the Pacific Northwest Electric Power and Conservation Planning Council, Portland, Oregon.

Hisata, J.S., M.R. Peterson, D.R. Gilliland, E.C. Winther, S.S. Smith, and J. Saurez-Pena. 1995. Implementation of the northern squawfish sport-reward fishery in the Columbia and Snake Rivers. Report A *in* Development of a system-wide predator control program: stepwise implementation of a predator index, predator control fisheries, and evaluation plan in the Columbia River Basin (Northern Squawfish Management Program). 1995 Annual Report, project number 90-077. Contract DE-B179-90BP07084, Bonneville Power Administration, Portland, Oregon.

Hone, J.D., R. Bruce, E.C. Winther, and J. Memarian. 2003. Implementation of the northern pikeminnow sport-reward fishery in the Columbia and Snake Rivers. *In* Development of a system-wide predator control program: stepwise implementation of a predator index, predator control fisheries, and evaluation plan in the Columbia River Basin (Northern Pikeminnow Management Program). 2003 Annual Report, project number 90-077. Contract DE-B179-90BP07084, Bonneville Power Administration, Portland, Oregon.

Hone, J.D., R. Bruce, J. Memarian, and E.C. Winther. 2004. Implementation of the northern pikeminnow sport-reward fishery in the Columbia and Snake Rivers. *In* Development of a system-wide predator control program: stepwise implementation of a predator index, predator control fisheries, and evaluation plan in the Columbia River Basin (Northern Pikeminnow Management Program). 2003 Annual Report, project number 90-077. Contract DE-B179-90BP07084, Bonneville Power Administration, Portland, Oregon.

Klaybor, D.C., C.C. Burley, S.S. Smith, E.N. Mattson, E.C. Winther, P. E. DuCommun, H.R. Bartlett, and S,L. Kelsey. 1993. Evaluation of the northern squawfish sport-reward fishery in the Columbia and Snake Rivers. Report B in C.F. Willis and D. L. Ward, editors. Development of a system-wide predator control program: stepwise implementation of a predator index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1993 Annual Report, Volume 1. Contract DE-B179-90BP07084, Bonneville Power Administration, Portland, Oregon.

Nelson, J. S. and five co-authors. 1998. Recommended changes in common fish names: pikeminnow to replace squawfish. Fisheries 23(9):37.

Normandeau Associates, Inc., and J.R. Skalski. 2005. Evaluation of training wall on fish condition at The Dalles Dam spillway, Columbia River. Report prepared for the Department of the Army, Corps of Engineers, Portland District, Portland, OR.

Northwest Power Planning Council. 1987a. Columbia River Basin Fish and Wildlife Program. Northwest Power Planning Council. Portland, Oregon.

Rieman, B.E., R. C. Beamssderfer, S. Vigg, and T.P. Poe. 1991. Predation by resident fish on juvenile salmonids in a mainstem Columbia reservoir: Part IV. Estimated total loss and mortality of juvenile salmonids to northern squawfish, walleye, and smallmouth bass. T. P. Poe, and B.E. Rieman editors. Resident fish predation on juvenile salmonids in John Day Reservoir, 1983-1986. Final Report (Contracts DE-A179-82 BP34796 and DE-A179-82BP35097) to Bonneville Power Administration, Portland, Oregon.

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

Smith, S.E., D.R. Gilliland, E.C. Winther, M.R. Petersen, E.N. Mattson, S.R. Kelsey, J. Suarez-Pena, and J. Hisata. 1994. (Implementation of the northern squawfish sport-reward fishery in the Columbia and Snake Rivers. *In* Development of a system-wide predator control program: Evaluation of the northern squawfish sport-reward fishery in the Columbia and Snake Rivers. Washington Department of Fish and Wildlife, Contract number DE-B179-90BP07084. 1994 Annual Report to the Bonneville Power Administration, Portland, Oregon.

Vigg, S. and C.C. Burley. 1989. Developing a predation index and evaluating ways to reduce salmonid losses to predation in the Columbia Basin. Report A in A.A. Nigro, editor. Developing a predation index and evaluating ways to reduce losses to predation in the Columbia Basin. Oregon Department of Fish and Wildlife, Contract Number DE-A179-88BP92122. Annual Report to Bonneville Power Administration, Portland, Oregon.

Vigg, S., C.C. Burley, D.L. Ward, C. Mallette, S. Smith, and M. Zimmerman. 1990. Development of a system-wide predator control program: Stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. Oregon Department of Fish and Wildlife, Contact number DE-B179-90BP07084. 1990 Annual Report to the Bonneville Power Administration, Portland, Oregon.

Winther, E.C., J.S. Hisata, M.R. Peterson, M.A. Hagen and R. C. Welling. 1996. Implementation of the northern squawfish sport-reward fishery in the Columbia and Snake Rivers. *In* Development of a system-wide predator control program: stepwise implementation of a predator index, predator control fisheries, and evaluation plan in the Columbia River Basin (Northern Squawfish Management Program). 1996 Annual Report, project number 90-077. Contract DE-B179-90BP07084, Bonneville Power Administration, Portland, Oregon.

Winther, E.C., L.G. Fox, M.L. Wachtel, and B.G. Glaser. 2001. Implementation of the northern pikeminnow sport-reward fishery in the Columbia and Snake Rivers. *In* Development of a system-wide predator control program: stepwise implementation of a predator index, predator control fisheries, and evaluation plan in the Columbia River Basin (Northern Pikeminnow Management Program). 2001 Annual Report, project number 90-077. Contract DE-B179-90-BP07084, Bonneville Power Administration, Portland, Oregon.

Winther, E.C., L.G. Fox, J.D. Hone, and J.A. Memarian. 2002. Implementation of the northern pikeminnow sport-reward fishery in the Columbia and Snake Rivers. *In* Development of a system-wide predator control program: stepwise implementation of a predator index, predator control fisheries, and evaluation plan in the Columbia River Basin (Northern Pikeminnow Management Program). 2002 Annual Report, project number 90-077. Contract DE-B179-90BP07084, Bonneville Power Administration, Portland, Oregon.

Report B

NORTHERN PIKEMINNOW SPORT REWARD PAYMENTS – 2005

Prepared by
Russell G. Porter

Pacific States Marine Fisheries Commission
205 S.E. Spokane St.
Portland, OR 97202

April, 2006

INTRODUCTION

The **Northern Pikeminnow Predator Control Program** was administered by PSMFC in 2005. The program is a joint effort between the fishery agencies of the states of Washington and Oregon, and the Pacific States Marine Fisheries Commission (PSMFC). Washington ran the sport-reward registration/creel check stations throughout the river and handled all fish checked in to the program. Oregon provided fish tagging services, population studies, food habit and reproductive studies, as well as exploitation rate estimates. PSMFC provided technical administration, and fiscal and contractual oversight for all segments of the Program and processed all reward vouchers for the sport-reward anglers.

CATCH AND PAYMENTS

In 2005 a total of 241,357 fish were harvested in the sport-reward fishery. Vouchers for 239,172 fish were submitted for payment totaling rewards of $1,460,724. Rewards were paid at $4 for the first 100 fish caught during the season, $5 for fish in the 101-400 range, and $8 for all fish caught by an angler above 400 fish. PSMFC maintained an accounting system during the season to determine the appropriate reward amount due each angler for particular fish. A total of 1,724 anglers who registered were successful in catching one or more fish in 2005. The 2005 season ran from May 2, 2004 through September 25, 2005.

TAGGED FISH PAYMENTS

A total of 171 tagged fish were caught. Anglers were issued a special tagged fish voucher for all tagged fish brought to the registration station. The tag voucher was then sent in with the tag for verification and payment of the special $500 tagged fish reward. This resulted in tag reward payments of $85,500 in addition to the regular reward payments.

ACCOUNTING

Total payments for the season of regular vouchers and tagged fish totaled $1,546,224 (tagged vouchers plus regular vouchers). All IRS form 1099 MIS. Statements were sent to the qualifying anglers for tax purposes in the third week of January, 2006. Appropriate reports and copies were provided to the IRS by the end of February, 2006.

A summary of the catch and rewards paid is provided in table 1. For further information contact Russell Porter, PSMFC, field programs administrator at (503) 595-3100 or email at: russell_porter@psmfc.org.

2005 SPORT REWARD PAYMENTS SUMMARY

The following is a summary of the vouchers received and paid as of December 8, 2005

Fish $ Paid Fish paid @ tier 1 ($4.00 each): 59,996	$239,984
Fish paid @ tier 2 ($5.00 each): 70,892	$354,460
Fish paid @ tier 3 ($8.00 each): 108,286	$866,288
Tags paid (@ $500.00 each): 171	$85,500
Total: 239,345	**$1,546,232**

Anglers @ tier 1 1,347
Anglers @ tier 2 209
Anglers @ tier 3 168
Number of separate anglers 1,724

Anglers with 10 fish or less: 790
Anglers with 2 fish or less: 315

*Top Twenty Anglers **	TIER 1	TIER 2	TIER 3	TAGS	TOTAL FISH	BALANCE
1. ZAREMSKIY, NIKOLAY N	100	300	4,398	2	4,800	$38,084
2. VASILCHUK, DAVID R	100	300	4,340	6	4,746	$39,620
3. HISTAND,TIMOTHY L	100	300	3,397	3	3,800	$30,576
4. PAPST,THOMAS H	100	300	3,020	6	3,426	$29,060
5. VASILCHUK, IVAN R	100	300	2,809	5	3,214	$26,872
6. BROWN, JOHN G	100	300	2,712	1	3,113	$24,096
7. WEBER, STEVEN A	100	300	2,369	0	2,769	$20,852
8. UPPENDAHL, LANCE G	100	300	2,074	1	2,475	$18,992
9. PLACHTA,REED N	99	300	2,048	1	2,448	$18,780
10. CAGLE, CARL D	100	300	2,048	0	2,448	$18,284
11. CALDWELL,TIMOTHY E	100	300	2,023	2	2,425	$19,084
12. BELOGUB, ANATOLIY I	100	300	1,861	2	2,263	$17,788
13. STEVENS, TODD G	100	300	1,812	0	2,212	$16,396
14. LAIS, RAY C	100	299	1,558	1	1,958	$14,859
15. KEILWITZ,DANIEL D	99	300	1,414	1	1,814	$13,708
16. ESSEX,JANE A	100	300	1,369	1	1,770	$13,352
17. JONES, JOHN A	100	300	1,352	0	1,752	$12,716
18. VASILCHUK, VADIM R	100	300	1,341	0	1,741	$12,628
19. MCDONALD,ROBERT E	100	300	1,340	0	1,740	$12,620
20. MUCK,JAMES E	100	300	1,249	1	1,650	$12,392
* (by total fish caught)	1,998	5,999	44,534	33	52,564	$410,759

REPORT C

Development of a System-wide Predator Control Program: Indexing and Fisheries Evaluation

Prepared by

Martyne J. Reesman
Tucker A. Jones
Matthew W. Hutchinson
Thomas A. Friesen

Oregon Department of Fish and Wildlife
Columbia River Investigations
17330 S.E. Evelyn Street
Clackamas, Oregon 97015

February, 2006

ABSTRACT

The Northern Pikeminnow Management Program (NPMP), a fishery aimed at reducing predation on juvenile salmonids by northern pikeminnow *Ptychocheilus oregonensis*, was implemented for the 15th consecutive year in the mainstem Columbia and Snake rivers. We report on (1) northern pikeminnow exploitation rates; (2) reductions in northern pikeminnow potential predation on juvenile salmonids since program implementation; (3) spaghetti tag loss rates; (4) age validation work for northern pikeminnow; (5) population parameters of northern pikeminnow, smallmouth bass *Micropterus dolomieu*, and walleye *Sander vitreus* below Bonneville Dam and in Bonneville Reservoir, and (6) possible compensatory responses by these species.

To evaluate exploitation, we tagged and released 901 northern pikeminnow ≥ 200 mm fork length (FL) throughout the lower Columbia and Snake rivers in 2005, 708 of which were ≥ 250 mm FL. System-wide exploitation of northern pikeminnow ≥ 200 mm FL by the sport-reward fishery was 16.3% (95% confidence interval 11.3% - 21.3%); which incorporated a tag loss estimate of 8.1%. Exploitation of fish ≥ 250 mm FL was 19.0% (13.2% - 24.7%), the highest rate reported since the implementation of the program. Modeling results estimated potential predation by northern pikeminnow on juvenile salmonids in 2005 was 78% of pre-program levels.

Continuing our age validation study, we aged 549 scale and 254 opercle samples from northern pikeminnow in 2005. Complete agreement (i.e., zero discrepancy) on ages assigned by the three readers was 72.1% for scales, and 2.8-18.7% for opercles. We examined 235 opercle samples from northern pikeminnow caught by anglers; detectable oxytetracycline (OTC) marks were found in 183. We observed OTC mark failure was significantly ($P < 0.05$) related to mark year; 75% of the failed OTC marked fish came from 2005. When aging northern pikeminnow > 8-9 years of age, we aged opercles consistently older than their corresponding scale.

To evaluate changes in the predator community, we continued biological indexing in the lower Columbia River. Northern pikeminnow abundance index values in Bonneville Reservoir were the lowest observed since 1991. However, spring consumption indices for northern pikeminnow in Bonneville Dam tailrace were greater than 2004, and were the highest observed to date in The Dalles Dam tailrace. The summer consumption index value below Bonneville Dam for rkm 114-121 was the highest since 1995. Northern pikeminnow summer consumption and predation indices were zero for Bonneville Dam forebay. However, predation indices more than doubled between spring (2.8) and summer (6.8) for the Bonneville Dam tailrace boat restricted zone (BRZ).

Smallmouth bass relative densities in 2005 were similar in most areas to 2004. Spring consumption index values for smallmouth bass were greater than any previous year for rkm 172-178 and Bonneville Dam tailrace. Spring and summer consumption indices for Bonneville Reservoir were similar to previous years. Smallmouth bass spring predation index values for rkm 172-178 was greater than that of northern pikeminnow. In Bonneville mid-reservoir, predation index values increased substantially between spring (0.0) and summer (1.0).

Salmonids composed the majority of fish remains identified to species in the digestive tracts of northern pikeminnow below Bonneville Dam and Bonneville Reservoir. Though the percentage of remains identified to species in smallmouth bass varied by season, cottids, salmonids, and gasterosteids were the most prevalent. Cyprinids composed 100% of the remains found in walleye stomach samples.

Northern pikeminnow year-class analysis downstream of Bonneville Dam showed considerable variation from year to year in the percentage of age 3 and 4 fish. The percentage of age five northern pikeminnow has been relatively stable since 1993, accounting for 15 – 17% of the total. Smallmouth bass year-class analysis downstream of Bonneville Dam indicated a growing proportion of the population was composed of age 4 fish. Bonneville Reservoir smallmouth bass year class strength was varied. In 2005 and 1999 the percentages of age 5 fish were four to six times greater than 1990 and 1995, which may indicate increased survival of early life stages.

The proportional stock density (PSD) of northern pikeminnow below Bonneville Dam was 29% greater than all previous years. Smallmouth bass relative stock density of preferred length fish (RSD-P) and PSD values below Bonneville Dam were the lowest to date. Median relative weight (W_r) was significantly higher ($P < 0.01$) for male and female northern pikeminnow in 1993, 1994, 1999, 2004, and 2005. Smallmouth bass had significantly ($P < 0.01$) higher W_r in 2005 than in 1990, 1996, and 1999 in all areas. When solely considering PSD, RSD-P, and W_r data, a system-wide compensatory response by smallmouth bass and northern pikeminnow does not seem apparent.

INTRODUCTION

The Columbia and Snake rivers once supported large numbers of anadromous salmonids *Oncorhynchus* spp. Declines in adult returns have been attributed to many factors, including habitat degradation and overexploitation (Nehlsen et al. 1991; Wismar et al. 1994), hydroelectric and flood control activities during the 1970s (Raymond 1988), and predation (Rieman et al. 1991). The mean annual loss of juvenile salmonids to predators can be equivalent to mortality associated with dam passage (Rieman et al. 1991), which in past years could approach 30 percent at a single dam (Long and Ossiander 1974). The Northern Pikeminnow Management Program (NPMP) is a fishery aimed at reducing predation on juvenile salmonids by northern pikeminnow *Ptychocheilus oregonensis* in the lower Columbia and Snake rivers (Rieman and Beamesderfer 1990; Beamesderfer et al. 1996). The Oregon Department of Fish and

Wildlife (ODFW) established baseline levels of predation and northern pikeminnow population characteristics prior to the implementation of northern pikeminnow control fisheries. Abundance, consumption, and predation were estimated in Columbia River reservoirs in 1990 and 1993, Snake River reservoirs in 1991, and the unimpounded lower Columbia River downstream from Bonneville Dam in 1992 (Ward et al. 1992). We sampled northern pikeminnow in areas where adequate sample sizes allowed comparisons among and between years (Zimmerman and Ward 1999; Zimmerman et al. 2000; Jones et al. 2005) (Appendix Table A-1). This report describes our activities and findings for 2005, and wherever possible, evaluates changes from previous years.

Our 2005 objectives were to (1) evaluate the efficiency of the northern pikeminnow fishery by analyzing exploitation rates; (2) estimate reductions in northern pikeminnow predation on juvenile salmonids since program implementation; (3) estimate tag loss for spaghetti tags; (4) validate aging methods for northern pikeminnow; (5) estimate abundance, consumption, and predation indices for predator fishes within the study area; and (6) explore hook and line angling for northern pikeminnow.

Objectives (3) and (4) were implemented in 2000 based on recommendations from an independent review of the NPMP (Hankin and Richards 2000). Objective (5) is a continuation of population monitoring studies conducted in 1990-1996, 1999, and 2004, and will rotate annually among reservoirs. Objective (6) is intended to increase the number of northern pikeminnow tagged; we tested the feasibility of adding hook and line angling to our sampling methods.

METHODS

Fishery Evaluation, Predation Estimates, And Tag Loss

Field Procedures

The Washington Department of Fish and Wildlife (WDFW) administered the sport-reward fishery from 2 May 2005 (16 May 2005 upstream of John Day Dam) to 25 September 2005 throughout the lower Columbia and Snake rivers. Participating anglers received payment for northern pikeminnow ≥ 230 mm (9 inches) total length (TL). The size limit is approximately equivalent to 200 mm fork length (FL). The payment schedule was modified in 2005; payments decreased from $5 to $4 per fish for "Tier 1" anglers (< 100 fish caught), from $6 to $5 per fish for "Tier 2" anglers (100-400 fish caught), and remained $8 per fish for "Tier 3" (> 400 fish caught) (WDFW 2006). Rewards for spaghetti-tagged fish remained at $500.

We tagged and released northern pikeminnow ≥ 200mm FL with uniquely numbered spaghetti tags to estimate exploitation rates for the sport-reward fishery. To evaluate spaghetti tag retention, we injected a passive integrated transponder (PIT) tag into the dorsal sinus area of all spaghetti-tagged fish. We used electrofishing boats to collect northern pikeminnow from 2 April to 24 June 2005 (detailed methods are given in Friesen and Ward 1999). We allocated equal sampling effort in all river kilometers (rkm); however, some deviation was necessary due to sampling logistics and swift river flow in the Hanford Reach of the Columbia River and in the Snake River, near Asotin, Washington. We sampled in the Columbia River from rkm 76 (near Clatskanie, Oregon) upstream to rkm 639 (Priest Rapids Dam) and in the Snake River from rkm 172 (Lower Granite Dam) to rkm 248 (24 rkm upstream of Lewiston, Idaho) (Figure 1).

We completed northern pikeminnow tagging below Bonneville Dam and in Bonneville Reservoir before the start of the fishery to reduce bias in exploitation estimates (Styer 2003). However, tagging operations ran concurrently with the fishery in The Dalles, John Day, McNary, and Lower Granite reservoirs.

FIGURE 1.–The lower Columbia and Snake rivers. Northern pikeminnow were tagged from river kilometer (rkm) 76 to Priest Rapids Dam in the lower Columbia River and from Lower Granite Dam forebay to rkm 248 on the Snake River. Biological indexing was conducted below Bonneville Dam (rkm 114-121, 172-178, 190-197, and Bonneville Dam tailrace) and in Bonneville Reservoir (forebay, mid-reservoir, and The Dalles Dam tailrace) during spring and summer 2005.

We experimented with hook and line boat angling for northern pikeminnow in Bonneville Reservoir, 14 - 15 April and 18 – 20 April 2005. We selected specific angling sites at random, but each river mile was fished for approximately 40 minutes. We used a variety of fishing gear, including spinning and casting rods, lures, and baits.

Data Analysis

We used mark-and-recapture data to compare exploitation rates of northern pikeminnow ≥ 200 mm FL, 200-249 mm FL, and ≥ 250 mm FL among reservoirs. In areas where tagging was completed prior to the start of the fishery, we used the simple Peterson method (Ricker 1975) to calculate annual exploitation rates. This is given by the equation

$$u = R/M$$

where

u = annual exploitation estimate,
M = the number of fish that are tagged in a season, and
R = the number of tagged fish that are recaptured in a season.

We calculated 95% confidence intervals for exploitation estimates using the formula

$$R \pm z(R/M)^{0.5}$$

where
z = the multiplier from the standard normal distribution,
M = the number of fish that are tagged in a season, and
R = the number of tagged fish that are recaptured in a season (Styer 2003).

Using PIT tag return data from 2003 – 2005 enabled us to calculate multi-year exploitation rates in 2005 for areas below Bonneville Dam and within Bonneville Reservoir. We used a variable survival method (Everhart and Youngs 1981) to calculate multi-year exploitation rates for northern pikeminnow ≥ 200 mm FL. This is given by the equation

$$f_i = R_i/M_i * C_i/T_i$$

where

f_i = the minimum estimate of exploitation in year i,
M_i = the number of fish that are tagged in year i,
R_i = the total number of recaptures from a particular tagging release,
C_i = the total number of fish that are recaptured in any particular sample year,
$T_i = T_{i-1} + R_i - C_{i-1}$ where $T_1 \equiv R_1$.

We used a multiple sample approach to compute exploitation rates in areas where tagging and fishing occurred concurrently. Weekly estimates of exploitation were calculated by dividing the number of tagged northern pikeminnow recovered by the number of tagged fish at large. We then summed the weekly exploitation rates to yield total exploitation rates for the season (Beamesderfer et al. 1987).

We calculated 95% confidence intervals for exploitation estimates obtained by the multiple sample method by using the formula

$$u \pm t(k*s)^{0.5}$$

where

u = the annual exploitation estimate,
t = the multiplier from the Student's t-distribution,
k = the number of weeks in the fishing season, and
s = the standard deviation of the weekly exploitation estimates (Styer 2003).

We did not calculate exploitation rates for areas where the number of recaptures was less than four (Styer 2003), and exploitation estimates from previous years where fewer than four tags were recovered were excluded from this report. We adjusted exploitation estimates and confidence intervals for tag loss. Tag loss estimates were calculated using the formula

$$L = [m / (m + r)] * 100$$

where

L = tag loss rate,
m = the number of northern pikeminnow recaptured with a secondary mark (PIT tag)
and no spaghetti tag, and
r = the number of northern pikeminnow recaptured with year 2005 spaghetti tags intact.

To explore the effect of river flow on northern pikeminnow harvest, we plotted the annual (1995 - 2005) system-wide sport-reward exploitation rate for fish ≥ 250 mm FL versus mean Columbia River stage for May – September below Bonneville Dam (U.S. Geological Survey 2005).

We used the model of Friesen and Ward (1999) to estimate predation on juvenile salmonids relative to predation prior to implementation of NPMP. The model incorporates age-specific exploitation rates on northern pikeminnow and resulting changes in age structure to estimate changes in predation. We used a 10-year "average" age structure (based on catch curves) for a pre-exploitation base, and assumed constant recruitment. Age-specific consumption was incorporated; however, potential changes in consumption, growth, and fecundity due to removals were not considered likely (Knutsen and Ward 1999). The model therefore estimates changes in potential predation related directly to removals, allowing us to estimate the effects of removals if all variables except exploitation were held constant.

We estimated the potential relative predation in 2005 based on observed exploitation rates, and the eventual minimum potential predation assuming continuing exploitation at mean 1997 – 2005 levels. Because inputs to the model included three possible relations between age of northern pikeminnow and consumption, as well as three estimates of exploitation (point estimate and confidence limits), we calculated nine estimates of relative predation for each year (Friesen and Ward 1999). We report the maximum, median, and minimum estimates.

Age Validation

Field Procedures

To validate ages of northern pikeminnow, we collected scale samples from 20 northern pikeminnow per 25-mm FL size class, ranging from 0 – 600 mm FL, and from all tagged northern pikeminnow ≥ 425 mm FL during the 2005 tagging season. Additionally, each fish ≥ 200 mm FL was injected with a solution of oxytetracycline (OTC) at a dosage of 50 mg OTC per kg fish weight (McFarlane and Beamish 1987) to leave a fluorescent mark on aging structures. Scale and operculum samples were collected by WDFW from tagged northern pikeminnow recaptured in the sport-reward fishery.

Laboratory Procedures

We randomly selected 10 scale samples from each 25 mm size group (0 – 600 mm FL). Scales were cleaned, mounted on cards, and pressed onto acetate sheets for viewing on a microfiche reader. Parker et al. (1995) described methods of age determination for northern pikeminnow. We assigned two readers to independently age the scale samples. When the readers disagreed on an age, they reviewed the scale in question together until a final age was agreed upon.

We placed opercula, still in individual sample envelopes, into a water bath and microwaved them on high for 4-7 minutes (per group of five samples) to soften tissues and skin covering the opercular bone. We then removed the tissue using a knife, pair of tweezers, and a toothbrush. The thickened ridge radiating from the focus on the concave side of each operculum was ground down with a “Dremel Tool” (Robert Bosch Tool Corporation, Racine, Wisconsin) to enhance viewing of potential annuli near the focus (Scoppettone 1988). Readers used imaging software (Motic Instruments, Incorporated, British Columbia, Canada) examine each operculum on a computer monitor. Images were projected from a digital video microscope at 10x magnification using light transmitted from either above or below the operculum, whichever gave the best view of the annuli. Two experienced readers and one novice reader aged opercula in 2005; two of whom also aged the corresponding sport reward scales. We used the same technique to resolve operculum age differences as we had for scales. We inspected opercula from each fish tagged between 2002 and 2005 in a dark room under a dissecting microscope, and using a desk lamp fitted with a black light to fluoresce potential OTC marks.

Data Analysis

Continuing an age validation study initiated in 2000 (Takata and Ward 2001), we evaluated between-reader variation in ages assigned to both scales and opercula from northern pikeminnow. Aging discrepancies were calculated as

$$D = X_i - X_j,$$

where

D = age discrepancy
X_i = age assigned to a scale or opercle by X_i, and
X_j = age assigned to a scale or opercle by X_j.

This analysis allowed us to measure both magnitude and directionality of the discrepancy (e.g. - 2 years, - 1 year, 0 years, + 1 year, etc.) and enabled us to determine if differences were systematic. We then calculated the percentage of samples in each discrepancy category as a measure of between-reader agreement, and analyzed differences among scale and operculum reader discrepancies by looking at the differences in percentages of ± 1 year agreement. We determined reader discrepancies to be significantly different when 95% confidence intervals did not overlap.

We sought to validate our ability to detect scale annuli by comparing ages (agreed upon by both readers) assigned to scales collected at recapture to those for scales collected from the same fish at tagging. We used the formula

$$D = (A_R - A_T) - (Y_R - Y_T),$$

where

D = age discrepancy,
A_R = age assigned to a scale at recapture,
A_T = age assigned to scale at tagging,
Y_R = recapture year, and
Y_T = tagging year

to calculate discrepancies between ages determined at tagging and ages determined at recapture for the same fish. We then calculated the percentage of samples in each discrepancy category as we had done for the between-reader comparison.

Finally, to evaluate the potential use of opercula for aging northern pikeminnow, we compared the ages assigned to opercula and scales collected from the same fish at the same time. We calculated discrepancies using the formula

$$D = A_o - A_S,$$

where

D = age discrepancy,
A_o = age assigned to an opercle at recapture, and
A_S = age assigned to a scale at recapture.

We used t-tests to analyze operculum-scale discrepancies.

We checked opercula from northern pikeminnow tagged between 2002 and 2005 for the presence of OTC marks, and scored the quality of discernable marks. An easily observed and relatively wide fluorescent band along all or most of the operculum's edge was considered a "good" mark. If the fluorescent band was thin or patchy but went around one-half or more of the operculum's edge, the mark was considered "fair." If the fluorescent marking covered less than half of the operculum's edge it was considered a "poor" mark. We also continued efforts to validate our ability to detect operculum annuli. To do this we quantified any visible annuli after the OTC mark – as one to three years had elapsed between tagging and recapture for northern pikeminnow tagged between 2002 and 2004. Chi-square tests were used to analyze OTC mark quality, and overlapping 95% confidence intervals were used to indicate significant differences in correctly identified annuli by year and mark quality.

Biological Evaluation

Field Procedures

We used standardized electrofishing to evaluate changes in northern pikeminnow and smallmouth bass *Micropterus dolomieu* relative abundance, consumption and predation indices, growth and population structure, condition, and feeding habits. We also analyzed feeding habits of walleye *Sander vitreus*. Biological data was collected in spring (2 - 19 May) and summer (27 June - 15 July) 2005 in the following areas: downstream of Bonneville Dam (rkm 114–120, rkm 170–179, and rkm 186–194), Bonneville Dam tailrace (rkm 224–232), Bonneville Reservoir (forebay rkm 233-238, mid-reservoir rkm 272-283), and The Dalles Dam tailrace (rkm 299-306) (Figure 1). Sampling methods and gear specifications were described in Ward et al. (1995) and Zimmerman and Ward (1999).

We recorded biological data from all northern pikeminnow, smallmouth bass, and walleye collected by electrofishing. We measured all fish collected (mm FL) and recorded total body weight (g) from fish ≥ 200 mm. We collected scales from 20 northern pikeminnow and smallmouth bass per 25 mm FL size range, and from all walleye. Digestive tract contents from northern pikeminnow, smallmouth bass, and walleye ≥ 200 mm FL were collected and preserved using methods described by Ward et al. (1995). Northern pikeminnow ≥ 200 mm FL were sacrificed, enabling us to remove their digestive tract, establish sex (male, female, or undetermined) and maturity (undetermined, immature, developing, ripe, or spent), and collect gonads from ripe females.

Laboratory Procedures

We examined digestive tract contents of northern pikeminnow, smallmouth bass, and walleye to measure relative consumption rates of juvenile salmonids. Details of laboratory methods are given in Ward et al. (1995). Parker et al. (1995) described methods of age determination using scales.

Data Analysis

We used catch per unit effort (CPUE) of standardized (900 s) electrofishing runs for northern pikeminnow to calculate abundance and predation indices. Abundance indices of northern pikeminnow were calculated as the product of CPUE and reservoir or area-specific surface area (Ward et al. 1995). We compared abundance indices of northern pikeminnow in 2005 with those from 1990, 1992-1996, 1999, and 2004. We used transformed catch ($\log_{10}$ (catch + 1)) as an index of smallmouth bass relative density.

We used the following formulas to calculate consumption indexes (CI) for northern pikeminnow and smallmouth bass :

$$CI_{NPM} = 0.0209 \cdot T^{1.60} \cdot MW^{0.27} \cdot (S \cdot GW^{-0.61})$$ (Ward et al. 1995),

and

$$CI_{SMB} = 0.0407 \cdot e^{(0.15)(T)} \cdot MW^{0.23} \cdot (S \cdot GW^{-0.29})$$ (Ward and Zimmerman 1999),

where

CI_{NPM} = consumption index for northern pikeminnow,
CI_{SMB} = consumption index for smallmouth bass,
T = water temperature (^{o}C),
MW = mean predator weight (g),
S = mean number of salmonids per predator, and
GW = mean gut weight (g) per predator.

The consumption index is not a rigorous estimate of the number of juvenile salmonids eaten per day by an average predator; however, it is linearly related to the consumption rate of northern pikeminnow (Ward et al. 1995) and smallmouth bass (Ward and Zimmerman 1999). Spring (May) and summer (June-July) consumption indices for 2005 were compared to those from 1990, 1992-1996, 1999, and 2004 for sampling areas below Bonneville Dam and Bonneville Reservoir.

We used the product of abundance and consumption indices to calculate predation indices for northern pikeminnow for spring and summer periods, and compared northern pikeminnow predation among years for reservoirs and areas where data had been collected each year. The daily juvenile salmonid passage index at Bonneville Dam was plotted to compare timing of index sampling with concentrations of juvenile salmonids (FPC 2005). As in 2004, we calculated a predation index for smallmouth bass in response to reports of increased abundance in some areas. Ward and Zimmerman (1999) observed smallmouth densities varied seasonally in the Columbia and Snake rivers; we therefore calculated predation indices using CPUE as a season-specific relative abundance index. We multiplied the product of the season specific CPUE and reservoir or area-specific surface area by its corresponding consumption index to obtain a season specific predation index.

To evaluate age structure, we examined the change in frequency of age 3-5 northern pikeminnow and age 4-5 smallmouth bass from 1990 – 1996, 1999, 2004, and 2005. Because the relative abundances of northern pikeminnow year classes in electrofishing catches were biased by exploitation rates that varied among years (Friesen and Ward 1999), we limited our comparisons to abundance of northern pikeminnow large enough to be effectively sampled and small enough to be excluded from the NPMP (ages 3-5). We constructed smallmouth bass electrofishing catch curves (ODFW, unpublished data) and concluded that younger smallmouth bass (ages 1-3) were not sampled in proportion to their abundance. We therefore limited our comparisons to ages 4 and 5 smallmouth bass. We used the Kruskal-Wallis one-way ANOVA on ranks to analyze age among years; Dunn's test was used to determine pairwise differences between years. An alpha level of 0.05 was established prior to data collection, and used to establish significance in all fishery and biological evaluations. Walleye (n=8) in Bonneville Reservoir and below Bonneville Dam not sampled in sufficient numbers to analyze year class strengths or lengths at age.

Because northern pikeminnow exploitation rates are greater for larger fish than for smaller ones (Zimmerman et al. 1995), sustained fisheries should decrease the abundance of large fish relative to the abundance of smaller fish. We used proportional stock density (PSD; Anderson 1980), where PSD = 100 • (number of fish ≥ quality length / number of fish ≥ stock length) to compare size structure of northern pikeminnow and smallmouth bass populations among years in the Columbia River downstream from Bonneville Dam, and in Bonneville reservoir. Stock and quality sizes for northern pikeminnow are 250 and 380 mm FL (Beamesderfer and Rieman 1988; Parker et al. 1995). We used relative stock density (RSD-P) indices to examine smallmouth bass populations. Stock, quality, and preferred size classes for smallmouth bass are 180 mm, 280 mm, and 350 mm TL for smallmouth bass where RSD-P = 100 • (number of fish ≥ preferred length / number of fish ≥ stock length) (Gabelhouse 1984).

Changes in body condition (e.g., "plumpness") may indicate a response to sustained exploitation. We used relative weight (W_r; Anderson and Gutreuter 1983) to compare the condition of northern pikeminnow and smallmouth bass in 2005 with previous years. We used the standard weight (W_s) equations for northern pikeminnow developed by Parker et al. (1995), $\log_{10}(W_s) = -4.886 + 2.986[\log_{10}(FL)]$; and for smallmouth bass developed by Kolander et al. (1993), $\log_{10}(W_s) = -5.329 + 3.2[\log_{10}(TL)]$ to calculate relative weight ($W_r = 100[\text{weight}]/W_s$). We combined data from below Bonneville Dam and Bonneville Reservoir during 1990, 1992-1996, 1999, 2004, and 2005 to provide system-wide estimates of W_r. We calculated median W_r for male and female pikeminnow and all smallmouth bass, which were not sexed. To compare W_r among years, we used a Kruskal-Wallis one-way ANOVA on ranks; Dunn's test was applied to determine where pairwise differences occurred.

RESULTS

Fishery Evaluation, Predation Estimates, And Tag Loss

We tagged and released 901 northern pikeminnow ≥ 200 mm FL in the lower Columbia and Snake rivers in 2005 to estimate exploitation. We were unable to sample 43 rkms in John Day and McNary reservoirs due to high wind and high catch rates of adult salmonids. The number of fish tagged varied from 406 below Bonneville Dam to 21 in John Day Reservoir (Appendix Table B-1). The sport-reward fishing effort was 35,242 angler days, and anglers harvested 240,955 northern pikeminnow ≥ 200 mm FL; including 113 fish tagged in 2005 (WDFW, unpublished data). Based on WDFW sample catch proportions, an estimated 167,464 (69.5%) of harvested northern pikeminnow were ≥ 250 mm FL and 73,491 (30.5%) were 200 – 249 mm FL. The mean fork length of northern pikeminnow harvested by the sport-reward fishery was 294 ± 67 mm (mean ± SD) and the median fork length was 283 mm (R. Bruce, WDFW, personal communication).

We angled for northern pikeminnow for a total of 11 hours in Bonneville Reservoir and captured one northern pikeminnow. Incidental catch included five peamouth chub *Mylocheilus caurinus,* four smallmouth bass, and three white sturgeon *Acipenser transmontanus*. Our fishing effort was reduced to three days due to windy conditions and boat problems. The single northern pikeminnow tagged during our hook and line experiment was caught using a worm as bait.

We recaptured ten fish that were tagged in 2005 and had shed or otherwise lost their spaghetti tags but still possessed PIT tags (8.1% tag loss); exploitation rates were adjusted accordingly. Additionally, three fish that were tagged and subsequently recaptured in different reservoirs were included in system-wide exploitation estimates but not area-specific calculations. We used the 113 northern pikeminnow tagged and recaptured in 2005 (71.7% from below Bonneville Dam) to calculate 2005 exploitation rates. The system-wide exploitation rate for northern pikeminnow ≥ 200 mm FL was 16.3% (Appendix Table B-2), with 95% confidence limits ranging from 11.3% to 21.3%. Exploitation varied among reaches, from 21.6% (95% confidence bounds, 17.1-26.1%)

below Bonneville Dam to 8.0% (95% confidence bounds, 4.1-11.9%) in Bonneville Reservoir (Figure 2). We did not calculate exploitation rates for John Day and Lower Granite reservoirs or for 200 – 249 mm FL sized fish in any area, as sample sizes were too low ($n < 4$) for robust calculations (Appendix Tables B-2 and B-3). Using data from the last three years yielded multi-year exploitation estimates of 21.7% below Bonneville Dam and 7.9% in Bonneville Reservoir, similar to the single year estimates of 21.6% and 8.0%.

Exploitation rate for northern pikeminnow ≥ 250 mm FL was 19.0% (Appendix Table B-4), with 95% confidence intervals ranging from 13.2% to 24.7% (Figure 3). The highest exploitation rate among reaches was 23.1% (95% confidence bounds 18.2 – 28.0%) below Bonneville Dam and the lowest was 8.2% (95% confidence bounds 4.1 – 12.4%) in Bonneville Reservoir. In areas where tagging efforts ran concurrently with the sport reward fishery we calculated weekly exploitation rates (Appendix Table B-5 through B-9). In 2005 we continued our examination of below Bonneville Dam exploitation rates and mean gage heights to system-

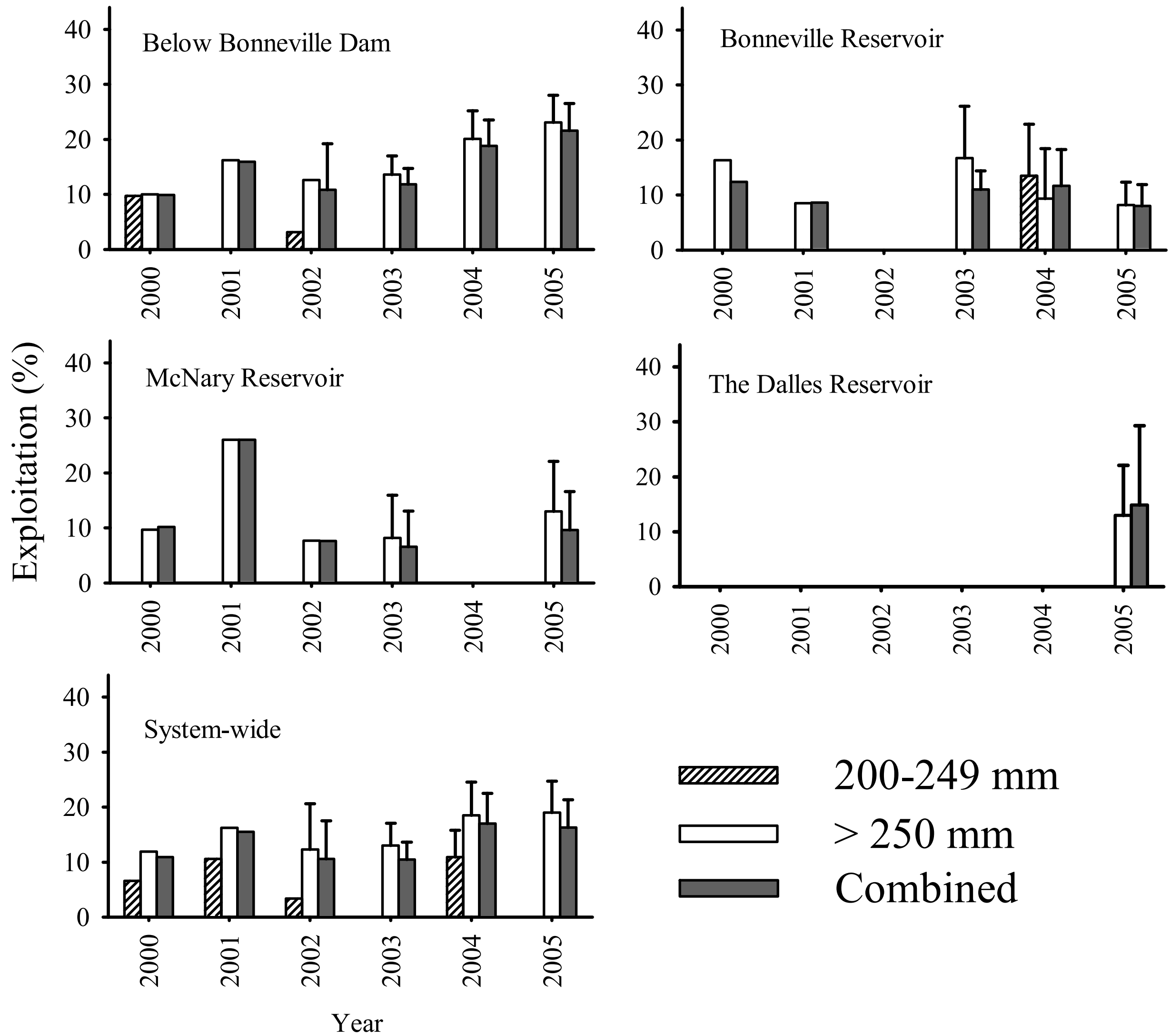


FIGURE 2. — Northern pikeminnow exploitation rates by reservoir or area for the sport-reward fishery, 2000 - 2005. Exploitation rates for John Day Reservoir and Lower Granite Reservoir are not shown due to insufficient ($n < 4$) tag returns from those areas. Exploitation rates for 2000 – 2002 were not adjusted for tag loss. Error bars indicate the upper bounds of the 95% confidence interval.

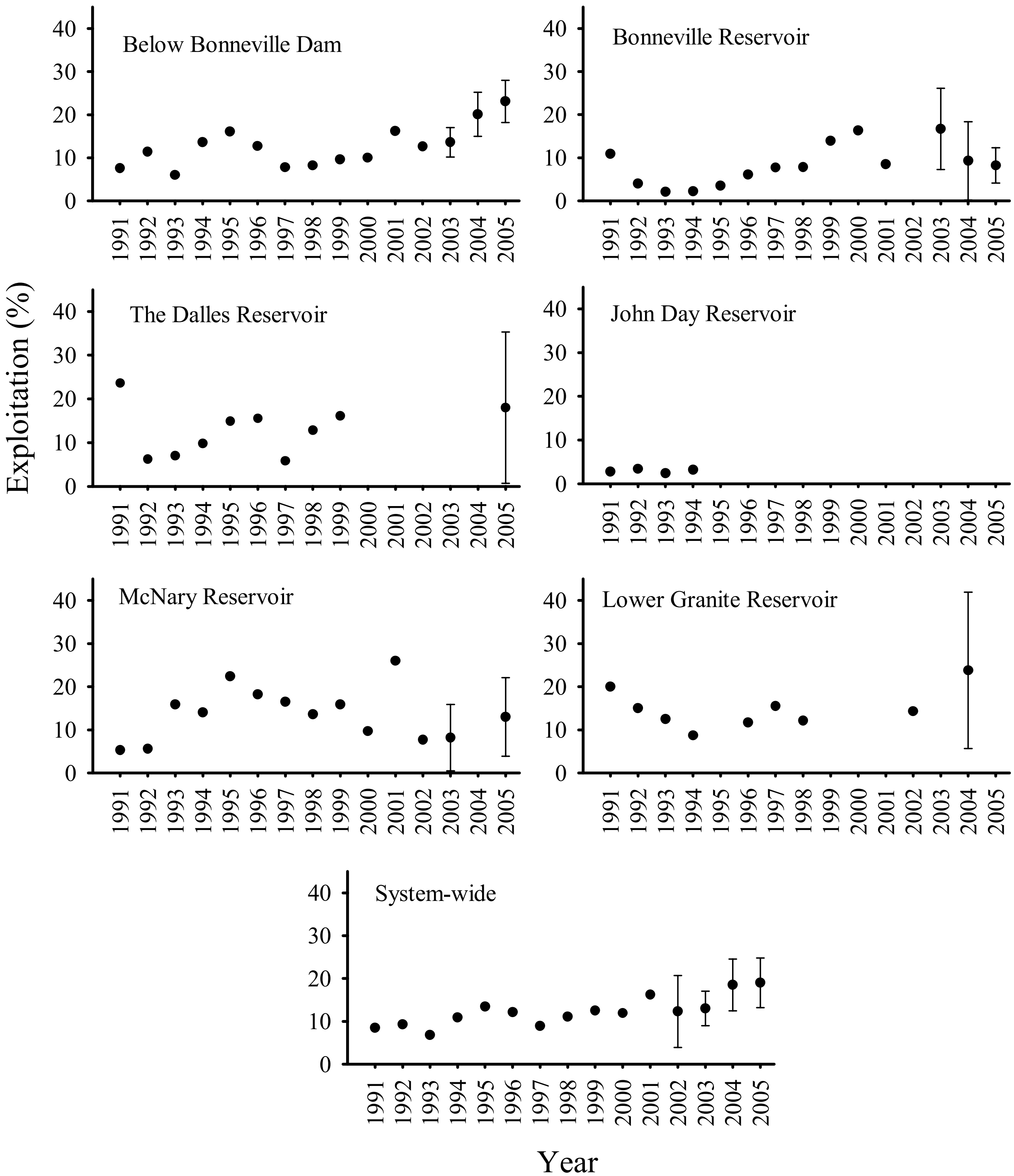


FIGURE 3. — Sport-reward fishery exploitation rates of northern pikeminnow ≥ 250 mm fork length in each reservoir or area, 1991 - 2005. Exploitation rates were not calculated where number of recaptured tags was low ($n < 4$). Exploitation rates for 2000 – 2002 were not adjusted for tag loss. Error bars denote the 95% confidence interval.

wide exploitation relationships. A significant positive linear relationship exists between system-wide and below Bonneville Dam exploitation rates for both ≥ 200 mm FL (r = 0.92, $P < 0.05$) and ≥ 200 mm FL (r = 0.93, $P < 0.05$) size classes of northern pikeminnow. However, we found only a weak relationship (r = 0.37; $P < 0.05$) between system-wide exploitation rate of northern pikeminnow ≥ 250 mm FL and mean Columbia River gage height measured below Bonneville Dam during the 2005 sport-reward season (Figure 4).

Modeling results indicated potential predation by northern pikeminnow on juvenile salmonids in additional reductions in predation.

Age Validation

We aged a 549 scale and 254 operculum samples from tagged, indexed, and recaptured northern pikeminnow in 2005. Complete agreement (i.e., zero discrepancy) on scale ages assigned by the two readers was 72.1%, and discrepancies did not appear to be directional (Figure 6). Complete agreement among operculum readers ranged from 2.8-18.7% with the two experienced readers (readers 1 and 3) consistently aging opercula older than the novice reader (reader 2; Figure 7). Successful agreement on ages (i.e. ± 1 year) was significantly different among the three operculum readers – with the two experienced readers agreeing significantly more often with each other than with the novice reader (Figure 8). Within one year agreement on scales was 97.4% (95% confidence bounds, 96.4–98.9%; Figure 8), and was significantly higher than between reader operculum agreement.

When final ages assigned to scales collected at tagging in 2003 and recaptured in 2005 were compared, the ages accounted exactly for the time at-large less than 10% of the time (Figure 9, panel A), and agreement within one year was 23.8%. Final ages assigned to scales collected at tagging between 2000 and 2002 and recaptured in 2005 did not correctly account for the time at-large (Figure 9, panel B), and within one year agreement was only 10.5%. The number of years at-large for northern pikeminnow tagged in 2003 or earlier was generally underestimated by ages assigned to those same fish when recaptured in 2005.

Corresponding 2005 recaptured scale and operculum age discrepancies were dependent on the size (fl) of northern pikeminnow (f = 13.75, $p < 0.05$). Northern pikeminnow larger than 350 mm fl were aged significantly older than fish < 350 mm fl (t = 3.71, $p < 0.05$). For fish < 350 mm fl, ages assigned to scales matched ages assigned to corresponding opercula within one year 80.8% of the time (figure 10, panel a); though ages assigned were significantly different than zero (t = 3.03, $p < 0.05$). For fish ≥ 350 mm fl, scale ages matched with corresponding operculum ages within one year 61.4% of the time (figure 10, panel b), and were also significantly different from zero (t = 7.43, $p < 0.05$). We found a significant positive relationship between scale and operculum age (f = 637.45, $p < 0.01$; $r^2 = 0.74$), regardless of fl, with opercula assigned ages older than corresponding scales 55% of the time (figure 11).

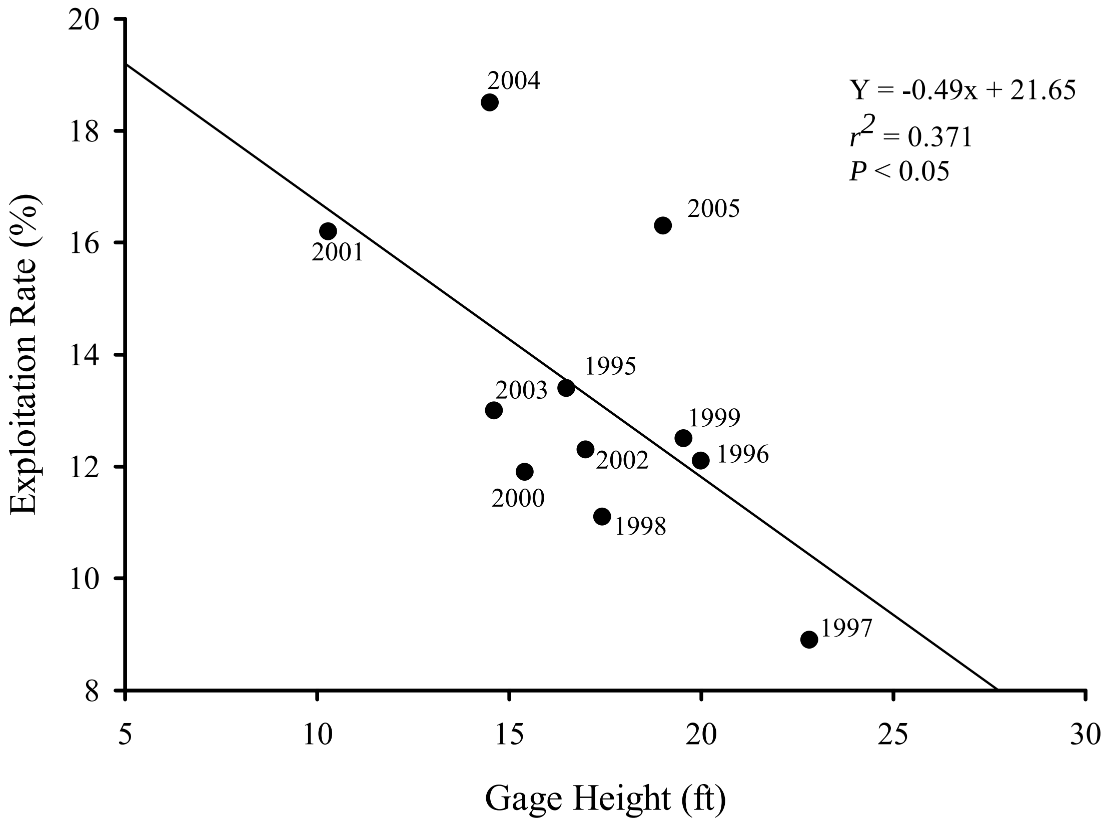


FIGURE 4. — Relationship between system-wide sport-reward exploitation rate of northern pikeminnow ≥ 250 mm FL and mean Columbia River gage height below Bonneville Dam during the sport-reward season (May – September), 1995 - 2005.

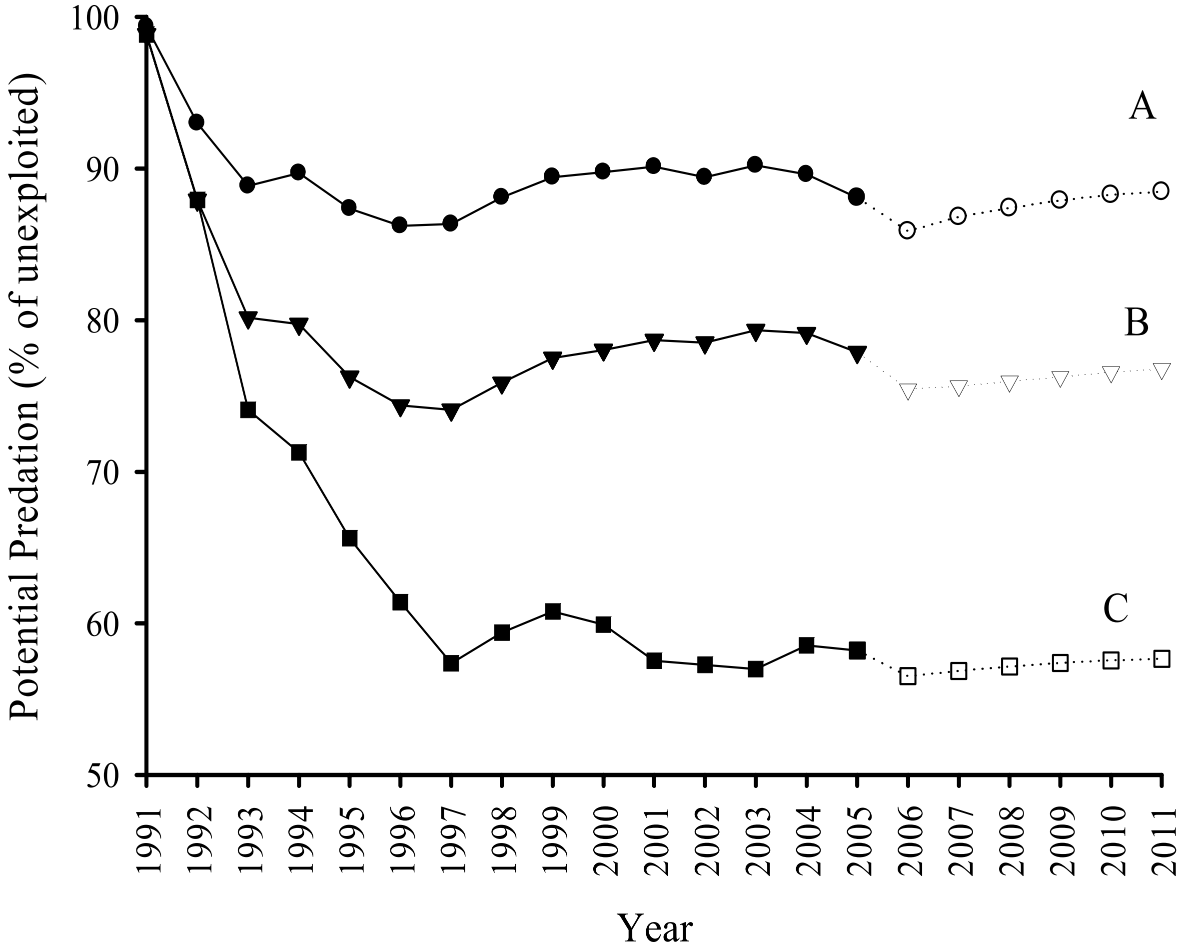


FIGURE 5.—Maximum (A), median (B), and minimum (C) estimates of potential predation on juvenile salmonids by northern pikeminnow relative to predation prior to implementation of the Northern Pikeminnow Management Program. Estimates of predicted predation after 2005 are based on 1996 – 2005 average values.

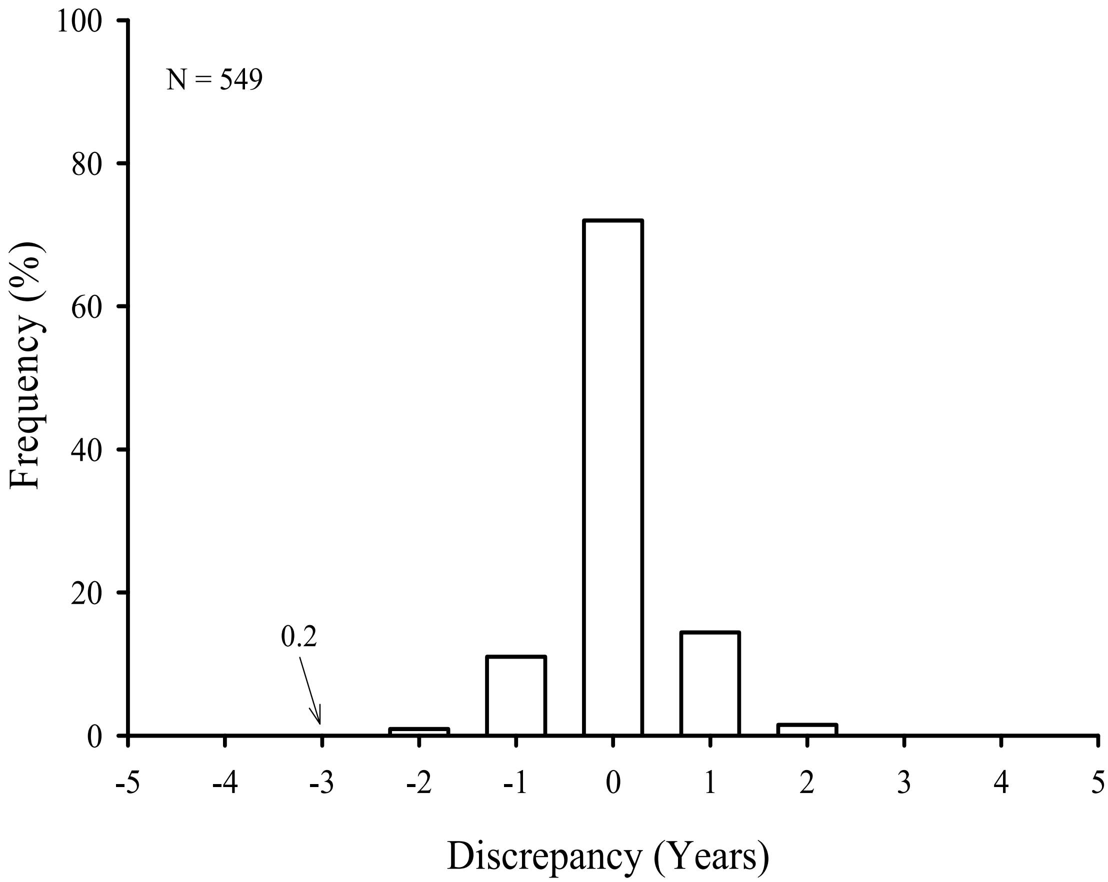


FIGURE 6.—Distribution of between reader aging discrepancies for northern pikeminnow scales collected in 2005.

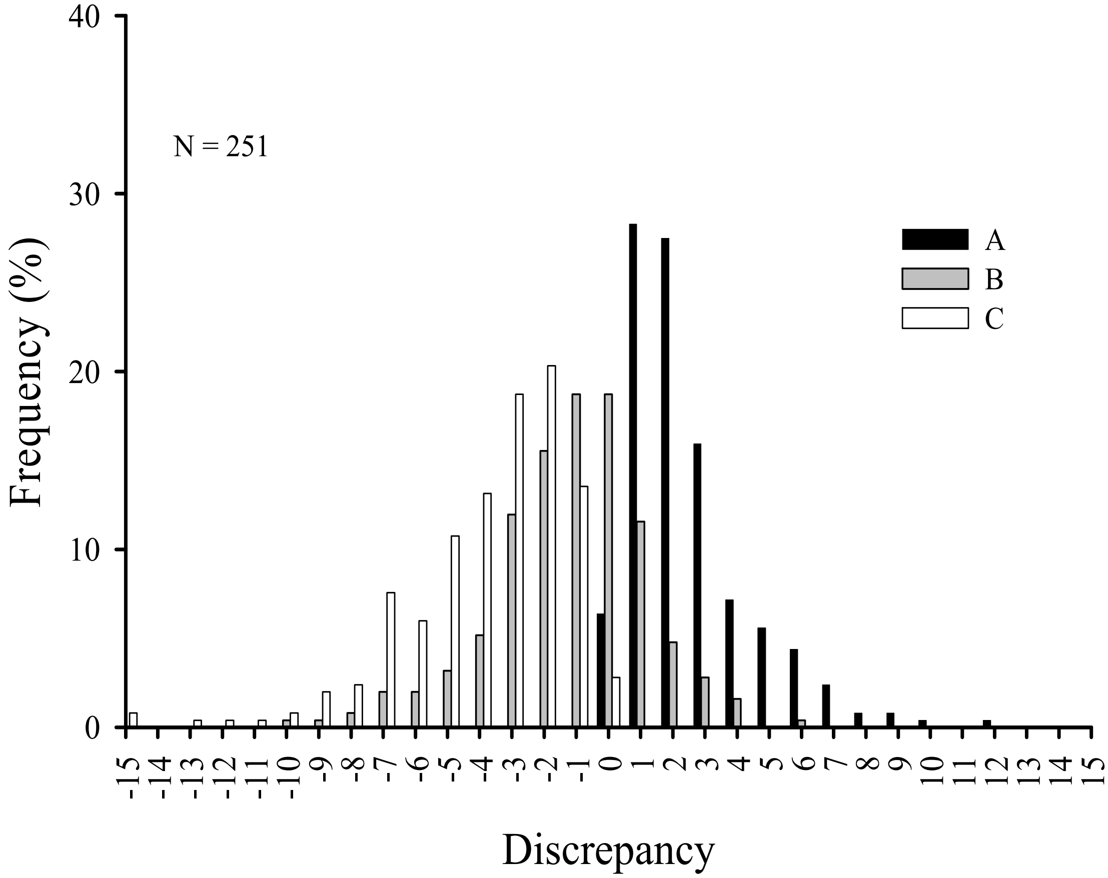


FIGURE 7.—Distribution of aging discrepancies between readers 1 and 2 (A), readers 1 and 3 (B), and readers 2 and 3 (C) for northern pikeminnow opercula collected in 2005.

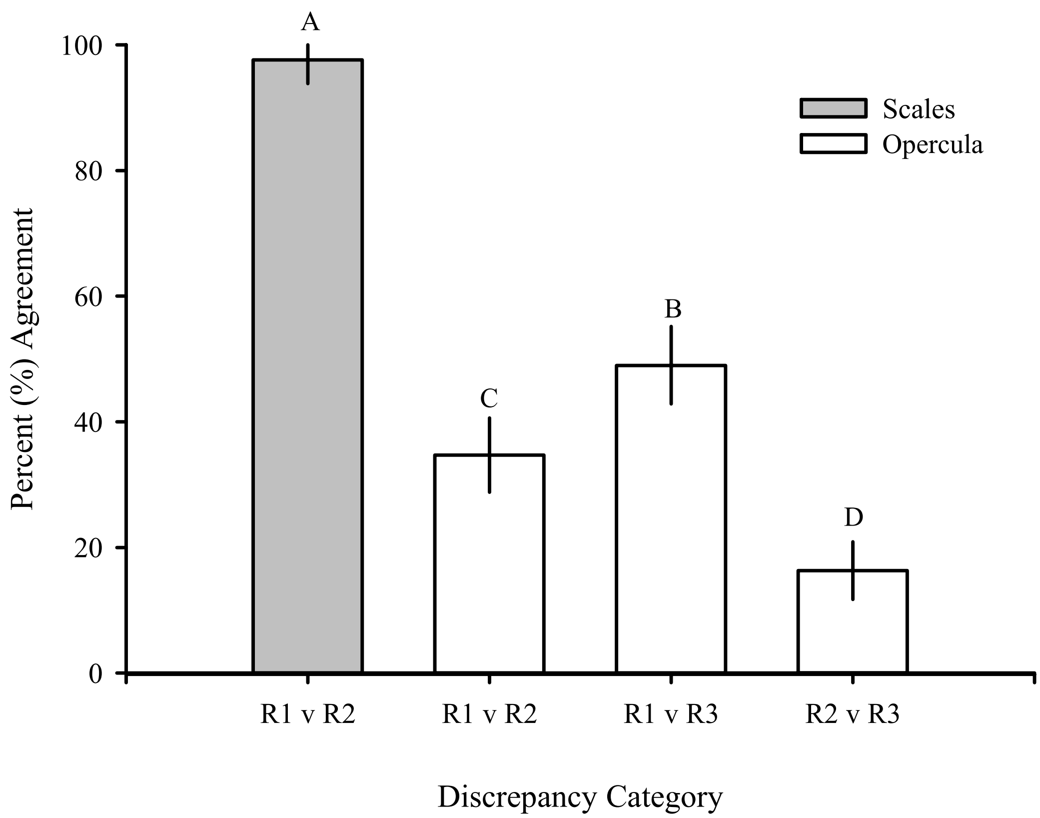


FIGURE 8.—Within (±) one-year agreement on ages assigned by scale and operculum readers for 2005. R1 = reader 1, R2 = reader 2, and R3 = reader 3. Readers 1 and 2 aged both scales and opercula. Columns without a letter in common differ significantly ($P < 0.05$); error bars are 95% confidence intervals.

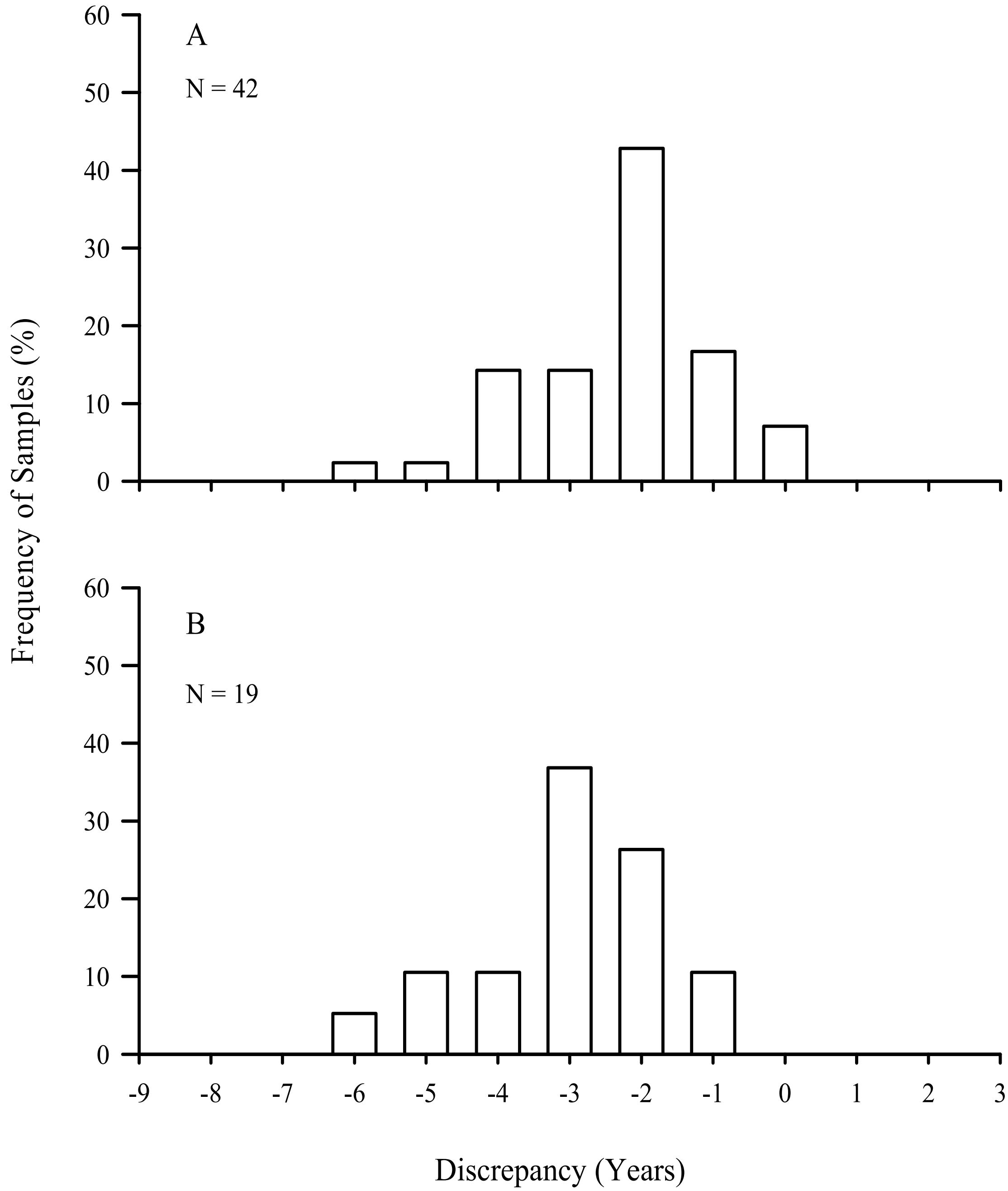


FIGURE 9.—Distribution of aging discrepancies for northern pikeminnow scales tagged in 2003 (A) and scales tagged in 2002 or earlier (B) recaptured in 2005. A potential discrepancy is defined as recapture year minus tagging year subtracted from the difference between recapture age and tagging age.

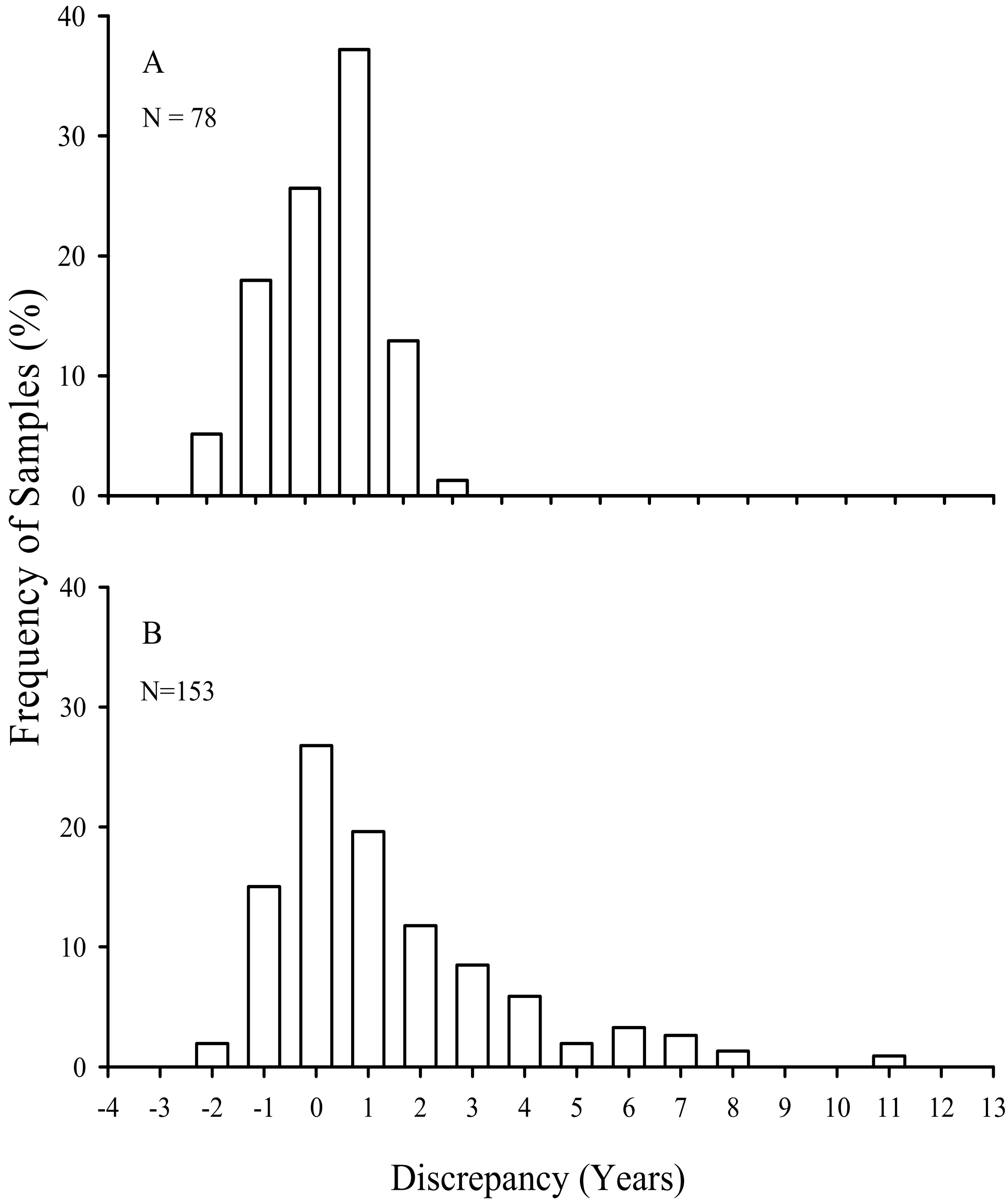


FIGURE 10.—Frequency distribution of aging discrepancies between scales and opercles taken from the same fish: northern pikeminnow < 350 mm fork length (A), northern pikeminnow ≥ 350 mm fork length (B). A discrepancy is defined as the scale age subtracted from the opercle age.

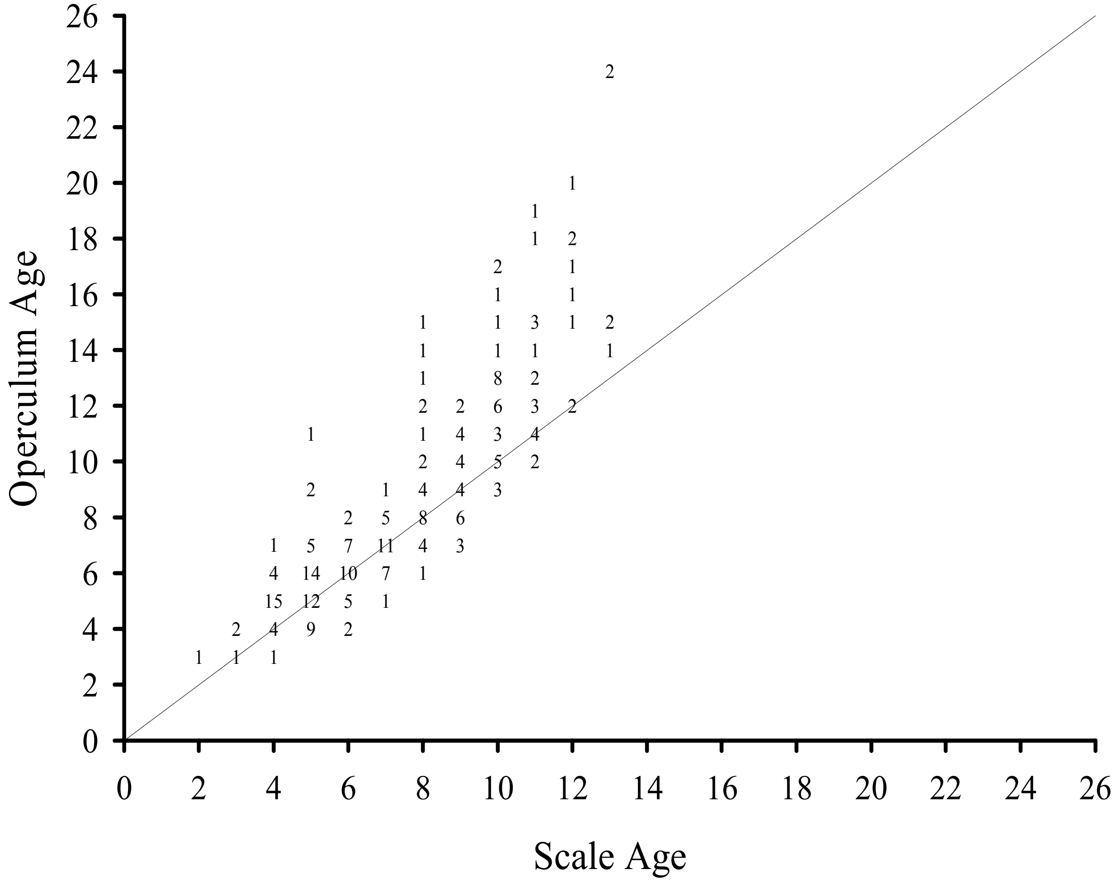


FIGURE 11.—Plot of ages assigned to corresponding scales and opercula from northern pikeminnow recaptured in 2005. The 45° line represents the point where scale and operculum ages would be the same. Numbers denote the quantity at each scale/operculum combination (n = 232).

We examined 235 operculum samples from northern pikeminnow captured in the sport-reward in 2005. We found 183 (78%) exhibited a detectable OTC mark and were examined for mark quality; of these, 10 were from 2002, 45 from 2003, 51 from 2004, and 83 were from northern pikeminnow that had been tagged in 2005. We found OTC mark failure to be significantly related to mark year (χ^2 = 13.00, df=1, P < 0.05) with 39 of 52 (75%) of failed marks coming from northern pikeminnow OTC injected in 2005. We also have insufficient evidence to conclude that mark quality of the 183 fish that exhibited an OTC mark is dependent on the tagging year (χ^2 = 3.76, df=4, P = 0.44). However, mark quality of fish recaptured in 2005 was not distributed randomly (χ^2 = 7.11, df = 2, P < 0.05; Figure 12, panel A), with OTC marks more likely to be of poor quality than good (χ^2 = 5.53, df = 1, P < 0.05), and more likely to be fair than good (χ^2 = 5.53, df = 1, P < 0.05). We noted the correct number of annuli after the OTC mark 75.4% (95% confidence bounds, 69.2–81.7%) of the time for 2005 fish, and though

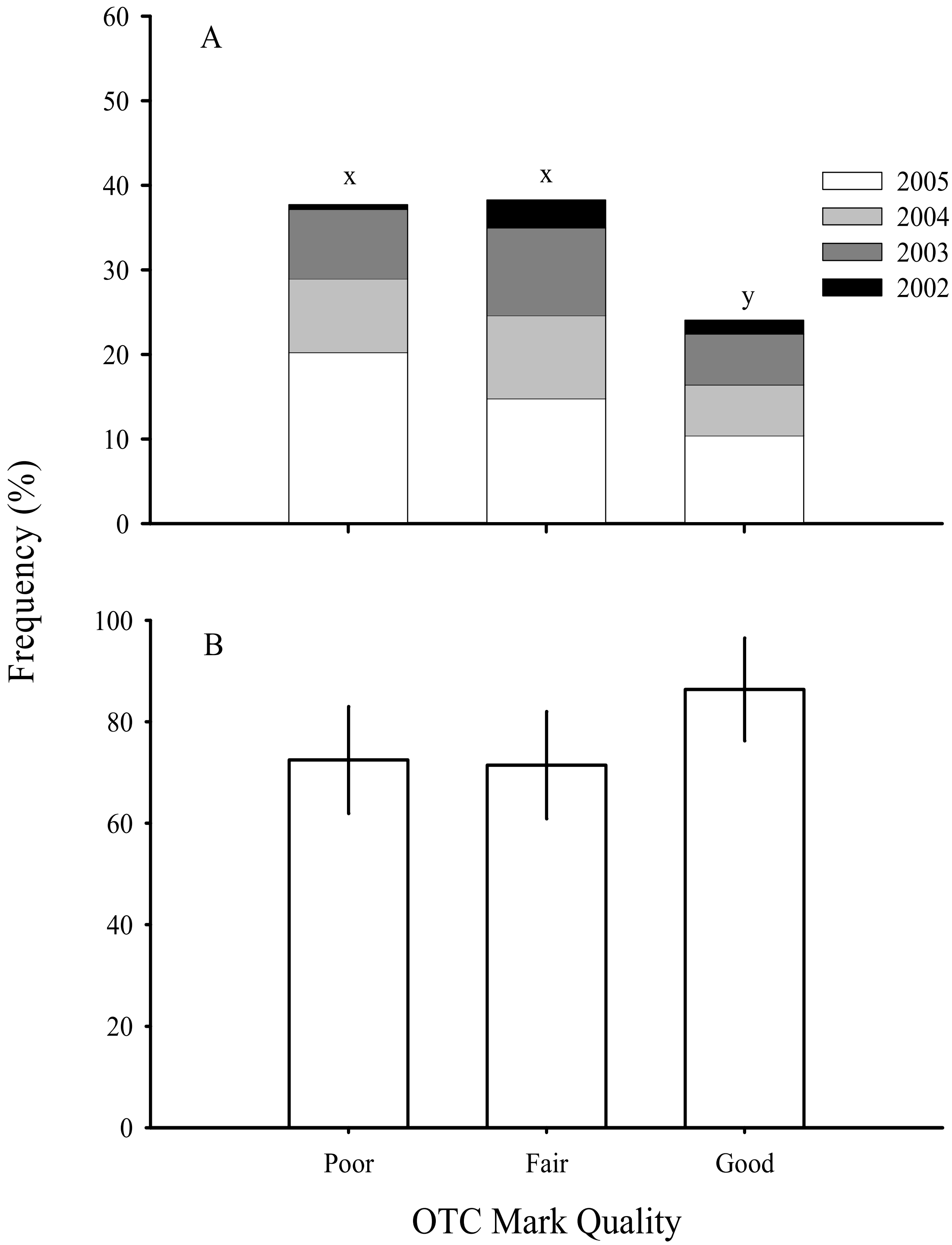


FIGURE 12.—Frequency distribution of OTC mark quality on opercula from northern pikeminnow tagged between 2002 and 2005 and recaptured in 2005 (A) and correctly identified annuli after the OTC mark (B). Bars without a letter in common are significantly different ($P < 0.05$). Error bars represent 95% confidence intervals.

this percentage appeared marginally higher when considering marks of good quality, there was not a significant difference based on 95% confidence intervals (Figure 12, panel B). Our ability to successfully identify the correct number on annuli after an OTC mark was dependent on mark year (Figure 13); with the probability of correctly identifying the correct number of annuli in 2005 (zero) significantly higher than identifying the correct number in 2003 (two). When we incorrectly identified the number of annuli after the OTC mark, we generally underestimated (19 out of 22 misidentifications) the number of annuli for fish marked in 2003 or earlier, and overestimated (19 out of 23) the number of annuli in northern pikeminnow marked in 2004 or later.

Biological Evaluation

Predator sampling near lower Columbia River dams generally coincided with peaks in juvenile salmonid passage indices (Appendix Figure C-1). However, in 2005 we were unable to sample within the boat-restricted zone at The Dalles Dam due to high water velocities and unsafe conditons. The mean abundance index value for northern pikeminnow below Bonneville Dam in 2005 was 14% lower than in 2004 (Table 1). The combined abundance (excluding tailrace BRZs) below Bonneville Dam and Bonneville Reservoir were 38% and 59% lower than the average of the previous five years (1994 – 1996, 1999, and 2004).

In 2005, smallmouth bass relative densities in spring were 16% lower below Bonneville Dam compared to the previous five years (Table 2). In Bonneville Reservoir spring densities have remained relatively stable. Summer densities in all areas were similar to 1994-1996, 1999, and 2004 (Table 3).

Salmonids composed the majority of fish remains identified to species in the digestive tracts of northern pikeminnow below Bonneville Dam and in Bonneville Reservoir (Table 4). We observed a 62% increase from 2004 in the percent of clupeids found in northern pikeminnow digestive tracts collected below Bonneville Dam. Bonneville Dam tailrace had both the highest (18%; summer) and lowest (6%; spring) percent of northern pikeminnow stomach samples that contained identifiable salmonids (Table 5).

Smallmouth bass stomach samples containing identifiable fish were generally comprised of cottids, gasterostieds, and salmonids (Table 4). Smallmouth bass below Bonneville Dam consumed equal percentages of salmonids and cottids (27%). In Bonneville Reservoir, smallmouth bass stomach samples contained 9% fewer salmonids and 58% more cottids than those collected below Bonneville Dam. Smallmouth bass collected during summer below Bonneville Dam tailrace contained the highest percentage (14%) of identifiable salmonids (Table 5).

We collected very few walleye below Bonneville Dam (*n*=4) and in Bonneville Reservoir (*n*=2). All walleye stomach samples that contained food were collected in spring (Table 5). All fish remains found in walleye stomach samples were peamouth chub (Table 4).

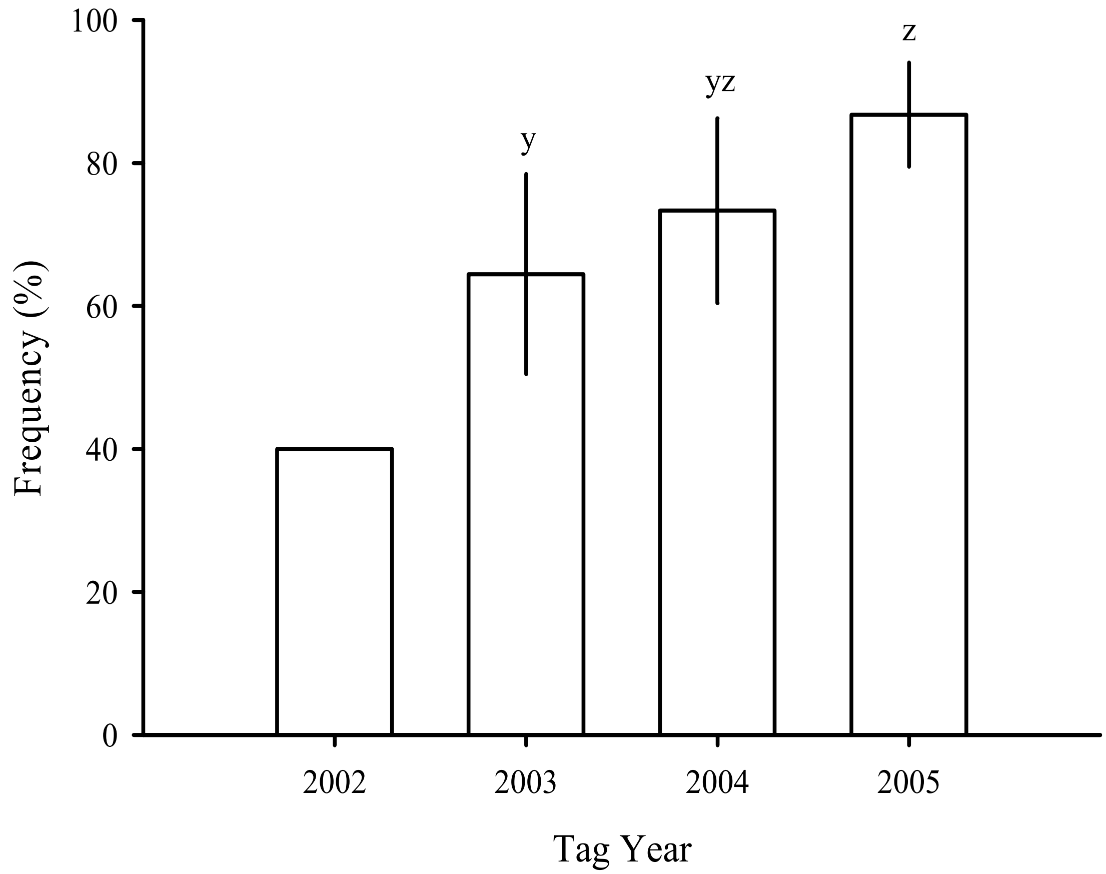


FIGURE 13.—Frequency distribution by tagging year of correctly identified annuli after the OTC mark on opercula from northern pikeminnow recaptured in 2005. Bars without a letter in common are significantly different ($P < 0.05$). Error bars represent 95% confidence intervals. Confidence intervals were not calculated for 2002 due to insufficient sample size.

TABLE 1.—Abundance index values for northern pikeminnow ≥ 250 mm fork length in the lower Columbia River, 1990, 1992-1996, 1999, 2004, and 2005. rkm = river kilometer; BRZ = boat-restricted zone, and -- = not sampled.

	Abundance index								
Area, reach	1990	1992	1993	1994	1995	1996	1999	2004	2005
Below Bonneville Dam									
rkm 114-121	--	20.1	--	15.4	14.5	12.2	9.8	10.6	11.2
rkm 172-178	--	20.5	--	23.2	17.4	18.7	11.8	8.1	9.2
rkm 190-197	--	30.4	--	22.1	14.2	16.4	17.4	13.3	8.2
Tailrace	4.5	2.7	7.6	2.3	1.8	2.2	2.7	1.3	0.6
Tailrace BRZ	3.0	2.8	3.2	4.1	1.0	1.3	--	2.6	1.8
Bonneville Reservoir									
Forebay	5.5	--	2.1	2.3	2.3	1.3	1.0	0.9	0.7
Mid-reservoir	15.1	--	8.5	5.0	7.4	4.9	2.2	2.3	1.9
Tailrace	0.4	--	0.8	0.5	0.8	0.7	1.1	1.3	0.2
Tailrace BRZ	0.9	--	0.2	1.1	--	--	--	--	--

TABLE 2.—Spring relative density of smallmouth bass ≥ 200 mm fork length in the lower Columbia River, 1990-1996, 1999, 2004, and 2005. River kilometer = rkm; dashes indicate areas not sampled. Relative density is mean transformed catch ($\log_{10}$ (catch+1)) per 15-minute electrofishing run.

Reservoir or area	Relative density									
	1990	1991	1992	1993	1994	1995	1996	1999	2004	2005
Below Bonneville Dam										
rkm 114-121	--	--	0.0	--	0.0	<0.1	0.0	0.0	0.0	<0.1
rkm 172-178	--	--	0.2	--	0.2	0.5	0.3	0.1	0.3	0.1
rkm 190-197	--	--	0.1	--	0.1	0.4	0.1	<0.1	0.1	0.2
Tailrace	--	--	0.1	--	0.1	0.4	0.1	0.1	0.3	0.2
Bonneville										
Forebay	<0.1	<0.1	--	0.1	<0.1	0.1	0.1	0.1	0.2	0.2
Mid-reservoir	0.3	<0.1	--	0.1	0.3	0.3	0.2	0.1	--	0.3
Tailrace	0.3	0.3	--	0.7	0.5	0.4	0.6	0.4	0.5	0.3

TABLE 3.— Summer relative density of smallmouth bass ≥ 200 mm fork length in the lower Columbia River, 1990-1996, 1999, 2004, and 2005. River kilometer = rkm; dashes indicate areas not sampled. Relative density is mean transformed catch ($\log_{10}$ (catch+1)) per 15-minute electrofishing run.

Reservoir or area	Relative density									
	1990	1991	1992	1993	1994	1995	1996	1999	2004	2005
Below Bonneville Dam										
rkm 114-121	--	--	<0.1	--	0.1	<0.1	<0.1	0.0	<0.1	<0.1
rkm 172-178	--	--	0.1	--	0.2	0.2	0.1	0.1	0.1	0.2
rkm 190-197	--	--	0.1	--	0.1	0.2	0.1	0.1	0.2	0.2
Tailrace	--	--	0.2	--	0.1	0.2	0.1	0.2	0.1	0.1
Bonneville										
Forebay	0.1	0.0	--	0.1	<0.1	0.1	<0.1	0.2	--	0.2
Mid-reservoir	0.1	0.1	--	0.2	0.2	0.1	0.1	0.1	0.3	0.3
Tailrace	0.2	0.4	--	0.4	0.4	0.5	0.2	0.4	0.4	0.2

TABLE 4.—Percent family composition of fish consumed by northern pikeminnow, smallmouth bass, and walleye in the lower Columbia River, 2005. BBD = below Bonneville Dam, BON = Bonneville Reservoir, and *n* = number of gut samples containing fish.

	Northern pikeminnow		Smallmouth bass		Walleye	
Family	BBD (*n*=68)	BON (*n*=18)	BBD (*n*=37)	BON (*n*=57)	BBD (*n*=3)	BON (*n*=0)
Salmonidae	54.4	55.6	27.0	24.6	0.0	0.0
Cottidae	11.8	16.7	27.0	64.9	0.0	0.0
Clupeidae	25.0	5.6	8.1	1.8	0.0	0.0
Cyprinidae	7.4	11.1	10.8	7.0	100.0	0.0
Catostomidae	0.0	0.0	2.7	1.8	0.0	0.0
Cobitidae	1.5	0.0	0.0	0.0	0.0	0.0
Percopsidae	0.0	0.0	0.0	5.3	0.0	0.0
Gasterosteidae	7.4	5.6	24.3	10.5	0.0	0.0
Centrarchidae	0.0	5.6	5.4	1.8	0.0	0.0
Percidae	0.0	0.0	0.0	3.5	0.0	0.0

TABLE 5.—Number (N) of northern pikeminnow, smallmouth bass, and walleye digestive tracts examined from the lower Columbia River in 2005, and percent that contained food, fish, and juvenile salmonids (Sal).

	Northern pikeminnow				Smallmouth bass				Walleye			
		Percent				Percent				Percent		
Season, area	N	Food	Fish	Sal	N	Food	Fish	Sal	N	Food	Fish	Sal
Spring												
Below Bonneville Dam tailrace	66	68	24	6	36	89	42	11	2	100	100	0
Bonneville Dam tailrace	110	41	23	11	32	66	22	0	1	100	100	0
Bonneville Reservoir	68	56	26	15	132	73	28	5	1	0	0	0
All areas	244	52	24	11	200	75	30	6	4	75	75	0
Summer												
Below Bonneville Dam tailrace	33	76	30	18	35	77	46	14	0	0	0	0
Bonneville Dam tailrace	92	51	41	16	28	82	46	4	0	0	0	0
Bonneville Reservoir	71	41	4	0	166	80	23	4	0	0	0	0
All areas	196	52	26	11	229	79	30	6	0	0	0	0

Spring 2005 CI values for northern pikeminnow in rkm 190-197 were greater than 1996, 1999, and 2004 values (Table 6). Spring consumption in The Dalles Dam tailrace was the highest to date. Below Bonneville Dam (rkm 114-121 and rkm 190-197) summer consumption was greater than in 1996, 1999, and 2004 (Table 7). Summer 2005 CI values were zero in Bonneville Dam forebay. In the remaining Bonneville Reservoir locations, too few northern pikeminnow ($n \leq 5$) were collected to calculate summer consumption indices.

Spring CI values for smallmouth bass in 2005 were greater than any previous year for rkm 172-178 and Bonneville Dam tailrace (Table 8). Spring consumption in Bonneville Reservoir was consistently low and similar to previous years. Summer consumption in rkm 190-197 and The Dalles Dam tailrace was greater than those in 1996, 1999, and 2004 (Table 9). Summer consumption was greater in Bonneville mid-reservoir than all previous years. Spring and summer consumption for rkm 114-121 was not calculated due to insufficient sample size ($n \leq 5$).

Northern pikeminnow predation indices varied by location and season. Spring predation below Bonneville Dam for rkm 172-178 was lower than every previous year (Table 10); conversely, spring predation for Bonneville mid-reservoir and The Dalles Dam tailrace was the highest to date. Summer predation for rkm 114-121 was greater than 1996, 1999, and 2004 (Table 11). The summer index value for Bonneville forebay was zero, and in the remaining Bonneville Reservoir sites indices were not calculated due to insufficient sample sizes ($n \leq 5$).

TABLE 6.—Spring consumption indices for northern pikeminnow ≥ 250 mm fork length in the lower Columbia River, 1990, 1992-1996, 1999, 2004, and 2005. BRZ = boat-restricted zone; rkm = river kilometer; -- = area not sampled, and X = no consumption index calculated ($n \leq 5$).

	Consumption index								
Area, reach	1990	1992	1993	1994	1995	1996	1999	2004	2005
Below Bonneville Dam									
rkm 114-121	--	0.5	--	0.5	0.5	0.4	0.8	0.2	0.2
rkm 172-178	--	1.0	--	1.1	0.2	0.1	0.4	0.3	0.0
rkm 190-197	--	1.1	--	1.5	0.7	0.4	0.4	0.1	0.5
Tailrace	1.2	0.5	0.8	3.2	0.8	0.4	0.1	0.3	0.4
Tailrace BRZ	2.7	1.0	1.1	0.6	1.7	0.6	--	1.0	1.6
Bonneville Reservoir									
Forebay	0.6	--	0.7	0.2	0.3	0.0	0.0	0.5	0.3
Mid-reservoir	0.0	--	0.0	0.2	0.0	0.1	0.6	--	X
Tailrace	0.3	--	0.0	0.0	0.2	0.0	0.2	0.0	1.5
Tailrace BRZ	2.3	--	--	--	--	--	--	X	--

TABLE 7.—Summer consumption indices for northern pikeminnow ≥ 250 mm fork length in the lower Columbia River, 1990, 1992-1996, 1999, 2004, and 2005. BRZ = boat-restricted zone; rkm = river kilometer; -- = area not sampled, and X = no consumption index calculated ($n \leq 5$).

	Consumption index								
Area, reach	1990	1992	1993	1994	1995	1996	1999	2004	2005
Below Bonneville Dam									
rkm 114-121	--	0.3	--	1.8	1.5	0.0	1.0	0.4	1.2
rkm 172-178	--	1.3	--	1.5	0.4	0.0	0.0	0.7	0.3
rkm 190-197	--	1.9	--	0.4	1.2	0.0	0.5	0.2	0.6
Tailrace	0.5	2.1	1.2	0.4	0.9	0.6	0.2	0.2	0.0
Tailrace BRZ	5.5	7.8	1.0	2.1	1.3	3.1	--	4.0	3.8
Bonneville Reservoir									
Forebay	1.8	--	0.5	0.3	0.0	0.3	0.0	--	0.0
Mid-reservoir	0.0	--	0.0	0.0	0.0	0.0	0.0	0.0	X
Tailrace	X	--	0.0	0.0	0.8	0.0	0.3	1.1	X

Tailrace BRZ	0.8	--	1.0	3.2	--	--	--	X	--

TABLE 8.—Spring consumption indices for smallmouth bass ≥ 200 mm fork length in the lower Columbia River, 1990, 1992-1996, 1999, 2004, and 2005. rkm = river kilometer; -- = area not sampled, and X = no consumption index calculated ($n \leq 5$).

	Consumption index								
Area, reach	1990	1992	1993	1994	1995	1996	1999	2004	2005
Below Bonneville Dam									
rkm 114-121	--	X	--	X	X	--	--	X	X
rkm 172-178	--	0.1	--	0.0	0.1	0.0	X	0.0	0.3
rkm 190-197	--	X	--	0.3	0.0	0.0	X	0.2	0.1
Tailrace	--	X	--	0.0	0.0	0.0	X	0.0	0.1
Bonneville Reservoir									
Forebay	X	--	X	X	0.1	0.0	0.0	0.0	0.1
Mid-reservoir	X	--	X	0.0	0.1	0.0	X	--	0.0
Tailrace	0.0	--	0.0	0.0	0.0	0.0	<0.1	0.0	<0.1

TABLE 9.—Summer consumption indices for smallmouth bass ≥ 200 mm fork length in the lower Columbia River, 1990, 1992-1996, 1999, 2004, and 2005. rkm = river kilometer; -- = area not sampled, and X = no consumption index calculated ($n \leq 5$).

	Consumption index								
Area, reach	1990	1992	1993	1994	1995	1996	1999	2004	2005
Below Bonneville Dam									
rkm 114-121	--	X	--	0.0	X	X	--	X	X
rkm 172-178	--	0.0	--	0.2	0.3	X	0.0	0.0	0.2
rkm 190-197	--	0.4	--	0.3	0.8	0.0	0.0	0.2	0.6
Tailrace	--	X	--	0.0	0.0	X	0.0	0.4	0.1
Bonneville Reservoir									
Forebay	X	--	X	0.4	0.0	0.0	0.2	--	0.1
Mid-reservoir	X	--	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Tailrace	X	--	0.0	0.1	0.1	0.0	0.0	0.0	0.1

TABLE 10.—Spring predation indices for northern pikeminnow ≥ 250 mm fork length in the lower Columbia River, 1990, 1992-1996, 1999, 2004, and 2005. BRZ = boat-restricted zone; rkm = river kilometer, and -- = not sampled.

	Predation index								
Area, reach	1990	1992	1993	1994	1995	1996	1999	2004	2005
Below Bonneville Dam									
rkm 114-121	--	10.4	--	8.0	7.3	4.9	7.5	1.8	2.0
rkm 172-178	--	20.9	--	26.2	3.5	1.9	5.0	2.5	0.0
rkm 190-197	--	34.4	--	33.3	9.9	6.6	7.1	1.5	4.4
Tailrace	5.5	1.4	6.1	7.4	1.4	0.9	0.4	0.3	0.3
Tailrace BRZ	8.0	2.8	3.5	2.5	1.7	0.8	--	2.5	2.8
Bonneville Reservoir									
Forebay	3.3	--	1.5	0.3	0.7	0.0	0.0	0.5	0.2
Mid-reservoir	0.0	--	0.0	1.0	0.0	0.5	1.3	--	2.2
Tailrace	0.1	--	0.0	0.0	0.2	0.0	0.2	0.0	0.3
Tailrace BRZ	2.0	--	--	--	1.5	--	--	--	--

TABLE 11.—Summer predation indices for northern pikeminnow ≥ 250 mm fork length in the lower Columbia River, 1990, 1992-1996, 1999, 2004, and 2005. BRZ = boat-restricted zone; rkm = river kilometer; -- = not sampled, and X = no predation index calculated ($n \leq 5$).

	Predation index								
Area, reach	1990	1992	1993	1994	1995	1996	1999	2004	2005
Below Bonneville Dam									
rkm 114-121	--	6.2	--	27.3	14.5	0.0	9.4	4.7	13.3
rkm 172-178	--	27.0	--	35.0	7.0	0.0	0.0	5.8	3.1
rkm 190-197	--	57.8	--	9.5	17.0	0.0	9.5	2.3	5.1
Tailrace	2.3	5.7	9.1	1.0	1.6	1.3	0.6	0.3	0.0
Tailrace BRZ	16.4	21.9	3.2	8.9	1.2	4.0	--	10.2	6.8
Bonneville Reservoir									
Forebay	9.9	--	1.1	0.6	0.0	0.4	0.0	--	0.0
Mid-reservoir	0.0	--	0.0	0.0	0.0	0.0	0.0	0.0	X
Tailrace	0.0	--	0.0	0.0	0.6	0.0	0.3	1.4	X
Tailrace BRZ	0.7	--	0.2	3.5	--	--	--	--	--

Smallmouth bass predation indices were calculated for the first time in 2004 and continued in 2005 using season-specific CPUE data (Appendix Table D-2). The spring smallmouth bass predation below Bonneville Dam rkm 172-178 was substantially greater than the 2004 value (Table 12). Summer predation for rkm 190-197 was 58% higher in 2005 than 2004. Smallmouth bass predation below Bonneville Dam was greater than that of northern pikeminnow for rkm 172-178 (spring) and rkm 190-197 (summer) (Table 13). Smallmouth bass predation for rkm 190-197 increased 89% between spring and summer.

Northern pikeminnow year-class analysis downstream of Bonneville Dam showed considerable variation from year to year in the percentage of age 3 and 4 fish (Figure 14). The percentage of age 5 northern pikeminnow has been relatively stable since 1993, accounting for 15 – 17% of the total. In Bonneville Reservoir, year class strength appears to be more variable than below Bonneville Dam, with a stable long-term oscillation in the percentage of age 5 fish (Figure 14).

Smallmouth bass year-class analysis downstream of Bonneville Dam indicates that a growing proportion of the population is composed of age 4 fish (Figure 15, panel A), and the average age assigned to fish differed significantly among years ($\chi^2 = 50.68$, df = 6, $P < 0.05$); smallmouth bass sampled were significantly ($P < 0.05$) younger in 1999 and 1992 than in 1994, 1996, and 2004 – 2005 (Figure 15, panel B). In Bonneville Reservoir year class strength appears to vary from year to year, although the percentages of age 5 fish in 1999 and 2005 were four to six times greater than between 1990 and 1995 (Figure 16, panel A) and the average age assigned to fish differed significantly among years ($\chi^2 = 122.96$, df = 8, $P < 0.05$; Figure 16, panel B). Smallmouth bass sampled in

Bonneville Reservoir were significantly ($P < 0.05$) older in 1999, 2004, and 2005 than in 1990, 1991, and 1993.

The 2005 northern pikeminnow PSD value for below Bonneville Dam was 29% higher than all previous years (Table 14). In Bonneville Reservoir, PSD was the highest since 1994. We observed the lowest proportional and relative stock densities of smallmouth bass below Bonneville Dam since the implementation of the NPMP (Table 15); however, in Bonneville Reservoir, smallmouth bass RSD-P was greater than all previous years.

Median W_r differed significantly ($P < 0.01$) among years for male and female northern pikeminnow (Figure 17). Both sexes exhibited a similar pattern; W_r was comparatively low in 1990-1992 and 1995-1996, and significantly higher in 1993-1994, 1999, 2004, and 2005. Median W_r was highest for male northern pikeminnow in 2004, and for female northern pikeminnow in 1999; however, these values did not differ significantly from those in 1993, 1994,

TABLE 12.—Spring and summer predation indices for smallmouth bass ≥ 200 mm fork length in the lower Columbia River, 2004 and 2005. BRZ = boat-restricted zone; rkm = river kilometer; -- = area not sampled, and X = no predation index calculated ($n \le 5$).

	Predation index			
	Spring		Summer	
Area, reach	2004	2005	2004	2005
Below Bonneville Dam				
rkm 114-121	X	X	X	X
rkm 172-178	0.0	2.1	0.0	1.7
rkm 190-197	2.2	0.6	2.2	5.3
Tailrace[a]	0.0	0.0	0.2	0.1
Bonneville Reservoir				
Forebay	0.0	0.1	--	0.2
Mid-reservoir	--	0.0	0.0	1.0
Tailrace[a]	0.0	<0.1	0.0	0.1

[a]Tailrace and tailrace BRZ numbers combined.

TABLE 13.—Spring and summer predation indices for northern pikeminnow ≥ 250 mm fork length and smallmouth bass ≥ 200 mm fork length in the lower Columbia River, 2005. BRZ = boat-restricted zone; rkm = river kilometer; -- = area not sampled, and X = no predation index calculated ($n \le 5$).

	Predation index			
	Northern pikeminnow		Smallmouth bass	
Area, reach	Spring	Summer	Spring	Summer
Below Bonneville Dam				
rkm 114-121	2.0	1.3	X	X
rkm 172-178	0.0	3.1	2.1	1.7
rkm 190-197	4.4	5.1	0.6	5.3
Tailrace[a]	3.1	6.8	0.0	0.1
Bonneville Reservoir				
Forebay	0.2	0.0	0.1	0.2
Mid-reservoir	X	X	0.0	1.0
Tailrace[a]	0.3	X	<0.1	0.1

[a]Tailrace and tailrace BRZ numbers combined.

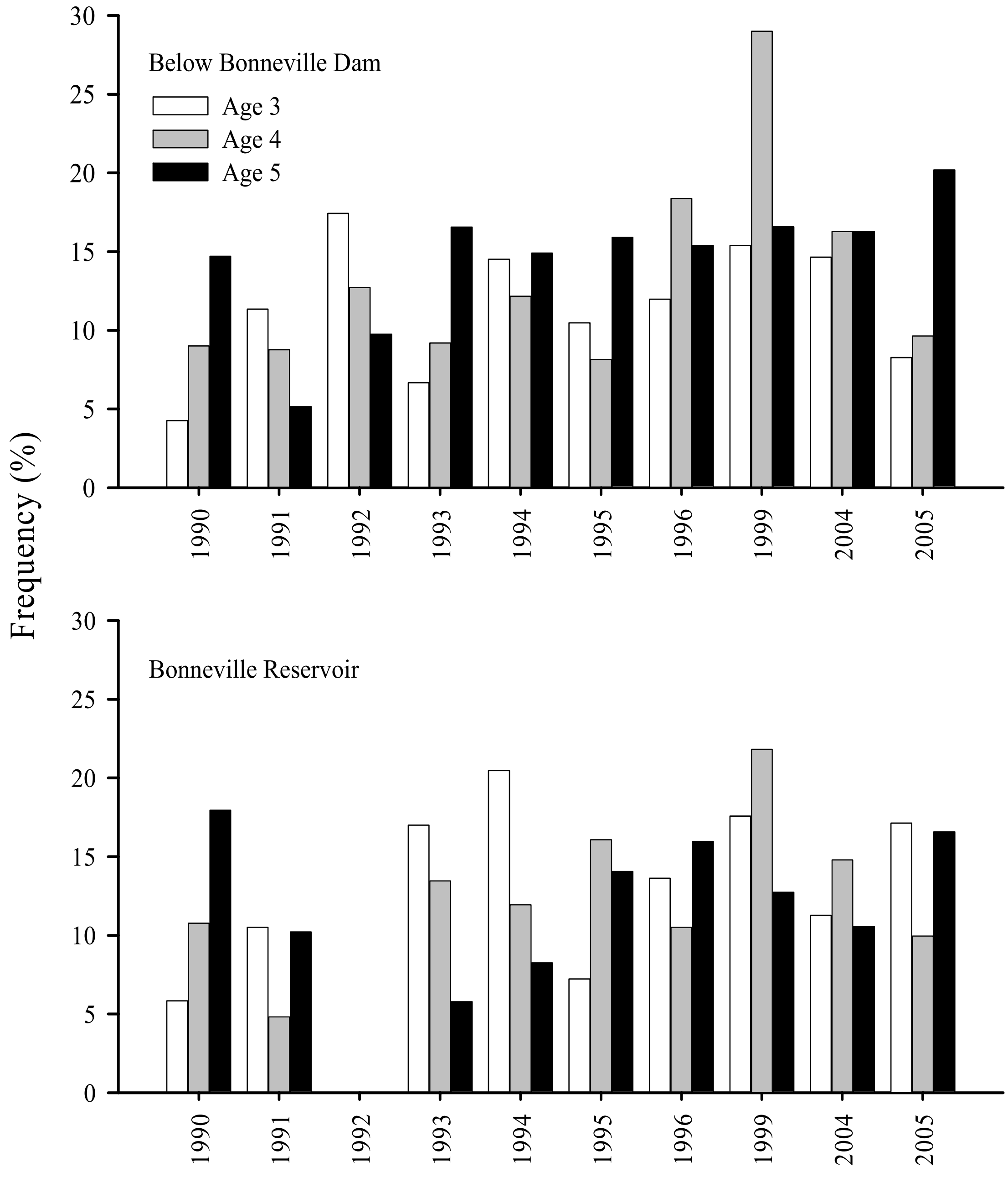


FIGURE 14.—Percent composition of age 3-5 northern pikeminnow, relative to the total sample, in the Columbia River downstream from Bonneville Dam and Bonneville Reservoir (1990 to 2005).

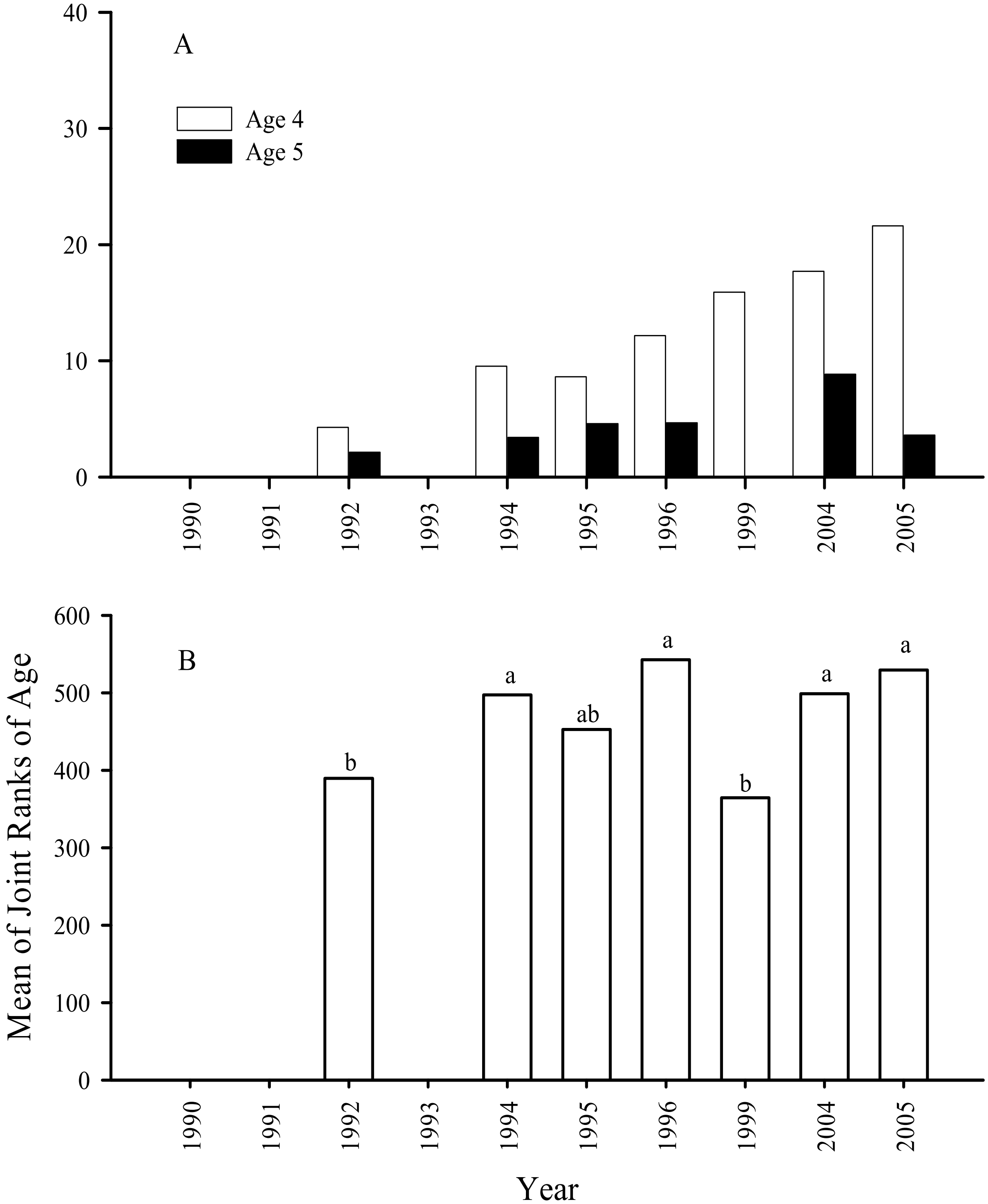


FIGURE 15.—Percent composition of age 4-5 smallmouth bass relative to the total sample (A) and the mean of joint ranks of age (B) in the Columbia River downstream from Bonneville Dam 1990 to 2005. Bars without a letter in common are significantly different ($P < 0.05$).

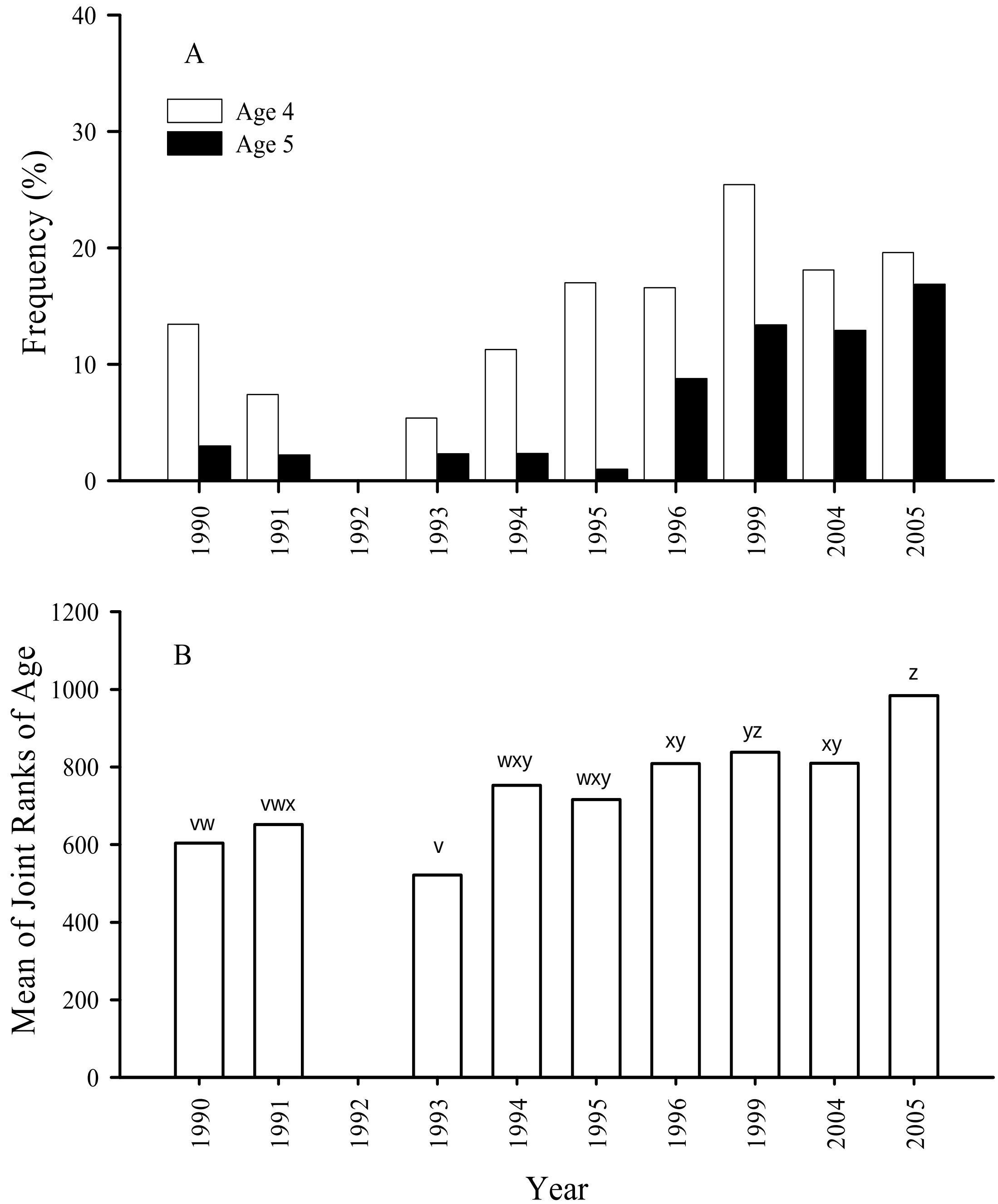


FIGURE 16.—Percent composition of age 4-5 smallmouth bass relative to the total sample (A) and the mean of joint ranks of age (B) in the Bonneville Reservoir 1990 to 2005. Bars without a letter in common are significantly different ($P < 0.05$).

TABLE 14.—Proportional stock density (PSD) and sample size (N) of northern pikeminnow in the lower Columbia River, 1990, 1992 – 1996, 1999, 2004, and 2005. -- = area not sampled.

Location, Parameter	1990	1992	1993	1994	1995	1996	1999	2004	2005
Below Bonneville Dam									
PSD	--	29	--	33	41	33	39	35	49
N	--	710	--	409	206	245	226	356	287
Bonneville Reservoir									
PSD	43	--	44	40	26	24	33	18	40
N	245	--	213	378	319	199	169	136	106

TABLE 15.— Proportional stock density (PSD), relative stock density of preferred length fish (RSD-P), and sample size (N) of smallmouth bass in the lower Columbia River, 1990, 1992 – 1996, 1999, 2004, and 2005. -- = area not sampled.

Location, Parameter	1990	1992	1993	1994	1995	1996	1999	2004	2005
Below Bonneville Dam									
PSD	--	22	--	31	41	30	46	30	19
RSD-P	--	7	--	12	15	6	13	6	2
N	--	153	--	141	181	83	54	172	238
Bonneville Reservoir									
PSD	39	--	26	37	33	58	46	44	40
RSD-P	15	--	10	12	11	14	13	17	19
N	111	--	236	332	285	256	239	235	418

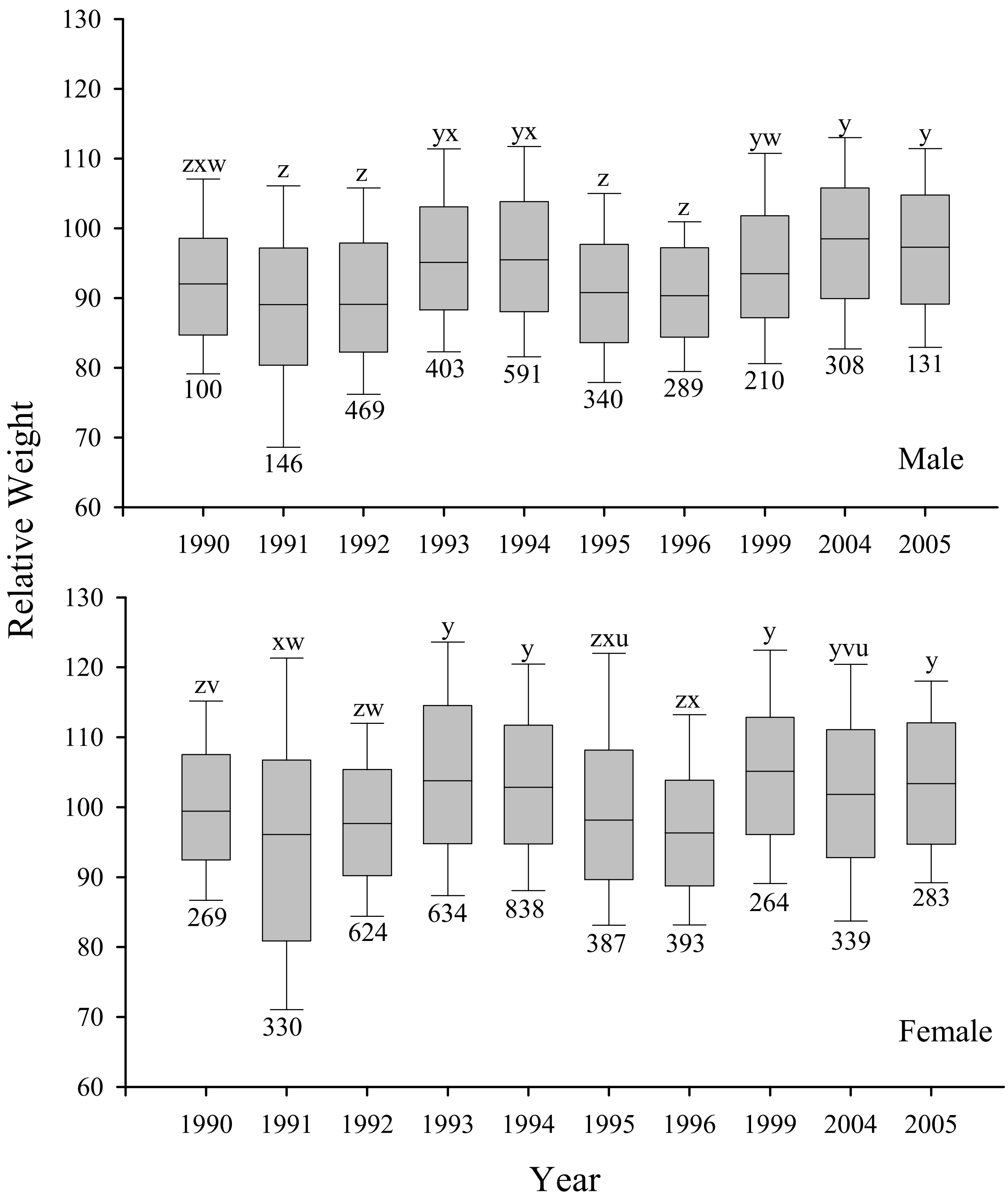


FIGURE 17.–Relative weight of male and female northern pikeminnow in the lower Columbia and Snake rivers, 1990-1996, 1999, 2004, and 2005. The horizontal line near the center of each bar is the median, the ends of the bar are 25th and 75th percentiles, and the whiskers are the 10th and 90th percentiles. Bars without a letter in common differ significantly ($P < 0.05$); numbers below the bars are the sample size.

and 2005. Smallmouth bass median W_r was significantly ($P < 0.01$) higher in 2005 than in 1996 and 1999 (Figure 18).

DISCUSSION

Fishery Evaluation, Predation Estimates, and Tag Loss

In 2005, system-wide exploitation of northern pikeminnow ≥ 250 mm FL (19%) continued an increasing trend from previous years and was the highest observed since implementation of the NPMP. Exploitation has exceeded the minimum target rate of 10% (Rieman and Beamesderfer 1990) in 13 of 15 years. We continue to find a high degree of variability in area-specific exploitation rates, with the exception of the reach below Bonneville Dam. Because exploitation above Bonneville Dam appears to be highly variable, continued close monitoring of these areas is prudent. Below Bonneville Dam, exploitation has increased each year since 2002. The increasing exploitation rates seen below Bonneville Dam and system-wide are positively correlated and seem to mirror each other. Prior to 2004, sport-reward harvest of northern pikeminnow (≥ 250 mm FL) appeared to be driven by river flow, with exploitation increasing as river levels decreased (Takata and Koloszar 2004). However, the amount of variability explained by river flow has continually weakened over the last three years (Takata and Koloszar 2004; Jones et al. 2005), suggesting additional factors may influence exploitation. Increased exploitation in 2004 and 2005 may be related to the modified incentives applied to the reward structure of the sport-reward fishery during these years, and may act to weaken the river flow model. We expect the new reward structure to continue, and any models developed to predict exploitation should take this into account. Beginning in 2006, we will tag northern pikeminnow and monitor exploitation in Little Goose Reservoir, as sport-reward catches there have increased considerably in recent years (E. Winther, WDFW, personal communication).

Exploitation rates for northern pikeminnow 200-249 mm FL have been more erratic than their larger counterparts in the five years they have been targeted. It appears that smaller tagged fish may be less likely to be recovered in the fishery, limiting sample sizes and potentially biasing exploitation estimates. From 2000 to 2005 these smaller fish composed, on average, about 19% of the northern pikeminnow tagged and released each year. However, 30.5% of the untagged northern pikeminnow harvested by the sport-reward fishery consisted of fish 200-249 mm FL. Higher mortality on smaller fish after tagging may prevent them from being recaptured in the fishery at a rate more consistent with their share of the overall catch (Takata and Koloszar 2004).

We were unable to completely assess angling as a means to capture and tag additional northern pikeminnow. In the short time we did fish, incidentally-caught species outnumbered northern pikeminnow 12 to 1, possibly due to our high use of bait (worms and chicken liver). Because tagging effort must occur non-randomly (the same sampling effort is expended in each river mile), we concluded that successful angling would likely require additional boats and personnel. The short amount of angling time we allocated to each river mile (about 40 minutes) also hampered our ability to find likely fishing locations.

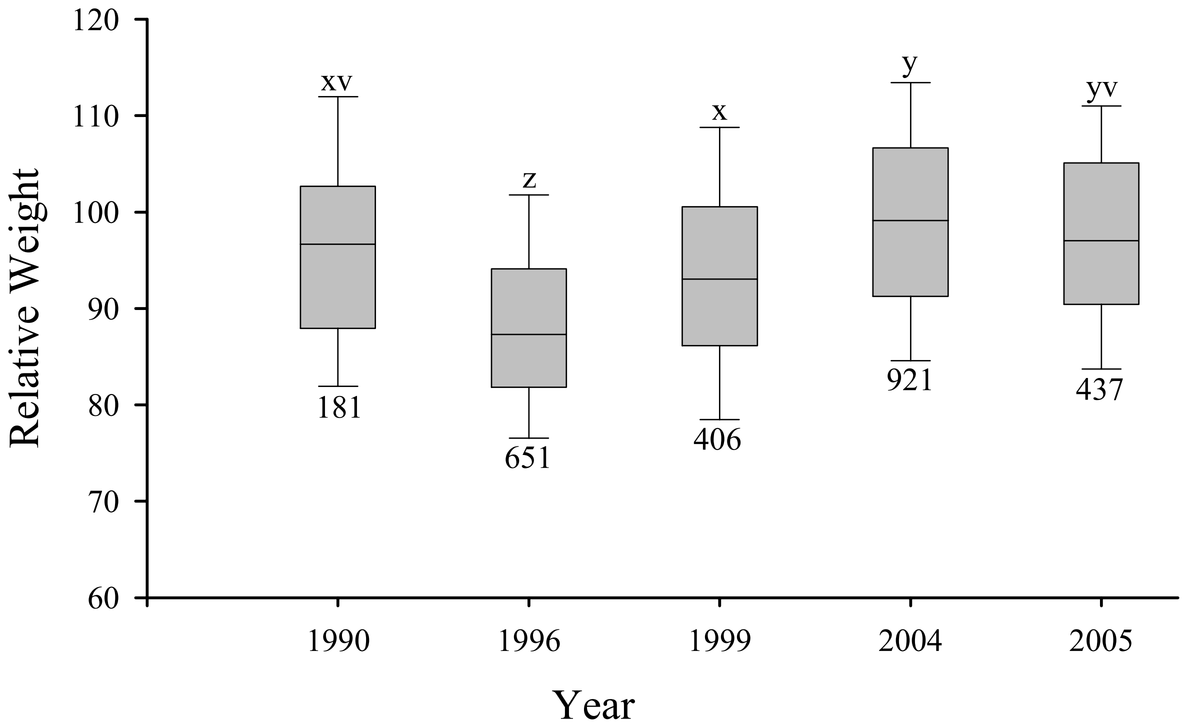


FIGURE 18.–Smallmouth bass relative weight in the lower Columbia and Snake rivers for 1990, 1996, 1999, 2004, and 2005. The horizontal line near the center of each bar is the median, the ends of the bar are the 25th and 75th percentiles, and the whiskers are the 10th and 90th percentiles. Bars without a letter in common differ significantly ($P < 0.05$); numbers below the bars are the sample size.

We calculated a tag loss estimate of 8.1% in 2005, which was lower than the 11.3% estimated in 2004 (Jones et al. 2005) and higher than the 4.2% used to adjust exploitation estimates prior to 2000 (Zimmerman et al. 2000). Although spaghetti tags are designed for a long retention time, they are prone to snagging due to their loop configuration (Guy et al. 1996), and Timmons and Howell (1995) observed a 50% tag loss rate in two catostomid species after 190 days. Our estimated tag loss rate in 2005 seems reasonable considering the reported tag loss range (5 – 25%) of similar studies (Ebener and Copes 1982; Muoneke 1992).

We were able to accurately discern the year each tag loss fish was marked between 2003 and 2005 by utilizing PIT tags as secondary marks for our tag loss study. This allowed us to calculate multi-year exploitation rates for the first time. Although these multi-year estimates appeared similar to single-year 2005 exploitation rates, having them will enable us to calculate between year survival and new estimates of fishing, natural and total mortality (Everhart and Youngs 1981). We plan to employ PIT tags as our secondary mark again in 2006, and to calculate new mortality estimates in the future.

Based on the model of Friesen and Ward (1999), it appears most of the reduction in potential predation was realized in the first seven years of the NPMP. After slight increases in 1998 and 1999, predicted potential predation has stabilized at approximately 75-80% of pre-program levels. If exploitation rates remain similar to mean 1995-2005 levels, further reductions in potential predation are likely to be minimal. If exploitation rates are maintained at 2005 levels, long-term projections indicate further reductions in predation will be minimal (ODFW, unpublished data). Therefore, maintaining potential predation near the current levels may be a more realistic goal for the future rather than trying to gain additional large reductions in predation. In response to recommendations made in an audit of the NPMP (Hankin and Richards 2000), we are currently working on an updated predation model that takes into account size-at-age differences between males and females and includes updated mortality estimates. We plan to use the new model once our aging and tag loss assessments are completed.

Age Validation

From 2001 to 2003 the readers in our aging study were the same two individuals. In 2004 three different readers aged northern pikeminnow scales – two of which aged opercula. In 2005 the two scale readers included one from 2004 and one new reader, and the two scale readers and one of the 2001-2003 readers read opercula. Complete agreement on scale ages between readers in 2005 (~ 72%) was higher than 2002 - 2004 (~ 50%), and agreement within one year continued to improve from 2002 – 2003 (~ 85%) and 2004 (~ 90%) to over 97% in 2005. The between reader agreement among the three readers who aged opercula was significantly lower than between reader agreement for scales in 2005. Training procedures and experience may influence these differences. Readers generally have more experience aging scales than they do opercula, and the methodology for aging northern pikeminnow scales has been thoroughly documented in our internal laboratory procedures manual (ODFW, unpublished report). A similar detailed aging methodology has yet to be devised for northern pikeminnow opercula. We found that agreement on ages assigned to opercula to be lower amongst readers in 2005 than in previous years. In 2001 – 2004, complete reader agreement had gradually increased, but in 2005 the experienced reader (≥ two years experience) agreement was the lowest (22%) observed since opercula were included in the validation study (Takata and Ward 2001). Aging precision may be increased by reader experience (Baker and McCormish 1998). However, the potential for incorrectly identifying annuli still exists, especially in older fish that may have thicker opercular bones and slower growth obscuring annuli near the edge of the operculum (Frost and Kipling 1959; Baker and McCormish 1998). Frost and Kipling (1959) noted that annuli, especially on thicker bones, were more easily discerned if read in a xylol bath. Modifying our reading techniques might provide a clearer view of annuli and enable us to increase between reader precision. The novice reader consistently assigned younger ages to opercula than the two more experienced readers. In addition to difficulties near the edge of larger opercula, Le Cren (1947), Frost and Kipling (1959), and Donald et al. (1992) have all noted difficulties detecting annuli that lie near the focus. When reviewing the opercula to assign final ages, the novice reader noticed that he had consistently failed to identify interior annuli. If the novice reader had known to look closely for annuli nearer the focus, between reader agreements might have increased. Our opercular aging precision may yet increase as we continue to learn more about reading northern pikeminnow opercula, refine our aging techniques, and incorporate this knowledge when further developing our aging protocols.

There is a strong tendency to underestimate the time at-large when reading the scales of northern pikeminnow recaptured several years after tagging. This has been the case in every year this aspect of our age validation study has been conducted (Takata and Koloszar 2004). We do not know why this underestimation of recapture ages consistently occurs, though researchers working on other relatively long lived species have speculated that as fish shift more energy from somatic to gonadal growth, annuli near the edge of scales become increasingly difficult to discern (Scoppettone 1988; Donald et al. 1992). It is possible that we are unable to detect recent annuli on scales due to a similar phenomenon in northern pikeminnow, though examination of opercula with OTC marks indicates that fish continue to add visible annuli to their opercula after tagging.

Comparisons between scale and operculum derived ages have been consistent among the four years we have conducted this analysis. Beyond 8-9 years of age, northern pikeminnow opercula are consistently aged older than their corresponding scales. Studies by Campbell and Babaluk (1979), Scoppettone (1988), Donald et al. (1992), and the Washington Department of Fish and Wildlife (J. Sneva, WDFW, personal communication) also found that ages derived from opercula tended to be older than those from scales. Methods that provide older estimates of fish age, such as opercula, are generally thought of as more accurate relative to true fish age than those methods that yield younger estimates (Dubois and Lagueux 1968; Donald et al. 1992). We did find a significant positive linear relationship between scale age and operculum ages; indicated that ages assigned to opercula could be predicted from scale ages, with a certain degree of error.

In 2005 we continued to evaluate the utility of OTC as an operculum age validation tool. The percentage of “good” quality fluorescent OTC marks in 2005 (~ 24%) was similar to that seen in 2004, and did not vary by tagging year. However, the presence of a discernible OTC mark in 2005 (78%) was less than that reported by Rien and Beamesderfer (1994) in white sturgeon (98%), and higher than McFarlane and Beamish (1987) reported for sablefish *Bacalao negro* (70%). Failed OTC marks were more likely to be from northern pikeminnow tagged in 2005, skewing our success rate. Our ability to detect the correct number annuli after the successful OTC marks did not vary by mark quality, and we noted the correct number of annuli more than 75% of the time. However, correctly detecting the appropriate number of annuli was related to year tagged, and we were significantly more likely to misidentify fish marked in 2003 than in 2005. Rien and Beamesderfer (1994) saw a similar decline in the accuracy of OTC age interpretations as time at-large increased in white sturgeon. Opercula may provide a more accurate representation of the true age in certain fish species than scales (Donald et al. 1992); however, of the 22 fish marked in 2003 or earlier that we misidentified annuli in, we underestimated the age 86% of the time. The ages we derived from scales during our validation efforts also seemed to consistently underage northern pikeminnow. Our underestimates of age may be leading us to overestimate growth and natural mortality rates (Leaman and Nagtegaal 1987; Casey and Natanson 1992; Rien and Beamesderfer 1994), and may impact our northern pikeminnow exploitation rate estimates. Given our lack of success in validating both scale and operculum derived ages, that our aging precision for opercula is currently lower than that of scales, and the current lack of a better alternative, we will continue to utilize both parts in our aging analysis while working to modify procedures to increase accuracy. Until we can increase the precision and accuracy of ages assigned to northern pikeminnow we should be cautious about any age related interpretations we make.

Biological Evaluation

Reductions in the northern pikeminnow population may improve outmigrating salmonid survival, if an equal compensatory response by the remaining northern pikeminnow or other predators does not minimize the benefits (Beamesderfer et al. 1996; Friesen and Ward 1999). An increase in the population size structure or condition factor might be an indication of such a response (Knutsen and Ward 1999). Sustained exploitation should decrease the proportion of large fish to small fish (Zimmerman et al. 1995), and smaller northern pikeminnow consume fewer salmonids than their larger counterparts (Vigg et al. 1991). Northern pikeminnow stock density indices have remained relatively stable in nearly all reservoirs across most indexing years below Bonneville Dam, though the PSD did reach a program high in 2005. The increase in PSD corresponded to an increase in the percentage (~ 20%) of the indexing sample made up of age 5 fish – also a new program high. Until 2005, PSD had decreased in Bonneville Reservoir through time, but rebounded to levels similar to the early 1990's, and the percentage of age 5 fish (~ 17%) was the second highest observed. The possible long-term oscillation in year class strength within Bonneville Reservoir may help to explain the variations in the size structure of Bonneville Reservoir northern pikeminnow. Decreasing PSDs may indicate the sport-reward fishery is having its desired effect, decreasing the size structure of northern pikeminnow in certain areas (Rieman and Beamesderfer 1990). However, when multiple-age spawning stocks with stable oscillations in year class strength are overexploited, reductions in population size and decreases in the amplitude and time period of the oscillation can occur (Everhart and Youngs 1981). Changes in northern pikeminnow abundance, year class strength, and size structure may be related to exploitation, and continued monitoring of the northern pikeminnow population in Bonneville Reservoir for changes in stock density indices and year class strength should be continued.

Other factors, such as increasing northern pikeminnow consumption and predation indices, might also be signs of compensation by remaining northern pikeminnow to prolonged exploitation by the NPMP (Zimmerman and Ward 1999). Although generally lower than previous years, northern pikeminnow consumption and predation indices have increased, relative to recent years, within several localized reaches of the study area (e.g., the tailraces of Bonneville and The Dalles dams), which may be attributed to the discontinuation of dam angling in 2002. Dam angling, while contributing less to exploitation, harvested localized concentrations of northern pikeminnow that may have aggregated to feed on juvenile salmonids (Beamesderfer and Rieman 1991; Poe et al. 1991; Collis et al. 1995). In addition, the dam angling fishery was able to harvest northern pikeminnow in boat restricted zones below dams that are inaccessible to sport-reward anglers (Takata and Ward 2001). In spring 2005, northern pikeminnow consumption indices in Bonneville Reservoir (with the exception of Bonneville forebay) were higher than any previous year. These increases in consumption correspond to increases in the percentage of stomach remains identified as salmonids. Below Bonneville Dam and Bonneville Reservoir had the highest and second highest northern pikeminnow sport-reward harvests in 2005 (WDFW 2006B), consistent with 2004 harvests. Intra-specific competition for home range and forage resources can have deleterious effects on fish populations (Crowder 1990; Byorth and Magee 1998). Based on localized increases in northern pikeminnow consumption in high harvest areas, a localized reduction of intra-specific competition could be occurring, and is possibly a compensatory response by remaining northern pikeminnow. We collected northern pikeminnow digestive tracts during times of peak juvenile salmonid abundance at most sampling areas. The predation index is composed of two components, consumption and abundance (Ward et al. 1995). Overall, reductions in northern pikeminnow predation below Bonneville Dam and for Bonneville Reservoir can be attributable to changes in abundance; which was generally lower in 2005 than in previous indexing years.

The efficacy of the NPMP also depends, in part, on the lack of response by other piscivores in the Columbia Basin to the sustained removal of northern pikeminnow (Ward and Zimmerman 1999). Remaining northern pikeminnow may modify their diets and habitat selection in the presence of introduced piscivores (Poe et al. 1994), and in areas of high smallmouth bass abundance this behavior may be exacerbated. Smallmouth bass stock density indices varied by area. Stock density indices for below Bonneville Dam have varied through time but are frequently within ranges that would generally be considered balanced for black bass populations in other systems (Green 1989). The size structure for the Bonneville Reservoir population of smallmouth bass appears more balanced and stable than the population in the reaches downstream of Bonneville Dam. However, within the relatively stable size structure of Bonneville Reservoir smallmouth bass, a shift in age structure has occurred, with the average age of smallmouth bass increasing through time. Critical periods during a fish's early life may govern year class strength and recruitment (Miranda and Hubbard 1994; Van Den Avyle and Hayward 1999). It is unclear what factors may affect this critical period in Bonneville Reservoir smallmouth bass; but the increasing age of fish over time may indicate increased early life survival.

Average northern pikeminnow W_r varied significantly over time; appearing to be random in nature, without an obvious trend. These random oscillations in W_r are possibly density independent in nature. Density independent factors, such as fluctuating numbers of migrating juvenile salmonids, unstable water levels, and changes in water temperature from year to year, are all factors unrelated to northern pikeminnow abundance that could affect the population (Van Den Avyle and Hayward 1999). When solely considering PSD and W_r data, a system-wide compensatory response by smallmouth bass and northern pikeminnow does not seem apparent.

In the past, juvenile salmonids have composed small but consistent portions of smallmouth bass diets in the Columbia River (Poe et al. 1991; Zimmerman 1999; Naughton et al. 2004). In 2005, smallmouth bass consumed equal percentages of juvenile salmonids and cottids below Bonneville Dam in spring. Despite localized increases, smallmouth bass consumption indices in the lower Columbia River have remained relatively stable. This year we did observe an increase in the predation index for rkm 172-178 and rkm 190-197, but this may be due to small sample sizes collected below Bonneville Dam and localized shifts in diet. Ward and Zimmerman (1999) suggested the first evidence of any response by smallmouth bass would likely be a change in diet; smallmouth bass predation should continue to be monitored.

In spring and summer 2005, we collected a total of six walleye below Bonneville Dam and in Bonneville Reservoir, compared to 2004 when we collected 185 walleye systemwide–most from John Day and McNary reservoirs (Jones et al. 2005). Below Bonneville Dam, cyprinids were the only prey item in walleye digestive tracts, and walleye collected in Bonneville Reservoir appeared to have empty stomachs. Poe et al. (1991), Vigg et al. (1991), and Zimmerman (1999) found juvenile salmonids to be an important component of lower Columbia River walleye diets; however their effects on salmonid populations are likely to be minimal considering their apparent low abundance, especially below Bonneville Dam.

Previous evaluations of the NPMP have not detected responses by the predator community to the sustained removal of northern pikeminnow (Ward et al. 1995; Ward and Zimmerman 1999; Zimmerman and Ward 1999). Observable responses to fishery management programs can lag by more than 15 years from project inception (Hilborn and Winton 1993; Beamesderfer et al. 1996), and it is possible that enough time has simply not elapsed for a response to be witnessed in most reservoirs. In 2005 and 1999 the percentages of age 5 smallmouth bass in Bonneville Reservoir were four to six times greater than 1990 and 1995, which may indicate increased early life survival. Additionally, smallmouth bass may be exhibiting a compensatory response in localized areas. In 2004, Jones et al. (2005) reported smallmouth bass relative densities for the John Day Dam forebay doubled from 1990 and 1999 levels. Moreover, northern pikeminnow abundance dropped an order of magnitude within the same area. The John Day Reservoir was the site of the original northern pikeminnow test fishery fifteen years ago (Parker et al. 1995), so it would not be surprising if it was the first area to exhibit a response to the NPMP.

Considering the overall reductions in northern pikeminnow abundance and predation, the 20 – 25% reduction in potential predation predicted by Friesen and Ward's (1999) model may underestimate the true reduction in juvenile salmonid predation by northern pikeminnow. With the continuation of the NPMP and the modification to the current reward structure, a system-wide response from the predator community may be possible, emphasizing the need for continued monitoring and an updated potential predation model.

ACKNOWLEDGMENTS

We are particularly grateful to those who worked long (and sometimes miserable) hours in the field to collect the data presented in this report. Thanks to Jim Koloszar, Matt Powell, Kelly Sparks, Jessica Vogt, and Garth Wyatt. Additional thanks to George Reed for his work with boat repair and maintenance, Howard Takata for his assistance in planning our field season, Mark Engelking for the use of his laboratory space, and Bonnie Cunningham for her assistance with opercle reading. Tom Rien of ODFW and Russell Porter of PSMFC (Pacific States Marine Fish Commission) administered the contract. We thank Eric Winther and his staff (WDFW) for their cooperation and help with project coordination. Kathleen Moyer of WDFW provided PIT tag recovery data and opercle samples. The U.S. Army Corps of Engineers was very cooperative regarding entry into boat-restricted zones near dams. In particular, we appreciate the assistance of John Bailey, Brad Eby, Mike Halter, Wayne John, Jon Rerecich, and Miro Zyndol. Thanks to Mike Ritter of the U.S. Fish and Wildlife Service for access to the White Bluff boat ramp. Passive integrated transponder tags were provided by PSMFC. This research project was funded by the Bonneville Power Administration (Contract DE-B1719-94BI24514), John Skidmore, COTR.

REFERENCES

Anderson, R. O. 1980. Proportional stock density (PSD) and relative weight (W_r): interpretive indices for fish populations and communities. Pages 27-33 *in* S. Gloss and B. Shupp, editors. Practical fisheries management: more with less in the 1980s. New York Chapter American Fisheries Society, Bethesda, MD.

Anderson, R. O., and S. J. Gutreuter. 1983. Length, weight, and associated structural indices. Pages 280-300 *in* L. A. Nielsen and D. L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Baker, E. A., and T. S. McComish. 1998. Precision of ages determined from scales and opercles for yellow perch *Perca flavescens*. Journal of Great Lakes Research 24:658-665.

Beamesderfer, R. C., B. E. Rieman, J. C. Elliott, A. A. Nigro, and D. L. Ward. 1987. Distribution, abundance, and population dynamics of northern squawfish, walleye, smallmouth bass, and channel catfish in John Day Reservoir, 1986. Oregon Department of Fish and Wildlife, Contract number DE-AI79-82BP35097. 1986 Annual Report to Bonneville Power Administration, Portland, Oregon.

Beamesderfer, R. C., and B. E. Rieman. 1988. Size selectivity and bias in estimates of population statistics of smallmouth bass, walleye, and northern squawfish in a Columbia River reservoir. North American Journal of Fisheries Management 8:505-510.

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

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

Byorth, P. A., and J. P. Magee. 1998. Competitive interactions between arctic grayling and brook trout in the Big Hole River drainage, Montana. Transactions of the American Fisheries Society 127:921-931.

Campbell, J. S., and J. A. Babaluk. 1979. Age determination of walleye, *Stizostedion vitreum vitreum* (Mitchill), based on the examination of eight different structures. Department of Fisheries and the Environment, Fisheries and Marine Service Technical Report number 849.

Casey, J. G., and L. J. Natanson. 1992. Revised estimates of age and growth of the sandbar shark (*Carcharhinus plumbeus*) from the western North Atlantic. Canadian Journal of Fisheries and Aquatic Sciences. 49:1474-1477.

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

Crowder, L. B. 1990. Community ecology. Pages 609-632 *in* C. B. Schreck and P. B. Moyle, editors. Methods for Fish Biology. American Fisheries Society, Bethesda, Maryland.

Donald, D. B., J. A. Babaluk, J. F. Craig, and W. A. Musker. 1992. Evaluation of the scale and operculum methods to determine age of adult goldeyes with special reference to a dominant year-class. Transactions of the American Fisheries Society 121:792-796.

Dubois, A. and R. Lagueux. 1968. Etude comparée de l'âge scalaire et de l'âge otolithique de la touladi (*Salvelinus namaycush*), Lac Mistassini, Quebec . Naturaliste canadien (Quebec) 95:907-928.

Ebener, M. P., and F. A. Copes. 1982. Loss of Floy anchor tags from lake whitefish. North American Journal of Fisheries Management 2:90-93.

Everhart, W. H., and W. D. Youngs. 1981. Principles of fishery science, 2nd edition. Cornell University Press, Ithaca, New York.

FPC (Fish Passage Center). 2005. Daily passage data for the smolt monitoring project, March – October 2004. Fish Passage Center. Available: www.fpc.or/smolt/SMP_queries.html. (December 2004).

Friesen, T. A., and D. L. Ward. 1999. Management of northern pikeminnow and implications for juvenile salmonid survival in the lower Columbia and Snake rivers. North American Journal of Fisheries Management 19:406-420.

Frost, W. E., and C. Kipling. 1959. The Determination of the Age and Growth of Pike (*Esox lucius* L.) from scales and opercular bones. Journal du conseil. 24:314-341.

Gabelhouse, D. W., Jr. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273-285.

Green, D. M. 1989. N.Y.S. Bureau of Fisheries centrarchid sampling manual. Warmwater Fisheries Unit. Cornell Biological Field Station, Bridgeport, New York.

Guy, C. S., H. L. Blankenship, and L. B. Nielsen. 1996. Tagging and marking. Pages 353-383 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Hankin, D. G., and J. Richards. 2000. The northern pikeminnow management program: An independent review of program justification, performance, and cost-effectiveness. Report to the Pacific Northwest Electric Power and Conservation Planning Council, Portland, Oregon.

Hilborn, R., and J. Winton. 1993. Learning to enhance salmon production: lessons from the salmonid enhancement program. Canadian Journal of Fisheries and Aquatic Sciences 50:2043-2056.

Jones, T. A., J. A. Koloszar, M. J. Reesman, T. A. Friesen, and H. K Takata. 2005. Development of a system-wide predator control program: fisheries evaluation. Oregon Department of Fish and Wildlife, Contract Number DE-B1719-94BI24514. 2003 Annual Report to the Bonneville Power Administration, Portland, Oregon.

Knutsen, C. J., and D. L. Ward. 1999. Biological characteristics of northern pikeminnow in the Lower Columbia and Snake Rivers before and after sustained exploitation. Transactions of the American Fisheries Society 128:1008-1019.

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

Le Cren, E. D. 1947. The determination of age and growth of the perch (*Perca fluviatilis*) from the opercular bone. Journal of Animal Ecology. 16:188-204.

Leaman, B. M., and D. A. Nagtegaal. 1987. Age validations and revised natural mortality rate for yellowtail rockfish. Transactions of the American Fisheries Society. 116:171-175.

Long, C. W., and F. J. Ossiander. 1974. Survival of coho salmon fingerlings passing through a perforated bulkhead in an empty turbine bag and through flow deflectors (with and without dentates) on the spillways of Lower Monumental Dam, Snake River, April-May 1973. Final Report (Contract DACW68-84-H-0034) to U.S. Army Corps of Engineers, Portland, Oregon.

McFarlane, G. A., and R. J. Beamish. 1987. Selection of dosages of oxytetracycline for age validation studies. Canadian Journal of Fisheries and Aquatic Sciences 44:905-909.

Miranda, L. E., and W. D. Hubbard. 1994. Length-dependent winter survival and lipid composition of Age-0 largemouth bass in Bay Springs Reservoir, Mississippi. Transactions of the American Fisheries Society 123:80-87.

Muoneke, M. I. 1992. Loss of Floy anchor tags from white bass. North American Journal of Fisheries Management 12:819-824.

Naughton, G. P., D. H. Bennet, and K. B. Newman. 2004. Predation on juvenile salmonids by smallmouth bass in the Lower Granite Reservoir system, Snake River. North American Journal of Fisheries Management 24:534-544.

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16:4-21.

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

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

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

Raymond, H. L. 1988. Effects of hydroelectric development and fisheries enhancement on spring and summer Chinook salmon and steelhead in the Columbia River basin. North American Journal of Fisheries Management 8:1-24.

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

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

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

Rien, T. A. and R. C. Beamesderfer. 1994. Accuracy and precision of white sturgeon age estimates from pectoral fin rays. Transactions of the American Fisheries Society 123:225-265.

Scoppettone, G. G. 1988. Growth and longevity of the cui-ui and longevity of other catostomids and cyprinids in western North America. Transactions of the American Fisheries Society 117:301-307.

Styer, P. 2003. Statistical consulting report to review computational methods in the northern pikeminnow management program. Report to the Oregon Department of Fish and Wildlife, Clackamas.

Takata, H. K., and D. L. Ward. 2001. Development of a system-wide predator control program: fisheries evaluation. Oregon Department of Fish and Wildlife, Contract Number DE-B1719-94BI24514. 2000 Annual Report to the Bonneville Power Administration, Portland, Oregon.

Takata, H. K., and J. A. Koloszar. 2004. Development of a system-wide predator control program: fisheries evaluation. Oregon Department of Fish and Wildlife, Contract Number DE-B1719-94BI24514. 2003 Annual Report to the Bonneville Power Administration, Portland, Oregon.

Timmons, T. J., and M. H. Howell. 1995. Retention of anchor and spaghetti tags by paddlefish, catfishes, and buffalo fishes. North American Journal of Fisheries Management 15:504-506.

USGS (U.S. Geological Survey). 2005. NWISWeb data for Oregon 1995 – 2005. U.S. Geological Survey. Available: www.waterdata.usgs.gov/or/nwis. (November 2005).

Van Den Avyle, M. J., and R. S. Hayward. 1999. Dynamics of exploited fish populations. Pages 127-166 *in* C. C. Kohler and W. A. Hubert, editors. Inland Fisheries Management in North America, 2nd edition. American Fisheries Society, Bethesda, Maryland.

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

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

Ward, D. L., and M. P. Zimmerman. 1999. Response of smallmouth bass to sustained removals of northern pikeminnow in the lower Columbia and Snake Rivers. Transactions of the American Fisheries Society 128:1020-1035.

WDFW (Washington Department of Fish and Wildlife). 2006. 2005 northern pikeminnow sport reward payment schedule. Northern pikeminnow sport reward program. Available: http://www.pikeminnow.org/. (January 2006).

WDFW. 2006B. 2005 northern pikeminnow catch data summary. Northern pikeminnow sport reward program. Available: www.pikeminnow.org/catch.html. (January 2006).

Wismar, R. C., and five coauthors. 1994. A history of resource use and disturbance in riverine basins of eastern Oregon and Washington (early 1800s-1900s). Northwest Science 68(Special Issue):1-35.

Zimmerman, M. P., C. Knutsen, D. L. Ward, and K. Anderson. 1995. Development of a system-wide predator control program: Indexing and fisheries evaluation. Oregon Department of Fish and Wildlife, Contract number DE-AI79-90BP07084. 1993 Annual Report to the Bonneville Power Administration, Portland, Oregon.

Zimmerman, M. P. 1999. Food habits of smallmouth bass, walleyes, and northern pikeminnow in the lower Columbia River Basin during outmigration of juvenile anadromous salmonids. Transactions of the American Fisheries Society 128:995-1007.

Zimmerman, M. P., and D. L. Ward. 1999. Index of predation on juvenile salmonids by northern pikeminnow in the lower Columbia River basin, 1994-1996. Transactions of the American Fisheries Society 128:995-1007.

Zimmerman, M. P., T. A. Friesen, D. L. Ward, and H. K. Takata. 2000. Development of a system-wide predator control program: indexing and fisheries evaluation. Oregon Department of Fish and Wildlife, Contract Number DE-B1719-94BI24514. 1999 Annual Report to the Bonneville Power Administration, Portland, Oregon.

APPENDIX A

Electrofishing Effort for Biological Evaluation in the Lower Columbia and Snake Rivers, 1990 – 2005

APPENDIX TABLE A-1.–Sampling effort (number of 15-minute electrofishing runs) for biological indexing in the lower Columbia and Snake rivers, 1990-1996, 1999, 2004, and 2005. rkm = river kilometer and – = area not sampled.

Reservoir or area, reach	Effort									
	1990	1991	1992	1993	1994	1995	1996	1999	2004	2005
Below Bonneville Dam										
rkm 114-121	–	–	68	–	36	45	43	44	22	48
rkm 172-178	–	–	65	–	33	36	35	47	31	48
rkm 190-197	–	–	64	–	43	40	40	40	32	48
Tailrace	39	–	60	25	35	24	31	29	55	82
Bonneville										
Forebay	47	–	–	35	97	79	80	62	35	101
Mid-reservoir	52	–	–	28	84	45	57	57	35	58
Tailrace	52	–	–	31	68	80	69	71	43	74
The Dalles										
Forebay	62	–	–	31	92	62	59	–	–	–
Tailrace	56	–	–	26	48	35	31	71	5	–
John Day										
Forebay	56	61	68	44	91	75	75	52	28	–
Mid-reservoir	61	58	62	43	43	94	94	–	15	–
Tailrace	55	59	64	46	74	80	80	62	51	–
Lower Monumental										
Tailrace	–	56	–	–	44	46	32	14	30	–
Little Goose										
Tailrace	–	57	–	–	39	40	37	29	30	–
Lower Granite										
rkm 222-228	–	55	–	–	85	89	89	75	34	–

APPENDIX B

Exploitation Rates for Northern Pikeminnow

APPENDIX TABLE B-1. — Number of northern pikeminnow tagged and recaptured in 2005.

Area or reservoir	≥ 200 mm FL		200 - 249 mm FL		≥ 250 mm FL	
	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recaptured
Below Bonneville Dam	406	81	36	2	370	79
Bonneville	203	16[a]	19	1	184	15[a]
The Dalles	31	5[a]	5	0	26	5[a]
John Day	21	0	7	0	14	0
McNary	148[b]	9	52[b]	0	95[b]	9
Lower Granite	92	2[c]	59	0	33	2[c]
All areas	901	113	178	3	722	110

[a] includes fish tagged in another reservoir, not included in exploitation rate calculations.
[b] FL not recorded for one northern pikeminnow in McNary Reservoir.
[c] includes fish recaptured in another reservoir, not included in exploitation rate calculations.

APPENDIX TABLE B-2. — Exploitation rates (%) of northern pikeminnow ≥ 200 mm FL for all fisheries, 2001 – 2005. Exploitation rates were not corrected for tag loss in 2001 and 2002. X = no exploitation rate calculated ($n < 4$).

Area or reservoir	2001	2002	2003[a]	2004[a]	2005[a]
Below Bonneville Dam	15.9	10.8	11.8	18.8	21.6
Bonneville	8.6	5.0	11.0	11.7	8.0
The Dalles	X	X	X	X	14.9
John Day	X	X	X	X	X
McNary	26.0	7.6	6.6	X	9.6
Lower Granite	9.4	11.6	X	19.6	X
All areas	15.5	10.6	10.5	17.0	16.3

[a] sport-reward fishery only

APPENDIX TABLE B-3. — Exploitation rates (%) of northern pikeminnow 200 - 249 mm FL for all fisheries, 2001 – 2005. Exploitation rates were not corrected for tag loss in 2001 and 2002. X = no exploitation rate calculated (*n* < 4).

Area or reservoir	2001	2002	2003[a]	2004[a]	2005[a]
Below Bonneville Dam	X	3.1	X	X	X
Bonneville	X	X	X	13.5	X
The Dalles	X	X	X	X	X
John Day	X	X	X	X	X
McNary	X	X	X	X	X
Lower Granite	X	X	X	X	X
All areas	10.6	3.4	X	10.9	X

[a] sport-reward fishery only

APPENDIX TABLE B-4. — Exploitation rates (%) of northern pikeminnow ≥ 250 mm FL for all fisheries, 2001 – 2005. Exploitation rates were not corrected for tag loss in 2001 and 2002. X = no exploitation rate calculated (*n* < 4).

Area or reservoir	2001	2002	2003[a]	2004[a]	2005[a]
Below Bonneville Dam	16.2	12.6	13.6	20.1	23.1
Bonneville	8.5	6.0	16.7	9.3	8.2
The Dalles	X	X	X	X	18.0
John Day	X	X	X	X	X
McNary	26.0	7.7	8.2	X	13.0
Lower Granite	X	14.3	X	23.8	X
All areas	16.2	12.3	13.0	18.5	19.0

[a] sport-reward fishery only

APPENDIX TABLE B-5.—System-wide weekly exploitation rates of northern pikeminnow ≥ 200 mm FL in 2005. Dashes indicate either no tagging effort, no recapture effort, or no exploitation calculated. See Appendix E for sampling week dates.

Sampling Week	Tagged	Recaptured	At-Large	Exploitation[a] (%)
14	8	--	0	--
15	141	--	8	--
16	128	--	149	--
17	159	--	277	--
18	190	--	436	--
19	17	4	626	0.7
20	6	2	639	0.3
21	12	2	643	0.3
22	49	5	653	0.8
23	3	9	697	1.4
24	8	9	691	1.4
25	86	15	690	2.4
26	94	8	761	1.1
27	--	10	847	1.3
28	--	5	837	0.6
29	--	8	832	1.0
30	--	2	824	0.3
31	--	3	822	0.4
32	--	4	819	0.5
33	--	2	815	0.3
34	--	3	813	0.4
35	--	6	810	0.8
36	--	1	804	0.1
37	--	5	803	0.7
38	--	6	798	0.8
39	--	4	792	0.5
Total	901	113		16.3

[a] exploitation rates adjusted for tag loss (8.1%)

APPENDIX TABLE B-6.— Weekly exploitation rates of northern pikeminnow ≥ 200 mm FL in The Dalles Reservoir for 2005. Dashes indicate either no tagging effort, no recapture effort, or no exploitation calculated. See Appendix E for sampling week dates.

Sampling Week	Tagged	Recaptured	At-Large	Exploitation[a] (%)
14	--	--	0	--
15	--	--	0	--
16	--	--	0	--
17	--	--	0	--
18	17	--	0	--
19	13	0	17	0.0
20	--	0	30	0.0
21	--	1	30	3.6
22	--	0	29	0.0
23	--	0	29	0.0
24	--	0	29	0.0
25	1	1	29	3.7
26	--	0	29	0.0
27	--	1	29	3.7
28	--	0	28	0.0
29	--	1	28	3.9
30	--	0	27	0.0
31	--	0	27	0.0
32	--	0	27	0.0
33	--	0	27	0.0
34	--	0	27	0.0
35	--	0	27	0.0
36	--	0	27	0.0
37	--	0	27	0.0
38	--	0	27	0.0
39	--	0	27	0.0
Total	31	4		14.9

[a] exploitation rates adjusted for tag loss (8.1%)

APPENDIX TABLE B-7.— Weekly exploitation rates of northern pikeminnow ≥ 200 mm FL in John Day Reservoir for 2005. Dashes indicate either no tagging effort, no recapture effort, or no exploitation calculated. See Appendix E for sampling week dates.

Sampling Week	Tagged	Recaptured	At-Large	Exploitation[a] (%)
14	--	--	0	--
15	--	--	0	--
16	--	--	0	--
17	--	--	0	--
18	--	--	0	--
19	4	0	0	0.0
20	6	0	4	0.0
21	10	0	10	0.0
22	--	0	20	0.0
23	--	0	20	0.0
24	--	0	20	0.0
25	1	0	20	0.0
26	--	0	21	0.0
27	--	0	21	0.0
28	--	0	21	0.0
29	--	0	21	0.0
30	--	0	21	0.0
31	--	0	21	0.0
32	--	0	21	0.0
33	--	0	21	0.0
34	--	0	21	0.0
35	--	0	21	0.0
36	--	0	21	0.0
37	--	0	21	0.0
38	--	0	21	0.0
39	--	0	21	0.0
Total	21	0		0.0

[a] exploitation rates adjusted for tag loss (8.1%)

APPENDIX TABLE B-8. — Weekly exploitation rates of northern pikeminnow ≥ 200 mm FL in McNary Reservoir for 2005. Dashes indicate either no tagging effort, no recapture effort, or no exploitation calculated. See Appendix E for sampling week dates.

Sampling Week	Tagged	Recaptured	At-Large	Exploitation[a] (%)
14	--	--	0	--
15	--	--	0	--
16	--	--	0	--
17	--	--	0	--
18	--	--	0	--
19	--	0	0	0.0
20	--	0	0	0.0
21	2	0	0	0.0
22	49	0	2	0.0
23	3	0	51	0.0
24	--	1	54	2.1
25	--	0	53	0.0
26	94	1	53	2.1
27	--	2	146	1.5
28	--	2	144	1.5
29	--	1	142	0.8
30	--	0	141	0.0
31	--	1	141	0.8
32	--	1	140	0.8
33	--	0	139	0.0
34	--	0	139	0.0
35	--	0	139	0.0
36	--	0	139	0.0
37	--	0	139	0.0
38	--	0	139	0.0
39	--	0	139	0.0
Total	148	9		9.6

[a] exploitation rates adjusted for tag loss (8.1%)

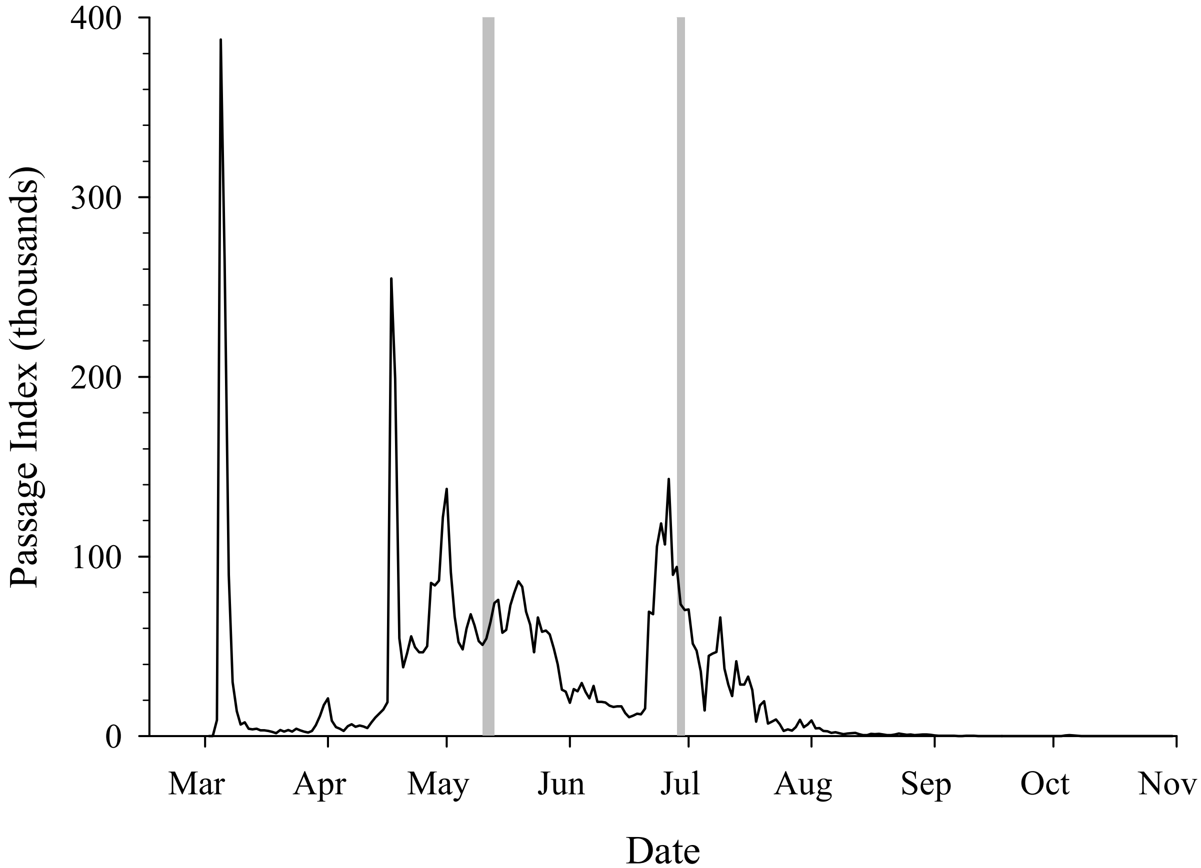
APPENDIX TABLE B-9. — Weekly exploitation rates of northern pikeminnow ≥ 200 mm FL in Lower Granite Reservoir for 2005. Dashes indicate either no tagging effort, no recapture effort, or no exploitation calculated. See Appendix E for sampling week dates.

Sampling Week	Tagged	Recaptured	At-Large	Exploitation[a] (%)
14	--	--	0	--
15	--	--	0	--
16	--	--	0	--
17	--	--	0	--
18	--	--	0	--
19	--	0	0	0.0
20	--	0	0	0.0
21	--	0	0	0.0
22	--	0	0	0.0
23	--	0	0	0.0
24	8	0	0	0.0
25	84	0	8	0.0
26	--	0	92	0.0
27	--	1	92	1.2
28	--	0	91	0.0
29	--	0	91	0.0
30	--	0	91	0.0
31	--	0	91	0.0
32	--	0	91	0.0
33	--	0	91	0.0
34	--	0	91	0.0
35	--	0	91	0.0
36	--	0	91	0.0
37	--	0	91	0.0
38	--	0	91	0.0
39	--	0	91	0.0
Total	92	1		1.2

[a] exploitation rates adjusted for tag loss (8.1%)

APPENDIX C

Timing of 2005 Index Sampling in Relation to Juvenile Salmonid Passage Indices at Lower Columbia and Snake River Dams



APPENDIX FIGURE C-1. –Timing of index sampling in 2005 with respect to juvenile salmonid passage (all species) at Bonneville Dam. Shaded areas indicate dates of sampling in the tailrace and forebay areas of Bonneville Dam. The passage index is the number of fish passing the dam, adjusted for river flow.

APPENDIX D

Catch Rates for Northern Pikeminnow and Smallmouth Bass in the Lower Columbia and Snake Rivers, 1990 – 2005

APPENDIX TABLE D-1. — Catch per 15-minute electrofishing run (CPUE) of northern pikeminnow ≥ 250 mm fork length captured during biological indexing of the lower Columbia River in 1990, 1992-1996, 1999, 2004, and 2005. rkm = river kilometer, BRZ = boat restricted zone, -- = area not sampled.

Area, reach	CPUE								
	1990	1992	1993	1994	1995	1996	1999	2004	2005
Below Bonneville Dam									
rkm 114-121	--	1.3	--	1.0	0.9	0.8	0.6	0.7	0.7
rkm 172-178	--	1.6	--	1.8	1.4	1.5	0.9	0.6	0.7
rkm 190-197	--	2.4	--	1.7	1.1	1.3	1.4	1.1	0.6
Tailrace	5.8	3.4	9.6	2.9	2.2	2.8	3.5	1.6	0.9
Tailrace BRZ	13.7	12.9	14.5	18.9	4.6	5.8	--	11.8	8.1
Bonneville									
Forebay	5.7	--	2.2	2.4	2.4	1.3	1.0	0.9	0.7
Mid-reservoir	2.1	--	1.2	0.7	1.0	0.7	0.3	0.3	0.3
Tailrace	0.5	--	1.1	0.6	1.1	0.8	0.8	1.7	0.3
Tailrace BRZ	5.5	--	1.5	6.8	--	--	--	--	--

APPENDIX TABLE D-2. — Spring and summer catch per 15-minute electrofishing run (CPUE) of smallmouth bass ≥ 200 mm FL captured in 2005 during biological indexing in the lower Columbia River. rkm = river kilometer.

Area, reach	CPUE	
	Spring	Summer
Below Bonneville Dam		
rkm 114-121	0.1	0.0
rkm 172-178	0.5	0.8
rkm 190-197	0.9	0.7
Tailrace	1.0	0.7
Bonneville		
Forebay	1.1	1.3
Mid-reservoir	1.2	1.7
Tailrace	1.7	0.8

APPENDIX TABLE D-3. — Spring and summer catch per 15-minute electrofishing run (CPUE) of northern pikeminnow ≥ 250 mm FL captured in 2005 during biological indexing in the lower Columbia River. rkm = river kilometer, BRZ = boat restricted zone, -- = area not sampled.

Area, reach	CPUE	
	Spring	Summer
Below Bonneville Dam		
rkm 114-121	1.0	0.4
rkm 172-178	0.9	0.5
rkm 190-197	0.8	0.5
Tailrace	1.0	0.7
Tailrace BRZ	9.5	6.8
Bonneville		
Forebay	0.6	0.6
Mid-reservoir	0.8	0.2
Tailrace	0.3	0.2
Tailrace BRZ	--	--

APPENDIX E

2005 Sampling Dates

APPENDIX TABLE E-1. ─ Dates of 2005 sampling weeks.

Sampling Week	Dates	Sampling Week	Dates
14	27 March - 2 April	27	26 June - 2 July
15	3 April - 9 April	28	3 July - 9 July
16	10 April - 16 April	29	10 July - 16 July
17	17 April - 23 April	30	17 July - 23 July
18	24 April - 30 April	31	24 July - 30 July
19	1 May - 7 May	32	31 July - 6 August
20	8 May - 14 May	33	7 August - 13 August
21	15 May - 21 May	34	14 August - 20 August
22	22 May - 28 May	35	21 August - 27 August
23	29 May - 4 June	36	28 August - 3 September
24	5 June - 11 June	37	4 September - 10 September
25	12 June - 18 June	38	11 September - 17 September
26	19 June - 25 June	39	18 September - 24 September