REPORT ON THE PREDATION INDEX, PREDATOR CONTROL FISHERIES, AND PROGRAM EVALUATION FOR THE COLUMBIA RIVER BASIN NORTHERN PIKEMINNOW SPORT REWARD PROGRAM

2016 ANNUAL REPORT
April 1, 2016 thru March 31, 2017

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2016 Executive Summary
by

Steve Williams

This report presents results for year twenty-six in the basin-wide Northern Pikeminnow Sport Reward Program designed to harvest Northern Pikeminnow[1] (Ptychocheilus oregonensis) in the Columbia and Snake Rivers. 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 as much as 40%.

To test this hypothesis, we implemented a sport-reward angling fishery and a commercial long-line fishery in the John Day Pool in 1990. We also conducted a hook and line 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 long-line 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 long-line 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 long-line 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 trapnets and gillnets at specific locations where concentrations of Northern Pikeminnow were known or suspected to occur during the 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,

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

and 1997, promotional activities and incentives were further improved based on the favorable response in 1994. Results of these and other lessons learned over the 26 year period are subjects of this annual report.

Evaluation of the success of 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 is responsible for coordination and administration of the program; PSMFC subcontracted various tasks and activities to ODFW and WDFW based on the expertise each brings to the tasks involved in implementing the program. Roles and responsibilities of each cooperator are 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.

4. **WDFW (Report D)**: Implement dam angling at The Dalles and John Day dams.

Background and rationale for the Northern Pikeminnow Management Program can be found in Report A of our 1990 annual report (Vigg et al. 1990).

REPORT A

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

2016 Annual Report

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This project is funded by the Bonneville Power Administration (BPA), William Maslen, Project Manager, and David Roberts, COTR (Contract DE-BI719-94BI24514). We thank Mac Barr and Adam Storch and their staff at the Oregon Department of Fish and Wildlife (ODFW) and Steve Williams and his staff at the Pacific States Marine Fisheries Commission (PSMFC) for their cooperation in implementing this program during the 2016 season.

We are thankful 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 Bingen for the use of Bingen Marina; The Port of Camas/Washougal for the use of the Camas/Washougal boat ramp; the Port of Cascade Locks for the use of Marine Park; 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 Ridgefield for the use of the Ridgefield boat ramp; the Port of The Dalles for the use of The Dalles Boat Basin; the Port of Umatilla for the use of the Umatilla Marina; the Portland Metro 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 Washington Department of Transportation for the use of the Vernita Bridge Rest Area; Washington State Parks for the use of Beacon Rock State Park; Jim MacArthur for the use of Lyon's Ferry Marina; and Leo and Terry Haas for the use of Boyer Park.

We appreciate the efforts of Kyle Beckley, Dick Buitenbos, Kevin Clawson, Sheila Evans, Mark Flahaut, Bill Fleenor, Leif Fox, Roger Fox, Fred Haberman, Brandie Harpine, Travis Harwood, Mark Helman, Steve Lines, Eric Meyer, Jordan Miller, Tim Miller, Nancy Platt, Amber Santangelo, Steve Summers, Laura Rickets, John Paul Viviano, Robert Warrington, Alyce Wells, Dennis Werlau, and Megan Wusterbarth for operating the sport-reward fishery registration stations.

We also recognize Diana Murillo for her excellent work in computer data entry and document verification, Mike Luepke for his efficient rendering services in the lower and mid-river areas, Kristine Hand for her numerous phone survey interviews, Ruthanna Shirley for serving as the PIT tag recovery Lead, and Dennis Werlau for producing our weekly field activity reports throughout the season.

This project is funded by the Bonneville Power Administration (project number 1990-077-00) and the COTR is Mr. David Roberts. Steve Williams of Pacific States Marine Fish Commission (PSMFC) administered this contract.

ABSTRACT

We are reporting on the progress of the Northern Pikeminnow Sport Reward Fishery (NPSRF) implemented by the Washington Department of Fish and Wildlife (WDFW) on the Columbia and Snake Rivers from May 1 through September 30, 2016. The objectives of this project were to (1) implement a recreational fishery that rewards recreational anglers for harvesting Northern Pikeminnow ≥ 228mm (9 inches) total length (TL), (2) collect, compile, and report data on angler participation, catch and harvest of Northern Pikeminnow and other fish species, as well as success rates of participants 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 Passive Integrated Transponder (PIT) tags implanted into Northern Pikeminnow by ODFW as secondary tags, and/or from Northern Pikeminnow containing consumed salmonids with PIT tags, and (6) survey non-returning NPSRF participants targeting Northern Pikeminnow in order to obtain catch and harvest data on Northern Pikeminnow and other specified fish species.

A total of 225,350 Northern Pikeminnow ≥ 228 mm fork length (FL) and 5,268 Northern Pikeminnow < 228 mm FL were harvested during a very successful 2016 NPSRF season. There were a total of 3,718 different individual anglers who spent 27,775 angler days of effort participating in the NPSRF during the 2016 season. Catch per unit effort for combined returning and non-returning anglers was 8.11 fish/angler day. The Oregon Department of Fish and Wildlife (ODFW) estimated that the Northern Pikeminnow harvest activities from the 2016 NPSRF resulted in an overall exploitation rate of 12.1% (Carpenter et al. 2017).

Anglers submitted 228 Northern Pikeminnow with external ODFW spaghetti tags and all but one of these fish also had internal PIT tags. There were also 174 Northern Pikeminnow with ODFW PIT tags only, but missing spaghetti tags. An additional 87 PIT tags were recovered from juvenile salmonids ingested by Northern Pikeminnow received during the 2016 NPSRF.

Peamouth *Mylocheilus caurinus*, Smallmouth Bass *Micropterus dolomieue*, Sculpin *Cottus* spp, and Yellow Perch *Perca flavescens*, were the fish species most frequently caught by NPSRF anglers targeting Northern Pikeminnow. The incidental catch of salmonids *Oncorhynchus* spp, by participating anglers targeting Northern Pikeminnow continued to remain below established limits for the Northern Pikeminnow Management Program (NPMP).

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 (Northwest Power Planning Council 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 FL (11 inches total length). The Northern Pikeminnow Management Program (NPMP) was created in 1990, with the goal of implementing fisheries to 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-effectiveness (Hankin and Richards 2000). Beginning in 1991, the Washington Department of Fish and Wildlife (WDFW) was contracted to conduct the NPSRF 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 using a monetary reward system. Since 1991, NPSRF anglers have harvested over 4.5 million reward sized Northern Pikeminnow and spent nearly 882,000 angler days of effort to become the NPMP's most successful component for achieving the annual 10-20% exploitation rate on Northern Pikeminnow within the program boundaries (Klaybor et al. 1994, Friesen and Ward 1999).

In an effort to reverse declining angler participation seen from 2009-2014, the tiered angler reward system developed in 1995 (Hisata et al. 1996) which paid anglers higher rewards per fish based on achieving designated harvest levels was modified prior to the 2015 season (Winther et al. 2016). Reward changes generally made higher tier levels easier to reach and raised the base reward to $5 per fish. The goal was to grow the number of proficient individual anglers (Tier 2 and Tier 3 anglers), and to incentivize them to expend additional effort. At the same time, the higher base reward and more attainable 2nd and 3rd tier levels would attract and recruit additional anglers to the NPSRF. The 2016 NPSRF also maintained the bonus reward for returning Northern Pikeminnow spaghetti and/or PIT 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 both returning anglers, and a sub-sample of non-returning anglers in order to continue to monitor the potential effects of the NPSRF on other Columbia basin fishes.

The objectives of the 2016 NPSRF were to (1) implement a public fishery that rewards recreational anglers for harvesting Northern Pikeminnow ≥ 228 mm (9 inches) total length, (2) collect, compile, and report data on angler participation, catch rates and harvest of Northern Pikeminnow and other fish species 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 Passive Integrated Transponder (PIT) tags implanted into Northern Pikeminnow by ODFW as secondary tags, and/or from Northern Pikeminnow containing consumed salmonids with PIT tags, and (6) survey non-returning fishery participants targeting Northern Pikeminnow in order to obtain catch and harvest data on Northern Pikeminnow and other fish species.

METHODS OF OPERATION

Fishery Operation

Boundaries and Season

The 2016 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. The NPSRF was fully implemented, with all stations operating during a regular season extending from May 1 through September 30, 2016.

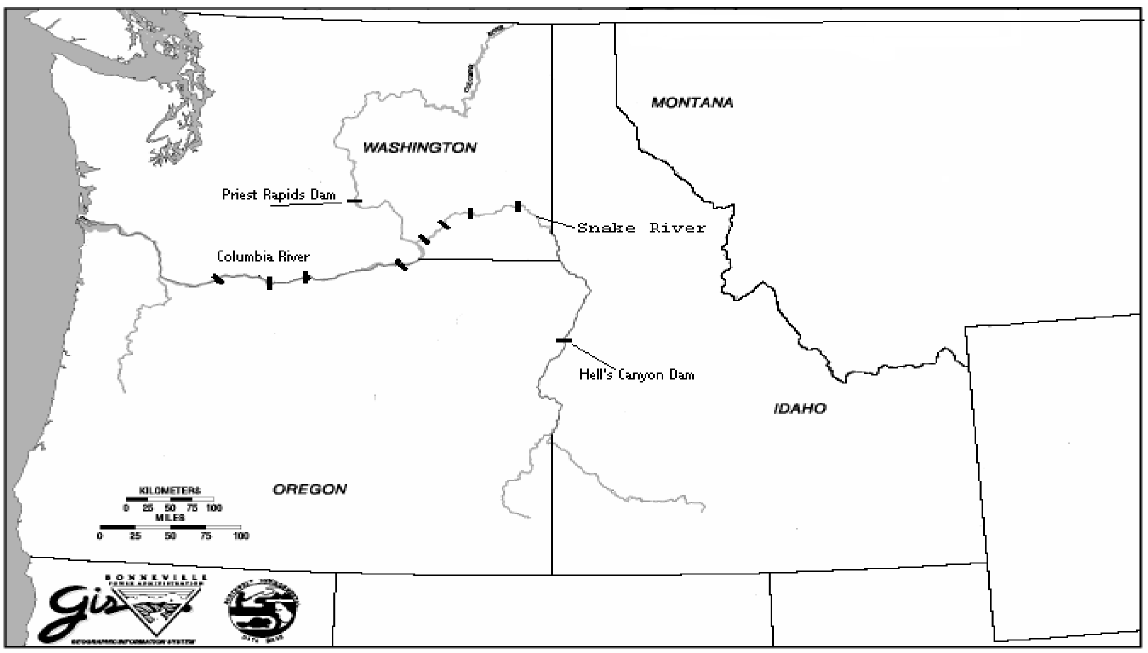
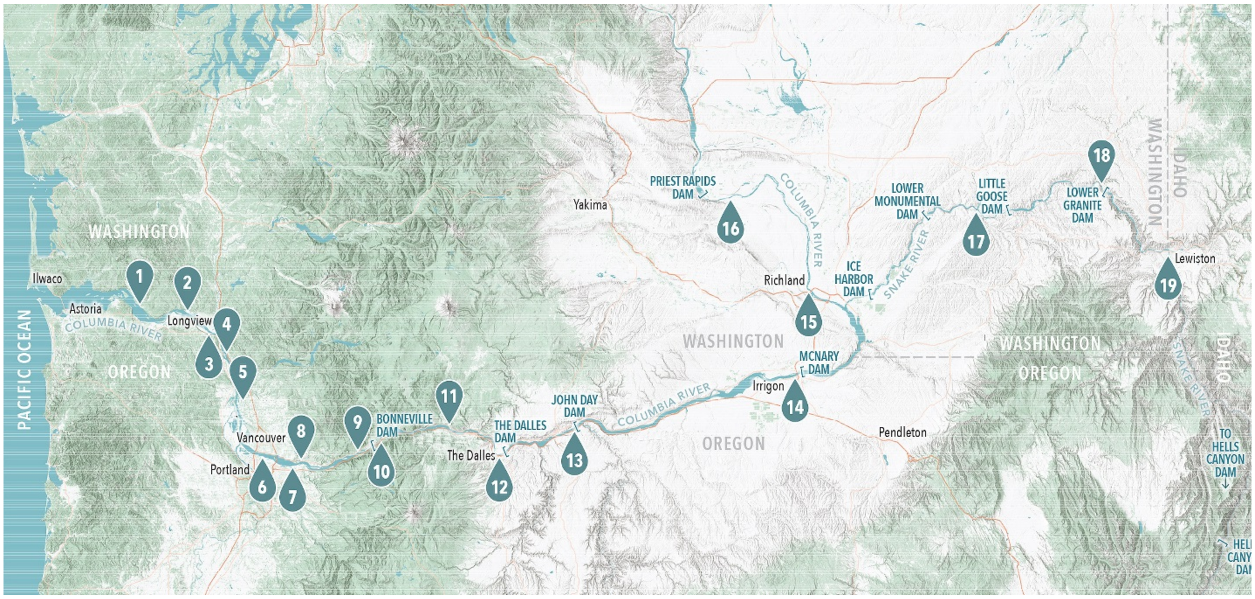


Figure 1. Northern Pikeminnow Sport Reward Fishery Program Area

Registration Stations

Nineteen 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 registration stations daily (seven days a week) at designated locations (normally public boat ramps or parks) which were available to anglers at specified times of between two and 8.5 hours per day during the season. Technicians assisted in registering anglers and compiled registered anglers participating in the NPSRF, collected angler 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.



1. Cathlamet Marina (10:00 am-1:30 pm)
2. Willow Grove Boat Ramp (2:00 pm-5:00 pm)
3. Rainier Marina (9:30am-1:00 pm)
4. Kalama Marina (1:30 pm-5:30 pm)
5. Ridgefield (9:00 am- 12:00 pm)
6. M. James Gleason Boat Ramp (12:00 pm-5:30 pm)
7. Chinook Landing (9:00 am-11:30 am)
8. Washougal Boat Ramp (12:30 pm- 5:30 pm)
9. Beacon Rock (9:30 am-12:30 pm)
10. Cascade Locks Boat Ramp (1:00 pm-5:30 pm)
11. Bingen Marina (9:00 am-12:30 pm)
12. The Dalles Boat Basin (9:00 am-5:30 pm)
13. Giles French (1:30 pm-5:30 pm)
14. Umatilla Marina (9:30 am-12:30 pm)
15. Columbia Point Park (1:30 pm-6:00 pm)
16. Vernita Bridge (2:00 pm-5:00 pm)
17. Lyon's Ferry (10:00 am-12:00 pm)
18. Boyer Park (10:00 am-2:00 pm)
19. Greenbelt (3:30 pm-6:00 pm)

Figure 2. 2016 Northern Pikeminnow Sport Reward Fishery Registration Stations and Hours

Reward System

The 2016 NPSRF rewarded anglers for harvesting Northern Pikeminnow $\geq$ 228mm TL (9 inches) using a tiered reward system first implemented in 1995 (Hisata et al. 1996), which 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. WDFW technicians verified fish species and issued them 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 NPSRF (Vigg et al. 1990), were issued a separate tag payment voucher that was mailed to ODFW for tag verification before payment was made to the angler by PSMFC.
Significant changes were made to the NPSRF's tiered reward system for the 2015 (Winther et al. 2016) and 2016 NPSRF seasons. First developed in 1995 (Hisata et al. 1996), the tiered reward system paid anglers higher rewards per fish based on achieving designated harvest levels. In response to declining angler participation seen from 2009-2014, this tiered angler reward system was modified (for the first time in program history) prior to the 2015 season. Implementing the reward changes raised the base reward to $5 per fish and made achieving tiers 2 and 3 more attainable. The goal of modifying the tiered reward system was to grow the number of

individual, proficient anglers (Tier 2 and Tier 3 anglers), and to incentivize them to expend additional effort. At the same time, it was predicted that the higher base reward and more attainable 2nd and 3rd Tier levels would attract and recruit additional anglers to the NPSRF. Since 2015, the NPSRF has paid a higher Tier 1 base reward of $5 for Northern Pikeminnow ≥ 9” total length ($4 prior to 2015). In addition, Tier 1 paid anglers $5 each for their first 25 Northern Pikeminnow, Tier 2 paid anglers $6 each for fish numbers 26-200, and Tier 3 paid anglers $8 each for all fish over 200.

Anglers continued to be paid $500 for each Northern Pikeminnow which retained a valid spaghetti tag used by ODFW for the biological evaluation of the NPMP. 2016 NPSRF anglers continued to be paid $100 for each Northern Pikeminnow missing a spaghetti tag but still retaining the ODFW PIT tag.

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. Anglers were asked if they specifically fished for Northern Pikeminnow at any time during their fishing trip. A “No” response ended the exit interview. A “Yes” response prompted technicians to ask the angler (and record data), 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”.

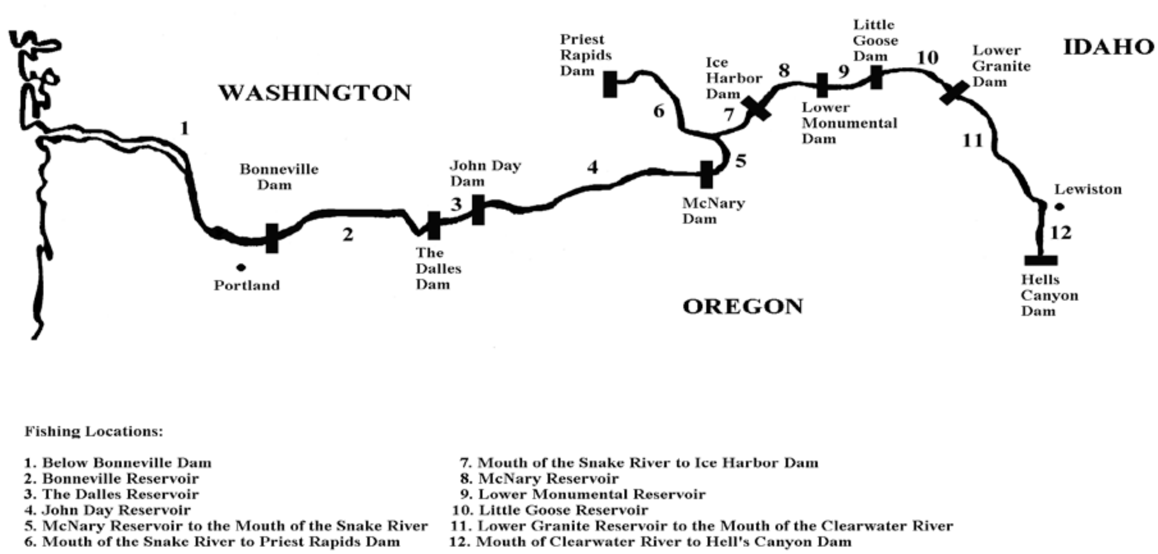


Figure 3. Fishing Location Codes used for the 2016 Northern Pikeminnow Sport Reward Fishery

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 were 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 surveyed a minimum of 20% of the NPSRF's non-returning anglers using a telephone survey 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 non-returning anglers who did not target Northern Pikeminnow on their fishing trip. Non-returning angler catch and harvest data for non-salmonid species were not collected in 2016 per NPSRF protocol (Fox et al. 2000).

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 checked all Northern Pikeminnow for the presence of external tags (spaghetti, floy, dart, etc.), fin-clip marks, and signs of tag loss. Fork lengths and sex of Northern Pikeminnow as well as any other harvested fish species were recorded whenever possible. Complete biological data were collected from all tag-loss and spaghetti tagged Northern Pikeminnow including Fork Length (FL), sex (determined by evisceration), and scale samples (if specified). Spaghetti tagged and tag-loss Northern Pikeminnow carcasses were then labeled and frozen for data verification and/or tag recovery at a later date. Data from spaghetti tags were recorded on a tag envelope as well as on WDFW data forms. The spaghetti tag was then removed from the Northern Pikeminnow and placed in the tag envelope, stapled to the tag payment voucher and given to the angler to submit to ODFW for verification.

PIT Tag Detection

All Northern Pikeminnow collected during the 2016 NPSRF were also scanned for passive integrated transponder (PIT) tags. Northern Pikeminnow harvested by anglers participating in the NPSRF have been found to ingest juvenile salmonids which have been PIT tagged by other studies within the basin (Glaser et al. 2001). In addition, PIT tags have also been used by ODFW as a secondary mark in all Northern Pikeminnow fitted with spaghetti tags (beginning in 2003) as part of the NPMP's biological evaluation activities (Takata and Koloszar 2004). The use of PIT tags rather than fin clips as a secondary mark in Northern Pikeminnow was intended to improve the NPSRF's estimate of tag loss, and result in a more accurate estimate of exploitation for the NPSRF. WDFW technicians were required to scan 100% of all Northern Pikeminnow returned to registration stations for PIT tags using PIT tag "readers". Northern Pikeminnow submitted for payment to the NPSRF were scanned using either Destron Fearing portable transceivers (model #FS2001F) or Biomark portable transceivers (model #HPR.PLUS.04V1) to record information from PIT tag detections for submission to the Columbia Basin PIT tag information System (PTAGIS). Scanning began on the first day of the NPSRF season and continued at all stations throughout the rest of the season. Technicians individually scanned all reward sized Northern Pikeminnow for PIT tag presence, and complete biological data were recorded from all 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 recovery data were provided to ODFW and/or the PIT Tag Information System (PTAGIS) on a regular basis. Data from verified tag-loss Northern Pikeminnow with ODFW PIT tags were forwarded to PSMFC for which anglers were paid a $100 bonus reward.

Northern Pikeminnow Processing

During biological sampling, all Northern Pikeminnow were either 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. As in recent years, most Northern Pikeminnow harvested in 2016 were caudal clipped rather than eviscerated in order to facilitate more accurate recovery of 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 2016 NPSRF harvested a total of 225,350 reward size Northern Pikeminnow ($\geq$ 228 mm TL) over the course of a 23 week field season. Harvest was 25,137 fish higher than 2015 harvest (Winther et al. 2016), and higher than the mean 1991-2016 harvest of 176,353 fish (Figure 4). The 2016 NPSRF harvest equated to an exploitation rate of 12.1% (Carpenter et al. 2017). In addition to harvesting 225,350 reward size Northern Pikeminnow, anglers participating in the 2016 NPSRF also harvested 5,268 Northern Pikeminnow < 228 mm TL.

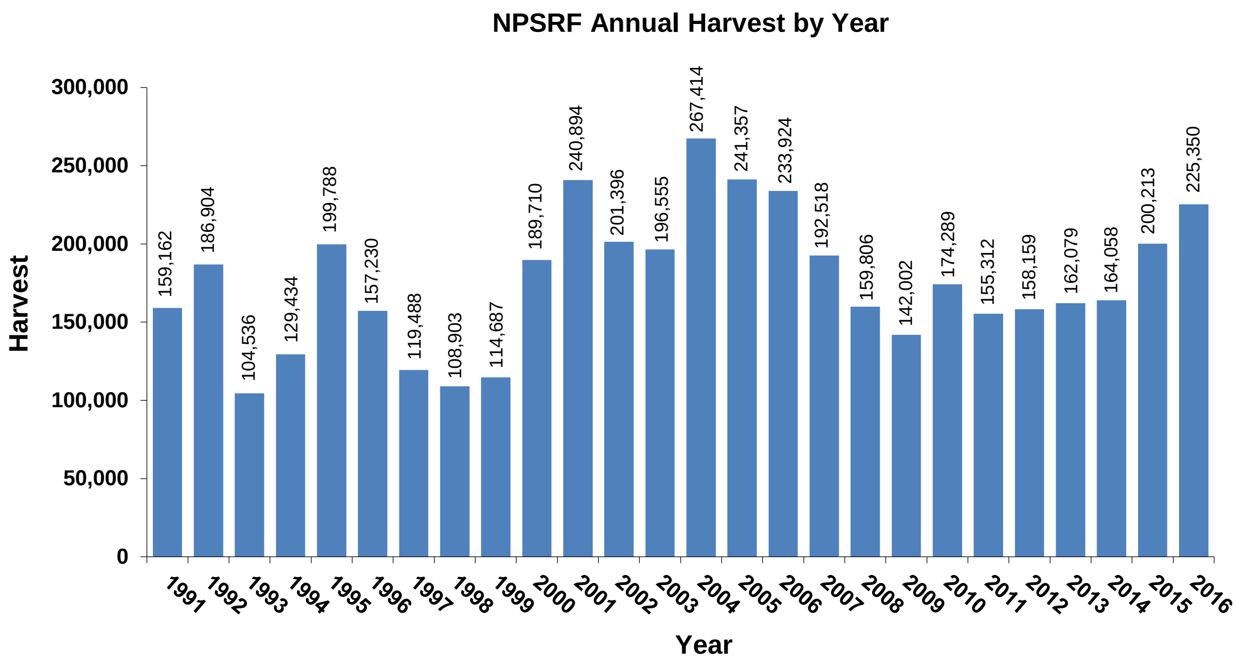


Figure 4. Annual Harvest Totals for the Northern Pikeminnow Sport Reward Fishery

Harvest by Week

Peak weekly harvest was 15,029 Northern Pikeminnow and occurred in week 19 (Figure 5), three weeks earlier than in 2015 (week 22), and was 981 fish more than in 2015 (14,048). Weekly harvest in 2016 was above 2015 weekly harvest for 13 weeks of the 23 week season (Figure 6), and mean weekly harvest was 12.6% higher in 2016 (9,798) than in 2015 (8,705). Favorable water conditions in effect during the first part of the 2016 NPSRF resulted in weekly harvest totals exceeding 10,000 fish per week for 11* of the first 12 weeks of the season (*week 18 consisted of only one data day as May 1st fell on a Sunday). Peak harvest occurred five weeks earlier (week 19) than the NPSRF's historical 1991-2015 peak in week 26 (Fox et al. 2000), and did not as strongly show the second, late season peak as in past seasons (Figure 7).

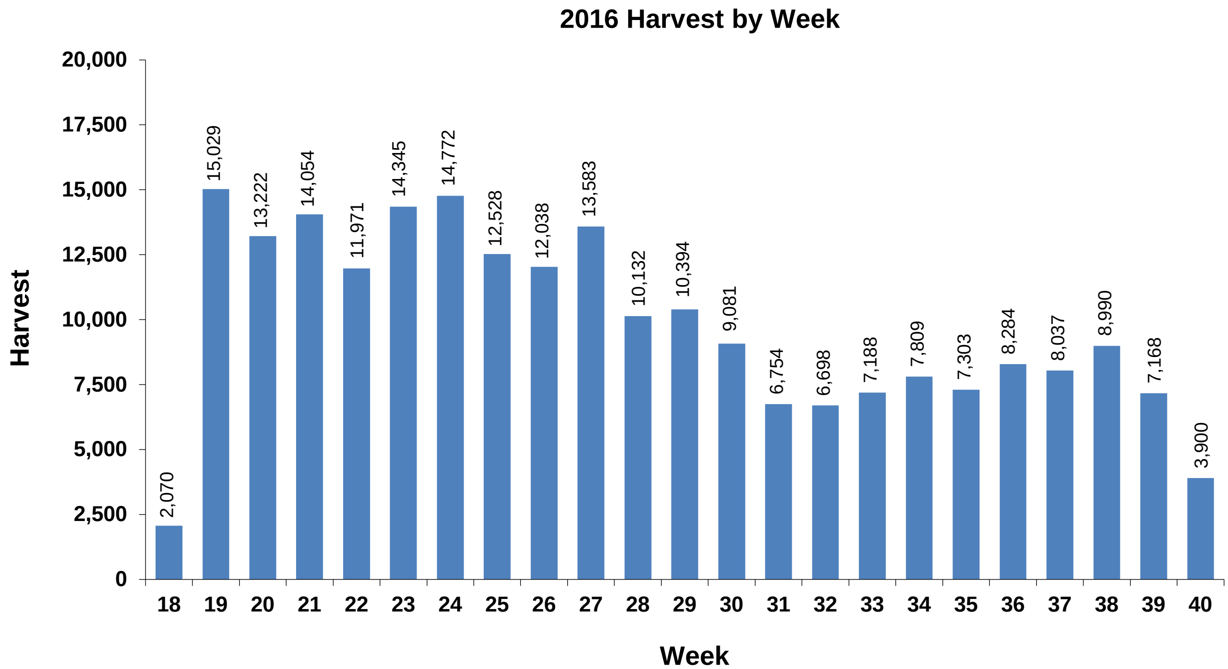


Figure 5. 2016 Weekly Northern Pikeminnow Sport Reward Fishery Harvest

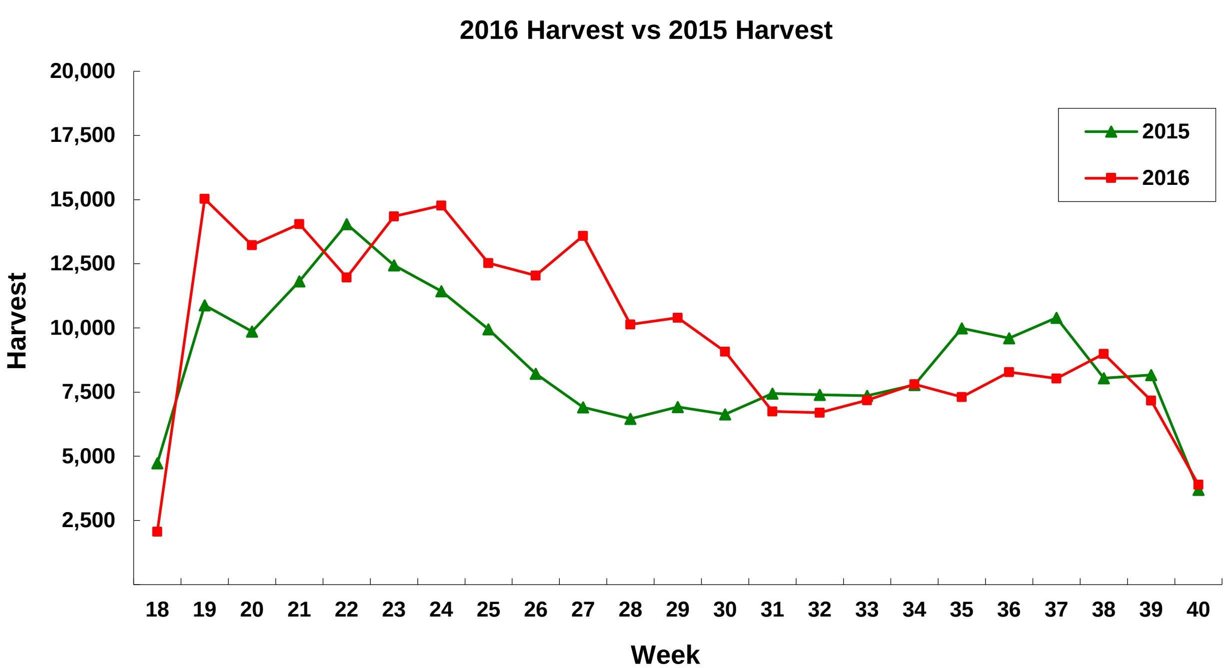


Figure 6. 2016 Weekly NPSRF Harvest vs 2015 Weekly Harvest

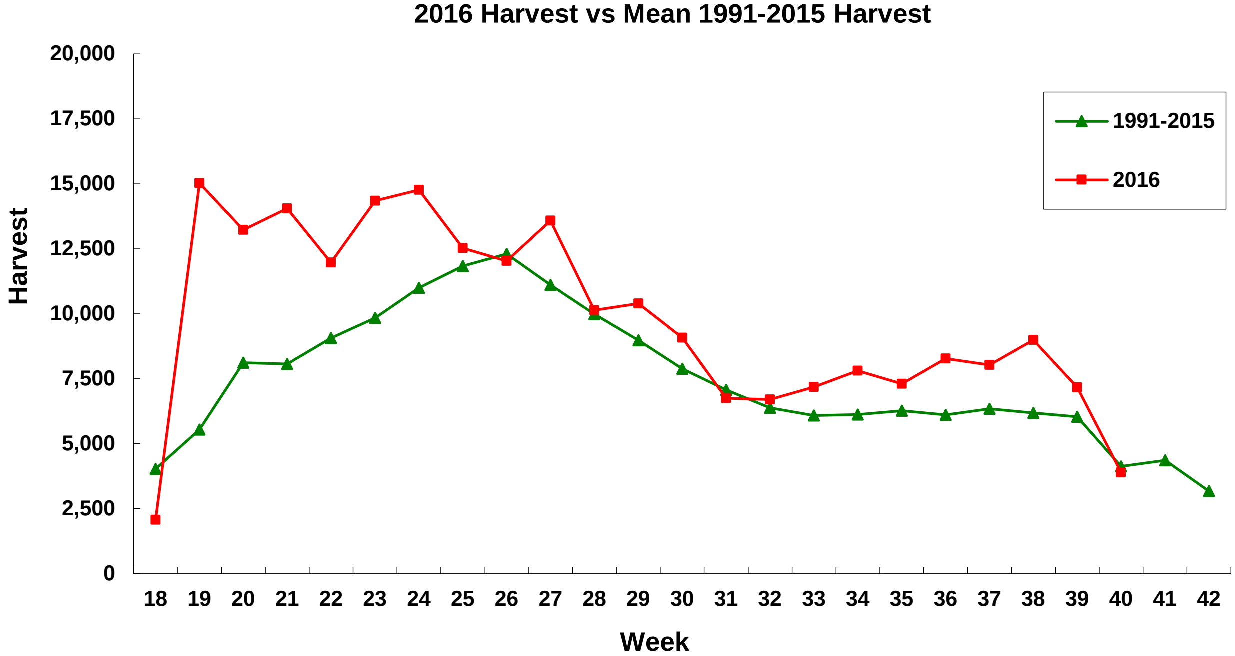


Figure 7. Comparison of 2016 NPSRF Weekly Harvest to 1991-2015 Mean Weekly Harvest

Harvest by Fishing Location

The mean harvest by fishing location for the 2016 NPSRF was 18,779 Northern Pikeminnow and ranged from 77,778 reward size Northern Pikeminnow in fishing location 01 (Below Bonneville Dam) to only 23 Northern Pikeminnow from fishing location 11 (Lower Granite Dam to the mouth of the Clearwater River) (Figure 8). Harvest from fishing location 01 (the Columbia River below Bonneville Dam) accounted for 34.52% of total NPSRF harvest and was the highest producing location again in 2016 as it has been for all but one season since the NPSRF began system wide implementation in 1991 (Hone et al. 2012). Fishing location 02 (Bonneville Reservoir) accounted for an additional 29.56% of the total 2016 NPSRF harvest, while fishing location 10 accounted for another 16.72% of the 2016 harvest.

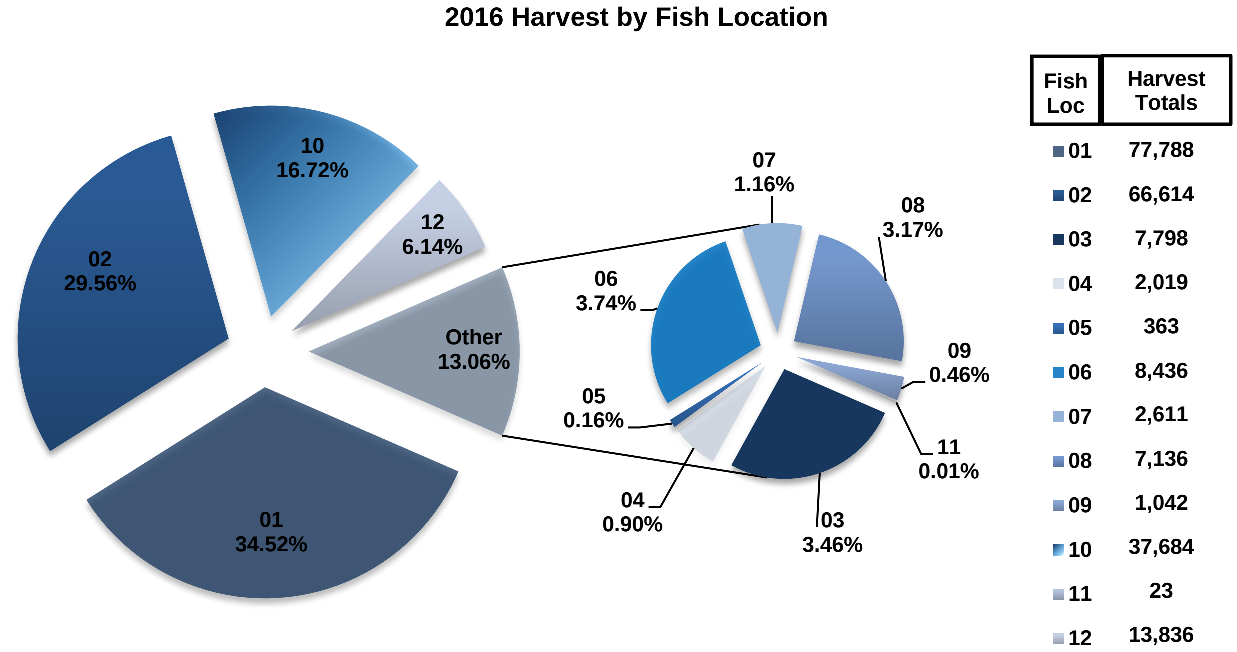


Figure 8. 2016 Northern Pikeminnow Sport Reward Fishery Harvest by Fishing Location*
*Fishing Location Codes for **Columbia River**; 01 = Below Bonneville Dam, 02 = Bonneville Reservoir, 03 = The Dalles Reservoir, 04 = John Day Reservoir, 05 = McNary Dam to the mouth of the Snake River, 06 = Mouth of the Snake River to Priest Rapids Dam. **Snake River;** 07 = Mouth of the Snake River to Ice Harbor Dam, 08 = Ice Harbor Reservoir, 09 = Lower Monumental Reservoir, 10 = Little Goose Reservoir, 11 = Lower Granite Dam to the mouth of the Clearwater River, 12 = Mouth of the Clearwater River to Hell's Canyon Dam.

Harvest by Registration Station

Harvest in 2016 was up from 2015 at 11 of the 19 registration stations. The Dalles registration station reclaimed the title of the NPSRF's top producing station (as it has been for five of the six years since 2010) where anglers harvested 41,479 Northern Pikeminnow, equaling 18.4% of total 2016 NPSRF harvest (Figure 9). The Boyer Park registration station finished with the second highest total of 37,337 Northern Pikeminnow (16.6% of total) harvested in 2016. The average harvest per registration station was 11,861 reward size Northern Pikeminnow, up from 10,011 per station in 2015. The registration station with the smallest harvest was Vernita where anglers harvested only 1,274 Northern Pikeminnow during the 2016 season. The Dalles registration station also showed the largest increase in harvest during the 2016 NPSRF with 14,126 more reward size Northern Pikeminnow turned in than in 2015 (Winther et al. 2016).

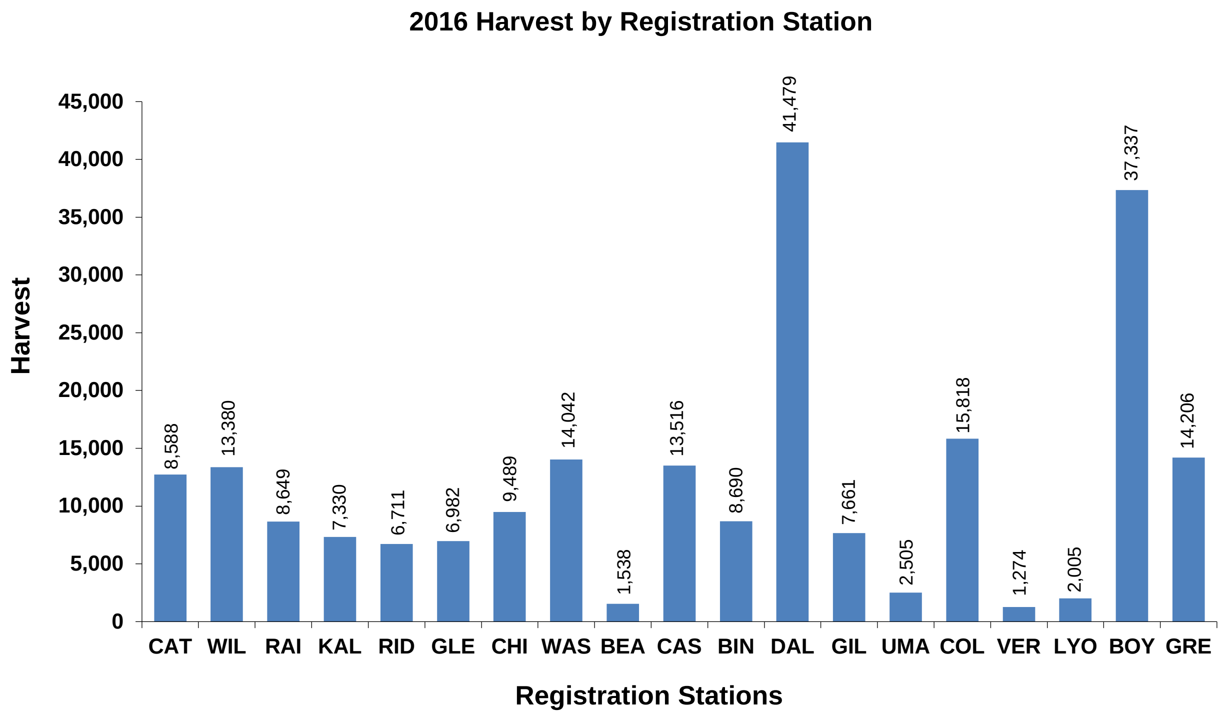


Figure 9. 2016 Northern Pikeminnow Sport Reward Fishery Harvest by Registration Station
CAT-Cathlamet, WIL-Willow Grove, RAI-Rainier, KAL-Kalama, RID-Ridgefield, GLE-Gleason, CHI-Chinook, WAS-Washougal, BEA-Beacon Rock, CAS-Cascade Locks, BIN-Bingen, DAL- The Dalles, GIL-Giles, UMA-Umatilla, COL-Columbia Point, VER-Vernita, LYO-Lyon's Ferry, BOY-Boyer Park, GRE-Greenbelt.

Harvest by Species/ Incidental Catch

Returning anglers

In addition to catching Northern Pikeminnow, returning anglers participating in the 2016 NPSRF also reported that they incidentally caught the salmonids listed in Table 1. Incidental salmonid catch by returning NPSRF anglers consisted mostly of juvenile steelhead and juvenile chinook.

Table 1. Catch and Harvest of Salmonids by Returning Anglers Targeting Northern Pikeminnow in 2016.

Salmon

Species	Caught	Harvest	Harvest Percent
Steelhead Juvenile (Hatchery)	104	0	0%
Chinook (Juvenile)	72	0	0%
Steelhead Juvenile (Wild)	42	0	0%
Trout (Unknown)	42	3	7.14%
Chinook (Jack)	18	1	5.56%
Cutthroat trout (unknown)	17	1	5.88%
Chinook Adult	15	4	26.67%
Steelhead Adult (Hatchery)	11	3	27.27%
Steelhead Adult (Wild)	10	0	0%
Sockeye Adult	5	0	0%
Coho (Juvenile)	2	0	0%

Anglers reported that all juvenile salmonids caught during the 2016 NPSRF, were released. Technicians recorded all juvenile steelhead caught by NPSRF anglers (except those specifically reported as missing the adipose fin), as "wild". Adult salmonids (primarily hatchery steelhead with missing adipose fins) and adult Chinook were caught incidentally during the 2016 NPSRF, but were only retained during legal salmonid fisheries. Instances where NPSRF anglers reported harvesting "trout" were from the Snake River during legal fisheries and were residualized hatchery steelhead smolts caught and kept by anglers and typically identified as "trout". NPSRF protocol for anglers who report illegally harvesting salmonids during the exit interview (whether juvenile or adult salmonids), is for that information to be immediately forwarded to the appropriate enforcement entity for action.

Other fish species incidentally caught by returning NPSRF anglers targeting Northern Pikeminnow were most often Peamouth, Smallmouth Bass, Yellow Perch, Sculpin, White Sturgeon, channel catfish, and suckers (Table 2).

Table 2. Catch and Harvest of Non-Salmonids by Returning Anglers Targeting Northern Pikeminnow in 2016

Non-Salmonid

Species	Caught	Harvest	Harvest Percent
Northern Pikeminnow >228mm	225,363	225,350	99.99%
Northern Pikeminnow <228mm	51,035	5,268	10.32%
Peamouth	42,629	19,162	44.95%
Smallmouth Bass	21,013	2,053	9.77%
Sculpin (unknown)	7,603	4,386	57.69%
Yellow Perch	4,102	825	20.11%
White Sturgeon	3,916	3	.08%
Channel Catfish	2,814	384	13.65%
Walleye	1,821	518	28.45%
Sucker (unknown)	1,682	250	14.86%
Bullhead (unknown)	918	148	16.12%
Catfish (unknown)	419	72	17.18%
Carp	418	39	9.33%
Bluegill	413	24	5.81%
Chiselmouth	293	56	19.11%
Pumpkinseed	230	38	16.52%
American Shad	196	91	46.43%
Starry Flounder	121	7	5.79%
Sandroller	63	1	1.59%
Crappie (unknown)	36	0	0%
Largemouth Bass	31	4	12.9%
Whitefish	10	2	20%
Redside Shiner	1	0	0%

Non-Returning Anglers Catch and Harvest Estimates

As in past years, we conducted telephone interviews to randomly survey non-returning participants at each of the NPSRF's 19 stations in order to determine and record their catch and/or harvest of reward sized Northern Pikeminnow and other incidentally caught salmonid species. In 2016, there were 8,172 non-returning angler days recorded and a total of 1,833 calls were completed to non-returning anglers (22.4% of all non-returning anglers). Surveyed non-returning anglers targeting Northern Pikeminnow reported that they caught and/or harvested the fish species listed in column 1 of Table 3 during the 2016 NPSRF. A simple estimator was applied to the catch and harvest totals obtained from the surveyed anglers to obtain estimated for Total Catch and Total Harvest for all non-returning anglers participating in the 2016 NPSRF. Estimated totals are listed in columns 5 and 6 of Table 3.

Table 3. 2016 NPSRF Non-Returning Angler Phone Survey Results with Total Catch & Harvest estimates

Species	Caught	Harvest	%Harvested	Estimated Total Catch	Estimated Total Harvest
Northern Pikeminnow ≥ 228 mm	330	58	17.6%	1471	259
Northern Pikeminnow <228 mm	134	123	91.8%	597	548
Chinook Salmon (juvenile)	52	0	0%	232	0
Trout (Unknown)	7	3	42.9%	31	13
Chinook Salmon (Adult)	7	3	42.9%	31	13
Chinook Salmon (Jack)	3	0	0%	13	0
Steelhead (Juvenile)	3	0	0%	13	0
Steelhead Adult (Wild)	2	0	0%	9	0
Salmon (Juvenile Unknown)	2	0	0%	9	0
Steelhead Adult (Hatchery)	1	1	100%	4	4

N=8,172 n=1,833

Fork Length Data

The length frequency distribution for harvested Northern Pikeminnow (≥ 200 mm) from the 2016 NPSRF is presented in Figure 10. Fork length data from a total of 116,589 Northern Pikeminnow ≥ 200 mm FL (51.7% of total harvest) were taken during the 2016 NPSRF. The mean fork length for all measured Northern Pikeminnow (≥ 200 mm) in 2016 was 275.2 mm (SD= 60.63 mm), down from 277.91 in 2015.

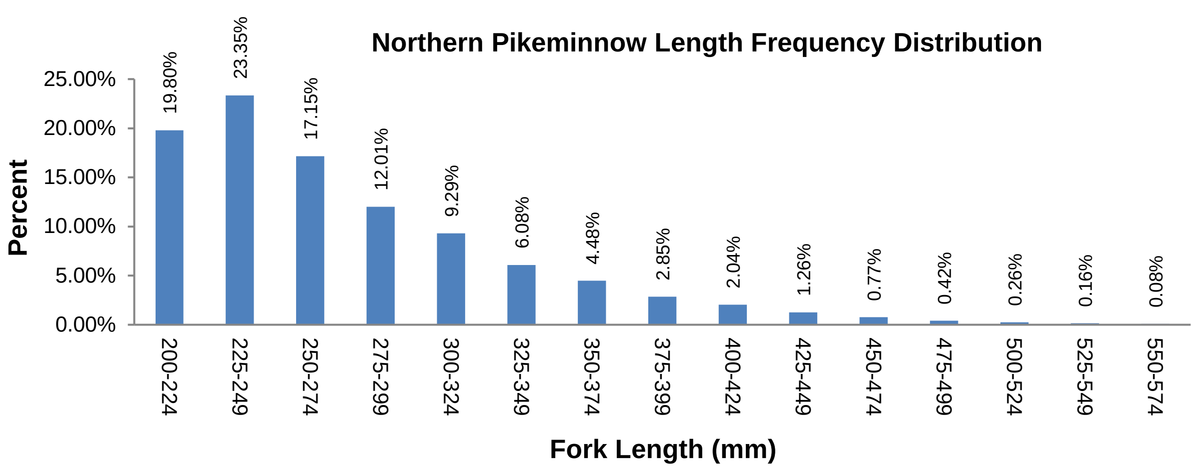


Figure 10. Length Frequency Distribution of Northern Pikeminnow ≥ 200 mm FL from 2016 NPSRF

Angler Effort

The 2016 NPSRF recorded total effort of 27,775 angler days spent during the season, an increase of 3,735 from 2015 (Winther et al. 2016) (Figure 11). Angler effort has also increased 8,267 angler days from 2014 prior to the change in reward tiers (Dunlap et al. 2015). When total effort is divided into returning and non-returning angler days, 19,603 angler days (70.6%) were recorded by returning anglers, and 8,172 angler days were spent by non-return anglers. The percentage of returning anglers in 2016 (70.6%) was lower than for the 2014 (72%) and 2015 (72.3%) NPSRF seasons. In addition, 61.2% of total effort, and 86.7% of returning angler effort (17,001 angler days), was attributed to successful anglers who harvested at least 1 Northern Pikeminnow in 2016.

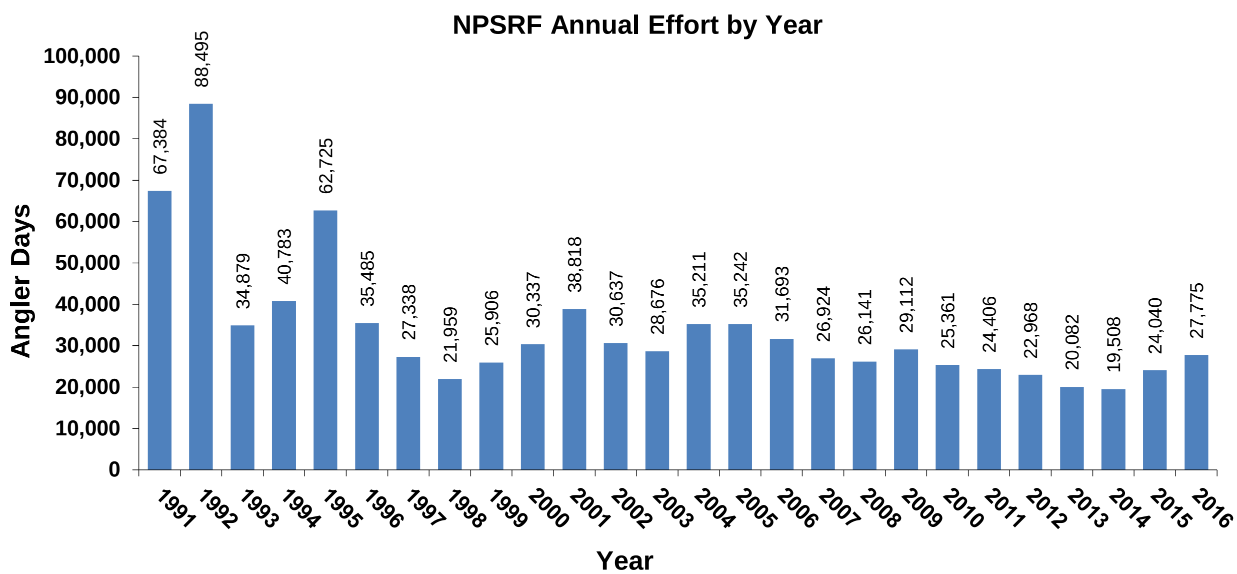


Figure 11. Annual Northern Pikeminnow Sport Reward Fishery Effort

Effort by Week

Mean weekly effort for the 2016 NPSRF was 1,208 angler days during the season, with the peak occurring in week 19 during the second week of the season (Figure 12). When we compare weekly effort totals for 2016 with last season, weekly effort totals from all but one week exceeded those of 2015. Peak weekly effort in 2016 once again occurred on the same week as peak harvest (week 19) (Figure 13) and overall mean weekly effort increased from 1,045 in 2015 to 1,208 in 2016 (Winther et al. 2016). Weekly effort totals for the 2016 NPSRF generally followed the same seasonal pattern as historical 1991-2015 effort levels, but weekly effort in weeks 19 and 39 exceeded the historical average. (Figure 14).

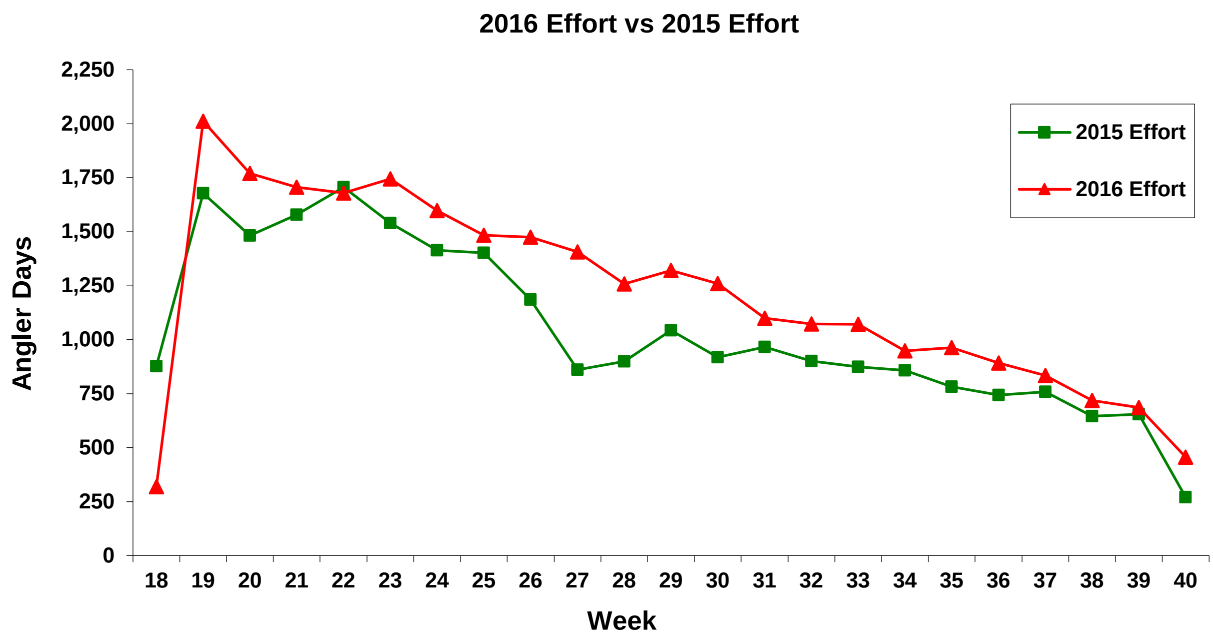


Figure 12. 2016 Northern Pikeminnow Sport Reward Fishery Effort vs 2015 Effort

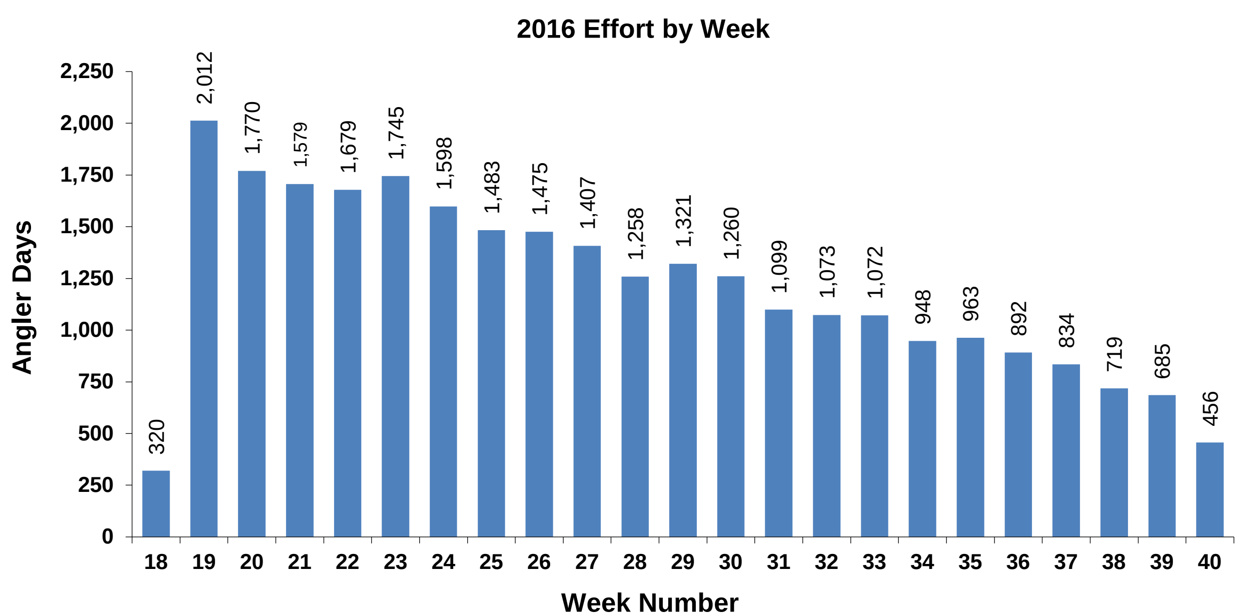


Figure 13. 2016 Weekly Northern Pikeminnow Sport Reward Fishery Effort

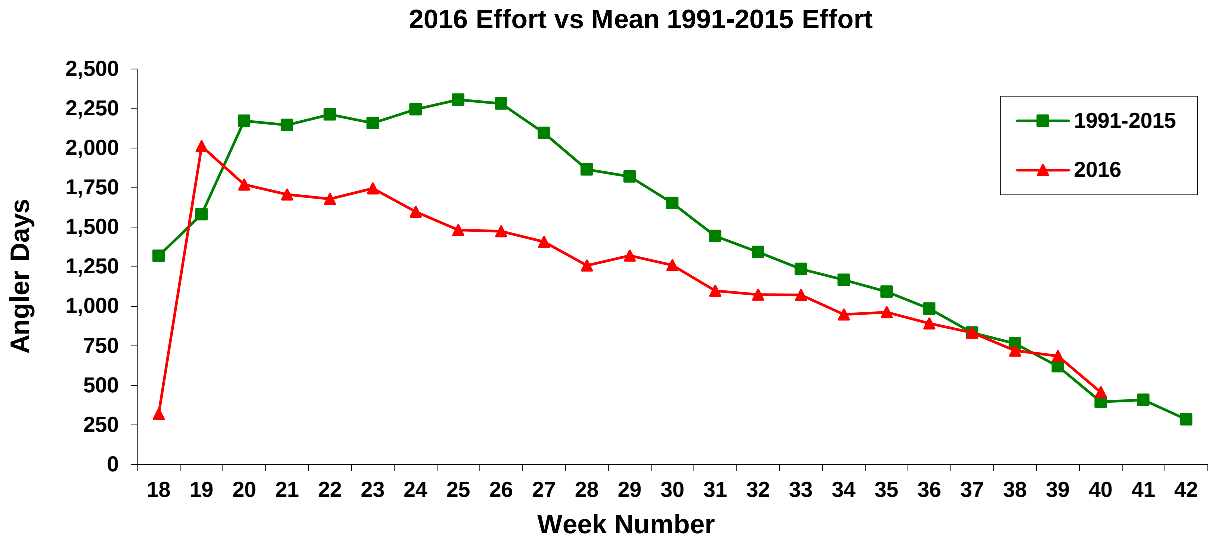


Figure 14. 2016 NPSRF Weekly Effort vs Mean 1991-2015 Effort

Effort by Fishing Location

Mean annual effort by fishing location for the 2016 NPSRF (returning anglers only) increased by nearly 60% from 1,448 angler days in 2015 to 2,315 angler days in 2016. Effort totals ranged from 7,939 angler days spent in fishing location 01 (below Bonneville dam) to only 7 angler days spent in fishing location 11 on the Snake River (Lower Granite Dam to the mouth of the Clearwater River) (Figure 15). Effort increased 13.1% below Bonneville Dam (fishing location 01) from 7,017 angler days recorded in 2015 to 7,939 angler days in 2016 and increased at eight of the twelve NPSRF fishing locations.

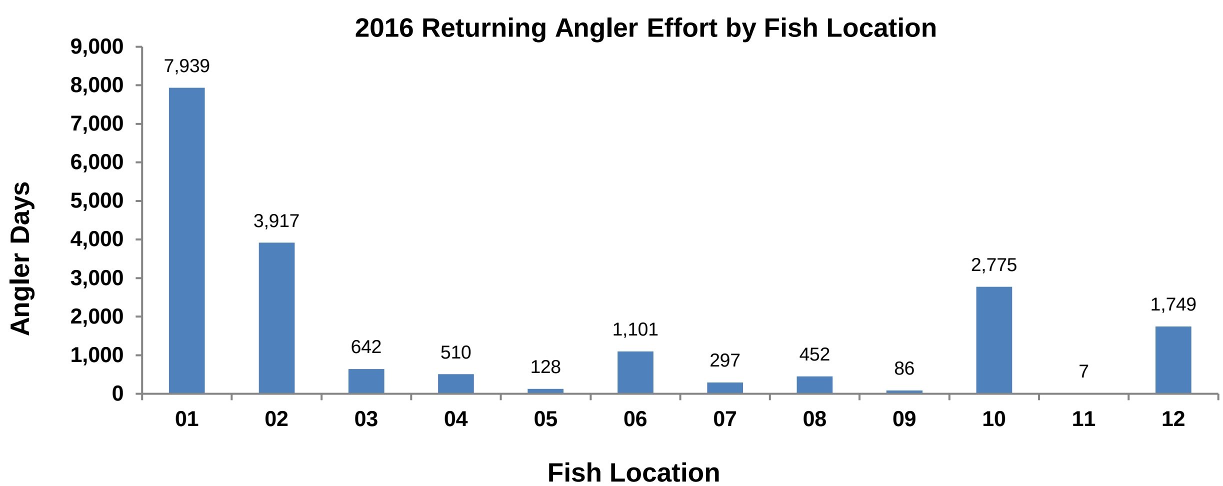


Figure 15. 2016 NPSRF Angler Effort by Fishing Location (returning anglers only).*
Fishing Location Codes for **Columbia River**; 01 = Below Bonneville Dam, 02 = Bonneville Reservoir, 03 = The Dalles Reservoir, 04 = John Day Reservoir, 05 = McNary Dam to the mouth of the Snake River, 06 = Mouth of the Snake River to Priest Rapids Dam. **Snake River;** 07 = Mouth of the Snake River to Ice Harbor Dam, 08 = Ice Harbor Reservoir, 09 = Lower Monumental Reservoir, 10 = Little Goose Reservoir, 11 = Lower Granite Dam to the mouth of the Clearwater River, 12 = Mouth of the Clearwater River to Hell's Canyon Dam.

Effort by Registration Station

Mean effort per registration station during the 2016 NPSRF was 1,462 angler days compared to 1,202 angler days in 2015. Effort totals ranged from 3,520 angler days at The Dalles station to 233 angler days at the Beacon Rock station (Figure 16). Effort during the 2016 NPSRF increased at fourteen of the nineteen registration stations, most notably at the Cathlamet station where effort increased 830 angler days from 2015.

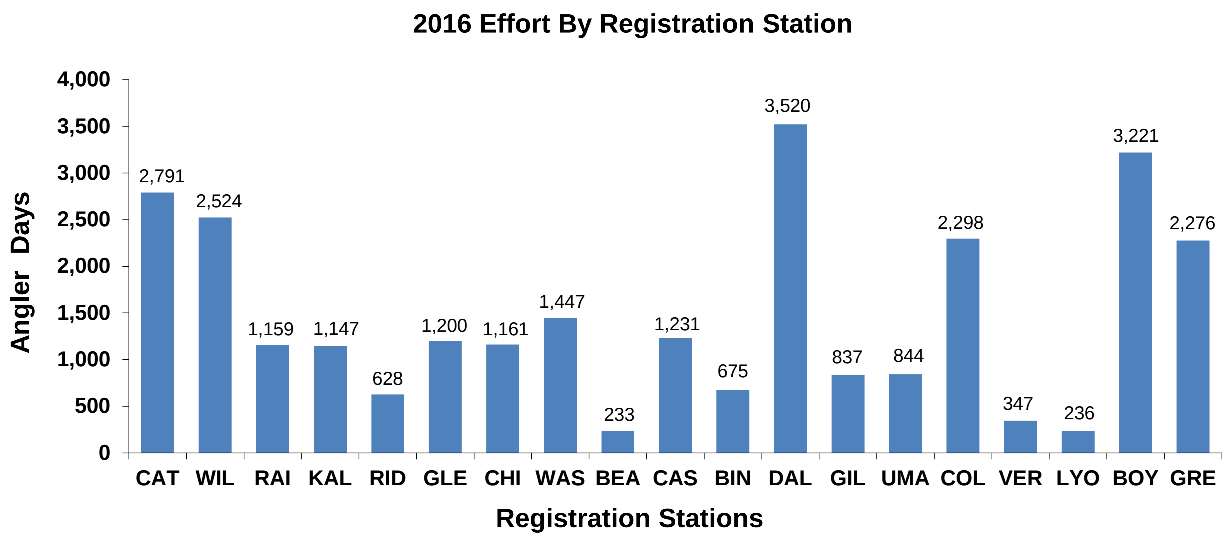


Figure 16. 2016 Northern Pikeminnow Sport Reward Fishery Angler Effort by Registration Station
CAT-Cathlamet, WIL-Willow Grove, RAI-Rainier, KAL-Kalama, RID-Ridgefield, GLE-Gleason, CHI-Chinook, WAS-Washougal, BEA-Beacon Rock, CAS-Cascade Locks, BIN-Bingen, DAL-The Dalles, GIL-Giles, UMA-Umatilla, COL-Columbia Point, VER-Vernita, LYO-Lyon's Ferry, BOY-Boyer Park, GRE-Greenbelt.

Catch Per Angler Day (CPUE)

The 2016 NPSRF recorded an overall (returning + non-returning anglers) catch per unit of effort (CPUE) of 8.11 Northern Pikeminnow harvested per angler day during the season. This catch rate was the NPSRF's third highest to date (8.41 CPUE in 2014 and 8.33 in 2015) (Dunlap et al. 2015, Winther et al. 2016) (Figure 17). Angler CPUE has increased throughout the NPSRF's 26 year history although there was a slight downturn in CPUE in 2016 as a result of an increase in angler effort and an influx of new anglers. Returning angler CPUE during the 2016 NPSRF was 9.21 Northern Pikeminnow per angler day, down from the 2015 CPUE of 11.53. The estimated CPUE for non-returning anglers remained the same as last year at 0.10 reward size Northern Pikeminnow per angler day based on 2016 NPSRF phone survey results.

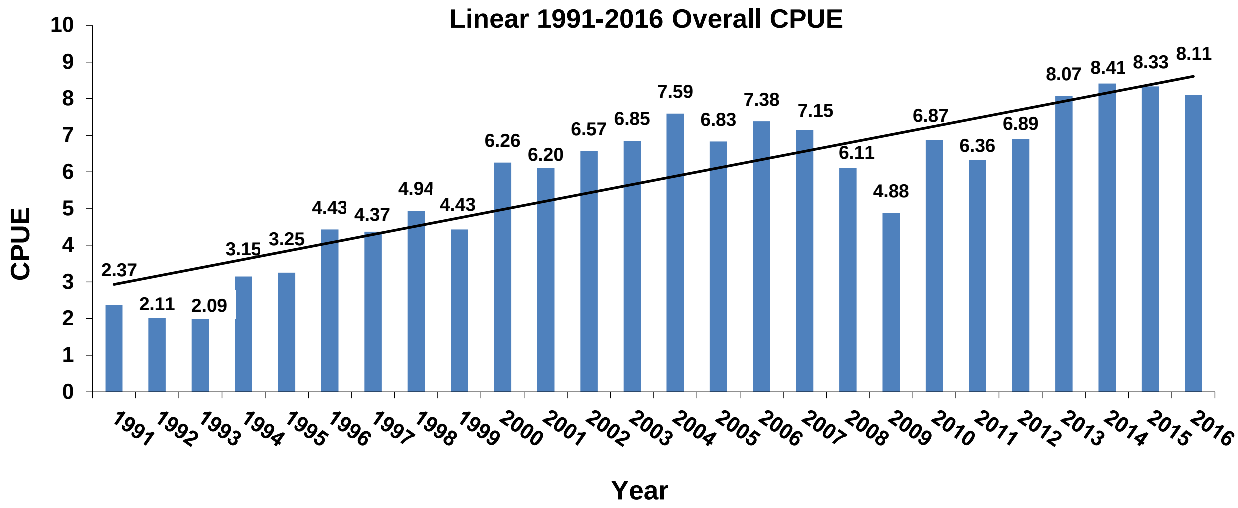


Figure 17. Annual NPSRF CPUE (Returning + Non-Returning Anglers) for the years 1991-2016

CPUE by Week

Mean angler CPUE by week for the 2016 NPSRF was 8.22 fish per angler day compared to 8.91 in 2015. CPUE ranged from a peak of 12.5 in week 38 (September 12-18) to a low of 6.15 in week 31 (Aug 1-7) (Figure 18). Weekly CPUE for the 2016 NPSRF followed a less obvious two peak pattern where catch rates were higher than 2014 for weeks 18-30, but the first peak did not happen until week 27 (week 22 in 2015) (Winther et al. 2016). Peak weekly CPUE did spike upward again late in the season (week 38) as seen in previous years (Winther et al. 2011).

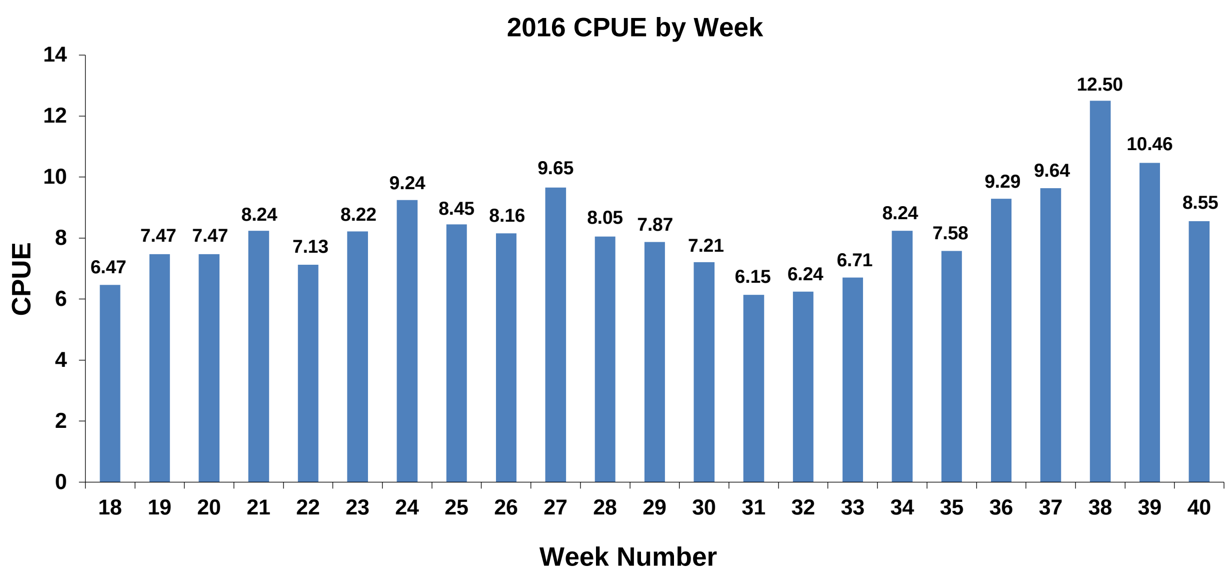


Figure 18. 2016 Northern Pikeminnow Sport Reward Fishery Angler CPUE by Week

CPUE by Fishing Location

Angler success rates for the 2016 NPSRF (as indicated by CPUE), are available for returning anglers only and varied by fishing location. Success rates ranged from a high of 17.01 Northern Pikeminnow per angler day in fishing location 02 (Bonneville Reservoir) to 2.84 fish per angler per day in fishing location 05 (McNary Dam to the mouth of the Snake River) (Figure 19). Catch rates were up from 2015 at five of the twelve fishing locations, highlighted by CPUE at fishing locations 02, which increased from 12.89 in 2015 to 17.01 in 2016. The average CPUE by fishing location was 9.58 Northern Pikeminnow per angler day in 2016 compared to 9.33 in 2015.

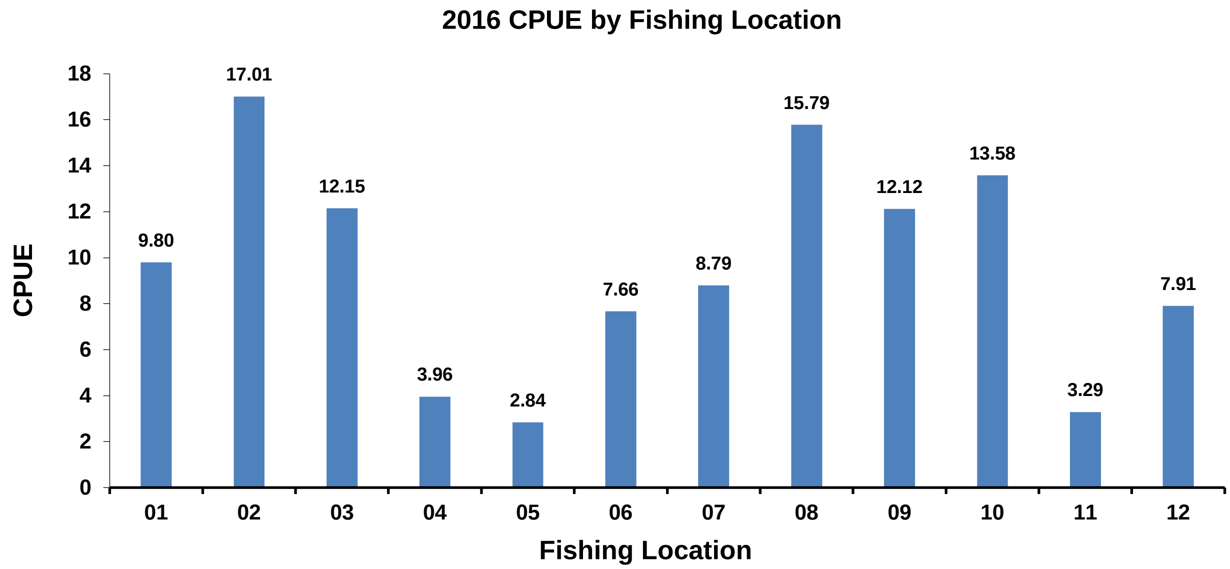


Figure 19. 2016 Northern Pikeminnow Sport-Reward Fishery Angler CPUE by Fishing Location.*
Fishing Location Codes for **Columbia River**; 01 = Below Bonneville Dam, 02 = Bonneville Reservoir, 03 = The Dalles Reservoir, 04 = John Day Reservoir, 05 = McNary Dam to the mouth of the Snake River, 06 = Mouth of the Snake River to Priest Rapids Dam. **Snake River**; 07 = Mouth of the Snake River to Ice Harbor Dam, 08 = Ice Harbor Reservoir, 09 = Lower Monumental Reservoir, 10 = Little Goose Reservoir, 11 = Lower Granite Dam to the mouth of the Clearwater River, 12 = Mouth of the Clearwater River to Hell's Canyon Dam.

CPUE by Registration Station

The registration station with the highest CPUE during the 2016 NPSRF was the Bingen station where anglers averaged 12.87 Northern Pikeminnow per angler day (Figure 20). The registration station with the lowest CPUE was the Umatilla station with a CPUE of 2.97 Northern Pikeminnow per angler day. The station average for angler CPUE was 7.86 in 2016, down from 8.33 in 2015. Angler CPUE by registration station increased at eight stations during the 2016 NPSRF. The largest increase in CPUE occurred at the Bingen station where CPUE increased from 9.22 in 2015 to 12.87 in 2016.

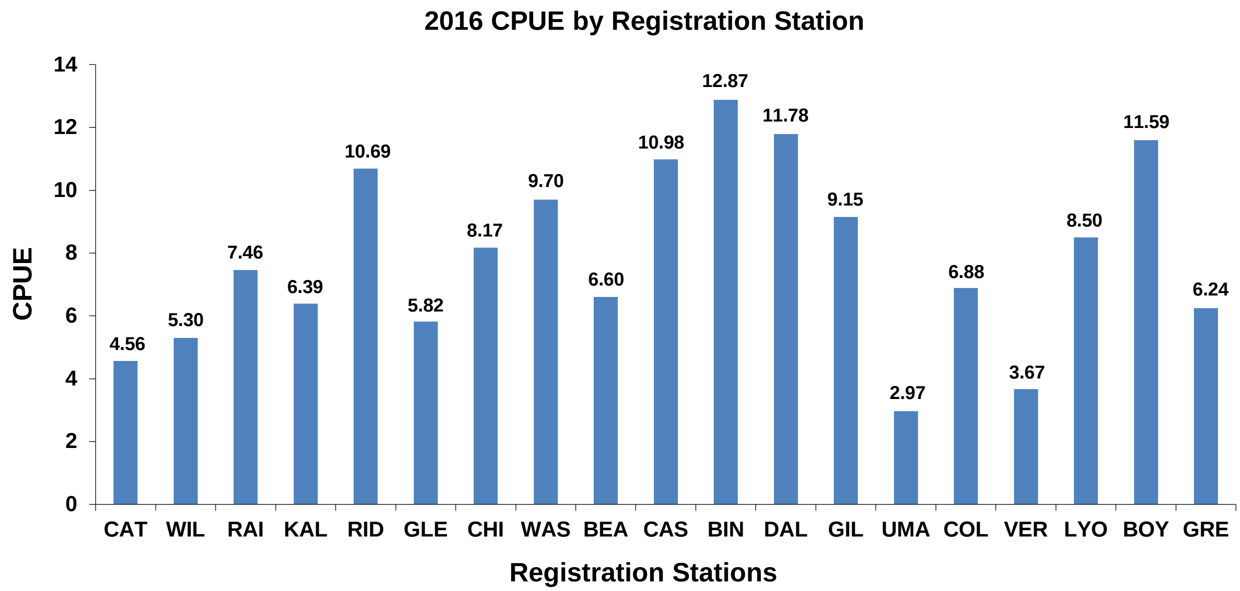


Figure 20. 2016 Northern Pikeminnow Sport Reward Fishery Angler CPUE by Registration Station
CAT-Cathlamet, WIL-Willow Grove, RAI-Rainier, KAL-Kalama, RID-Ridgefield, GLE-Gleason, CHI-Chinook, WAS-Washougal, BEA-Beacon Rock, CAS-Cascade Locks, BIN-Bingen, DAL-The Dalles, GIL-Giles, UMA-Umatilla, COL-Columbia Point, VER-Vernita, LYO-Lyon's Ferry, BOY-Boyer Park, GRE-Greenbelt.

Angler Totals

There were 3,718 separate anglers who participated in the 2016 NPSRF, an increase of 15.8% (508 participants) from 2015 (Winther et al. 2016). One thousand, six hundred and nineteen of these anglers (43.5% of total vs. 43.2% in 2015) were classified as successful since they harvested at least one reward size Northern Pikeminnow (for which a voucher was issued) during the 2016 season. Of the successful anglers, 73.3% (1,186 anglers) sent in their vouchers to PSMFC for payment (PSMFC 12/12/16 Angler Payment Summary) while 433 anglers (26.7%) did not. The average successful angler harvested 139 Northern Pikeminnow during the 2016 NPSRF compared to 144 in 2015. When we break down the 1,619 successful anglers by tier, 1,140 anglers (70.41%) harvested fewer than 25 Northern Pikeminnow and were classified as Tier 1 anglers (Figure 21). This is up from 977 anglers in 2014 and 986 anglers in 2015. Using the updated angler reward system implemented in 2015, the percentage of Tier 1 anglers continues to contract from 84% of successful anglers in 2014 to 71.04% in 2015 and to 70.41% in 2016. The percentage of anglers at Tier 1 declined even though the number of individual anglers has grown from 977 anglers in 2014, to 986 in 2015, and up to 1,140 anglers in 2016. The percentage of Tier 2 anglers grew from 8.25% in 2014, to 17% in 2015, and is up to 18.22% of total anglers in 2016. The percentage of Tier 3 anglers (known as "highliners") was down slightly from 12% in 2015 to 11.37 in 2016, but the total number of these anglers still increased from 163 anglers in 2015 to 184 in 2016 and has more than doubled from what it was in 2014 when there were only 91 Tier 3 anglers (prior to the changes to the tier system implemented in 2015). The increase in the percentage of anglers at tiers 2 and 3 is important to achieving NPSRF harvest and exploitation objectives since Tier 2 and Tier 3 anglers have a much higher CPUE than Tier 1 anglers. Having a larger percentage of more proficient anglers as part of the NPSRF's overall successful angler population increases overall NPSRF harvest.

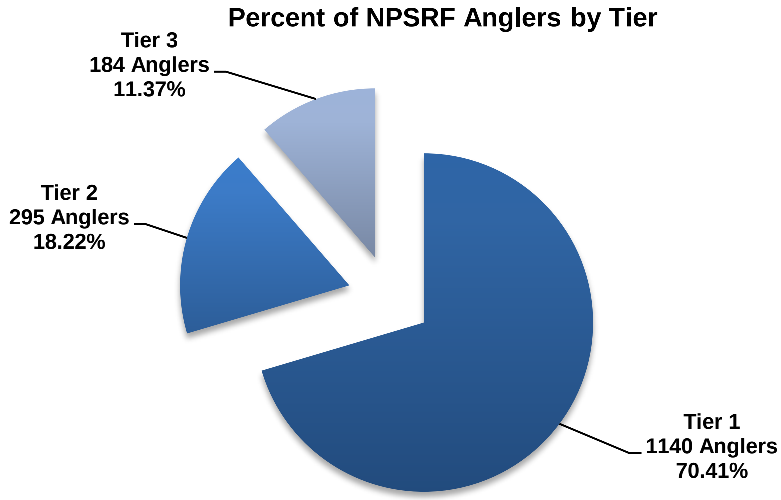


Figure 21. 2016 NPSRF Anglers by Tier (Returning Anglers) Based on Total Harvest

While Tier 1 anglers made up 70.41% of all successful NPSRF participants in 2016, they accounted for only 2.76% of total NPSRF harvest (6,217 Northern Pikeminnow) (Figure 22). The 295 Tier 2 anglers caught 9.42% of total harvest (21,229 fish), while 87.82% of total harvest (197,904 fish) was caught by the 184 anglers who reached Tier 3. Tier 3 anglers represented 4.95% of all participants (both returning and non-returning anglers), and 11.37% of successful anglers participating in the 2016 NPSRF. Average annual harvest for Tier 1 anglers was 4.92 fish (versus 5.4 fish in 2015), while Tier 2 anglers harvested an annual average of 73.26 fish (versus 72.2 fish in 2015). Tier 3 anglers averaged 1,079 fish per angler, per year, compared to 1,090 fish per year in 2015 (Winther et al. 2016).

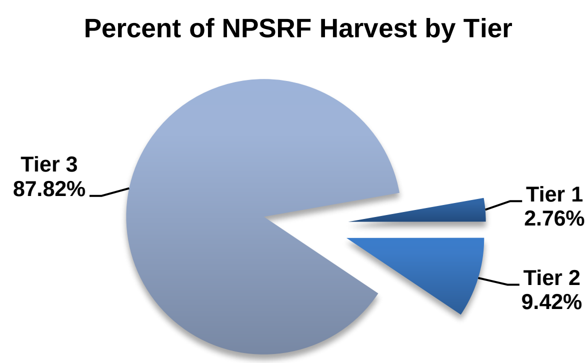


Figure 22. 2016 NPSRF Harvest by Angler Tier (Tier 1 = ≤25, Tier 2 =26-200, Tier 3 = > 200)

The overall average NPSRF participant (returning + non-returning anglers) expended slightly less effort pursuing Northern Pikeminnow during the 2016 season than in 2015 (7.47 vs. 7.49 angling days of effort). When we look at successful anglers only, the average successful angler increased their average annual effort spent to 15.11 angler days during the 2016 NPSRF compared to 10.54

days in 2015 and 10.12 days in 2014 (Winther et al. 2016) This equates to a 49.3% increase from prior to the tier structure change. When we break it down by tier, average annual effort increased at only one of the three tier levels in 2016. Tier 1 anglers spent an average of 4 days fishing in 2016 and 5 days fishing in 2015. Tier 2 anglers spent an average of 22 days fishing in both 2016 and 2015. Tier 3 anglers spent an average of 71 days fishing in 2016 compared to 69 days in 2015 (Figure 23). Recall that the 2016 Effort totals reflect expanded participation by anglers at all three tiers levels caused by the NPMP's decision to adjust tiers downward beginning in 2015 as a strategy to increase participation.

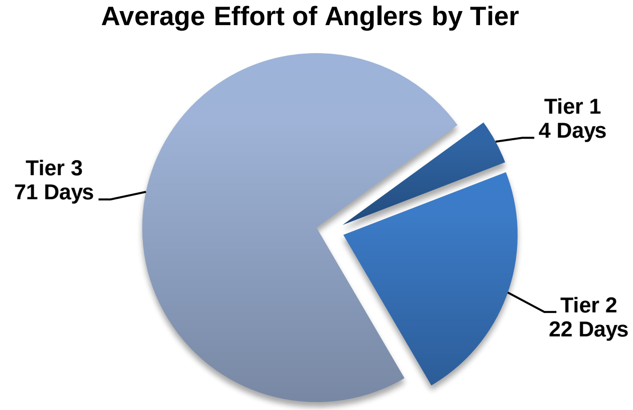


Figure 23. Average Effort of 2016 NPSRF Anglers by Tier (Tier 1 = ≤ 25, Tier 2 = 26-200, Tier 3 = > 200)

Overall angler CPUE for the 2016 NPSRF decreased slightly from 2015 (Winther et al. 2016) while the changes in CPUE at the three tier levels varied. CPUE for anglers at Tier 1 increased from 1.14 in 2015 to 1.23 in 2016 (Figure 24). CPUE for Tier 2 anglers remained the same in 2016 as it had been in 2015 at 3.33 fish per angler day. CPUE for Tier 3 anglers decreased slightly from 15.72 in 2015 to 15.19 in 2016, but it is not unusual for CPUE to go down as additional anglers and increased angler effort are added to the fishery.

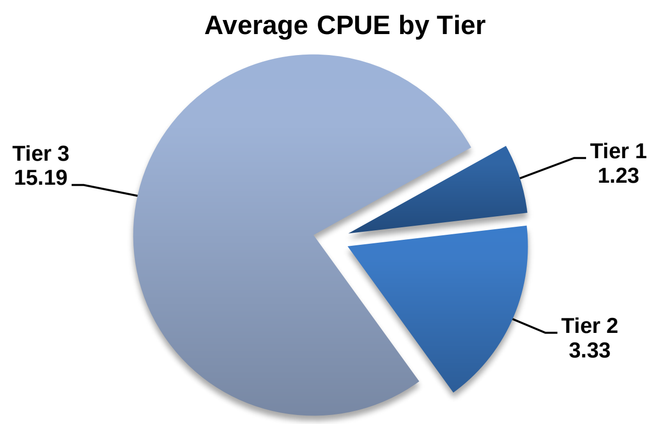


Figure 24. Average CPUE of 2016 NPSRF Anglers by Tier (Tier 1 = ≤25, Tier 2 =26-200, Tier 3 = > 200)

The top individual angler (based on number of fish caught) for the 2016 NPSRF harvested a record number of Northern Pikeminnow (14,019), which also included 12 spaghetti tagged Northern Pikeminnow, and 17 tag-loss Northern Pikeminnow worth a total earnings record of $119,341 (PSMFC 12/12/2016 Angler Reward Payment Summary). The 2016 top angler caught 1,966 more reward sized Northern Pikeminnow than he did as the top angler in 2015, and once again more than doubled the harvest of the second place angler. The CPUE for this year's top angler (128.6 fish per angler day) was up from what he had as the top angler in 2015 (103.9 fish per angler day). The top angler for the 2016 season spent the same number of days of effort (109 days) as he did in 2015 as the top angler. By comparison, the top angler in terms of participation (rather than harvest) for the 2016 NPSRF fished 153 days (100% of available days) and harvested 2,014 Northern Pikeminnow.

Tag Recovery

Northern Pikeminnow Tags

Returning anglers harvested 228 Northern Pikeminnow tagged by ODFW with external spaghetti tags during the 2016 NPSRF compared to 196 spaghetti tags harvested in 2015 (Winther et al., 2016). Tag recoveries peaked during weeks 23 and 24 (vs week 23 in 2015), a full four weeks later than peak NPSRF harvest (Figure 25). All but one of the 228 spaghetti tagged Northern Pikeminnow recovered in the 2016 NPSRF, retained PIT tags added by ODFW as a secondary mark. WDFW technicians also recovered an additional 174 Northern Pikeminnow which had ODFW PIT tags with wounds and/or scars indicating that the fish had "lost" an ODFW spaghetti tag. The recovered spaghetti and PIT tags, as well as the potential tag-loss data was estimated by ODFW to equal a 12.1% exploitation rate for the 2016 NPSRF (Carpenter et al. 2017).

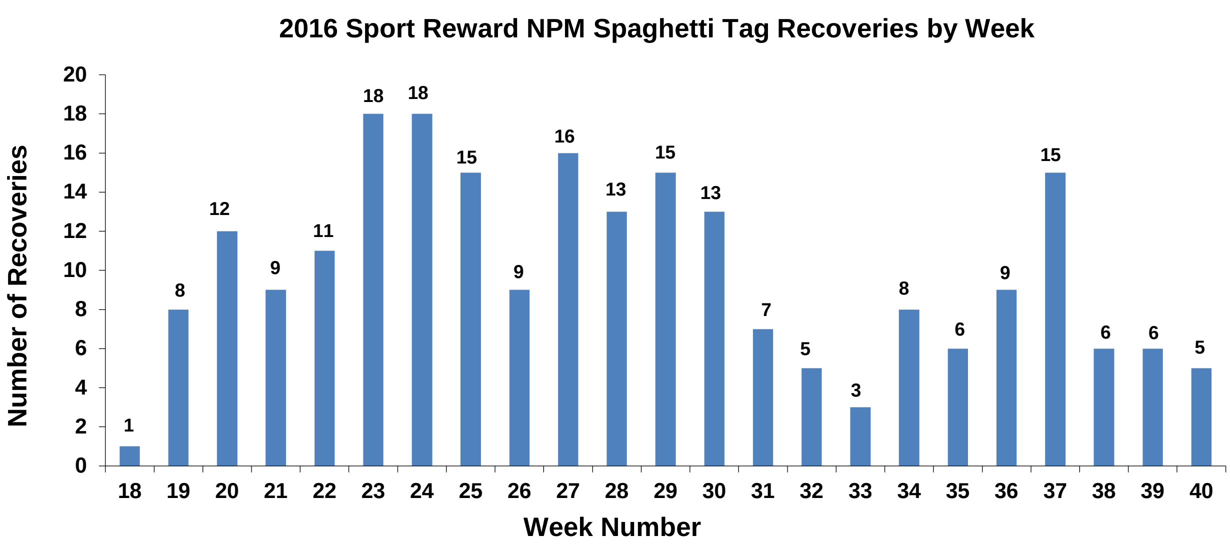


Figure 25. 2016 NPSRF Spaghetti Tag Recoveries by Week

Ingested PIT Tags

A total of 225,350 Northern Pikeminnow were individually scanned for the presence of PIT tags. This represents 100% of the total harvest of reward-size fish for the 2016 NPSRF (Northern Pikeminnow not qualifying for rewards were also scanned whenever possible). Technicians recovered a total of 87 PIT tags from consumed smolts that had been ingested by Northern Pikeminnow harvested during the 2016 NPSRF, an overall occurrence ratio of 1:2,590 compared to 1:1,300 in 2015. Total ingested PIT tag recoveries in 2016 were 67 recoveries lower than the previous year. While total harvest was much higher in 2016 than in 2015, the rate of occurrence for ingested PIT tags fell from 1:1,300 in 2015 to 1:2,590 in 2016 (Winther et al., 2016). PIT tag recoveries of salmonid smolts ingested by Northern Pikeminnow peaked during week 21 of the 2016 season where 21 ingested smolts were recovered (compared to 33 in 2015). Our last recovery occurred during week 36 (August 29th – September 4th) (Figure 26).

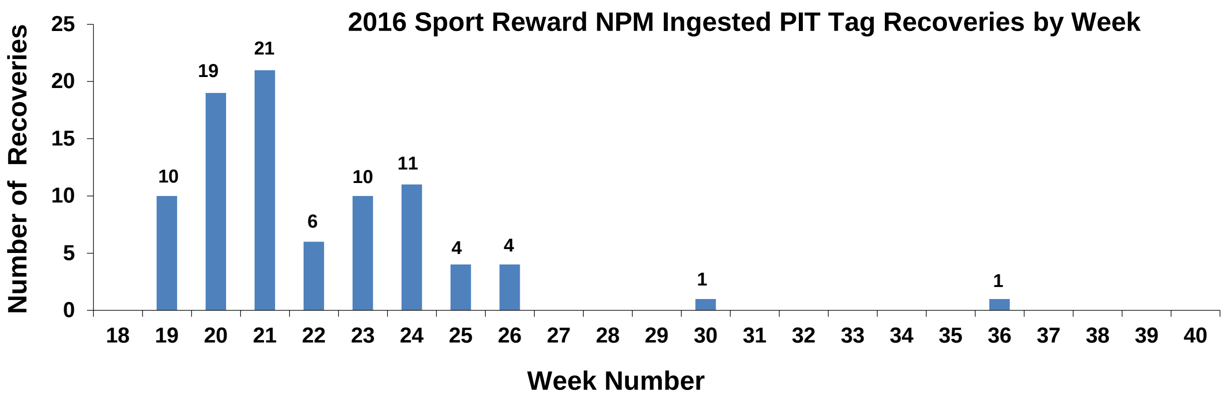


Figure 26. 2016 NPSRF Ingested PIT Tag Recoveries by Week

Ingested PIT tag recoveries by fishing location during the 2016 NPSRF showed that Northern Pikeminnow harvested from fishing location 02 (Bonneville Reservoir) had ingested the largest number of salmonid smolts containing PIT tags (Figure 27).

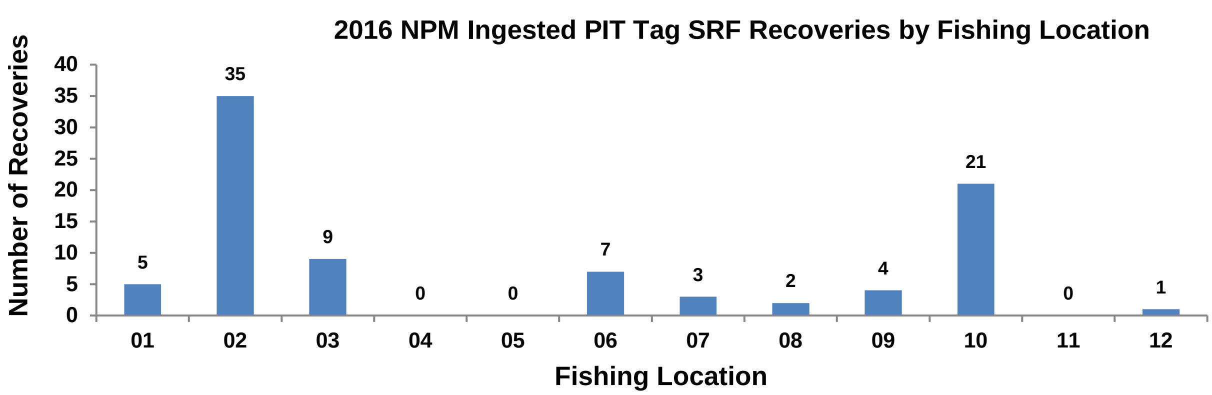


Figure 27. 2016 NPSRF ingested PIT Tag Recoveries by Fishing Location

Fishing Location Codes – **Columbia River**; 01 = Below Bonneville Dam, 02 = Bonneville Reservoir, 03 = The Dalles Reservoir, 04 = John Day Reservoir, 05 = McNary Dam to the mouth of the Snake River, 06 = Mouth of the Snake River to Priest Rapids Dam. **Snake River**; 07 = Mouth of the Snake River to Ice Harbor Dam, 08 = Ice Harbor Reservoir, 09 = Lower Monumental Reservoir, 10 = Little Goose Reservoir, 11 = Lower Granite Dam to the mouth of the Clearwater River, 12 = Mouth of the Clearwater River to Hell's Canyon Dam.

Species composition of PIT tagged smolts ingested by Northern Pikeminnow harvested in the 2016 NPSRF was obtained from PTAGIS and indicated that sixty-eight (78.2%) of the 87 ingested PIT tag recoveries were from Chinook smolts (Figure 27). Fifty-six of the 68 Chinook PIT tags were of hatchery origin (82.4%). PTAGIS queries revealed that these PIT tag recoveries consisted of 21 Spring Chinook, 23 Fall Chinook, 11 Summer Chinook, and 1 unknown hatchery origin Chinook. PIT tag queries revealed that the other 19 non-Chinook PIT tags were from 7 Sockeye, 7 Coho, and 4 Steelhead (1 orphan tag).

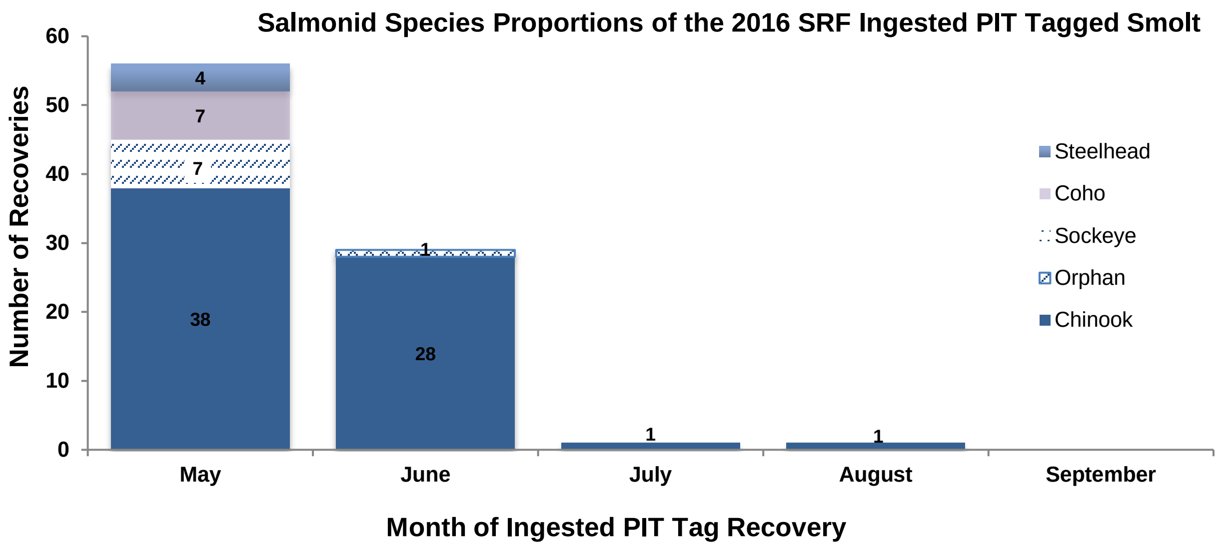


Figure 28. Recoveries of Ingested Salmonid PIT Tags From the 2016 NPSRF

Analysis of PIT tag recovery data from the 2016 NPSRF continues to document actual Northern Pikeminnow predation on downstream migrating juvenile salmonids. 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 2016 NPSRF succeeded in reaching the NPMP's 10-20% exploitation goal for the nineteenth consecutive year, achieving an estimated exploitation rate of 12.1%. NPSRF harvest in 2016 was 25,137 more Northern Pikeminnow than 2015 and more than 61,000 fish higher than in 2014 (prior to the tier system modification). Annual angler effort in 2016 increased by 3,735 angler days (15.5%) over 2015 and has grown by more than 8,000 angler days over the two seasons since the tier modification (19,058 in 2014). The number of individual anglers has increased by 508 new individual anglers in 2016 (15.8%) over 2015, and has increased by 945 new anglers since the tier modification. The updated reward structure has nearly doubled the percentage of Tier 2 and Tier 3 anglers (more proficient anglers) from 16% in 2014 to 29.6% of total successful anglers in 2016. Despite these increases, angler CPUE declined slightly with the influx of new anglers and additional effort. Peak weekly harvest occurred during week 19 (May 2-8), three weeks earlier than in 2015 and seven weeks earlier than the historical 1991-2015 peak harvest in week 26. The Dalles registration station was the NPSRF's top station for harvest in 2016 for the fifth time in the past six years with 41,479 reward sized Northern Pikeminnow harvested, while also recording the most effort with 3,520 angler days of effort spent. We recovered 228 Northern Pikeminnow that were spaghetti tagged by ODFW, and an additional 174 Northern Pikeminnow which were missing spaghetti tags but retained ODFW PIT tags (tag-loss). Mean fork length for Northern Pikeminnow harvested in the 2016 NPSRF was 275.2 mm, down from 277.9 mm in 2015. Incidental catch consisted primarily of Peamouth, Smallmouth Bass, Sculpin, and Yellow Perch (mostly released), and reflected similar catch patterns to previous NPSRF seasons.

For the 2016 NPSRF, several locations stuck out as "Hot Spots" as indicated by high CPUE or harvest rates. These areas included Fishing location 02 (Bonneville Reservoir) where angler CPUE was 17.01 Northern Pikeminnow per angler day, the Bingen, Dalles and Boyer Park registration stations were angler CPUE was 12.87, 11.78, and 11.59 fish per angler day respectively, and the NPSRF's top station (The Dalles) where anglers harvested 41,479 reward sized Northern Pikeminnow. The top angler during the 2016 NPSRF set NPSRF records for the total number of fish caught with 14,019 fish and for earnings with $119,341 in reward payments.

Detection of PIT tags from juvenile salmonids ingested and retained in the gut of Northern Pikeminnow continues to yield valuable data about Northern Pikeminnow predation on juvenile salmonids. The occurrence rate ingested salmonids dropped to 1:2,590 in 2016 and was more in line with occurrence rates seen in previous years. Species composition of the 87 recovered PIT tags again showed that they were primarily from Chinook smolt of hatchery origin. We also recovered PIT tags from ingested Sockeye (7), as well as Coho (7), and Steelhead (4), according to PTAGIS.

RECOMMENDATIONS

1.) Continue to use standardized season dates (May 1st-Sept 30th) for implementation of the 2017 NPSRF in order to enhance promotional opportunities, build angler familiarity, and ultimately to optimize removal of predatory Northern Pikeminnow from within the NPMP program area.

2.) Continue to implement angler incentives such as the $5 base reward level used in 2016 as an incentive designed to recruit new anglers to the 2017 NPSRF. Continue to utilize the lower Tier 2 and Tier 3 levels used in 2016 designed to incentivize current, proficient anglers to expend additional effort participating in the 2017 NPSRF.

   a) Review NPSRF station times and routes for efficiencies which may allow adding additional stations or provide additional angler opportunities for participation.

   b) Continue use of angler clinics, coupons, and sport show booths as tools to recruit new anglers and promote NPSRF awareness.

   c) Continue to develop video content for use in improving angler education, NPMP awareness.

   d) Investigate use of internet and social media for advertising NPSRF and for angler recruitment and education.

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

5.) Continue to scan all Northern Pikeminnow for PIT tags from ingested juvenile salmonids, from Northern Pikeminnow tagged by ODFW as part of the biological evaluation of the NPMP, and as a way to deter fraud by identifying PIT tagged northern pikeminnow coming from outside NPSRF boundaries.

6.) Survey a minimum of 20% of non-returning NPSRF anglers to record non-returning angler catch of Northern Pikeminnow and all salmonids and estimate total catch and harvest of Northern Pikeminnow and all salmonids per NPMP protocol. Analyze and monitor this data to identify any changes in non-returning angler catch trends.

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REPORT B

Northern Pikeminnow Sport-Reward Payments – 2016

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ABSTRACT

Northern Pikeminnow Sport-Reward Program Payments: *PSMFC toprovide 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.*

For 2016 the rewards paid to anglers were the same as in the 2015 season. Anglers were paid $5, $6, and $8 per fish for the three payment tiers (1-25 fish, 26-200 fish and 201 and up) during the season. The rewards for a tagged fish were $500 per fish. 223,192 fish were paid at the standard tiered-reward of $5, $6 and $8 per fish. The season total reward paid for these fish (excluding coupon amounts, tagged fish and tag-loss bonus payments) was $1,644,217.

A total of 227 tagged fish (having an external spaghetti tag) were paid at $500 each. The season total paid for tag rewards was $113,500. A total of 174 tag-loss fish (external spaghetti missing but still possessing a verifiable pit tag) were paid a *bonus* reward of $100. The season total paid for tag-loss *bonus* was $17,400

A total of 961 anglers attached a one-time *$10 bonus coupon* to their reward voucher before submission for payment. The season total paid for *$10 bonus coupons* was $9,610

A total of 1,186 separate successful anglers caught one or more fish and received payments during the season. A total of 3,718 separate anglers registered to fish, of which 31.9% returned vouchers for payment. The total value for all 223,419 Northern Pikeminnow submitted for payment in 2015 (including all coupons, tagged fish and tag-loss *bonus* payments) was $1,784,727.

INTRODUCTION

The **Northern Pikeminnow Sport Reward Program** was administered by PSMFC in 2016. The program is a joint effort between the fishery agencies of the states of Washington (WDFW) and Oregon (ODFW), and the Pacific States Marine Fisheries Commission (PSMFC). WDFW was responsible for the sport-reward registration/creel check stations throughout the river, handled all fish checked in to the program and conducted dam angling at John Day Dam and The Dalles Dam. ODFW provided fish tagging services, population studies, and food habit studies, as well as exploitation rate estimates. PSMFC provided technical administration, and the fiscal and contractual oversight for all segments of the Program and processed all reward vouchers for the sport-reward anglers.

CHANGES FOR THE 2016 SEASON

The 2016 season ran from May 1, 2016 through September 30, 2016.

PSMFC maintained an accounting system during the season to determine the appropriate reward amount due each angler for particular fish. Rewards were paid at $5 for the first 25 fish caught during the season, $6 for fish in the 26-200 range, and $8 for all fish caught by an angler above 200 fish.

ONE-TIME $10 BONUS COUPON

Prior to the opening of the season, coupons were issued to anglers in the pikeminnow database who participated in the program within the past 5 years (2011 – 2015) and to those who signed up for our mailing list at the various sportsmen's shows. The 2016 Coupon was worth a *one-time $10 bonus* when attached to a voucher for qualifying pikeminnow caught and turned in for the reward payment. A total of 961 anglers attached the *one-time $10 bonus coupon* to their reward voucher before submission for payment. The season total paid for *$10 bonus coupons* was $9,610

PARTICIPATION AND PAYMENT

A total of 1,619 anglers who registered were successful in catching one or more fish in 2016. Of those anglers; 1,186 caught one or more fish, submitted their voucher prior to the payment deadline (with no unresolved issues preventing payment) and received payment during the season.

In 2016 a total of 225,350 fish were harvested in the sport-reward fishery. Of this total, 223,419 fish were submitted for payment and paid prior to the 2016 payment deadline (To obtain payment, vouchers must have been received no later than November 15, 2016). In addition, any *received* vouchers with issues preventing payment (missing information, voiding of voucher for program violations, etc.) not resolved by November 15, 2016 also became null and void.

TAGGED FISH AND PAYMENTS

Registered anglers caught and submitted a total of 227 tagged fish (showing an external spaghetti tag) to station technicians. For each tagged fish, the angler was issued a special tag voucher. The tag was placed in a special tag envelope which was stapled to the tag voucher. It was the angler's responsibility to then mail both the tag and voucher to ODFW for verification. Once the tag was verified, the information was forwarded to PSMFC for payment of the special $500 tagged fish reward. The season total paid for tag rewards was $113,500.

TAG-LOSS BONUS PAYMENT

All tagged Northern Pikeminnow initially have both a spaghetti tag and a PIT tag. However, the special $500 tagged fish reward was valid only for fish that still retained the original spaghetti tag. That said; all qualifying Northern Pikeminnow submitted by registered anglers were scanned to check for the presence of a PIT tag. When a PIT tag was detected on a fish with no spaghetti tag, the fish was considered a *standard* fish (and paid at the standard tier rate of $5, $6, and $8 per fish) but was also flagged for verification (by ODFW) of a valid program PIT tag. Upon positive confirmation by ODFW; the angler was then sent an additional $100 *bonus* check and congratulatory letter which included the tagging date and approximate area of release. A total of 174 tag-loss fish qualified for and were paid the *bonus* reward of $100. The season total paid for tag-loss *bonus* was $17,400

TOTAL ACCOUNTING

Total payments for the season of regular vouchers, *$10 bonus coupons*, tag vouchers and *tag-loss bonus* payments was $1,784,727.

All IRS Form 1099-MISC Statements were sent to the qualifying anglers for tax purposes in the fifth week of January, 2017. Appropriate reports and copies were provided to the IRS by the end of February, 2017.

A summary of the catch and rewards paid is provided in Table 1. For further information contact Steve Williams, PSMFC, Field Programs Administrator at (503) 595-3100 or email at swilliams@psmfc.org

2016 SPORT REWARD PAYMENTS SUMMARY

	Fish	Incentives	Reward
Fish paid @ tier 1 ($5 each):	16,507	-	$82,535
Fish paid @ tier 2 ($6 each):	45,899	-	$275,394
Fish paid @ tier 3 ($8 each):	160,786	-	$1,286,288
Tags paid (@ $500 each):	227	-	$113,500
Coupons issued (@ $10 each):	-	961	$9,610
Tag-loss issued (@ $100 each):	-	174	$17,400
Total:	223,419		$1,784,727

Anglers @ tier 1	*713*
Anglers @ tier 2	*289*
Anglers @ tier 3	*184*
Number of separate anglers	*1,186*
Anglers with 10 fish or less:	*551*
Anglers with 2 fish or less:	*255*

	Total Fish	$500 Tags	Tag Loss Tags	Coup.	Total Reward Paid
1.	14,019	12	$1,700	$ 10	$ 119,341
2.	6,625	5	$ 200	$ 10	$ 55,245
3.	6,389	4	$ 500	$ 10	$ 53,165
4.	5,561	7	$ 300	$ 10	$ 47,817
5.	4,688	4	$ -	$ 10	$ 39,057
6.	4,184	8	$ 200	$ 10	$ 37,193
7.	4,181	5	$ 100	$ 10	$ 35,593
8.	3,987	4	$ -	$ 10	$ 33,449
9.	3,919	0	$ 400	$ 10	$ 31,337
10.	3,868	16	$ 900	$ 10	$ 39,301
11.	3,501	2	$ 300	$ 10	$ 28,877
12.	3,006	3	$ 200	$ 10	$ 25,309
13.	2,981	4	$ 400	$ 10	$ 25,801
14.	2,942	0	$ 100	$ 10	$ 23,221
15.	2,681	2	$ 200	$ 10	$ 22,217
16.	2,588	2	$ 200	$ 10	$ 21,473
17.	2,578	1	$ -	$ 10	$ 20,701
18.	2,533	3	$ 300	$ 10	$ 21,625
19.	2,486	3	$ 200	$ 10	$ 21,149
20.	2,274	1	$ 200	$ 10	$ 18,469
	84,991	86	$6,400	$ 200	$ 720,340

Report C

System-wide Predator Control Program: Fisheries and Biological Evaluation

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ABSTRACT

Since 1990, the Northern Pikeminnow Management Program (NPMP) has applied targeted removal fisheries in the Columbia and Snake rivers to restructure populations of Northern Pikeminnow *Ptychocheilus oregonensis* in an effort to reduce predation on out-migrating juvenile Pacific salmon and steelhead *Oncorhynchus* spp. During 2016, the Oregon Department of Fish and Wildlife evaluated the continued efficacy of the program and assessed potential outcomes of the fisheries through a combination of field and laboratory activities and data analyses. This report augments historical information with current data and seeks to 1) estimate rates of exploitation of Northern Pikeminnow; 2) quantify the potential reduction in predation of juvenile salmonids resulting from the targeted removal fisheries; 3) characterize population parameters of Northern Pikeminnow, Smallmouth Bass *Micropterus dolomieu* and Walleye *Sander vitreus* in four Snake River reservoirs; and 4) assess evidence of possible intra- and inter-specific compensatory responses by Northern Pikeminnow, Smallmouth Bass, and Walleye related to the sustained removal of Northern Pikeminnow from the lower Columbia and Snake rivers. To quantify exploitation during 2016, we used standardized boat electrofishing to tag and release Northern Pikeminnow throughout the lower Columbia and Snake rivers. Tags recovered in the NPMP Sport Reward Fishery were used to calculate exploitation rates for Northern Pikeminnow in the area covered by program implementation. Analyses of recaptures indicated that system-wide exploitation of Northern Pikeminnow greater than or equal to 250 mm FL in the Sport Reward Fishery during 2016 was 12.1% (95% confidence interval, 9.7-14.5%). This value was within the NPMP targeted range of 10-20%. Based on this level of exploitation, we estimate 2017 predation levels to be 29% (range: 16-44%) lower than pre-program levels. Model projections assuming continuation of the current fishery, population structure, and mean rates of exploitation suggest predation on juvenile salmon by Northern Pikeminnow will remain at a relatively stable reduced level through 2020. Predation behavior by Northern Pikeminnow caught in the Dam Angling Fishery in the Bonneville and The Dalles reservoirs was similar to previous years with the greatest consumption of juvenile salmonids, lamprey, and American Shad *Alosa sapidissima* coinciding with their respective outmigration peaks. Northern Pikeminnow caught and removed during the Dam Angling Fishery continue to be larger than the fish caught in the Sport Reward Fishery. Abundance index estimates for 2016 in most areas of Snake River reservoirs indicate a continued decrease since the early 1990s in Northern Pikeminnow greater than or equal to 250 mm FL, though large increases were observed in the Little Goose reservoir. Overall, highly variable abundance, consumption, and predation index values for the predators considered in our study provide no obvious indication of a long term compensatory response to the targeted removal of Northern Pikeminnow. Yet, given the dynamic nature of these systems (both biotic and abiotic), we encourage continued monitoring efforts to assess trends in predator populations throughout the Columbia and Snake rivers to help elucidate potential local and system-wide effects.

INTRODUCTION

The Columbia and Snake rivers once supported large numbers of naturally produced anadromous Pacific salmon *Oncorhynchus* spp. Declines in adult returns have been attributed to factors including habitat degradation and overexploitation (Nehlsen et al. 1991; Wismar et al. 1994), hydroelectric and flood control activities (Raymond 1988), and predation on out migrating juveniles (Rieman et al. 1991; Collis et al. 2002). Escalating concern in the 1980s surrounding the impacts of predation on juvenile salmon prompted researchers to examine more closely the degree to which predation by resident fishes in particular may constrain juvenile salmon survival in the Columbia River Basin. To this end, the John Day Reservoir in the Columbia River was selected as a "model" system to test several hypotheses given: (1) the reservoir was known to be an important area for rearing of subyearling Chinook Salmon *Oncorhynchus tsawytscha*, (2) passage and residualism of juvenile salmonids was considered an issue in the reservoir, and (3) John Day reservoir supported substantial populations of resident predatory fishes (Poe and Rieman 1988). Based on information existing at that time (i.e., Hjort et al. 1981), four species – Smallmouth Bass *Micropterus dolomieu*, Walleye *Sander vitreus*, Channel Catfish *Ictalurus punctatus*, and Northern Pikeminnow *Ptychocheilus oregonensis* – were identified as potentially important sources of juvenile salmon mortality. Ultimately, research in John Day Reservoir provided evidence that of the species considered, Northern Pikeminnow was the most abundant and dominant predator on juvenile salmon, accounting for 78% of the predation-related mortality observed during the study period (Beamesderfer and Rieman 1991; Poe et al. 1991; Rieman et al. 1991).

While data indicated predation by Northern Pikeminnow contributed appreciably to juvenile salmon mortality in John Day reservoir, questions remained surrounding impacts of Northern Pikeminnow predation in other areas of the lower Columbia and Snake rivers. To elucidate these questions, indices were developed to allow rapid assessment of the extent of predation by Northern Pikeminnow throughout the system. From 1991 through 1993, researchers applied these indices to data collected in other Columbia River reservoirs (1990 and 1993), the Columbia River downstream of Bonneville Dam (1991), and several Snake River reservoirs (1992) to characterize abundance, consumption, and predation (Ward et al. 1995). Results from these evaluations showed, although variable in time, predation by Northern Pikeminnow on juvenile salmonids was problematic in areas throughout the lower Columbia and Snake River reservoirs. With the extent of the issue identified, work was conducted to further examine management strategies that could limit predation based on the thesis that even modest exploitation of Northern Pikeminnow (i.e., 10-20%) could precipitate a disproportionate reduction in predation (i.e., up to 50%; Rieman and Beamesderfer 1990). Ultimately, assessments of various management strategies identified targeted removal fisheries as a favorable option to address this issue and provided the foundation for the contemporary Northern Pikeminnow Management Program (NPMP).

From its inception, the NPMP has operated based on two underlying objectives: (1) implementation of the predator control program (see reports A, B, and D) and (2) evaluation of the predator control strategy. To address the latter objective, researchers from the Oregon Department of Fish and Wildlife (ODFW) have sampled standardized areas since the early 1990s in the Columbia and Snake rivers to evaluate the efficacy of targeted removals to reduce predation and assess possible compensatory consequences of the program (e.g., intra- and inter-specific responses to management actions) that may be related to sustained removals of Northern Pikeminnow. This report augments historical information with data collected during 2016 in areas of the Columbia and Snake rivers and, wherever possible, evaluates temporal and spatial changes. Specific goals for this reporting period were to:

(1) estimate rates of exploitation of Northern Pikeminnow and quantify potential reduced predation resulting from the targeted removal fisheries;
(2) characterize population parameters of Northern Pikeminnow, Smallmouth Bass, and Walleye in Ice Harbor, Lower Monumental, Little Goose, and Lower Granite reservoirs; and
(3) assess evidence of possible intra- and inter-specific compensatory responses by Northern Pikeminnow, Smallmouth Bass, and Walleye related to the sustained removal of Northern Pikeminnow from the lower Columbia and Snake rivers.

METHODS

Sampling during 2016 was conducted using Smith-Root™ 18-EH model electrofishing boats equipped with a 5.0 or 7.5 generator powered pulsator electrofisher powered by either a Kohler Power Systems™ or Briggs and Stratton™ gas generator. When engaged, the electrofishing unit applies pulsed direct current (DC) at a rate of 60 pulses/s; pulsed DC is applied to maximize capture efficiency with minimal injury to fish. Boats are configured with anodes suspended from two boom arms extending forward from the bow. Each boom arm supports a single array composed of six electrodes, while the boat hull functions as the cathode. Electrofishing controls are set according to federal guidelines where peak output does not exceed 800 V at water conductivity 100 to 300 µS/cm (NMFS 2000). The targeted average current during all electrofishing events was 3 – 4 A. All controls were standardized across boats with minor adjustments to the duty cycle to achieve target output. Program electrofishing protocols were developed to minimize fish exposure to electric current to induce electrotaxis (uncontrolled convulsion which causes a fish to swim toward the anode) while avoiding tetany (when a fish becomes stiff). Additionally, protocols to limit interactions with species listed under the Endangered Species Act (ESA) guide sampling efforts.

Sport Reward Fishery Evaluation and Predation Reduction Estimates

Field Procedures

To address our first objective, we tagged Northern Pikeminnow and estimated exploitation rates with tag recovery data from the Sport Reward Fishery. Northern Pikeminnow were collected using boat electrofishing in the Columbia River from river kilometer (rkm) 76 (near Clatskanie, Oregon) upstream to rkm 637 (Priest Rapids Dam) and in the Snake River from rkm 81 (Little Goose Dam) to rkm 256 upstream of Lower Granite Dam (Figure 1). Four sampling events consisting of 900 seconds of electrofishing effort were conducted within each river kilometer. The efficacy of boat electrofishing tends to be limited to a maximum depth of approximately 3 m; thus, sampling was conducted primarily along shallow shoreline areas. Sampling occurred from 6 April to 23 June 2016 between 1800 and 0500 hours, except in the Hanford Reach of the Columbia River (rkm 557–637), where safe river navigation necessitated daytime sampling. A total of 27 rkm in the Columbia River were not sampled due to weather related constraints. Sampling plans were adjusted in the field to ensure, to the extent possible, weather related sampling disruptions affected only sampling in areas with historically low catch rates. Ideally, all tagging would be performed prior to the start of the Sport Reward and Dam Angling fisheries, but due to time constraints this was unachievable. All fish captured downstream of John Day Dam (rkm 306) were tagged prior to the start of the fisheries (1 May 2016). Upstream of John Day Dam, Northern Pikeminnow were tagged concurrent with the fisheries.

We tagged, and subsequently released Northern Pikeminnow ≥ 200 mm fork length (FL) with uniquely numbered Floy FT-4 lock-on external loop tags. Each loop tag was inserted through the pterygiophores just below the midpoint of the dorsal fin. All loop-tagged fish were also marked with a 134.2 MHz passive integrated transponder (PIT) tag inserted into the dorsal sinus.

Working with the Washington Department of Fish and Wildlife (WDFW), tag recovery information was obtained from the Sport Reward and Dam Angling fisheries. The Sport Reward Fishery occurred daily from 1 May to 30 September 2016 (see Report A). Participating anglers received payment for all harvested Northern Pikeminnow greater than or equal to 230 mm (9 in) total length (TL). This size criterion for total length corresponds approximately to the minimum FL (200 mm) of Northern Pikeminnow marked during tagging operations. The reward payment schedule consisted of three tiers (see Report B for details). Further, anglers were eligible for a $500 reward for each external loop tagged fish returned to a check station and a $100 reward for each “tag-loss” fish (i.e., those fish for which an external tag had been lost in the environment, but a functioning PIT tag remained present). Given this, we assumed 100% of the Northern Pikeminnow marked with an external and/or an internal PIT tag removed from the fishery were submitted to a check station for reward payment.

In addition to the Sport Reward Fishery, an NPMP-administered Dam Angling Fishery (see Report D for details) was conducted from 3 May to 18 August 2016 in the powerhouse tailrace areas of The Dalles (sampling Bonneville reservoir) and John Day (sampling The Dalles reservoir) dams. A team of anglers used hook-and-line gear to remove Northern Pikeminnow; all fish were examined for presence of external loop and internal PIT tags. Tagged Northern Pikeminnow removed in this fishery were accounted for when estimating exploitation rates for the Sport Reward Fishery (see Data Analysis).

Data Analysis

The proportion of the Northern Pikeminnow population removed during program fisheries was quantified using mark-recapture data for both continuous zones separated by dams (area-specific) and the entire area sampled (system-wide). To account for a reduction in the minimum length of Northern Pikeminnow eligible for sport-reward payment from 11 in TL (≥ 278 mm TL; ≥ 250 mm FL) to 9 in TL (≥ 230 mm TL; ≥ 200 mm FL) beginning in the year 2000, rates of exploitation were calculated for three size-classes: 1) ≥ 200 mm FL (all tagged fish), 2) 200-249 mm FL, and 3) ≥ 250 mm FL. The subset of fish ≥ 250 mm FL was used for long-term temporal comparisons.

To control the introduction of known bias into area-specific estimates of annual exploitation, we applied two different models: one for areas where Northern Pikeminnow were tagged prior to the beginning of the Sport Reward Fishery and a second for areas where tagging occurred during the fishery (Styer 2003). Under each of these scenarios, rates of exploitation were estimated only for those areas where the number of recaptured Northern Pikeminnow was greater than three. When tagging was completed before the start of the fishery, we calculated the rate of exploitation (u) of the population using the Petersen estimator (Ricker 1975) as:

$$u_j = \frac{R_j}{M_j}, \tag{1}$$

where

R_j = the number of tagged fish recaptured during the season in area j, and
M_j = the number of fish tagged in area j.

Beginning in 2014, the NPMP incentivized the return of tag-loss Northern Pikeminnow. Thus, unlike during earlier years of the program, a correction for tag retention was not necessary to estimate 2016 exploitation rates.

Confidence intervals (95%) for exploitation estimates were calculated using the normal approximation to a Poisson random variable as:

$$u_j \pm \frac{z \times \sqrt{R_j}}{M_j}, \quad (2)$$

where

z = a multiplier from the standard normal distribution,
R_j = as described above, and
M_j = as described above.

When tagging and fishing efforts occurred concurrently, each week was treated as a separate sampling period according to the function:

$$u_{weekly_j} = \frac{R_{ij}}{M_{ij}}, \quad (3)$$

where

R_{ij} = the number of tagged fish recaptured in area j during the i^{th} week, and
M_{ij} = the number of marked fish at large in area j at the beginning of the i^{th} week of the Sport Reward Fishery.

To account for positive bias associated with insufficient mixing, for the few instances where fish were captured during the same week in which they were released, we excluded those recaptures from the analysis.

The magnitude of negative bias associated with exploitation rates calculated using the Petersen estimator can be ambiguous when tagging and fishing are conducted concurrently (Styer 2003). To minimize uncertainty surrounding estimates of system-wide annual rates of exploitation, we applied a multiple sample approach as follows:

$$u_{annual_j} = \sum_{i=1}^{n_j} \frac{R_{ij}}{M_{ij}}, \quad (4)$$

where

n_j = the number of weeks in the season in area j,
R_{ij} = as described above, and
M_{ij} = as described above.

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

$$u_{annual_j} \pm t \times \sqrt{n_j} \times s_j, \tag{5}$$

where

t = a multiplier from the Student's *t*-distribution for *k - 1* degrees of freedom,
s_j = the standard deviation of the weekly exploitation estimates for area *j*, and
n_j = as described above.

We applied a model based on Friesen and Ward (1999) to estimate current predation on juvenile salmon relative to predation before the implementation of the program. The model estimates potential predation reduction from pre-program levels by incorporating: (1) Northern Pikeminnow population size structure before removals by fisheries, (2) area- and size-specific annual exploitation rates, (3) an estimate of natural mortality, (4) area- and size-specific abundance estimates, and (5) area-specific estimates of consumption of juvenile salmon by specific size classes of Northern Pikeminnow. Based on estimated levels of abundance and consumption for the current year, the model estimates system-wide total annual loss of juvenile salmon to Northern Pikeminnow predation in the following year and compares those losses to pre-program levels. As such, the model assumes removal of Northern Pikeminnow until October of the current year will be realized in reduced predation on out migrating juvenile salmon in spring and summer of the following year. A ten-year mean age-structure (based on catch curves) was applied for a pre-program baseline and constant recruitment was assumed. Since its development, the model has been revised to include FL increments derived from annual mark-recapture growth observations rather than growth estimates obtained from length and age data. Given these inputs, the model predicts changes in potential predation that were directly related to removals, if all other variables remain constant. We estimate the potential predation during 2017 based on observed exploitation rates from 2016 and predict three future predation rates (maximum, median, and minimum) using the mean level of exploitation observed during contemporary program rules (2001; 2004–2016). Additional model documentation is described in Friesen and Ward (1999).

To test for differences in the size of Northern Pikeminnow captured in the 2016 Sport Reward versus the Dam Angling fisheries, we applied area-specific ordinary least-squares models ('lm' in package 'stats'; R Core Team 2013) to FL data using the R programming environment (R Core Team 2013). In this way, lengths of Northern Pikeminnow captured in the Dam Angling Fishery at The Dalles Dam were compared to lengths of fish harvested in the Sport Reward Fishery in Bonneville Reservoir, and lengths of Northern Pikeminnow captured at John Day Dam were compared to lengths of fish harvested in the Sport Reward Fishery in The Dalles Reservoir. A review of model assumptions ('modelAssumptions' in package 'lmSupport'; Curtin 2016) showed residuals from each model were non-normal and suffered from heteroscedasticity. We log transformed the data to correct for non-normality and applied corrected variance-covariance matrices ('hccm' in package 'car'; Fox and Weisberg 2011) to account for non-constant variance.

Biological Evaluation

Field Procedures

We used standardized boat electrofishing techniques (Ward et al. 1995; Zimmerman and Ward 1999) to evaluate Northern Pikeminnow, Smallmouth Bass, and Walleye population parameters in Ice Harbor, Lower Monumental, Little Goose, and Lower Granite reservoirs. Early morning (0200–1200 hours) sampling was conducted during spring (10 May–25 May 2016) in areas of Ice Harbor (forebay, rkm 16-23; mid-reservoir, rkm 28-39; and Lower Monumental Dam tailrace, rkm 60-67), Lower Monumental (forebay, rkm 67-72; mid-reservoir, rkm 92-100; and Little Goose Dam tailrace, rkm 105-112), Little Goose (forebay, rkm 112-120; mid-reservoir, rkm 128-136; and Lower Granite Dam tailrace, rkm 165-172), and Lower Granite (upper-reservoir, rkm 219-228) reservoirs. Randomly selected fixed-site transects, approximately 500 m long, in each reservoir area were sampled along both shores of the river. Effort at each transect consisted of a 15-min (900-s) electrofishing period with continuous output of approximately 4 A. Summer sampling in Ice Harbor Reservoir and the forebay of Lower Monumental Reservoir (scheduled for 5-9 July 2016) was not conducted because shoreline water temperatures exceeded 18°C– an environmental threshold specified in federally assigned scientific collection permits (NMFS 2000). Additionally, a similar situation occurred in that location in 2013, therefore, Ice Harbor reservoir was revisited in 2014 for make-up sampling. These data were not presented in the 2014 report and thus are presented in this report in addition to the 2016 data.

We recorded catch and biological data for all Northern Pikeminnow, Smallmouth Bass, and Walleye collected. Fork length (nearest mm) and mass (nearest 10 g) were measured for all fish collected. Scale samples were removed from 25 fish per 25-mm FL increment for all three species in all reservoirs. All untagged Northern Pikeminnow greater than or equal to 200 mm FL were sacrificed and digestive tracts were collected for subsequent analyses. Digestive tracts were removed by securing both ends with hemostats and pulling free of connective tissue. External tissue was then removed and digestive tracts were placed in sample bags for storage. Whenever possible, we recorded sex and stage of maturity for each sacrificed fish. Stomach contents from Smallmouth Bass and Walleye greater than or equal to 200 mm FL were collected by non-lethal gastric lavage using a modified Seaburg sampler (Seaburg 1957). Contents from the foregut of each fish were flushed into a 425-µm sieve and then transferred into individual sample bags. All samples were stored on ice while in the field and then transferred to a freezer until analysis in the laboratory.

Using the protocol described above, we also collected digestive tracts from Northern Pikeminnow captured during the 2016 Dam Angling Fishery of the NPMP. Digestive tracts were collected from a representative subsample of catches at each dam weekly from 3 May to 18 August 2016, generally three days per week. In addition, morphometric (FL and mass), sex, and maturity data were collected for each fish sampled.

Laboratory Procedures

We examined the contents of digestive tracts from Northern Pikeminnow, Smallmouth Bass, and Walleye collected during biological evaluation of the Sport Reward Fishery, and Northern Pikeminnow collected during the Dam Angling Fishery to quantify relative consumption of juvenile salmon. Due to the large number of Smallmouth Bass diet samples collected during the biological evaluation of the Sport Reward Fishery, a random subsample of approximately 30 guts from each sampling area/season combination were processed in the laboratory. If less than 30 Smallmouth Bass gut contents were collected for a given area/season, then all samples were processed in the laboratory. All Northern Pikeminnow and Walleye gut contents were processed in the laboratory. For 2016, 503 Smallmouth Bass, 84 Walleye, and 58 Northern Pikeminnow gut contents were processed. Due to the large number of Northern Pikeminnow collected during the Dam Angling Fishery, a random subsample of approximately 11 guts from each dam/sample day combination were processed in the laboratory. If less than 11 samples from a given dam and day were available, all samples from that dam and day were processed in the laboratory. For 2016, 889 Northern Pikeminnow diet samples were processed from the Dam Angling Fishery.

Frozen field samples were thawed in the laboratory and the contents sorted into general prey categories (i.e., fish, crayfish, other crustaceans, insects and other invertebrates, and miscellaneous). Parasitic invertebrates (e.g., tapeworms) found in the gut contents were noted in the comments, but not weighed or categorized as prey items. Material was weighed (blotted wet mass) to the nearest 0.01 g according to prey category. For Smallmouth Bass and Walleye, portions of stomach contents containing fish hard structures (e.g., bones, otoliths), tissue, or other possible fish remnants were then returned to the original sample bags for chemical digestion to allow for further determination of prey fish taxa. To ensure complete recovery of diagnostic structures from Northern Pikeminnow diet samples, entire gastrointestinal tracts were digested along with fish parts. To digest soft tissues, a 20-ml solution of pancreatin and sodium sulfide nonahydrate (Na_2O_9S) – mixed at 20 g/L and 10 g/L with tap water, respectively – was added to each sample. Sample bags were then placed in a desiccating oven at approximately 48°C for 24 hours. After removal from the oven, a 20-ml solution of sodium hydroxide (lye, NaOH; mixed at 30g/L of tap water) was added to samples to dissolve remaining fatty materials. Contents of each bag were then poured into a 425-µm sieve and rinsed with tap water. In some cases, the presence of fish was noted during the initial sorting and weighing, but no diagnostic bones, otoliths, or fish hard parts were found post-cook. When this occurred, it was assumed that those hard parts were lost, and an unidentified fish present was recorded for diet analysis.

Hard parts remaining after chemical digestion were examined to identify prey to the lowest possible taxon under dissecting microscopes using standard keys (Hansel et al. 1988, Frost 2000, and Parrish et al. 2006). Wherever possible, paired structures were enumerated to arrive at minimum counts of a given prey taxon in a diet sample; however, only presence/absence could be evaluated for certain prey items. For example, ventral scutes of American Shad *Alosa sapidissima* were encountered commonly in diet samples. Because the total number of scutes associated with an individual fish is ambiguous, both meristically and because of differential digestion, we assumed one fish had been consumed if no other diagnostic structures were present. The same assumption was made for instances in which lamina of lamprey (family Petromyzontidae) were encountered in stomach contents. Further, for samples where only fish vertebrae were encountered, prey fishes were identified as either salmonid or non-salmonid.

Given these constraints, in addition to comparing the relative size and quality of diagnostic bones encountered, the total numbers of prey fish enumerated in samples were necessarily conservative. Lastly, to calibrate identification accuracy among analysts throughout examination, 10% of all samples were re-analyzed at random by a second reviewer.

Data Analysis

Following the methods of Ward et al. (1995), we calculated seasonal abundance index values for each predator species by summing the seasonal catches and dividing by the total number of standard electrofishing runs, then multiplying the seasonal catch per effort by the surface area (ha) of specific sampling locations in each river reach or reservoir area. We then applied the models of Ward et al. (1995) and Ward and Zimmerman (1999) to calculate consumption index values for Northern Pikeminnow (CI_{NPM}) and Smallmouth Bass (CI_{SMB}) using the formulas:

$$CI_{\text{NPM}} = 0.0209 \times T^{1.60} \times W^{0.27} \times (S \times GW^{-0.61}), \qquad (6)$$

and

$$CI_{\text{SMB}} = 0.0407 \times e^{(0.15)(T)} \times W^{0.23} \times (S \times GW^{-0.29}), \qquad (7)$$

where

T = mean water temperature per season-area stratum (°C),
W = mean predator mass (g),
S = mean number of juvenile salmon per predator, and
GW = mean gut mass (g) per predator.

Although these consumption indices do not provide direct estimates of the number of juvenile salmon eaten per day by an average predator; the output values have been shown to be correlated with consumption rates for Northern Pikeminnow (Ward et al. 1995) and Smallmouth Bass (Ward and Zimmerman 1999). The abundance and consumption indices therefore provide a means to characterize relative predation impacts. We used the product of seasonal abundance and consumption index values to generate period- and location-specific predation index estimates for Northern Pikeminnow and Smallmouth Bass. Currently, no comparable model exists to evaluate Walleye consumption and predation. Consumption index values were calculated only when sample sizes exceeded five fish for a given species and sampling event.

Rates of exploitation of Northern Pikeminnow are believed to increase with increasing fish size (Zimmerman et al. 1995). Thus, sustained fisheries should decrease the abundance of larger fish in the population. With this in mind, we applied a model describing proportional stock density (PSD_i; Anderson 1980) to characterize variation in size structure for Northern Pikeminnow sampled both in the Dam Angling Fishery and during biological evaluation of the Sport Reward Fishery, and Smallmouth Bass and Walleye populations sampled during biological evaluation of the Sport Reward Fishery using the formula:

$$PSD_i = 100 \times \frac{FQ_i}{FS_i}, \qquad (8)$$

where

FQ_i = number of fish ≥ quality length for species i, and
FS_i = number of fish ≥ stock length for species i.

Where possible, we also calculated relative stock density of preferred length fish ($RSD\text{-}P_i$) for Smallmouth Bass and Walleye (Gabelhouse 1984) sampled during biological evaluation using the equation

$$RSD - P_i = 100 \times \frac{FP_i}{FS_i}, \tag{9}$$

where

FP_i = number of fish ≥ preferred length for species i, and
FS_i = number of fish ≥ stock length for species i.

Stock and quality minimum length categories used for Northern Pikeminnow were 250 and 380 mm FL, respectively (Beamesderfer and Rieman 1988; Parker et al. 1995). For Smallmouth Bass, stock, quality, and preferred minimum length categories are considered 180, 280, and 350 mm TL. Because we only measure FL, these minimum values were converted from TL to FL using species-specific models ($FL_{SMB} = TL_{SMB}/1.040$). Stock, quality, and preferred minimum FL categories are 173, 269, and 337 mm, respectively. Similarly, categories for Walleye were: stock 250, quality 380, and preferred 510 mm TL (Willis et al. 1985). These values were also converted to FL values of stock 236, quality 358, and preferred 481 mm using the species-specific model for Walleye ($FL_{WAL} = TL_{WAL}/1.060$). Both *PSD* and *RSD-P* values were calculated only when sample sizes exceeded 19 stock-length fish in a reservoir. To characterize uncertainty (95% confidence intervals) surrounding *PSD* and *RSD-P* values, we applied a non-parametric bootstrap approach using the 'boot' package (Fox and Weisberg 2011) in the R programming environment (R Core Team 2013).

Similar to shifts in size-structure, changes in body condition may indicate a compensatory response by remaining predators to the sustained exploitation of Northern Pikeminnow. We used relative weight (W_r; Anderson and Neumann 1996) to compare the condition of Northern Pikeminnow, Smallmouth Bass, and Walleye in 2016 with previous years. Length-specific standard weights predicted by a length-mass regression model ($\log_{10}(W_s)=a'+b\cdot\log_{10}(L)$) for Northern Pikeminnow (Parker et al. 1995), Smallmouth Bass (Kolander et al. 1993), and Walleye (Murphy et al. 1990) were used to calculate relative weight according to the equation:

$$W_r = 100 \times \frac{W}{W_s}, \tag{10}$$

where

W = the mass of an individual fish, and
W_s = predicted standard weight.

To account for potential sexual dimorphism, we calculated W_r values separately for male and female Northern Pikeminnow. Because sampling methodologies precluded diagnosis of sex for

Smallmouth Bass and Walleye in the field, we did not differentiate among sexes when calculating W_r for these species. As for *PSD* and *RSD-P*, we estimated 95% confidence intervals for W_r values using a non-parametric bootstrap approach (Fox and Weisberg 2011; R Core Team 2013).

Temporal monotonic trends in median W_r for Northern Pikeminnow, Smallmouth Bass, and Walleye were assessed by applying a non-parametric Mann-Kendall test (Mann 1945). To diagnose potential serial dependence among median W_r data, we reviewed autocorrelation functions (acf) and partial autocorrelation functions (pacf) applied to time series objects (R Core Team 2013). If autocorrelation was found to be meaningful, trends were evaluated using a block bootstrap technique (Davidson and Hinkley 1997; McLeod 2011) after applying spline interpolation to account for data gaps. Otherwise, traditional Mann-Kendall tests were conducted. Lastly, to help visualize trends, we fit locally weighted scatterplot smoothing (LOWESS) curves to the data. All analyses were conducted in the R programming environment using the 'Kendall' (McLeod 2011) and, where necessary, the 'boot' or 'tsboot' (Fox and Weisberg 2011) packages. Tests were considered significant at $\alpha = 0.05$.

RESULTS

Sport Reward Fishery Evaluation and Predation Reduction Estimates

We tagged and released 2,466 Northern Pikeminnow greater than or equal to 200 mm FL throughout the lower Columbia and Snake rivers during 2016, of which 1,189 were known to be greater than or equal to 250 mm FL (Table 1). One fish was tagged in The Dalles Reservoir without recording length and thus was not incorporated in calculations of size-specific rates of exploitation. One-hundred sixty Northern Pikeminnow tagged in 2016 were recaptured during the Sport Reward Fishery (Table 1); one tagged Northern Pikeminnow was recaptured during dam angling activities. Of the 160 recaptured fish, two fish recovered in The Dalles Reservoir and three in Little Goose Reservoir were at large for less than one week and thus excluded in analyses of exploitation. Fish tagged in 2016 and subsequently recaptured in the Sport Reward Fishery were at large from 2 to 156 days (mean = 75 d; SD = 42). Sport Reward Fishery recaptures greater than or equal to 250 mm FL accounted for 80% of all 2016 tag recoveries (Table 1). The median length of the Sport Reward Fishery catch was 258 mm FL (E.C. Winther, WDFW, personal communication).

System-wide exploitation of Northern Pikeminnow greater than or equal to 200 mm FL during the Sport Reward Fishery was 7.5% (Table 2). Tag returns were sufficient ($n \geq 4$) to calculate area-specific exploitation estimates for all sampling areas with the exception of The Dalles and John Day pools. For areas that rates could be calculated, values varied from 2.3 to 9.2%. For Northern Pikeminnow within the 200–249 mm FL size class, system-wide exploitation was estimated to be 2.8% (Table 3). Area-specific rates of exploitation for this size class were only estimated for below Bonneville (1.6%), Bonneville (3.8%), Little Goose (4.8%), and Lower Granite Reservoir (2.8%). The system-wide exploitation rate for Northern Pikeminnow greater than or equal to 250 mm FL exceeded those of the other size classes at 12.1% (95% confidence interval 9.7–14.5%; Figure 2). Area-specific exploitation rates of those fish greater than or equal to 250 mm FL were: 11.6% for the Columbia River downstream of Bonneville Dam, 8.9% for Bonneville Reservoir, 4.6% for McNary Reservoir, 24.8% for Little Goose Reservoir, and 14.4% for Lower Granite Reservoir (Table 4).

We applied a model based on Friesen and Ward (1999) to estimate current predation on juvenile salmon relative to predation before the implementation of the program. The model-estimated median reduction in predation on juvenile salmonids relative to pre-program levels for 2016 was 32% (range: 17–49%) and for 2017 will be 29% (range: 16–44%; Figure 3). Model projections based on continuation of the current fishery, population structure, and mean rates of exploitation suggest predation on juvenile salmon by Northern Pikeminnow will remain relatively stable through 2020.

A quasi-t test showed that mean fork lengths of Northern Pikeminnow captured in the 2016 Sport Reward Fishery in Bonneville Reservoir (mean = 278 mm; SD = 59) were significantly less than those of fish captured in the Dam Angling Fishery of the same reservoir (mean = 313 mm; SD = 61; $t = -33.86$, $df = 29731$, $p < 0.01$). Similarly, a quasi-t test showed that mean fork lengths of Northern Pikeminnow captured in the Sport Reward Fishery in The Dalles Reservoir (mean = 319; SD = 60) were significantly smaller than those of fish captured in the Dam Angling Fishery at John Day Dam, the upstream terminus of The Dalles Reservoir (mean = 343; SD = 69; t = -16.35, df = 7372, p < 0.01).

The greater length of individuals caught in the Dam Angling Fishery relative to catches in the Sport Reward Fishery in Bonneville and The Dalles reservoirs is further evidenced by greater stock densities. Proportional stock densities of the Sport Reward catches were 13 and 18 in Bonneville and The Dalles reservoirs respectively compared to 16 and 25 for dam angling catches.

Biological Evaluation

We conducted 328 electrofishing runs during 2016 in the forebay, mid-reservoir, and tailrace sampling areas of Ice Harbor, Little Goose, and Lower Monumental reservoirs and in the upper section of Lower Granite Reservoir to collect fish for biological evaluation (Table 5). We also conducted 38 electrofishing runs during the summer of 2014 in the forebay, mid-reservoir, and tailrace sampling areas of Ice Harbor reservoir, where we were unable to sample during the summer of 2013. Results from 2014 are included in this report. In prior years, sampling was conducted in boat-restricted zones of the forebay and tailraces of many of the reservoirs we sampled. Due to changes in proportions of flows spilled over the dams and logistical constraints maneuvering around bypass outfalls, we have not been able to effectively sample these areas consistently in recent years. Because of this, none of the data from either forebay or tailrace boat-restricted zones across all years are presented in this report. Spring sampling coincided with the end of yearling salmon and steelhead outmigration and summer sampling occurred during the subyearling outmigration as evidenced by smolt passage through Lower Granite, Little Goose, and Lower Monumental dams (Figure 4). During the scheduled summer sampling period (22 June and 9 July 2016), water temperatures in Ice Harbor reservoir and the forebay of Lower Monumental reservoir exceeded the upper threshold prescribed by federal guidelines (i.e., 18 °C; NMFS 2000) to conduct electrofishing for anadromous salmonids and no data were collected.

Across all sample sites, spring 2016 CPUE ranged from 0.00 to 0.22 fish/run for Northern Pikeminnow, 1.65 to 19.86 fish/run for Smallmouth Bass, and 0.00 to 2.00 fish/run for Walleye (Table 6). Across the sites we were able to sample during the summer of 2016, CPUE ranged from 0.00 to 0.25 fish/run for Northern Pikeminnow, 1.45 to 18.88 fish/run for Smallmouth Bass, and 0.00 to 0.25 fish/run for Walleye. Across the sites we sampled in the Ice Harbor Reservoir during the summer of 2014, CPUE ranged from 0.50 to 1.92 fish/run for Smallmouth Bass and 0.00 to 0.08 fish/run for Walleye. No Northern Pikeminnow were caught in Ice Harbor Reservoir during the 2014 summer sampling. Catch rates for Smallmouth Bass were the highest of all species sampled in 2014 and 2016 across all areas sampled. Catch rates for Northern Pikeminnow were greatest in the tailrace area of Little Goose Reservoir and the upper area of Lower Granite Reservoir. For Smallmouth Bass, CPUE was greatest in the tailrace area of Lower Monumental Reservoir in both seasons. Further, in every sampling area, CPUE for Smallmouth Bass was more than 5 times greater than CPUE for Northern Pikeminnow. Walleye were encountered at the highest rate in the mid-reservoir section of Lower Monumental Reservoir and were absent in Lower Granite Reservoir.

Abundance index values calculated for Northern Pikeminnow (≥250 mm FL) in 2016 ranged from 0.00 to 0.08 in Lower Monumental Reservoir, 0.03 to 0.09 in Little Goose Reservoir, and was 0.07 in Lower Granite Reservoir (Table 7). In Ice Harbor Reservoir, abundance index values were 0.00 across all sites. In most areas sampled, estimates were among the lowest calculated since sampling was first conducted in 1991. Exceptions to this occurred in Little Goose Reservoir where the abundance index values for the forebay, mid-reservoir, and tailrace areas in 2016 were greater than the abundance index values of the respective sampling areas in 2010 and 2013. Further, in areas sampled during 2016, abundance index values were below the mean of estimates throughout each time series.

Across all areas sampled during the spring and summer of 2016, Smallmouth Bass abundance index values were greatest in the tailrace area of Lower Monumental Reservoir and lowest in the tailrace area of Little Goose Reservoir (Table 8). Values calculated for 2016 in both the spring and summer seasons were the highest observed since 1991 in Ice Harbor and Lower Monumental reservoirs. In 2014, the abundance index values for all the sampling areas of Ice Harbor Reservoir were less than the mean of the respective estimates since 1991. The abundance index values of Smallmouth Bass in most of the sampling areas have generally increased over time.

In the spring of 2016, Walleye were encountered in all three areas of Ice Harbor Reservoir (Table 9). However, they were absent in the forebay of Lower Monumental Reservoir, all three areas of Little Goose Reservoir, and the upper area of Lower Granite Reservoir. The greatest abundance index observed was in the middler of Lower Monumental Reservoir in spring and summer. The spring value was over 8 times greater than summer. In the summer of 2016, Walleye were only encountered in the mid-reservoir and tailrace areas of Lower Monumental Reservoir and the tailrace area of Little Goose Reservoir. In the summer of 2014, Walleye were only encountered in the tailrace of Ice Harbor Reservoir. Area-specific abundance index estimates for Walleye in 2016 were generally greater than the previous sampling year, especially in the mid-reservoir of Lower Monumental Reservoir. Walleye abundance index values during spring were the highest observed in Ice Harbor and Lower Monumental reservoirs. Walleye were observed in Little Goose Reservoir for the first time since 1991. Whether the two fish observed there are recruits from within the reservoir or swam upstream from Lower Monumental Reservoir is unknown.

We examined contents from the digestive tracts of 57 Northern Pikeminnow captured in Ice Harbor (n = 2), Lower Monumental (n = 11), Little Goose (n = 30), and Lower Granite (n = 14) reservoirs to characterize consumption (Table 10). Across reservoirs and areas, all but three Northern Pikeminnow gut content samples examined contained food items. Fish were the third most numerous diet item after crayfish and insects/other invertebrates in the examined samples in the spring ($\hat{p}$ = 0.33) and in the summer ($\widehat{p}$ = 0.14). No fish prey taxa were identified in samples from Ice Harbor and Lower Monumental reservoirs. Equal frequency of occurrence of salmon and sunfishes (0.07) was observed in Little Goose Reservoir (Table 11). Salmonids were observed most frequently in samples from Lower Granite Reservoir (0.21).

From the 2016 biological evaluation, we examined 450 spring and 336 summer diet samples from Smallmouth Bass in the lower Snake River reservoirs with large proportions of the diets containing prey items ($\hat{p}_{\text{Spring}}$ = 0.86, $\hat{p}_{\text{Summer}}$ = 0.93). Salmonids made up only 0.05 and < 0.01 of the proportion of diet of samples taken for spring and summer evaluations, respectively. Sand

Rollers *Percopsis transmontana* (Percopsidae) were the greatest represented taxon in diets containing fish for Smallmouth Bass, particularly in Little Goose ($\hat{p}$ = 0.17) and Lower Granite reservoirs ($\hat{p}$ = 0.39).

We collected 84 Walleye diet samples from Ice Harbor, Lower Monumental, and Little Goose reservoirs. As was found for Smallmouth Bass, a large proportion of samples collected in spring and summer contained prey items ($\hat{p}_{Spring}$ = 0.93, $\hat{p}_{Summer}$ = 1.00). Fish material was found in proportions of 0.27 in spring and 0.56 in summer samples. Proportions of all diet samples containing salmonids were 0.18 in Ice Harbor (n=11), 0.10 in Lower Monumental (n=71), and 0.50 in Little Goose (n=2) reservoirs. Salmonids were the only fish taxon present in Walleye diets in three reservoirs. Sunfishes were an important prey item in Ice Harbor Reservoir ($\hat{p}$ = 0.18) and minnows were observed in both of the two walleye sampled in Little Goose Reservoir.

Seasonal area-specific consumption and predation indices were not evaluated for Northern Pikeminnow in any reservoir sampled in 2014 or 2016 due to sample size constraints (i.e., $n \leq 5$; Tables 12 and 13). Low sample sizes of Northern Pikeminnow in the lower Snake River reservoirs are a result of low index catch rates that may be a result of lower population abundance.

We collected sufficient information to calculate consumption indices for Smallmouth Bass in all areas sampled with the exception of mid-reservoir Ice Harbor in 2014 (Table 14). Consumption index values for Smallmouth Bass sampled during the spring of 2016 was 0.04 for all areas sampled in Ice Harbor, ranged from 0.00 to 0.13 in Lower Monumental, from 0.00 to 0.18 in Little Goose, and was 0.08 in Lower Granite reservoirs. Summer 2016 values were 0.00 in all areas sampled with the exception of Little Goose forebay at 0.03. Summer 2014 values were also 0.00 for the forebay and tailrace of Ice Harbor Reservoir. Predation index values for Smallmouth Bass sampled during the spring of 2016 ranged from 0.22 to 0.59 in Ice Harbor, 0.00 to 1.04 in Lower Monumental, 0.00 to 2.34 in Little Goose, and was 0.35 in Lower Granite reservoirs (Table 15). Six of the ten spring values were the highest observed since 1991. Summer predation index values were 0.00 across all areas sampled in 2016, with the exception of 0.84 for the Little Goose forebay. Ice Harbor Reservoir summer 2014 values were 0.00 for the forebay and tailrace and two few samples were collected to calculate a value for mid-reservoir.

We were unable to calculate *PSD* for Northern Pikeminnow for 2014 or 2016 due to sample size constraints ($n_s \leq 19$; Table 16). In Little Goose Reservoir, seven stock-length fish were encountered. One quality-length fish was encountered in both Lower Granite and Lower Monumental reservoirs, where the number of stock-length fish were five and two fish respectively. No Northern Pikeminnow were captured in Ice Harbor Reservoir during biological evaluation in either 2014 or 2016.

In 2014, a large increase in *PSD* and *RSD-P* for Smallmouth Bass was observed (48% and 13% respectively; Table 17; Figures 5 and 6). For Ice Harbor in 2016, *PSD* was much lower compared to previous years. *PSD* and *RSD-P* of Smallmouth Bass were highest in Little Goose Reservoir at 19% and 4% respectively. The remaining three reservoirs had relatively similar *PSD* and *RSD-P*; these values were the lowest documented for these reservoirs since monitoring began in 1991.

Smallmouth Bass *PSD* values in 2016 were 9% in Ice Harbor, 7% in Lower Monumental, 19% in Little Goose, and 5% in Lower Granite reservoirs. In 2014, Smallmouth Bass *PSD* was 48% in Ice Harbor, the highest observed in that reservoir. *PSD* values for Smallmouth Bass in the lower Snake River reservoirs have been variable through time and 2016 values are relatively low compared to historical values. Across time, *PSD* values for Smallmouth Bass in the lower Snake River reservoir displayed no obvious trends (Figure 5). Estimates of *RSD-P* for Smallmouth Bass were high in 2014 in Ice Harbor reservoir at 13%, the highest observed in the lower Snake River reservoirs. All reservoirs in 2016 had relatively low *RSD-P*, consistent with estimates calculated since 1991 (Figure 6).

No *PSD* or *RSD-P* values were calculated in 2014 or 2016 in any lower Snake Reservoir for Walleye due to sample size constraints (Table 18). The single Walleye captured in 2014 from Ice Harbor Reservoir was preferred length. No quality-length Walleye were caught in Little Goose Reservoir during 2016. In 2016, Ice Harbor had two quality and one preferred length Walleye. Two quality length Walleye were encountered in Lower Monumental Reservoir.

Although statistical significance of trends in *PSD* values calculated based on the lengths of Northern Pikeminnow subsampled from the Dam Angling Fishery for diet analyses was not tested directly, estimates since the inception of the NPMP for each dam appear to exhibit a long-term decrease (c.f., 1990–1995 and 2006–2016; Figure 7). Estimates for Northern Pikeminnow *PSD* in Bonneville Reservoir (i.e., The Dalles Dam) in the first years of removals at the dams were around 70-80%. During that early period, estimates for *PSD* in The Dalles Reservoir (i.e., John Day Dam) were more variable. Since 2006, *PSD* estimates for both reservoirs have steadily declined, to levels of 30% in Bonneville and 38% in The Dalles reservoirs.

Median relative weight (W_r) for male Northern Pikeminnow in Ice Harbor was higher in 2016 than previously seen (W_r = 106), although this was only for one observation (Figure 8). Analyses of the trends over time indicated there were no significant monotonic trends for either male (Mann-Kendall τ = 0.333, p = 0.734) or female (Mann-Kendall τ = 0.667, p = 0.308) Northern Pikeminnow in Ice Harbor. In Lower Monumental Reservoir, median relative weight was relatively similar between sexes in 2016 ($W_{r\ \text{female}}$ = 96, $W_{r\ \text{male}}$ = 92; Figure 9). Diagnostic plots showed evidence for autocorrelation for both sexes, so Mann-Kendall statistics were calculated. Relative weight for both sexes in Lower Monumental Reservoir appear to have little inter-annual variability and no significant trends for either male (Mann-Kendall τ = 0.298, p = 0.113) or female (Mann-Kendall τ = -0.194, p = 0.311) Northern Pikeminnow were observed. Female Northern Pikeminnow median relative weight in Little Goose Reservoir was greater than male values ($W_{r\ \text{female}}$ = 101, $W_{r\ \text{male}}$ = 92; Figure 10). Neither sex displayed significant monotonic trends in median relative weight for Little Goose Reservoir (female: Mann-Kendall τ = -0.378, p = 0.152; male: Mann-Kendall τ = -0.067, p = 0.858). In contrast to Little Goose reservoir, male median relative weight in Lower Granite Reservoir was larger than for females ($W_{r\ \text{female}}$ = 90, $W_{r\text{male}}$ = 101), though only two females were sampled (Figure 11). Analysis using the Mann-Kendall test revealed a significant increasing trend for male relative weight (Mann-Kendall τ = 0.556, p = 0.048), though there was not a significant trend observed for female Northern Pikeminnow (Mann-Kendall τ = 0.111, p = 0.721).

The median W_r values for Smallmouth Bass collected in the Lower Snake River were relatively similar among reservoirs ($W_{r\ \text{Ice Harbor}}$ = 94; $W_{r\ \text{Lower Monumental}}$ = 96, $W_{r\ \text{Little Goose}}$ = 89; $W_{r\ \text{Lower Granite}}$ =

99; Figure 12). Comparing the relative weights in each area over time, there were no significant monotonic trends in Ice Harbor (Mann-Kendall τ = 0.467, p = 0.260), Little Goose (Mann-Kendall τ = 0.378, p = 0.152), Lower Granite (Mann-Kendall τ = 0.111, p = 0.721), or Lower Monumental reservoirs (Mann-Kendall τ = 0.467, p = 0.074). A large data gap for Ice Harbor Reservoir prohibited data from being fitted with a LOWESS curve.

Median relative weight of Walleye in Ice Harbor and Lower Monumental reservoirs were similar ($W_{r\text{ Ice Harbor 2014}}$ = 91; $W_{r\text{ Ice Harbor 2016}}$ = 89, $W_{r\text{ Lower Monumental}}$ = 86) and largest in Little Goose Reservoir ($W_{r\text{ Little Goose 2016}}$ = 106, n=2). Condition factor for Walleye caught in Lower Monumental Reservoir displays a decreasing trend in median relative weight, though the trend is not significant (Mann-Kendall τ = -0.600, p = 0.221; Figure 13).

In 2016, 1,361 Northern Pikeminnow digestive tracts were collected from fish harvested in the Dam Angling Fishery. These fish ranged in size from 208 to 584 mm FL ($\bar{x}_{\text{Bonneville}}$ = 312 mm, $\bar{x}_{\text{The Dalles}}$ = 341 mm; Table 19). Of these, a sub-sample of 889 digestive tracts were examined for dietary analyses. In both reservoirs, large proportions of the digestive tracts of Northern Pikeminnow greater than or equal to 250 mm FL examined contained food ($\hat{p}_{\text{Bonneville}}$ = 0.74 and $\hat{p}_{\text{The Dalles}}$ = 0.76; Table 20). Other invertebrates were observed in larger proportions of diet samples of both reservoirs than all of the other prey types including fish. We observed visually a large proportion of the "Other Invertebrates" weight category consisted of the invasive Siberian Prawn (*Exopalaemon modestus*), although we did not weigh it separately from the other invertebrates we observed (i.e., other crustaceans, insects, and mollusks). The proportion of lamprey found in Dam Angling gut samples ($\hat{p}_{\text{Bonneville}}$ = 0.15 and $\hat{p}_{\text{The Dalles}}$ = 0.05) were considerably less in 2016 than previous sampling years. Juvenile lamprey were encountered in the greatest proportion of Northern Pikeminnow diet samples during May ($\hat{p}_{Lam}$ = 0.22) and June ($\hat{p}_{Lam}$ = 0.09) followed by salmon and steelhead (May $\hat{p}_{Sal}$ = 0.12, June $\hat{p}_{Sal}$ = 0.16; Table 21). Juvenile salmon and steelhead were observed relatively infrequently during July ($\hat{p}_{Sal}$ = 0.10) and August ($\hat{p}_{Sal}$ = 0.00). American Shad were encountered at relatively low rates until August when proportions of samples containing the taxon increased to 0.49. Diversity of prey fish families consumed by Northern Pikeminnow was greatest during July and included five native and three non-native taxa, along with unidentified fishes. In Bonneville and The Dalles reservoirs, weekly consumption index estimates peaked during the week of 30 June (statistical week 27) and coincided with peak subyearling Chinook Salmon passage rates (Figure 14). Consumption remained high throughout mid-July, statistical week 31, even though the rate of smolt passage at both John Day and The Dalles dams had dramatically decreased.

DISCUSSION

Since its inception, the NPMP has operated under the assumption that modest exploitation (i.e., 10-20%) of the most piscivorous size-classes of Northern Pikeminnow could lead to a disproportionate reduction in predation (Rieman and Beamesderfer 1990) while serving to maintain viable populations of the native Northern Pikeminnow. The 2016 estimate of the system-wide exploitation rate is 12.1% (95% confidence interval 9.7–14.5%) for Northern Pikeminnow greater than or equal to 250 mm FL and is lower than the average exploitation rate during the previous 10 years (15.7%; Table 4; Figure 2). This is within the target exploitation range of 10 to 20% predicted to reduce predation on juvenile salmon up to 50% from predation prior to Northern Pikeminnow removal efforts (Rieman and Beamesderfer 1990). Despite the lower exploitation rate in 2016, the Sport Reward Fishery harvest (n=225,350) was the highest since 2009, the number of Northern Pikeminnow tagged was the greatest since 1994 (2,465 and 2,476 tagged in 2016 and 1994, respectively), and angler effort in the Sport Reward Fishery was at its highest level since 2009. This could be an indication that a very strong year class of fish grew into the harvestable size range (>200mm FL) in 2016, resulting in high catch rates but low overall exploitation relative to a large total population. While a direct relationship between angler effort and exploitation likely exists, it seems plausible that other biological and environmental factors may play a greater role in determining annual exploitation. Further examination of the relationships between these factors and exploitation may provide for greater predictability and certainty with regard to in-season management of the Sport Reward Fishery.

Area-specific exploitation rates were estimated for all reservoirs and areas in 2016 except The Dalles and John Day reservoirs. Low tagging rates coupled with insufficient tag recoveries have precluded calculation of Northern Pikeminnow (≥ 250 mm FL) exploitation rates in these reservoirs for the last seven years. Sport Reward Fishery catches in John Day Reservoir are among the lowest system-wide and while relatively consistent across years, numbers of fish tagged are also among the lowest. Calculating exploitation rates for John Day Reservoir may require increased Sport Reward Fishery participation and catches and/or increased effort to tag more fish. The larger size of the reservoir and distance from metropolitan areas could impede the ability to acquire sufficient information. However, it may be possible to use alternative analyses, such as maximum likelihood approaches, to estimate exploitation in areas or during periods otherwise precluded due to sample size constraints. We hope to explore these analyses in the future. Finally, it is also possible that current low tag and return rates reflect demographic shifts (i.e., low abundance of Northern Pikeminnow ≥ 250 mm FL) due to biotic processes such as competition with other predatory fishes and (or) abiotic processes such as physical changes to the environment.

Regardless of specific reason precluding estimation of exploitation rates in certain areas or during specific periods, administrative changes to provide incentive to return external tag-loss fish (retains internal PIT tag) continue to help increase accuracy of estimates of exploitation rates. Some PIT-tagged Northern Pikeminnow have remained at large for up to 11 years before being caught in the Sport Reward Fishery. Continued accumulation of this information and application of maximum likelihood approaches considering multi-year capture histories to estimate parameters would allow the use of fish tagged in previous years to increase precision of system-wide exploitation rate estimates, and provide exploitation rate estimates for areas (e.g., John Day Reservoir) or during years where tag recoveries have been too low previously. This approach applied to the growing numbers of PIT-tagged fish at large would also allow for assessments of inter-annual variation in rates of natural mortality.

Catches of fish in the Sport Reward Fishery that were tagged in one reservoir, but harvested in a different reservoir during the same year remain negligible. Thus, based on current information, the assumption of a closed population is substantiated. Nonetheless, whether this assumption is valid across multiple years could be further investigated by reviewing detections of PIT tag secondary marks at detection sites such as the adult fish ways at the dams or arrays in tributaries like the Deschutes and John Day rivers in addition to Sport Reward Fishery catches.

To quantify the efficacy of the NPMP since the early 1990s, ODFW has applied a model that considers the cumulative effects of sustained exploitation on predation by Northern Pikeminnow (Friesen and Ward 1999). This model is structured in such a way that harvest of Northern Pikeminnow by the Sport Reward Fishery in a given year will limit recruitment of Northern Pikeminnow into larger, more piscivorous size classes, thereby resulting in reduced predation of juvenile salmonids in subsequent years. In this way, a reduction in predation is dependent on the ability of the Sport Reward fishery to restructure the population during both the current and previous years. Following the 2016 Sport Reward Fishery season, the model predicts that predation is about 29% below predation levels prior to implementation of the Sport Reward Fishery and will increase slightly during 2017 (Figure 3). Given the fragmented structure of the Columbia and Snake River systems, it is likely insufficient to consider the whole without also accounting for variability contributed by individual reservoirs or reaches. As reported previously (Tinus et al. 2015), sensitivity analyses appear to indicate area-specific exploitation downstream of Bonneville Dam may have a disproportionate influence on predation reduction. This is presumably due to high densities of juvenile salmon and steelhead in that area and a related functional feeding response. To maintain the efficacy of the NPMP, we recommend continued annual evaluation of exploitation rates and estimates of reductions in predation and suggest efforts continue to examine differential area-specific contributions to predation reduction.

The 2016 Dam Angling Fishery accounted for 3.9% of the total system-wide Northern Pikeminnow harvest, equaling that of 2015. The proportion of the Dam Angling catch to the total Northern Pikeminnow harvest of reservoir-specific populations in Bonneville and The Dalles reservoirs was about 10% and 40%, respectively (WDFW unpublished data; personal communication Paul Hone, WDFW). Thus, although the system-wide proportion of total fish harvested by the Dam Angling Fishery may be comparatively small, the relative impact on Northern Pikeminnow predation reduction efforts could be substantial on a per reservoir basis. Northern Pikeminnow collected during the 2016 Dam Angling Fishery at The Dalles and John Day dams were significantly larger than those captured in the Sport Reward Fishery in both Bonneville and The Dalles reservoirs. Vigg et al. (1991) provided evidence that larger Northern Pikeminnow consumed a disproportionately greater number of juvenile salmonids than smaller fish predators. Given both the apparent discrepancy in length distributions among Dam Angling and Sport Reward Fisheries and the putative size-related bias in consumption of juvenile salmonids in the tailrace areas relative to other areas of the reservoir, dam anglers may have better opportunity to harvest larger, more predacious, Northern Pikeminnow than sport anglers (Martinelli and Shively 1997). Additionally, dam anglers harvest fish from the boat-restricted zones, which are not accessible to sport anglers. The relatively few tags that are recovered in the Dam Angling Fishery may further provide some evidence dam anglers are harvesting a unique subset of the overall Northern Pikeminnow population. Samples of dam angling catch provide annual insight to Northern Pikeminnow predatory behavior whereas the indexing samples are collected every three years. For these reasons, we support continued angling from the dams accompanied by concurrent monitoring of diet during future dam angling activities.

Removal of larger individuals from Northern Pikeminnow populations sustain survival improvements among migrating juvenile salmon if a compensatory response by remaining Northern Pikeminnow or other predatory fishes does not offset the net benefit of removal (Beamesderfer et al. 1996; Friesen and Ward 1999). Potential signs of a compensatory response by predators may be increased abundance, condition factor, consumption and predation index values, changes in diet, or a shift in population size-structure toward larger individuals (Knutsen and Ward 1999). These responses could be inter- or intra-specific and the scale at which a response would be apparent is not definite. Abundance index estimates of Northern Pikeminnow for 2016 in all areas of the lower Snake River reservoirs were relatively low, though we have not historically caught many Northern Pikeminnow in this area. Sample size was also limiting for our evaluation of the population using *PSD* in all areas both spring and summer. Prior years' (1991, 1994-1996) sample sizes of stock-length fish allowed *PSD* estimates to be calculated, which may provide evidence that culling populations of Northern Pikeminnow in these areas are effective. In contrast, we documented large increases in abundance index values for Smallmouth Bass in the lower Snake River reservoirs in 2016 in several areas. Large increases were sometimes seasonal (summer Little Goose forebay), while others such as Lower Monumental tailrace and mid-reservoir had large increases in both seasons. While these values may be indications of trends, they do not explain the significance of changes in abundance estimates given the current analysis of data, as they do not present estimates of variability. Developing our data analyses further could allow more concrete conclusions to be made. In 2016, we caught the highest number of stock-length Smallmouth Bass documented for Lower Monumental and Little Goose reservoirs since monitoring began in 1991 and *PSD* and *RSD-P* were relatively low in all areas. These observations could be evidence of a potential inter-specific compensatory response in the form of a recent and strong year class of fish that may grow into the quality size class. Alternatively, smaller sizes could result from decreased growth rates of individuals. We hope to clarify this observation in future biological evaluations, though comparison among years is limiting, especially for lower longevity fishes, like Smallmouth Bass, when considering the complexity of the environment and the three-year lag between reservoir sampling events.

The abundance of Walleye evaluated during 2016 in Lower Monumental Reservoir was much greater compared to previous years and Walleye were observed for the first time in Little Goose Reservoir. The 2016 abundance index for Walleye in Lower Monumental Reservoir was the fourth highest observed among all areas from below Bonneville Dam to above Lower Granite Dam since 1991 (Tinus et al., 2015; Barr et al., 2016). Our examination of Walleye stomach contents showed proportions of salmonids in the fish prey component of diets were generally consistent with past sampling results from the lower Snake River (e.g., Takata et al., 2011; Barr et al., 2014). However, the proportion of invertebrates in Walleye diets was higher than previously observed. In light of the apparent variability in predatory potential of Walleye on juvenile salmon, further monitoring of demographic characteristics, diets, and spatial distribution is necessary to detect changes in impacts to juvenile salmon and assess with greater precision long-term trends.

Analyses to elucidate temporal trends in W_r data indicated no significant increase or decrease in the condition of both male and female Northern Pikeminnow in Ice Harbor, Lower Monumental, and Little Goose reservoirs and female Northern Pikeminnow in Lower Granite Reservoir. However, there was a significant increase in the condition of male Northern Pikeminnow in Lower Granite Reservoir over time. Additionally, median W_r values for Smallmouth Bass and Walleye did not exhibit any significant increasing or decreasing trends for any of the reservoirs sampled. Unfortunately, data are limited (i.e., small sample sizes and large data gaps in time series) for Northern Pikeminnow and Smallmouth Bass in Ice Harbor Reservoir and for Walleye in Ice Harbor, Lower Monumental, and Little Goose reservoirs. Therefore, trends in W_r values over time for these species/areas should be interpreted cautiously. Nevertheless, there is evidence that the sustained removal of large Northern Pikeminnow is not contributing to an increase in condition factor for smaller female Northern Pikeminnow and Smallmouth Bass in Lower Monumental, Little Goose, and Lower Granite reservoirs, for smaller male Northern Pikeminnow in Lower Monumental and Little Goose reservoirs, and for Walleye in Lower Monumental Reservoir. However, an increase in condition factor over time for smaller male Northern Pikeminnow in Lower Granite Reservoir has been observed. While it remains unclear whether these results are indicative of an intra-specific compensatory mechanism, our findings from 2016 support results from 2014 and 2015, underscoring the possibility of differential responses to sustained removal not only in space (i.e., reservoir/area-specific), but also demographically and among species.

In 2016, the presence of salmonids in diet samples was relatively low; 12% of Walleye samples contained salmonids, followed by Northern Pikeminnow with 10% and Smallmouth Bass with 3%. Further analysis of Walleye and Northern Pikeminnow is difficult because we do not have a model for consumption or predation index values for Walleye, and sample sizes for Northern Pikeminnow are insufficient. Comparatively, large increases in consumption index values were observed for Smallmouth Bass in the spring in Lower Monumental and Little Goose reservoirs. Predation index values were the highest observed since 1991 in the mid areas of Ice Harbor, Lower Monumental, and Little Goose reservoirs. The greatest predation index estimate recorded occurred in spring of 2016 in Little Goose mid-reservoir. A similar phenomenon was observed in John Day Reservoir during 2015 (Barr et al. 2016). Higher consumption and predation index values can be an artifact of sampling large predators in warm water at peak prey densities. Vigg et al (1991) found temperature as the most influential single variable regulating consumption rates. These changes emphasize the need for continued monitoring, especially since environmental conditions of recent years have prevented sampling, such as summer sampling of Ice Harbor and the forebay of Lower Monumental during 2016. Additionally, current comparisons in this report are at times constrained, emphasizing the need to develop more robust comparisons to allow Sport Reward Fishery biological evaluations to elucidate current piscivore population dynamics in the Columbia and lower Snake rivers. A recent review of the NPMP by the Independent Scientific Advisory Board (ISAB 2016) reported some areas of potential improvement concerning quantifying the size of juvenile salmonids found in the diets of all of our study species and attempting to identify salmonids to species. These data may shed light on whether piscivores in the Columbia and lower Snake River reservoirs are selective in their predation upon salmonids with respect to species, size, or body condition.

Inter- and intra-specific changes effecting predation on salmonids by Northern Pikeminnow, Walleye, and Smallmouth Bass could occur independently from the NPMP due to several factors. Population dynamics, food webs, and environmental factors are likely to have overlapping and undefined influences on consumption rates for these fishes, making monitoring and resource management difficult. Changes over time that could influence salmonid predation rates in the lower Snake River independent of any interplay between piscivore populations include outmigration timing of juvenile salmonids compared to index sampling time; growing levels of hatchery production of both Sockeye and Fall Chinook Salmon upstream of Lower Granite Dam; changes in proportions of juvenile salmonids bypassed, collected, and transported; increased spill levels particularly in summer since 2005; changes in dam configurations with provision of surface passage and locations of bypass outfalls; size and behavior of colonial avian piscivore populations; increasing water temperatures; and changes in food webs and primary production. For example, while we do not weigh or enumerate invertebrates in diet samples by taxa other than crayfish, we note anecdotally that Siberian Prawns appeared to be the most abundant prey item observed in 2016 compared to previous years. About one quarter of smallmouth bass diet samples and one-half of Walleye diet samples contained Siberian Prawns. Only three of 53 Northern Pikeminnow samples contained prawns. Interestingly, almost one-half of the Northern Pikeminnow stomachs collected from the Dam Angling Fishery at John Day Dam contained Siberian Prawns, while less than 10% of samples from the The Dalles Dam contained prawns.

It is important to acknowledge that environmental factors and limits to resources (e.g., time and money) can introduce additional uncertainty into the time series we rely upon to evaluate dynamics within and among predator communities. Guidelines surrounding temperature maxima can limit our ability at times, to sample waters inhabited by ESA-listed juvenile salmonids or utilized by them during downstream migrations. Similar to previous years, elevated water temperatures during 2016 prevented us from electrofishing in some indexing areas during the summer season. Inter-annual fluctuations in water levels can influence available shoreline habitat in which to sample. Flow regimes, water clarity, and changes in wind velocity can affect our ability to locate and catch fish over short time scales and subsequently affect catch-per-unit-effort. While these factors can affect catches through time, it likely has an equal effect among species and does not change our ability to evaluate inter-specific compensatory responses in a given year. Similarly, factors including time, money and staffing constrain sampling during the biological evaluation component of the NPMP to a three-year rotation. While it is difficult, and in some cases impossible, to control for these externalities in our sampling design, we must nonetheless recognize added sources of uncertainty (e.g., data gaps) when assessing dynamics in space and time and understand the limits to our scope of inference.

Data collected during 2016 provided no unambiguous indication of the presence of a compensatory response. Previous evaluations of the NPMP also detected no responses by the predator community related directly to the sustained removal of Northern Pikeminnow (Ward et al. 1995; Ward and Zimmerman 1999; Zimmerman and Ward 1999). However, effective fishery management programs require sustained annual sampling to detect such a response should one occur (Beamesderfer et al. 1996). When designed properly, a long-term monitoring program can quantify the status and trends of key resources, aid in understanding system dynamics in response to stressors, and allow for evaluation of alternative management actions. Thus, continued monitoring to assess both direct and indirect implications of the Northern Pikeminnow Management Program are warranted.

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TABLES

Table 1. Numbers of Northern Pikeminnow tagged and recaptured in the Sport Reward Fishery during 2016 by location and size class.

	200-249 mm FL		≥250 mm FL		Combined	
Reach/Reservoir	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recaptured
Below Bonneville	250	4	773	90	1,023	94
Bonneville	371	14	183	17	554	31
The Dalles	103	1	30	0	133[b]	1
John Day	71	1[a]	18	2	89	3
McNary	193	1	119	4	312	5
Little Goose	110	5[a]	22	5	132	10
Lower Granite	178	5	44	6	222	11
Combined	1,276	31	1,189	124	2,465	155

Note: [a]Two fish recaptured in John Day and three in Little Goose reservoirs were recaptured the same week in which it was tagged, and therefore not included in this table or in calculations of exploitation to avoid violating mark-recapture assumptions (i.e., incomplete mixing).

[b]Fork Length for one tagged Northern Pikeminnow in The Dalles Reservoir was not recorded. Thus, this fish was not included in this table or in calculations of size-specific exploitation rates (i.e., 200–249 mm or ≥ 250 mm).

Table 2. Time series of annual exploitation rates (%) of Northern Pikeminnow (≥ 200 mm) in the Sport Reward Fishery by location.

Year	Below Bonneville	Bonneville	The Dalles	John Day	McNary	Little Goose	Lower Granite	All areas
2000	9.9	12.4	*a*	*a*	10.2	*a*	10.5	10.9
2001	15.9	8.6	*a*	*a*	26.0	—	9.4	15.5
2002	10.8	5.0	*a*	*a*	7.6	—	11.6	10.6
2003	11.8	11.0	*a*	*a*	6.6	—	*a*	10.5
2004	18.8	11.7	*a*	*a*	*a*	—	19.6	17.0
2005	21.6	8.0	14.9	*a*	9.6	—	*a*	16.3
2006	14.6	10.5	22.4	*a*	10.7	20.0	*a*	14.6
2007	18.4	9.6	*a*	*a*	5.9	35.0	11.8	15.3
2008	20.6	9.6	13.8	*a*	14.1	8.3	4.1	14.8
2009	8.4	15.2	*a*	*a*	8.4	9.0	*a*	8.8
2010	17.2	10.1	*a*	*a*	9.2	15.0	63.1	15.9
2011	14.9	9.1	*a*	*a*	14.8	*a*	*a*	13.5
2012	15.4	8.6	*a*	*a*	8.8	*a*	*a*	11.0
2013	8.8	10.9	*a*	*a*	12.6	6.9	4.7	9.6
2014	7.7	8.5	5.5	*a*	11.3	11.1	3.7	9.0
2015	13.8	12.9	*a*	*a*	*a*	*a*	15.6	12.4
2016	9.2	5.4	*a*	*a*	2.3	8.0	5.1	7.5
mean (s.d.)	14 (4.4)	9.8 (2.5)	14.2 (6.9)	*b*	10.5 (5.3)	14.2 (9.5)	14.5 (16.9)	12.5 (3)

Note: *a* = no exploitation calculated (n ≤ 3), dashes (—) = no sampling conducted, b = no mean exploitation calculated (n ≤ 2). Sport Reward Fishery regulations changed in 2000 to allow angler retention of Northern Pikeminnow ≥ 200 mm FL. During prior years (1991-1999), Sport Reward Fishery retention was limited to Northern Pikeminnow ≥ 250 mm FL.

Table 3. Time series of annual exploitation rates (%) of Northern Pikeminnow (200–249 mm) in the Sport Reward Fishery by location.

Year	Below Bonneville	Bonneville	The Dalles	John Day	McNary	Little Goose	Lower Granite	All areas
2000	9.7	4.1	*a*	*a*	*a*	*a*	*a*	6.6
2001	*a*	*a*	*a*	*a*	*a*	—	*a*	10.6
2002	3.1	*a*	*a*	*a*	*a*	—	*a*	3.4
2003	*a*	*a*	*a*	*a*	*a*	—	*a*	*a*
2004	*a*	13.5	*a*	*a*	*a*	—	*a*	10.9
2005	*a*	*a*	*a*	*a*	*a*	—	*a*	*a*
2006	9.6	6.7	*a*	*a*	*a*	17.4	*a*	9.9
2007	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*
2008	4.6	5.8	10.5	*a*	4.9	4.8	1.3	5.7
2009	*a*	*a*	*a*	*a*	*a*	5.6	*a*	1.8
2010	*a*	*a*	*a*	*a*	12.4	*a*	*a*	7.6
2011	17.9	*a*	*a*	*a*	11.0	*a*	*a*	9.8
2012	7.8	5.8	*a*	*a*	4.5	*a*	*a*	6.0
2013	6.7	10.1	*a*	*a*	5.8	*a*	*a*	7.7
2014	3.0	*a*	*a*	*a*	3.7	11.0	*a*	5.3
2015	*a*	*a*	*a*	*a*	*a*	*a*	10.6	4.5
2016	1.6	3.8	*a*	*a*	*a*	4.8	2.8	2.8
mean (s.d.)	7.1 (5)	7.1 (3.5)	*b*	*b*	7.1 (3.7)	8.7 (5.5)	4.9 (5)	6.6 (2.9)

Note: *a* = no exploitation calculated (n ≤ 3), dashes (—) = no sampling conducted, b = no mean exploitation calculated (n ≤ 2). Sport Reward Fishery regulations changed in 2000 to allow angler retention of Northern Pikeminnow ≥ 200 mm FL. During prior years (1991-1999), Sport Reward Fishery retention was limited to Northern Pikeminnow ≥ 250 mm FL.

Table 4. Time series of annual exploitation rates (%) of Northern Pikeminnow (≥ 250 mm) in the Sport Reward Fishery by location.

Year	Below Bonneville	Bonneville	The Dalles	John Day	McNary	Little Goose	Lower Granite	All areas
1991	7.6	10.9	23.6	2.8	5.3	2.4	20.0	8.5
1992	11.4	4.0	6.2	3.4	5.6	11.9	15.0	9.3
1993	6.0	2.1	7.0	2.4	15.9	3.3	12.5	6.8
1994	13.6	2.2	9.8	3.2	14.0	6.1	8.7	10.9
1995	16.1	3.5	14.9	*a*	22.4	2.9	6.4	13.4
1996	12.7	6.1	15.5	*a*	18.2	8.9	11.7	12.1
1997	7.8	8.0	5.8	*a*	16.5	*a*	15.5	8.9
1998	8.2	7.8	12.8	*a*	13.6	*a*	12.1	11.1
1999	9.6	13.9	16.1	3.7	15.9	*a*	6.1	12.5
2000	10.0	16.3	*a*	*a*	9.7	*a*	8.7	11.9
2001	16.2	8.5	*a*	*a*	26.0	—	*a*	16.2
2002	12.6	6.0	*a*	*a*	7.7	—	14.3	12.3
2003	13.6	16.7	*a*	*a*	8.2	—	*a*	13.0
2004	20.1	9.3	*a*	*a*	*a*	—	23.8	18.5
2005	23.1	8.2	18.0	*a*	13.0	—	*a*	19.0
2006	15.6	13.7	25.3	*a*	11.2	26.3	*a*	17.1
2007	19.4	11.1	*a*	*a*	7.5	*a*	17.3	17.8
2008	22.2	10.5	15.0	*a*	16.8	21.7	9.2	19.5
2009	11.3	15.9	*a*	*a*	11.6	25.8	*a*	12.8
2010	19.8	13.1	*a*	*a*	*a*	*a*	*a*	18.8
2011	14.5	10.4	*a*	*a*	17.8	*a*	*a*	15.6
2012	17.4	13.5	*a*	*a*	17.6	*a*	*a*	15.9
2013	9.6	11.2	*a*	*a*	26.5	*a*	11.4	10.8
2014	9.2	6.9	*a*	*a*	17.9	*a*	11.3	11.5
2015	16.7	14.3	*a*	*a*	*a*	*a*	24.4	17.2
2016	11.6	8.9	*a*	*a*	4.6	24.8	14.4	12.1
mean (s.d.)	13.7 (4.7)	9.7 (4.2)	14.2 (6.3)	3.1 (0.5)	14.1 (6.2)	13.4 (10.2)	13.5 (5.3)	13.6 (3.6)

Note: *a* = no exploitation calculated (n ≤ 3), dashes (—) = no sampling conducted.

Table 5. Number of 15-minute boat electrofishing runs by sampling year and location conducted during biological evaluation in the lower Snake River reservoirs, 1990–2016. FB = forebay; Mid = mid-reservoir; TR = tailrace, and Rkm = river kilometer.

	Ice Harbor			Lower Monumental			Little Goose			Lower Granite
Year	FB	Mid	TR	FB	Mid	TR	FB	Mid	TR	Rkm 222–228
1991	44	58	49	49	61	40	42	55	40	55
1994	—	—	—	—	—	39	—	—	31	85
1995	—	—	—	—	—	38	—	—	32	89
1996	—	—	—	—	—	24	—	—	33	89
1999	—	—	—	—	—	11	—	—	28	63
2004	—	—	—	—	—	37	—	—	33	72
2007	37	40	40	40	36	37	40	48	40	96
2010	36	39	40	40	48	30	33	35	39	91
2013	20	24	20	20	45	36	19	31	31	65
2014	14	12	12	—	—	—	—	—	—	—
2016	19	20	19	19	40	30	40	40	40	58

Note: dashes (—) = no sampling conducted.
2016 sampling effort in Ice Harbor and Lower Monumental forebay was reduced due to water temperatures exceeding 18°C, a federally mandated limit (NMFS 2000).

Table 6. Catch per 900-s boat electrofishing run (CPUE) of Northern Pikeminnow (≥ 250 mm FL), Smallmouth Bass (≥ 200 mm FL), and Walleye (≥ 200 mm FL) that were captured during biological evaluation in the lower Snake River reservoirs during summer 2014, spring 2016, and summer 2016. FB = forebay, Mid = mid-reservoir, TR = tailrace, and Rkm = river kilometer.

Species,	Ice Harbor			Lower Monumental			Little Goose			Lower Granite
Season and Year	FB	Mid	TR	FB	Mid	TR	FB	Mid	TR	Rkm 222—228
Northern Pikeminnow,										
Summer 2014	0.00	0.00	0.00	—	—	—	—	—	—	—
Spring 2016	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.22
Summer 2016	—	—	—	—	0.10	0.00	0.05	0.00	0.25	0.00
Smallmouth Bass,										
Summer 2014	1.50	0.50	1.92	—	—	—	—	—	—	—
Spring 2016	3.95	4.40	8.79	4.53	7.85	19.86	2.70	3.61	1.65	5.26
Summer 2016	—	—	—	—	6.15	18.88	9.45	3.82	1.45	2.57
Walleye,										
Summer 2014	0.00	0.00	0.08	—	—	—	—	—	—	—
Spring 2016	0.05	0.10	0.42	0.00	2.00	1.71	0.00	0.00	0.00	0.00
Summer 2016	—	—	—	—	0.25	0.13	0.00	0.00	0.10	0.00

Note: dashes (—) = no sampling conducted; standard effort = 15 min boat electrofishing run at 4 A.
Summer sampling in Ice Harbor and Lower Monumental forebay 2016 was precluded by water temperatures exceeding 18°C, a federally mandated limit (NMFS 2000).

Table 7. Annual abundance index values (catch per 900-s electrofishing run, scaled to surface area) for Northern Pikeminnow (≥ 250 mm FL) in the lower Snake River reservoirs, 1991–2016. FB = forebay; Mid = mid-reservoir; TR = tailrace, and Rkm = river kilometer.

	Ice Harbor			Lower Monumental			Little Goose			Lower Granite
Year	FB	Mid	TR	FB	Mid	TR	FB	Mid	TR	Rkm 222—228
1991	0.06	0.99	0.32	0.36	2.94	1.29	0.39	1.74	0.72	1.56
1994	—	—	—	—	—	0.28	—	—	0.17	0.45
1995	—	—	—	—	—	0.09	—	—	0.03	0.19
1996	—	—	—	—	—	0.14	—	—	0.12	0.25
1999	—	—	—	—	—	0.00	—	—	0.14	0.23
2004	—	—	—	—	—	0.05	—	—	0.13	0.06
2007	0.04	0.00	0.12	0.03	0.26	0.00	0.04	0.00	0.01	0.10
2010	0.00	0.00	0.00	0.00	0.32	0.06	0.00	0.00	0.05	0.13
2013	0.00	0.00	0.03	0.00	0.17	0.05	0.00	0.00	0.01	0.10
2014	0.00	0.00	0.00	—	—	—	—	—	—	—
2016	0.00	0.00	0.00	0.00	0.08	0.00	0.04	0.09	0.06	0.07
mean (s.d.)	0.02 (0.03)	0.17 (0.4)	0.08 (0.13)	0.08 (0.16)	0.75 (1.23)	0.2 (0.39)	0.09 (0.17)	0.37 (0.77)	0.14 (0.21)	0.31 (0.45)

Note: dashes (—) = no sampling conducted.

Table 8. Annual abundance index values (catch per 900-s electrofishing run, scaled to surface area) for Smallmouth Bass (≥ 200 mm FL) in the lower Snake River reservoirs, 1991–2016. FB = forebay, Mid = mid-reservoir, TR = tailrace, and Rkm = river kilometer.

Season,	Ice Harbor			Lower Monumental			Little Goose			Lower Granite
Year	FB	Mid	TR	FB	Mid	TR	FB	Mid	TR	Rkm 222—228
Spring,										
1991	1.65	11.30	2.74	1.56	3.81	3.26	3.42	11.94	1.08	0.70
1994	—	—	—	—	—	1.65	—	—	2.13	4.68
1995	—	—	—	—	—	0.89	—	—	1.52	1.68
1996	—	—	—	—	—	0.64	—	—	1.11	1.74
1999	—	—	—	—	—	2.70	—	—	0.80	1.42
2004	—	—	—	—	—	0.00	—	—	0.00	1.54
2007	1.79	6.50	3.84	2.65	5.36	5.04	6.81	5.99	0.42	3.80
2010	1.07	8.85	3.43	1.66	6.45	4.10	3.11	11.34	0.16	1.38
2013	3.86	4.04	2.52	1.72	5.76	10.08	4.83	15.53	0.72	6.49
2016	5.64	15.79	5.92	4.71	12.03	16.86	4.00	13.31	0.73	4.42
mean (s.d.)	2.8 (1.91)	9.3 (4.52)	3.69 (1.35)	2.46 (1.33)	6.68 (3.14)	4.52 (5.22)	4.43 (1.48)	11.62 (3.54)	0.87 (0.63)	2.79 (1.92)
Summer,										
1991	0.71	5.18	1.21	0.89	1.69	0.96	4.33	8.72	1.75	3.72
1994	—	—	—	—	—	2.25	—	—	0.93	1.10
1995	—	—	—	—	—	0.85	—	—	0.83	1.68
1996	—	—	—	—	—	1.06	—	—	0.35	0.46
1999	—	—	—	—	—	—	—	—	0.00	0.00
2004	—	—	—	—	—	9.01	—	—	0.47	2.01
2007	5.04	11.21	3.74	3.80	3.38	4.54	6.36	9.52	0.38	2.77
2010	3.84	8.07	2.83	3.33	6.51	13.16	2.96	11.73	0.68	3.25
2013	—	—	—	—	7.15	7.39	—	25.15	0.49	4.40
2014	2.14	1.79	1.29	—	—	—	—	—	—	—
2016	—	—	—	—	9.42	16.02	13.99	14.07	0.64	2.16
mean (s.d.)	2.93 (1.9)	6.56 (4.02)	2.27 (1.23)	2.67 (1.56)	5.63 (3.08)	6.14 (5.65)	6.91 (4.92)	13.84 (6.66)	0.65 (0.47)	2.15 (1.41)

Note: dashes (—) = no sampling conducted.

Table 9. Annual abundance index values (catch per 900-s electrofishing run, scaled to surface area) for Walleye (≥ 200 mm FL) in the lower Snake River reservoirs, 1991-2016. FB = forebay, Mid = mid-reservoir, TR = tailrace, and Rkm = river kilometer.

Season,	Ice Harbor			Lower Monumental			Little Goose			Lower Granite
Year	FB	Mid	TR	FB	Mid	TR	FB	Mid	TR	Rkm 222—228
Spring,										
1991	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	—	—	—	—	—	0.00	—	—	0.00	0.00
1995	—	—	—	—	—	0.00	—	—	0.00	0.00
1996	—	—	—	—	—	0.00	—	—	0.00	0.00
1999	—	—	—	—	—	0.08	—	—	0.00	0.00
2004	—	—	—	—	—	0.00	—	—	0.00	0.00
2007	0.00	0.00	0.00	0.00	0.89	0.35	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
2013	0.00	0.00	0.00	0.00	0.29	0.16	0.00	0.00	0.00	0.00
2016	0.08	0.36	0.28	0.00	3.06	1.46	0.00	0.00	0.00	0.00
mean (s.d.)	0.02 (0.04)	0.07 (0.16)	0.06 (0.13)	0 (0)	0.85 (1.29)	0.21 (0.45)	0 (0)	0 (0)	0 (0)	0 (0)
Summer,										
1991	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	—	—	—	—	—	0.00	—	—	0.00	0.00
1995	—	—	—	—	—	0.00	—	—	0.00	0.00
1996	—	—	—	—	—	0.00	—	—	0.00	0.00
1999	—	—	—	—	—	—	—	—	0.00	0.00
2004	—	—	—	—	—	0.00	—	—	0.00	0.00
2007	0.00	0.00	0.00	0.00	0.32	0.59	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.26	0.14	0.00	0.00	0.00	0.00
2013	—	—	—	—	0.32	0.17	—	0.00	0.00	0.00
2014	0.00	0.00	0.06	—	—	—	—	—	—	—
2016	—	—	—	—	0.38	0.11	0.00	0.00	0.04	0.00
mean (s.d.)	0 (0)	0 (0)	0.02 (0.03)	0 (0)	0.26 (0.15)	0.11 (0.19)	0 (0)	0 (0)	0 (0.01)	0 (0)

Note: dashes (—) = no sampling conducted.

Table 10. Number (n) of Northern Pikeminnow, Smallmouth Bass, and Walleye (≥ 200 mm FL) digestive tracts examined during biological evaluation in the lower Snake River reservoirs in summer 2014, spring and summer 2016, and proportion of samples containing food, fish, and salmonids (Sal).

Season,	Northern Pikeminnow					Smallmouth Bass					Walleye				
Area	$n_{non\text{-}empty}$	n_{empty}	$\hat{p}_{Food}$	$\hat{p}_{Fish}$	$\hat{p}_{Sal}$	$n_{non\text{-}empty}$	n_{empty}	$\hat{p}_{Food}$	$\hat{p}_{Fish}$	$\hat{p}_{Sal}$	$n_{non\text{-}empty}$	n_{empty}	$\hat{p}_{Food}$	$\hat{p}_{Fish}$	$\hat{p}_{Sal}$
Spring															
Ice Harbor	2	0	1.00	0.00	0.00	114	22	0.84	0.38	0.04	9	2	0.82	0.36	0.18
Lower Monumental	5	0	1.00	0.20	0.00	173	22	0.89	0.15	0.06	61	3	0.95	0.25	0.11
Little Goose	10	1	0.91	0.27	0.00	77	17	0.82	0.45	0.05	0	0	—	—	—
Lower Granite	10	1	0.91	0.45	0.27	23	2	0.92	0.88	0.08	0	0	—	—	—
All 2016 Spring	27	2	0.93	0.33	0.10	387	63	0.86	0.32	0.05	70	5	0.93	0.27	0.12
Summer															
Ice Harbor 2014	1	0	1.00	0.00	0.00	41	4	0.91	0.27	0.00	1	0	1.00	0.00	0.00
Ice Harbor 2016	0	0	—	—	—	0	0	—	—	—	0	0	—	—	—
Lower Monumental	6	0	1.00	0.17	0.00	175	10	0.95	0.05	0.00	7	0	1.00	0.43	0.00
Little Goose	19	0	1.00	0.11	0.11	96	8	0.92	0.33	0.01	2	0	1.00	1.00	0.50
Lower Granite	2	1	0.67	0.33	0.00	42	5	0.89	0.49	0.00	0	0	—	—	—
All 2016 Summer	27	1	0.96	0.14	0.07	313	23	0.93	0.20	<0.01	9	0	1.00	0.56	0.11

Table 11. Proportion of diet samples containing specific prey fish families collected from Northern Pikeminnow, Smallmouth Bass, and Walleye during spring and summer biological evaluation in the lower Snake River reservoirs, 2016.

	Northern Pikeminnow				Smallmouth Bass					Walleye			
Common name (Family)	Ice Harbor 2016 (n = 2)	Lower Monumental (n = 11)	Little Goose (n = 30)	Lower Granite (n = 14)	Ice Harbor 2014 (n = 45)	Ice Harbor 2016 (n = 136)	Lower Monumental (n = 380)	Little Goose (n = 198)	Lower Granite (n = 72)	Ice Harbor 2016 (n = 11)	Lower Monumental (n = 71)	Little Goose (n = 2)	Lower Granite (n = 0)
salmon and trout (Salmonidae)	0.00	0.00	0.07	0.21	0.00	0.04	0.03	0.03	0.03	0.18	0.10	0.50	–
minnows (Cyprinidae)	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.04	0.06	0.00	0.01	1.00	–
suckers (Catostomidae)	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.04	0.00	0.01	0.00	–
catfish (Ictaluridae)	0.00	0.00	0.00	0.00	0.00	0.01	<.01	0.01	0.00	0.00	0.00	0.00	–
Sand Roller (Percopsidae)	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.17	0.39	0.00	0.01	0.00	–
Threespine Stickleback (Gasterosteidae)	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	–
sculpins (Cottidae)	0.00	0.00	0.00	0.07	0.09	0.07	0.01	0.04	0.00	0.00	0.03	0.00	–
sunfishes (Centrarchidae)	0.00	0.00	0.07	0.00	0.00	0.11	0.03	0.04	0.00	0.18	0.03	0.00	–
perches (Percidae)	0.00	0.00	0.00	0.00	0.00	0.00	<0.01	0.00	0.00	0.00	0.00	0.00	–
unidentified	0.00	0.18	0.03	0.07	0.11	0.15	0.03	0.10	0.15	0.00	0.08	0.00	–

Note: Multiple families may be represented in the gut contents of some individual fish. Sample sizes (n) listed below each reservoir.

Table 12. Annual consumption index values for Northern Pikeminnow (≥ 250 mm FL) that were captured during biological evaluation from the lower Snake River reservoirs by river reach and season, 1991–2016. FB = forebay, Mid = mid-reservoir, TR = tailrace, and Rkm = river kilometer.

Season,	Ice Harbor			Lower Monumental			Little Goose			Lower Granite
Year	FB	Mid	TR	FB	Mid	TR	FB	Mid	TR	Rkm 222-228
Spring										
1991	*a*	0.36	1.02	0.00	0.00	0.68	0.90	0.00	0.72	0.42
1994	—	—	—	—	—	0.77	—	—	2.32	0.77
1995	—	—	—	—	—	*a*	—	—	*a*	1.27
1996	—	—	—	—	—	*a*	—	—	0.71	0.31
1999	—	—	—	—	—	*a*	—	—	*a*	2.18
2004	—	—	—	—	—	*a*	—	—	*a*	*a*
2007	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	0.97
2010	*a*	*a*	*a*	*a*	0.00	*a*	*a*	*a*	*a*	*a*
2013	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	5.10
2016	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*
Summer										
1991	—	—	—	—	—	—	—	—	—	—
1994	—	—	—	—	—	*a*	—	—	*a*	—
1995	—	—	—	—	—	*a*	—	—	*a*	*a*
1996	—	—	—	—	—	*a*	—	—	*a*	*a*
1999	—	—	—	—	—	—	—	—	*a*	*a*
2004	—	—	—	—	—	*a*	—	—	0.00	*a*
2007	*a*	*a*	2.05	*a*	*a*	*a*	*a*	*a*	*a*	*a*
2010	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	1.70
2013	—	—	—	—	*a*	*a*	—	*a*	*a*	*a*
2014	*a*	*a*	*a*	—	—	—	—	—	—	—
2016	—	—	—	—	*a*	*a*	*a*	*a*	*a*	*a*

Note: *a* = no consumption index calculated (n ≤ 5), dashes (—) = no sampling conducted.

Table 13. Annual predation index values for Northern Pikeminnow (≥ 250 mm FL) that were captured during biological evaluation from the lower Snake River reservoirs by river reach and season, 1991–2016. FB = forebay, Mid = mid-reservoir, TR = tailrace, and Rkm = river kilometer.

Season,	Ice Harbor			Lower Monumental			Little Goose			Lower Granite
Year	FB	Mid	TR	FB	Mid	TR	FB	Mid	TR	Rkm 222-228
Spring										
1991	*a*	0.48	0.45	0.00	0.00	1.34	0.37	0.00	1.04	1.12
1994	—	—	—	—	—	0.31	—	—	1.03	0.72
1995	—	—	—	—	—	*a*	—	—	*a*	0.36
1996	—	—	—	—	—	*a*	—	—	0.18	0.15
1999	—	—	—	—	—	*a*	—	—	*a*	0.70
2004	—	—	—	—	—	*a*	—	—	*a*	*a*
2007	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	0.19
2010	*a*	*a*	*a*	*a*	0.00	*a*	*a*	*a*	*a*	*a*
2013	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	0.86
2016	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*
Summer										
1991	—	—	—	—	—	—	—	—	—	—
1994	—	—	—	—	—	*a*	—	—	*a*	—
1995	—	—	—	—	—	*a*	—	—	*a*	*a*
1996	—	—	—	—	—	*a*	—	—	*a*	*a*
1999	—	—	—	—	—	—	—	—	*a*	*a*
2004	—	—	—	—	—	*a*	—	—	0.00	*a*
2007	*a*	*a*	0.48	*a*	*a*	*a*	*a*	*a*	*a*	*a*
2010	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	0.40
2013	—	—	—	—	*a*	*a*	—	*a*	*a*	*a*
2014	*a*	*a*	*a*	—	—	—	—	—	—	—
2016	—	—	—	—	*a*	*a*	*a*	*a*	*a*	*a*

Note: *a* = no predation index calculated (n≤5), dashes (—) = no sampling conducted.

Table 14. Annual consumption index values for Smallmouth Bass (≥ 200 mm FL) that were captured during biological evaluation from the lower Snake River reservoirs by river reach and season, 1991–2016. FB = forebay, Mid = mid-reservoir, TR = tailrace, and Rkm = river kilometer.

Season,	Ice Harbor			Lower Monumental			Little Goose			Lower Granite
Year	FB	Mid	TR	FB	Mid	TR	FB	Mid	TR	Rkm 222-228
Spring										
1991	0.00	0.01	0.00	0.08	0.00	0.00	0.03	0.01	0.02	0.11
1994	—	—	—	—	—	0.07	—	—	0.09	0.17
1995	—	—	—	—	—	0.00	—	—	0.00	0.08
1996	—	—	—	—	—	0.00	—	—	0.02	0.02
1999	—	—	—	—	—	0.01	—	—	0.02	0.06
2004	—	—	—	—	—	*a*	—	—	*a*	0.10
2007	0.07	0.04	0.01	0.07	0.04	0.03	0.08	0.07	0.00	0.08
2010	0.05	0.00	0.03	0.08	0.01	0.01	0.03	0.02	0.00	0.14
2013	0.00	0.03	0.05	0.05	0.04	0.02	0.08	0.10	0.05	0.09
2016	0.04	0.04	0.04	0.13	0.09	0.00	0.08	0.18	0.00	0.08
Summer										
1991	—	—	—	—	—	—	—	—	—	—
1994	—	—	—	—	—	*a*	—	—	*a*	—
1995	—	—	—	—	—	0.00	—	—	0.00	0.00
1996	—	—	—	—	—	0.00	—	—	0.00	0.00
1999	—	—	—	—	—	—	—	—	*a*	*a*
2004	—	—	—	—	—	*a*	—	—	*a*	0.08
2007	0.05	0.05	0.01	0.00	0.00	0.00	0.05	0.00	0.12	0.19
2010	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.05	0.05	0.11
2013	—	—	—	—	0.06	0.00	—	0.08	0.00	0.20
2014	0.00	*a*	0.00	—	—	—	—	—	—	—
2016	—	—	—	—	0.00	0.00	0.06	0.00	0.00	0.00

Note: *a* = no consumption index calculated (n ≤ 5), dashes (—) = no sampling conducted

Table 15. Annual predation index values for Smallmouth Bass (≥ 200 mm FL) that were captured during biological evaluation from the lower Snake River reservoirs by river reach and season, 1991–2016. FB = forebay, Mid = mid-reservoir, TR = tailrace, and Rkm = river kilometer.

Season,	Ice Harbor			Lower Monumental			Little Goose			Lower Granite
Year	FB	Mid	TR	FB	Mid	TR	FB	Mid	TR	Rkm 222-228
Spring										
1991	0.00	0.11	0.00	0.12	0.00	0.00	0.10	0.12	0.02	0.08
1994	—	—	—	—	—	0.11	—	—	0.19	0.80
1995	—	—	—	—	—	0.00	—	—	0.00	0.13
1996	—	—	—	—	—	0.00	—	—	0.02	0.03
1999	—	—	—	—	—	0.04	—	—	0.02	0.09
2004	—	—	—	—	—	*a*	—	—	*a*	0.15
2007	0.12	0.26	0.04	0.19	0.21	0.16	0.54	0.42	0.00	0.30
2010	0.05	0.00	0.10	0.13	0.06	0.06	0.09	0.23	0.00	0.19
2013	0.00	0.12	0.13	0.09	0.23	0.19	0.39	1.55	0.04	0.58
2016	0.22	0.59	0.24	0.59	1.04	0.00	0.32	2.34	0.00	0.35
Summer										
1991	—	—	—	—	—	—	—	—	—	—
1994	—	—	—	—	—	*a*	—	—	*a*	—
1995	—	—	—	—	—	0.00	—	—	0.00	0.00
1996	—	—	—	—	—	0.00	—	—	0.00	0.00
1999	—	—	—	—	—	—	—	—	*a*	*a*
2004	—	—	—	—	—	*a*	—	—	*a*	0.16
2007	0.25	0.56	0.04	0.00	0.00	0.00	0.32	0.00	0.05	0.53
2010	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.59	0.03	0.36
2013	—	—	—	—	0.43	0.00	—	2.01	0.00	0.88
2014	0.00	*a*	0.00	—	—	—	—	—	—	—
2016	—	—	—	—	0.00	0.00	0.84	0.00	0.00	0.00

Note: *a* = no predation index calculated (n ≤ 5), dashes (—) = no sampling conducted.

Table 16. Number of stock length Northern Pikeminnow (n_s) collected by boat electrofishing and proportional stock density (*PSD*, %) in the lower Snake River reservoirs, 1991-2016.

	Ice Harbor		Lower Monumental		Little Goose		Lower Granite	
Year	n_s	PSD (%)	n_s	PSD (%)	n_s	PSD (%)	n_s	PSD (%)
1991	116	29	473	12	621	29	499	34
1994	—	—	19	*a*	64	66	45	33
1995	—	—	35	23	84	60	20	30
1996	—	—	12	*a*	13	*a*	26	38
1999	—	—	0	*a*	9	*a*	17	*a*
2004	—	—	8	*a*	30	53	5	*a*
2007	8	*a*	7	*a*	2	*a*	11	*a*
2010	0	*a*	12	*a*	6	*a*	14	*a*
2013	1	*a*	7	*a*	1	*a*	8	*a*
2014	0	*a*	—	—	—	—	—	—
2016	0	*a*	2	*a*	7	*a*	5	*a*

Note: a = no *PSD* value calculated ($n_s \leq 19$), dashes (—) = no sampling conducted.

Table 17. Number of stock length Smallmouth Bass (n_s) collected by boat electrofishing, proportional stock density (*PSD*, %), and relative stock density of preferred length fish (*RSD-P*, %) in the lower Snake River reservoirs, 1991-2016.

	Ice Harbor			Lower Monumental			Little Goose			Lower Granite		
Year	n_s	PSD	RSD-P	n_s	PSD	RSD-P	n_s	PSD	RSD-P	n_s	PSD	RSD-P
1991	499	21	4	460	21	3	640	21	3	1,095	16	4
1994	—	—	—	173	9	1	160	6	1	447	9	2
1995	—	—	—	74	12	3	131	14	5	275	17	6
1996	—	—	—	39	10	0	57	21	5	132	29	11
1999	—	—	—	42	62	2	30	70	0	83	37	6
2004	—	—	—	255	16	1	48	35	13	306	12	2
2007	671	13	3	542	14	3	520	18	5	518	14	3
2010	485	15	2	780	8	1	338	23	7	451	16	6
2013	220	24	3	661	24	1	408	20	4	731	9	2
2014	61	48	13	—	—	—	—	—	—	—	—	—
2016	516	9	2	1,222	7	1	628	19	4	391	5	1

Note: a = no *PSD* or *RSD-P* value calculated ($n_s \leq 19$), dashes (—) = no sampling conducted.

Table 18. Number of stock length Walleye (n_s) collected by boat electrofishing, proportional stock density (*PSD*, %), and relative stock density of preferred length fish (*RSD-P*, %) in the lower Snake River reservoirs, 1991-2016.

	Ice Harbor			Lower Monumental			Little Goose			Lower Granite		
Year	n_s	PSD	RSD-P	n_s	PSD	RSD-P	n_s	PSD	RSD-P	n_s	PSD	RSD-P
1991	0	*a*	*a*	0	*a*	*a*	0	*a*	*a*	0	*a*	*a*
1994	—	—	—	0	*a*	*a*	0	*a*	*a*	0	*a*	*a*
1995	—	—	—	0	*a*	*a*	0	*a*	*a*	0	*a*	*a*
1996	—	—	—	0	*a*	*a*	0	*a*	*a*	0	*a*	*a*
1999	—	—	—	1	*a*	*a*	0	*a*	*a*	0	*a*	*a*
2004	—	—	—	0	*a*	*a*	0	*a*	*a*	0	*a*	*a*
2007	0	*a*	*a*	31	35	6	0	*a*	*a*	0	*a*	*a*
2010	0	*a*	*a*	6	*a*	*a*	0	*a*	*a*	0	*a*	*a*
2013	0	*a*	*a*	15	*a*	*a*	0	*a*	*a*	0	*a*	*a*
2014	1	*a*	*a*	—	—	—	—	—	—	—	—	—
2016	4	*a*	*a*	9	*a*	*a*	2	*a*	*a*	0	*a*	*a*

Note: a = no *PSD* or *RSD-P* value calculated ($n_s \leq 19$), dashes (—) = no sampling conducted.

Table 19. Fork length (mm) characteristics of Northern Pikeminnow sampled annually for evaluation of diet from Below Bonneville (2006), Bonneville (2006-2016), and The Dalles (2007-2016) reservoirs.

Reservoir, Year	n	Minimum	Maximum	Mean	Median
Below Bonneville,					
2006	22	267	544	425	438
Bonneville,					
2006	128	212	549	360	342
2007	340	229	550	343	333
2008	209	200	518	356	350
2009	223	187	545	377	370
2010	391	185	545	366	364
2011	321	219	574	366	368
2012	324	210	525	332	314
2013	226	234	534	329	314
2014	496	222	600	347	337
2015	563	184	570	315	306
2016	685	210	584	312	298
The Dalles,					
2007	393	230	553	366	358
2008	64	265	550	377	365
2009	223	251	572	403	394
2010	384	210	575	376	376
2011	282	230	515	361	359
2012	492	230	545	344	320
2013	463	208	548	346	323
2014	363	251	578	384	365
2015	422	220	590	349	345
2016	676	208	565	341	328
All reservoirs and years	7,690	184	600	358	348

Table 20. Number (n) of Northern Pikeminnow (FL ≥ 250 mm) digestive tracts examined from Below Bonneville (2006), Bonneville (2006-2016), and The Dalles (2007-2016) reservoirs, and proportion of samples containing specific prey items (Sal = salmon/steelhead, Lam = lamprey, Ash = American Shad).

Reservoir, Year	$n_{\text{non-empty}}$	n_{empty}	$\hat{p}_{\text{food}}$	$\hat{p}_{\text{fish}}$	$\hat{p}_{\text{crayfish}}$	$\hat{p}$ other invert.	$\hat{p}_{\text{misc.}}$	$\hat{p}_{\text{Sal}}$	$\hat{p}_{\text{Lam}}$	$\hat{p}_{\text{Ash}}$	$\hat{p}_{\text{other}}$ fish
Below Bonneville,											
2006	18	4	0.82	0.41	0.09	0.23	0.23	0.36	0.00	0.00	0.09
Bonneville,											
2006	46	83	0.36	0.21	0.08	0.04	0.11	0.04	0.17	0.00	0.05
2007	207	133	0.61	0.40	0.04	0.22	0.09	0.13	0.31	0.00	0.06
2008	132	77	0.63	0.44	0.04	0.33	0.05	0.11	0.31	0.00	0.12
2009	156	67	0.70	0.64	0.06	0.19	0.10	0.09	0.50	0.01	0.14
2010	245	150	0.62	0.49	0.06	0.14	0.17	0.16	0.18	0.15	0.18
2011	217	112	0.66	0.44	0.07	0.19	0.17	0.36	0.09	0.00	0.08
2012	212	63	0.77	0.57	0.09	0.19	0.25	0.15	0.18	0.00	0.00
2013	166	50	0.77	0.43	0.12	0.34	0.16	0.17	0.22	0.04	0.06
2014	282	207	0.58	0.46	0.07	0.13	0.08	0.19	0.47	0.19	0.42
2015	357	117	0.75	0.53	0.13	0.29	0.13	0.07	0.53	0.21	0.15
2016	302	104	0.74	0.38	0.03	0.43	0.26	0.08	0.15	0.13	0.08
The Dalles,											
2007	263	190	0.58	0.37	0.02	0.27	0.03	0.13	0.08	0.11	0.21
2008	52	12	0.81	0.36	0.03	0.69	0.11	0.09	0.23	0.00	0.08
2009	137	87	0.61	0.56	0.08	0.31	0.04	0.11	0.40	0.00	0.14
2010	210	172	0.55	0.29	0.07	0.34	0.25	0.16	0.10	0.02	0.07
2011	198	85	0.70	0.22	0.06	0.56	0.04	0.15	0.07	0.00	0.02
2012	369	110	0.77	0.39	0.13	0.48	0.09	0.15	0.12	0.04	0.00
2013	349	98	0.78	0.47	0.22	0.34	0.04	0.23	0.16	0.09	0.05
2014	263	100	0.72	0.44	0.31	0.27	0.01	0.18	0.46	0.14	0.36
2015	266	71	0.79	0.45	0.24	0.37	0.04	0.14	0.45	0.12	0.16
2016	313	101	0.76	0.31	0.04	0.57	0.07	0.14	0.05	0.07	0.07

Table 21. Proportion of diet samples containing specific prey fish families for Northern Pikeminnow collected during Dam Angling from the tailraces of Bonneville and The Dalles reservoirs May through August 2016.

Common name (Family)	May[a] (n = 181)	June (n = 307)	July (n = 229)	August[b] (n = 172)	Total (n = 889)
lampreys (Petromyzontidae)	0.22	0.09	0.05	0.01	0.09
shad (Clupeidae)	0.00	< 0.01	0.01	0.49	0.10
salmon and trout (Salmonidae)	0.12	0.16	0.10	0.00	0.10
minnows (Cyprinidae)	0.00	0.00	0.01	0.01	0.00
sand rollers (Percopsidae)	0.00	< 0.01	< 0.01	0.00	< 0.01
sculpins (Cottidae)	0.01	0.01	0.01	0.00	0.01
sunfishes (Centrarchidae)	0.01	0.00	0.04	0.02	0.02
perches (Percidae)	0.01	0.00	< 0.01	0.00	< 0.01
unidentified	0.05	0.03	0.05	0.05	0.04

Note: [a] Sampling began 3 May 2016, [b] sampling ended 18 August 2016.

Multiple families may be represented in the gut contents of some individual fish. Sample sizes (n) listed below each month.

FIGURES

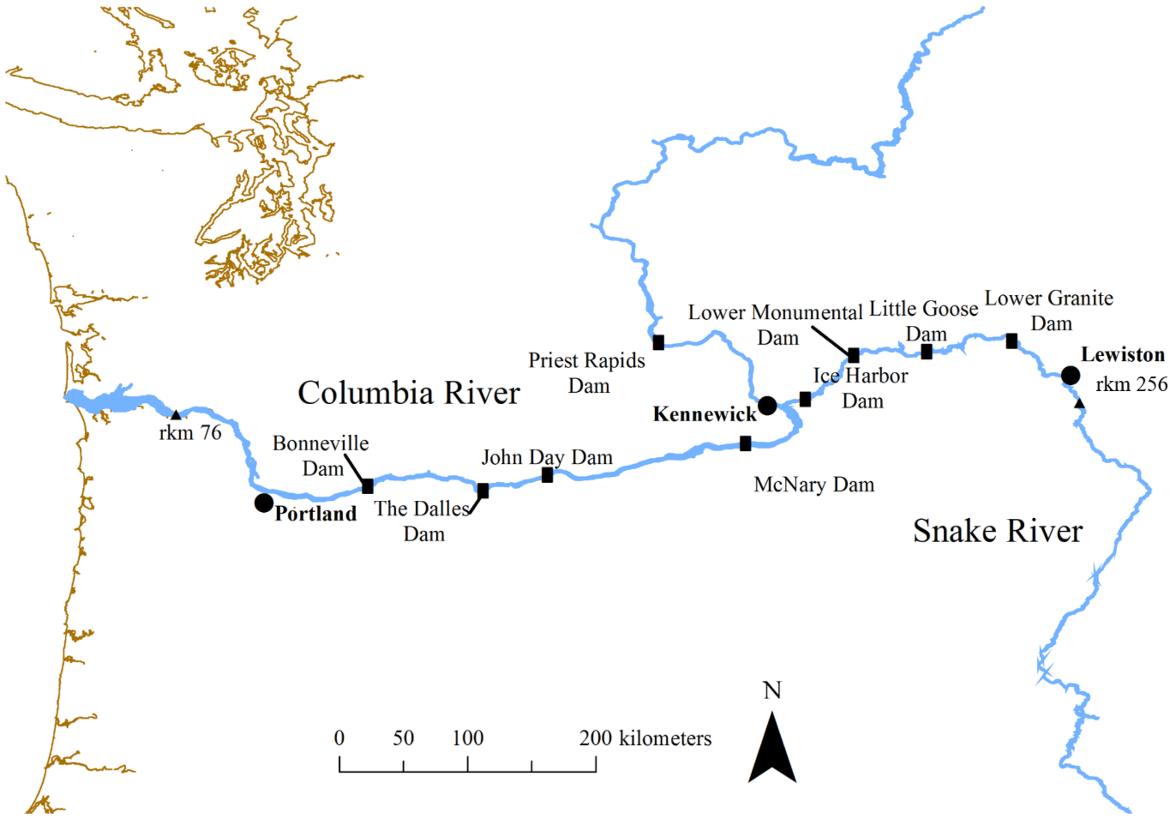

Figure 1. Study area in the Columbia and Snake rivers.

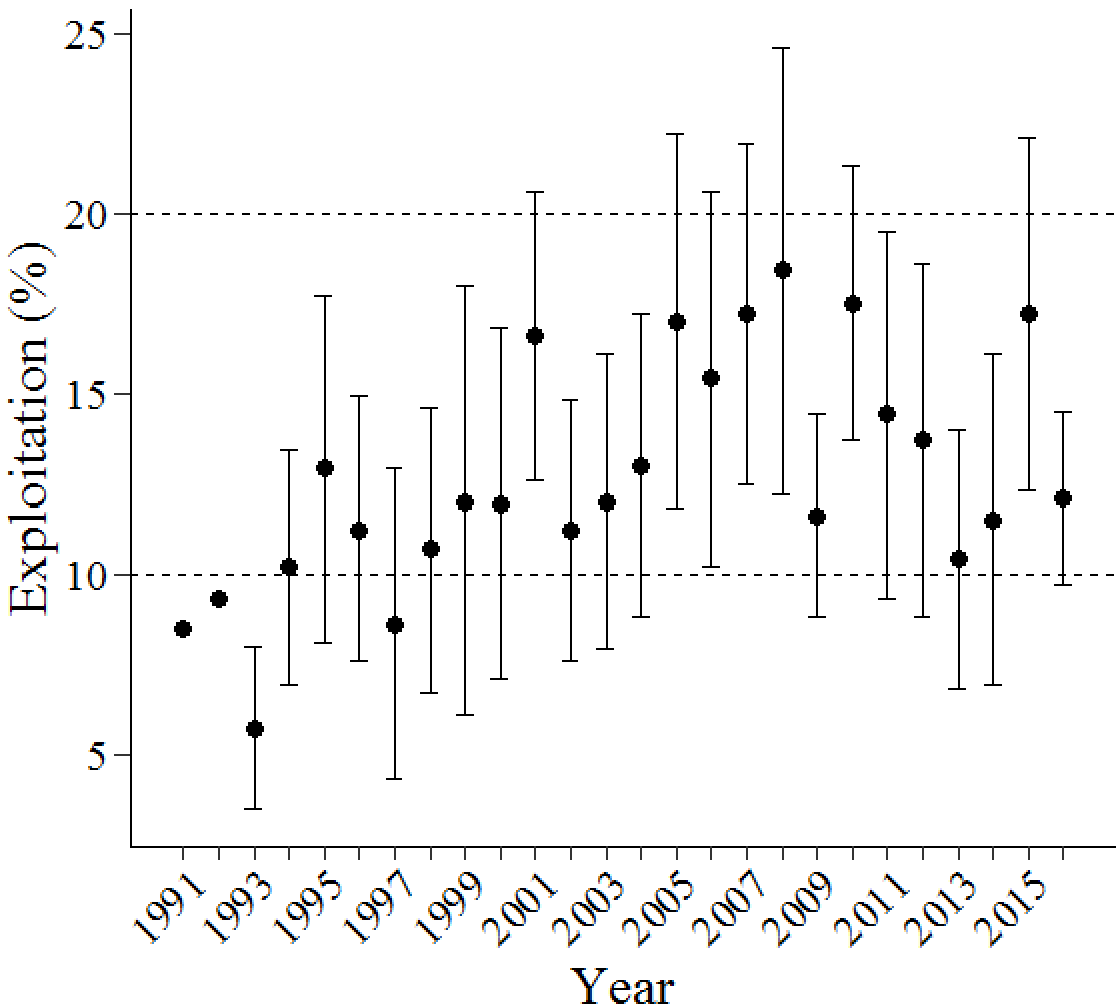

Figure 2. System-wide exploitation rates of Northern Pikeminnow (≥ 250 mm FL) in the Sport Reward Fishery, 1991–2016. Error bars represent 95% confidence intervals. Variation was not estimated for the years 1991–1992. Target exploitation is 10-20% (dashed lines).

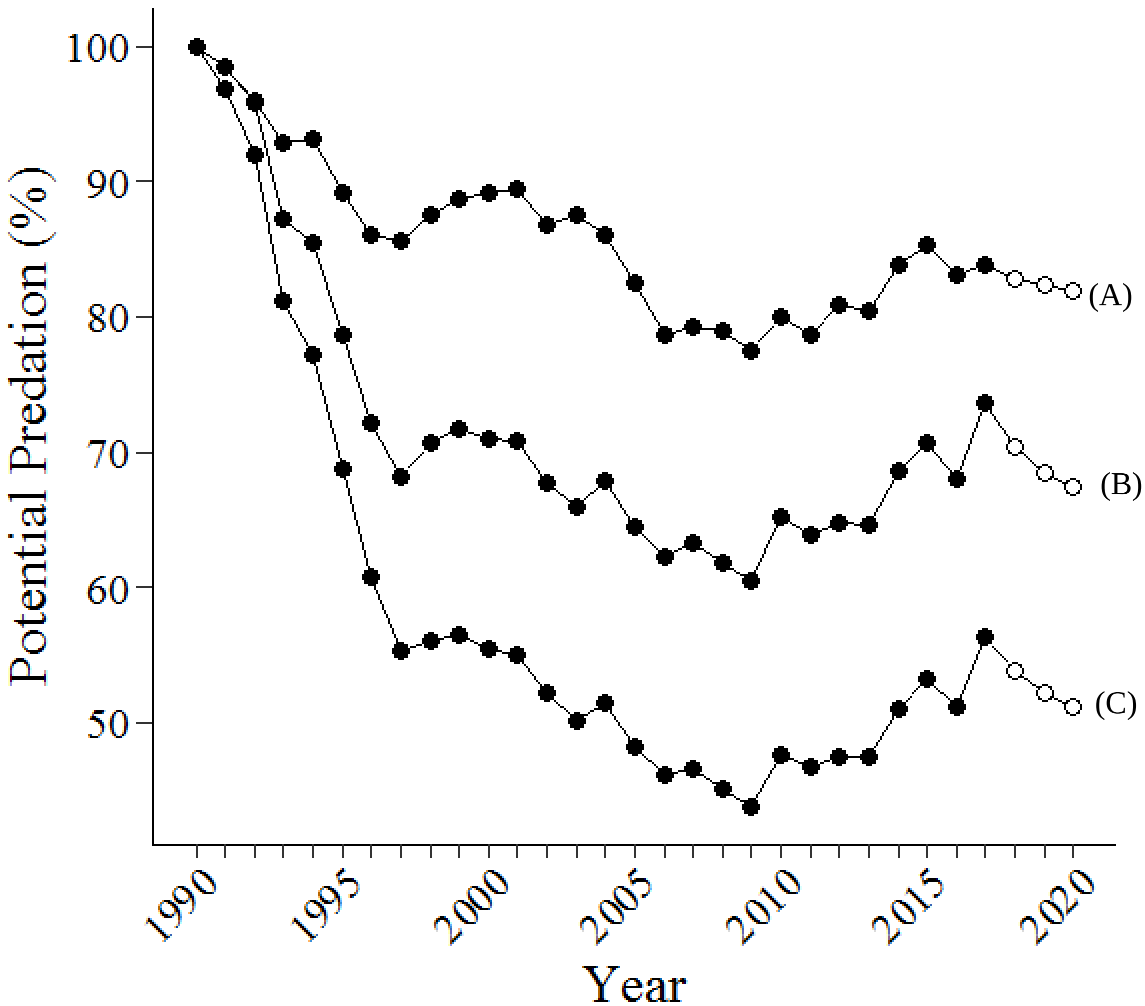

Figure 3. Maximum (A), median (B), and minimum (C) annual levels of potential predation by Northern Pikeminnow on juvenile salmon relative to predation levels before implementation of the Northern Pikeminnow Management Program. For the years 1991-2017, model estimates (filled circles) are based on exploitation levels from the previous year. Model forecast predictions after 2017 (open circles) are based on average exploitation estimates from years with similar fishery structure (2001, 2004-2017).

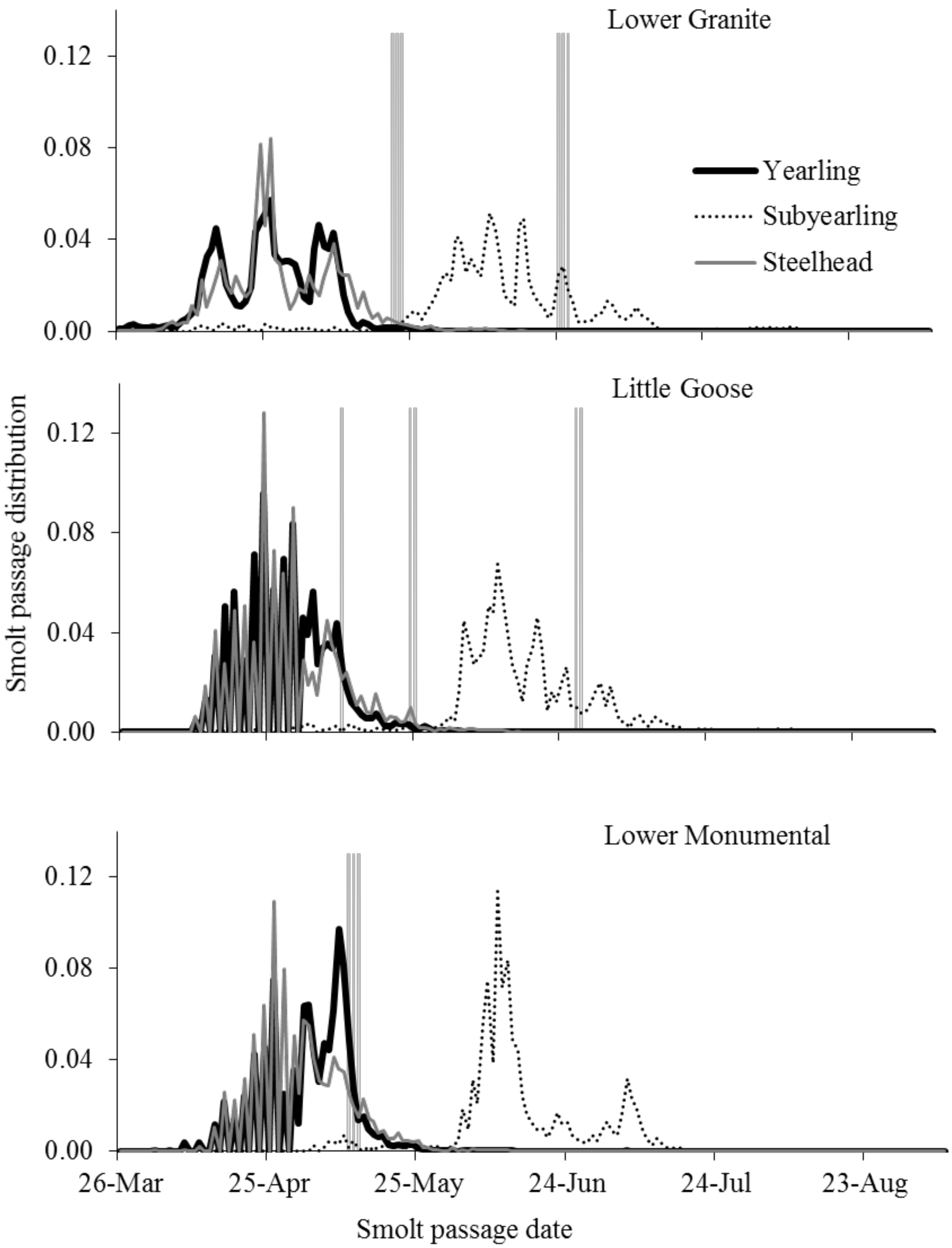

Figure 4. Periods of biological evaluation (shaded bars) in Lower Granite (top panel), Little Goose (middle panel), and Lower Monumental (bottom panel) reservoirs compared with salmon (yearling and subyearling) and steelhead smolt passage distribution during the 2016 smolt out-migration season.

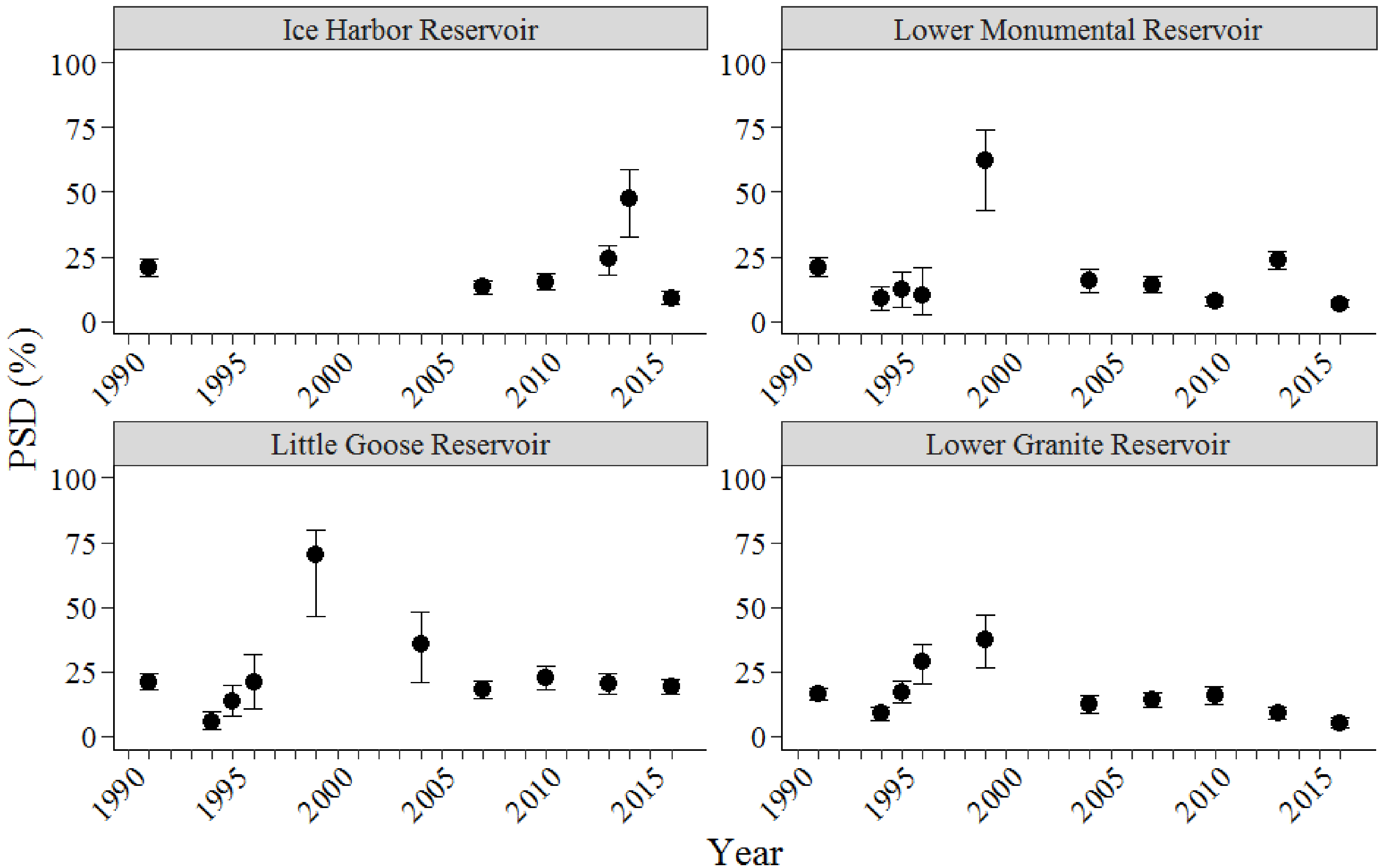

Figure 5. Estimates of proportional stock density (*PSD*) for Smallmouth Bass in the lower Snake River reservoirs, 1991–2016. Data were collected during biological evaluation. Error bars represent 95% bootstrap confidence intervals.

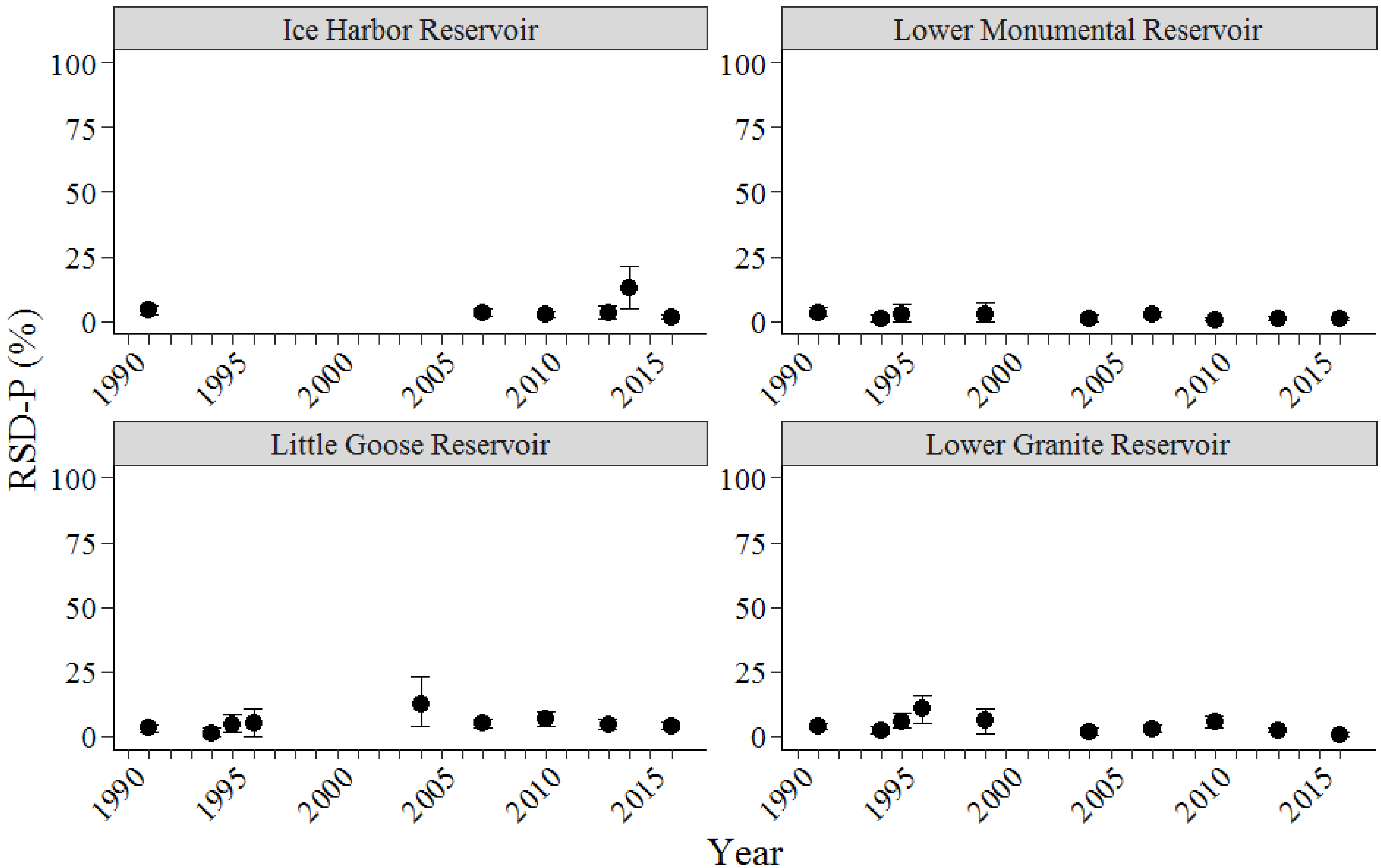

Figure 6. Estimates of relative stock density of preferred length (*RSD-P*) Smallmouth Bass in the lower Snake River reservoirs, 1991–2016. Data were collected during biological evaluation. Error bars represent 95% bootstrap confidence intervals.

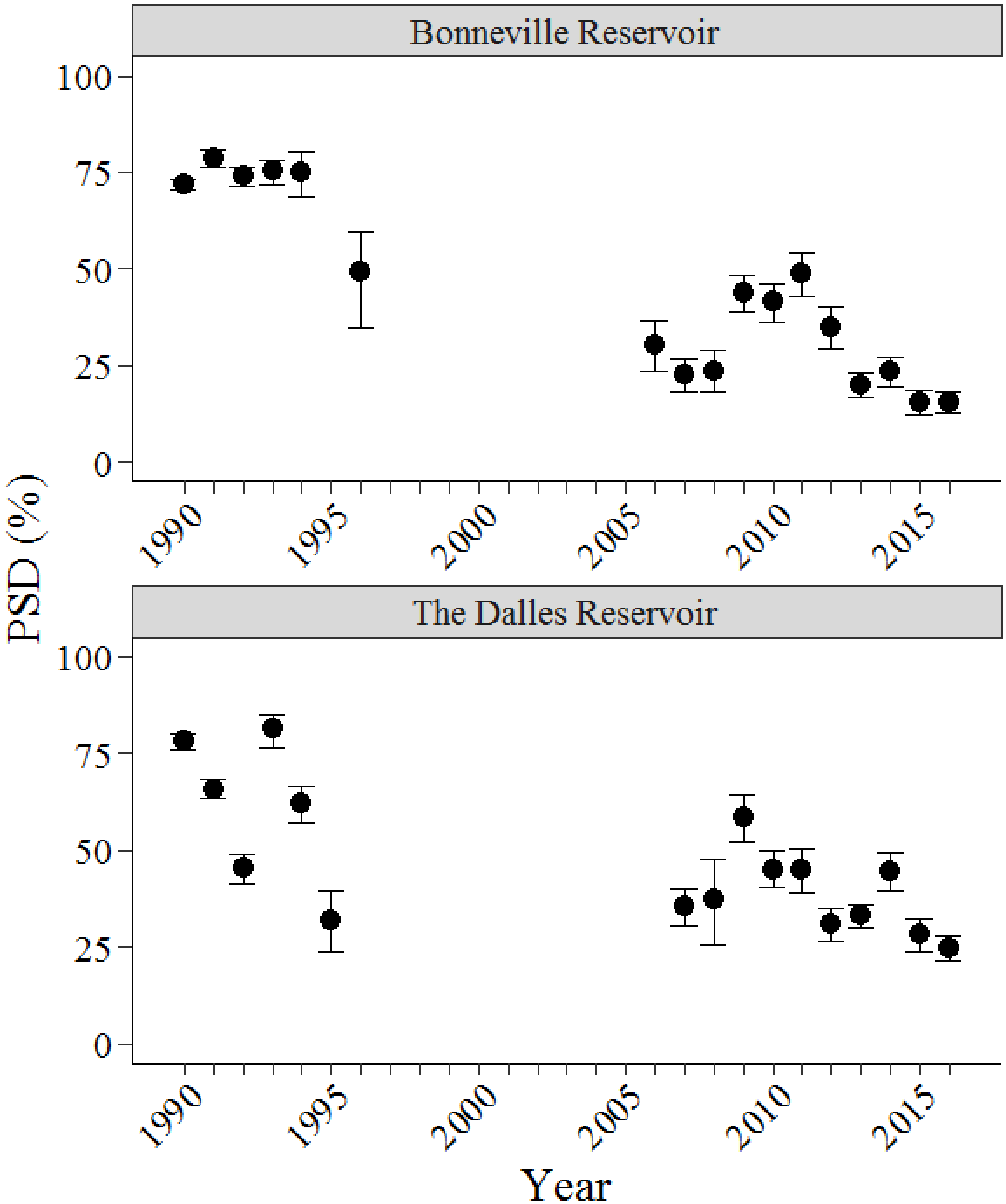

Figure 7. Estimates of proportional stock density (*PSD*) for Northern Pikeminnow sampled in Bonneville and The Dalles reservoirs during the annual Dam Angling Fishery, 1990–2016. Error bars represent 95% bootstrap confidence intervals.

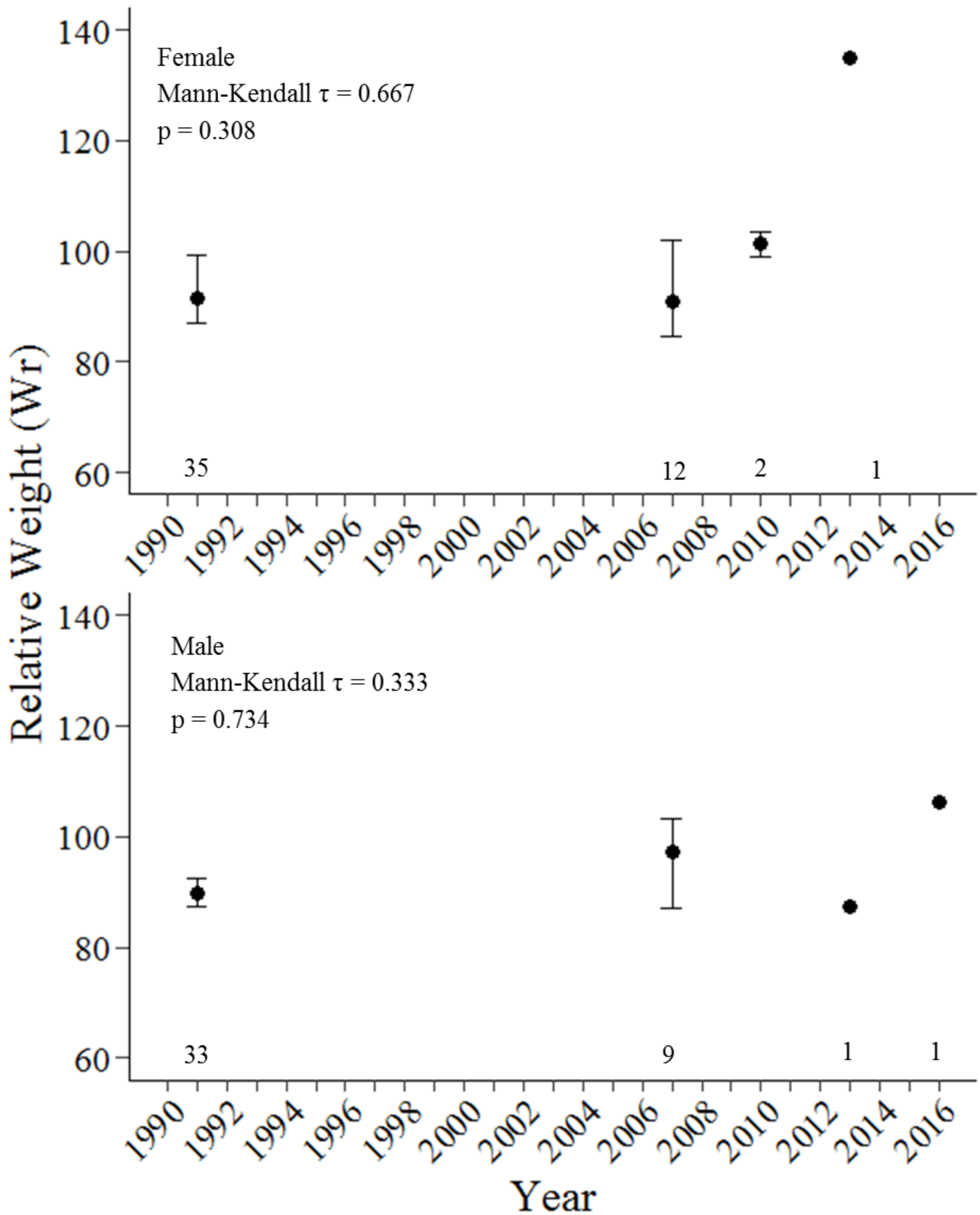

Figure 8. Median relative weight (*Wr*) for female and male Northern Pikeminnow in Ice Harbor Reservoir, 1991–2016. Error bars represent 95% bootstrap (percentile) confidence intervals. A large gap in data between 1991 and 2007 prohibited fitting the data with a LOWESS curve. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years with no data indicate sampling was not conducted or no fish were collected.

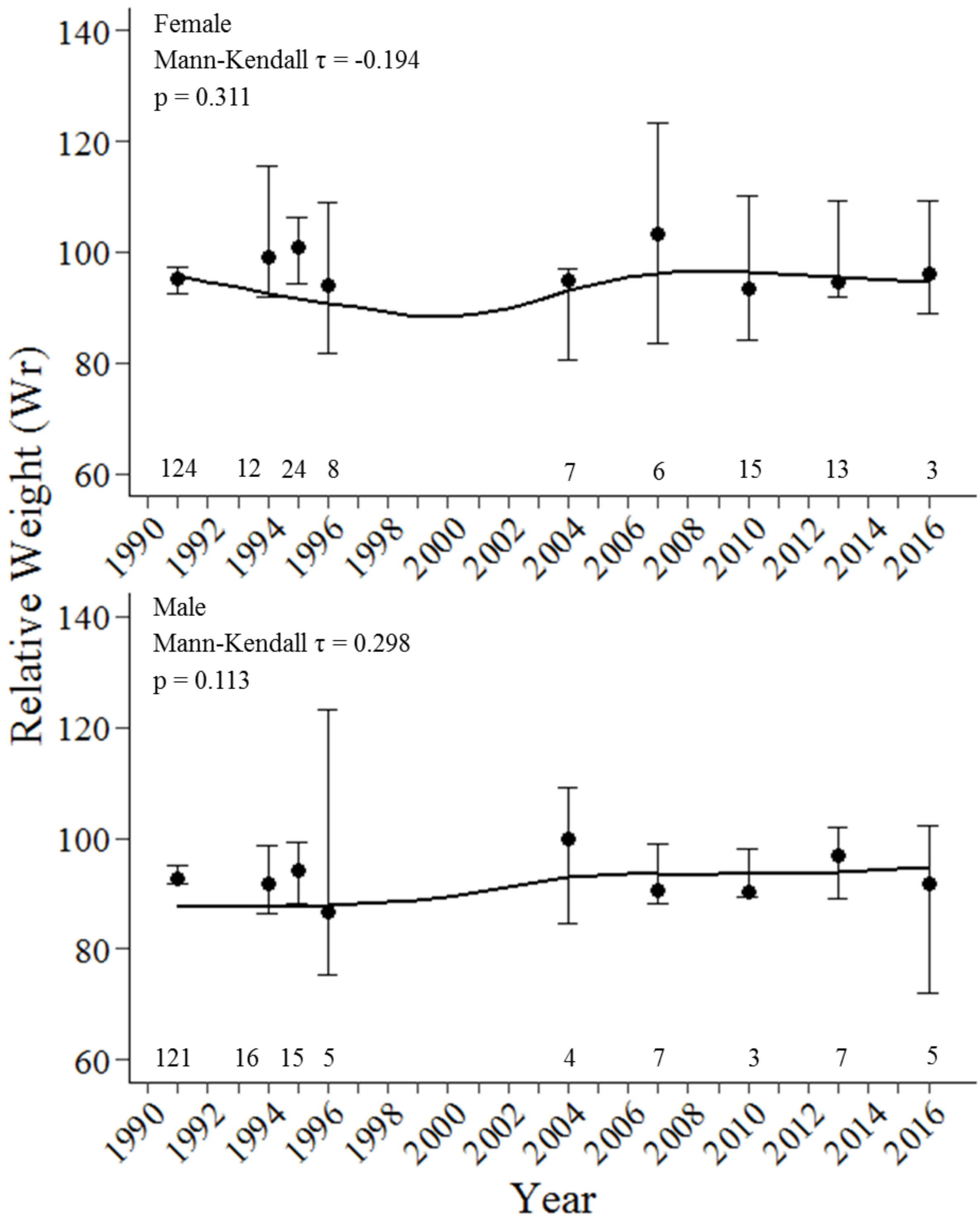

Figure 9. Median relative weight (*Wr*) for female and male Northern Pikeminnow in Lower Monumental Reservoir, 1990–2016. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years with no data indicate sampling was not conducted or no fish were collected.

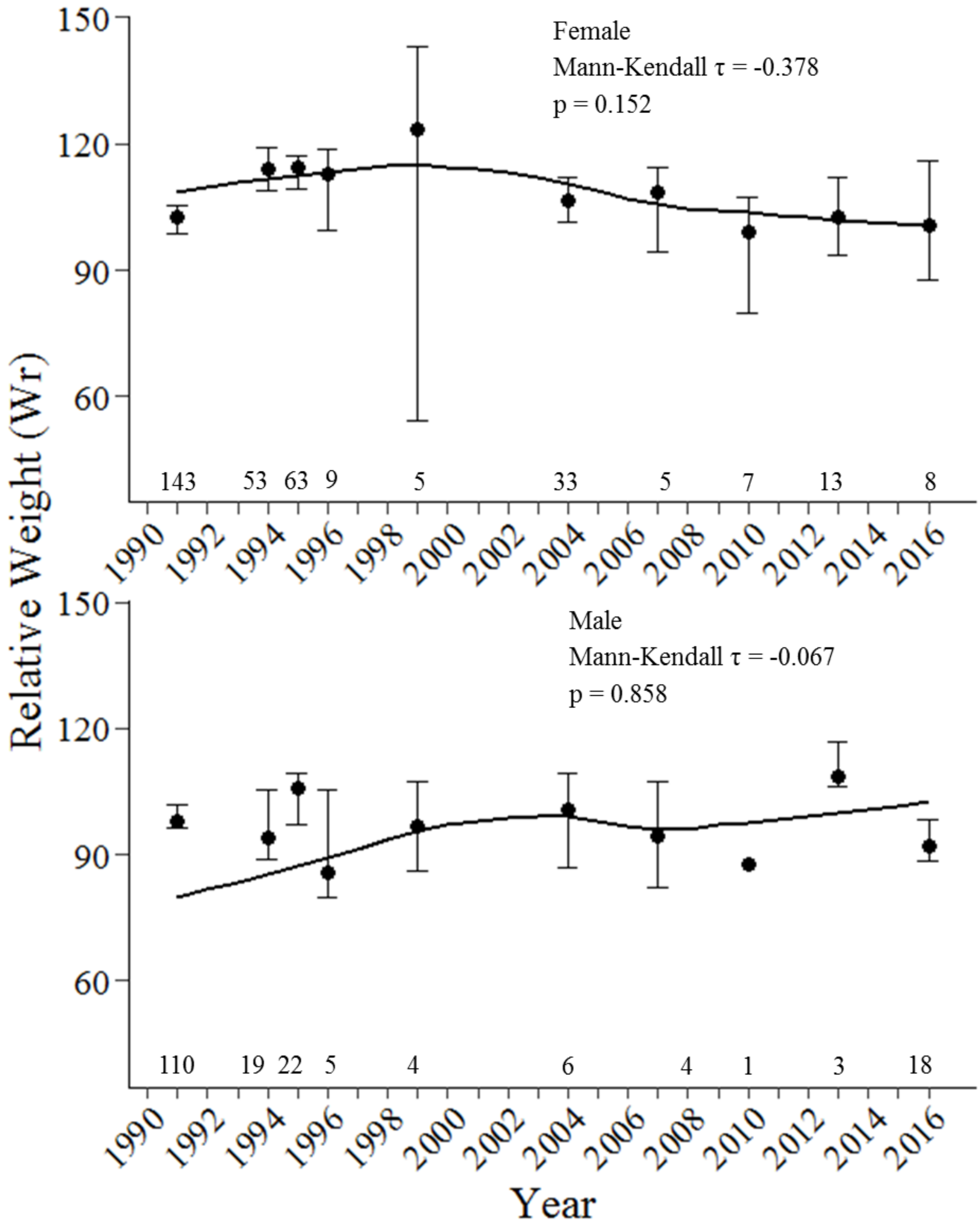

Figure 10. Median relative weight (*Wr*) for female and male Northern Pikeminnow in Little Goose Reservoir, 1990–2016. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years with no data indicate sampling was not conducted or no fish were collected.

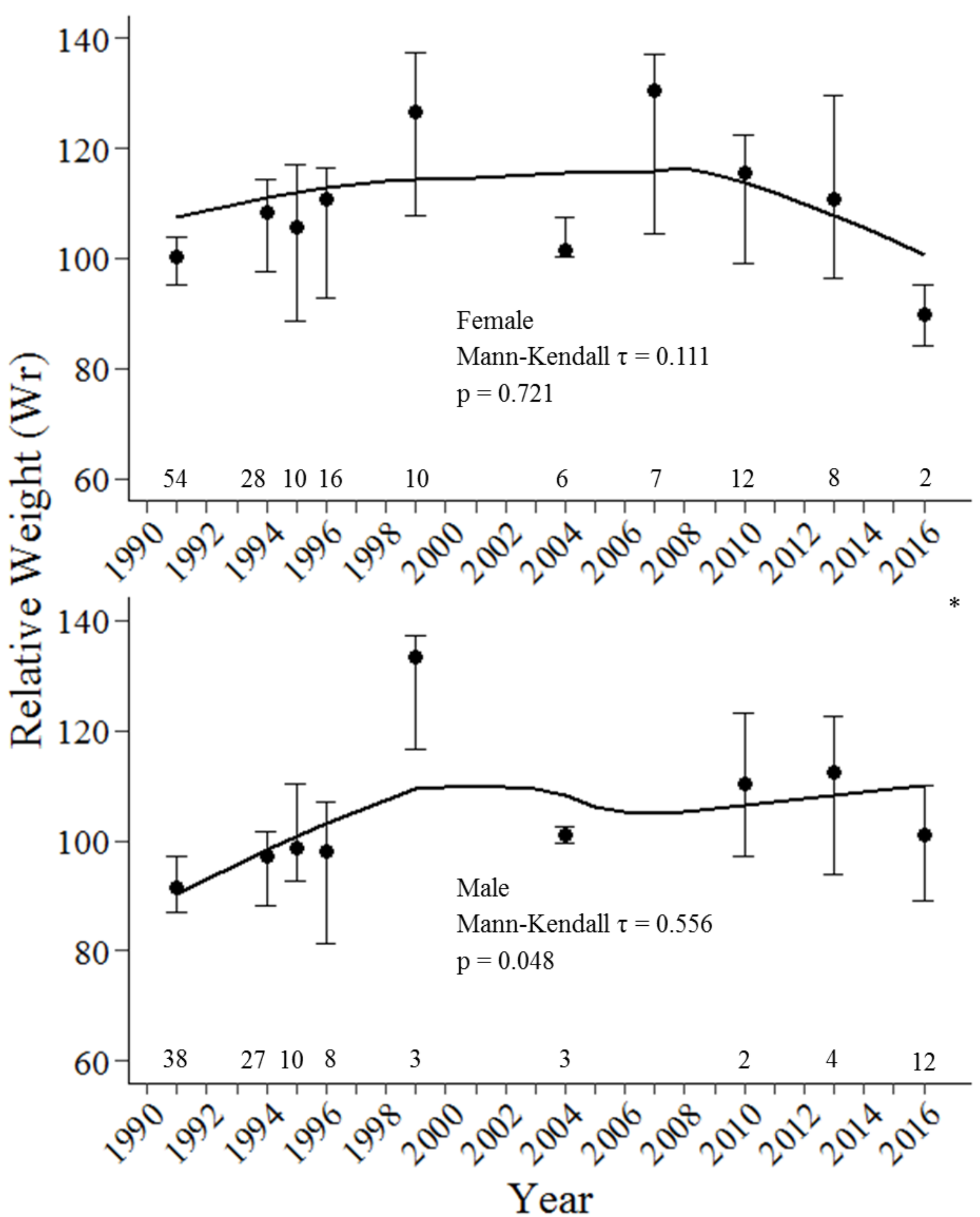

Figure 11. Median relative weight (*Wr*) for female and male Northern Pikeminnow in Lower Granite Reservoir, 1990–2016. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years with no data indicate sampling was not conducted or no fish were collected and asterisk (*) indicates significant result ($\alpha < 0.05$).

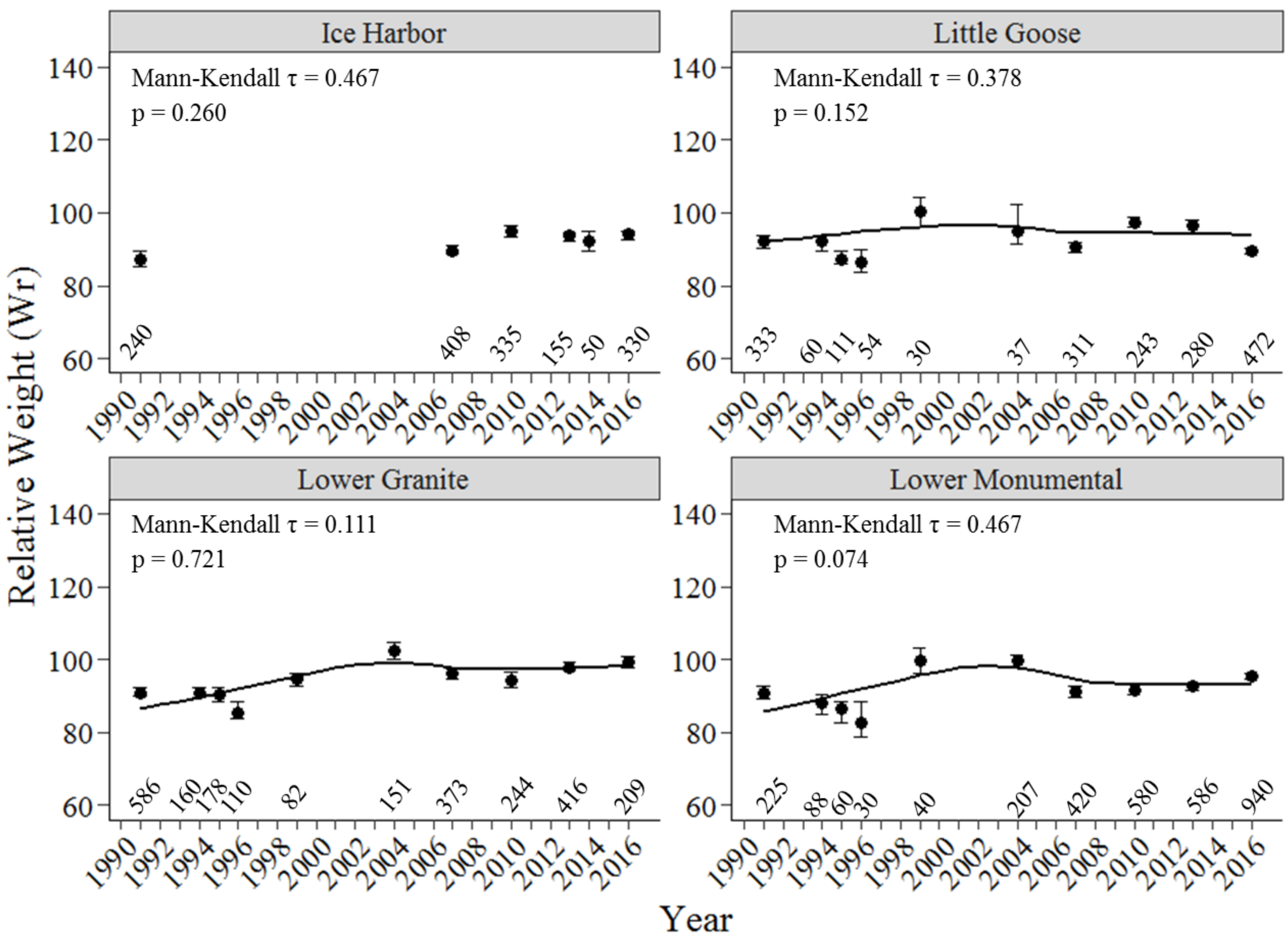

Figure 12. Median relative weight (*Wr*) for Smallmouth Bass in the lower Snake River reservoirs, 1991–2016. Error bars represent 95% bootstrap (percentile) confidence intervals. A large gap in data between 1991 and 2007 prohibited fitting the data with a LOWESS curve for Ice Harbor. For all other reservoirs, data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years with no data indicate sampling was not conducted or no fish were collected.

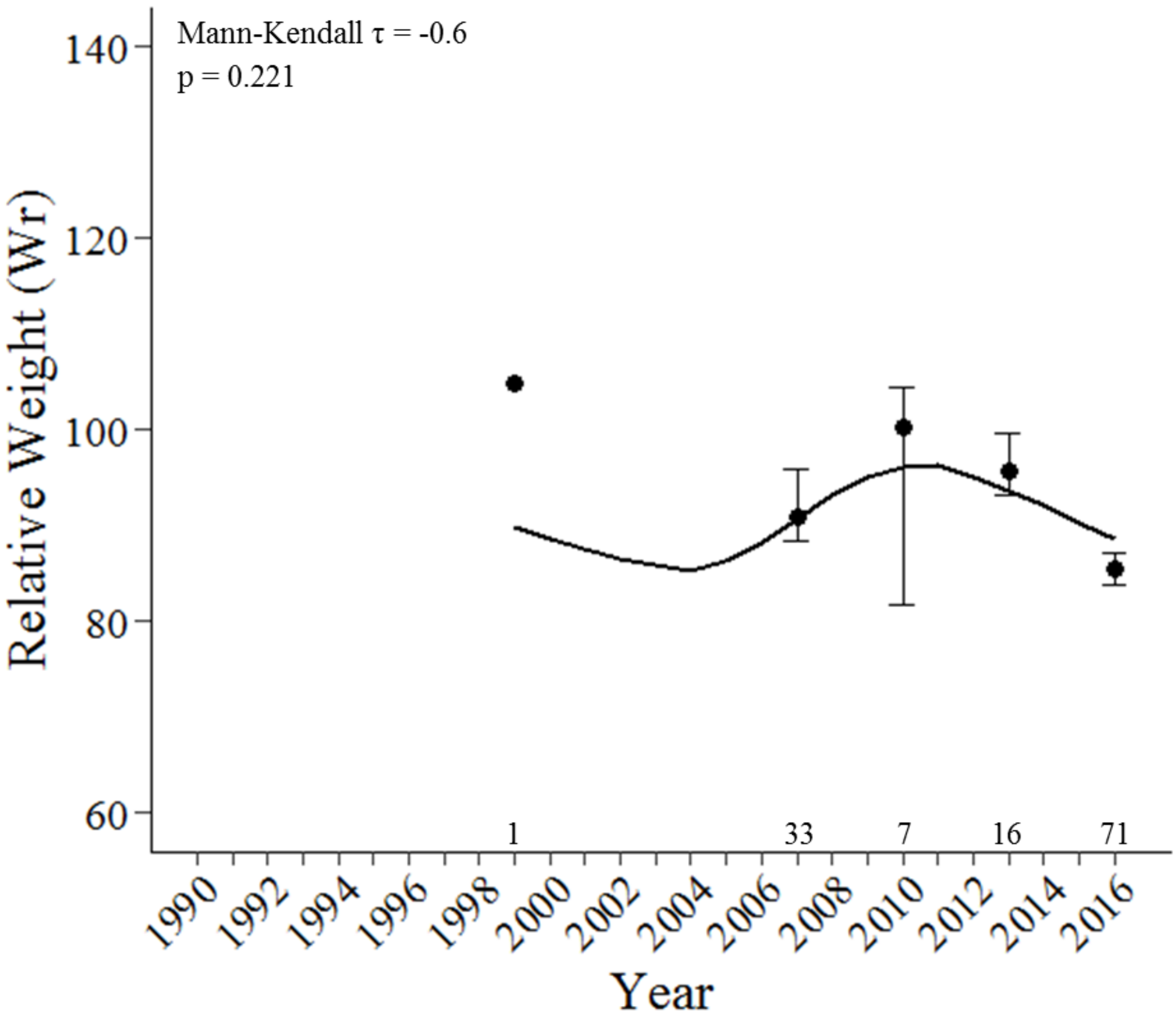

Figure 13. Median relative weight (*Wr*) for Walleye in Lower Monumental Reservoir, 1991–2016. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with a LOWESS curve. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years with no data indicate sampling was not conducted or no fish were collected.

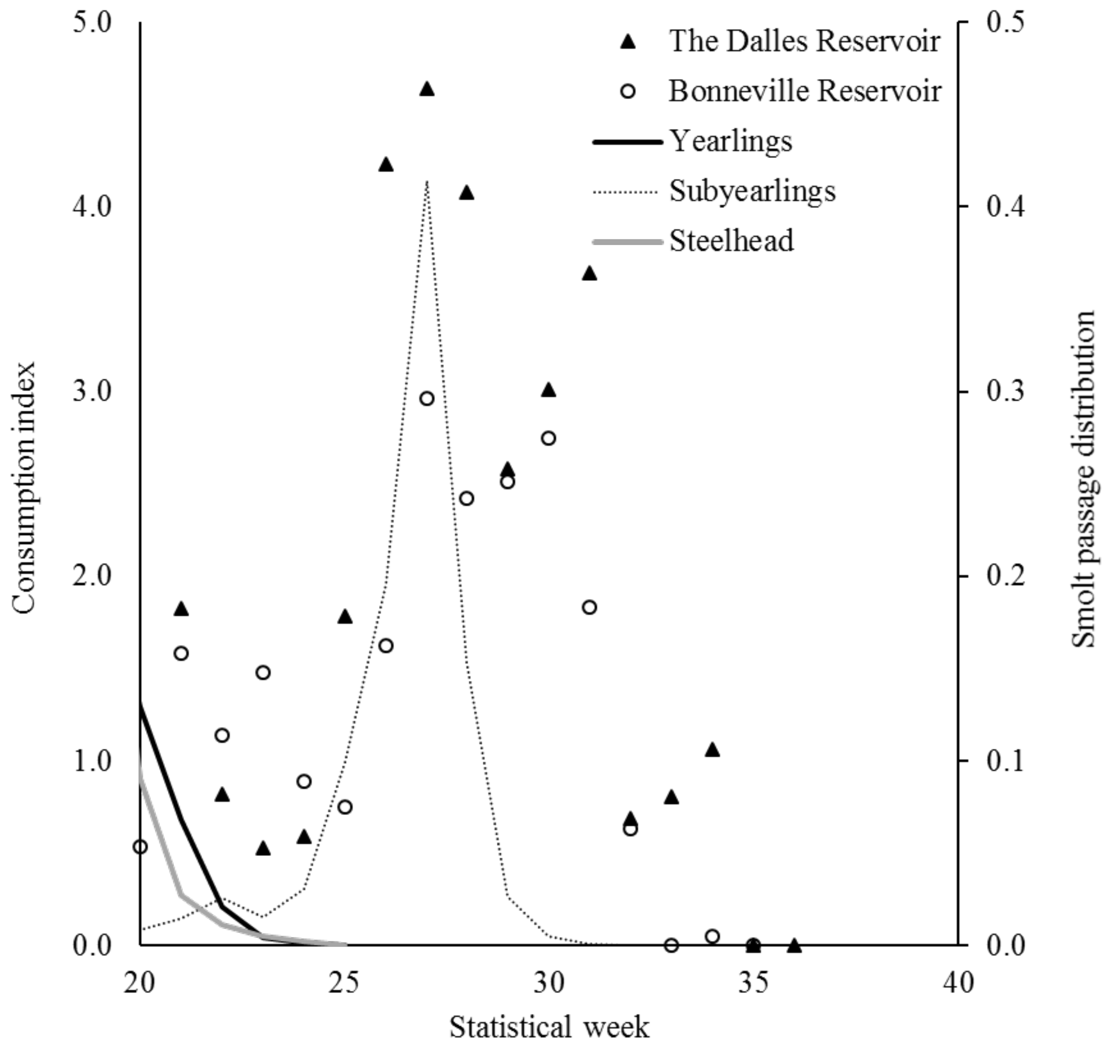

Figure 14. Mean weekly juvenile salmon consumption index for Northern Pikeminnow captured from Dam Angling in Bonneville and The Dalles reservoirs compared with the smolt passage index at John Day Dam during 2016. Smolt passage data are summarized from Fish Passage Center (unpublished data).

REPORT D

Northern Pikeminnow Dam Angling on the Columbia River

2016 Annual Report

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We appreciate the efforts of Scott Mengis as the Pikeminnow Dam Angling crew leader, along with Kyle Beckley, Steve Lines, Tim Miller and Mark Helman who served as our 2016 dam angler crew.

We also recognize Diana Murillo for her work on Dam Angler data entry and document verification, and Dennis Werlau for producing the Dam Angling Weekly Field Activity Reports throughout the 2016 season.

ABSTRACT

We are reporting on the 2016 Northern Pikeminnow Dam Angling component of the Northern Pikeminnow Management Program (NPMP) as implemented by the Washington Department of Fish and Wildlife (WDFW). The Dam Angling component of the NPMP was shortened in 2016 to address potential shortfalls in funding for the 2016 Northern Pikeminnow Sport-Reward Fishery (NPSRF). Angling took place within the boat restricted tailrace areas of The Dalles and John Day dams during 16 weeks from May 3th through August 18th 2016. The objectives of this project were to (1) implement a recreational-type hook and line fishery that harvests Northern Pikeminnow from within the boat restricted areas (BRZ) unavailable to the public at The Dalles and John Day dams, (2) allocate Dam Angler effort between the The Dalles and John Day dams based on angler CPUE in order to maximize harvest of Northern Pikeminnow, (3) collect, compile and report data on angler harvest, CPUE, gear/techniques and incidental catch for each project, (4) scan, record and report Passive Integrated Transponder (PIT) tag data from all Northern Pikeminnow, Smallmouth Bass, Walleye, and Channel Catfish caught by the angling crew and record with the presence of any external spaghetti tags, fin-clips, or signs of tag loss from these fishes for use in coordination with other Oregon Department of Fish and Wildlife (ODFW) predation studies, (5) collect relevant biological data on all Northern Pikeminnow and other fishes caught by the 2016 Dam Angling crew.

A Dam Angling crew of four anglers harvested 6,162 Northern Pikeminnow in 2016. Of those, 3,064 Northern Pikeminnow were harvested at The Dalles Dam and 3,098 were harvested at the John Day Dam. The crew fished a total of 1511.5 hours during the 16 week fishery, averaging 385 fish per week and for a combined overall average catch per angler hour of 4.1 Northern Pikeminnow. At The Dalles Dam, the crew averaged 4.3 fish per angler hour (CPUE), and cumulatively 54 Northern Pikeminnow per day. At the John Day Dam, the crew averaged 3.9 fish per angler hour (CPUE) with a cumulative crew total of 54 fish per day.

Based on the success of the WDFW Dam Angling crew in implementing the Dam Angling project from 2010-15, the 2016 Dam Angling crew continued to use back bouncing soft plastic lures as the primary angling method for harvesting Northern Pikeminnow from The Dalles and John Day dams. Incidental species most frequently caught and released by the Dam Angling crew in 2016 were Smallmouth Bass *Micropterus dolomieue*, Walleye *Sander vitreus* and Sculpin *Cottus* spp.

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 (Northwest Power Planning Council 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 FL (11 inches total length). The Northern Pikeminnow Management Program (NPMP) was created in 1990, with the goal of implementing fisheries to achieve the recommended 10-20% annual exploitation on Northern Pikeminnow >275 mm FL within the program area (Vigg and Burley 1989). The primary component of the NPMP is the Northern Pikeminnow Sport-Reward Fishery (NPSRF) implemented by the Washington Department of Fish and Wildlife (WDFW) (Burley et al. 1992). Beginning in 2010, WDFW was also contracted to conduct the Dam Angling component of the NPMP (Hone et al. 2011, Dunlap et al. 2012, Winther et al. 2013, Dunlap et al. 2014, Dunlap et al. 2015, Winther et al. 2016a) and 2016 marks the seventh consecutive year WDFW has implemented this component. The Dam Angling component of the NPMP utilized a four-person crew of experienced anglers using recreational-type hook and line angling techniques to harvest Northern Pikeminnow from within the boat restricted zones (BRZ's) below The Dalles and John Day dams on the Columbia River in 2016.

The objectives of the 2016 Dam Angling component of the NPMP were to (1) implement a recreational-type hook and line fishery that harvests Northern Pikeminnow from within the boat restricted areas (BRZ) unavailable to the public at The Dalles and John Day dams, (2) allocate Dam Angler effort between The Dalles and John Day dams based on angler CPUE in order to maximize harvest of Northern Pikeminnow, (3) collect, compile and report data on angler harvest, CPUE, gear/techniques and incidental catch for each project, (4) scan, record and report Passive Integrated Transponder (PIT) tag data from all Northern Pikeminnow, Smallmouth Bass, Walleye and Channel Catfish caught by the angling crew and record the presence of any external spaghetti tags, fin-clips or signs of tag loss from these fishes for use in coordination with other Oregon Department of Fish and Wildlife (ODFW) predation studies, and (5) collect biological data on all Northern Pikeminnow and other fishes caught by the 2016 Dam Angling crew.

METHODS

Project Area

In 2016, Northern Pikeminnow removal activities utilizing a Dam Angling crew were conducted by WDFW at The Dalles and John Day Dams on the Columbia River as a supplemental component to the NPMP (Figure 1). Dam Angling activities in 2016 were planned for a five month period scheduled to be from May 3th (week 19) through September 30th (week 40). Unforeseen budgetary issues forced Dam Angling to cease activities early so the last week worked was week 34 (August 18th) in 2016. At both The Dalles, and John Day Projects, all angling activities were conducted within the tailrace boat restricted zones (BRZ) where no public angling was permitted. At The Dalles Dam, the Dam Angling crew fished primarily along the turbine wall and near the ice-trash sluiceway as indicated in Figure 2. At the John Day Dam, the crew fished exclusively along the turbine wall (Figure 3).

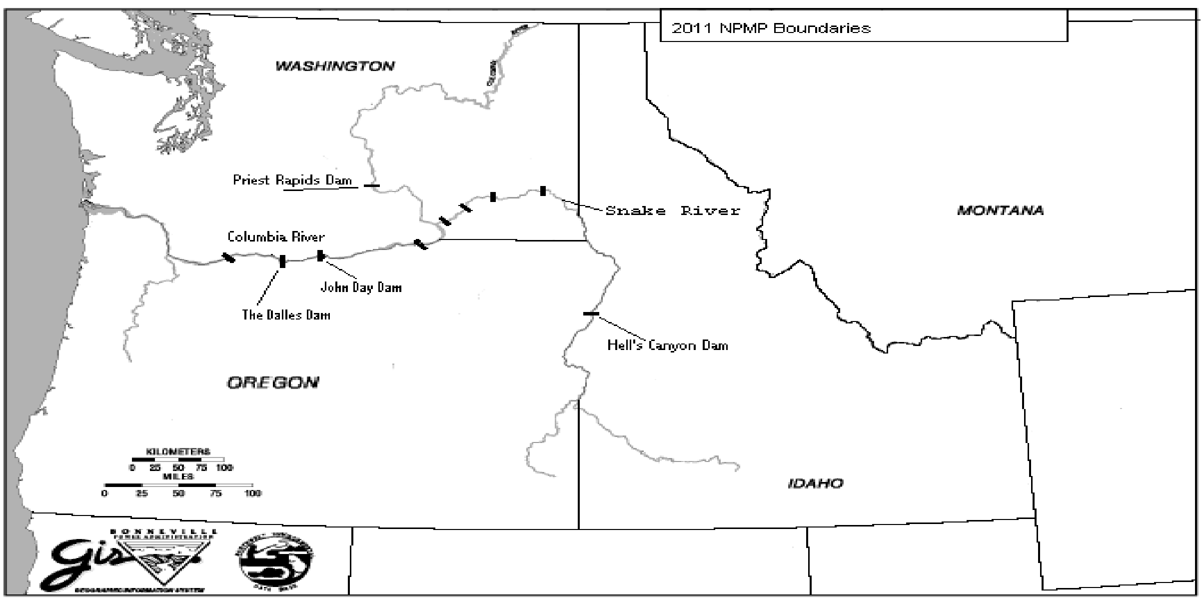

Figure 1. Northern Pikeminnow Management Program Boundaries, including 2016 Dam Angling sites

Figure 2. Angling Locations for the 2016 Dam Angling Crew at The Dalles Dam

Figure 3. Angling Locations for the 2016 Dam Angling Crew at the John Day Dam

The Dam Angling Season

In order to achieve the primary project objective of maximizing harvest of predatory Northern Pikeminnow, WDFW continued to use a Dam Angling Strategy (DAS) developed in 2011 (Dunlap et al. 2012) for allocating Dam Angler effort in 2016. The 2016 Dam Angler CPUE goal remained set at 2.0 fish/angler hour as established in our 2011 DAS. Full scale angling activities were conducted when CPUE was $\geq$ 2.0 fish/angler hour, and reduced scale angling was conducted when CPUE fell below 2.0 fish/angler hour.

The Dam Angling Crew

The four member angling crew typically worked four ten hour days a week, (usually Tuesday - Friday) during the 2016 season (Figure 4). Morning angling start times varied from approximately 4:30 am to 6:00 am at The Dalles Dam and from 5:00 am to 6:00 am at the John Day Dam. Evening times ranged from 6:00 pm to 1:00 am. Starting in late July the crew switched to all angling shifts in the evening at both Dams. In addition to the three person angling crew, a crew leader was also present each day for angler safety and supervision, to collect, record and compile data on Northern Pikeminnow harvest, other fish species caught, and to ensure that NPMP project protocols and Corps of Engineers (USACE) rules were adhered to.

Figure 4. The Dam Angling crew at John Day Dam

Angling Gear

Dam anglers used Berkley Air IM8 Graphite 10’6” (2-8 oz. extra heavy casting) rods equipped with either Daiwa TD Luna 253 or Shimano Calcutta 400 series reels. Each reel was spooled with a 20# test braided main line (Power Pro), tied to a size 7 barrel swivel and a 24”-30” monofilament leader of 15-20# Maxima (Figure 5). Cannonball sinkers were attached to the swivel using four to six inch dropper line of 12# monofilament leader. Cannonball weights varied from 1-6 ounces depending on river flow. Terminal gear consisted primarily of assorted soft plastic lures rigged with two octopus style hooks (size 1 to 1/0 Gamakatsu hooks) spaced at

1 1/8” apart (Figure 6). Hook size varied in order to match the size of the soft plastic lure. Soft plastic lures used were in the 2-5” size range and included tubes, flukes, grubs and sassy shad.

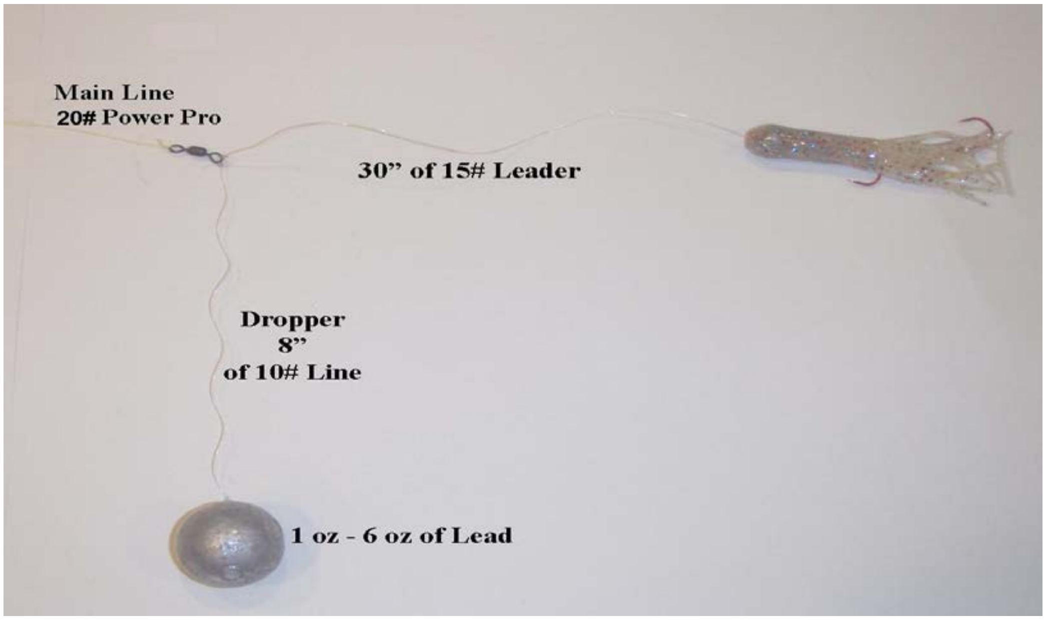

Figure 5. Example of Typical Rigging Used by 2016 NPMP Dam Anglers

Figure 6. Examples of Soft Plastic Tube Baits Used by 2016 NPMP Dam Anglers

Data collection

Creel data were recorded by each individual angler for their angling day and then were combined and summarized daily with weekly totals submitted separately for each project (The Dalles and John Day dams). Collected data included total angling hours of effort per angler, Northern Pikeminnow harvest per angler, incidental catch per angler, location and hour of all caught fishes by angler, as well as specific terminal gear (lure) used (and number of fish caught with that lure) by angler. Weekly catch and harvest totals (by project) for Dam Anglers were submitted to PSMFC using a Weekly Field Activity Report (WFAR) as is done for the NPSRF.

Biological Sampling

Fork lengths (FL) of all Northern Pikeminnow harvested by the Dam Angling crew were recorded on biological data sheets provided by the NPSRF. Technicians also examined all Northern Pikeminnow for the presence of external tags (spaghetti or dart), fin-clip marks, and signs of tag loss. Complete biological data were collected from all spaghetti tagged Northern Pikeminnow including FL, sex (determined by evisceration), and scale samples if specified. Spaghetti tagged Northern Pikeminnow carcasses were then labeled and frozen for data verification and/or tag recovery at a later date. Spaghetti tags from harvested Northern Pikeminnow along with biological data was recorded on a tag envelope provided by the NPSRF and all tag data was submitted to ODFW for verification.

PIT Tag Detection

All Northern Pikeminnow collected by Dam Anglers during 2016 were scanned for Passive Integrated Transponder (PIT) tags. Northern Pikeminnow harvested by anglers participating in the NPSRF have been found to ingest juvenile salmonids which have been PIT tagged by other studies within the basin (Glaser et al. 2001). In addition, PIT tags have also been used by ODFW as a secondary mark in all Northern Pikeminnow fitted with spaghetti tags (beginning in 2003) as part of the NPMP's biological evaluation activities (Takata and Koloszar 2004). Dam Angling technicians were required to scan 100% of all harvested Northern Pikeminnow for PIT tags using Destron Fearing portable transceiver systems (model #FS2001F). Technicians were also asked to scan incidental catch for PIT tags whenever possible and all incidentally caught Smallmouth Bass per ODFW request. Scanning began on the first day of angling and continued throughout the duration of Dam Angling activities. Technicians individually scanned all Northern Pikeminnow for PIT tag presence, and complete biological data were recorded from all pikeminnow with positive readings. All Northern Pikeminnow with PIT tags were labeled and preserved for later dissection and tag recovery. All PIT tag data were verified after recovery of PIT tags by WDFW personnel and all data were provided to ODFW and the PIT Tag Information System (PTAGIS).

Northern Pikeminnow Processing

During biological sampling, all Northern Pikeminnow were caudal clipped as an anti-fraud measure to eliminate the possibility of previously processed Northern Pikeminnow being resubmitted to the Sport-Reward Fishery for payment. 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

Combined The Dalles / John Day Dam Findings

2016 Dam Angling Season

The 2016 Dam Angling Season took place from May 3th through August 18th. River conditions were favorable early in the season when angling activities began in week 19, with weekly harvest building through the peak in week 24, and concluding in week 34 (Figure 7). Total harvest for The Dalles and John Day dams combined was 6,162 Northern Pikeminnow in 1511.5 angling hours, with a combined CPUE of 4.1 fish per angler hour. The dam angling crew exceeded the CPUE goal of 2.0 fish/angler hour in week 20, and remained above it for all but the final two weeks of the 2016 season (Figure 8).

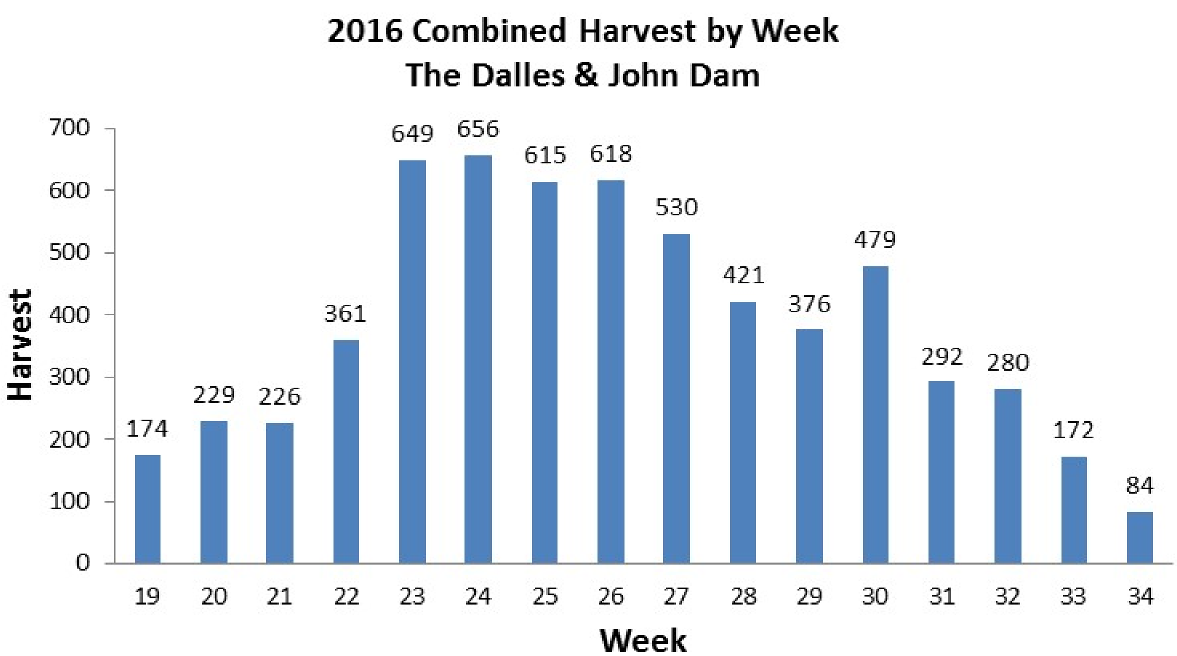

Figure 7. 2016 Weekly Harvest of The Dalles (TD) and John Day (JD) dams Combined

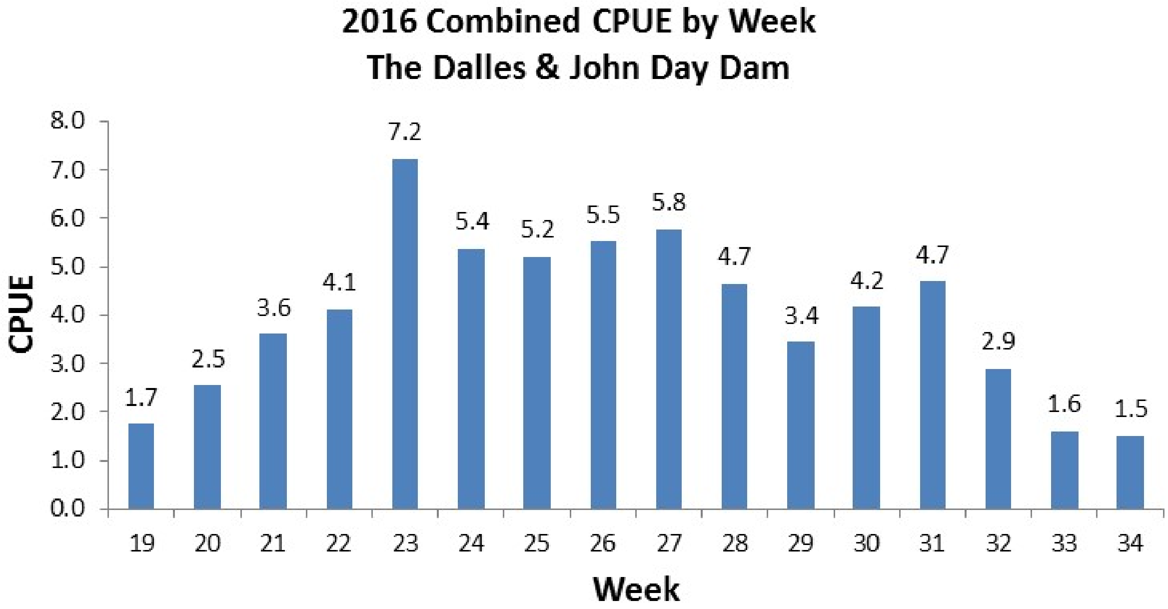

Figure 8. 2016 Weekly CPUE (fish/angler hour) of The Dalles (TD) and John Day (JD) dams Combined

Angling Gear and Technique

The 2016 Dam Angling crew primarily targeted fishing areas and fishing times at each dam that had been productive in the past (Hone et al. 2011, Dunlap et al. 2012, Winther et al. 2013, Dunlap et al. 2014, Dunlap et al. 2015, Winther et al. 2016a). Using the knowledge obtained during the four previous seasons in which WDFW had conducted the Dam Angling component of the NPMP, we believed that the majority of our angling success in 2016 would again come from back bouncing soft plastic lures off of the turbine decks. Our top producing lure in 2016 was the 3.75" Gitzit tube in Smoke/Black Red Glitter color, which accounted for 1,220 harvested Northern Pikeminnow. The top 5 most productive soft plastic lures used by the Dam Angling crew in 2016 are listed in Table 1.

Table 1. Top 5 Northern Pikeminnow Lures used by 2016 WDFW Dam Angling Crew

Northern Pikeminnow Lures

Brand/style	Size	Color	# N. Pikeminnow Caught
Gitzit/ tube bait	3.75"	Smoke/Black Red Glitter	1,220
Gitzit/ tube bait	2.50"	Mini Smoke/Black Copper Glitter	1,205
Gitzit/ tube bait	3.75"	Smoke/Black Copper Glitter	944
Gitzit/ tube bait	2.50"	Mini Pearl White/Black Back	720
Gitzit/ tube bait	2.50"	Mini Smoke/Black Red Glitter	498

Angling Times

Time of day continued to make a difference in harvest success during the 2016 season. Dam Angler catch data from previous seasons had indicated that morning hours prior to 11 a.m. were consistently the most productive times for harvesting Northern Pikeminnow (Hone et al. 2011, Dunlap et al. 2012, Winther et al. 2013, Dunlap et al. 2014, Dunlap et al. 2015, Winther et al 2016a). Results for the 2016 season once again indicated that a most Dam Angler harvest of Northern Pikeminnow (58%) occurred prior to 11:00 am (Table 2).

Table 2. Combined 2016 WDFW Dam Angler Hourly Harvest Totals for The Dalles (TD) and John Day (JD) dams

Hourly Northern Pikeminnow Harvest (combined TD and JD totals)

Time of day	Harvest	% of Harvest
4:30 a.m. to 6:00 a.m.	764	12%
6:00 a.m. - 7:00 a.m.	658	11%
7:00 a.m. - 8:00 a.m.	590	10%
8:00 a.m. - 9:00 a.m.	578	9%
9:00 a.m. - 10:00 a.m.	499	8%
10:00 a.m. - 11:00 a.m.	469	8%
11:00 a.m. - 12:00 p.m.	547	9%
12:00 p.m. - 1:00 p.m.	335	5%
After 1 p.m.	1722	28%

Table 3. 2016 WDFW Dam Angler Hourly Northern Pikeminnow Harvest Comparison (TD vs JD)

	The Dalles Dam		John Day Dam	
Time of day	Harvest	% of Harvest	Harvest	% of Harvest
4:30 a.m. - 6:00 a.m.	446	15%	318	10%
6:00 a.m. - 7:00 a.m.	318	10%	340	11%
7:00 a.m. - 8:00 a.m.	323	11%	267	9%
8:00 a.m. - 9:00 a.m.	248	8%	330	11%
9:00 a.m. - 10:00 a.m.	208	7%	291	9%
10:00 a.m. - 11:00 a.m.	134	4%	335	11%
11:00 a.m. - 12:00 p.m.	147	5%	400	13%
12:00 p.m. - 1:00 p.m.	92	3%	243	8%
1:00 p.m. - 6:00 p.m.	47	2%	80	3%
6:00 p.m. - 7:00 p.m.	44	1%	75	2%
7:00 p.m. – 8:00 p.m.	105	3%	105	3%
8:00 p.m. – 9:00 p.m.	150	5%	162	5%
9:00 p.m. – 10:00 p.m.	139	5%	136	4%

10:00 p.m. – 2:00 a.m.	663	22%	16	1%
Total	3,064	100%	3,098	100%

Incidental Catch

The Dam Angling crew incidentally caught the fish species listed in Table 4 while targeting Northern Pikeminnow at The Dalles and John Day dams in 2016. All incidentally caught fish species were released. Incidental species most often caught were Smallmouth Bass *Micropterus dolomieue*, Walleye *Sander vitreus* and sculpin *Cottus* spp. . The Dam Angling crew continued to note large numbers of juvenile lamprey *Entosphenus* spp. and/or *Lampetra* spp. regurgitated by Northern Pikeminnow caught at The Dalles Dam and John Day Dam during May and June.

Table 4. 2016 WDFW Dam Angler Incidental Catch by Project

Incidental Catch

Species	The Dalles Dam	John Day Dam
Smallmouth Bass	356	1156
Walleye	55	517
Sculpin	30	12
White Sturgeon	0	9
Channel Catfish	2	17
American Shad	18	18
Peamouth	2	7
Trout	0	1

Tag Recovery

All Northern Pikeminnow harvested by Dam Anglers in 2016 were visually examined for the presence of external spaghetti tags and 100% were individually scanned with PIT tag readers for the presence of any PIT tags. Four Northern Pikeminnow with external ODFW spaghetti tags were recovered by the Dam Angling crew in 2016. In addition, there were six Northern Pikeminnow recovered that had lost spaghetti tags, but retained PIT tags implanted by ODFW as a secondary tag mark as part of ODFW's biological evaluation of the NPMP (Launer et al. 2017). The 2016 Dam Angling crew also recovered 3 PIT tags from fishes ingested by Northern Pikeminnow harvested at The Dalles and John Day dams. The overall occurrence rate for ingested PIT tagged fishes recovered from Northern Pikeminnow caught by Dam Anglers in 2016 was 1:2,054 Northern Pikeminnow, compared to 1:1,538 for the Dam Angling crew in 2015 (Winther et al. 2016a) and 1:2,590 for the 2016 NPSRF (Winther et al. 2017).

The Dalles Dam

Harvest

The Dam Angling crew harvested 3,064 Northern Pikeminnow in 16 weeks at The Dalles Dam in 2016, down from 4,566 fish in 2015 (Winther et al. 2016a). Weekly harvest for the Dam Angling crew averaged 192 fish per week and ranged from peak harvest of 485 Northern Pikeminnow in week 23 (May 31 – June 2) to only 28 fish in week 28 (Figure 9). Peak weekly harvest decreased 20.5% from 2015 and occurred one week earlier than in 2015. Peak harvest for Dam Angling was four weeks later than for the 2016 NPSRF (Winther et al. 2017).

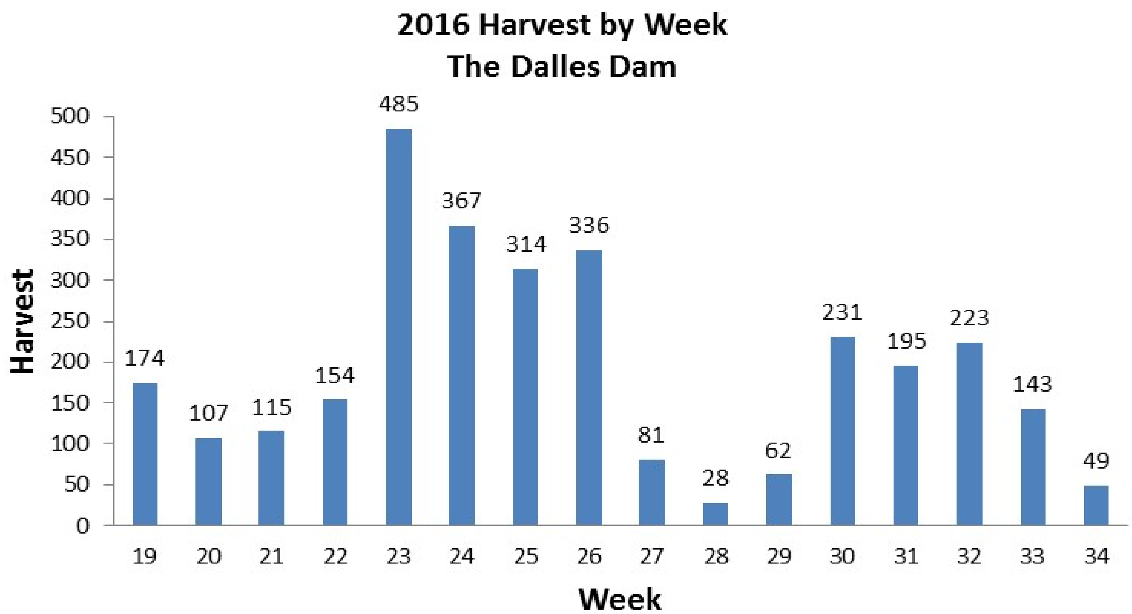

Figure 9. 2016 Weekly Dam Angler Harvest of Northern Pikeminnow at The Dalles Dam

River outflows at The Dalles Dam were not much of a factor related to Dam Angler success in 2016 (Figure 10). The 3,064 Northern Pikeminnow harvested at The Dalles Dam in 2016 included two spaghetti tagged, and three tag loss (PIT tag only) Northern Pikeminnow which were from ODFW's biological evaluation of the NPMP. The 2016 Dam Angling crew also recovered one Northern Pikeminnow containing an ingested PIT tag from a juvenile lamprey.

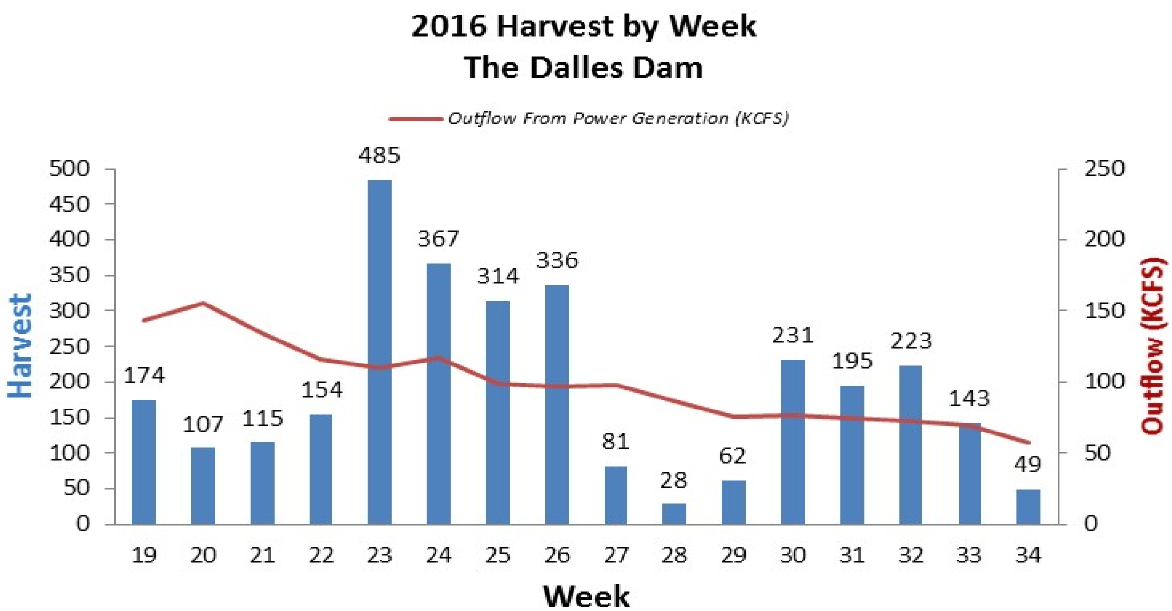

Figure 10. 2016 Weekly Northern Pikeminnow Harvest Compared to Outflow

As was the case in past Dam Angling seasons, certain areas and/or turbines at The Dalles Dam produced better harvest than others in 2016. The angling areas between Turbine #4 (T4) and the Ice/Trash Sluiceway accounted for 66% of total harvest at The Dalles Dam in 2016 (Figure 11), with the Fishway and the rock shore above the ice trash sluiceway being the two best areas.

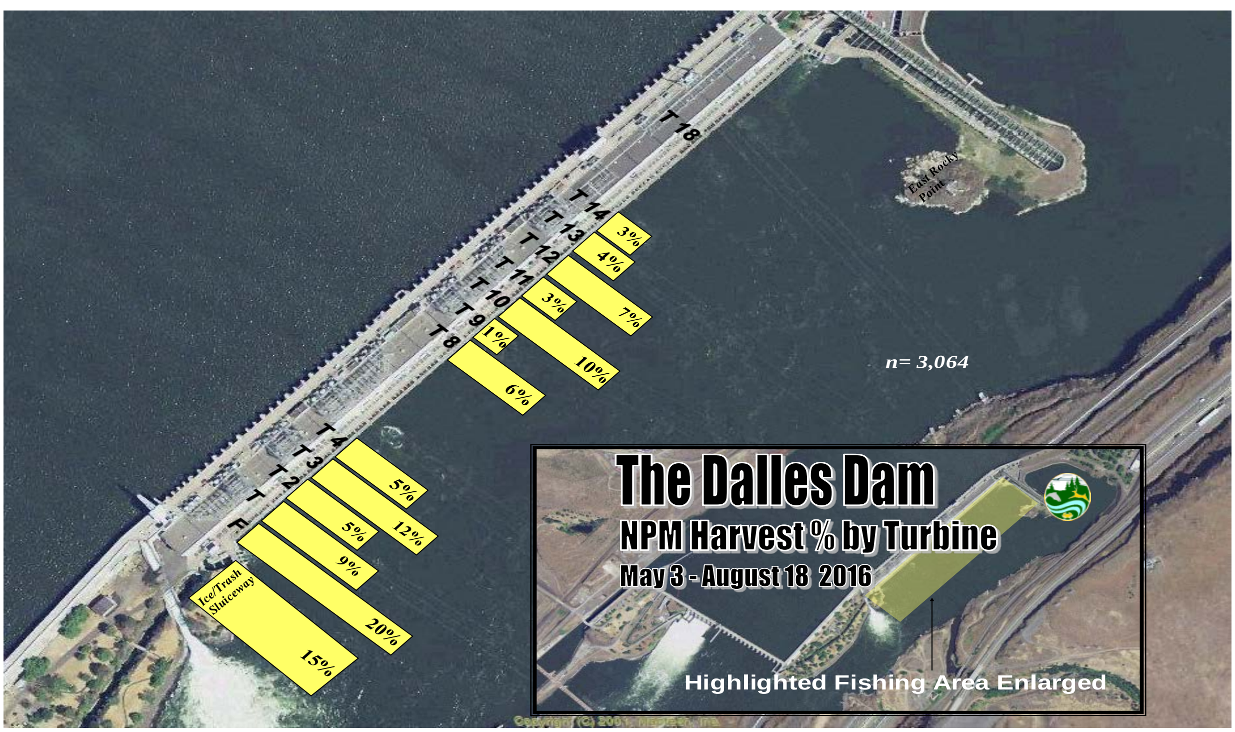

Figure 11. 2016 Overall Percent of Northern Pikeminnow Harvest by Area (T=turbine #, F = fishway)

The Dalles Dam NPM Harvest % by Turbine

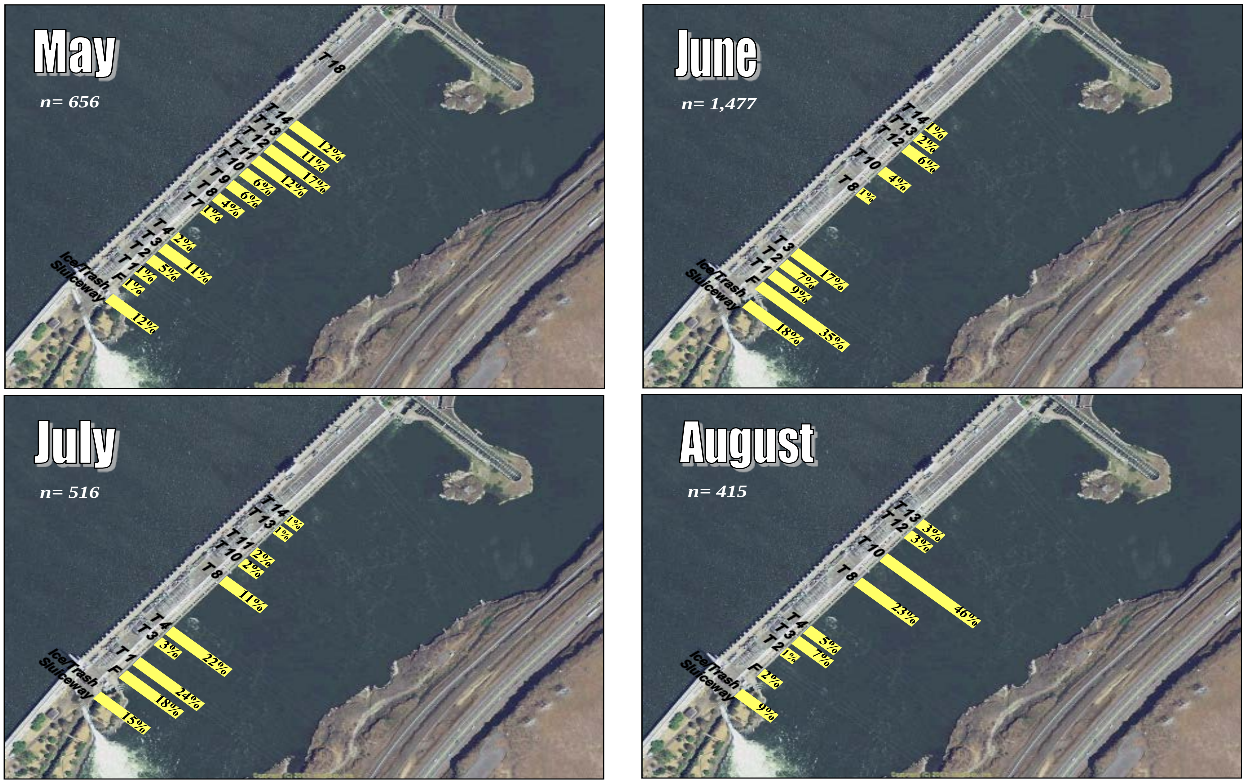

Figure 12. 2016 Monthly Harvest Percent (*rounded) by Area at The Dalles Dam (T=turbine#, F = fishway)

When we look at Northern Pikeminnow harvest at The Dalles Dam over the course of the 2016 Dam Angling season, our harvest data indicates some shift in harvest areas over the course of the May through August Dam Angling season (Figure 12). In general, 2016 data shows some harvest shifting towards the ice/trash sluiceway between May and July, but then becoming more scattered before the season ended in August. After that point, what little harvest occurred was mainly near the sluiceway.

Incidental Catch

While the Dam Angling crew did not target other fish species in their angling activities during 2016, Smallmouth Bass (smb) were the most common species incidentally caught at The Dalles Dam. The Dam Angling crew caught 356 Smallmouth Bass at The Dalles Dam in 2016, compared to 161 in 2015. Most Smallmouth Bass were caught near the Ice/Trash sluiceway (Figure 13) and, as in past seasons, all Smallmouth Bass were scanned for PIT tags and released.

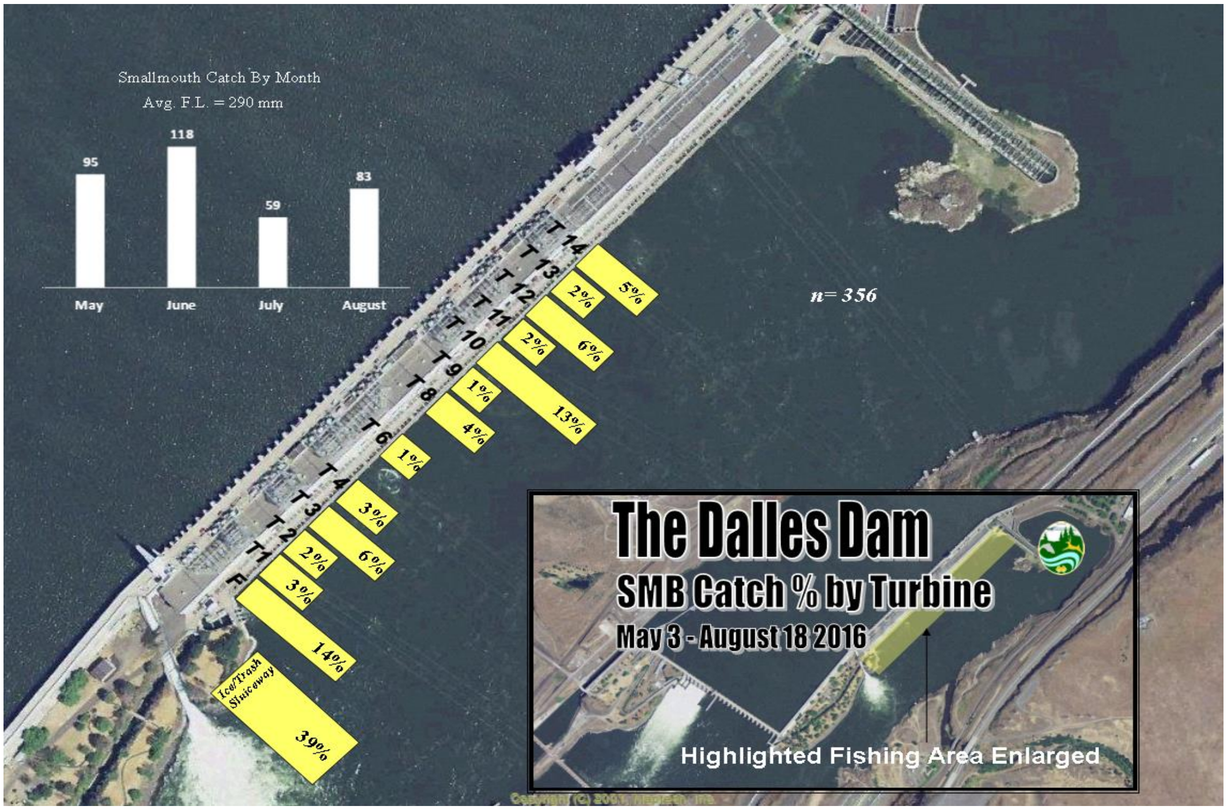

Figure 13. 2016 Incidental Catch of Smallmouth Bass (*rounded) by Dam Angling Crew at The Dalles Dam

Effort

Total angler hours of effort at The Dalles Dam decreased to 712.25 hours in 2016 from 1,251.25 hours in 2015 (Winther et al. 2016a). The decrease in effort for 2016 Dam Angling crew at The Dalles Dam was mandated as an NPMP action intended to help mitigate an expected 2016 NPSRF reward fund shortfall (Winther et al. 2017). In response to that mandate, the level of effort for the 2016 Dam Angling crew dropped to 57 days over 16 weeks compared to 84 days over 22 weeks in 2015 (47% of total effort spent by the Dam Angling crew at The Dalles Dam in 2016).

CPUE

The Dam Angling crew harvested 3,064 Northern Pikeminnow in 712.25 angler hours at The Dalles Dam in 2016 for an overall average CPUE of 4.3 fish/angler hour. Overall CPUE at The Dalles Dam in 2016, exceeded the 2.0 fish/angler hour goal and was the Dam Angling crew's highest annual CPUE to date (Winther et al. 2016a, Dunlap et al. 2015, Dunlap et al. 2014, Winther et al. 2013, Dunlap et al. 2012, Hone et al. 2011). Weekly CPUE was above the 2.0 CPUE goal for 15 of the 16 weeks fished (Figure 14) and ranged from 1.7 fish/angler hour in week 19 to 8.5 fish/angler hour in week 23.

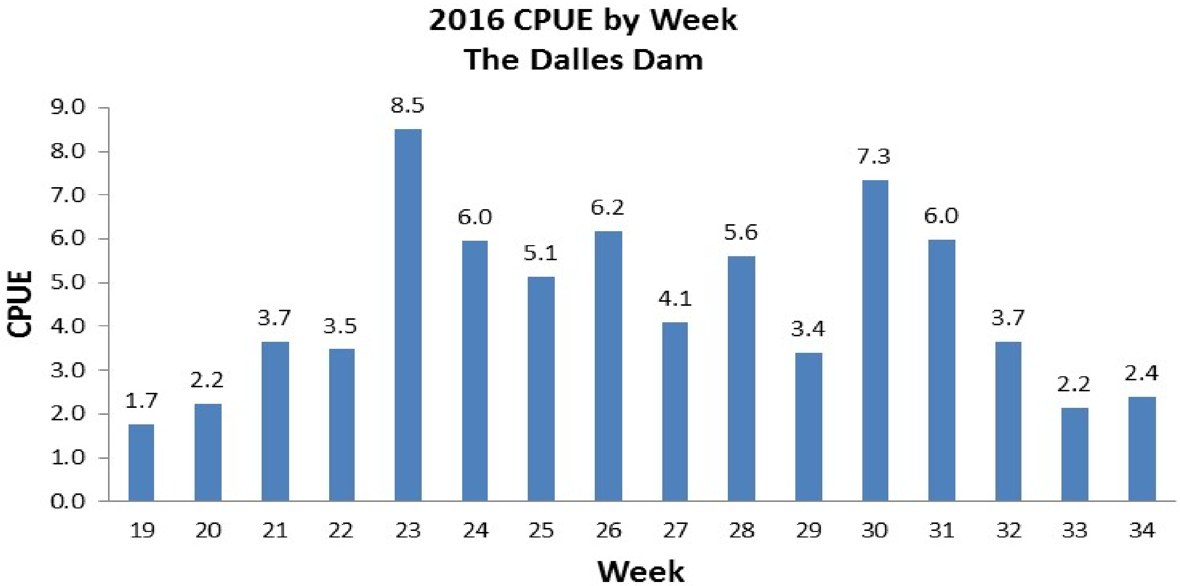

Figure 14. 2016 Weekly Dam Angler CPUE at The Dalles Dam

Fork Length Data

Fork lengths were taken from 3,064 (100%) Northern Pikeminnow harvested by the Dam Angling crew at The Dalles Dam during the 2016 Season. The length frequency distribution of Northern Pikeminnow harvested at The Dalles Dam in 2016 is presented in Figure 15. Mean fork length for all measured Northern Pikeminnow at The Dalles Dam in 2016 was 313 mm (SD=61.4), up from 308 mm in 2015 (Winther et al. 2016a). By comparison, the mean fork length for the 2016 NPSRF was 275.2 mm (Winther et al. 2017).

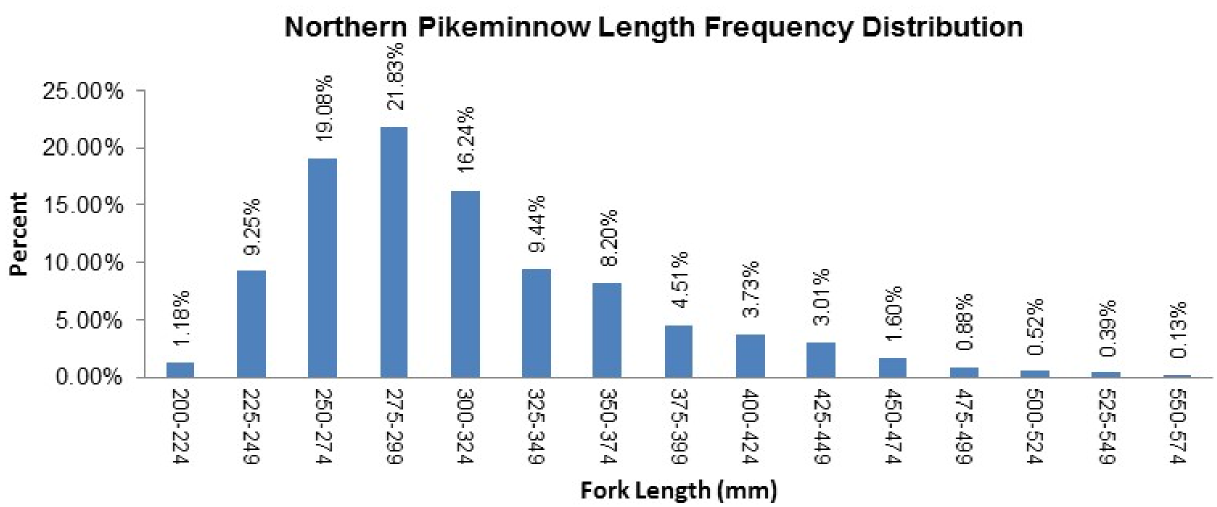

Figure 15. Northern Pikeminnow Length Frequency Distribution at The Dalles Dam in 2016

John Day Dam

Harvest

The Dam Angling crew harvested 3,098 Northern Pikeminnow over 15 weeks at the John Day Dam in 2016. Weekly harvest averaged 207 fish per week and ranged from a peak of 449 in week 27 (June 27 – July 1) to only 29 fish in week 33 (Figure 16). Peak weekly harvest at the John Day Dam occurred three weeks later than in 2015 (week 24) (Winther et al. 2016a) and was 8 weeks later than the week 19 peak for the 2016 Sport Reward Fishery (Winther et al. 2017). The 3,098 harvested Northern Pikeminnow included two spaghetti tagged and three tag loss (PIT tag only) Northern Pikeminnow which were part of ODFW's biological evaluation of the NPMP (Launer et al. 2017). There were also two PIT tags recovered from juvenile salmonids ingested by Northern Pikeminnow harvested by the Dam Angling crew at the John Day Dam in 2016.

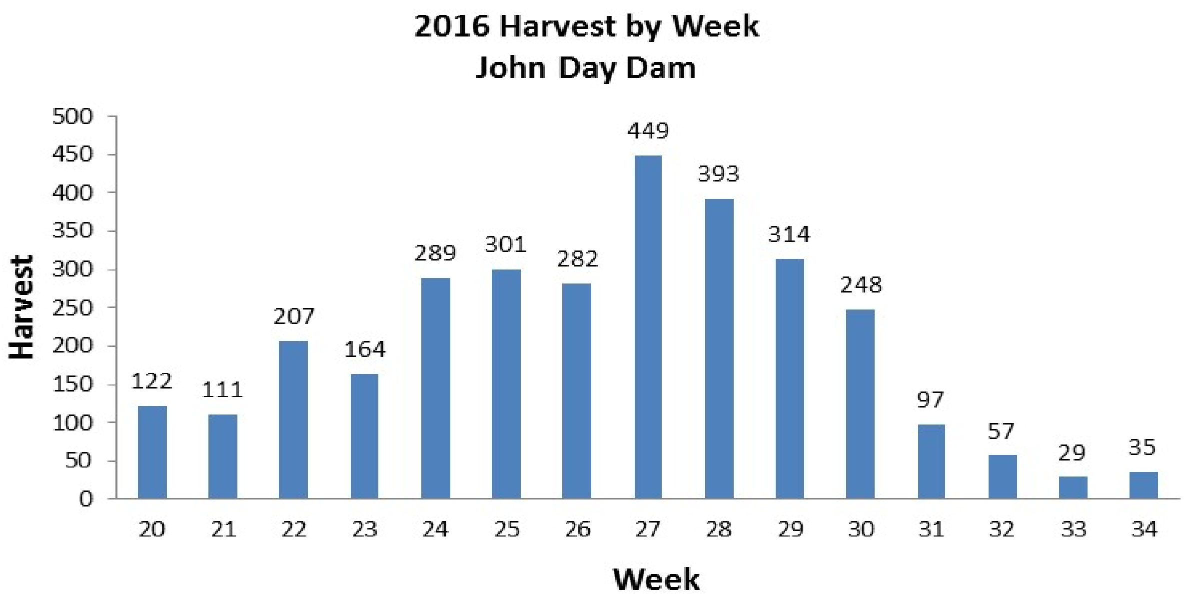

Figure 16. 2016 Weekly Dam Angler Harvest of Northern Pikeminnow at the John Day Dam

Unlike the 2016 NPSRF season, Dam Angling harvest at the John Day Dam peaked well after the week 19 peak of the NPSRF (Winther et al. 2017). Average outflows at the John Day Dam during the best harvest weeks of 2016 ranged 100-150 150 kcfs (Figure 17) and created good angling conditions as indicated by high harvest rates. The higher outflow levels in effect during the early part of the 2016 season had not been present during the 2015 Dam Angling season when outflows were below 150 kcfs and the crew harvested an average of 340 Northern Pikeminnow per week (Winther et al. 2016a).

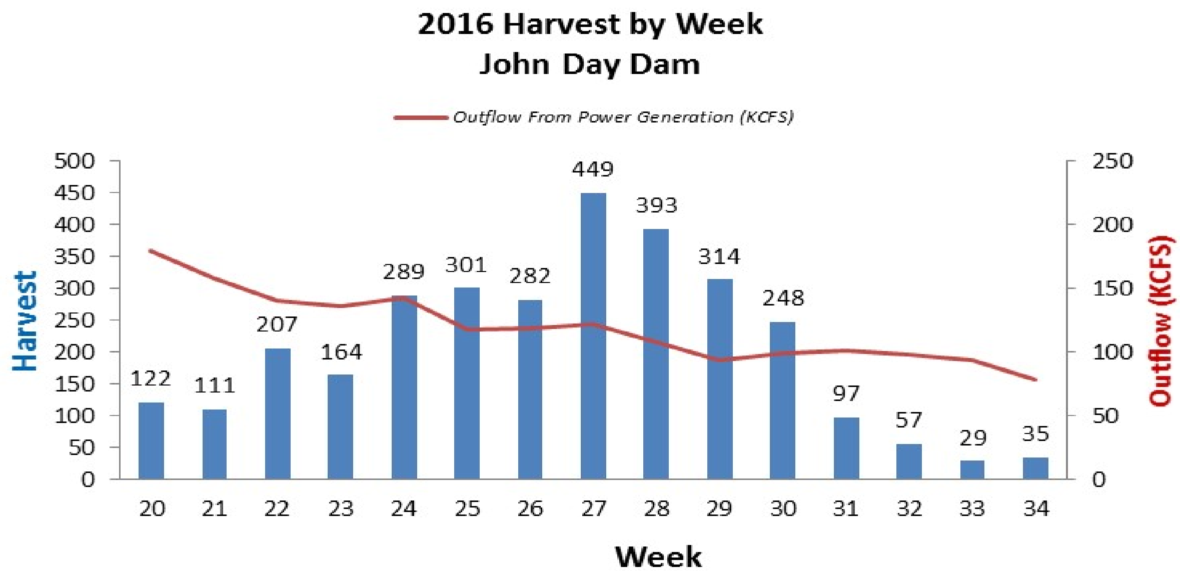

Figure 17. 2016 Weekly Dam Angler Harvest of Northern Pikeminnow at the John Day Dam vs Outflow

As documented in previous Dam Angling Reports (Winther et al. 2016a, Dunlap et al. 2015, Dunlap et al. 2014, Winther et al. 2013, Dunlap et al. 2012, Hone et al. 2011), certain turbines at the John Day Dam created water flow conditions more favorable for harvesting Northern Pikeminnow than others. Of the total pikeminnow harvest at the John Day Dam in 2016, turbine #5 (T5) was the single best producing area with 33% of the total documented harvest (Figure 18). T5 was also the best producing location in 2015 38% of the total harvest in 2015.

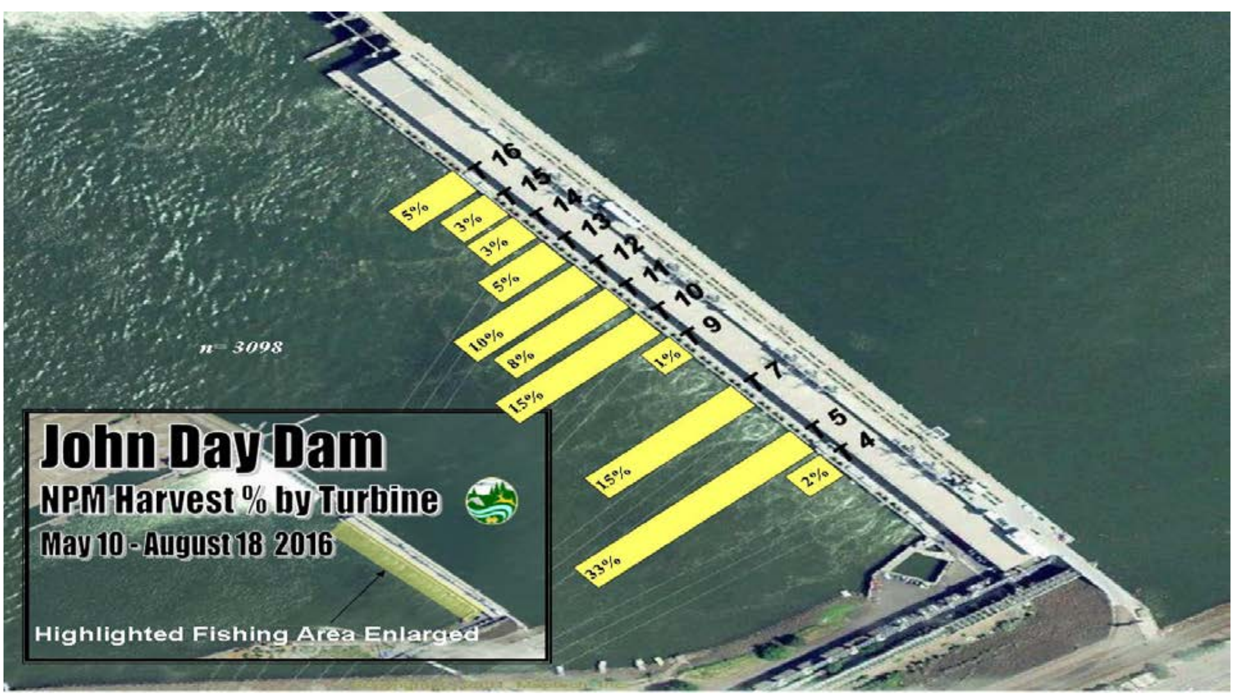

Figure 18. 2016 Overall Percent of Northern Pikeminnow Harvest by Area (T=turbine#)

One limiting factor at the John Day Dam in 2016, and which first became a real issue in 2013 (Dunlap et al. 2014) was turbine inactivity. From an angling and harvest point of view the most productive turbines are those that are actively generating power and pushing river water (Hone et al. 2011). Often during the 2016 Dam Angling season, the John Day dam would only have one turbine generating power at a time as occurred frequently in August (Figure 19). The turbine that was generating power was typically the only location where the Dam Angling crew could consistently catch Northern Pikeminnow. Since a single turbine can only be effectively fished by one or two Dam Anglers at a time, occasionally all but one turbine was shut down during the Dam Angling shift, which created inefficiencies where the full Dam Angling crew could not all effectively fish at the John Day Dam. This would also likely have a negative effect on angler CPUE. In response to these types of situations, the 2016 Dam Angling crew was forced to improvise by splitting crews between the two dams and/ or by conducting more evening angling.

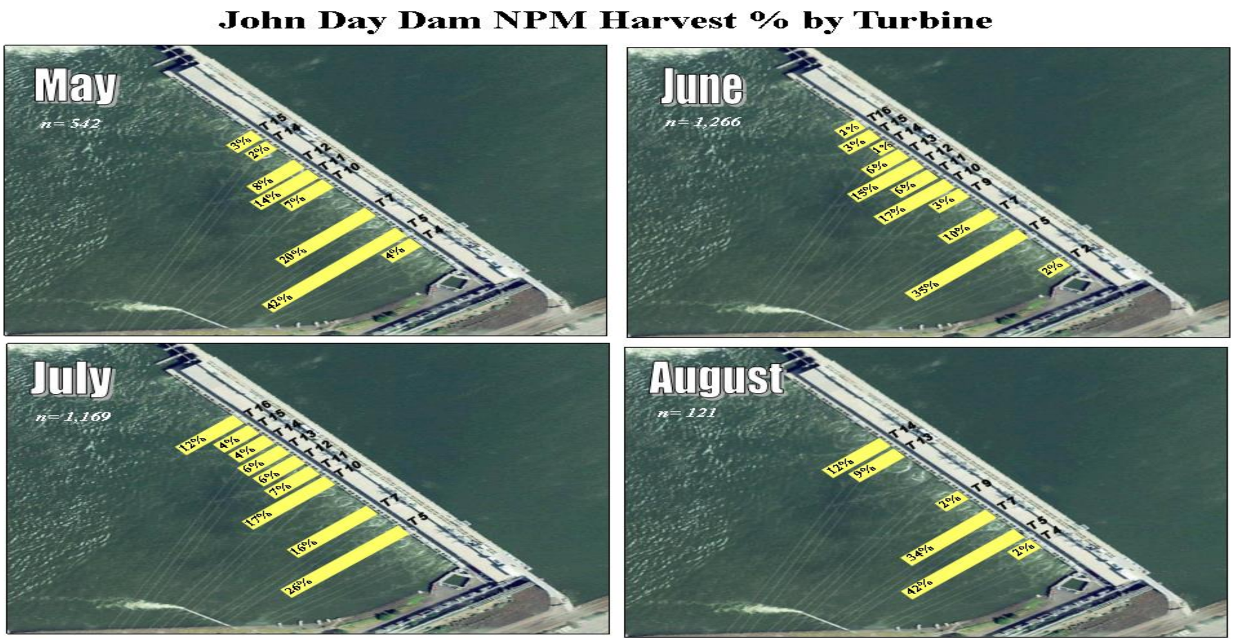

Figure 19. 2016 Monthly Percent (*rounded) of Northern Pikeminnow Harvest by Area (T=turbine#)

Incidental Catch

While the Dam Angling crew did not target fish species other than Northern Pikeminnow in their angling activities, Smallmouth Bass (smb) were the most common species incidentally caught at the John Day Dam in 2016. The Dam Angling crew caught and released 1,156 Smallmouth Bass at the John Day Dam in 2016, mostly on turbines T5 and T7 (Figure 20). The Dam Angling crew also caught and released 517 Walleye (wal), and 9 white sturgeon (ws) at the John Day Dam in 2016. All incidental species caught at the John Day Dam in 2016 were released.

Figure 20. 2016 Incidental Catch (*rounded) of Smallmouth Bass by Dam Angling crew at John Day Dam

Effort

Total effort at the John Day Dam was 799.25 angler hours, down from 996.5 hours in 2015 (Winther et al. 2016a). The crew averaged a combined 53.3 angler hours of effort per week and 14 angler hours of effort per day at the John Day Dam in 2016. The decrease in effort for 2016 Dam Angling was mandated as an NPMP action intended to help mitigate an expected 2016 NPSRF reward fund shortfall (Winther et al. 2017). In response to that mandate, the level of effort for the 2016 Dam Angling crew at the John Day Dam crew dropped to only 57 days over 15 weeks compared to 74 days over 20 weeks in 2015 (53% of total effort spent by the Dam Angling crew at the John Day Dam in 2016).

CPUE

The Dam Angling crew harvested 3,098 Northern Pikeminnow in 799.25 angler hours at the John Day Dam in 2016 for an overall average CPUE of 3.9 fish/angler hour. This CPUE was the highest to date for Dam Angling from 2010-15 (Winther et al. 2016a, Dunlap et al. 2015, Dunlap et al. 2014, Winther et al. 2013, Dunlap et al. 2012, Hone et al. 2011) and ranged from 0.7 fish/angler hour in week 33 to 6.2 fish/angler hour in week 27 (Figure 21). Peak weekly CPUE at the John Day Dam occurred during week 27. The Dam Angling crew exceeded the overall CPUE goal of 2.0 fish/angler hour at the John Day Dam for 12 of the 15 weeks fished.

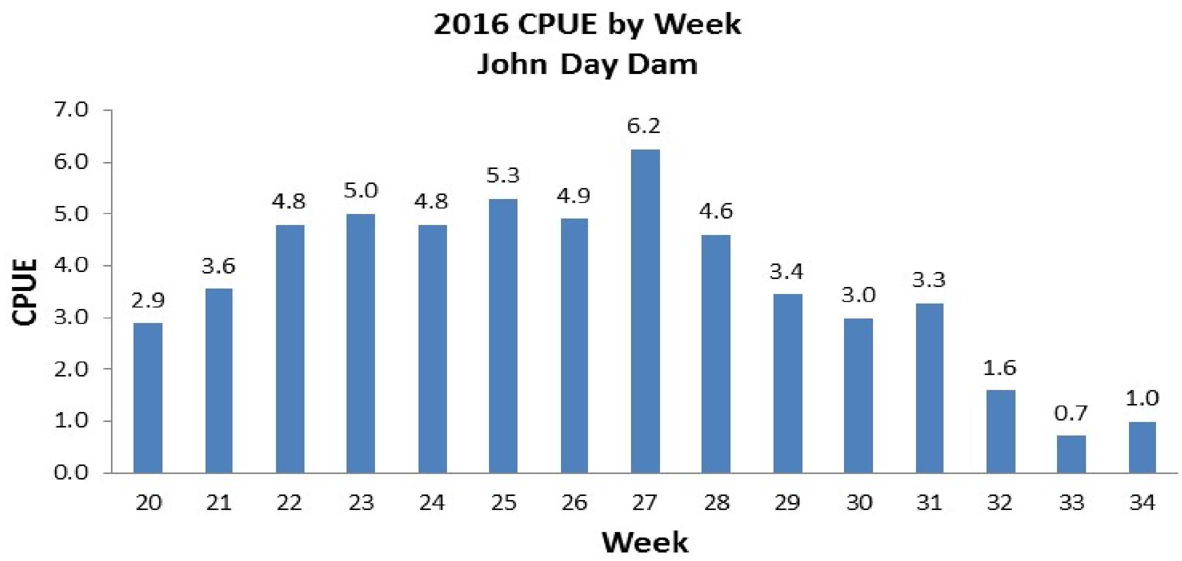

Figure 21. 2016 Weekly Dam Angling CPUE at John Day Dam

Fork Length Data

Fork lengths were taken from 3,098 Northern Pikeminnow (100% of harvest) at the John Day Dam during the 2016 Dam Angling Season. The length frequency distribution of harvested Northern Pikeminnow from the John Day Dam in 2016 is presented in Figure 22. Mean fork length for all Northern Pikeminnow harvested from the John Day Dam in 2016 was 343 mm (SD=68.7) compared to 340 mm in 2015 (Winther et al. 2016a). By comparison, the mean fork length for the 2016 NPSRF was 275.2 mm (Winther et al. 2017).

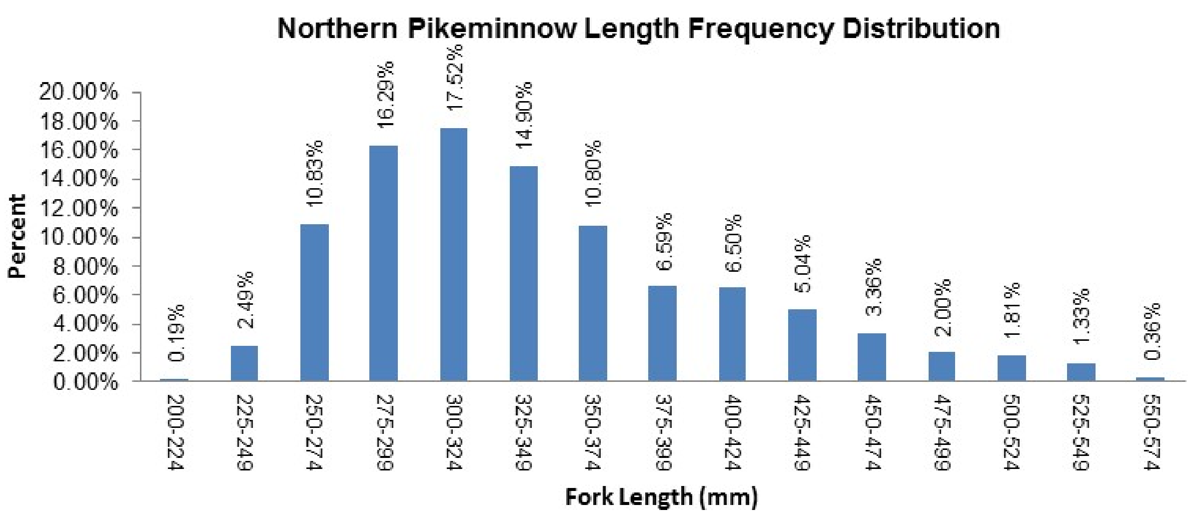

Figure 22. Northern Pikeminnow Length Frequency Distribution at the John Day Dam in 2016

SUMMARY

The Dam Angling component of the NPMP harvested 6,162 Northern Pikeminnow (from the John Day and Dalles dams) during an abbreviated 2016 Dam Angling season. During the shortened 2016 season, the Dam Angling crew recorded the third highest annual harvest, with peak harvest occurring five weeks later than for the 2016 NPSRF peak, but was only one week later than the historical NPSRF peak. The 2016 Dam Angling crew also recorded the highest Dam Angler CPUE (4.1 fish per angler hour) since WDFW began conducting Dam Angling in 2010, and the highest ever CPUE for a Dam Angling crew since the NPMP initiated dam angling in 1991.

Fork length data for Northern Pikeminnow harvested by the 2016 Dam Angling crew continued to show that mean fork lengths of Northern Pikeminnow harvested by Dam Anglers at both The Dalles and John Day dams were considerably larger than the mean fork length of Northern Pikeminnow harvested in the Sport-Reward Fishery (313 mm at The Dalles Dam, 343 mm John Day Dam and 275.2 mm in the NPSRF. Tag recovery data indicated the 2016 Dam Angling crew also recovered 4 spaghetti tagged Northern Pikeminnow, in addition to 6 tag-loss Northern Pikeminnow, as well as 3 PIT tags from fishes ingested by Northern Pikeminnow (2 juvenile salmonids and 1 juvenile lamprey). The overall occurrence rate for ingested PIT tags was 1:2,054 between the two Projects.

The 2016 Dam Angling crew incidentally caught 1,512 Smallmouth Bass, 572 Walleye, 42 sculpin and 9 white sturgeon between the two projects while harvesting 6,162 Northern Pikeminnow. As has been the case for all years that WDFW has conducted the Dam Angling component of the NPMP, all incidental species caught by the Dam Angling crew were released (Hone et al. 2011, Dunlap et al. 2012, Winther et al. 2013, Dunlap et al. 2014, Dunlap et al. 2015, Winther et al. 2016a).

RECOMMENDATIONS FOR 2017

1.) Maintain the Dam Angling component of the NPMP in order to remove predatory Northern Pikeminnow from the Boat Restricted Zones in the tailrace areas of The Dalles and John Day dams where participants in the Northern Pikeminnow Sport-Reward Fishery are not allowed.

2.) Plan for 2017 Dam Angling activities to conduct a full Dam Angling season during similar times of year as the 2015 NPSRF in order to take advantage of fishery knowledge/information and to achieve efficiencies in fish handling and data collection gained during previous Dam Angling seasons.

3.) Continue to utilize and refine the Defined Angling Strategy (DAS) protocol developed in 2011, which uses a minimum CPUE goal as a tool for determining where to allocate Dam Angler effort in order to best maximize harvest of Northern Pikeminnow.

4.) Continue to improve data collection in the areas of scanning other incidentally caught predator fishes for PIT tags, and in scanning and enumerating juvenile lamprey regurgitated by Northern Pikeminnow caught by Dam Anglers in 2017.

5.) Continue to investigate and further develop Northern Pikeminnow angling techniques in 2017 that will improve Dam Angler CPUE and/or allow exploitation of Northern Pikeminnow in areas not currently fishable.

6.) Investigate the feasibility of recording data and retaining carcasses of non-native predator fishes for other Columbia River research projects.

7.) Continue to explore the logistics of using split crews to optimize efficiencies when water conditions warrant or when there are high CPUE levels at both projects at the same time.

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APPENDIX A
Terminal lures used by 2016 Dam Angler crew