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

2017 ANNUAL REPORT
April 1, 2017 thru March 31, 2018

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2017 Executive Summary
by

Steve Williams

This report presents results for year twenty-seven 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 27 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 conducted. 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) (http://www.pikeminnow.org/wp-content/uploads/2017/03/1990-Pikeminnow-AR.pdf).

REPORT A

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

2017 Annual Report

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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 the Cascade Locks 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. James 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 Ricardo Angel, Kyle Beckley, Dick Buitenbos, Kevin Clawson, Mark Flahaut, Bill Fleenor, Leif Fox, Roger Fox, Fred Haberman, Ashley Jahns, Daniel Kukloch, Steve Lines, Eric Meyer, Jordan Miller, Laura Rickets, Amber Santangelo, Elizabeth Shotman, John Paul Viviano, Robert Warrington, Lyndon Watkins, Dennis Werlau, Heather Wiedenhoft, 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, and Dennis Werlau for producing our weekly field activity reports throughout the season.

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, 2017. 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 from this segment of NPSRF participants.

A total of 191,479 Northern Pikeminnow ≥ 228 mm fork length (FL) and 5,633 Northern Pikeminnow < 228 mm FL were harvested during the 2017 NPSRF season. There were a total of 3,462 different individual anglers who spent 25,963 angler days of effort participating in the NPSRF during the 2017 season. Catch per unit effort for combined returning and non-returning anglers was 7.38 fish/angler day. The Oregon Department of Fish and Wildlife (ODFW) estimated that the Northern Pikeminnow harvest activities from the 2017 NPSRF resulted in an overall exploitation rate of 17.4% (Carpenter et al. 2018).

Anglers submitted 269 Northern Pikeminnow with external ODFW spaghetti tags and all of which had internal ODFW PIT tags. There were also 134 Northern Pikeminnow with ODFW PIT tags only, but missing spaghetti tags. Additionally, 25 PIT tags from ingested juvenile salmonids were recovered from Northern Pikeminnow received during the 2017 NPSRF.

Peamouth *Mylocheilus caurinus*, Smallmouth Bass *Micropterus dolomieue*, 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 4.7 million reward sized Northern Pikeminnow and spent nearly 908,000 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 new anglers to the NPSRF. The 2017 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 total effects of the NPSRF on other Columbia basin fishes.

The objectives of the 2017 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) from this segment of NPSRF participants.

METHODS OF OPERATION

Fishery Operation

Boundaries and Season

The 2017 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 expected to operate during a regular season extending from May 1 through September 30, 2017.

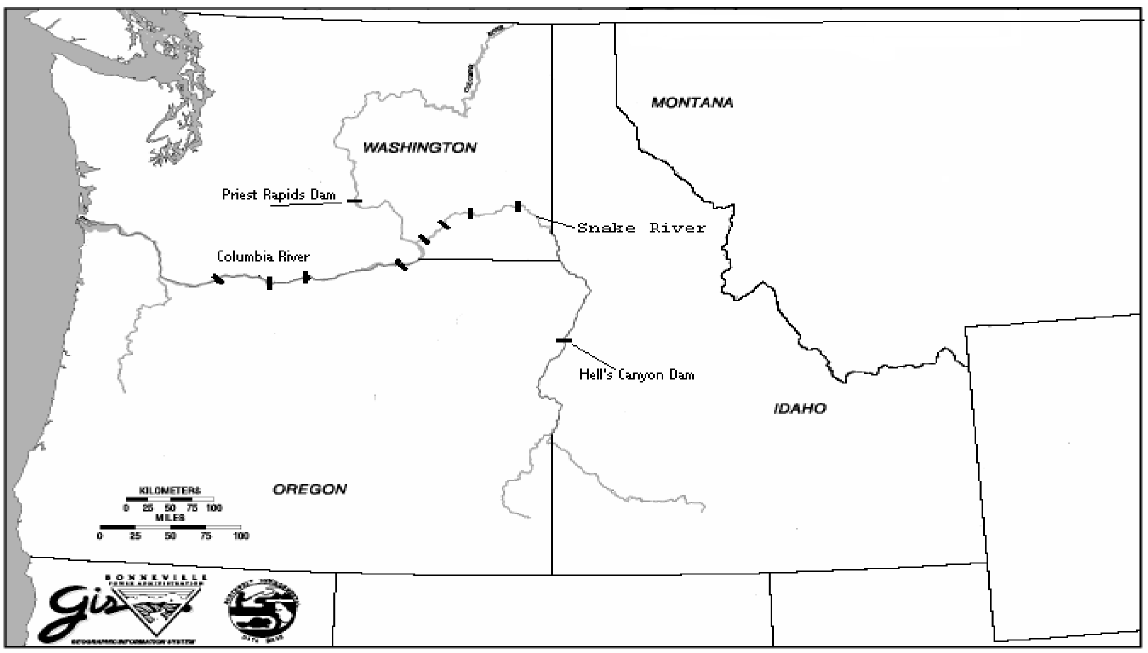
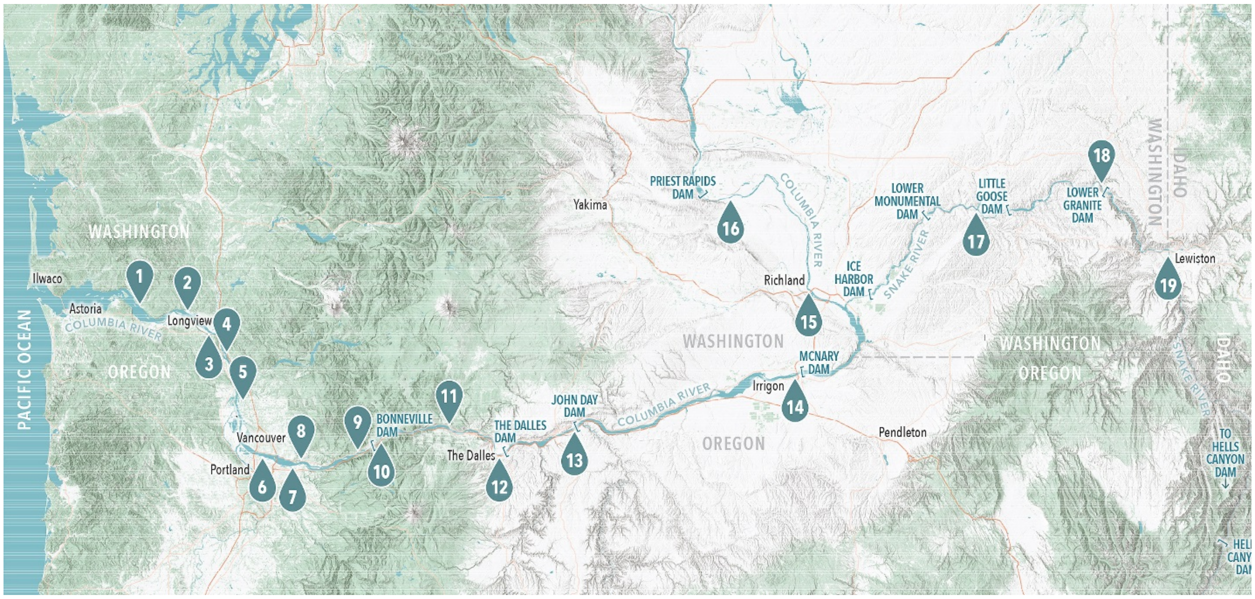


Figure 1. Northern Pikeminnow Sport-Reward Fishery Program Area

Registration Stations

Nineteen registration stations (Figure 2) were located along 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 (1:30 pm-5:30 pm)
7. Chinook Landing (9:00 am-1:00 pm)
8. Washougal Boat Ramp (1:00 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. 2017 Northern Pikeminnow Sport-Reward Fishery Registration Stations and Hours

Reward System

The 2017 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.

The tiered reward system used during the 2017 season reflected the changes that were made to the NPSRF's tiered reward system in 2015 (Winter et al. 2016). First developed in 1995 (Hisata et al. 1996), the tiered reward system paid anglers higher rewards per fish based on achieving designated harvest levels. 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 that retained a valid spaghetti tag used by ODFW for the biological evaluation of the NPMP. 2017 NPSRF anglers continued to be paid $100 for each Northern Pikeminnow missing a spaghetti tag, but retaining the ODFW PIT tag (tag-loss).

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".

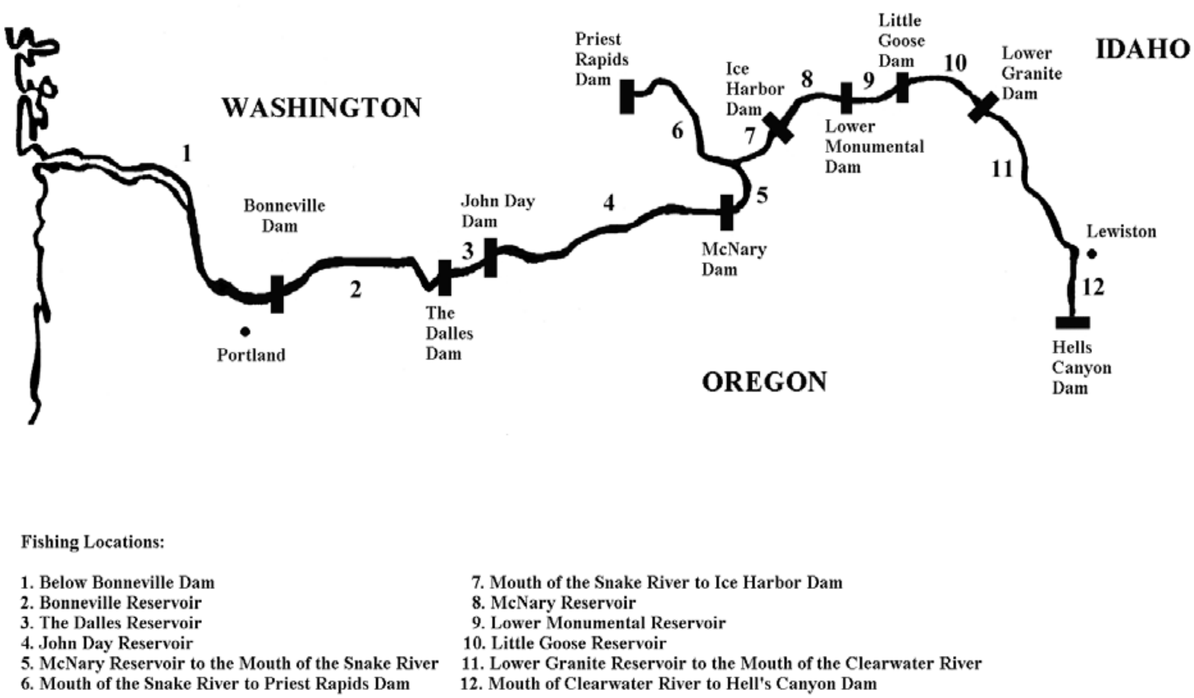


Figure 3. Fishing Location Codes used for the 2017 Northern Pikeminnow Sport-Reward Fishery

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 retained 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 2017 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 processed or 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 2017 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 that 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). 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 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 Northern Pikeminnow with positive readings. All PIT tagged Northern Pikeminnow were processed or labeled and preserved for later dissection and tag recovery. All data were verified by WDFW tag lead biologist after recovery of PIT tags and all PIT tag recovery data were provided to ODFW and 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 2017 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 2017 NPSRF harvested a total of 191,479 reward size Northern Pikeminnow ($\geq$ 228 mm TL) over the course of a 22 week field season. Harvest was higher than mean 1991-2016 harvest of 176,353 fish, but 33,871 fish lower than 2016 harvest (Winther et al. 2017) (Figure 4). The 2017 NPSRF harvest was estimated to equal an exploitation rate of 17.4% (Carpenter et al. 2018). In addition to harvesting 191,479 reward size Northern Pikeminnow, anglers participating in the 2017 NPSRF also harvested 5,633 Northern Pikeminnow < 228 mm TL.

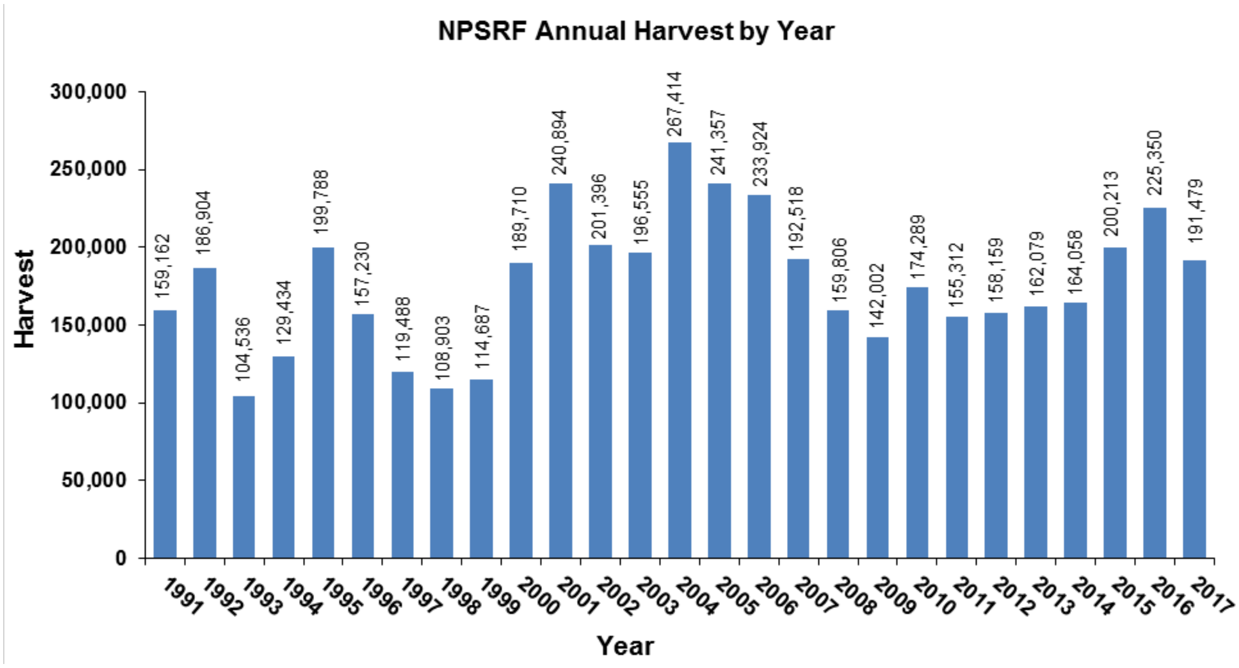


Figure 4. Annual Harvest Totals for the Northern Pikeminnow Sport-Reward Fishery

Harvest by Week

Peak weekly harvest was 14,554 Northern Pikeminnow and occurred in week 25 (Figure 5), six weeks later than in 2016 (week 19), and was 475 fish less than in 2016 (15,029). Weekly harvest in 2017 was above 2016 weekly harvest for 4 weeks of the 22 week season (Figure 6), and mean weekly harvest was 12.6% lower in 2017 (8,704) than in 2016 (9,798). Water conditions were not as favorable during the first part of the 2017 NPSRF as they were in 2016, which resulted in weekly harvest totals under 10,000 fish per week for 3 of the first 10 weeks of the season. Peak harvest occurred one week earlier (week 25) than the NPSRF's historical 1991-2015 peak in week 26 (Fox et al. 2000), and did show the typical late season peak in week 37 (Figure 7).

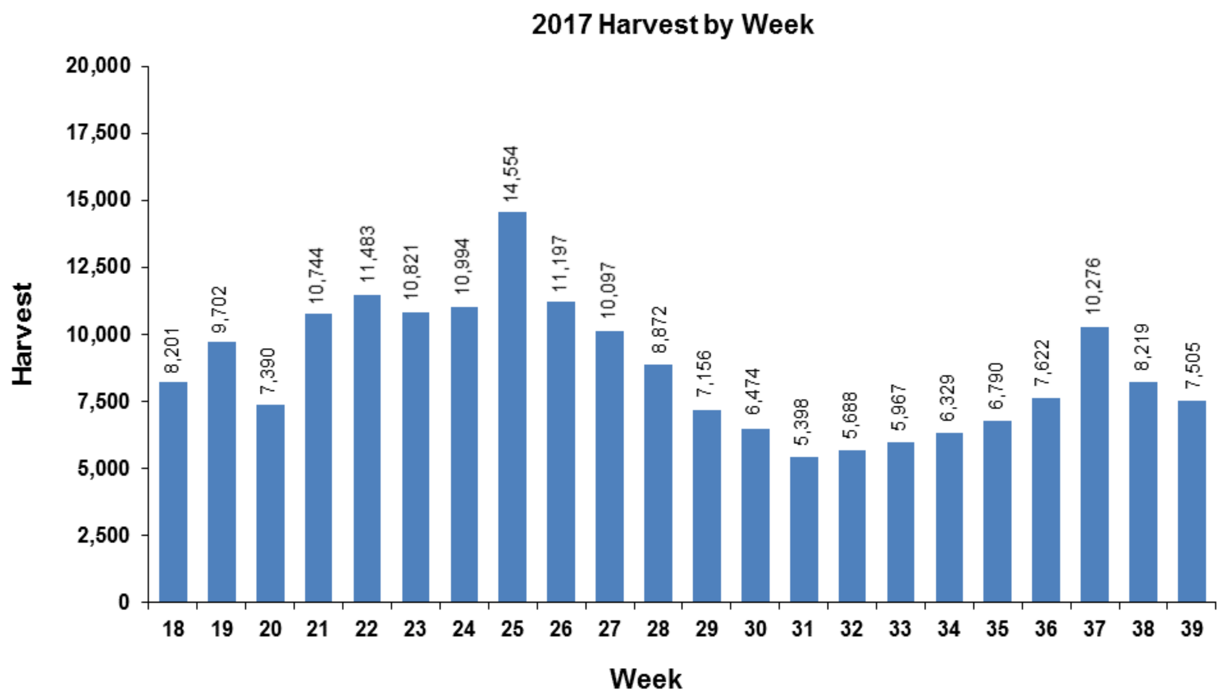


Figure 5. 2017 Weekly Northern Pikeminnow Sport-Reward Fishery Harvest

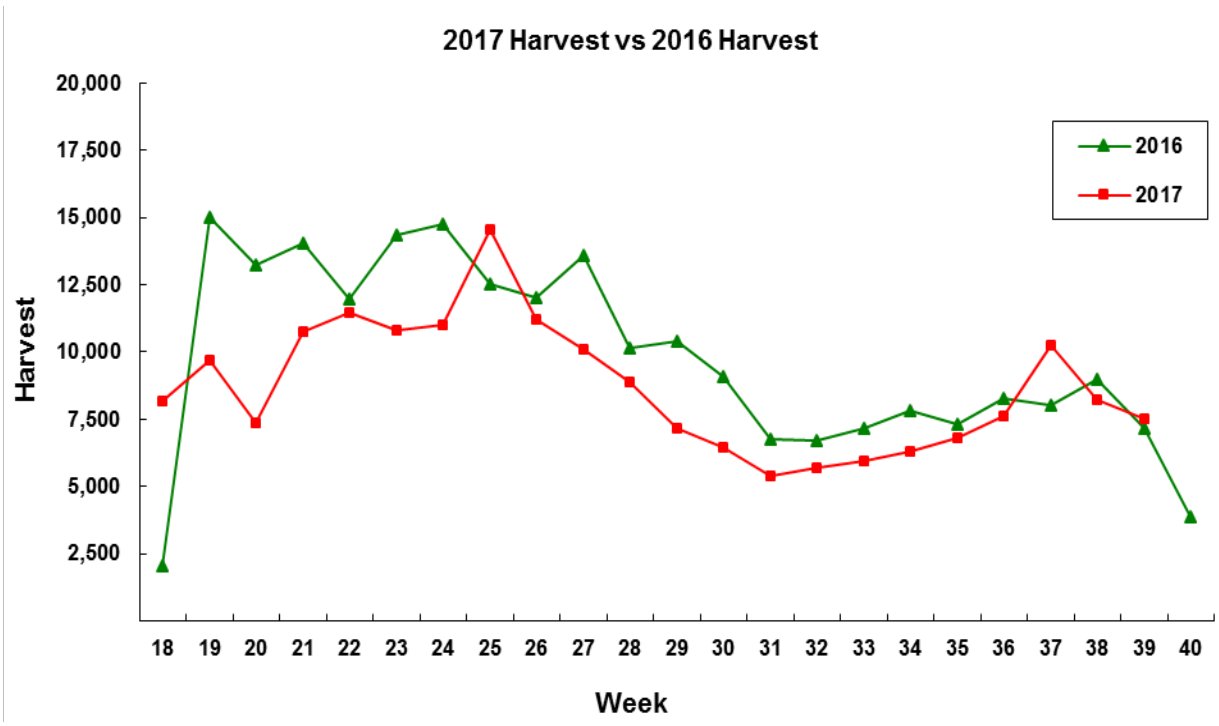


Figure 6. 2017 Weekly NPSRF Harvest vs 2016 Weekly Harvest

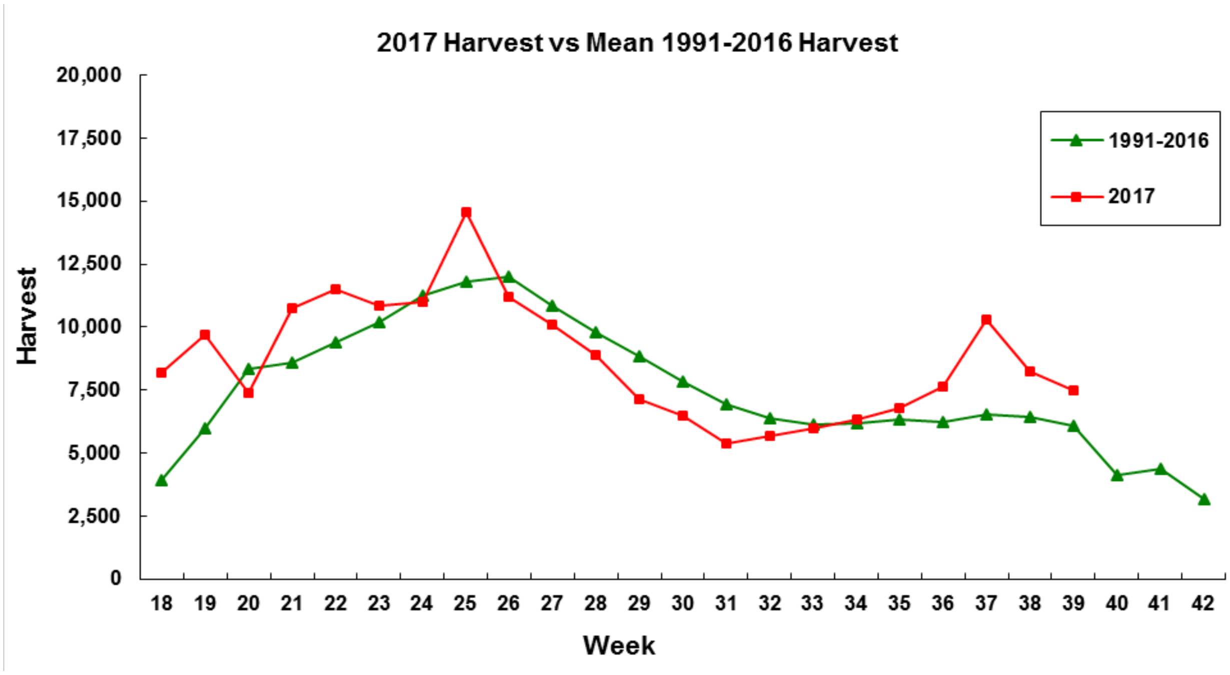


Figure 7. Comparison of 2017 NPSRF Weekly Harvest to 1991-2016 Mean Weekly Harvest

Harvest by Fishing Location

The mean harvest by fishing location for the 2017 NPSRF was 15,957 Northern Pikeminnow and ranged from 70,024 reward size Northern Pikeminnow in fishing location 01 (Below Bonneville Dam) to only 6 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 36.57% of total NPSRF harvest and was the highest producing location again in 2017 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 31.18% of the total 2017 NPSRF harvest, while fishing location 10 (Little Goose Reservoir) accounted for another 12.48% of the 2017 harvest.

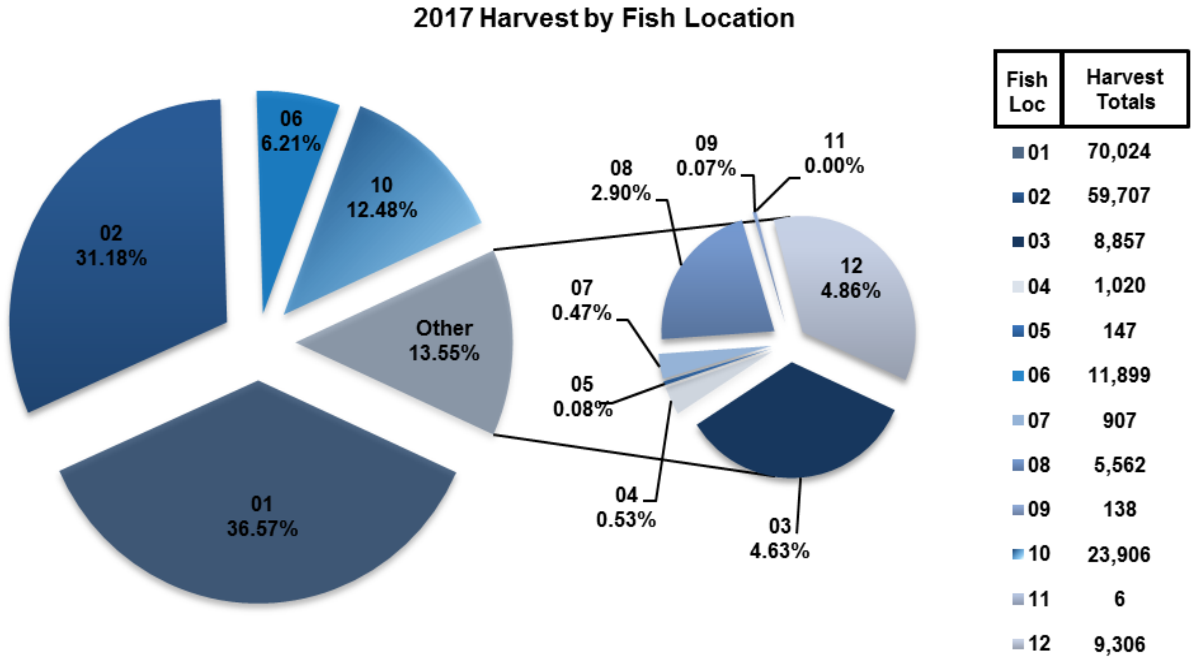


Figure 8. 2017 Northern Pikeminnow Sport-Reward Fishery Harvest by Fishing Location*
*Fishing Location Codes for **Columbia River**; 01 = Below Bonneville Dam, 02 = Bonneville Reservoir, 03 = The Dalles Reservoir, 04 = John Day Reservoir, 05 = McNary Dam to the mouth of the Snake River, 06 = Mouth of 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 Hells Canyon Dam.

Harvest by Registration Station

Harvest in 2017 was up from 2016 at 8 of the 19 registration stations. The Dalles registration station once again claimed the title of the NPSRF's top producing station (as it has been for six of the past seven years) where anglers harvested 44,607 Northern Pikeminnow, equaling 23.3% of total 2017 NPSRF harvest (Figure 9). The Boyer Park registration station finished with the second highest total of 24,046 Northern Pikeminnow (12.6% of total) harvested in 2017. The average harvest per registration station was 10,078 reward size Northern Pikeminnow, down from 11,861 per station in 2016 (Winther et al. 2017). The registration station with the smallest harvest was Vernita where anglers harvested only 929 Northern Pikeminnow during the 2017 season. The Dalles registration station also showed the largest increase in harvest during the 2017 NPSRF with 3,128 more reward size Northern Pikeminnow turned in than in 2016 (Winther et al. 2017).

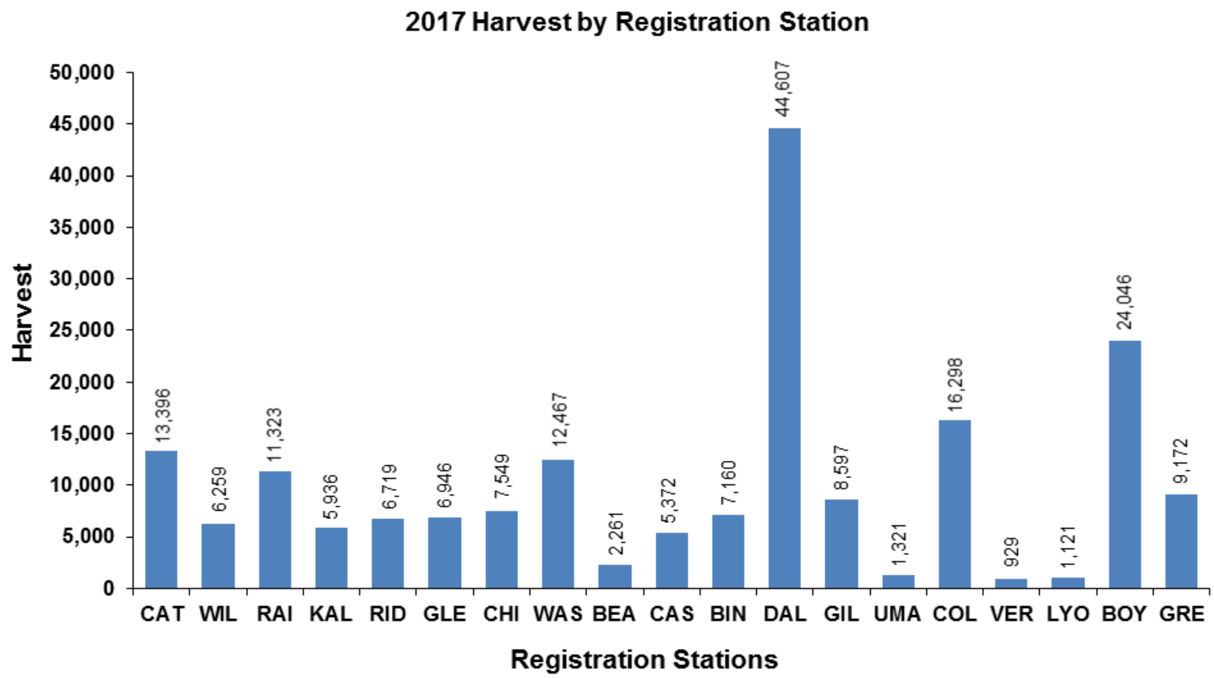


Figure 9. 2017 Northern Pikeminnow Sport-Reward Fishery Harvest by Registration Station
CAT-Cathlamet, WIL-Willow Grove, RAI-Rainier, KAL-Kalama, RID-Ridgefield, GLE-Gleason, CHI-Chinook, WAS-Washougal, BEA-Beacon Rock, CAS-Cascade Locks, BIN-Bingen, DAL- The Dalles, GIL-Giles, UMA-Umatilla, COL-Columbia 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 2017 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 2017.

Salmon

Species	Caught	Harvest	Harvest Percent
Steelhead Juvenile (Hatchery)	44	0	0%
Chinook (Juvenile)	33	0	0%
Steelhead Juvenile (Wild)	24	0	0%
Trout (Unknown)	20	1	5%
Cutthroat (Unknown)	18	1	5.56%
Chinook (Adult)	12	1	8.33%
Steelhead Adult (Wild)	11	0	0%
Steelhead Adult (Hatchery)	10	1	10%
Chinook (Jack)	6	4	66.67%
Sockeye (Adult)	5	5	100%
Coho (Juvenile)	1	0	0%
Bull Trout	1	0	0%

Anglers reported that all juvenile salmonids caught during the 2017 NPSRF, were released. Per NPSRF protocol, technicians recorded all juvenile steelhead caught by NPSRF anglers (except those specifically reported as missing the adipose fin), as “wild”. Harvested adult salmonids that were caught incidentally during the 2017 NPSRF were only retained during legal salmonid fisheries. NPSRF protocol is to report anglers illegally harvesting any salmonids (whether juvenile or adult) 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, and Yellow Perch (Table 2).

Table 2. Catch and Harvest of Non-Salmonids by Returning Anglers Targeting Northern Pikeminnow in 2017

Non-Salmonid Species	Caught	Harvest	Harvest Percent
Northern Pikeminnow >228mm	191,479	191,479	100%
Northern Pikeminnow <228mm	46,531	5,633	12.11%
Peamouth	42,706	17,738	41.54%
Smallmouth Bass	16,932	1,731	10.22%
Yellow Perch	11,235	2,684	23.89%
White Sturgeon	4,933	3	.06%
Walleye	4,834	2,369	49.01%
Sculpin (unknown)	4,527	2,868	63.35%
Channel Catfish	4,016	424	10.56%
Sucker (unknown)	2,133	289	13.55%
Catfish (unknown)	1,460	212	14.52%
Bullhead (unknown)	706	102	14.45%
Chiselmouth	556	31	5.58%
Carp	407	35	8.60%
American Shad	247	152	61.54%
Bluegill	160	12	7.5%
Starry Flounder	103	11	10.68%
Sandroller	36	0	0%
Whitefish	36	4	11.11%
Largemouth Bass	26	5	19.23%
Pumpkinseed	20	0	0%
Crappie (unknown)	18	1	5.56%

Non-Returning Anglers Catch and Harvest Estimates

As in past years, telephone interviews were conducted 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 2017, there were 7,590 non-returning angler days recorded and a total of 1,703 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 2017 NPSRF. A simple estimator was applied to the catch and harvest totals obtained from the surveyed anglers to obtain Total Catch and Total Harvest estimates for non-returning anglers participating in the 2017 NPSRF. Estimated totals are listed in columns 5 and 6 of Table 3.

Table 3. 2017 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	446	113	25.3%	1,975	500
Northern Pikeminnow ≥ 228 mm	60	52	86.7%	266	230
Steelhead Adult (Wild)	9	0	0%	40	0
Salmon (Juvenile Unknown)	8	0	0%	35	0
Chinook Salmon (juvenile)	6	0	0%	27	0
Steelhead (Juvenile Unknown)	5	0	0%	22	0
Chinook Salmon (Adult)	1	1	100%	4	4
Chinook Salmon (Jack)	1	0	0%	4	0
Steelhead Juvenile (wild)	1	0	0%	4	0
Sockeye (Adult)	1	1	100%	4	4
Coho (Adult)	1	1	100%	4	4
Trout (Unknown)	1	0	0%	4	0

N=7,590 n=1,703

Fork Length Data

The length frequency distribution for harvested Northern Pikeminnow (≥ 200 mm) from the 2017 NPSRF is presented in Figure 10. Fork length data from 113,739 Northern Pikeminnow ≥ 200 mm FL (59% of total harvest) were taken during the 2017 NPSRF. The mean fork length for all measured Northern Pikeminnow (≥ 200 mm) in 2017 was 279.8 mm (SD= 60.88 mm), up from 275.2 in 2016.

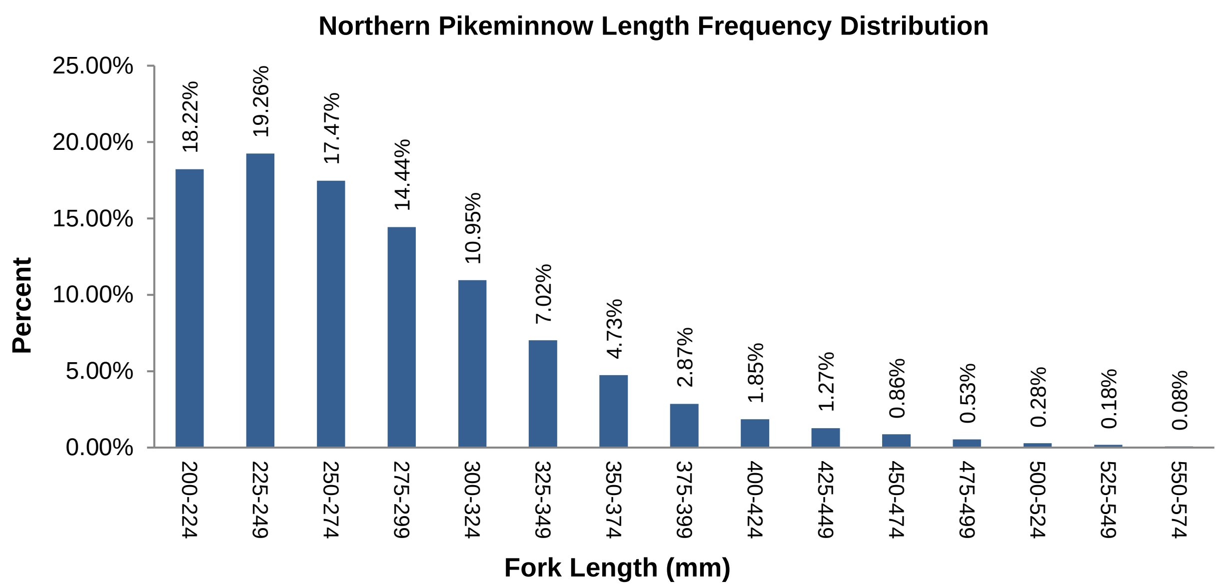


Figure 10. Length Frequency Distribution of Northern Pikeminnow ≥ 200 mm FL from 2017 NPSRF

Angler Effort

The 2017 NPSRF recorded total effort of 25,963 angler days spent during the season, a decrease of 1,812 angler days from 2016 (Winther et al. 2017) (Figure 11). Despite the decrease in angler effort, compared to mean 2010-2014 effort (prior to the change in reward tiers), 2017 total angler effort was 3,498 days higher. When total effort is divided into returning and non-returning angler days, 18,373 angler days (70.8%) were recorded by returning anglers, and 7,590 angler days (29.2%) were spent by non-return anglers. The percentage of returning anglers in 2017 (70.8%) was similar to 2016 (70.6%) season (Winther et al. 2017), but lower than the 2015 (72.3%) NPSRF season (Winther et al. 2016). In addition, 59.9% of total effort, and 84.6% of returning angler effort (15,541 angler days), was attributed to successful anglers who harvested at least 1 Northern Pikeminnow in 2017.

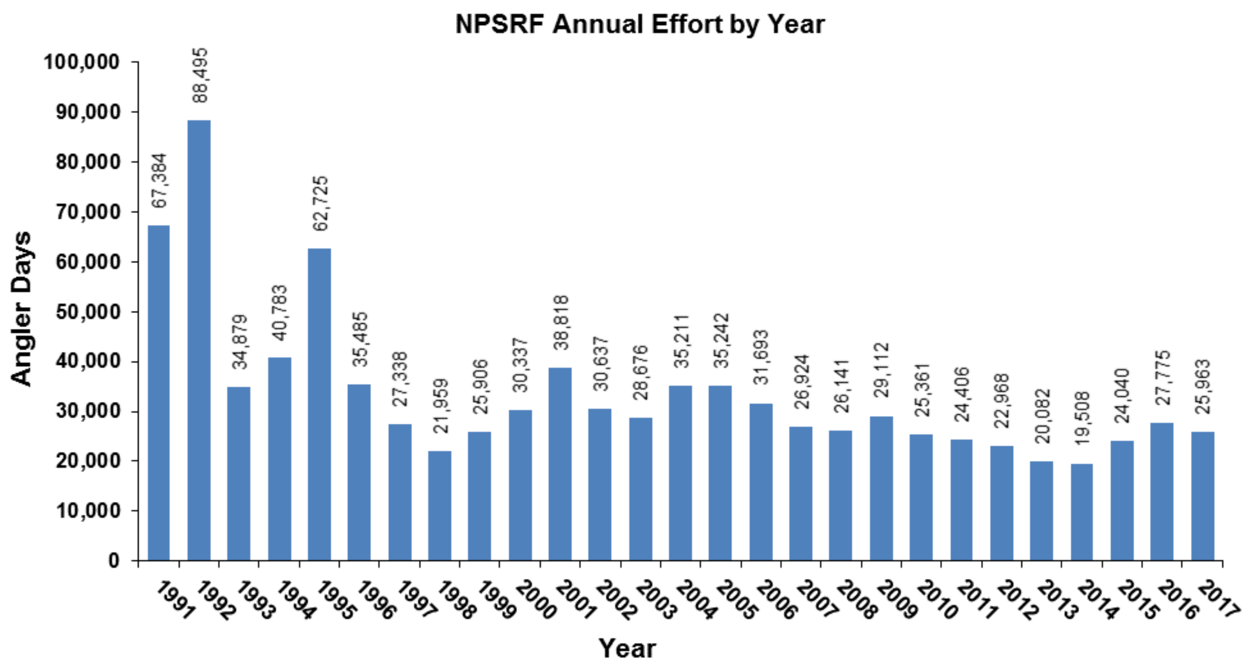


Figure 11. Annual Northern Pikeminnow Sport-Reward Fishery Effort

Effort by Week

Mean weekly effort for the 2017 NPSRF was 1,180 angler days during the season, with the peak occurring in week 18 during the first week of the season (Figure 12). When we compare weekly effort totals for 2017 with the 2016 season, weekly effort totals from 14 of the 19 weeks were down from those of 2016 (Winther et al 2017). Peak weekly effort in 2017 occurred in week 18 (Figure 13), which is seven weeks earlier than 2017 peak harvest (week 25) (Figure 5). Overall, mean weekly effort decreased slightly from 1,208 in 2016 to 1,180 in 2017 (Winther et al. 2017). Since the tier change in 2015, weekly effort totals have followed a pattern where peak effort occurs in the first full week of the season (Figure 14). This is different from historical 1991-2016 pattern where peak effort typically occurred on the same week as peak harvest.

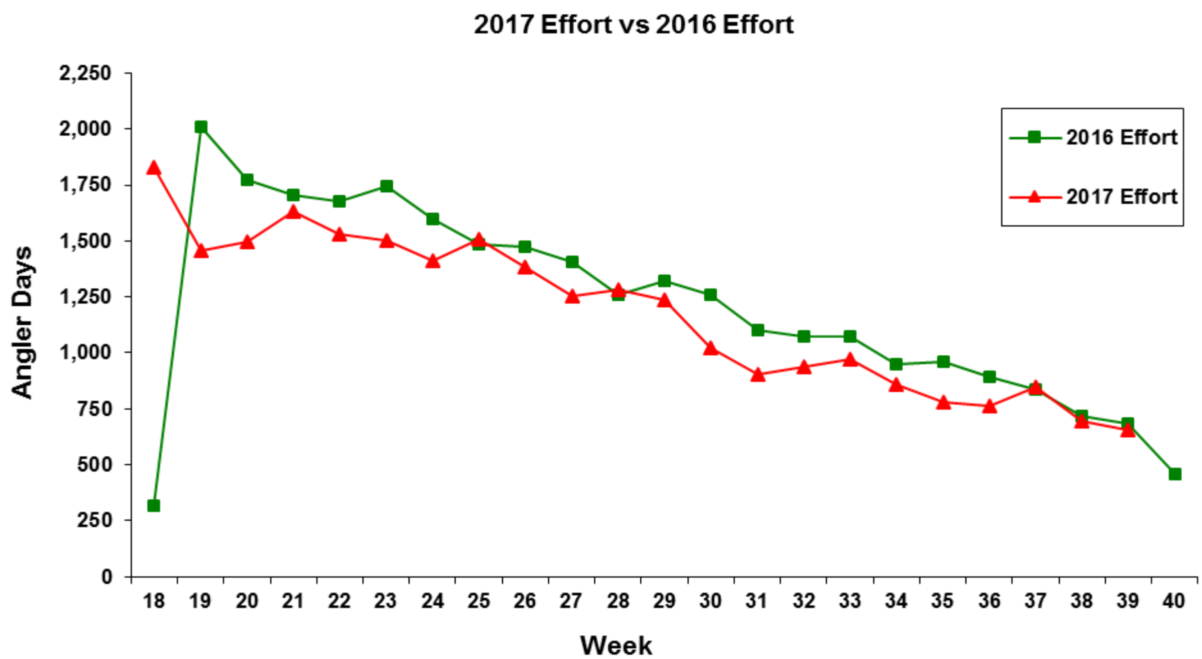


Figure 12. 2017 Northern Pikeminnow Sport-Reward Fishery Effort vs 2016 Effort

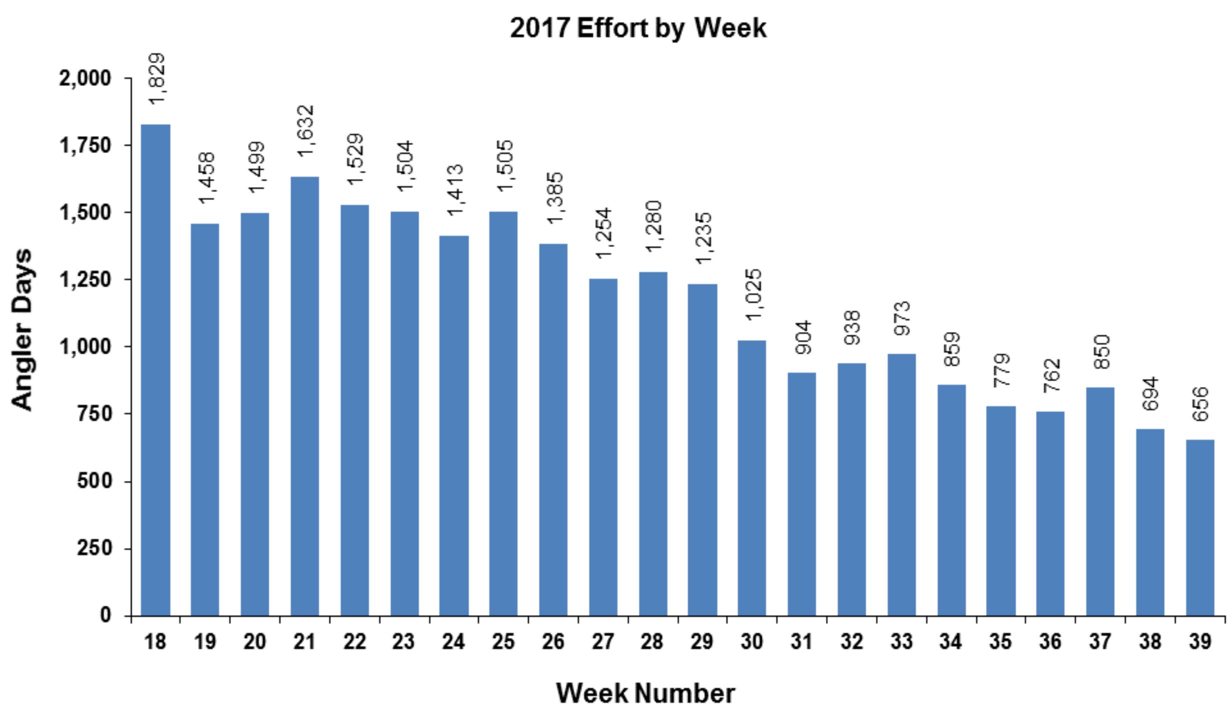


Figure 13. 2017 Weekly Northern Pikeminnow Sport-Reward Fishery Effort

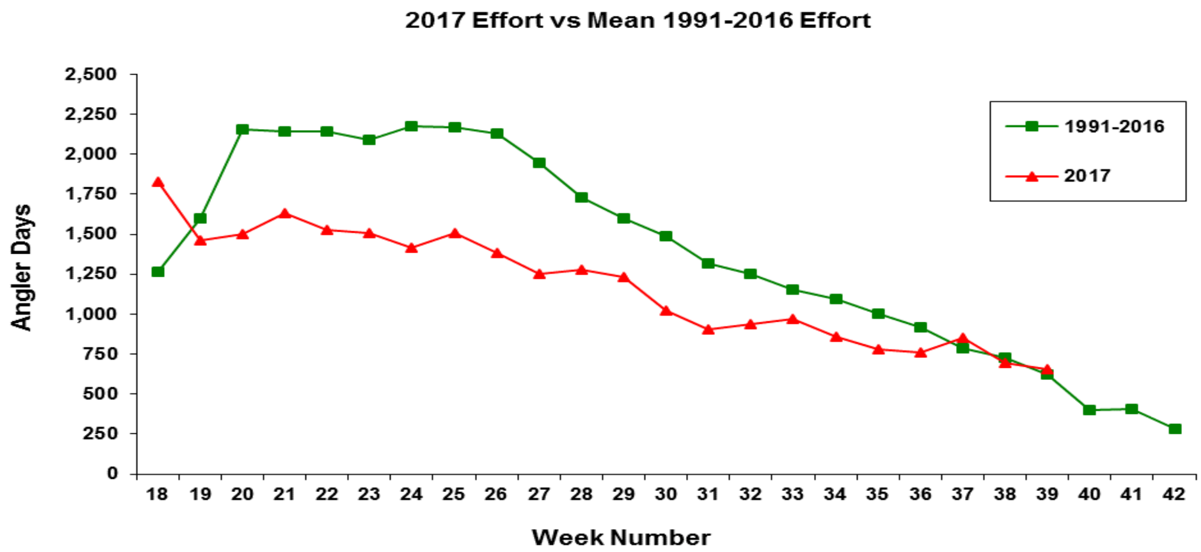


Figure 14. 2017 NPSRF Weekly Effort vs Mean 1991-2016 Effort

Effort by Fishing Location

Mean annual effort by fishing location for the 2017 NPSRF (returning anglers only) decreased from 1,634 angler days in 2016 (Winther et al. 2017) to 1,531 angler days in 2017. Effort totals ranged from 6,625 angler days spent in fishing location 01 (below Bonneville dam) to only 11 angler days spent in fishing location 11 on the Snake River (Lower Granite Dam to the mouth of the Clearwater River) (Figure 15). Effort decreased 16.6% below Bonneville Dam (fishing location 01) from 7,939 angler days recorded in 2016 (Winther et al. 2017) to 6,625 angler days in 2017 and increased or remained the same at 7 of the 12 NPSRF fishing locations.

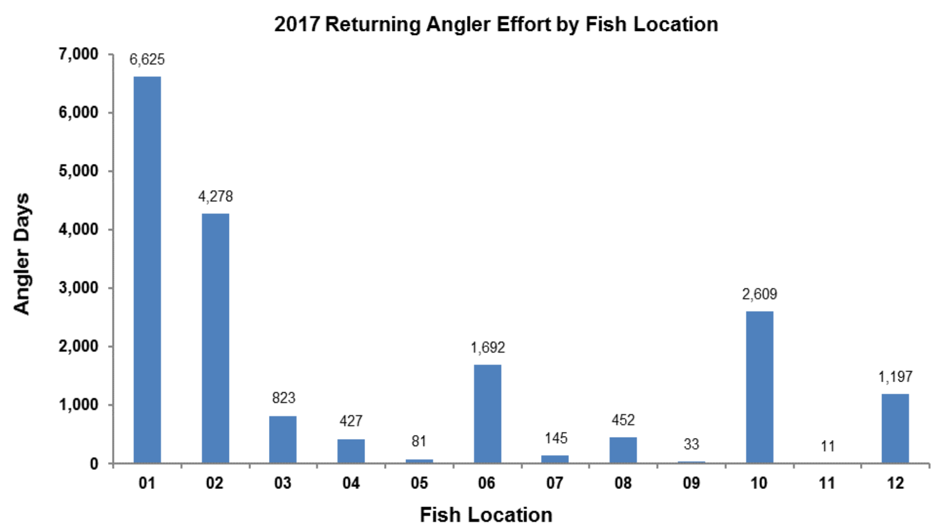


Figure 15. 2017 NPSRF Angler Effort by Fishing Location (returning anglers only).*
Fishing Location Codes for **Columbia River**; 01 = Below Bonneville Dam, 02 = Bonneville Reservoir, 03 = The Dalles Reservoir, 04 = John Day Reservoir, 05 = McNary Dam to the mouth of the Snake River, 06 = Mouth of the 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 Hells Canyon Dam.

Effort by Registration Station

Mean effort per registration station during the 2017 NPSRF was 1,366 angler days compared to 1,462 angler days in 2016 (Winther et al. 2017). Effort totals ranged from a high of 4,425 angler days at The Dalles station (an increase of 905 angler days from 2016) to a low of 172 angler days at the Lyons Ferry station (Figure 16). Effort during the 2017 NPSRF decreased at 11 of the 19 registration stations from 2016 (Winther et al. 2017).

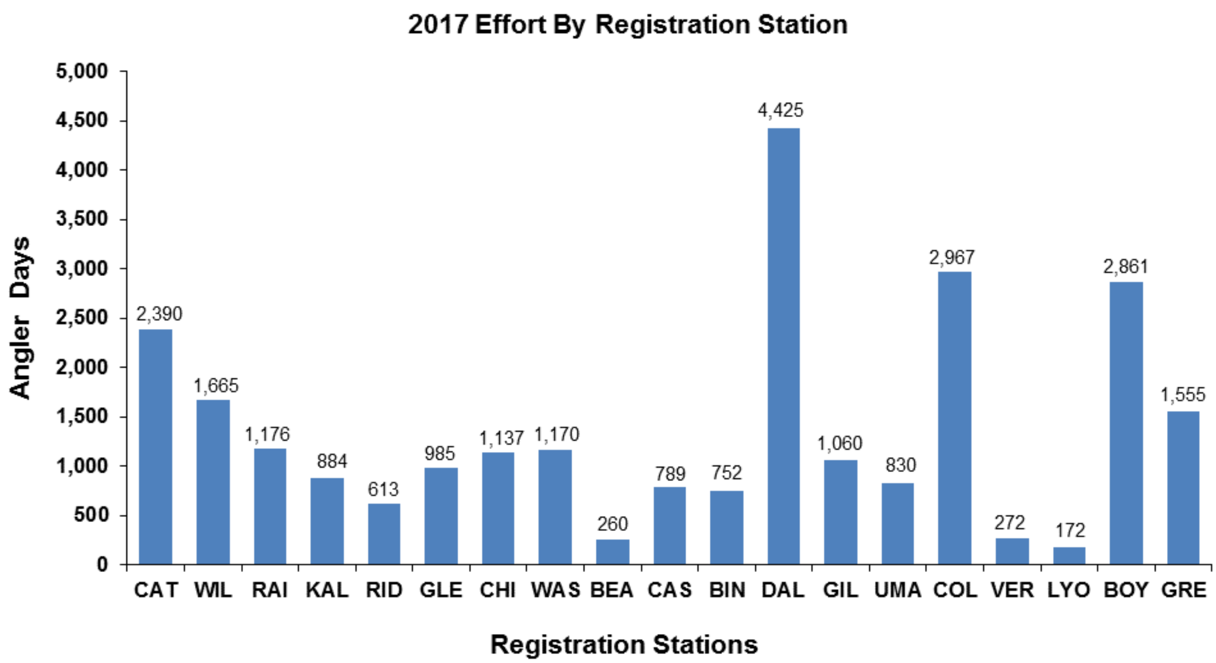


Figure 16. 2017 Northern Pikeminnow Sport-Reward Fishery Angler Effort by Registration Station
CAT-Cathlamet, WIL-Willow Grove, RAI-Rainier, KAL-Kalama, RID-Ridgefield, GLE-Gleason, CHI-Chinook, WAS-Washougal, BEA-Beacon Rock, CAS-Cascade Locks, BIN-Bingen, DAL-The Dalles, GIL-Giles, UMA-Umatilla, COL-Columbia Point, VER-Vernita, LYO-Lyon's Ferry, BOY-Boyer Park, GRE-Greenbelt.

Catch Per Angler Day (CPUE)

The 2017 NPSRF recorded an overall (returning + non-returning anglers) catch per unit of effort (CPUE) of 7.38 Northern Pikeminnow harvested per angler day during the season. This catch rate was lower than in 2016 (8.11) when river conditions were much more favorable (Figure 17). Angler CPUE has steadily increased throughout the NPSRF's 27-year history although there has been a slight downturn in CPUE the past two years as a result of a continuing influx of new anglers from the 2015 tier change. Returning angler CPUE during the 2017 NPSRF was 10.42 Northern Pikeminnow per angler day, down from the 2016 returning angler CPUE of 11.50. The estimated CPUE for non-returning anglers remained the same as 2016 (Winther et al. 2017) at 0.04 reward size Northern Pikeminnow per angler day based on 2017 NPSRF phone survey results.

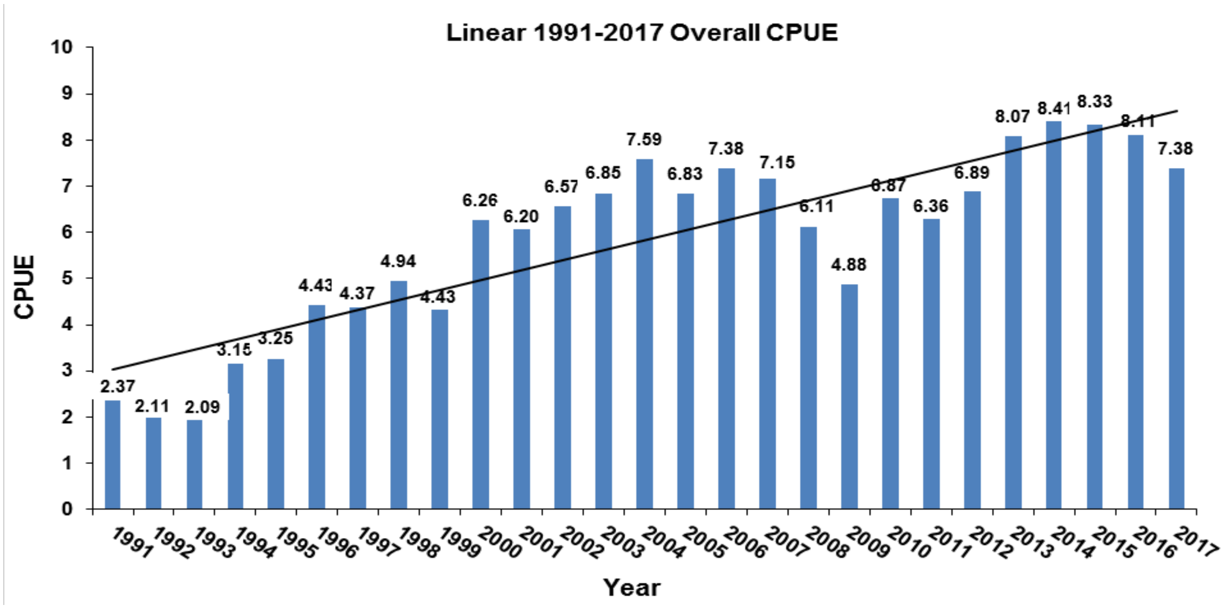


Figure 17. Annual NPSRF CPUE (Returning + Non-Returning Anglers) for the years 1991-2017

CPUE by Week

Mean angler CPUE by week for the 2017 NPSRF was 7.70 fish per angler day compared to 8.22 in 2016 (Winther et al. 2017) and ranged from a low of 4.48 in week 18 (May 1-7) to a peak of 12.09 in week 37 (September 11-17) (Figure 18). Weekly CPUE for the 2017 NPSRF followed a typical two-peak pattern where the first peak happened in week 25 near the historical Northern Pikeminnow spawning peak, and then again late in the season (week 37) when water become favorable in the lower Columbia and Snake rivers as seen in previous years (Winther et al. 2011).

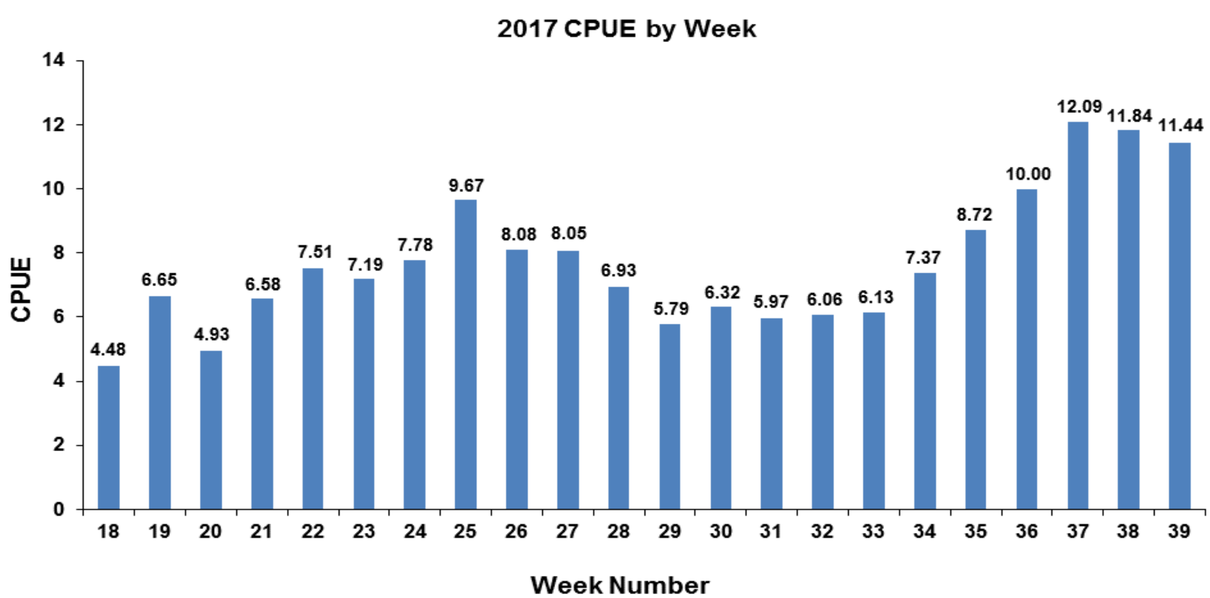


Figure 18. 2017 Northern Pikeminnow Sport-Reward Fishery Angler CPUE by Week

CPUE by Fishing Location

Angler success rates for the 2017 NPSRF (as indicated by CPUE), represent returning anglers only and varied by fishing location. Success rates ranged from a high of 13.96 Northern Pikeminnow per angler day in fishing location 02 (Bonneville Reservoir) to only 0.55 fish per angler per day in fishing location 11 (Lower Granite Reservoir to the Mouth of Clearwater River) (Figure 19). CPUE increased at only one of the 12 fishing locations (fishing location 01), rising from 9.80 in 2016 (Winther et al. 2017) to 10.57 in 2017. The average CPUE by fishing location was 7.23 Northern Pikeminnow per angler day in 2017 compared to 9.58 in 2016 (Winther et al. 2017).

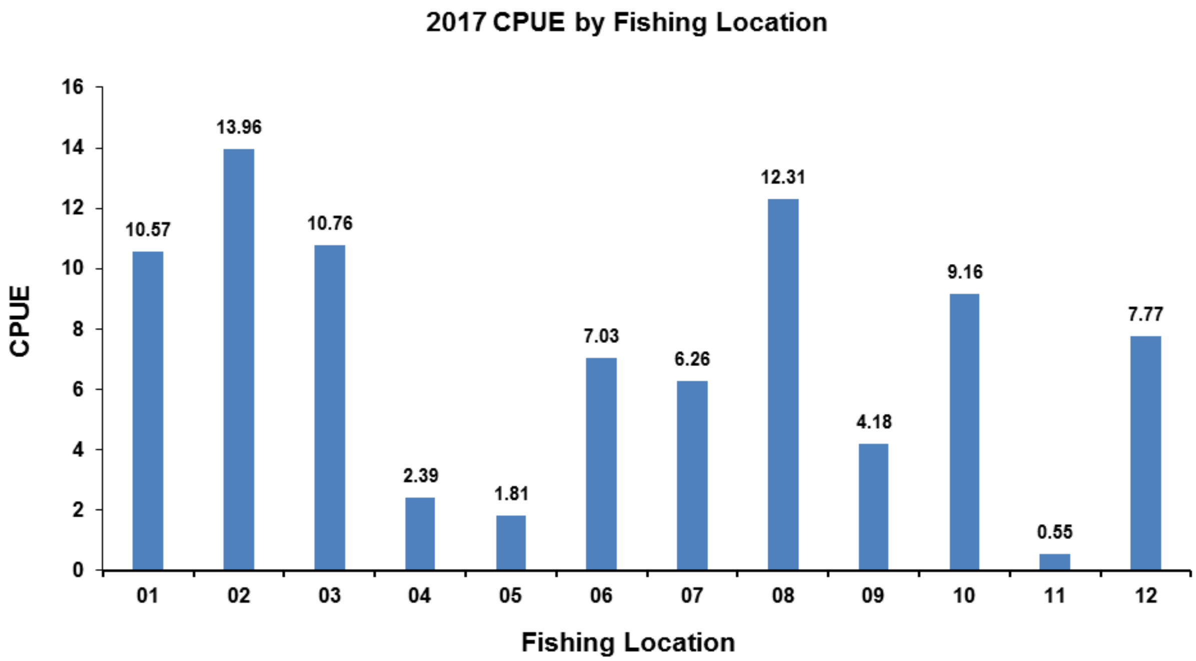


Figure 19. 2017 Northern Pikeminnow Sport-Reward Fishery Angler CPUE by Fishing Location.*
Fishing Location Codes for **Columbia River**; 01 = Below Bonneville Dam, 02 = Bonneville Reservoir, 03 = The Dalles Reservoir, 04 = John Day Reservoir, 05 = McNary Dam to the mouth of the Snake River, 06 = Mouth 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 Hells Canyon Dam.

CPUE by Registration Station

The registration station with the highest CPUE during the 2017 NPSRF was the Ridgefield station where anglers averaged 10.96 Northern Pikeminnow per angler day (Figure 20). The registration station with the lowest CPUE was the Umatilla station with a CPUE of 1.59 Northern Pikeminnow per angler day. The station average for angler CPUE was 7.13 in 2017, down from 7.86 in 2016 (Winther et al. 2017). Angler CPUE by registration station increased at seven stations during the 2017 NPSRF season. The largest increase in occurred at the Rainier station where CPUE increased from 7.46 in 2016 (Winther et al. 2017) to 9.63 in 2017.

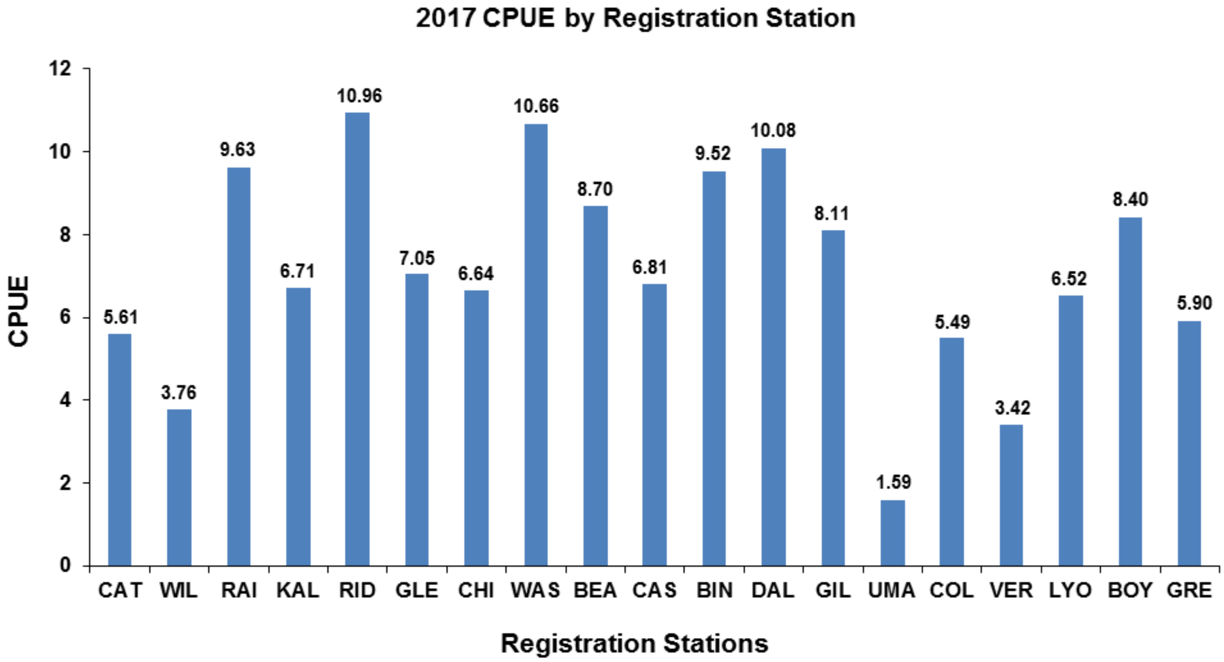


Figure 20. 2017 Northern Pikeminnow Sport-Reward Fishery Angler CPUE by Registration Station
CAT-Cathlamet, WIL-Willow Grove, RAI-Rainier, KAL-Kalama, RID-Ridgefield, GLE-Gleason, CHI-Chinook, WAS-Washougal, BEA-Beacon Rock, CAS-Cascade Locks, BIN-Bingen, DAL-The Dalles, GIL-Giles, UMA-Umatilla, COL-Columbia Point, VER-Vernita, LYO-Lyon's Ferry, BOY-Boyer Park, GRE-Greenbelt.

Angler Totals

There were 3,462 separate anglers who participated in the 2017 NPSRF, a decrease of 256 participants from 2016 (Winther et al. 2017). One thousand, four hundred and ninety of these anglers (43.0% of total vs. 43.5% in 2016 (Winther et al. 2017)) were classified as successful, harvesting at least one reward size Northern Pikeminnow (for which a voucher was issued) during the 2017 season. Of the successful anglers, 73.6% (1,096 anglers) sent in their vouchers to PSMFC for payment (PSMFC 12/12/17 Sport-Reward Payment Summary) while 394 anglers (26.4%) did not. The average successful angler harvested 129 Northern Pikeminnow during the 2017 NPSRF compared to 139 in 2016.

When we break down the 1,490 successful anglers by tier, 1,048 of these anglers (70.34%) harvested fewer than 25 Northern Pikeminnow and were classified as Tier 1 anglers (Figure 21). While this is down from the 1,140 individual Tier 1 anglers in 2016 (Winther et al. 2017), the total number of Tier 1 anglers did not change much before or after the 2015 tier change (Table 4). The number of Tier 2 anglers declined slightly to 287 in 2017 (down from 295 in 2016), although it is still nearly triple the mean number of Tier 2 anglers (101 anglers) recorded during the 2010-2014 NPSRF seasons prior to the tier change in 2015. The percentage of successful anglers that are Tier 2 anglers has grown from 8.25% in 2014, to 19.26% in 2017. The number of Tier 3 anglers (known as "highliners") decreased from 184 anglers in 2016 (Winther et al. 2017) to 155 anglers in 2017, but still remained 63% higher than the mean number of Tier 3 anglers recorded during the 2010-2014 NPSRF seasons (95 anglers).

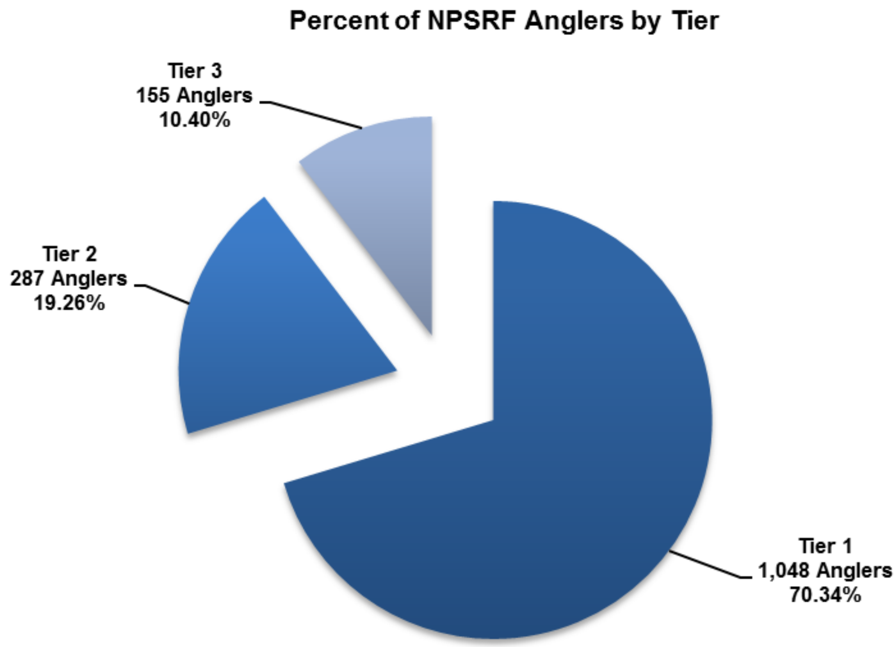


Figure 21. 2017 NPSRF Anglers by Tier (Returning Anglers) Based on Total Harvest

Table 4. Annual Comparison of NPSRF Successful Anglers by Tier (Before and After the 2015 Tier Change).

Year	Tier 1 Anglers	Tier 2 Anglers	Tier 3 Anglers	Successful Anglers	Separate Anglers	%Successful Anglers
2010	1,091	111	109	1,311	3,313	39.57
2011	1,226	113	87	1,426	3,624	39.35
2012	1,097	90	98	1,285	3,302	38.92
2013	941	97	92	1,130	2,618	43.16
2014	977	96	91	1,164	2,773	41.98
2010-2014 Mean	**1,066**	**101**	**95**	**1,263**	**3,126**	**40.41**
2015	986	239	163	1,388	3,210	43.24
2016	1,140	295	184	1,619	3,718	43.54
2017	1,048	287	155	1,490	3,462	43.04
2015-2017 Mean	**1,058**	**274**	**167**	**1,499**	**3,463**	**43.28**

The larger number, and higher percentage of individual anglers at Tiers 2 and 3, (as a component of successful anglers) compared to mean 2010-2014 totals, is especially important to achieving NPSRF harvest and exploitation objectives since Tier 2 and Tier 3 anglers historically have a much higher CPUE than Tier 1 anglers (Hisata et al. 1996). Additionally, at the same time that the number and percentage of anglers at Tiers 2 and 3 was growing, the NPSRF was able to maintain a similar number of Tier 1 anglers (which make up the largest group of successful anglers) even though they made up a smaller percentage of successful anglers.

While Tier 1 anglers made up 70.34% of all successful NPSRF participants in 2017, (well below the mean 2010-2014 level of 84.4%), they accounted for only 2.95% of total NPSRF harvest (5,647

Northern Pikeminnow) (Figure 22). Tier 2 anglers made up 19.26% of all successful anglers and harvested 11.13% of total NPSRF harvest (21,309 fish). Tier 3 anglers made up 4.5% of all participants (both returning and non-returning anglers), 10.40% of all successful anglers and accounted for 85.92% of total NPSRF harvest (164,523 fish).

Average annual harvest per angler was up for both Tier 1 and Tier 2 anglers. Tier 1 anglers annual average harvest was up from 4.92 fish per year in 2016 to 5.39 fish per year in 2017 (Winther et al. 2017). Tier 2 anglers harvested an annual average of 74.25 fish per year in 2017, up from 73.26 fish per year in 2016. Average annual harvest for Tier 3 anglers declined to 1,061.44 fish per angler, per year, compared to 1,079 fish per year in 2016.

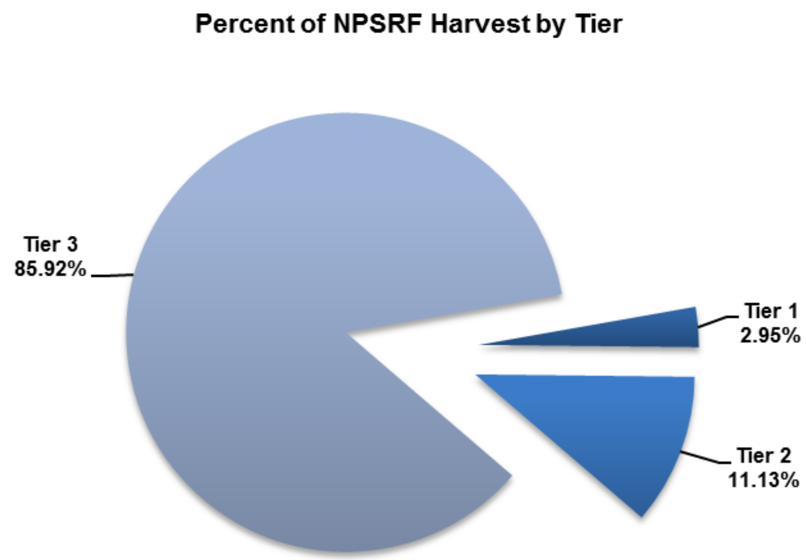


Figure 22. 2017 NPSRF Harvest by Angler Tier (Tier 1 = ≤25, Tier 2 =26-200, Tier 3 = > 200)

The overall average NPSRF participant (returning + non-returning anglers) expended slightly more effort pursuing Northern Pikeminnow during the 2017 season than in 2016 (7.50 vs. 7.47 angling days of effort) (Winther et al. 2017). When we look at successful anglers only, the average successful angler increased their average annual effort spent to 17.42 angler days during the 2017 NPSRF compared to 15.11 days in 2016 (Winther et al. 2017). Despite less favorable river conditions in 2017, when we break it down by tier, average annual effort increased or remained equal for anglers at all three tier levels. Tier 1 anglers spent an average of 5 days fishing in 2017 compared to 4 days (Figure 23) fishing in 2016 (Winther et al 2017). Tier 2 anglers spent an average of 23 days fishing in 2017 versus 22 days fishing in 2016 (Winther et al. 2017). Tier 3 anglers spent an average of 71 days fishing in both 2017 and 2016 (Winther et al. 2017).

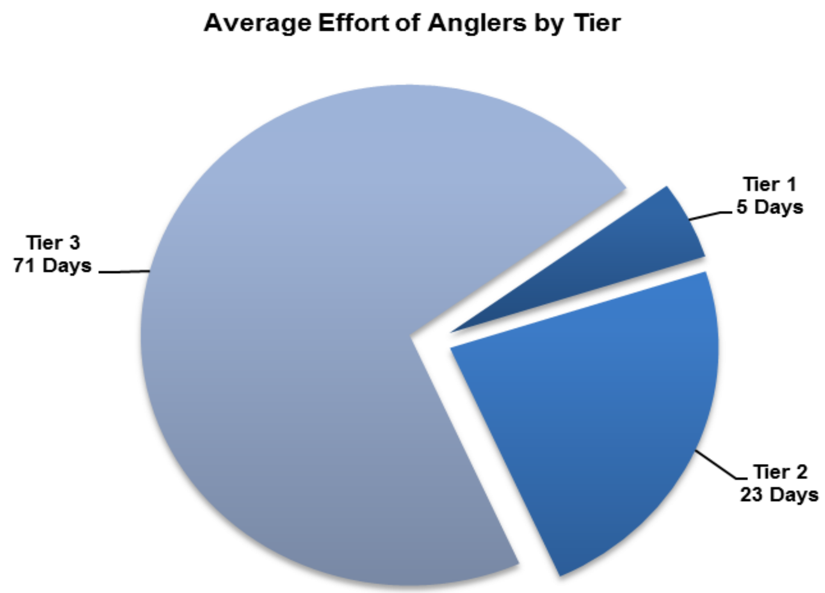


Figure 23. Average Effort of 2017 NPSRF Anglers by Tier (Tier 1 = ≤ 25, Tier 2 = 26-200, Tier 3 = > 200)

Overall angler CPUE for the 2017 NPSRF decreased slightly from 2016 (Winther et al. 2017) and all three tier levels showed a slight decrease in CPUE as well. CPUE for anglers at Tier 1 decreased from 1.23 in 2016 to 1.09 in 2017 (Figure 24). CPUE for Tier 2 anglers decreased from 3.33 fish per angler day in 2016 (Winther et al. 2017) to 3.27 in 2017. CPUE for Tier 3 anglers decreased from 15.19 in 2016 (Winther et al. 2017) to 14.93 in 2017. The decrease in CPUE at all three tier levels illustrates that 2017 river conditions were less favorable for angling than in 2016, regardless of angling skill.

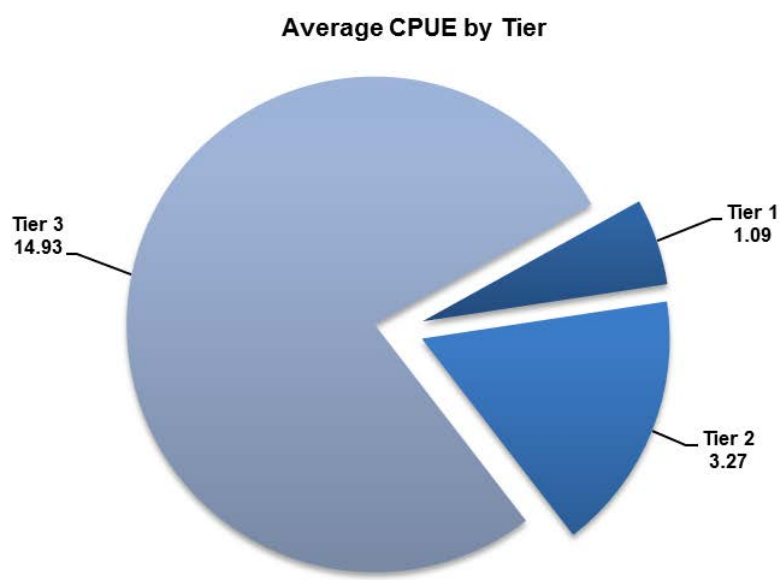


Figure 24. Average CPUE of 2017 NPSRF Anglers by Tier (Tier 1 = ≤25, Tier 2 =26-200, Tier 3 = > 200)

The top individual angler (based on number of fish caught) for the 2017 NPSRF harvested 10,277 Northern Pikeminnow, which also included 3 spaghetti tagged Northern Pikeminnow and 6 tag-loss Northern Pikeminnow worth a total earnings of $83,877 (PSMFC 12/12/2017 Sport-Reward Payment Summary). The 2017 top angler caught 3,742 less reward sized Northern Pikeminnow than he did as the top angler in 2016, and once again nearly doubled the harvest of the second place angler. The CPUE for this year's top angler (79.6 fish per angler day) was down from what he had as the top angler in 2016 (128.6 fish per angler day) reflecting that even the top angler had a more difficult time catching Northern Pikeminnow with 2017 river conditions (Winther et al. 2017). The top angler for the 2017 season spent 20 more days of effort (129 days) than he did in 2016 (109 days) as the top angler (Winther et al. 2017). By comparison, the top angler in terms of participation (rather than harvest) for the 2017 NPSRF fished 149 days of the 153 available days (97.4% of available days) and harvested 690 Northern Pikeminnow.

Tag Recovery

Northern Pikeminnow Tags

Returning anglers harvested 269 Northern Pikeminnow tagged by ODFW with external spaghetti tags during the 2017 NPSRF compared to 228 spaghetti tags harvested in 2016 (Winther et al., 2017). Tag recoveries peaked during week 21 (vs weeks 23 and 24 in 2016), four weeks earlier than peak NPSRF harvest (Figure 25) (Winther et al. 2017). All of the 269 spaghetti tagged Northern Pikeminnow recovered in the 2017 NPSRF, retained PIT tags added by ODFW as a secondary mark. WDFW technicians also recovered an additional 134 Northern Pikeminnow, which had retained ODFW PIT tags, but had "lost" the ODFW spaghetti tag (e.g. tag-loss). The recovered spaghetti and PIT tags from tag-loss data were estimated by ODFW to equal a 17.4% exploitation rate for the 2017 NPSRF (Carpenter et al. 2018).

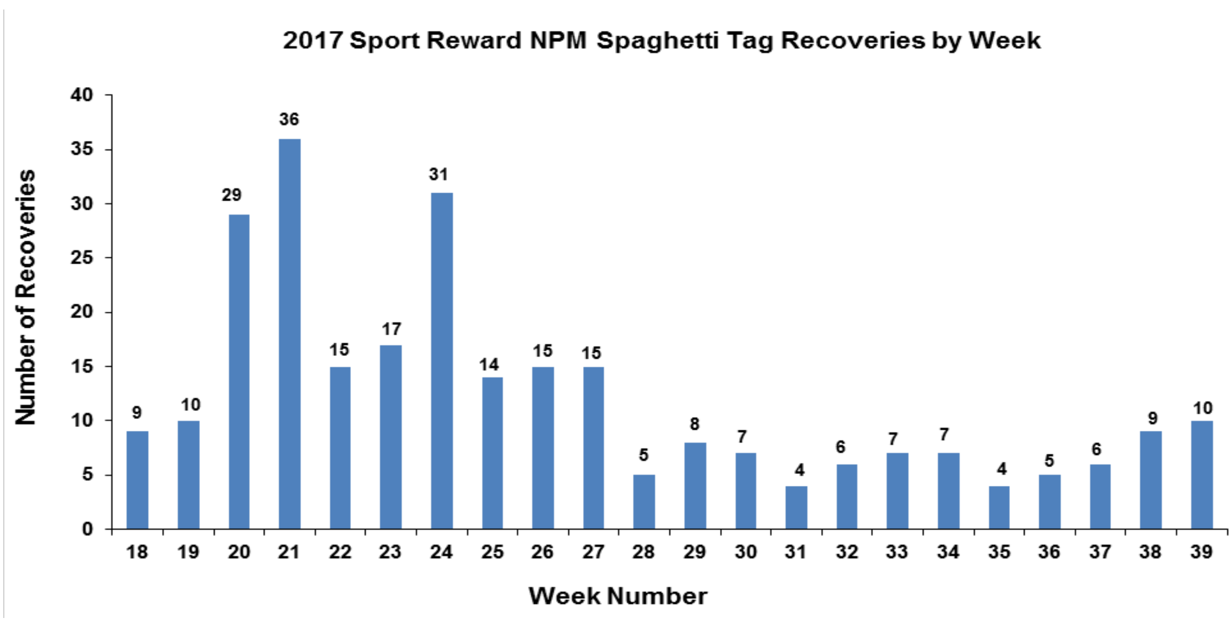


Figure 25. 2017 NPSRF Spaghetti Tag Recoveries by Week

Ingested PIT Tags

A total of 191,479 Northern Pikeminnow were individually scanned for the presence of PIT tags in 2017. This represents 100% of the total harvest of reward-size fish for the 2017 NPSRF (Northern Pikeminnow not qualifying for rewards were also scanned whenever possible). Technicians recovered a total of 25 PIT tags from consumed smolts that had been ingested by Northern Pikeminnow harvested during the 2017 NPSRF, an overall occurrence ratio of 1:7,659 compared to 1:2,590 in 2016. Total ingested PIT tag recoveries in 2017 were 62 recoveries lower than the previous year. While total harvest was lower in 2017 than in 2016, the rate of occurrence for ingested PIT tags also fell from 1:2,590 in 2016 to 1:7,659 in 2017 (Winther et al., 2016, 2017). PIT tag recoveries of salmonid smolts ingested by Northern Pikeminnow had peaks on three different occasions during week 19, week 22, and week 27 of the 2017 season (compared to 21 in 2016) (Winther et al. 2017). Our last ingested PIT tag recovery occurred during week 30 (July 23rd – July 29th) (Figure 26).

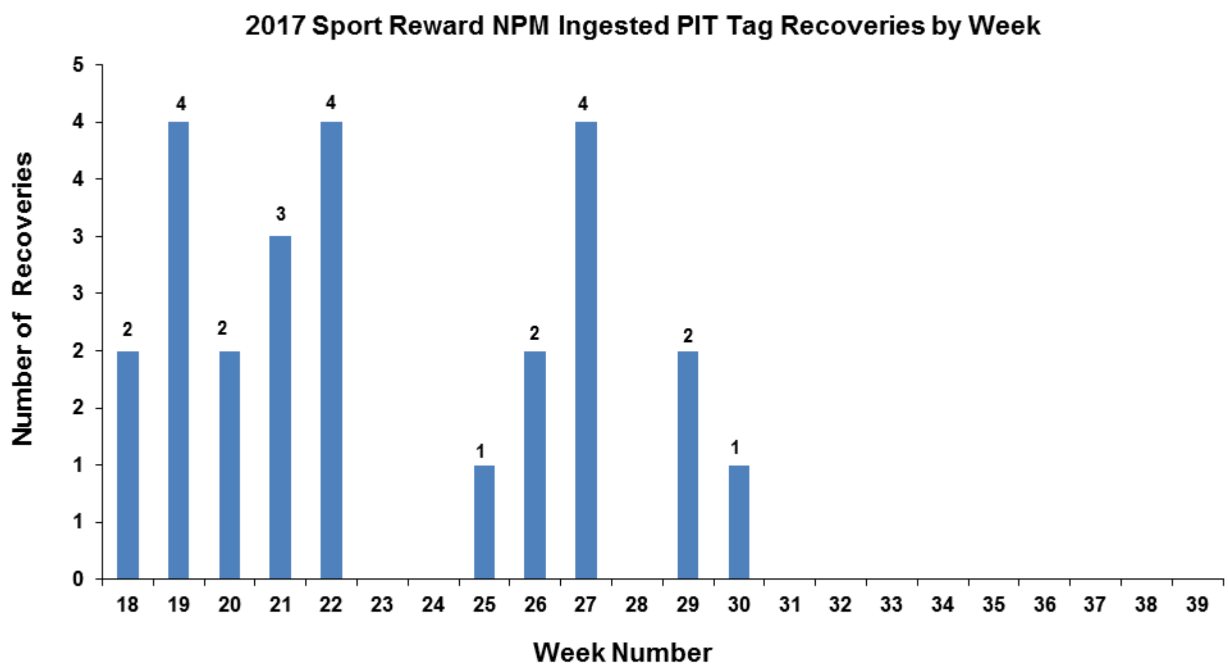


Figure 26. 2017 NPSRF Ingested PIT Tag Recoveries by Week

Ingested PIT tag recoveries by fishing location during the 2017 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).

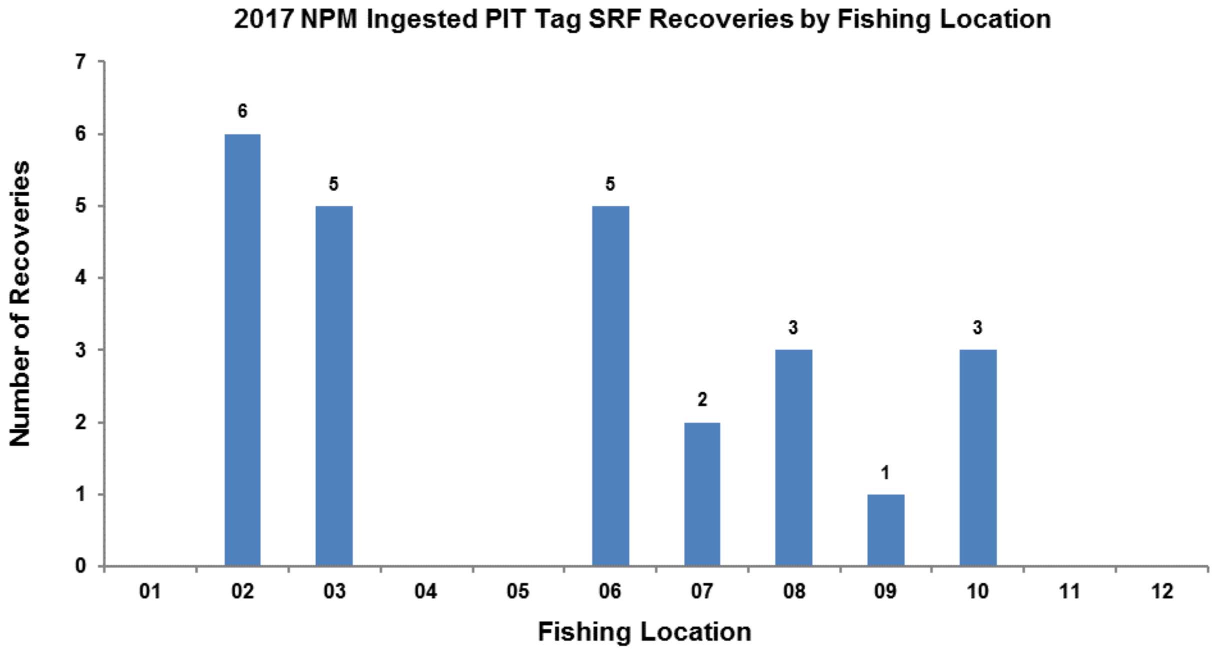


Figure 27. 2017 NPSRF ingested PIT Tag Recoveries by Fishing Location
Fishing Location Codes – **Columbia River**; 01 = Below Bonneville Dam, 02 = Bonneville Reservoir, 03 = The Dalles Reservoir, 04 = John Day Reservoir, 05 = McNary Dam to the mouth of the Snake River, 06 = Mouth of the Snake River to 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 Hells Canyon Dam.

Species composition of PIT tagged smolts ingested by Northern Pikeminnow harvested in the 2017 NPSRF was obtained from PTAGIS and indicated that 20 of the 25 ingested PIT tag recoveries (80.0%) were from Chinook smolts (Figure 27). In addition, 18 of the 20 Chinook PIT tags were of hatchery origin (90.0%). PTAGIS queries revealed that these PIT tag recoveries consisted of 10 Fall Chinook, 4 Spring Chinook, 3 Summer Chinook, and 1 unknown hatchery origin Chinook. Of the non-chinook PIT tags, PTAGIS queries revealed that the other 5 non-Chinook PIT tags were from 3 Steelhead, 1 Coho, and 1 orphan tag code not entered into PTAGIS.

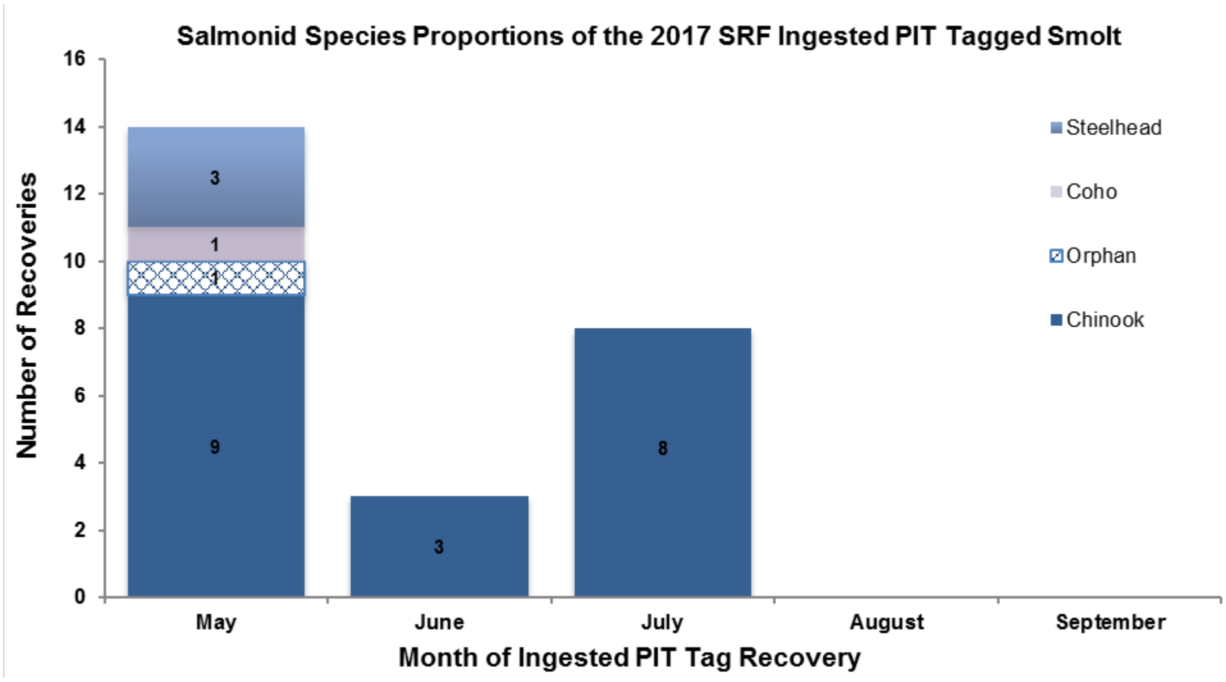


Figure 28. Recoveries of Ingested Salmonid PIT Tags From the 2017 NPSRF

Analysis of PIT tag recovery data from the 2017 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 2017 NPSRF succeeded in reaching the NPMP's 10-20% exploitation goal for the twentieth consecutive year, achieving an estimated exploitation rate of 17.4%. NPSRF harvest in 2017 was 33,871 fish lower than 2016 harvest, but well above mean 1991-2016 annual harvest of 176,353. The 2017 harvest total was also 28,700 more Northern Pikeminnow than mean 2010-2014 harvest (prior to the tier system modification). Annual angler effort in 2017 decreased by 1,812 angler days (6.9%) from 2016, but was still 6,455 angler days more than in 2014, prior to the tier modification. The number of individual anglers decreased by 256 anglers in 2017 (7.4%) from 2016, but is 689 anglers higher since the 2014 tier modification. Higher water made less favorable river conditions, which resulted in angler CPUE declining from 8.11 in 2016 to 7.38 in 2017. Peak weekly harvest occurred during week 25. Peak weekly effort occurred during the first week of the 2017 season (May 1-7), continuing a new trend that began in 2015 with the first year of the tier modification. The Dalles registration station was the NPSRF's top station for harvest in 2017 for the sixth time in the past seven years with 44,607 reward sized Northern Pikeminnow harvested, while also recording the most effort with 4,425 angler days of effort spent. We recovered 269 Northern Pikeminnow that were spaghetti tagged by ODFW, and an additional 134 Northern Pikeminnow which were missing spaghetti tags but retained ODFW PIT tags (tag-loss). Mean fork length for Northern Pikeminnow harvested in the 2017 NPSRF was 279.82 mm, up from 275.2 mm in 2016. Incidental catch consisted primarily of Peamouth, Smallmouth Bass, and Yellow Perch (mostly released), and reflected similar catch patterns to previous NPSRF seasons.

For the 2017 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 13.96 Northern Pikeminnow per angler day. The three stations with the highest CPUE in 2017 were Ridgefield (10.96), Washougal (10.66), and The Dalles (10.08). The Dalles remained the top NPSRF's station for the second consecutive year exceeding its last year's total where anglers harvested 44,607 reward sized Northern Pikeminnow compared to 41,479 in 2016 (Winther et al. 2017). The top angler during the 2017 NPSRF harvested 10,277 fish and earned $83,877 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 of ingested salmonids rose to 1:7,659 in 2017. Species composition of the 25 recovered PIT tags again showed that they were primarily from Chinook smolt of hatchery origin. We also recovered PIT tags from ingested Coho (1), and Steelhead (3), according to PTAGIS.

RECOMMENDATIONS

1.) Continue to use standardized season dates (May 1st-Sept 30th) for implementation of the 2018 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 2017 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 2017 designed to incentivize current, proficient anglers to expend additional effort participating in the 2018 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) Continue to 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) 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.

5.) 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 – 2017

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March, 2018

ABSTRACT

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

For 2017, the rewards paid to anglers were the same as in the 2016 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. One hundred eighty-nine thousand two hundred fifty-one 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 $1,386,612.

A total of 266 tagged fish (having an external spaghetti tag) were paid at $500 each. The season total paid for tag rewards was $133,000. A total of 134 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 $13,400

A total of 884 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 $8,840

A total of 3,462 separate anglers registered to fish, of which 1,100 (32%) caught one or more fish and received payments during the season. The total value for all 189,517 Northern Pikeminnow submitted for payment in 2017 (including all coupons, tagged fish and tag-loss *bonus* payments) was $1,541,852.

INTRODUCTION

The **Northern Pikeminnow Sport Reward Program** was administered by PSMFC in 2017. 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 2017 SEASON

The 2017 season ran from May 1, 2017 through September 30, 2017.

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 (2012 – 2016) and to those who signed up for our mailing list at the various sportsmen's shows. The 2017 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 884 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 $8,840

PARTICIPATION AND PAYMENT

A total of 1,490 anglers who registered were successful in catching one or more fish in 2017. Of those anglers; 1,100 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 2017 a total of 191,479 fish were harvested in the sport-reward fishery. Of this total, 189,517 fish were submitted for payment and paid prior to the 2017 payment deadline (To obtain payment, vouchers must have been received no later than November 15, 2017). In addition, any *received* vouchers with issues preventing payment (missing information, voiding of voucher for program violations, etc.) not resolved by November 15, 2017 became null and void.

TAGGED FISH AND PAYMENTS

Registered anglers caught and submitted a total of 266 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 $133,000.

TAG-LOSS BONUS PAYMENT

All tagged Northern Pikeminnow initially have both a spaghetti tag and a PIT (Passive Integrated Transponder) 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 134 tag-loss fish qualified for and were paid the *bonus* reward of $100. The season total paid for tag-loss *bonus* was $13,400

TOTAL ACCOUNTING

Total payments for the season of regular vouchers, *$10 bonus coupons*, tag vouchers and *tag-loss bonus* payments was $1,541,852.

All IRS Form 1099-MISC Statements were sent to the qualifying anglers for tax purposes in the fifth week of January, 2018. Appropriate reports and copies were provided to the IRS by the end of February, 2018.

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

2017 SPORT REWARD PAYMENTS SUMMARY

The following is a summary of all vouchers received and paid as of Nov 27, 2017

	Fish	Incentives	Reward
Fish paid @ tier 1 ($5 each):	15,090	-	$75,450
Fish paid @ tier 2 ($6 each):	41,063	-	$246,378
Fish paid @ tier 3 ($8 each):	133,098	-	$1,064,784
Tags paid (@ $500 each):	266	-	$133,000
Coupons issued (@ $10 each):	-	884	$8,840
Tag-loss issued (@ $100 each):	-	134	$13,400
Total:	189,517		$1,541,852

Anglers @ tier 1	*666*
Anglers @ tier 2	*278*
Anglers @ tier 3	*156*
Number of separate anglers	*1100*
Anglers with 10 fish or less:	*511*
Anglers with 2 fish or less:	*258*

	Total Fish	$500 Tags	Tag Loss Tags	Coup.	Total Reward Paid
1.	10,277	3	$ 600	$ 10	$ 83,877
2.	5,921	10	$ 400	$ 10	$ 52,273
3.	6,018	4	$ 500	$ 10	$ 50,197
4.	3,679	12	$ 800	$ 10	$ 35,721
5.	4,041	1	$ 200	$ -	$ 32,595
6.	3,634	6	$ 800	$ 10	$ 32,409
7.	3,396	3	$ -	$ 10	$ 28,229
8.	3,438	2	$ -	$ 10	$ 28,073
9.	2,943	8	$ 400	$ 10	$ 27,465
10.	3,127	1	$ 300	$ 10	$ 25,393
11.	2,968	2	$ -	$ 10	$ 24,313
12.	2,566	1	$ 100	$ 10	$ 20,705
13.	2,397	3	$ 400	$ 10	$ 20,637
14.	2,453	1	$ 100	$ 10	$ 19,801
15.	2,320	3	$ 100	$ 10	$ 19,721
16.	2,455	0	$ 100	$ 10	$ 19,325
17.	2,044	6	$ 100	$ 10	$ 18,989
18.	2,340	1	$ 100	$ 10	$ 18,897
19.	2,380	0	$ 200	$ 10	$ 18,825
20.	2,202	3	$ 100	$ 10	$ 18,777
	70,599	70	$5,300	$ 190	$ 596,222

NORTHERN PIKEMINNOW
SPORT-REWARD FISHERY VOUCHER

2017 STANDARD

TO ENSURE PROMPT PAYMENT:
1) Verify voucher is complete.
2) Fill out, detach and keep receipt.

MAIL TO: NORTHERN PIKEMINNOW SPORT-REWARD FISHERY
PO Box 82128
Portland, OR 97282-0128

LAST NAME | FIRST NAME | MI

ADDRESS

CITY | STATE | ZIP CODE

ANGLER TELEPHONE NUMBER
_ _ _ – _ _ _ – _ _ _ _

VOUCHER #

EMAIL (OPTIONAL)
@

MONTH | DAY | 2 0 1 7

DOCUMENT #

STATION

TOTAL # OF QUALIFYING NORTHERN PIKEMINNOW CLAIMED (EXCLUDING TAGGED FISH)

(NUMBER)

X ____________________
(WRITTEN TOTAL)

LAST 4 DIGITS SS#: –

I hereby swear under the penalty of perjury that the above information is true and correct and that I caught all fish claimed on this voucher in accordance with all Sport-Reward Fishery Rules and Regulations printed on the back of this voucher.

X
TECHNICIAN SIGNATURE

X
ANGLER SIGNATURE (Must be signed in the presence of Technician)

DATE

STATION

Fishing Date: ________________
Station: ________________
Voucher #: ________________
Document Number: ________________
Number of fish: ________________

*** * * DETACH & KEEP THIS STUB FOR YOUR RECORDS * * ***

REWARD VOUCHER INFORMATION
1-800-769-9362 (Toll Free)
E-MAIL: vouchers@pikeminnow.org

*****TO OBTAIN PAYMENT, THIS VOUCHER MUST BE RECEIVED BY PSMFC NO LATER THAN 11/15/17.*****

[ANY ISSUES PREVENTING PAYMENT (missing information, voiding of vouchers for sport-reward fishery rule violations ect.) MUST BE RESOLVED PRIOR TO THIS DATE OR THE VOUCHER BECOMES NULL AND VOID]

NORTHERN PIKEMINNOW SPORT-REWARD FISHERY VOUCHER

2017 TAG

LAST NAME

FIRST NAME

MI

ADDRESS

CITY

STATE

ZIP CODE

ANGLER TELEPHONE NUMBER

– –

TAG VOUCHER #

EMAIL (OPTIONAL)

@

MONTH DAY 2 0 1 7

DOCUMENT #

STATION

LOC FISHED

SPAGHETTI TAG #

PIT TAG #

TAG COLOR

LAST 4 DIGITS SS#: -

X

TECHNICIAN SIGNATURE

I hereby swear under the penalty of perjury that the above information is true and correct and that I caught all fish claimed on this voucher in accordance with all Sport-Reward Fishery Rules and Regulations printed on the back of this voucher.

X

ANGLER SIGNATURE (Must be signed in the presence of Technician)

DATE

STATION

STAPLE TAG ENVELOPE HERE

(Write Fork Length on Tag Envelope)

X

ODFW TAG VERIFICATION SIGNATURE

TO ENSURE PROMPT PAYMENT:

1) Verify voucher is complete.
2) Fill out, detach and keep receipt.

MAIL TO:

ODFW
NORTHERN PIKEMINNOW PROGRAM
PO Box 2290
Clackamas, OR 97015

Fishing Date: ____________________

Station: ____________________

Voucher #: ____________________

Document Number: ____________________

Tag Number: ____________________

*** * * DETACH & KEEP THIS STUB FOR YOUR RECORDS * * ***

REWARD VOUCHER INFORMATION

1-800-769-9362 (Toll Free)

E-MAIL: vouchers@pikeminnow.org

*****TO OBTAIN PAYMENT, THIS VOUCHER MUST BE RECEIVED BY PSMFC NO LATER THAN 11/15/17.*****

[ANY ISSUES PREVENTING PAYMENT (missing information, voiding of vouchers for sport-reward fishery rule violations ect.) MUST BE RESOLVED PRIOR TO THIS DATE OR THE VOUCHER BECOMES NULL AND VOID]

Report C

System-wide Predator Control Program: Fisheries and Biological Evaluation

Prepared by

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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 2017, 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* below Bonneville Dam and in Bonneville Reservoir; 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 2017, 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 fork length in the Sport Reward Fishery during 2017 was 17.4% (95% confidence interval, 10.8–24.0%). This value was within the NPMP targeted range of 10-20%. Based on this level of exploitation, we estimate 2018 predation levels will be 32% (range: 17–49%) 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 2021. Predation behavior by Northern Pikeminnow caught in the Dam Angling Fishery in Bonneville and The Dalles reservoirs was similar to previous years with the highest presence of juvenile salmonids, lamprey (family Petromyzontidae), and American Shad *Alosa sapidissima* in the diet coinciding with their respective outmigration peaks. Northern Pikeminnow caught and removed during the Dam Angling Fishery continue to have a longer fork length than the fish caught in the Sport Reward Fishery in Bonneville and The Dalles reservoirs. Abundance index estimates for 2017 in most areas of the lower Columbia River reservoirs indicate a decrease since the early 1990s in Northern Pikeminnow greater than or equal to 250 mm fork length. Overall, highly variable abundance, consumption, and predation index values for the predators monitored in our study provide no obvious indication of a long term compensatory response to the targeted removal of Northern Pikeminnow. Proportional size distribution of Northern Pikeminnow collected during Sport Reward Fishery evaluation indicate a significant decrease since the early 1990s in The Dalles, John Day, McNary, and Lower Granite reservoirs. 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 tshawytscha*, (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, the Oregon Department of Fish and Wildlife (ODFW) has 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 2017 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 below Bonneville Dam and in Bonneville Reservoir; 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 Columbia and lower Snake rivers.

METHODS

Sampling during 2017 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 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 that supports a single array composed of six electrodes, while electrodes hanging from the boat hull function as the cathodes. 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 U.S. Endangered Species Act 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 16 (Ice Harbor Dam) to rkm 66 (Lower Monumental Dam) and rkm 113 (Little Goose Dam) to rkm 251 upstream of Lower Granite Dam (Figure 1). Four sampling events consisting of 900 seconds (s) of boat 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 5 April to 29 June 2017 between 1800 and 0500 hours, except in the Hanford Reach of the Columbia River (rkm 561– 637) and near Asotin, WA on the Snake River (rkm 230–251), where safe river navigation necessitated daytime sampling. A total of 42 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 Bonneville Dam (rkm 233) were tagged prior to the start of the fisheries (1 May 2017). Upstream of Bonneville 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. Additionally in 2017, Walleye were opportunistically captured, measured for fork length, and weighed throughout the Columbia and lower Snake rivers in an attempt to gain some understanding of the populations in these areas and supplement data collected during biological evaluation activities (see below).

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 2017 (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 TL 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 during the season.

In addition to the Sport Reward Fishery, an NPMP-administered Dam Angling Fishery (see Report D for details) was conducted from 4 May to 4 October 2017 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, a correction for tag retention was not necessary to estimate 2017 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, we excluded the few fish that were recaptured during the same week they were tagged 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

$$u_{annual_j} \pm t \times \sqrt{n_j} \times s_j, \qquad (5)$$

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 2018 based on observed exploitation rates from 2017 and predict three future predation rates (maximum, median, and minimum) using the mean level of exploitation observed during contemporary program rules (2001; 2004–2017). Additional model documentation is described in Friesen and Ward (1999).

To test for differences in the size of Northern Pikeminnow captured in the 2017 Sport Reward fishery versus the Dam Angling fishery, we applied area-specific ordinary least-squares models ('lm' in package 'stats'; R Core Team 2013) to fork length 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 2017) 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 the Columbia River below Bonneville Dam and in Bonneville Reservoir during 2017. Early morning (0200–1200 hours) sampling was conducted during spring (9–25 May 2017) and summer (20–30 June 2017) in three areas of Bonneville Reservoir (forebay, rkm 235–241; mid-reservoir, rkm 275-286; and The Dalles Dam tailrace, rkm 303-307) and four areas below Bonneville Dam (rkm 116–121, rkm 173–181, rkm 188–194, and Bonneville Dam tailrace, rkm 226–234). 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 900 second boat electrofishing period with continuous output of approximately 4 A. Summer sampling downstream from Bonneville Dam tailrace (scheduled for 3–7 July 2017) was not conducted because shoreline water temperatures exceeded 18°C, an environmental threshold specified in federally assigned scientific collection permits (NMFS 2000).

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 increments for all three species in both areas. 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 processed in the laboratory.

Using the protocol described above, we also collected digestive tracts from Northern Pikeminnow captured during the 2017 Dam Angling Fishery of the NPMP. Digestive tracts were collected from a representative subsample of catches at each dam weekly from 10 May–24 August 2017, generally three days per week. In addition, morphometric measurements (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 in the mid-section of Bonneville reservoir, a random subsample was taken to match the highest number of samples from the other sections (forebay and tailrace) of that reservoir for each season and only these diet samples were processed in the laboratory. All other Smallmouth Bass, Northern Pikeminnow, and Walleye gut contents were processed in the laboratory. For 2017, 776 Smallmouth Bass, 30 Walleye, and 258 Northern Pikeminnow gut contents were processed. Due to the large number of Northern Pikeminnow digestive tracts collected during the Dam Angling fishery, a random subsample of approximately 10 digestive tracts from each dam/sample day combination were processed in the laboratory. If less than 10 samples from a given dam/sample day were available, all samples from that dam/sample day were processed along with additional samples from that week to total 30 samples per week, when available. For 2017, 748 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 crustacea, 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. Gut material was weighed (blotted wet mass) to the nearest 0.01 gram (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 h. After removal from the oven, a 20-ml solution of sodium hydroxide (lye, NaOH)—mixed at 30g/L with 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 was counted for diet analysis. Stomach samples of fishes that did not contain diet items (empty) were included in all analyses.

Hard parts remaining after chemical digestion were examined to identify prey to the lowest possible taxon (usually family) under stereoscopic 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 American Shad 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, a minimum of 10% of all samples were re-analyzed at random by a second reviewer.

We prepared acetate impressions of the scales collected from 30 Walleye sampled during 2017 biological evaluation boat electrofishing efforts below Bonneville Dam and in Bonneville Reservoir to read in a microfiche projector. We used standard methods to count the number of annuli to assign age at capture, to estimate year class of individuals, and to observe size (FL) at age (Jearld 1983; DeVries and Frie 1996). Two independent readers analyzed scales and few disagreements on age assignment were reconciled by reevaluation. Scales collected from Northern Pikeminnow and Smallmouth Bass were catalogued and archived for potential future analyses.

Data Analysis

Following the methods of Ward et al. (1995), we calculated seasonal abundance index values for each predator species by calculating the mean catch per 900 s boat electrofishing by season and area, then multiplying by the surface area (ha) of specific sampling locations in each river area and dividing by 1,000 for scale. 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:

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

and

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

where

T = mean water temperature per season-area stratum ($^{\circ}$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. Consumption index values were calculated only when sample sizes exceeded five fish for a given species, season, and sampling area. 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.

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 size distribution (PSD; Anderson 1980; Guy et al. 2006; Guy et al. 2007) 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:

$$PSD_i = 100 \times \frac{FQ_i}{FS_i}, \tag{8}$$

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 proportional size distribution of preferred-length fish (PSD-P) for Smallmouth Bass and Walleye (Gabelhouse 1984; Guy et al. 2006; Guy et al. 2007) sampled during biological evaluation using the equation:

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

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). Anderson (1980) and Gabelhouse (1984) define stock, quality, and preferred minimum length categories for Smallmouth Bass as 180, 280, and 350 mm total length (TL), respectively. This stock-length is smaller than our target size (200 mm FL) for Smallmouth Bass. To remove any bias in our data from variation in sampling procedures that affect the lower observed FL of Smallmouth Bass among years, we chose to use our target size (FL > 199 mm) as minimum stock-length for PSD and PSD-P analyses of those fish. Because we only measure FL, quality and preferred minimum values were converted from TL to FL using species-specific models ($FL_{SMB} = TL_{SMB}/1.040$). Thus, stock, quality, and preferred minimum FL categories for Smallmouth Bass were 200, 269, and 337 mm, respectively. Similarly, previously defined categories for Walleye are: stock 250, quality 380, and preferred 510 mm TL (Anderson 1980; Gabelhouse 1984). These values were also converted to FL values of stock 236, quality 358, and preferred 481 mm using the species-specific model for Walleye ($FL_{WAL} = TL_{WAL}/1.060$). Annual PSD and PSD-P values were calculated only when sample sizes exceeded 19 stock-length fish in an area. To characterize uncertainty surrounding PSD and PSD-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) to calculate 95% confidence intervals.

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 2017 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 W_r 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 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 between sexes when calculating W_r for these species. For these calculations, we only used fishes that met minimum target sizes (250 mm FL for Northern Pikeminnow and 200 mm FL for Smallmouth Bass and Walleye). As for PSD and PSD-P, we estimated 95% confidence intervals for median W_r values using a non-parametric bootstrap approach (Fox and Weisberg 2011; R Core Team 2013).

Temporal monotonic trends in PSD and median W_r for Northern Pikeminnow, Smallmouth Bass, and Walleye were assessed by applying a non-parametric Mann-Kendall test (Mann 1945). Similarly, PSD-P was also analyzed with this method for Smallmouth Bass and Walleye. To diagnose potential serial dependence among these 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. All tests were considered significant at $\alpha < 0.05$.

RESULTS

Sport Reward Fishery Evaluation and Predation Reduction Estimates

We tagged and released 1,413 Northern Pikeminnow greater than or equal to 200 mm FL throughout the lower Columbia and Snake rivers during 2017, of which 1,027 were known to be greater than or equal to 250 mm FL (Table 1). Four fish were tagged without recording length (one Below Bonneville Dam, two in Bonneville Reservoir, and one in McNary Reservoir) and thus were not incorporated in calculations of size-specific rates of exploitation. For Northern Pikeminnow that were tagged in 2017, Sport Reward Fishery anglers recaptured 172 during the season; two fish were recaptured in the Dam Angling Fishery. Twenty fish tagged in McNary Reservoir were recaptured within the same week they were tagged and therefore not included in our calculations of exploitation to avoid violating mark recapture assumptions (i.e., incomplete mixing). Fish tagged in 2017 and subsequently recaptured in the Sport Reward Fishery were at large from 5–166 d (mean = 60 d; SE = 3). Sport Reward Fishery recaptures greater than or equal to 250 mm FL accounted for 84% of all 2017 tag recoveries, while the median length of the systemwide Sport Reward Fishery catch was 267 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 15.0% and above average for the last 17 years (12.7%) (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, John Day, and Lower Granite pools. Tagged fish were released in Ice Harbor reservoir for the first time since 1992 and tag returns were sufficient to calculate exploitation at 5.7%. For areas where rates could be calculated, values varied from 5.7–20.3%. For Northern Pikeminnow within the 200–249 mm FL size class, system-wide exploitation was estimated to be 8.7% (Table 3). Fewer than half of the areas where tagging occurred received enough recaptures in the 200–249 mm size class to calculate exploitation. Area-specific rates of exploitation for Bonneville, McNary, and Little Goose reservoirs were 10.4, 7.3, and 10.6%, respectively. The 2017 system-wide exploitation rate for Northern Pikeminnow greater than or equal to 250 mm FL exceeded those of the other size classes at 17.4% (confidence interval 10.8–24.0%) and was above the program average (13.7%; Figure 2). Area-specific exploitation rates of those fish greater than or equal to 250 mm FL were 16.3% for the Columbia River below Bonneville Dam, 14.8% for Bonneville Reservoir, 28.1% for McNary Reservoir, and 8.4% for Ice Harbor 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 2017 was 30% (range: 16–47%) and for 2018 will be 32% (range: 17–49%; 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 and gradually decrease through 2021.

From data collected during fishery evaluation (i.e. tagging activities), we were able to calculate PSD for Northern Pikeminnow for 2017 and across our time series (Table 5). The area below Bonneville Dam and McNary Reservoir had higher PSD values for 2017 than the other reservoirs.

When looking over the time series, Northern Pikeminnow PSD appears to decrease, increase, and then decrease again for the majority of the reaches (Figure 4). Data are collected annually but annual sample sizes of Northern Pikeminnow ≥ 250 mm FL in John Day Reservoir were often too low to calculate PSD for prior years. Significant monotonic decreases in PSD were observed in The Dalles (Mann-Kendall $\tau = -0.46$, $P < 0.01$), John Day (Mann-Kendall $\tau = -0.71$, $P = 0.04$), McNary (Mann-Kendall $\tau = -0.31$, $P = 0.03$), and Lower Granite reservoirs (Mann-Kendall $\tau = -0.40$, $P < 0.01$).

A quasi *t*-test showed that mean FL of Northern Pikeminnow captured in the 2017 Sport Reward Fishery in Bonneville Reservoir (mean = 291 mm; SE = 0.4) was significantly less than that of fish captured in the Dam Angling Fishery at The Dalles Dam (mean = 332 mm; SE = 1.3; $t = -35.13$, df = 24,590, $P < 0.01$). Similarly, a quasi *t*-test showed that mean FL of Northern Pikeminnow captured in the Sport Reward Fishery in The Dalles Reservoir (mean = 341; SE = 0.7) was also significantly smaller than that of fish captured in the Dam Angling Fishery at John Day Dam, the upstream terminus of The Dalles Reservoir (mean = 362 mm; SE = 1.0; $t = -18.25$, df = 10,722, $P < 0.01$). The same pattern found in the FL comparison between fish caught in the Sport Reward and Dam Angling fisheries was repeated when comparing PSD. In Bonneville Reservoir, Sport Reward Fishery PSD was 9% compared to 15% from the Dam Angling Fishery. The Dalles Reservoir PSD for Sport Reward Fish was 23%, compared to 31% from fish collected from the Dam Angling Fishery.

The distribution of fork lengths for Walleye collected during Northern Pikeminnow tagging operations, suggests successful reproduction occurred in the three years before 2017 (Figure 5), given that 3 year old fish are typically less than 500 mm FL. Upstream of Bonneville Reservoir, size distribution is similar across reservoirs in the Columbia River, with varying levels of proportion at size (because of opportunistic collections, abundance, or both). Size distribution in Ice Harbor suggests successful year classes of reproduction also within the previous three years. In Little Goose Reservoir, few Walleye have been observed during past index sampling events, as well as 2017 opportunistic sampling. The three encounters sized 320, 465, and 475 mm FL provide insufficient evidence to inform whether Walleye move upstream from the Columbia River into upper Snake River reservoirs or whether reproduction occurs within them.

Through our opportunistic sampling of Walleye during 2017 Northern Pikeminnow tagging operations, we were able to calculate PSD and PSD-P values for five of the seven areas sampled (Table 6). Bonneville Reservoir had the highest PSD at 79% and PSD-P was the lowest at 2%. McNary Reservoir PSD was the second highest at 66% and had the highest PSD-P at 32%. Estimates of PSD in Bonneville and McNary reservoirs are greater than values suggested for balanced populations (PSD 30–60%; Anderson and Weithman 1978). John Day Reservoir had the lowest PSD and PSD-P was also low (10%). A decrease in PSD in John Day Reservoir from 2012 to 2017 shows the distribution of sizes within the population has become skewed towards smaller fish (236–357 mm FL). This could be the result of increased recruitment to the population from strong year classes, changes in annual growth of individuals, mortality of larger individuals, or combinations of those influences. In our time series for John Day Reservoir, PSD is much lower than observations during 2011 and 2012. We did not collect samples between 2012 and 2017. (Figure 6). When looking at developments across the time series, both John Day (Mann-Kendall $\tau = -0.50$, $P < 0.01$) and McNary reservoirs (Mann-Kendall $\tau = -0.50$, $P = 0.03$) had significant decreasing trends. In The Dalles Reservoir, there is a decreasing trend though it was not significantly monotonic (Mann-Kendall τ = -0.45, P = 0.09). When looking at changes to the preferred size category of Walleye, the same pattern was observed. While The Dalles Reservoir had a non-significant decreasing trend in PSD-P (Mann-Kendall τ = -0.31, P = 0.21), both trends from John Day (Mann-Kendall τ = -0.52, P < 0.01) and McNary reservoirs (Mann-Kendall τ = -0.45, P = 0.04) were significantly decreasing (Figure 7).

Biological Evaluation

We conducted 353 electrofishing runs during 2017 in four areas below Bonneville Dam and the forebay, mid-reservoir, and tailrace sampling areas of Bonneville Reservoir to collect fish for biological evaluation (Table 7). In prior years, sampling was conducted in boat-restricted zones of the forebay and tailraces of many of the areas 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 the tailrace boat-restricted zone of The Dalles Dam (in Bonneville Reservoir) in recent years. Because of this, none of these data 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 Bonneville Dam (Figure 8). During summer sampling scheduled 3–7 July 2017, water temperatures below Bonneville Dam tailrace exceeded the upper threshold prescribed by federal guidelines (i.e., 18°C; NMFS 2000) to conduct electrofishing for anadromous salmonids and accordingly, no data were collected.

Across all sample sites, spring 2017 mean CPUE ranged from 0.00 to 1.20 fish/900 s for Northern Pikeminnow, 0.00 to 4.66 fish/900 s for Smallmouth Bass, and 0.00 to 0.25 fish/900 s for Walleye (Table 8). Across the sites we were able to sample during the summer of 2017, mean CPUE ranged from 0.00 to 1.69 fish/900 s for Northern Pikeminnow, 1.95 to 7.67 fish/900 s for Smallmouth Bass, and 0.00 to 0.36 fish/900 s for Walleye. The highest catch rates of Northern Pikeminnow were observed below Bonneville Dam in both seasons. Smallmouth Bass were caught at the highest rate of any target species of any area or season with the exception of rkm 116–121 and the tailrace below Bonneville Dam during spring when Northern Pikeminnow were frequently caught. Walleye were inconsistently encountered during biological evaluation and catches only occurred in the tailrace below Bonneville Dam and in Bonneville mid-reservoir and tailrace areas.

Spring abundance index values calculated for Northern Pikeminnow (≥250 mm FL) in 2017 ranged from 0.00 to 0.94 fish/900 s/ha/1,000 below Bonneville and 0.00 to 0.47 fish/900 s/ha/1,000 in Bonneville Reservoir (Table 9). The highest abundance of Northern Pikeminnow occurred in the tailrace below Bonneville Dam in the summer at 2.13 fish/900 s/ha/1,000. When compared to the mean values for each season over the time series, 2017 values were below the mean in almost all areas.

Across all areas sampled during the spring and summer of 2017, Smallmouth Bass abundance index values were greatest in the summer (Table 10). For some areas, abundance index values calculated for 2017 were the highest observed since 1991 (spring Bonneville mid-reservoir, summer tailrace below Bonneville Dam, Bonneville forebay, Bonneville mid-reservoir, and Bonneville tailrace). However, over half of the abundance index values for all the sampling areas below Bonneville Dam and in Bonneville Reservoir were less than the mean of the respective estimates since 1990. The abundance index values of Smallmouth Bass in most of the sampling areas during summer have generally increased over time.

The greatest abundance index observed of Walleye was in the tailrace below Bonneville Dam during summer, which is similar to abundance indices from 1994 and 1995 in that area (Table 11). Area-specific abundance index estimates for Walleye are highly variable due to the inconsistent rate of encounter in 2017. This inconsistency makes interpretation of trends over time difficult in the lower reaches of the Columbia River.

We examined contents from the digestive tracts Northern Pikeminnow captured below Bonneville Dam (n = 124) and in Bonneville Reservoir (n = 134) to characterize consumption (Table 12). Across areas, 30 Northern Pikeminnow gut content samples examined did not contain food items. Fish were the second most frequent diet item ($\hat{p}$ = 0.33) after vegetation in the examined samples in the spring. During summer, crayfish, crustacea, and insects/other invertebrates were more frequently encountered than fish ($\hat{p}$ = 0.16) in Northern Pikeminnow diets. Salmonid fishes were encountered more frequently in Northern Pikeminnow diets of fish captured below Bonneville Dam ($\hat{p}$ = 0.19) and unidentified fishes were most frequent in fish captured in Bonneville Reservoir ($\hat{p}$ = 0.12; Table 13).

From the 2017 biological evaluation, we examined diet samples from Smallmouth Bass captured below Bonneville Dam (n = 89) and in Bonneville Reservoir (n = 687). Large proportions of the diets contained prey items (spring $\hat{p}$ = 0.94; summer $\hat{p}$ = 0.97) across reservoirs and seasons (Table 12). In both seasons, fish were the fourth most frequently encountered diet item behind vegetation, crayfish, and crustaceans (spring $\hat{p}$ = 0.31; summer $\hat{p}$ = 0.26). Salmonids were identified in 0.06 and 0.03 of the proportion of diet of samples taken for spring and summer evaluations, respectively. Across both seasons, diets of Smallmouth Bass captured below Bonneville Dam included salmonids ($\hat{p}$ = 0.12) more often than diets of fish captured in Bonneville Reservoir ($\hat{p}$= 0.03). Sculpins (Cottidae) were the greatest represented taxon in Smallmouth Bass diets below Bonneville Dam ($\hat{p}$ = 0.28) and the unidentified fish category was observed more frequently among the fish taxa in Bonneville Reservoir ($\hat{p}$ = 0.10; Table 13).

We collected 30 Walleye diet samples from below Bonneville Dam and Bonneville Reservoir. All Walleye diet samples contained prey items ($\hat{p}$ = 1.00; Table 12). From both areas combined, fish material was found in proportions of 0.86 in spring and 0.88 in summer. Proportions of all diet samples containing salmonids were 0.58 below Bonneville Dam (n = 12) and 0.61 in Bonneville Reservoir (n = 18; Table 13). In Walleye diet samples below Bonneville Dam, unidentified fishes were encountered as frequently as salmonids ($\hat{p}$ = 0.58). Unidentified fishes ($\hat{p}$ = 0.17) and minnows (Cyprinidae; $\hat{p}$ = 0.11) were also frequently encountered in samples collected in Bonneville Reservoir. One Walleye diet sampled in the spring in Bonneville Reservoir contained a PIT tag belonging to a wild Chinook Salmon originally tagged in the lower Snake River.

Seasonal area-specific consumption indices for Northern Pikeminnow did not follow a consistent pattern. However spring consumption indices were generally among the highest on record (Table 14). Consumption index values increased for all areas evaluated below Bonneville Dam and in Bonneville Reservoir tailrace in the spring and Bonneville forebay in the summer. One third of the seasonal area-specific estimates were not calculated due to low sample sizes (fewer than six fish per area). Similarly, predation indices for Northern Pikeminnow were inconsistent (Table 15).

In spring 2017, Bonneville Reservoir tailrace and rkm 116–121 below Bonneville Dam predation indices were there highest since we began sampling there in the early 1990s. We were unable to calculate 2017 values in either season due to low sample sizes of fish and number of sampling runs. Predation has historically been highest in the tailrace and forebay BRZ of Bonneville Dam

Unlike 2014, we collected sufficient information to calculate consumption indices for Smallmouth Bass in the majority of areas sampled in 2017 (Table 16). Spring values ranged from 0.01 to 0.19 and 0.02 to 0.35 during summer. With the exception of Bonneville Reservoir forebay in the summer, all 2017 calculated values were at or above the seasonal area-specific mean. Results were relatively consistent with values from recent sampling years with the exception of rkm 188–194 below Bonneville Dam, with a nearly fivefold increase over 2008. Consumption index was greater below Bonneville Dam than in Bonneville Reservoir for both seasons. The greatest Smallmouth Bass predation index was 2.20 during summer in the tailrace BRZ below Bonneville Dam (Table 17). The7 tailrace area below Bonneville Dam during summer had the second highest predation rate observed over the course of the study in the lower Columbia River. With the exception of Bonneville Reservoir tailrace, all predation index values were at or above the area-season specific mean for the time series.

Northern Pikeminnow PSD below Bonneville Dam was 52%, compared to 20% in Bonneville Reservoir (Table 18). These values are slightly above average for below Bonneville Dam (mean = 49%; SE = 3) and below average for Bonneville Reservoir (mean = 35%; SE 4) for our time series. Results from analyses of the trends revealed no significant monotonic trends for either reservoir (below Bonneville Mann-Kendall τ = 0.25, P = 0.23; Bonneville Reservoir Mann-Kendall τ = -0.44, P = 0.05; Figure 9). Though not significant, PSD below Bonneville Dam appears to be increasing over time and decreasing in Bonneville Reservoir.

Smallmouth Bass PSD decreased below Bonneville Dam (32%) and remained relatively the same in Bonneville Reservoir (57%; Table 19) as recent years. Opposite to the results of Northern Pikeminnow PSD, Smallmouth Bass PSD was below average below Bonneville Dam (mean = 44%; SE 3) and above average in Bonneville Reservoir (mean = 52%; SE 2). With respect to trends over time, neither area indicated significant monotonic increase or decrease (below Bonneville Mann-Kendall τ = -0.05, P = 0.81; Bonneville Reservoir Mann-Kendall τ = 0.25, P = 0.12), though data were autocorrelated for both (Figure 10). Below Bonneville Dam, 2017 PSD-P (11%) increased greatly compared to 2011 (5%; Figure 11). This is in contrast to the 2017 decrease in PSD-P (15%) observed in Bonneville Reservoir from 2014 (22%). No monotonic trends over time were observed in PSD-P below Bonneville Dam (Mann-Kendall τ = -0.42, P = 0.09) or in Bonneville Reservoir (Mann-Kendall τ = 0.24, P = 0.17).

No PSD or PSD-P values were calculated in 2017 in any area for Walleye due to sample size constraints ($n \leq 19$; Table 20). Below Bonneville Dam, 11 of the 12 stock-size Walleye were quality-length and seven were preferred-length. Eight of 10 stock-size Walleye captured in Bonneville Reservoir were quality-length and only one Walleye was preferred-length.

Median W_r for male Northern Pikeminnow below Bonneville Dam (101%) was similar to recent years (Figure 12). Analyses of the trends over time show an increasing monotonic trend for males below Bonneville Dam (Mann-Kendall τ = 0.52, P = 0.01). Median W_r of female Northern Pikeminnow slightly declined during recent years to 106% and no significant W_r trend was evident

(Mann-Kendall $\tau = 0.39$, $P = 0.06$). In Bonneville Reservoir, male median W_r (99%) was relatively similar to values for female W_r (103%; Figure 13). Both male and female W_r appear to exhibit increasing trends although not statistically significant (female Mann-Kendall $\tau = 0.33$, $P = 0.13$; male Mann-Kendall $\tau = 0.36$, $P = 0.10$).

The 2017 median W_r value for Smallmouth Bass collected below Bonneville Dam (105%) was higher than in Bonneville Reservoir (93%; Figure 14). Annual median W_r values below Bonneville Dam have varied over time but do not show statistically significant increasing or decreasing trends thoughout the time series (Mann-Kendall $\tau = -0.03$, $P = 0.86$). However, values over the last three sampling events have increased. Smallmouth Bass median W_r in Bonneville Reservoir has been consistent overtime and shows no significant monotonic trend (Mann-Kendall $\tau = 0.03$, $P = 0.86$).

Median W_r of Walleye was relatively similar below Bonneville Dam (91%) and in Bonneville Reservoir (85%) within overlapping confidence intervals (Figure 15). Both areas display a decreasing monotonic trend of condition factor that is not statistically significant.

Although relatively few walleye (30) were caught during biological evaluation, we observed individuals from age 1 through 7 across a FL interval of 200–692 mm below Bonneville Dam and in Bonneville Reservoir, suggesting successful recruitment occurred annually during 2011–2016 (Figure 16). This assumes successful reproduction occurred in each area, rather than individuals passing Bonneville Dam from one area to another. We do not know whether the absence of age-4 and age-5 Walleye below Bonneville Dam indicates low year class reproduction during 2012 and 2013 because few fish were captured ($n = 12$). Sizes of the observed age of the 18 Walleye in Bonneville Reservoir coincide with the length distribution observed during fishery evaluation.

In 2017, we collected 1,195 Northern Pikeminnow digestive tracts from fish harvested in the Dam Angling Fishery from the angler accessible areas in the powerhouse tailraces of The Dalles and John Day dams. These fish ranged in size from 245–556 mm FL in Bonneville Reservoir (mean = 330 mm; SE 2.1) and from 255–541 mm FL in The Dalles reservoir (mean = 354 mm; SE 2.3). Of these, a sub-sample of 748 digestive tracts were examined for dietary analyses. In both reservoirs, large proportions of the digestive tracts of Northern Pikeminnow examined contained food (Bonneville $\hat{p} = 0.76$; The Dalles $\hat{p} = 0.61$; Table 21). Other invertebrates were observed in larger proportions of diet samples in The Dalles Reservoir than all of the other prey types including fish. We observed visually a large proportion of the "Other Invertebrates" weight category consisted of amphipods, although we did not weigh them separately from the other invertebrates (i.e., insects, and mollusks). Fish were the most abundant diet item in Bonneville Reservoir ($\hat{p} = 0.53$) and second most abundant in The Dalles Reservoir ($\hat{p} = 0.30$. The proportion of lamprey found in 2017 Dam Angling gut samples (Bonneville $\hat{p} = 0.18$; The Dalles $\hat{p} = 0.07$), while greater than 2016, were less than previous samples from multiple years. Juvenile lamprey were encountered in the greatest proportion of Northern Pikeminnow diet samples during May ($\hat{p} = 0.36$) and June ($\hat{p} = 0.20$) followed by salmon and steelhead (May $\hat{p} = 0.11$; June $\hat{p} = 0.12$; Table 22). Juvenile salmon and steelhead were observed at their peak during July ($\hat{p} = 0.20$) and infrequently during August ($\hat{p} = 0.03$). American Shad were encountered at relatively low rates until August when it was the most frequent taxon observed in diet samples ($\hat{p} = 0.52$). 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 3 July (statistical week

28) and coincided with peak subyearling Chinook Salmon passage rates (Figure 17). Consumption remained high throughout July, statistical week 31, even though the rate of smolt passage at John Day Dam had decreased.

Although statistical significance of trends in PSD values calculated based on the FL 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 2006–2017; Figure 18). Results determined monotonic decreasing trends in both reservoirs were significant (Bonneville Mann-Kendall $\tau = -0.63$, $P < 0.001$; The Dalles Mann-Kendall $\tau = -0.57$, $P < 0.01$). Estimates for Northern Pikeminnow PSD in Bonneville Reservoir (i.e., The Dalles Dam) from 1990 to 1992 ranged between 75 and 82%. During that same period, estimates for PSD in The Dalles Reservoir (i.e., John Day Dam) were more variable from 42 to 77%. Since 2006, PSD estimates for both reservoirs have steadily declined, to levels of 15% in Bonneville and 26% in The Dalles reservoirs in 2017.

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 2017 estimate of the system-wide exploitation rate is 17.4% (confidence interval 10.8–24.0%; Figure 2) for Northern Pikeminnow greater than or equal to 250 mm FL and is higher than the average exploitation rate during the previous 10 years (15.2%; SE 0.9). This is toward the upper end of the target exploitation range of 10–20%, which is predicted to reduce predation on juvenile salmon up to 50% from predation prior to Northern Pikeminnow removal efforts (Rieman and Beamesderfer 1990). The variable nature of the exploitation estimate throughout the time series lends some support to the argument that continued evaluation of the sport reward program is necessary not only to evaluate the efficacy of the program to reduce predation of juvenile salmon, but also to ensure the population viability of a native species.

Area-specific exploitation rates were derived for half of the sampled reservoirs and areas in 2017. Recent increases in Sport Reward Fishery harvest in Ice Harbor Reservoir (E. C. Winther, WDFW, personal communication) prompted the need to more closely monitor exploitation in that area. Therefore, we tagged Northern Pikeminnow for the first time since 1992 in Ice Harbor Reservoir and were able to calculate an exploitation of 8.4%, though the 95% confidence interval was large (0.0–18.0%). Low tagging rates coupled with insufficient tag recoveries have precluded calculation of Northern Pikeminnow (≥ 250 mm FL) exploitation rates in The Dalles and John Day reservoirs for the last several years while estimates of exploitation for Little Goose and Lower Granite could only be calculated intermittently. 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. However, in 2017 there were more than double the amount of Northern Pikeminnow tagged in The Dalles Reservoir than John Day Reservoir, but the two reservoirs had the same small number of tag returns from the Sport Reward Fishery and neither produced an estimate of exploitation. There may be alternative analyses, such as maximum likelihood approaches, to estimate exploitation in areas or during periods otherwise excluded from analyses due to sample size constraints which we hope to explore 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 reasons precluding estimation of exploitation rates in certain areas or during specific periods, administrative changes to provide incentive to return external tag-loss fish (which still retain internal PIT tags) continue to help increase accuracy of estimates of exploitation rates. PIT-tagged Northern Pikeminnow have remained at large for up to 11 years before being caught in the Sport Reward Fishery. For the 2017 season, the greatest time at large was 1,858 days (> 5 years; fish originally tagged in 2012). 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. 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 (8 in 2017). 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 tags at 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 salmonid predation is dependent on the ability of the Sport Reward Fishery to restructure the population during both the current and previous years. Following the 2017 Sport Reward Fishery season, the model indicates that 2018 predation is about 32% below predation levels prior to implementation of the Sport Reward Fishery and will increase slightly during 2019 to 33% (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 Tinus et al. (2015) reported previously, sensitivity analyses appear to indicate area-specific exploitation downstream of Bonneville Dam may disproportionately influence predation reduction. This is presumably due to high densities of juvenile salmon and steelhead in that area and a related increased 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. Additionally, simulations by Rieman and Beamesderfer (1990) suggested that exploitation can lead to a large "stockpile" of Northern Pikeminnow below the target size and termination of exploitation would lead to a large population increase of predatory fish.

The 2017 Dam Angling Fishery accounted for 2.7% of the total system-wide Northern Pikeminnow harvest. 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 2.8% and 28.2%, respectively (WDFW unpublished data; Ruthanna Shirley, WDFW, personal communication). 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 2017 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, the Dam Angling Fishery harvests 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 they are harvesting a unique subset of the overall Northern Pikeminnow population that the sport anglers cannot harvest. Samples of the Dam Angling Fishery catch provide annual insight to Northern Pikeminnow predatory behavior whereas the indexing samples are collected every three years. In The Dalles Reservoir, consumption of salmonids by dam angled fish appears to have decreased over recent years as reflected in a decreasing proportion of their diet. In contrast, there appears a slight increase in the annual proportion of salmon in diet of dam angled fish from Bonneville Reservoir. Additionally, we have noticed a large decrease in lamprey consumption since 2014–2015 across both reservoirs. For these reasons, we support continued angling from the dams accompanied by concurrent monitoring of diet during future dam angling activities.

The removal of larger individuals from Northern Pikeminnow populations will 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 2017 in all areas of the lower Columbia River were relatively low compared to the mean of the time series, though we have not historically caught many Northern Pikeminnow in some of these areas (Table 9). Estimates of PSD below Bonneville Dam appeared to decrease 1990–1996 and has begun increasing (2004–2017) to initial levels (Figure 9). Alternatively in Bonneville Reservoir, PSD estimates have generally decreased over time with some oscillation (2005–2008). The same patterns in these reservoirs were observed when we analyzed FL of fish caught during fishery evaluation. From the same data set, however, we and found significant decreases of PSD in The Dalles, John Day, McNary, and Lower Granite reservoirs (Figure 4). This may provide some evidence that culling populations of Northern Pikeminnow in these areas are effective in changing the size distribution of the population in these reservoirs. Biological evaluation in 2018 will occur in The Dalles and John Day reservoirs and may elucidate the trend observed with Northern Pikeminnow PSD during fishery evaluation.

Analyses to elucidate temporal patterns for Northern Pikeminnow median W_r data showed all sexes and areas with increasing trends, but only a significant increase for males below Bonneville Dam and (Figure 12-13). Tinus et al. (2015) also found median *Wr* to have a significant increasing trend for males in Bonneville Reservoir, but it was not significant when 2017 data were added. The recent increases in condition factor for Northern Pikeminnow do not necessarily indicate the trend is related to the sustained removal of Northern Pikeminnow. It could indicate successful sustained beneficial environmental conditions for growth. We did not notice increases in abundance index estimates or significant trends in PSD sampled during biological evaluation in any area sampled in 2017. Whether these results are indicative of an intra-specific compensatory mechanism is unclear. However, the possibility of differential responses to sustained removal exists not only in space (i.e., reservoir/area-specific), but also demographically and among species.

In contrast, we documented some large increases in abundance index values for Smallmouth Bass in select areas of the lower Columbia River in 2017 (Table 10). Large increases were sometimes seasonal (summer Bonneville tailrace and below Bonneville Dam tailrace), while others such as Bonneville Dam forebay 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. In 2017, we caught the highest number of stock-length Smallmouth Bass documented for Bonneville Reservoir since monitoring began in 1990 though PSD and PSD-P oscillates around similar values throughout the time series (Table 19). Since our last evaluation of these areas, we altered our method of analysis for PSD for Smallmouth Bass where we modified our minimum stock-length size to line up with our minimum target size for biological evaluation (200 mm FL). Using the new method, values of PSD appear to track values from our old method that appeared in previous reports though the newer method reduces sample sizes. Additionally, values are likely more representative of the populations sampled and sampling methods are more consistent over time. Finally, median W_r values for Smallmouth Bass did not exhibit any significant increasing or decreasing trends for any of the areas sampled as annual median *Wr* values were variable or relatively unchanging.

The abundance of Walleye evaluated during 2017 was generally low as we only encountered 30 individual fish during biological evaluation. Despite the small sample size, Walleye had the greatest proportion of salmonids in their diets compared to Northern Pikeminnow and Smallmouth Bass (Table 13). Our crew administering tags to Northern Pikeminnow opportunistically measured and weighed Walleye which greatly outnumbered what was encountered during biological evaluation in Bonneville Reservoir. Additionally, this sampling observed more Walleye in 2017 than our biological evaluation of Ice Harbor, Lower Monumental, Little Goose reservoirs, and upriver of Lower Granite Dam in 2016 (Carpenter et al. 2017). Walleye were first observed during our project field work in Lower Monumental Reservoir in 1999 (Zimmerman et al. 1999).

From these data, PSD and length frequency information (Table 6; Figures 5–7) show evidence of a strong population recruitment that likely occurred in 2015 that are now being recruited to the fishery. A creel survey through 10 September 2017 estimated that 99,776 Walleye were harvested, with an additional 28,283 fish released, during the course of 28,674 angler trips in Bonneville, The Dalles, and John Day reservoirs (Peter Stevens, ODFW, personal communication). Though Walleye were opportunistically sampled, the number of Walleye sampled was the largest we have recorded since 1990, and though this is not a measure of abundance, it does indicate strong year classes in recent years, which was also evidenced by our ageing analyses from fish sampled during biological evaluation (Figure 16). In light of the apparent variability in predatory potential of Walleye on juvenile salmon and booms in population, further monitoring of demographic characteristics, diets, and spatial distribution is necessary to detect changes in impacts to juvenile salmon and assess long-term trends with greater precision.

In 2017, the presence of salmonids in diet samples was higher below Bonneville Dam than in Bonneville Reservoir for Northern Pikeminnow (19%) and Smallmouth Bass (12%), though Walleye consumption was much higher in both reservoirs (58% below Bonneville Dam; 61% in Bonneville Reservoir). Regardless of season, salmonid fishes were the first or second most abundant family for Northern Pikeminnow and Walleye in both areas sampled. Smallmouth Bass diets most frequently contained Cottidae fishes and unidentified fish. Tinus et al. (2015) found that predation index estimates for Northern Pikeminnow in 2014 were highly variable in the spring but much lower than the earliest years of the Program. Summer values could not be calculated due to low sample sizes. In 2017, our greatest predation values for Northern Pikeminnow and Smallmouth Bass occurred below Bonneville Dam and though they are in different seasons, neither sampling event coincided with peak smolt outmigration (Figure 8). Spring sampling in Bonneville Reservoir coincided with outmigration and we did observe a larger predation index at the tailrace for Northern Pikeminnow, but values remained relatively low for other areas in the reservoir and Smallmouth Bass.

Vigg et al (1991) found temperature to be the most influential variable regulating consumption rates. This emphasizes the need for continued monitoring, especially since water temperatures have been higher than average and increased earlier than average in recent years. Continuing warming of the global climate can influence predator-prey dynamics within aquatic habitat as noted by the Independent Scientific Advisory Board (ISAB 2007). Current comparisons in this report are at times constrained by the present scope of annual evaluations of the NPMP, 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 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. With this in mind, we reviewed the 2017 data and determined that a liberal estimate of 79% of biological evaluation samples and 62% of dam angling samples containing salmonids could potentially be identifiable to species based on diagnostic bones present in the samples, though the actual number would likely be lower.

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, which we rely on to evaluate dynamics within and among predator populations. Guidelines surrounding temperature maxima can limit our ability during summer months, to sample waters inhabited and utilized by U.S. Endangered Species Act-listed juvenile salmonids. Similar to previous years, elevated water temperatures during 2017 prevented us from electrofishing in some areas during the summer biological evaluation season. Additionally, inter-annual fluctuations in water levels can influence available shoreline habitat in which to sample. Spring biological evaluation sampling in 2017 occurred during very high water, which flooded areas that are not consistently available as habitat for fishes. This may have limited preferred resources and habitats for prey to deeper water. 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. Further, inter- and intra-specific changes affecting 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.

Given these constraints, data collected during 2017 did not provided an unambiguous indication of the presence of a compensatory response from the piscivorous fish community. 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). Long-term monitoring programs 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 2017 by location and size class.

	200–249 mm FL		≥ 250 mm FL		Combined	
Reach/Reservoir	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recaptured
Below Bonneville	38	3	252	41	291[b]	44
Bonneville	101	10	341	47	444[b]	57
The Dalles	31	0	70	3	101	3
John Day	27	1	23	1	50	2
McNary	106	7[a]	240	44[a]	347[b]	51[a]
Ice Harbor	23	0	49	4	72	4
Little Goose	49	5	13	3	62	8
Lower Granite	7	1	39	2	46	3
Combined	382	24	1,027	128	1,413	172

Note: [a]Twenty fish recaptured in McNary Reservoir were recaptured the same week in which they were tagged, and therefore not included in this table or in calculations of exploitation to avoid violating mark-recapture assumptions (i.e., incomplete mixing). [b]FL for four tagged Northern Pikeminnow were not recorded (one below Bonneville Dam, two in Bonneville Reservoir, and one in McNary Reservoir). Thus, these fish were 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. Mean and SE were calculated for each location across the time series.

Year	Below Bonneville	Bonneville	The Dalles	John Day	McNary	Ice Harbor	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
2017	15.1	13.8	*a*	*a*	20.3	5.7	13.6	*a*	15.0
mean (SE)	14.1 (1.0)	10.1 (0.6)	14.2 (3.5)	*b*	11.2 (1.4)	*b*	14.1 (3.0)	14.5 (5.1)	12.7 (0.7)

Note: *a* = no exploitation calculated ($n \leq 3$), dashes (—) = no sampling conducted, *b* = no mean exploitation calculated ($n \leq 2$). 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. Mean SE were calculated for each location across the time series.

Year	Below Bonneville	Bonneville	The Dalles	John Day	McNary	Ice Harbor	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
2017	*a*	10.4	*a*	*a*	7.3	*a*	10.6	*a*	8.7
mean (SE)	7.1 (1.7)	7.5 (1.2)	*b*	*b*	7.1 (1.3)	*b*	9.0 (2.0)	4.9 (2.9)	6.8 (0.7)

Note: *a* = no exploitation calculated ($n \leq 3$), dashes (—) = no sampling conducted, *b* = no mean exploitation calculated ($n \leq 2$). 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. Mean and SE were calculated for each location across the time series.

Year	Below Bonneville	Bonneville	The Dalles	John Day	McNary	Ice Harbor	Little Goose	Lower Granite	All areas
1991	7.6	10.9	23.6	2.8	5.3	6.9	2.4	20.0	8.5
1992	11.4	4.0	6.2	3.4	5.6	*a*	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
2017	16.3	14.8	*a*	*a*	28.1	8.4	*a*	*a*	17.4
mean (SE)	13.8 (0.9)	9.9 (0.8)	14.2 (1.8)	3.1 (0.2)	14.7 (1.4)	*b*	13.4 (3.2)	13.5 (1.2)	13.7 (0.7)

Note: *a* = no exploitation calculated ($n \leq 3$), dashes (—) = no sampling conducted, *b* = no mean exploitation calculated ($n \leq 2$).

Table 5. Number of stock-length (n_s) Northern Pikeminnow collected by boat electrofishing and proportional size distribution (PSD, %) as part of fishery evaluation by location. Mean and SE were calculated for each location across the time series.

	Below Bonneville		Bonneville		The Dalles		John Day		McNary		Ice Harbor		Little Goose		Lower Granite	
Year	n_s	PSD	n_s	PSD	n_s	PSD	n_s	PSD	n_s	PSD	n_s	PSD	n_s	PSD	n_s	PSD
1991	0	*a*	240	63	0	*a*	3	*a*	0	*a*	2	*a*	10	*a*	8	*a*
1992	779	39	408	50	122	58	264	65	86	56	4	*a*	490	29	108	13
1993	423	37	45	49	47	70	75	61	190	51	—	—	37	27	87	51
1994	369	34	70	74	53	43	96	85	197	75	—	—	61	46	0	*a*
1995	109	41	34	6	15	*a*	2	*a*	50	64	—	—	0	*a*	3	*a*
1996	247	32	57	35	19	*a*	9	*a*	20	65	—	—	10	*a*	39	21
1997	308	18	115	23	78	36	44	23	109	55	—	—	18	*a*	47	36
1998	248	27	108	27	43	23	14	*a*	296	61	—	—	18	*a*	94	35
1999	156	26	64	23	25	12	19	*a*	132	61	—	—	17	*a*	85	31
2000	363	29	138	25	26	31	6	*a*	180	57	—	—	9	*a*	41	20
2001	374	49	82	30	19	*a*	3	*a*	136	53	—	—	—	—	29	21
2002	532	34	27	48	24	21	15	*a*	88	70	—	—	—	—	98	9
2003	516	42	50	54	12	*a*	16	*a*	117	76	—	—	—	—	40	20
2004	262	54	48	40	10	*a*	5	*a*	62	60	—	—	—	—	28	11
2005	361	47	179	21	25	48	14	*a*	96	41	—	—	—	—	33	15
2006	397	38	277	19	45	36	24	42	100	73	—	—	37	3	20	10
2007	193	65	95	44	27	56	13	*a*	106	77	—	—	3	*a*	40	38
2008	267	54	77	47	26	31	18	*a*	187	75	—	—	30	13	47	19
2009	718	24	104	65	28	54	11	*a*	172	64	—	—	41	17	49	20
2010	446	41	57	58	13	*a*	6	*a*	98	56	—	—	10	*a*	28	36
2011	193	39	114	52	16	*a*	5	*a*	100	32	—	—	9	*a*	39	3
2012	338	31	110	32	109	8	8	*a*	229	50	—	—	5	*a*	44	2
2013	282	34	172	19	29	14	10	*a*	205	49	—	—	8	*a*	40	18
2014	444	31	74	31	33	24	13	*a*	296	55	—	—	9	*a*	39	8
2015	443	35	130	32	11	*a*	23	17	91	34	—	—	18	*a*	89	3
2016	789	26	185	19	30	7	18	*a*	119	23	—	—	22	5	44	9
2017	254	41	346	24	70	4	23	4	250	38	49	16	14	*a*	39	15
mean (SE)	363 (36)	37 (2)	126 (18)	37 (3)	35 (6)	32 (5)	28 (10)	43 (11)	137 (15)	57 (3)	18 (15)	*b*	40 (22)	20 (6)	47 (6)	19 (3)

Note: *a* = no PSD value calculated ($n_s \leq 19$), dashes (—) = no sampling conducted, *b* = no mean calculated ($n \leq 2$).

Table 6. Number of stock-length (n_s) Walleye opportunistically sampled by boat electrofishing, proportional size distribution (PSD, %), and proportional size distribution of preferred-length fish (PSD-P, %) as part of fishery evaluation by location. Mean and SE were calculated for each location across the time series.

	Below Bonneville			Bonneville			The Dalles			John Day			McNary			Ice Harbor			Little Goose		
Year	n_s	PSD	PSD-P	n_s	PSD	PSD-P	n_s	PSD	PSD-P	n_s	PSD	PSD-P	n_s	PSD	PSD-P	n_s	PSD	PSD-P	n_s	PSD	PSD-P
1992	17	*a*	*a*	11	*a*	*a*	14	*a*	*a*	16	*a*	*a*	2	*a*	*a*	0	*a*	*a*	0	*a*	*a*
1993	23	52	43	3	*a*	*a*	2	*a*	*a*	6	*a*	*a*	3	*a*	*a*	—	—	—	0	*a*	*a*
1994	1	*a*	*a*	9	*a*	*a*	4	*a*	*a*	11	*a*	*a*	2	*a*	*a*	—	—	—	0	*a*	*a*
1995	9	*a*	*a*	17	*a*	*a*	14	*a*	*a*	12	*a*	*a*	11	*a*	*a*	—	—	—	0	*a*	*a*
1996	28	50	36	0	*a*	*a*	18	*a*	*a*	26	100	85	17	*a*	*a*	—	—	—	0	*a*	*a*
1997	17	*a*	*a*	6	*a*	*a*	93	61	10	23	96	39	15	*a*	*a*	—	—	—	0	*a*	*a*
1998	4	*a*	*a*	8	*a*	*a*	23	70	30	18	*a*	*a*	43	95	79	—	—	—	0	*a*	*a*
1999	3	*a*	*a*	2	*a*	*a*	16	*a*	*a*	33	70	52	14	*a*	*a*	—	—	—	0	*a*	*a*
2000	9	*a*	*a*	1	*a*	*a*	18	*a*	*a*	15	*a*	*a*	24	100	71	—	—	—	0	*a*	*a*
2001	13	*a*	*a*	4	*a*	*a*	15	*a*	*a*	19	*a*	*a*	17	*a*	*a*	—	—	—	—	—	—
2002	15	*a*	*a*	2	*a*	*a*	45	89	31	45	60	36	19	*a*	*a*	—	—	—	—	—	—
2003	18	*a*	*a*	2	*a*	*a*	31	71	19	129	73	16	36	83	58	—	—	—	—	—	—
2004	6	*a*	*a*	3	*a*	*a*	2	*a*	*a*	22	68	41	33	100	91	—	—	—	—	—	—
2005	2	*a*	*a*	0	*a*	*a*	30	83	30	52	40	12	10	*a*	*a*	—	—	—	—	—	—
2006	3	*a*	*a*	5	*a*	*a*	51	94	39	97	69	12	56	100	96	—	—	—	0	*a*	*a*
2007	0	*a*	*a*	1	*a*	*a*	22	64	45	50	82	32	33	100	88	—	—	—	0	*a*	*a*
2008	10	*a*	*a*	2	*a*	*a*	29	69	17	49	57	20	73	59	52	—	—	—	0	*a*	*a*
2009	6	*a*	*a*	11	*a*	*a*	11	*a*	*a*	48	52	23	20	95	50	—	—	—	0	*a*	*a*
2010	20	75	0	2	*a*	*a*	15	*a*	*a*	37	32	5	68	71	47	—	—	—	0	*a*	*a*
2011	14	*a*	*a*	29	83	17	68	57	6	171	51	6	90	83	50	—	—	—	0	*a*	*a*
2012	6	*a*	*a*	21	100	24	47	49	9	53	81	9	98	66	55	—	—	—	0	*a*	*a*
2013	2	*a*	*a*	1	*a*	*a*	9	*a*	*a*	85	55	29	100	75	59	—	—	—	0	*a*	*a*
2014	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2015	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2016	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2017	4	*a*	*a*	131	79	2	276	45	3	214	24	10	243	66	32	31	52	16	3	*a*	*a*
mean (SE)	10 (2)	59 (8)	26 (13)	12 (6)	87 (6)	14 (6)	37 (12)	68 (5)	22 (4)	54 (11)	63 (5)	27 (5)	45 (11)	84 (4)	64 (5)	*b*	*b*	*b*	0 (0)	*b*	*b*

Note: *a* = no PSD value calculated ($n_s \leq 19$), dashes (—) = no sampling conducted, *b* = no mean calculated ($n \leq 2$).

Table 7. Number of 900-s boat electrofishing runs by sampling year and location conducted during biological evaluation in the Columbia River below Bonneville Dam and in Bonneville Reservoir, 1990–2017. FB = forebay; FB/BRZ = forebay boat restricted zone; Mid = mid-reservoir; TR = tailrace, TR/BRZ = tailrace boat restricted zone, and Rkm = river kilometer.

	Below Bonneville Dam					Bonneville Reservoir			
Year	Rkm 116–121	Rkm 173–181	Rkm 188–194	TR	TR/BRZ	FB/BRZ	FB	Mid	TR
1990	—	—	—	27	13	16	31	52	37
1991	—	—	—	21	7	10	26	38	22
1992	68	65	64	37	23	—	—	—	—
1993	—	—	—	16	9	11	24	28	25
1994	36	33	43	27	8	24	73	84	60
1995	45	36	40	16	8	18	61	45	80
1996	43	35	40	24	7	12	68	57	69
1999	44	47	40	29	—	—	62	57	63
2004	39	35	40	48	16	10	39	38	47
2005	48	48	48	66	16	23	78	58	74
2008	48	48	48	64	14	8	79	69	73
2011	48	48	38	66	6	3	77	96	64
2014	26	12	24	29	4	2	34	41	32
2017	24	17	31	58	9	6	74	68	66

Note: dashes (—) = no sampling conducted. In 2017, sampling effort downstream of Bonneville Dam tailrace was reduced due to water temperatures exceeding 18°C, a federally mandated limit (NMFS 2000).

Table 8. Mean catch per 900-s boat electrofishing (CPUE; and SE) of Northern Pikeminnow (≥ 250 mm FL), Smallmouth Bass (≥ 200 mm FL), and Walleye (≥ 200 mm FL) that were captured during biological evaluation in the Columbia River below Bonneville Dam and in Bonneville Reservoir during spring and summer 2017. FB = forebay; FB/BRZ = forebay boat restricted zone; Mid = mid-reservoir; TR = tailrace, TR/BRZ = tailrace boat restricted zone, and Rkm = river kilometer.

Species,	Below Bonneville Dam					Bonneville Reservoir			
Season and Year	Rkm 116–121	Rkm 173–181	Rkm 188–194	TR	TR/BRZ	FB/BRZ	FB	Mid	TR
Northern Pikeminnow,									
Spring	1.20 (0.10)	0.29 (0.03)	0.19 (0.01)	0.74 (0.05)	0.00 (0.00)	0.00 (0.00)	0.27 (0.04)	0.42 (0.08)	0.36 (0.05)
Summer	—	—	—	1.69 (0.07)	0.00 (0.00)	*a*	0.40 (0.02)	0.42 (0.04)	0.27 (0.03)
Smallmouth Bass,									
Spring	0.00 (0.00)	0.59 (0.07)	0.23 (0.01)	0.14 (0.01)	0.20 (0.09)	0.25 (0.13)	2.02 (0.08)	4.66 (0.16)	2.24 (0.06)
Summer	—	—	—	1.95 (0.08)	2.25 (0.52)	*a*	3.55 (0.10)	7.67 (0.16)	5.05 (0.13)
Walleye,									
Spring	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.04 (0.01)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.17 (0.03)	0.25 (0.03)
Summer	—	—	—	0.36 (0.03)	0.00 (0.00)	*a*	0.00 (0.00)	0.12 (0.01)	0.00 (0.00)

Note: dashes (—) = no sampling conducted, *a* = no mean calculated ($n \leq 2$). Summer sampling downstream of Bonneville Dam tailrace was precluded by water temperatures exceeding 18°C, a federally mandated limit (NMFS 2000).

Table 9. Spring and summer abundance index values (mean catch per 900-s boat electrofishing per surface area [ha] divided by 1,000; and SE) for Northern Pikeminnow (≥ 250 mm FL) in the Columbia River below Bonneville Dam and in Bonneville Reservoir, 1990–2017. FB = forebay; FB/BRZ = forebay boat restricted zone; Mid = mid-reservoir; TR = tailrace, TR/BRZ = tailrace boat restricted zone, and Rkm = river kilometer.

Season,	Below Bonneville Dam					Bonneville Reservoir			
Year	Rkm 116–121	Rkm 173–181	Rkm 188–194	TR	TR/BRZ	FB/BRZ	FB	Mid	TR
Spring,									
1990	—	—	—	4.06 (0.33)	44.24 (6.70)	63.92 (3.82)	4.81 (0.24)	0.38 (0.02)	1.01 (0.06)
1991	—	—	—	5.15 (0.64)	87.56 (16.26)	68.00 (12.44)	0.31 (0.04)	0.08 (0.01)	0.60 (0.07)
1992	0.09 (0.00)	0.23 (0.02)	0.20 (0.03)	2.35 (0.35)	88.71 (17.56)	—	—	—	—
1993	—	—	—	11.54 (2.32)	72.98 (10.99)	8.33 (3.40)	1.74 (0.25)	0.15 (0.02)	1.96 (0.26)
1994	—	—	—	—	—	40.00 (6.42)	2.28 (0.09)	0.13 (0.01)	1.37 (0.11)
1995	0.08 (0.00)	0.19 (0.01)	0.11 (0.01)	3.89 (0.38)	19.59 (4.64)	13.32 (1.63)	3.37 (0.12)	0.19 (0.01)	0.68 (0.03)
1996	0.08 (0.01)	0.18 (0.01)	0.13 (0.01)	2.53 (0.32)	12.29 (3.87)	5.00 (2.50)	1.87 (0.09)	0.11 (0.01)	1.52 (0.11)
1999	0.05 (0.00)	0.08 (0.00)	0.08 (0.00)	2.42 (0.27)	—	—	0.78 (0.04)	0.06 (0.01)	2.45 (0.35)
2004	0.07 (0.01)	0.05 (0.01)	0.10 (0.01)	1.56 (0.05)	76.66 (9.52)	20.74 (2.12)	0.88 (0.04)	—	2.28 (0.40)
2005	0.06 (0.00)	0.07 (0.01)	0.07 (0.00)	1.27 (0.05)	43.88 (6.45)	20.41 (1.57)	0.46 (0.02)	0.08 (0.01)	0.39 (0.04)
2008	0.08 (0.00)	0.07 (0.00)	0.03 (0.00)	1.65 (0.09)	45.64 (3.44)	10.00 (5.00)	0.29 (0.02)	0.01 (0.00)	0.54 (0.05)
2011	0.03 (0.00)	0.03 (0.00)	0.02 (0.00)	0.63 (0.03)	5.37 (1.41)	0.00 (0.00)	0.21 (0.02)	0.06 (0.01)	0.49 (0.04)
2014	0.05 (0.01)	0.01 (0.00)	0.03 (0.00)	0.39 (0.02)	0.00 (0.00)	*a*	0.03 (0.01)	0.03 (0.00)	0.37 (0.04)
2017	0.08 (0.01)	0.02 (0.00)	0.02 (0.00)	0.94 (0.05)	0.00 (0.00)	0.00 (0.00)	0.31 (0.03)	0.06 (0.01)	0.47 (0.03)
mean (SE)	0.07 (0.01)	0.09 (0.02)	0.08 (0.02)	2.95 (0.82)	41.41 (9.81)	22.70 (7.30)	1.33 (0.40)	0.11 (0.03)	1.09 (0.21)
Summer,									
1990	—	—	—	10.17 (0.96)	75.01 (7.21)	138.36 (19.37)	2.99 (0.14)	0.19 (0.01)	0.22 (0.03)
1991	—	—	—	12.55 (1.24)	87.56 (18.93)	233.47 (50.34)	0.63 (0.07)	0.21 (0.02)	1.60 (0.24)
1992	0.07 (0.00)	0.11 (0.00)	0.19 (0.00)	4.80 (0.31)	53.36 (4.66)	—	—	—	—
1993	—	—	—	12.80 (1.65)	55.15 (10.71)	62.00 (19.05)	2.23 (0.16)	0.17 (0.02)	0.96 (0.11)
1994	0.06 (0.00)	0.15 (0.01)	0.14 (0.00)	3.70 (0.22)	86.98 (12.76)	32.50 (5.18)	2.26 (0.09)	0.07 (0.00)	0.49 (0.04)
1995	0.04 (0.00)	0.07 (0.00)	0.07 (0.00)	1.74 (0.25)	19.59 (1.73)	15.00 (0.94)	2.80 (0.11)	0.10 (0.01)	2.15 (0.11)
1996	0.02 (0.00)	0.04 (0.00)	0.07 (0.01)	4.91 (0.77)	37.62 (8.98)	8.75 (0.80)	1.34 (0.07)	0.09 (0.00)	0.79 (0.05)
1999	0.02 (0.00)	0.07 (0.00)	0.14 (0.01)	5.70 (0.42)	—	—	1.41 (0.06)	0.03 (0.00)	1.50 (0.08)
2004	0.02 (0.00)	0.05 (0.00)	0.07 (0.00)	3.37 (0.41)	85.97 (7.72)	—	—	0.04 (0.00)	2.22 (0.14)
2005	0.03 (0.00)	0.04 (0.00)	0.04 (0.00)	0.89 (0.05)	31.09 (3.21)	3.91 (0.50)	0.84 (0.06)	0.02 (0.00)	0.28 (0.02)
2008	0.03 (0.00)	0.03 (0.00)	0.02 (0.00)	1.85 (0.10)	69.37 (6.39)	0.00 (0.00)	0.09 (0.01)	0.01 (0.00)	0.14 (0.01)
2011	0.01 (0.00)	0.01 (0.00)	0.04 (0.00)	2.75 (0.11)	—	—	0.24 (0.02)	0.02 (0.00)	0.67 (0.06)
2014	0.01 (0.00)	—	0.01 (0.00)	—	—	—	—	—	—
2017	—	—	—	2.13 (0.08)	0.00 (0.00)	*a*	0.47 (0.02)	0.06 (0.00)	0.35 (0.03)
mean (SE)	0.03 (0.01)	0.06 (0.01)	0.08 (0.02)	5.18 (1.13)	54.70 (8.95)	61.75 (29.39)	1.39 (0.31)	0.08 (0.02)	0.95 (0.21)

Note: dashes (—) = no sampling conducted, *a* = no mean CPUE calculated ($n \leq 2$). Summer sampling downstream of Bonneville Dam tailrace was precluded by water temperatures exceeding 18°C, a federally mandated limit (NMFS 2000).

Table 10. Spring and summer abundance index values (mean catch per 900-s boat electrofishing per surface area [ha] divided by 1,000; and SE) for Smallmouth Bass (≥ 200 mm FL) in the Columbia River below Bonneville Dam and in Bonneville Reservoir, 1990–2017. FB = forebay; FB/BRZ = forebay boat restricted zone; Mid = mid-reservoir; TR = tailrace, TR/BRZ = tailrace boat restricted zone, and Rkm = river kilometer.

Season,	Below Bonneville Dam					Bonneville Reservoir			
Year	Rkm 116–121	Rkm 173–181	Rkm 188–194	TR	TR/BRZ	FB/BRZ	FB	Mid	TR
Spring,									
1990	—	—	—	0.09 (0.02)	2.76 (0.82)	0.00 (0.00)	0.03 (0.01)	0.11 (0.01)	1.92 (0.23)
1991	—	—	—	0.23 (0.07)	0.00 (0.00)	2.00 (0.89)	0.08 (0.02)	0.02 (0.00)	3.01 (0.48)
1992	0.00 (0.00)	0.04 (0.01)	0.01 (0.00)	0.18 (0.07)	5.76 (2.18)	—	—	—	—
1993	—	—	—	0.00 (0.00)	6.87 (2.75)	1.67 (0.68)	0.58 (0.10)	0.09 (0.02)	5.98 (0.49)
1994	—	—	—	—	—	0.00 (0.00)	0.20 (0.01)	0.18 (0.01)	3.79 (0.18)
1995	0.01 (0.00)	0.31 (0.03)	0.15 (0.01)	2.05 (0.30)	14.98 (4.64)	0.00 (0.00)	0.49 (0.04)	0.23 (0.01)	3.22 (0.10)
1996	0.00 (0.00)	0.11 (0.01)	0.04 (0.01)	0.09 (0.02)	7.68 (4.43)	0.00 (0.00)	0.55 (0.03)	0.15 (0.01)	5.78 (0.19)
1999	0.00 (0.00)	0.02 (0.00)	0.01 (0.00)	0.31 (0.05)	—	—	0.32 (0.03)	0.03 (0.00)	2.56 (0.11)
2004	0.00 (0.00)	0.12 (0.01)	0.06 (0.01)	1.49 (0.06)	13.48 (1.98)	5.99 (1.35)	0.77 (0.03)	—	3.80 (0.35)
2005	0.01 (0.00)	0.04 (0.00)	0.07 (0.00)	0.83 (0.04)	10.84 (1.18)	9.99 (1.28)	1.31 (0.04)	0.16 (0.02)	2.22 (0.07)
2008	0.01 (0.00)	0.11 (0.01)	0.09 (0.01)	1.46 (0.07)	19.22 (1.73)	12.47 (3.74)	2.54 (0.11)	0.08 (0.01)	4.38 (0.11)
2011	0.00 (0.00)	0.05 (0.00)	0.00 (0.00)	0.13 (0.01)	5.37 (0.90)	3.18 (1.84)	0.50 (0.02)	0.33 (0.01)	3.30 (0.12)
2014	0.00 (0.00)	0.01 (0.00)	0.02 (0.00)	0.17 (0.02)	2.30 (0.67)	*a*	0.51 (0.03)	0.21 (0.01)	3.86 (0.11)
2017	0.00 (0.00)	0.05 (0.01)	0.02 (0.00)	0.18 (0.02)	0.92 (0.41)	2.50 (1.25)	2.34 (0.09)	0.65 (0.02)	2.92 (0.08)
mean (SE)	0.00 (0.00)	0.09 (0.03)	0.05 (0.01)	0.55 (0.19)	7.52 (1.73)	3.44 (1.29)	0.79 (0.22)	0.19 (0.05)	3.60 (0.34)
Summer,									
1990	—	—	—	0.17 (0.03)	3.24 (0.94)	0.00 (0.00)	0.19 (0.04)	0.03 (0.00)	1.10 (0.10)
1991	—	—	—	0.72 (0.16)	8.06 (1.45)	0.00 (0.00)	0.00 (0.00)	0.07 (0.01)	2.87 (0.18)
1992	0.01 (0.00)	0.04 (0.00)	0.05 (0.00)	0.80 (0.05)	2.18 (0.20)	—	—	—	—
1993	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.47 (0.12)	17.51 (4.81)	4.00 (1.10)	0.41 (0.05)	0.10 (0.01)	2.87 (0.18)
1994	0.01 (0.00)	0.11 (0.01)	0.04 (0.00)	0.61 (0.06)	4.61 (1.19)	0.00 (0.00)	0.27 (0.02)	0.09 (0.00)	2.35 (0.05)
1995	0.01 (0.00)	0.07 (0.00)	0.06 (0.00)	1.26 (0.19)	0.00 (0.00)	3.75 (0.93)	0.33 (0.02)	0.05 (0.00)	3.17 (0.07)
1996	0.00 (0.00)	0.02 (0.00)	0.03 (0.00)	0.75 (0.13)	0.00 (0.00)	0.00 (0.00)	0.29 (0.02)	0.07 (0.00)	1.07 (0.05)
1999	0.00 (0.00)	0.03 (0.00)	0.05 (0.00)	0.97 (0.11)	—	—	0.88 (0.03)	0.06 (0.00)	3.03 (0.09)
2004	0.01 (0.00)	0.02 (0.00)	0.07 (0.00)	0.63 (0.08)	0.92 (0.29)	—	—	0.22 (0.01)	2.72 (0.08)
2005	0.00 (0.00)	0.06 (0.00)	0.05 (0.00)	0.85 (0.05)	4.03 (0.57)	10.82 (1.10)	1.53 (0.06)	0.24 (0.01)	1.09 (0.04)
2008	0.02 (0.00)	0.14 (0.01)	0.10 (0.01)	0.67 (0.04)	7.68 (1.73)	19.99 (2.04)	2.20 (0.09)	0.27 (0.01)	4.02 (0.10)
2011	0.00 (0.00)	0.06 (0.00)	0.05 (0.00)	1.02 (0.05)	—	—	1.92 (0.07)	0.43 (0.01)	4.89 (0.11)
2014	0.00 (0.00)	—	0.03 (0.00)	—	—	—	—	—	—
2017	—	—	—	2.47 (0.11)	10.37 (2.38)	*a*	4.11 (0.12)	1.06 (0.02)	6.60 (0.17)
mean (SE)	0.01 (0.00)	0.06 (0.01)	0.05 (0.01)	0.88 (0.15)	5.33 (1.59)	4.82 (2.54)	1.10 (0.38)	0.22 (0.08)	2.98 (0.47)

Note: dashes (—) = no sampling conducted, *a* = no mean CPUE calculated ($n \leq 2$). Summer sampling downstream of Bonneville Dam tailrace was precluded by water temperatures exceeding 18°C, a federally mandated limit (NMFS 2000).

Table 11. Spring and summer abundance index values (mean catch per 900-s boat electrofishing per surface area [ha] divided by 1,000; and SE) for Walleye (≥ 200 mm FL) in the Columbia River below Bonneville Dam and in Bonneville Reservoir, 1990–2017. FB = forebay; FB/BRZ = forebay boat restricted zone; Mid = mid-reservoir; TR = tailrace, TR/BRZ = tailrace boat restricted zone, and Rkm = river kilometer.

Season,	Below Bonneville Dam					Bonneville Reservoir			
Year	Rkm 116–121	Rkm 173–181	Rkm 188–194	TR	TR/BRZ	FB/BRZ	FB	Mid	TR
Spring,									
1990	—	—	—	0.00 (0.00)	0.92 (0.41)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
1991	—	—	—	0.57 (0.11)	3.07 (0.89)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.30 (0.06)
1992	0.00 (0.00)	0.00 (0.00)	0.02 (0.00)	0.36 (0.09)	1.15 (0.58)	—	—	—	—
1993	—	—	—	0.16 (0.06)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.22 (0.04)
1994	—	—	—	—	—	0.00 (0.00)	0.03 (0.01)	0.02 (0.00)	0.20 (0.03)
1995	0.00 (0.00)	0.03 (0.01)	0.00 (0.00)	0.79 (0.17)	2.30 (1.15)	0.00 (0.00)	0.00 (0.00)	0.01 (0.00)	0.20 (0.02)
1996	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.27 (0.05)	7.68 (3.20)	0.00 (0.00)	0.00 (0.00)	0.02 (0.00)	0.30 (0.02)
1999	0.00 (0.00)	0.00 (0.00)	0.01 (0.00)	0.21 (0.04)	—	—	0.00 (0.00)	0.01 (0.00)	0.05 (0.01)
2004	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.40 (0.03)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	—	0.22 (0.04)
2005	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.12 (0.01)	0.58 (0.20)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.03 (0.01)
2008	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.03 (0.01)	0.58 (0.20)	0.00 (0.00)	0.00 (0.00)	0.01 (0.00)	0.11 (0.01)
2011	0.00 (0.00)	0.01 (0.00)	0.01 (0.00)	0.25 (0.02)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.01 (0.00)	0.69 (0.06)
2014	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.26 (0.02)	0.00 (0.00)	*a*	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2017	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.05 (0.01)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.02 (0.00)	0.33 (0.04)
mean (SE)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.27 (0.06)	1.36 (0.64)	0.00 (0.00)	0.00 (0.00)	0.01 (0.00)	0.20 (0.05)
Summer,									
1990	—	—	—	0.26 (0.07)	0.53 (0.19)	0.00 (0.00)	0.00 (0.00)	0.01 (0.00)	0.07 (0.02)
1991	—	—	—	0.13 (0.04)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.15 (0.05)
1992	0.00 (0.00)	0.01 (0.00)	0.00 (0.00)	0.04 (0.01)	0.00 (0.00)	—	—	—	—
1993	—	—	—	0.00 (0.00)	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)	0.01 (0.00)	0.01 (0.00)	0.56 (0.07)	2.88 (0.81)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
1995	0.00 (0.00)	0.01 (0.00)	0.01 (0.00)	0.47 (0.12)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.01 (0.00)	0.13 (0.01)
1996	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.37 (0.08)	2.26 (0.65)	0.00 (0.00)	0.00 (0.00)	0.01 (0.00)	0.10 (0.01)
1999	0.00 (0.00)	0.00 (0.00)	0.01 (0.00)	0.22 (0.03)	—	—	0.00 (0.00)	0.00 (0.00)	0.10 (0.01)
2004	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.11 (0.03)	0.92 (0.19)	—	—	0.01 (0.00)	0.04 (0.01)
2005	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2008	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.18 (0.02)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2011	0.00 (0.00)	0.00 (0.00)	0.01 (0.00)	0.17 (0.01)	—	—	0.00 (0.00)	0.01 (0.00)	0.04 (0.01)
2014	0.00 (0.00)	—	0.00 (0.00)	—	—	—	—	—	—
2017	—	—	—	0.46 (0.04)	0.00 (0.00)	*a*	0.00 (0.00)	0.02 (0.00)	0.00 (0.00)
mean (SE)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.23 (0.05)	0.60 (0.31)	0.00 (0.00)	0.00 (0.00)	0.01 (0.00)	0.05 (0.02)

Note: dashes (—) = no sampling conducted, *a* = no mean CPUE calculated ($n \leq 2$). Summer sampling downstream of Bonneville Dam tailrace was precluded by water temperatures exceeding 18°C, a federally mandated limit (NMFS 2000).

Table 12. Number (n) of Northern Pikeminnow, Smallmouth Bass, and Walleye (≥ 200 mm FL) digestive tracts examined during biological evaluation in the Columbia River below Bonneville Dam and in Bonneville Reservoir during spring and summer 2017 and proportion of samples containing food, fish, and salmonids (sal).

Season,	Northern Pikeminnow					Smallmouth Bass					Walleye				
Area	$n_{\text{non-empty}}$	n_{empty}	$\hat{p}_{\text{food}}$	$\hat{p}_{\text{fish}}$	$\hat{p}_{\text{sal}}$	$n_{\text{non-empty}}$	n_{empty}	$\hat{p}_{\text{food}}$	$\hat{p}_{\text{fish}}$	$\hat{p}_{\text{sal}}$	$n_{\text{non-empty}}$	n_{empty}	$\hat{p}_{\text{food}}$	$\hat{p}_{\text{fish}}$	$\hat{p}_{\text{sal}}$
Spring															
Below Bonneville Dam	63	5	0.93	0.49	0.29	22	0	1.00	0.41	0.14	1	0	1.00	1.00	1.00
Bonneville	71	9	0.89	0.20	0.03	230	15	0.94	0.30	0.05	13	0	1.00	0.85	0.69
All	134	14	0.91	0.33	0.15	252	15	0.94	0.31	0.06	14	0	1.00	0.86	0.71
Summer															
Below Bonneville Dam	45	11	0.80	0.23	0.07	66	1	0.99	0.60	0.12	11	0	1.00	1.00	0.55
Bonneville	49	5	0.91	0.09	0.02	429	13	0.97	0.20	0.02	5	0	1.00	0.60	0.40
All	94	16	0.85	0.16	0.05	495	14	0.97	0.26	0.03	16	0	1.00	0.88	0.50

Table 13. 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 Columbia River below Bonneville Dam and in Bonneville Reservoir, 2017.

	Northern Pikeminnow		Smallmouth Bass		Walleye	
Common name (Family)	Below Bonneville Dam (*n* = 124)	Bonneville Reservoir (*n* = 134)	Below Bonneville Dam (*n* = 89)	Bonneville Reservoir (*n* = 687)	Below Bonneville Dam (*n* = 12)	Bonneville Reservoir (*n* = 18)
lampreys (Petromyzontidae)	0.04	0.01	0.00	0.00	0.00	0.00
minnows (Cyprinidae)	0.00	0.00	0.01	0.01	0.08	0.11
catfish (Ictaluridae)	0.00	0.00	0.00	0.00	0.00	0.00
salmon and trout (Salmonidae)	0.19	0.02	0.12	0.03	0.58	0.61
sunfishes (Centrarchidae)	0.00	0.00	0.00	0.01	0.00	0.00
perches (Percidae)	0.01	0.00	0.01	0.00	0.00	0.00
Threespine Stickleback (Gasterosteidae)	0.03	0.00	0.03	0.00	0.00	0.00
sculpins (Cottidae)	0.06	0.01	0.28	0.09	0.08	0.06
unidentified	0.07	0.12	0.18	0.10	0.58	0.17

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

Table 14. Annual consumption index values for Northern Pikeminnow (≥ 250 mm FL) captured during biological evaluation from the Columbia River below Bonneville Dam and in Bonneville Reservoir by season, 1990–2017. Mean and SE were calculated for each location across the time series. FB = forebay; FB/BRZ = forebay boat restricted zone; Mid = mid-reservoir; TR = tailrace, TR/BRZ = tailrace boat restricted zone, and Rkm = river kilometer.

Season,	Below Bonneville Dam					Bonneville Reservoir			
Year	Rkm 116–121	Rkm 173–181	Rkm 188–194	TR	TR/BRZ	FB/BRZ	FB	Mid	TR
Spring,									
1990	—	—	—	1.28	2.34	0.95	0.06	0.00	0.32
1992	0.81	1.97	2.16	0.91	1.41	—	—	—	—
1993	—	—	—	0.53	0.82	*a*	0.46	0.00	0.00
1994	—	—	—	—	—	0.47	0.04	0.25	0.00
1995	0.54	0.34	1.03	0.91	1.76	0.72	0.45	0.00	0.23
1996	0.37	0.07	0.41	0.37	0.60	*a*	0.00	0.12	0.00
1999	0.77	0.44	0.42	0.14	—	—	0.00	0.59	0.16
2004	0.17	0.31	0.11	0.26	0.97	0.80	0.52	—	0.00
2005	0.17	0.00	0.54	0.42	1.58	0.47	0.28	*a*	1.47
2008	0.79	0.98	0.00	1.02	0.94	*a*	1.31	*a*	0.64
2011	0.57	0.58	*a*	0.71	1.00	*a*	0.00	0.00	0.49
2014	0.27	*a*	*a*	1.31	*a*	*a*	*a*	0.00	0.29
2017	2.47	*a*	2.97	2.07	*a*	*a*	0.00	0.00	1.78
mean (SE)	0.69 (0.21)	0.59 (0.22)	0.95 (0.38)	0.83 (0.16)	1.27 (0.18)	0.68 (0.09)	0.28 (0.12)	0.11 (0.07)	0.45 (0.17)
Summer,									
1990	—	—	—	0.54	4.79	2.12	0.00	0.00	*a*
1992	0.00	2.34	4.28	2.89	9.02	—	—	—	—
1993	—	—	—	—	—	0.60	0.36	0.00	0.27
1994	1.28	1.74	1.58	3.32	1.17	1.10	0.00	0.00	0.00
1995	2.14	0.44	1.22	1.25	0.94	0.00	0.00	0.00	0.92
1996	0.00	0.00	0.00	0.60	3.04	0.00	0.00	0.00	0.00
1999	1.25	0.00	0.55	0.24	—	—	0.00	0.00	0.30
2004	0.45	0.71	0.17	0.20	3.99	—	—	0.00	1.07
2005	1.19	0.34	0.62	0.00	3.84	*a*	0.00	*a*	*a*
2008	1.66	1.19	0.39	0.25	0.91	*a*	*a*	*a*	*a*
2011	*a*	*a*	0.00	0.32	—	—	0.00	0.00	0.84
2014	*a*	—	*a*	—	—	—	—	—	—
2017	—	—	—	0.23	*a*	*a*	0.32	0.00	0.00
mean (SE)	1.00 (0.27)	0.85 (0.30)	0.98 (0.45)	0.90 (0.35)	3.46 (0.96)	0.77 (0.40)	0.08 (0.05)	0.00 (0.00)	0.42 (0.16)

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

Table 15. Annual predation index values for Northern Pikeminnow (≥ 250 mm FL) captured during biological evaluation from the Columbia River below Bonneville Dam and in Bonneville Reservoir by season, 1990–2017. Mean and SE were calculated for each location across the time series. FB = forebay; FB/BRZ = forebay boat restricted zone; Mid = mid-reservoir; TR = tailrace, TR/BRZ = tailrace boat restricted zone, and Rkm = river kilometer.

Season,	Below Bonneville Dam					Bonneville Reservoir			
Year	Rkm 116–121	Rkm 173–181	Rkm 188–194	TR	TR/BRZ	FB/BRZ	FB	Mid	TR
Spring,									
1990	—	—	—	5.21	103.61	60.53	0.27	0.00	0.32
1992	0.07	0.44	0.44	2.13	124.66	—	—	—	—
1993	—	—	—	6.17	59.65	*a*	0.81	0.00	0.00
1994	—	—	—	—	—	18.80	0.10	0.03	0.00
1995	0.04	0.06	0.11	3.52	34.38	9.59	1.50	0.00	0.15
1996	0.03	0.01	0.05	0.94	7.37	*a*	0.00	0.01	0.00
1999	0.04	0.03	0.03	0.34	—	—	0.00	0.04	0.39
2004	0.01	0.02	0.01	0.40	74.71	16.59	0.46	—	0.00
2005	0.01	0.00	0.04	0.53	69.13	9.59	0.13	*a*	0.57
2008	0.06	0.06	0.00	1.69	42.72	*a*	0.38	*a*	0.35
2011	0.01	0.02	*a*	0.45	5.37	*a*	0.00	0.00	0.24
2014	0.01	*a*	*a*	0.51	*a*	*a*	*a*	0.00	0.11
2017	0.19	*a*	0.05	1.94	*a*	*a*	0.00	0.00	0.84
mean (SE)	0.05 (0.02)	0.08 (0.05)	0.09 (0.05)	1.99 (0.57)	57.96 (13.47)	23.02 (9.56)	0.33 (0.14)	0.01 (0.01)	0.25 (0.08)
Summer,									
1990	—	—	—	5.52	359.24	293.98	0.00	0.00	*a*
1992	0.00	0.25	0.80	13.89	481.51	—	—	—	—
1993	—	—	—	—	—	37.20	0.80	0.00	0.26
1994	0.08	0.26	0.22	12.29	101.59	35.80	0.00	0.00	0.00
1995	0.08	0.03	0.09	2.18	18.45	0.00	0.00	0.00	1.98
1996	0.00	0.00	0.00	2.92	114.50	0.00	0.00	0.00	0.00
1999	0.02	0.00	0.08	1.36	—	—	0.00	0.00	0.45
2004	0.01	0.03	0.01	0.67	342.88	—	—	0.00	2.38
2005	0.03	0.01	0.02	0.00	119.32	*a*	0.00	*a*	*a*
2008	0.04	0.04	0.01	0.46	62.94	*a*	*a*	*a*	*a*
2011	*a*	*a*	0.00	0.89	—	—	0.00	0.00	0.57
2014	*a*	—	*a*	—	—	—	—	—	—
2017	—	—	—	0.50	*a*	*a*	0.15	0.00	0.00
mean (SE)	0.03 (0.01)	0.08 (0.04)	0.14 (0.09)	3.70 (1.48)	200.05 (59.80)	73.40 (55.75)	0.11 (0.09)	0.00 (0.00)	0.70 (0.33)

Note: *a* = no predation index calculated ($n_{fish} \leq 5$ or $n_{runs} \leq 2$), dashes (—) = no sampling conducted.

Table 16. Annual consumption index values for Smallmouth Bass (≥ 200 mm FL) captured during biological evaluation from the Columbia River below Bonneville Dam and in Bonneville Reservoir by season, 1990–2017. Mean and SE were calculated for each location across the time series. FB = forebay; FB/BRZ = forebay boat restricted zone; Mid = mid-reservoir; TR = tailrace, TR/BRZ = tailrace boat restricted zone, and Rkm = river kilometer.

Season,	Below Bonneville Dam					Bonneville Reservoir			
Year	Rkm 116–121	Rkm 173–181	Rkm 188–194	TR	TR/BRZ	FB/BRZ	FB	Mid	TR
Spring,									
1990	—	—	—	*a*	0.38	*a*	*a*	*a*	0.00
1992	*a*	0.08	*a*	*a*	*a*	—	—	—	—
1993	—	—	—	*a*	0.11	*a*	*a*	*a*	0.00
1994	—	—	—	—	—	*a*	*a*	0.00	0.00
1995	*a*	0.05	0.00	0.00	0.00	*a*	0.08	0.03	0.00
1996	*a*	0.00	0.00	*a*	*a*	*a*	0.00	0.00	0.00
1999	*a*	0.00	*a*	*a*	—	—	0.00	*a*	0.01
2004	*a*	0.00	0.23	0.00	0.00	*a*	0.00	—	0.00
2005	*a*	0.34	0.05	0.00	0.00	0.11	0.10	0.00	0.03
2008	*a*	0.04	0.04	0.02	0.00	*a*	0.05	0.00	0.02
2011	*a*	0.07	*a*	*a*	0.12	*a*	0.11	0.04	0.00
2014	*a*	*a*	*a*	*a*	*a*	*a*	0.00	0.06	0.05
2017	*a*	0.11	0.19	*a*	*a*	*a*	0.04	0.09	0.01
mean (SE)	*b*	0.08 (0.04)	0.09 (0.04)	0.00 (0.00)	0.09 (0.05)	*b*	0.04 (0.02)	0.03 (0.01)	0.01 (0.00)
Summer,									
1990	—	—	—	*a*	*a*	*a*	*a*	*a*	*a*
1992	*a*	0.00	0.52	*a*	*a*	—	—	—	—
1993	—	—	—	*a*	*a*	*a*	*a*	0.00	0.00
1994	0.00	0.04	0.30	0.00	0.00	*a*	0.39	0.00	0.04
1995	*a*	0.29	0.80	0.00	*a*	*a*	0.00	0.00	0.03
1996	*a*	*a*	0.00	0.00	*a*	*a*	0.00	0.00	0.00
1999	*a*	0.20	0.00	0.00	—	—	0.12	0.00	0.00
2004	*a*	0.00	0.21	*a*	*a*	—	—	0.00	0.00
2005	*a*	0.18	0.63	0.09	0.00	0.00	0.17	0.08	0.09
2008	*a*	0.52	0.65	0.10	0.00	0.00	0.10	0.13	0.03
2011	*a*	0.44	0.11	0.10	—	—	0.11	0.05	0.00
2014	*a*	—	*a*	—	—	—	—	—	—
2017	—	—	—	0.35	0.21	*a*	0.04	0.04	0.02
mean (SE)	*b*	0.21 (0.07)	0.36 (0.10)	0.08 (0.04)	0.05 (0.05)	*b*	0.12 (0.04)	0.03 (0.01)	0.02 (0.01)

Note: *a* = no consumption index calculated ($n \leq 5$), dashes (—) = no sampling conducted, *b* = no mean calculated ($n \leq 2$).

Table 17. Annual predation index values for Smallmouth Bass (≥ 200 mm FL) captured during biological evaluation from the Columbia River below Bonneville Dam and in Bonneville Reservoir by season, 1990–2017. Mean and SE were calculated for each location across the time series. FB = forebay; FB/BRZ = forebay boat restricted zone; Mid = mid-reservoir; TR = tailrace, TR/BRZ = tailrace boat restricted zone, and Rkm = river kilometer.

Season,	Below Bonneville Dam					Bonneville Reservoir			
Year	Rkm 116–121	Rkm 173–181	Rkm 188–194	TR	TR/BRZ	FB/BRZ	FB	Mid	TR
Spring,									
1990	—	—	—	*a*	1.05	*a*	*a*	*a*	0.00
1992	*a*	0.00	*a*	*a*	*a*	—	—	—	—
1993	—	—	—	*a*	0.77	*a*	*a*	*a*	0.00
1994	—	—	—	—	—	*a*	*a*	0.00	0.00
1995	*a*	0.02	0.00	0.00	0.00	*a*	0.04	0.01	0.00
1996	*a*	0.00	0.00	*a*	*a*	*a*	0.00	0.00	0.00
1999	*a*	0.00	*a*	*a*	—	—	0.00	*a*	0.03
2004	*a*	0.00	0.01	0.00	0.00	*a*	0.00	—	0.00
2005	*a*	0.01	0.00	0.00	0.00	1.10	0.13	0.00	0.07
2008	*a*	0.00	0.00	0.03	0.00	*a*	0.11	0.00	0.10
2011	*a*	0.00	*a*	*a*	0.62	*a*	0.05	0.01	0.00
2014	*a*	*a*	*a*	*a*	*a*	*a*	0.00	0.01	0.21
2017	*a*	0.01	0.00	*a*	*a*	*a*	0.11	0.06	0.03
mean (SE)	*b*	0.01 (0.00)	0.00 (0.00)	0.01 (0.01)	0.35 (0.17)	*b*	0.05 (0.02)	0.01 (0.01)	0.04 (0.02)
Summer,									
1990	—	—	—	*a*	*a*	*a*	*a*	a	*a*
1992	*a*	0.00	0.03	*a*	*a*	—	—	—	—
1993	—	—	—	*a*	*a*	*a*	*a*	0.00	0.00
1994	0.00	0.00	0.01	0.00	0.00	*a*	0.11	0.00	0.09
1995	*a*	0.02	0.05	0.00	*a*	*a*	0.00	0.00	0.08
1996	*a*	*a*	0.00	0.00	*a*	*a*	0.00	0.00	0.00
1999	*a*	0.01	0.00	0.00	—	—	0.11	0.00	0.00
2004	*a*	0.00	0.01	*a*	*a*	—	—	0.00	0.00
2005	*a*	0.01	0.03	0.08	0.00	0.00	0.25	0.02	0.09
2008	*a*	0.07	0.06	0.07	0.00	0.00	0.22	0.04	0.13
2011	*a*	0.02	0.01	0.10	—	—	0.20	0.02	0.00
2014	*a*	—	*a*	—	—	—	—	—	—
2017	—	—	—	0.86	2.20	*a*	0.17	0.04	0.12
mean (SE)	*b*	0.02 (0.01)	0.02 (0.01)	0.14 (0.10)	0.55 (0.55)	*b*	0.13 (0.03)	0.01 (0.01)	0.05 (0.02)

Note: *a* = no predation index calculated ($n_{fish} \leq 5$ or $n_{runs} \leq 2$), dashes (—) = no sampling conducted, *b* = no mean calculated ($n \leq 2$).

Table 18. Number of stock-length (n_s) Northern Pikeminnow and proportional size distribution (PSD, %) collected by boat electrofishing during biological evaluation in the Columbia River below Bonneville Dam and in Bonneville Reservoir, 1990–2017. Mean and SE were calculated across the time series.

	Below Bonneville Dam		Bonneville Reservoir	
Year	n_s	PSD	n_s	PSD
1990	366	49	541	48
1991	278	64	287	68
1992	1,353	38	—	—
1993	281	51	148	37
1994	401	33	378	40
1995	206	41	319	26
1996	245	33	199	24
1999	226	38	169	33
2004	357	35	136	18
2005	287	49	106	40
2008	344	65	40	45
2011	139	68	70	20
2014	29	66	18	*a*
2017	113	52	75	20
mean (SE)	330 (83)	49 (3)	191 (42)	35 (4)

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

Table 19. Number of stock-length (n_s) Smallmouth Bass, proportional size distribution (PSD, %), and proportional size distribution of preferred-length fish (PSD-P, %) collected by boat electrofishing during biological evaluation in the Columbia River below Bonneville Dam and in Bonneville Reservoir, 1990–2017. Mean and SE were calculated across the time series.

	Below Bonneville Dam			Bonneville Reservoir		
Year	n_s	PSD	PSD-P	n_s	PSD	PSD-P
1990	12	*a*	*a*	95	46	18
1991	15	*a*	*a*	85	56	22
1992	148	34	11	—	—	—
1993	28	68	14	137	33	12
1994	92	48	18	231	54	17
1995	156	47	17	260	37	12
1996	63	40	8	231	66	16
1999	42	60	17	195	56	16
2004	130	40	7	199	54	20
2005	142	32	4	308	54	25
2008	244	34	5	515	53	17
2011	87	44	5	548	58	27
2014	14	*a*	*a*	172	54	22
2017	90	32	11	882	57	15
mean (SE)	90 (18)	44 (3)	11 (2)	297 (63)	52 (2)	18 (1)

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

Table 20. Number of stock-length (n_s) Walleye, proportional size distribution (PSD, %), and proportional size distribution of preferred-length fish (PSD-P, %) collected by boat electrofishing during biological evaluation in the Columbia River below Bonneville Dam and in Bonneville Reservoir, 1990–2017. Mean and SE were calculated across the time series.

	Below Bonneville Dam			Bonneville Reservoir		
Year	n_s	PSD	PSD-P	n_s	PSD	PSD-P
1990	5	*a*	*a*	5	*a*	*a*
1991	8	*a*	*a*	7	*a*	*a*
1992	31	94	81	—	—	—
1993	0	*a*	*a*	1	*a*	*a*
1994	26	50	26	9	*a*	*a*
1995	19	*a*	*a*	10	*a*	*a*
1996	16	*a*	*a*	16	*a*	*a*
1999	9	*a*	*a*	6	*a*	*a*
2004	16	*a*	*a*	6	*a*	*a*
2005	4	*a*	*a*	2	*a*	*a*
2008	7	*a*	*a*	4	*a*	*a*
2011	18	*a*	*a*	22	86	41
2014	6	*a*	*a*	0	*a*	*a*
2017	12	*a*	*a*	10	*a*	*a*
mean (SE)	13 (2)	*b*	*b*	8 (2)	*b*	*b*

Note: *a* = no PSD or PSD-P value calculated ($n_s \leq 19$), dashes (—) = no sampling conducted, *b* = no mean calculated ($n \leq 2$).

Table 21. Number (*n*) of Northern Pikeminnow digestive tracts examined from Bonneville (2006–2017) and The Dalles (2007–2017) 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}	$\hat{p}_{\text{food}}$	$\hat{p}_{\text{fish}}$	$\hat{p}_{\text{crayfish}}$	$\hat{p}_{\text{other invert.}}$	$\hat{p}_{\text{misc.}}$	$\hat{p}_{\text{sal}}$	$\hat{p}_{\text{lam}}$	$\hat{p}_{\text{ash}}$	$\hat{p}_{\text{other fish}}$
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	345	118	0.73	0.37	0.03	0.44	0.24	0.07	0.14	0.13	0.08
2017	316	99	0.76	0.53	0.03	0.35	0.19	0.14	0.18	0.17	0.14
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	113	0.73	0.31	0.04	0.57	0.06	0.14	0.04	0.06	0.07
2017	202	127	0.61	0.30	0.05	0.48	0.10	0.11	0.07	0.09	0.08

Table 22. Proportion of all diet samples containing specific prey fish families for Northern Pikeminnow collected during the Dam Angling Fishery from the angling-accessible zones of the powerhouse tailraces of Bonneville (The Dalles Dam) and The Dalles (John Day Dam) reservoirs May–August 2017.

Common name (Family)	May[a] (*n* = 83)	June (*n* = 237)	July (*n* = 241)	August[b] (*n* = 187)	Total (*n* = 748)
lampreys (Petromyzontidae)	0.36	0.20	0.07	0.03	0.13
shad (Clupeidae)	0.00	0.00	0.02	0.52	0.14
minnows (Cyprinidae)	0.00	0.00	<0.01	0.09	0.02
catfish (Ictaluridae)	0.00	0.00	0.00	0.02	<0.01
salmon and trout (Salmonidae)	0.11	0.12	0.20	0.03	0.12
Mountain Whitefish (Salmonidae)	0.00	0.00	<0.01	0.00	<0.01
sunfishes (Centrarchidae)	0.00	0.00	0.02	0.06	0.02
sculpins (Cottidae)	0.01	0.01	<0.01	0.01	0.01
unidentified	0.07	0.07	0.07	0.06	0.07

Note: [a]Sampling began 10 May 2017, [b]sampling ended 24 August 2017. Multiple families may be represented in the gut contents of some individual fish. Sample sizes (*n*) listed below each month.

FIGURES

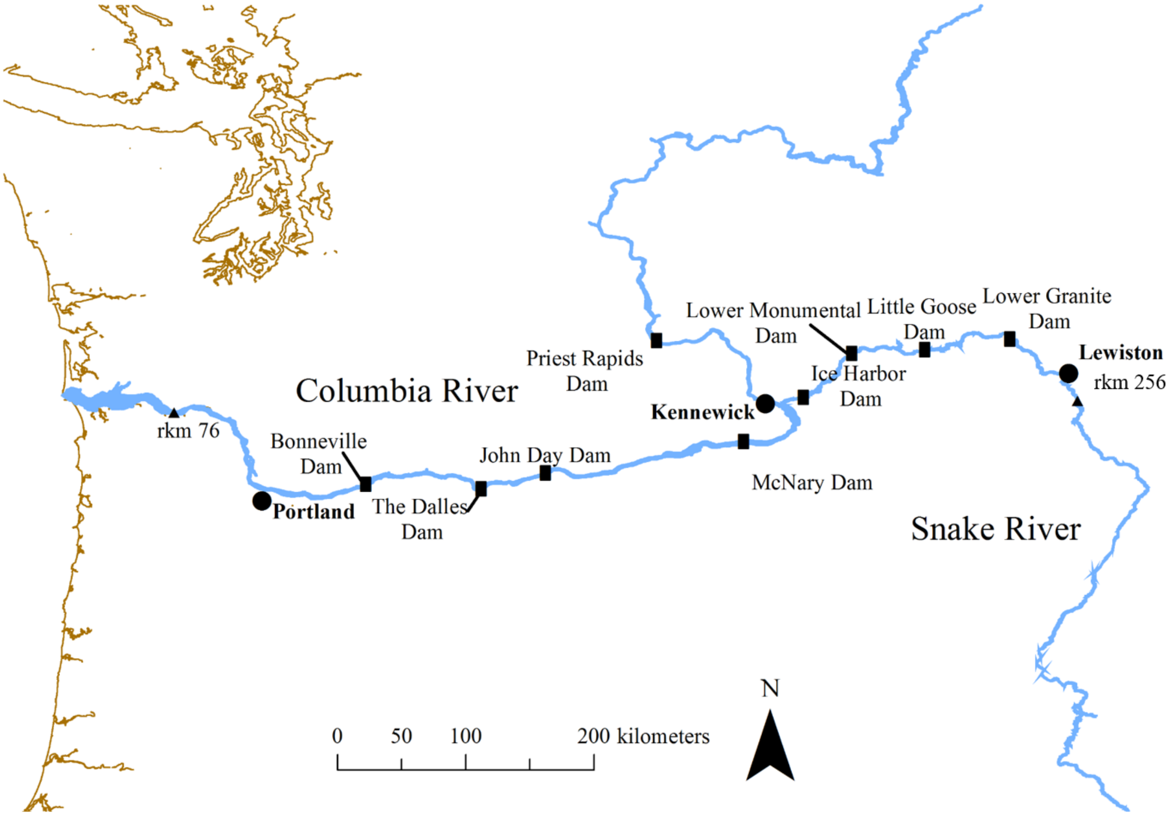

Figure 1. Study area in the Columbia and Snake rivers.

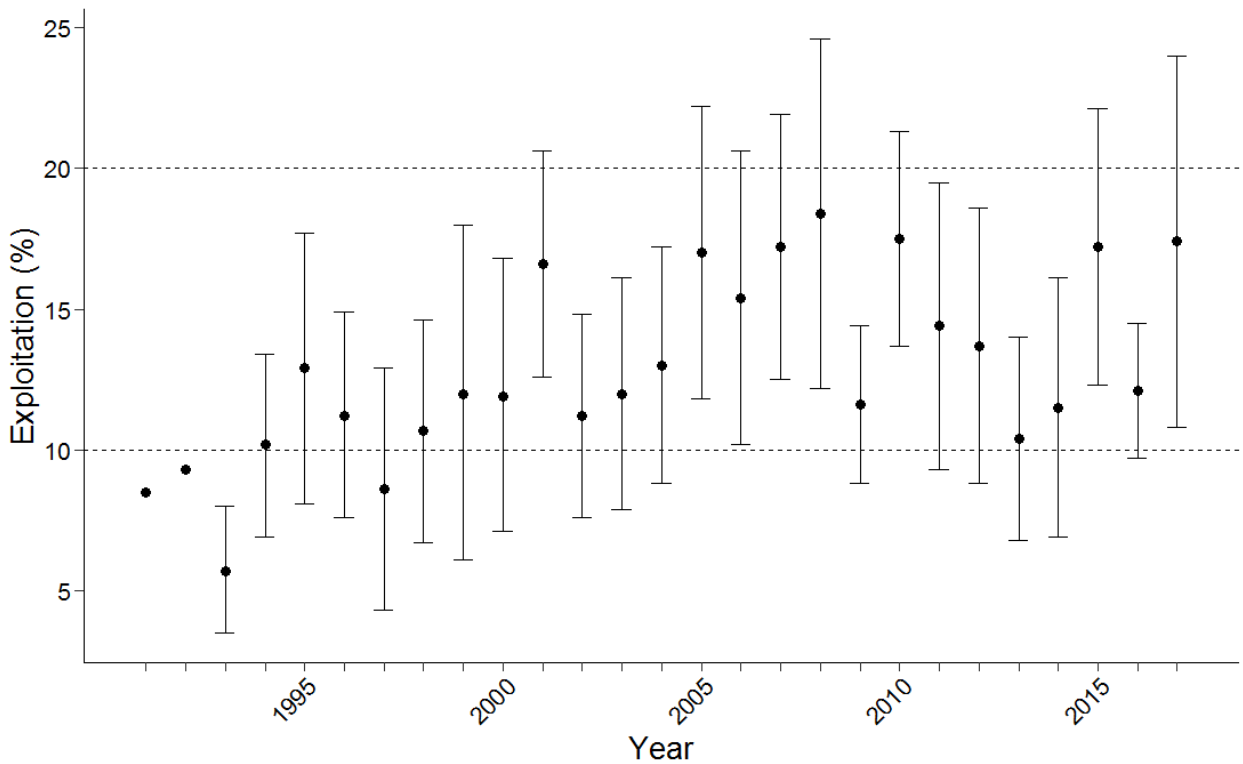

Figure 2. System-wide exploitation rates of Northern Pikeminnow (≥ 250 mm FL) in the Sport Reward Fishery, 1991–2017. Error bars represent 95% confidence intervals. Variation was not estimated for the years 1991–1992. Target exploitation is 10–20% (dashed lines).

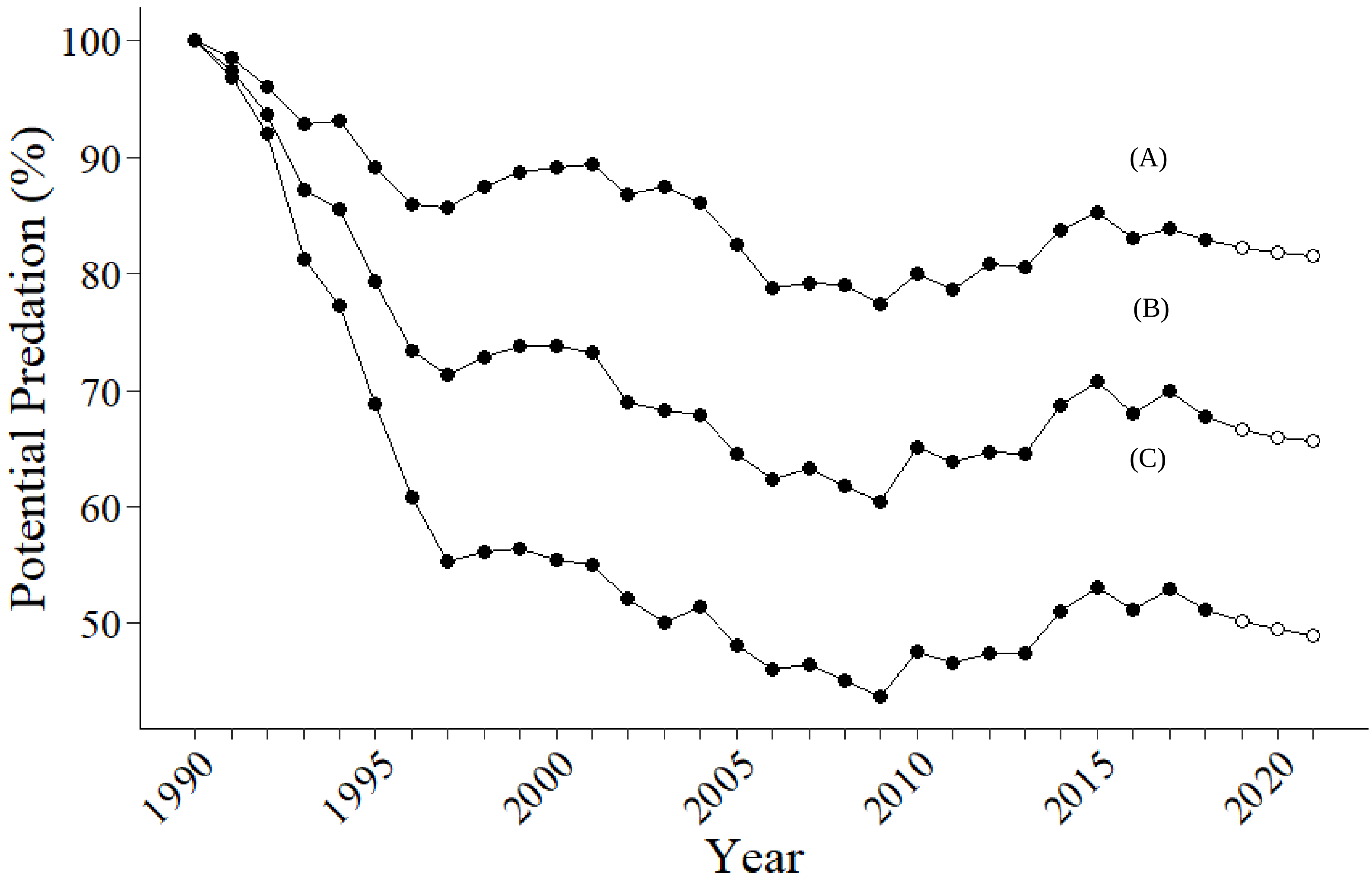

Figure 3. Estimates of (A) maximum, (B) median, and (C) minimum annual levels of potential predation by Northern Pikeminnow on juvenile salmon relative to predation levels before implementation of the Northern Pikeminnow Management Program. For the years 1991–2018, model estimates (filled circles) are based on exploitation levels from the previous year. Model forecast predictions after 2018 (open circles) are based on average exploitation estimates from years with similar fishery structure (2001, 2004–2017).

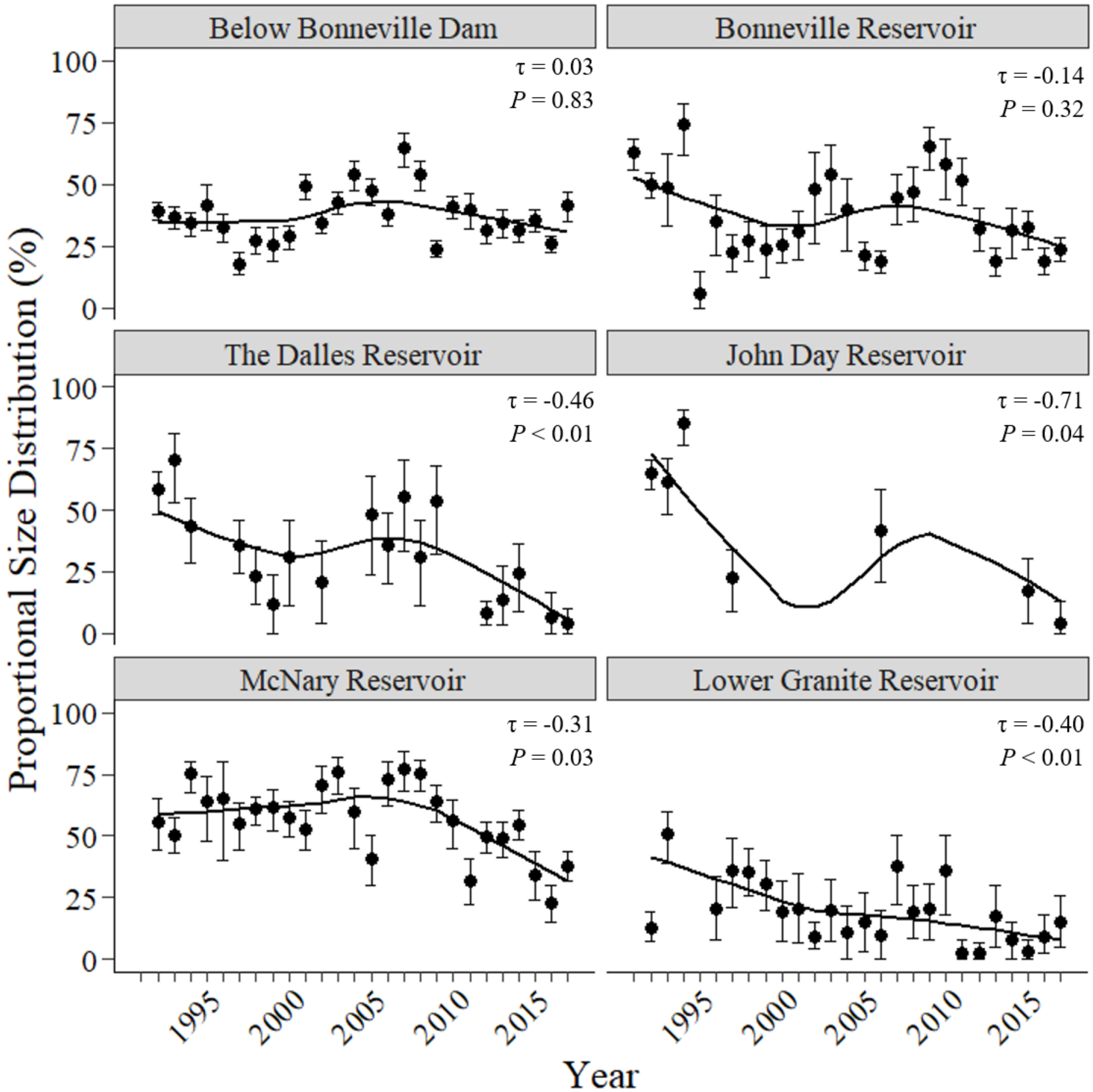

Figure 4. Estimates of proportional size distribution (PSD, %) for Northern Pikeminnow in the Columbia and lower Snake river, 1991–2017. Data were collected during fishery evaluation. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years with no data indicate sample sizes were insufficient for analysis ($n_s \leq 19$).

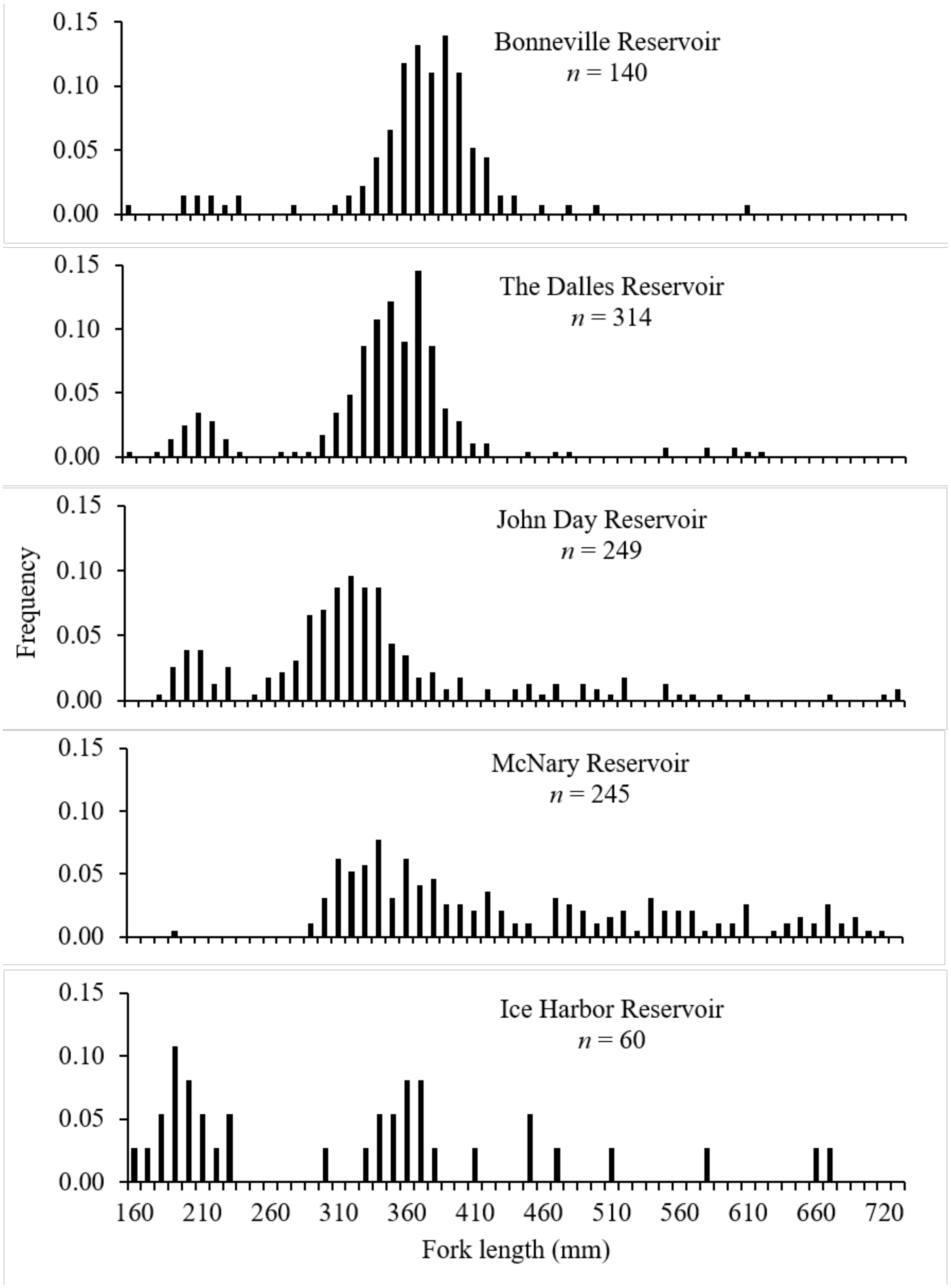

Figure 5. Length-frequency histogram of Walleye observed opportunistically during fishery evaluation during 2017 in the Columbia and lower Snake rivers. Size bins are 10 mm. Not shown are six Walleye observed below Bonneville Dam and three in Little Goose Reservoir.

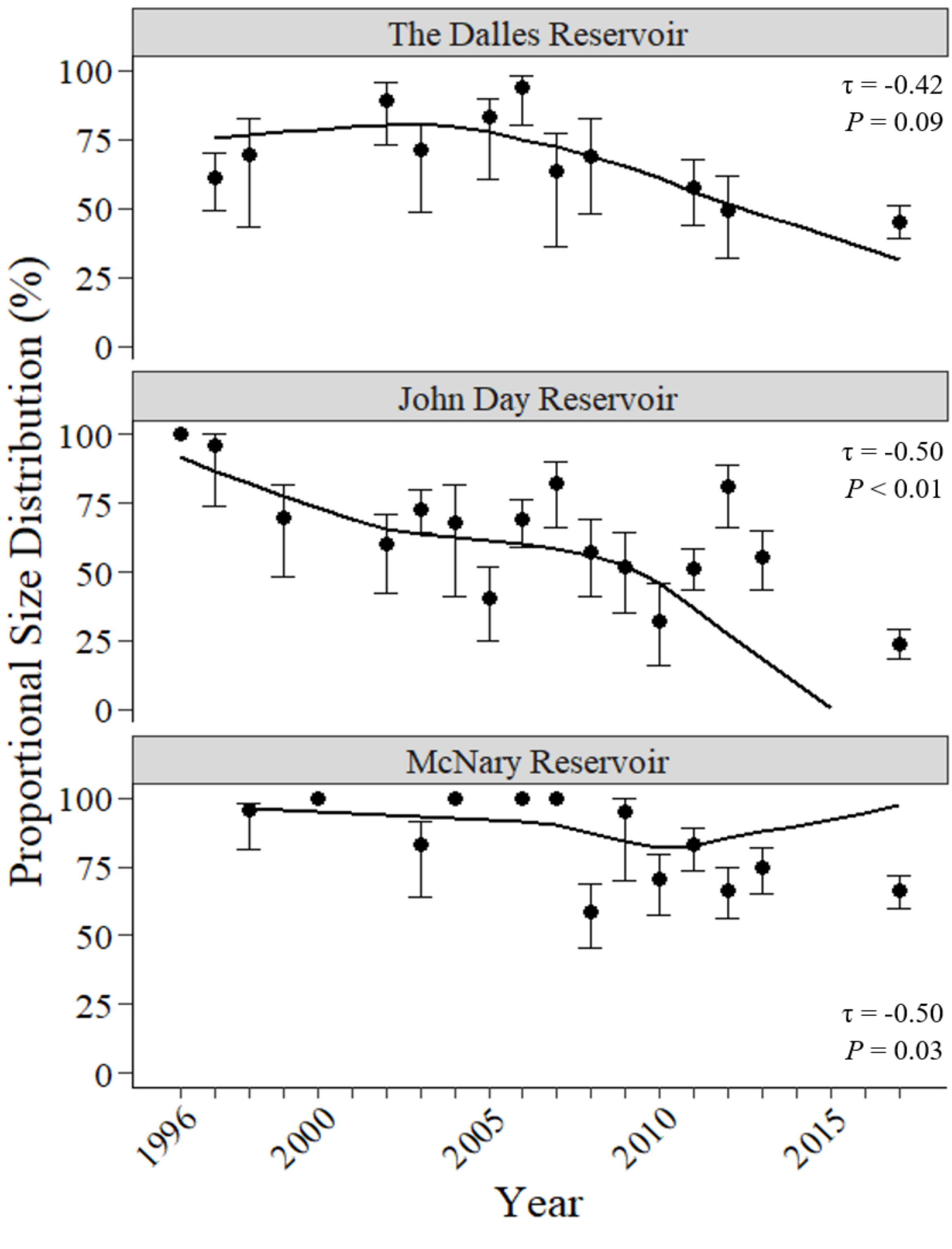

Figure 6. Estimates of proportional size distribution (PSD, %) of Walleye in The Dalles, John Day, and McNary reservoirs, 1996–2017. Data were collected during fishery evaluation. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years with no data indicate no sampling or sample sizes were insufficient for analysis ($n_s \leq 19$).

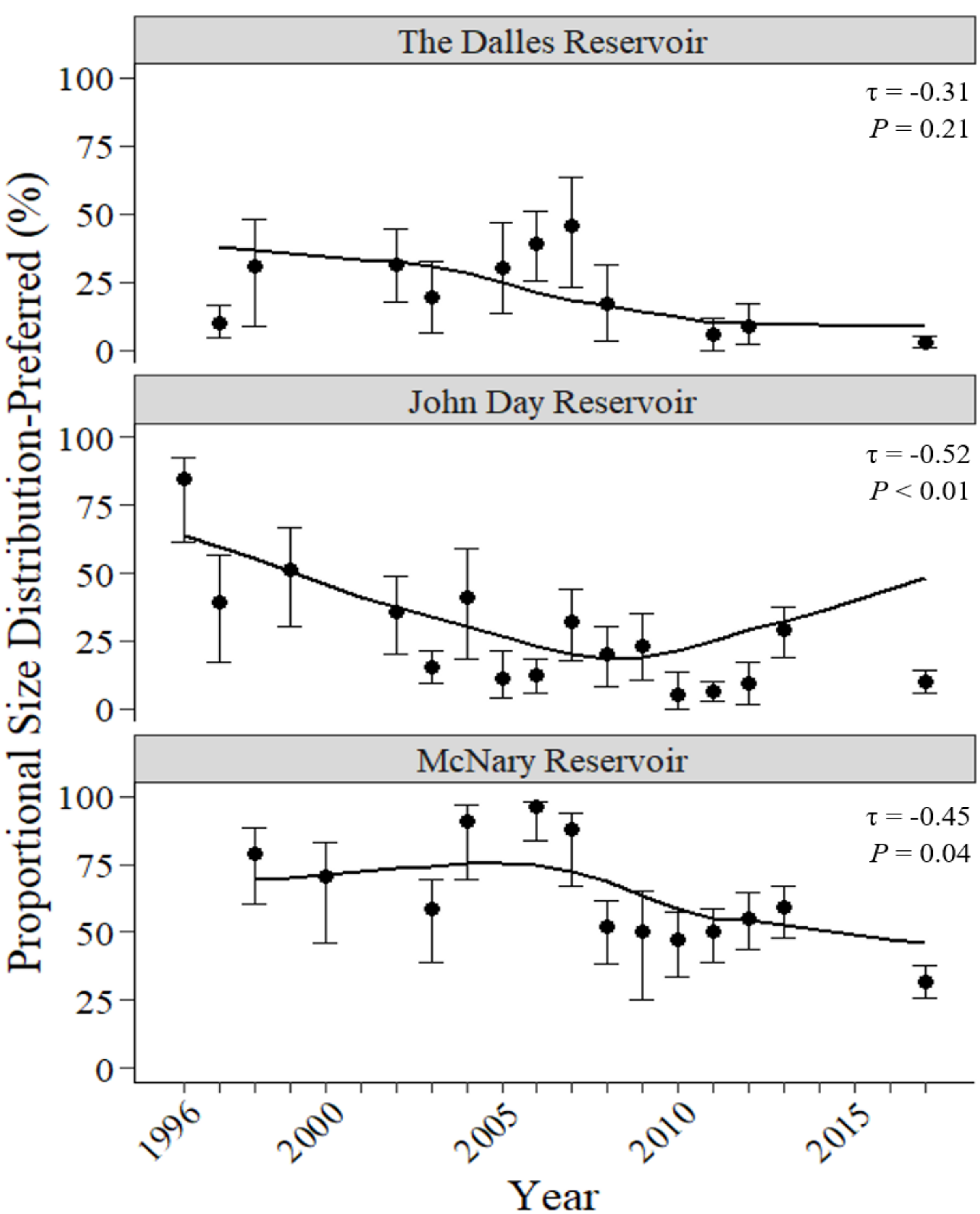

Figure 7. Estimates of proportional size distribution of preferred-length (PSD-P, %) Walleye in The Dalles, John Day, and McNary reservoirs, 1996–2017. Data were collected during fishery evaluation. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years with no data indicate no sampling or sample sizes were insufficient for analysis ($n_s \leq 19$).

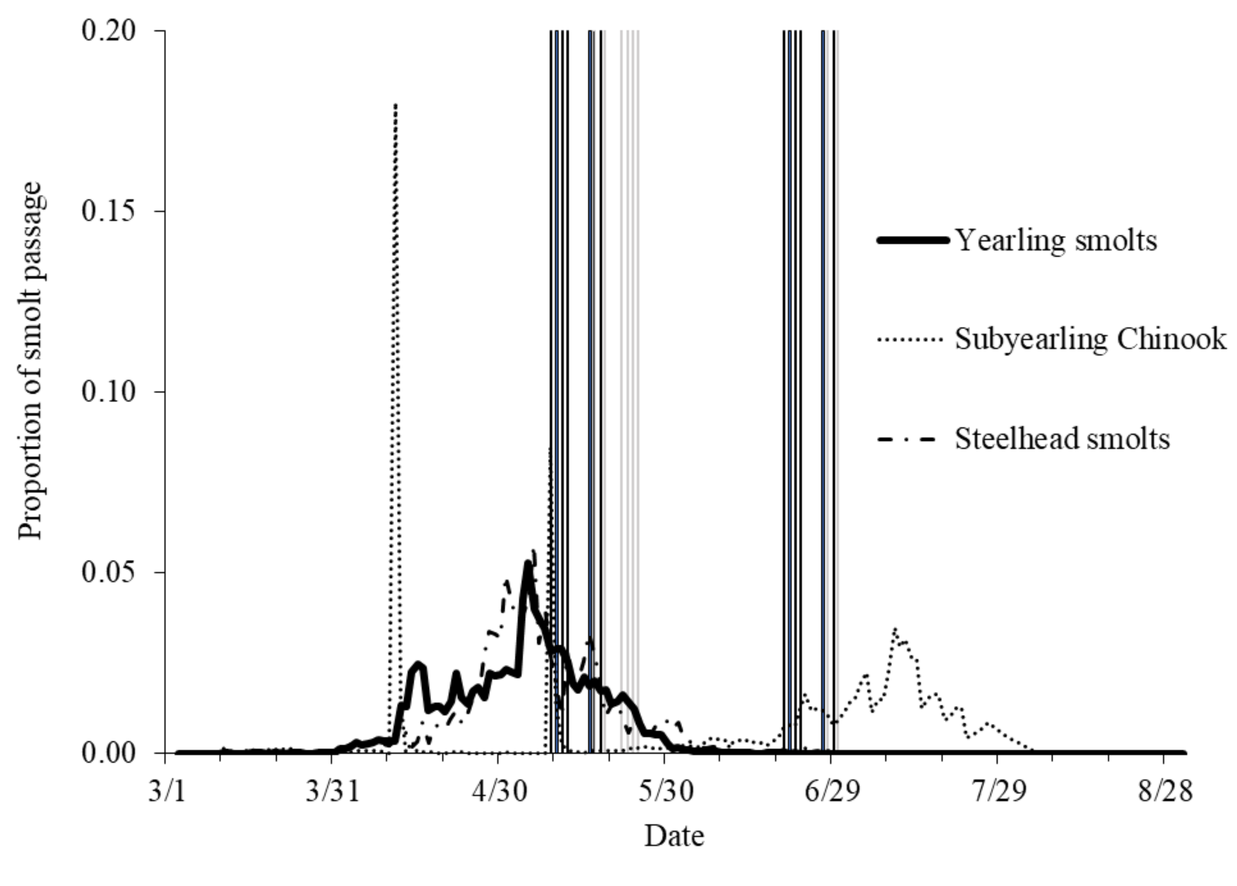

Figure 8. Periods of index sampling in the Columbia River below Bonneville Dam (light gray bars), Bonneville Reservoir (dark gray bars), and index of juvenile salmon and steelhead passage through Bonneville Dam, March–August 2017 (Fish Passage Center, unpublished data). Passage data are daily smolt passage index values standardized to total passage from 1 March–31 August 2017. Index sampling periods for Bonneville Reservoir are superimposed on passage data collected at Bonneville Dam because no comparable data exist for The Dalles Dam.

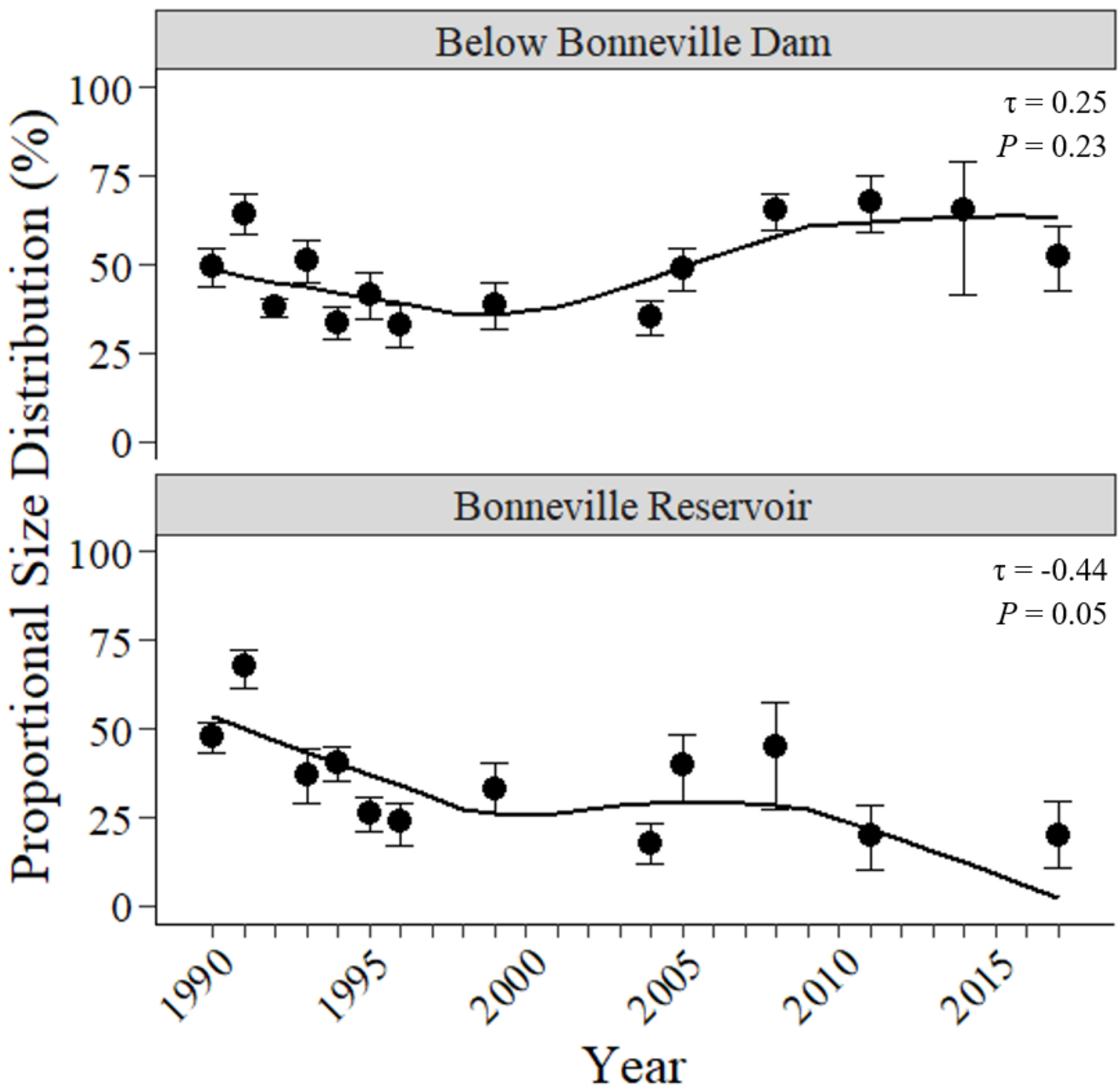

Figure 9. Estimates of proportional size distribution (PSD, %) of Northern Pikeminnow collected during biological evaluation in the Columbia River below Bonneville Dam and in Bonneville Reservoir, 1990–2017. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years with no data indicate sampling was not conducted or sample sizes were insufficient for analysis ($n_s \leq 19$).

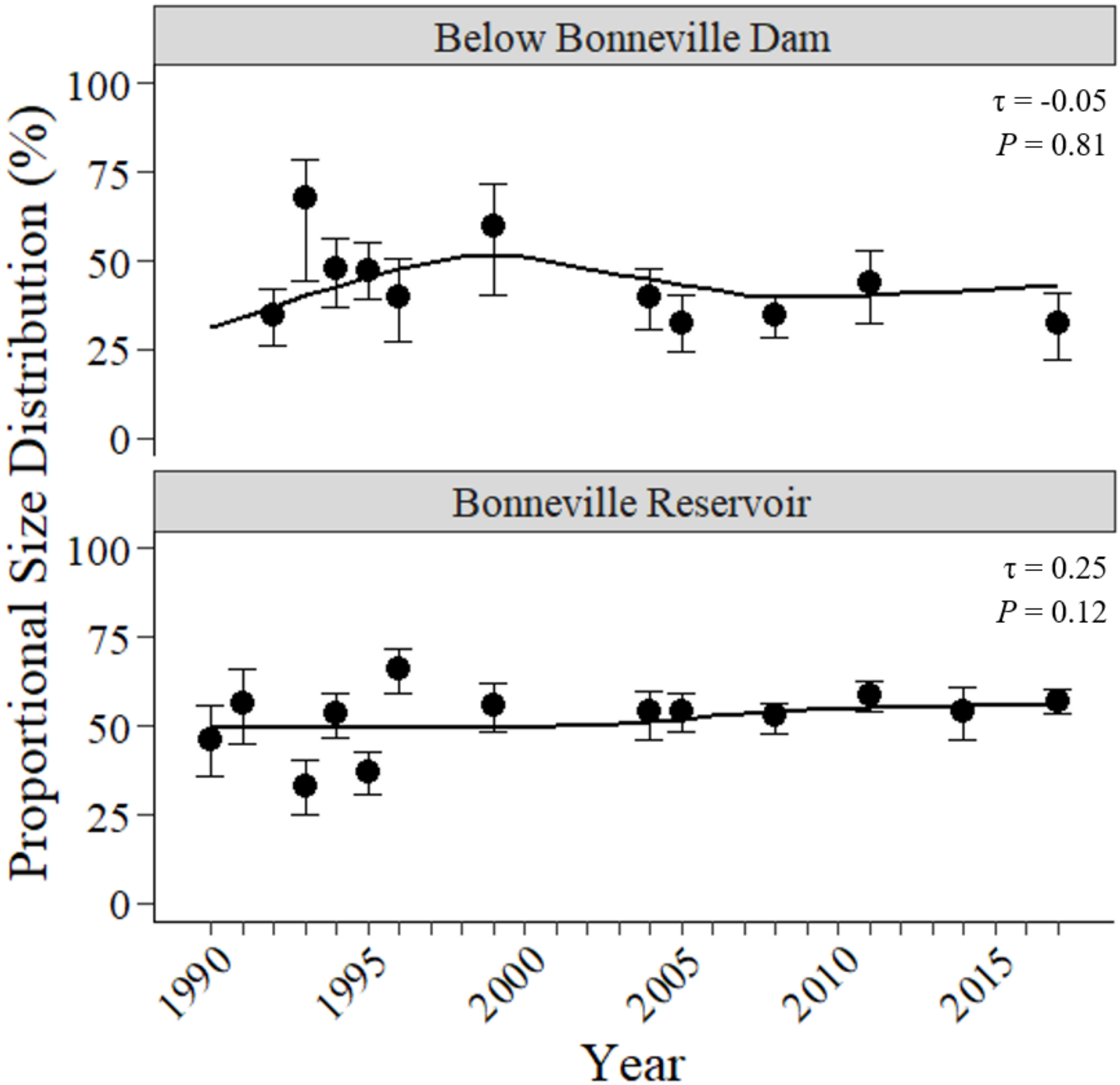

Figure 10. Estimates of proportional size distribution (PSD, %) of Smallmouth Bass collected during biological evaluation in the Columbia River below Bonneville Dam and in Bonneville Reservoir, 1990–2017. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years with no data indicate sampling was not conducted or sample sizes were insufficient for analysis ($n_s \leq 19$).

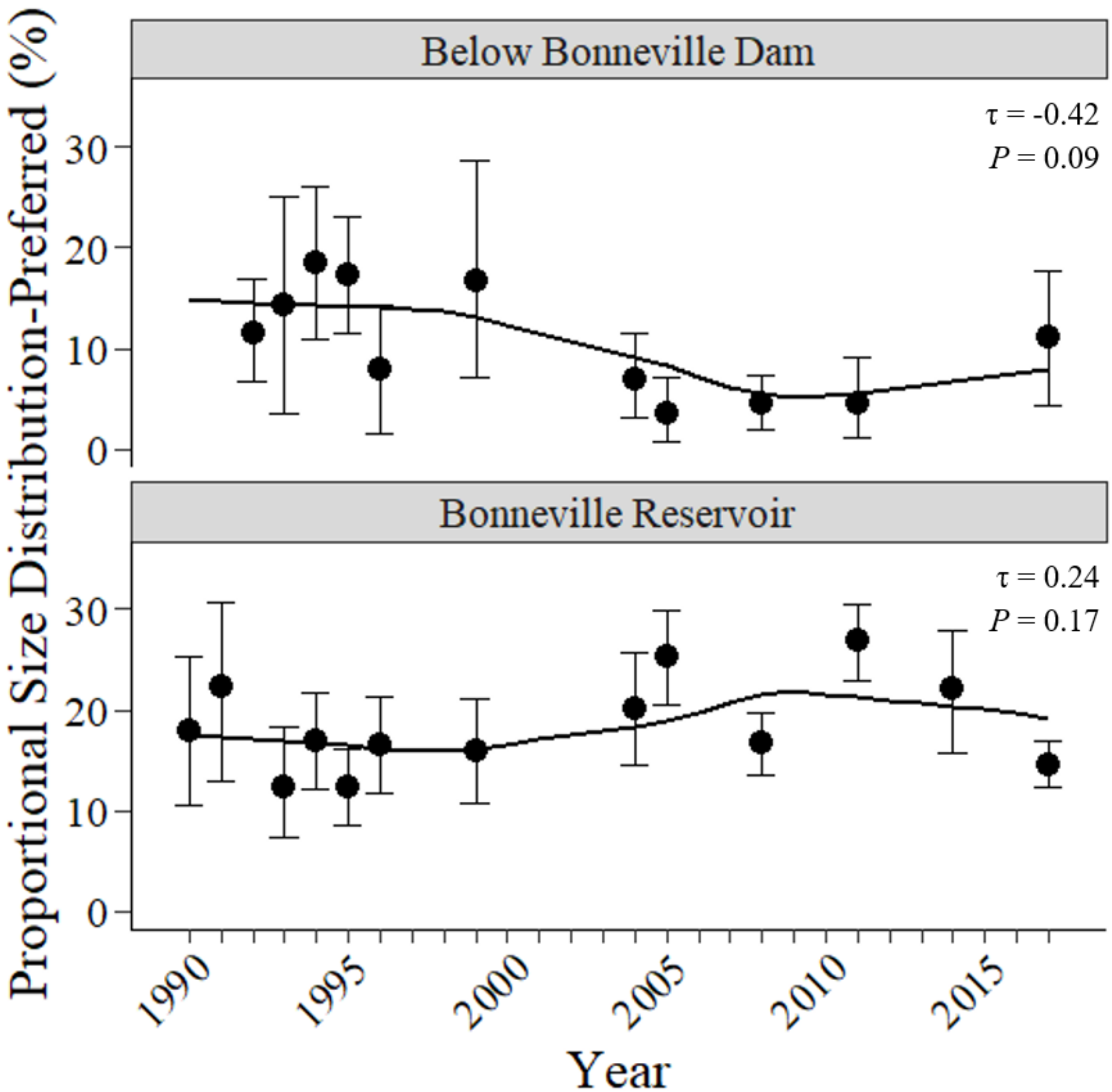

Figure 11. Estimates of proportional size distribution of preferred-length (PSD-P, %) Smallmouth Bass collected during biological evaluation in the Columbia River below Bonneville Dam and in Bonneville Reservoir, 1990–2017. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS 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 sample sizes were insufficient for analysis ($n_s \leq 19$).

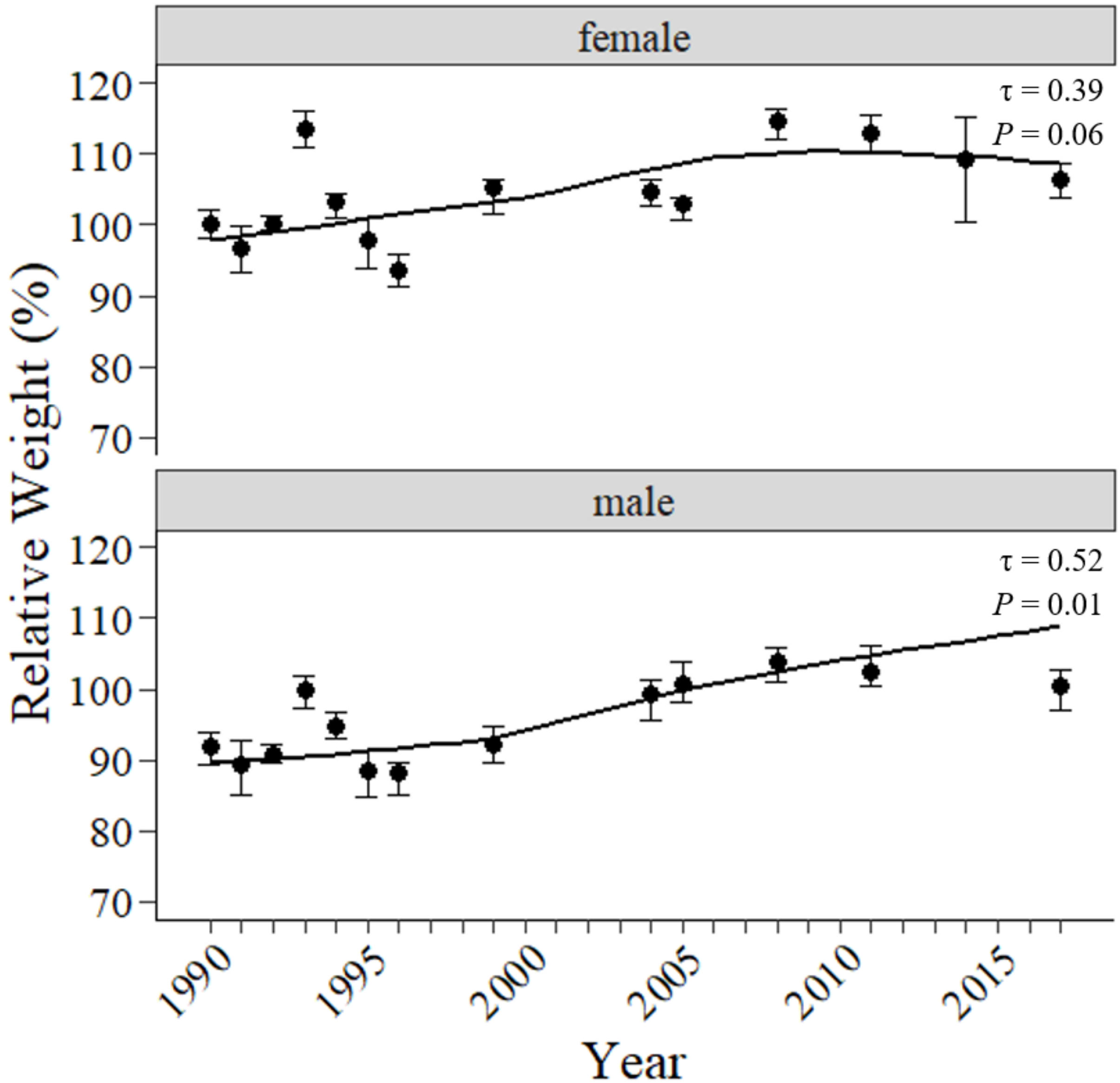

Figure 12. Median relative weight (W_r, %) for female and male Northern Pikeminnow collected during biological evaluation in the Columbia River below Bonneville Dam, 1990–2017. Error bars represent 95% bootstrap (percentile) confidence intervals. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years with no data indicate sampling was not conducted or sample sizes were insufficient for analyses.

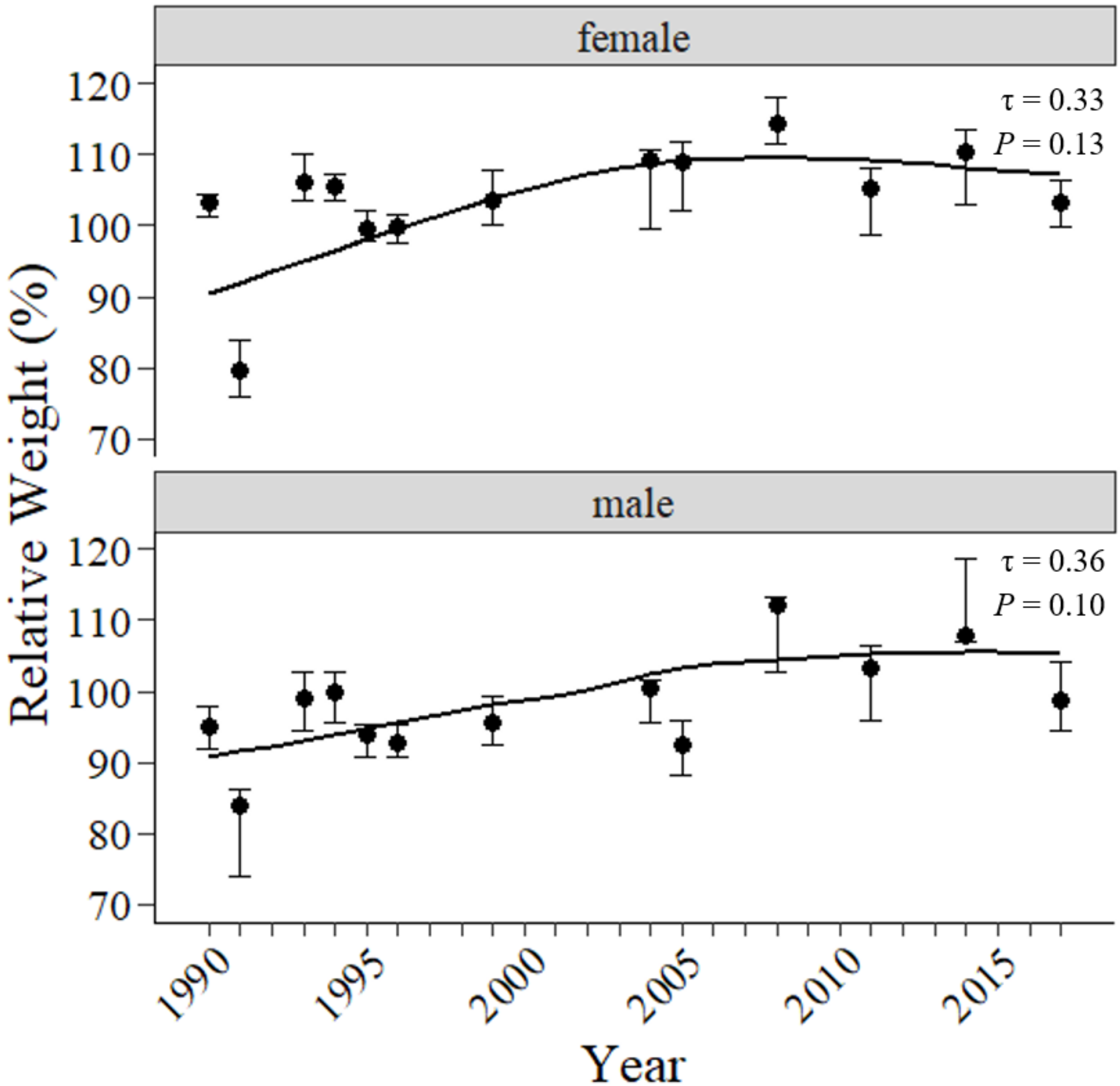

Figure 13. Median relative weight (W_r, %) for female and male Northern Pikeminnow collected during biological evaluation in Bonneville Reservoir, 1990–2017. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years with no data indicate sampling was not conducted or sample sizes were insufficient for analyses.

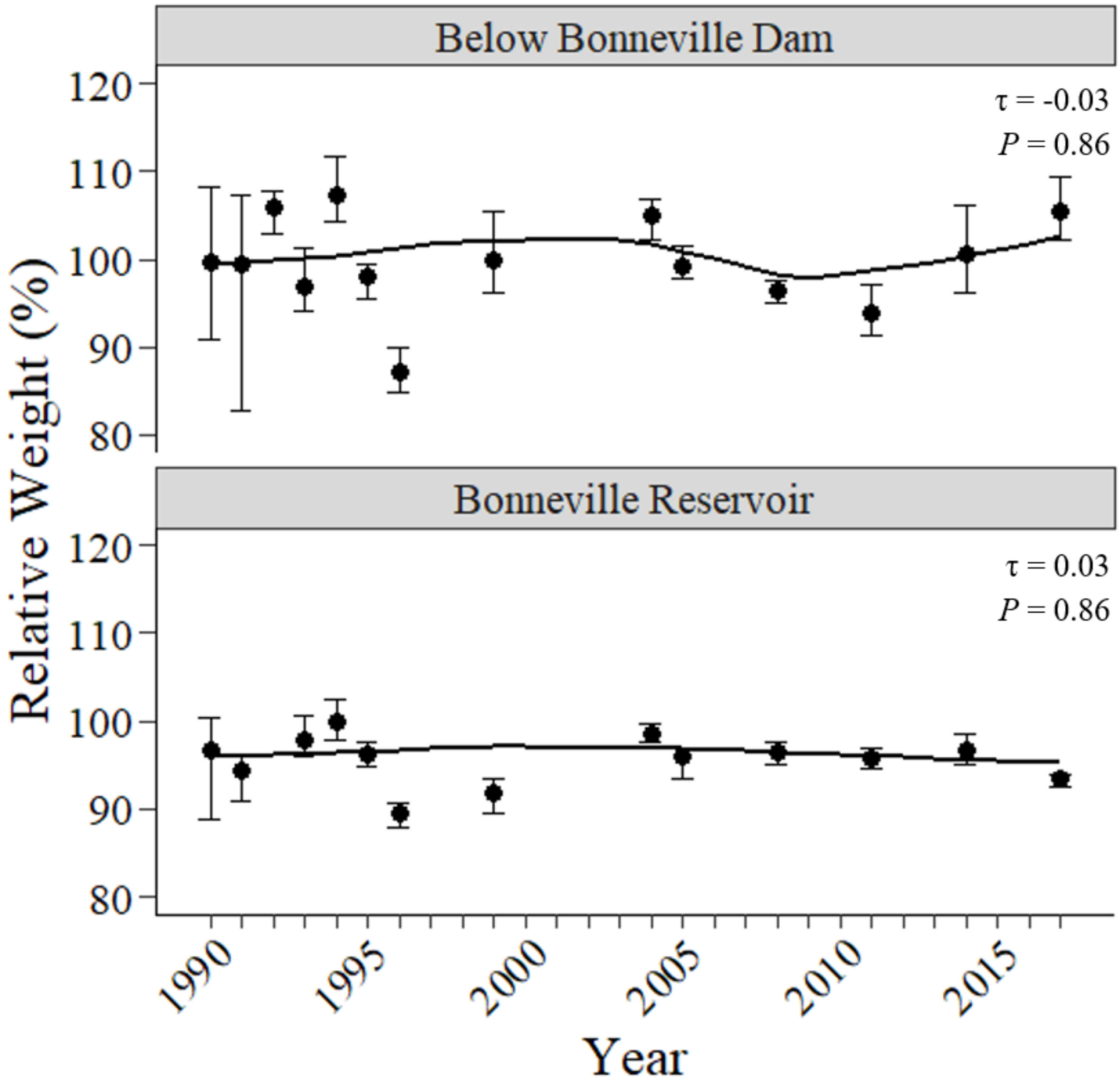

Figure 14. Median relative weight (W_r, %) for Smallmouth Bass collected during biological evaluation in the Columbia River below Bonneville Dam and in Bonneville Reservoir, 1990–2017. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years with no data indicate sampling was not conducted or sample sizes were insufficient for analyses.

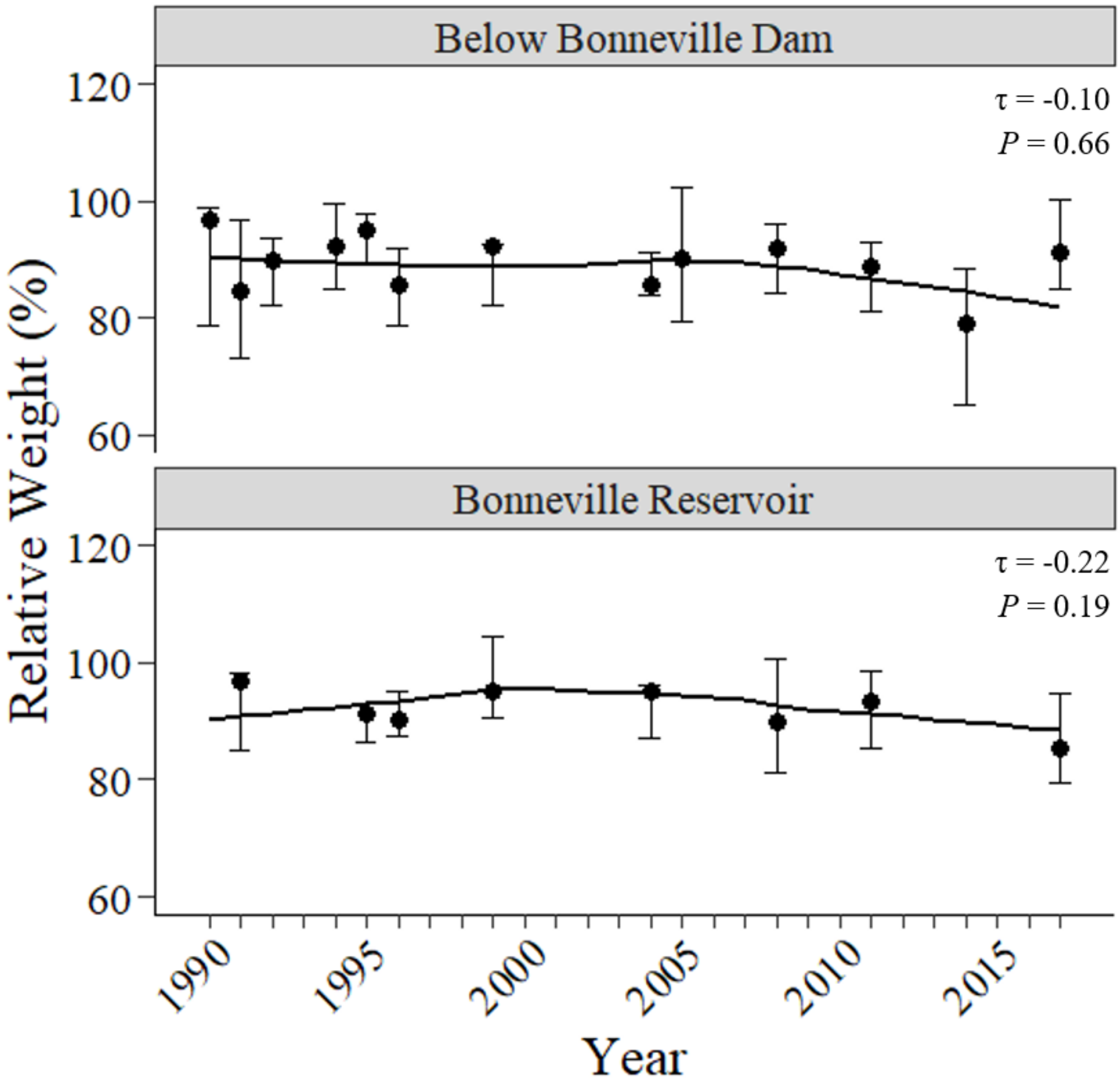

Figure 15. Median relative weight (W_r, %) for Walleye collected during biological evaluation in Columbia River below Bonneville Dam and Bonneville Reservoir, 1990–2017. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with a LOWESS curve. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years with no data indicate sampling was not conducted or sample sizes were insufficient for analyses.

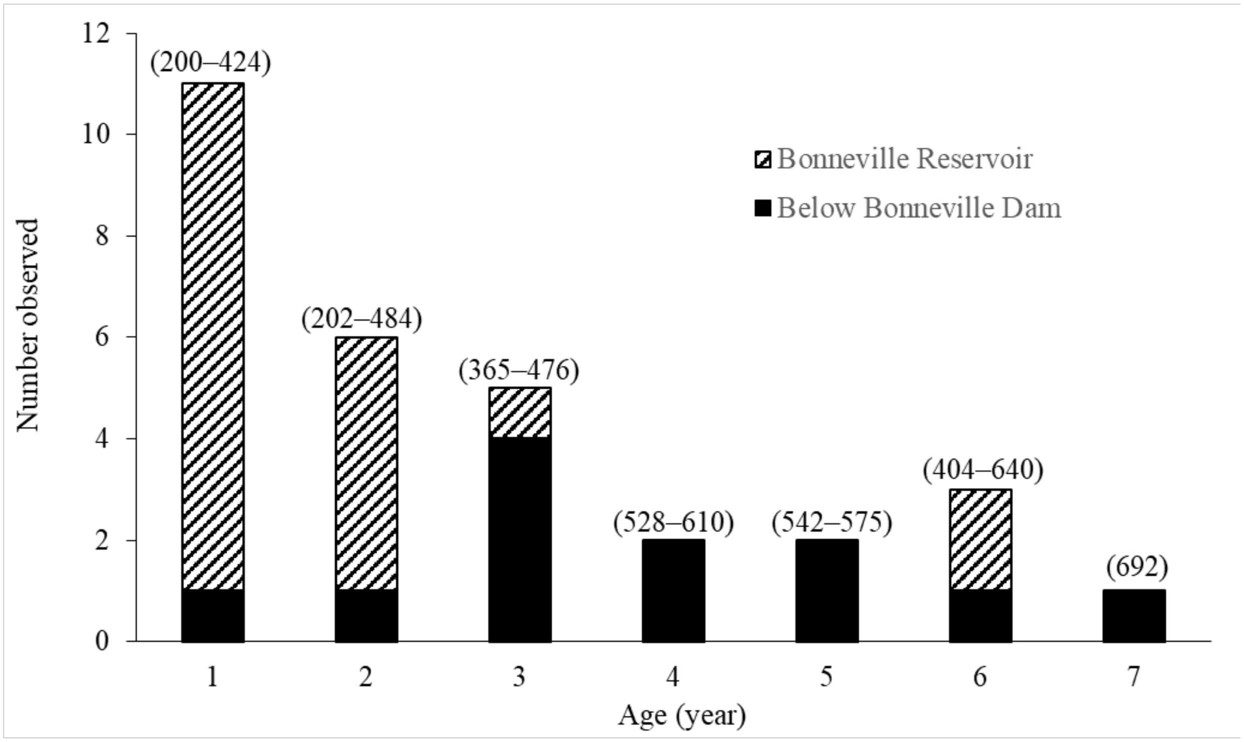

Figure 16. Number of Walleye observed at age in Bonneville Reservoir (*n* = 18) and below Bonneville Dam (*n* = 12) in the samples collected by boat electrofishing during biological evaluation, 2017. Numbers in parentheses above bars indicate the range of fish FL (mm) for each age (year).

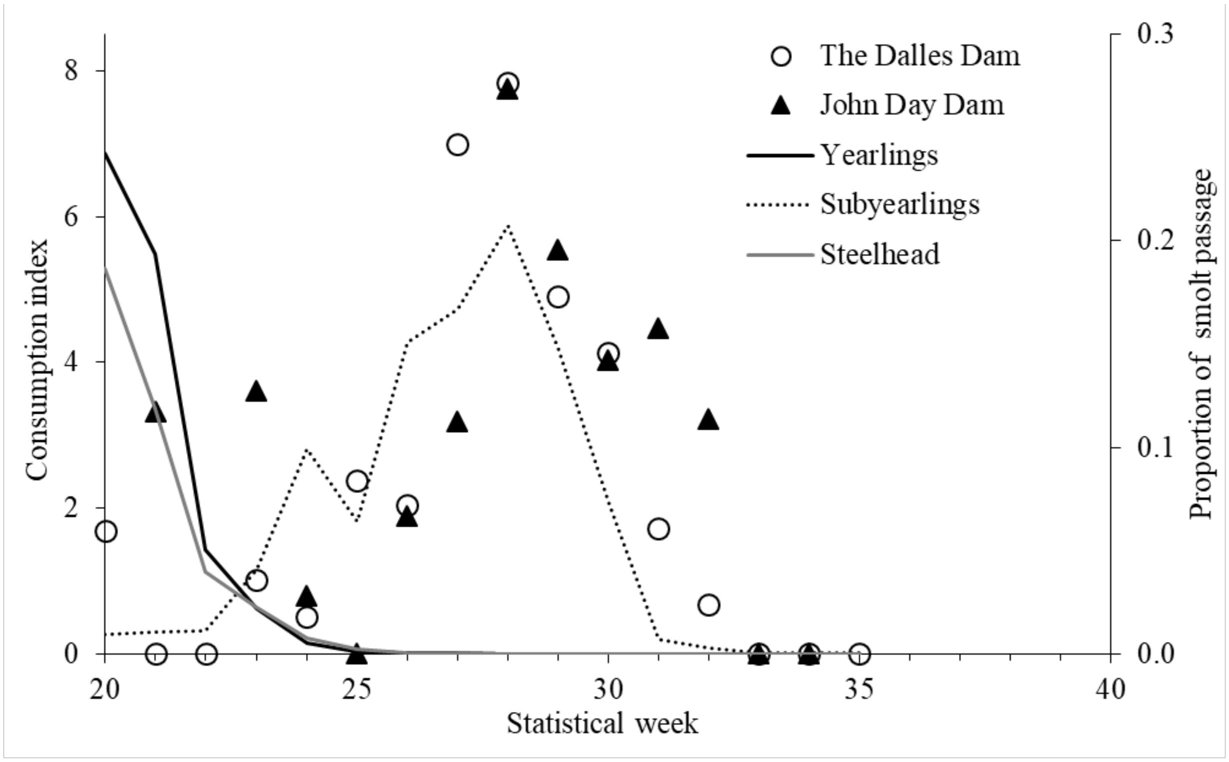

Figure 17. Mean weekly juvenile salmon consumption index for Northern Pikeminnow captured from the Dam Angling Fishery in Bonneville (open circles) and The Dalles (filled triangles) reservoirs compared with the smolt passage index at John Day Dam, 2017. Smolt passage data are summarized from Fish Passage Center (unpublished data).

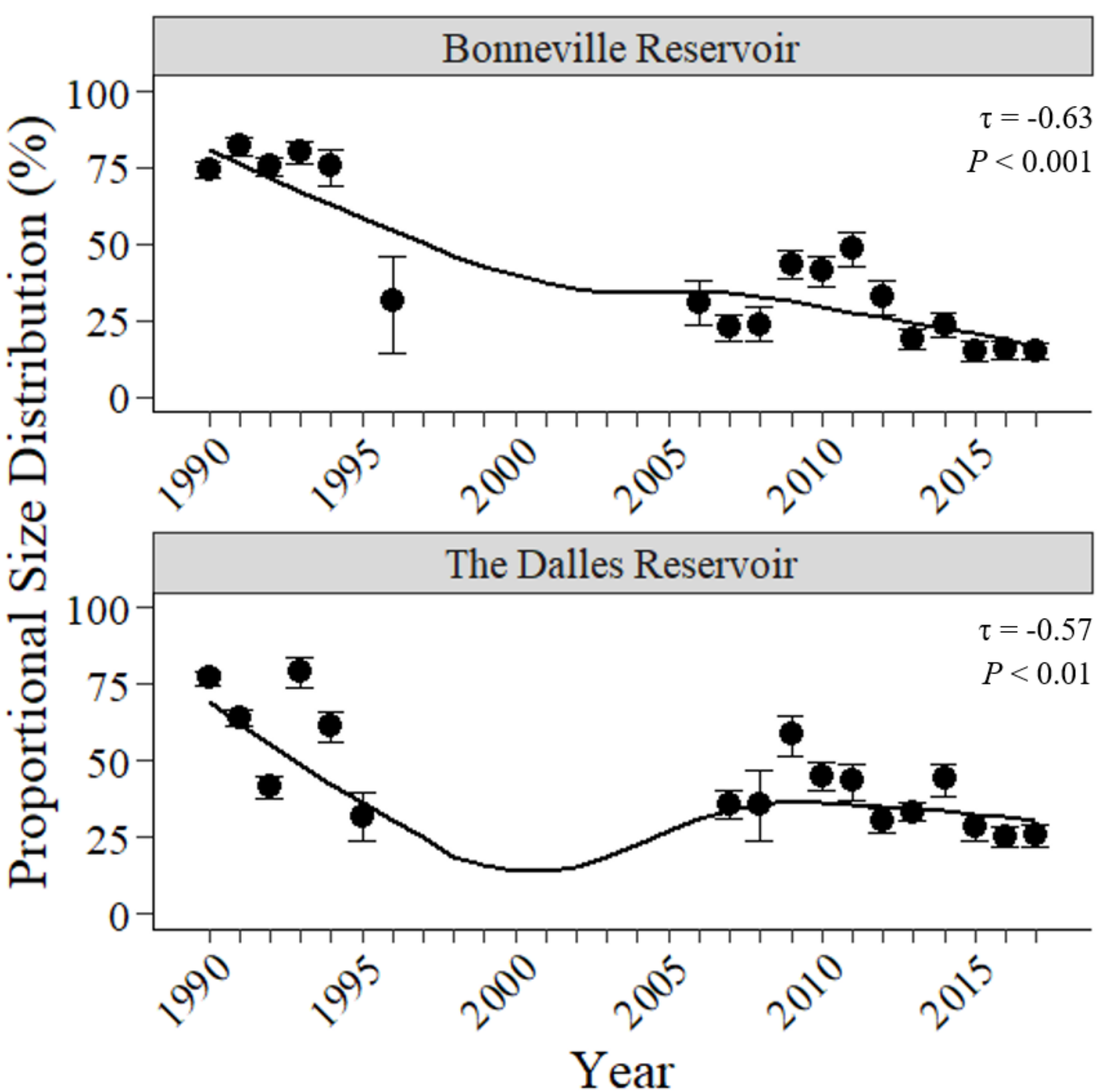

Figure 18. Estimates of proportional size distribution (PSD, %) of Northern Pikeminnow sampled in Bonneville and The Dalles reservoirs during the Dam Angling Fishery, 1990–2017. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years with no data indicate sampling was not conducted or sample sizes were insufficient for analyses ($n_s \leq 19$).

REPORT D

Northern Pikeminnow Dam Angling on the Columbia River

2017 Annual Report

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We appreciate the efforts of Scott Mengis as the Pikeminnow Dam Angling crew leader, along with Kyle Beckley, Tim Levandowsky and Lyndon Watkins who served as our 2017 dam angler crew.

We also recognize Diana Murillo and Dennis Werlau for their work on Dam Angler data entry and document verification, and Dennis Werlau for producing the Dam Angling Weekly Field Activity Reports throughout the 2017 season.

ABSTRACT

We are reporting on the 2017 Northern Pikeminnow Dam Angling component of the Northern Pikeminnow Management Program (NPMP) as implemented by the Washington Department of Fish and Wildlife (WDFW). Angling took place within the boat restricted tailrace areas of The Dalles and John Day dams during 23 weeks from May 4th through October 4th 2017. 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 zones (BRZs) unavailable to Northern Pikeminnow Sport-Reward Fishery (NPSRF) anglers and 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 Dam 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 predation studies, (5) collect relevant biological data on all Northern Pikeminnow and other fishes caught by the 2017 Dam Angling crew.

A Dam Angling crew of four anglers harvested 5,248 Northern Pikeminnow during the 2017 season. Of those, 1,776 Northern Pikeminnow were harvested at The Dalles Dam and 3,472 were harvested at the John Day Dam. The crew fished a total of 1,821 hours during the 23 week fishery, averaging 228 fish per week and for a combined overall average catch per angler hour (CPUE) of 2.9 Northern Pikeminnow. At The Dalles Dam, the crew averaged 2.3 fish per angler hour, and cumulatively 30 Northern Pikeminnow per day. At the John Day Dam, the crew averaged 3.3 fish per angler hour with a cumulative crew total of 53 fish per day.

Based on the success of the WDFW Dam Angling crew in implementing the Dam Angling project from 2010-16, the 2017 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 2017 were Smallmouth Bass *Micropterus dolomieue* and Walleye *Sander vitreus.*

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 contracted to conduct the Dam Angling component of the NPMP and 2017 marks the eighth 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 2017.

The objectives of the 2017 Dam Angling component of the NPMP were to (1) implement a recreational-type hook and line fishery harvesting Northern Pikeminnow from within the boat restricted zones (BRZs), where angling is 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 Dam 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 2017 Dam Angling crew.

METHODS

Project Area

In 2017, as a continuing supplemental component to the NPMP, Northern Pikeminnow removal activities were conducted at The Dalles and John Day Dams on the Columbia River utilizing a Dam Angling crew. (Figure 1). Dam Angling activities in 2017 were planned for a five month season scheduled to be from May through September. At both The Dalles, and John Day Dams, all angling activities were conducted within the tailrace BRZs 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).

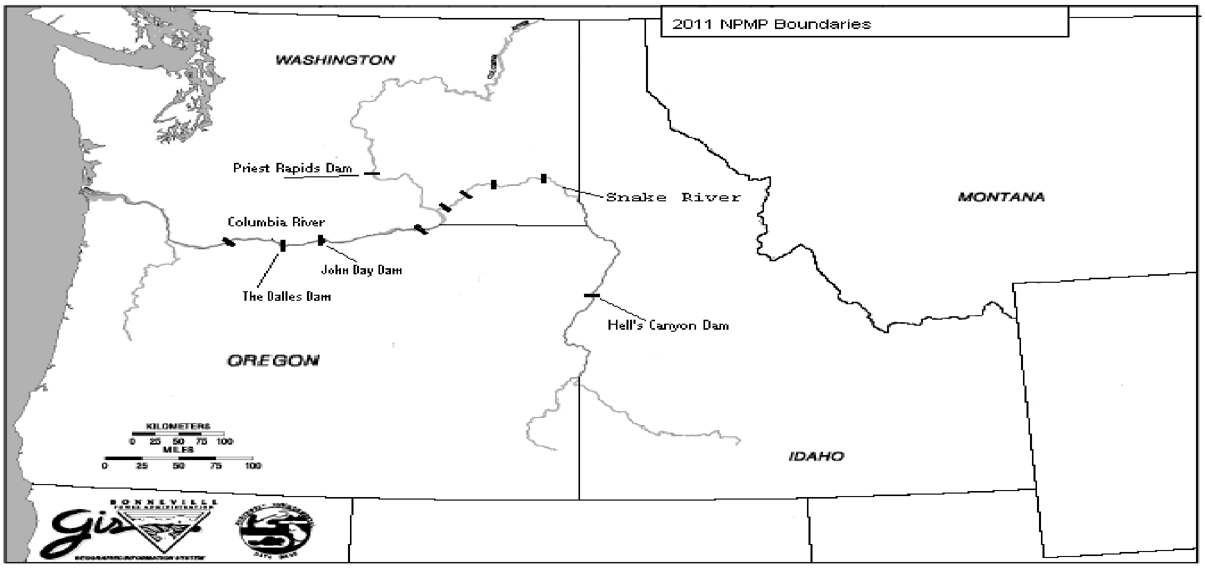

Figure 1. Northern Pikeminnow Management Program Boundaries, including 2017 Dam Angling sites

Figure 2. Angling Locations for the 2017 Dam Angling Crew at The Dalles Dam

Figure 3. Angling Locations for the 2017 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 in 2017, WDFW continued to use the Dam Angling Strategy (DAS) developed in 2011 (Dunlap et al. 2012) where 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 2017 Dam Angler CPUE goal remained set at 2.0 fish/angler hour as established in our original 2011 DAS.

The Dam Angling Crew

The four member Dam Angling crew typically worked four ten hour days a week, (usually Tuesday - Friday) during the 2017 season (Figure 4). Angling start times in the morning 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. As part of the four person angling crew, a crew leader was present each day to ensure angler safety and supervision, to collect, record and compile data on Northern Pikeminnow harvest, other fish species caught, and so 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 a 4-6” 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.

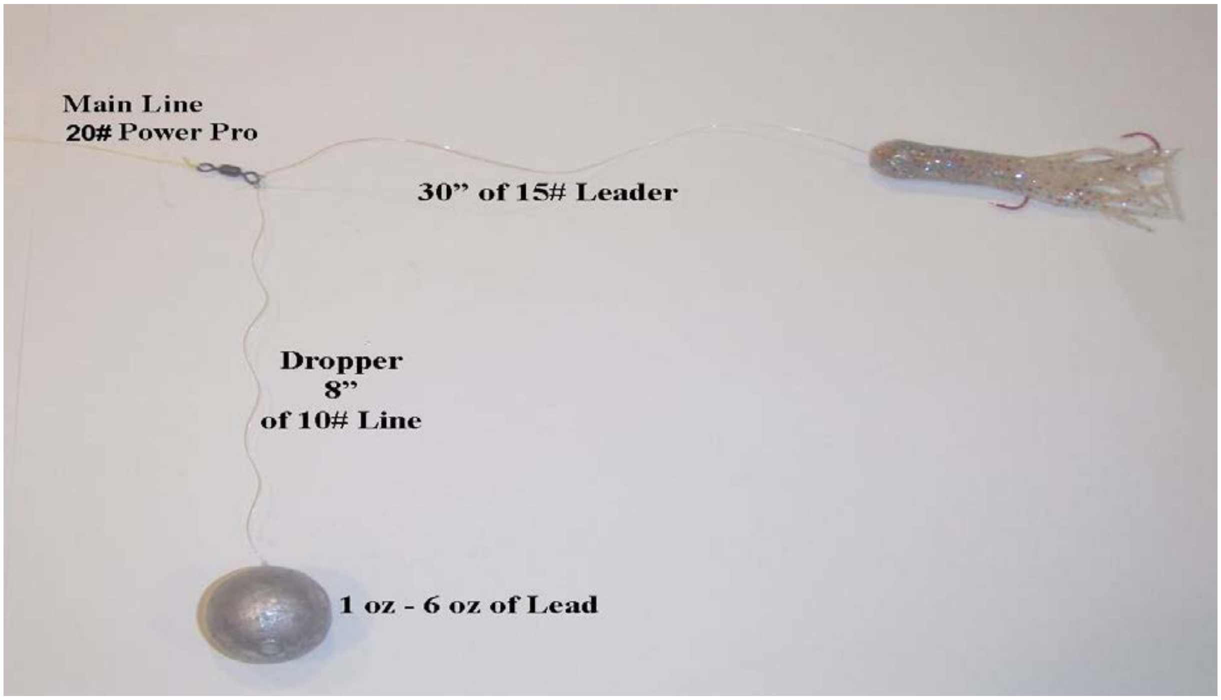

Figure 5. Example of Typical Rigging Used by 2017 NPMP Dam Anglers

Figure 6. Examples of Soft Plastic Tube Baits Used by 2017 NPMP Dam Anglers

Data collection

Creel data were recorded onto data sheets by each individual angler for each angling day. Angler data sheets were then combined and summarized into daily crew totals, which were then combined into weekly crew totals submitted for each of the two projects (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 lures used (and number of fish caught with each color/type 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 were recorded on a NPSRF tag envelopes and all tag data were submitted to WDFW Tag Lead Biologist for processing. Processed tag recovery data were then provided to ODFW for NPMP exploitation estimates.

PIT Tag Detection

All Northern Pikeminnow collected by Dam Anglers during 2017 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 Biomark portable transceivers (model #HPR.PLUS.04V1). Technicians also scanned all incidental catches of Walleye, Smallmouth Bass and Channel Catfish for PIT tags from ingested salmonids. 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 Northern 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 Tag Lead Biologist and entered into the PIT Tag Information System (PTAGIS) and provided to ODFW.

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

2017 Dam Angling Season

The 2017 Dam Angling Season took place from May 4th through October 4th. River conditions were challenging and harvest was low during the first four weeks of the season (weeks 18-21) as reflected in Figure 7. Harvest did not really start to take off until high spring runoff receded in week 22, and then remained good through week 32. Late season angling was also challenging as Northern Pikeminnow in larger numbers could not be consistently found. Total harvest for The Dalles and John Day dams combined was 5,248 Northern Pikeminnow in 1,821 angling hours, with a combined CPUE of 2.9 fish per angler hour. The dam angling crew exceeded the CPUE goal of 2.0 fish/angler hour in week 22, and remained above it through week 32 during the 2017 season (Figure 8). Per our DAS protocol, weeks with CPUE under the 2.0 fish/angler hour goal were typically due to the Dam Angling Crew deploying only a partial crew (< 50% effort) and "prospecting", to locate and/or determine if catchable numbers of fish were present and/or available.

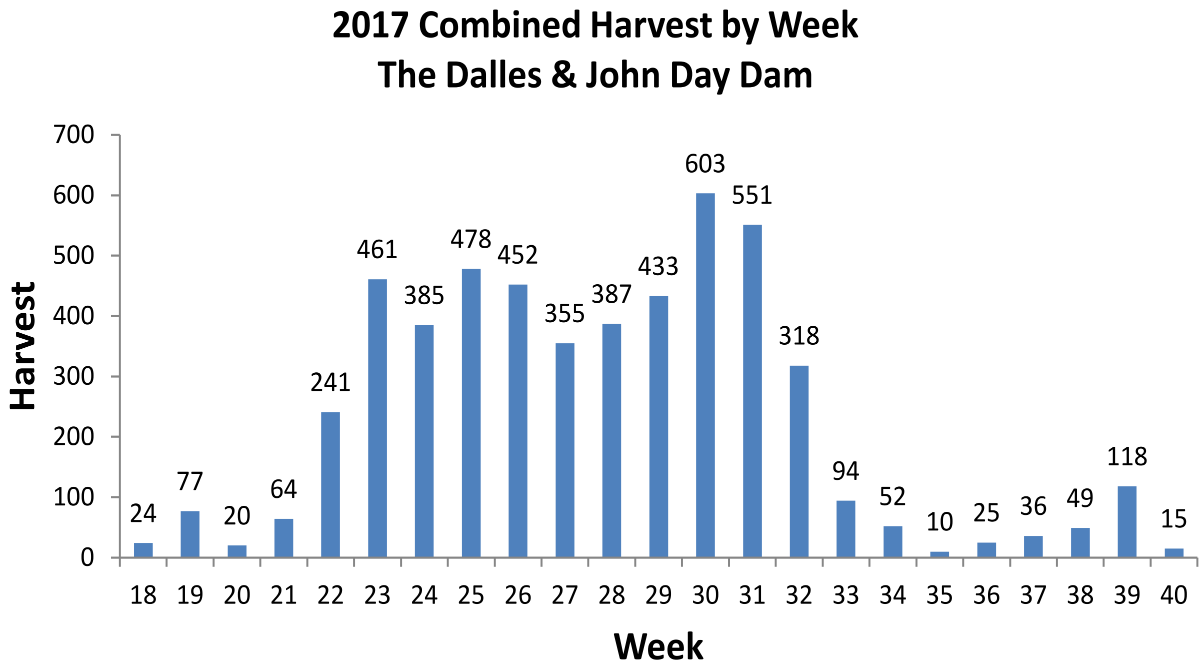

Figure 7. 2017 Weekly Harvest of The Dalles (TD) and John Day (JD) dams Combined

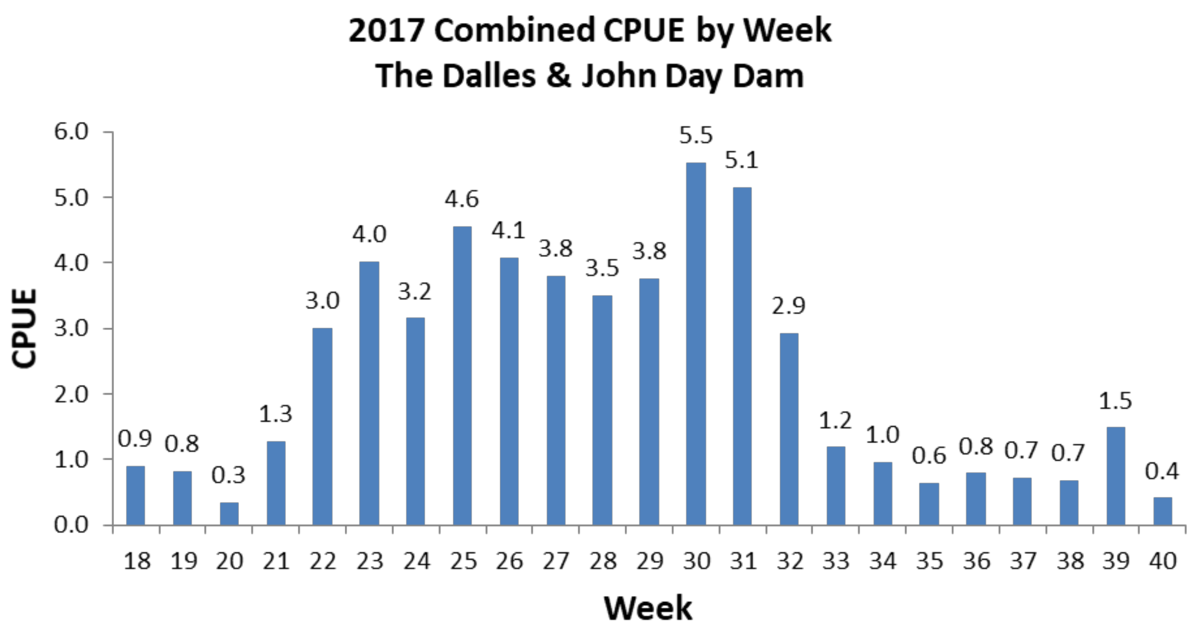

Figure 8. 2017 Weekly CPUE (fish/angler hour) of The Dalles (TD) and John Day (JD) dams Combined

Angling Gear and Technique

The 2017 Dam Angling crew primarily targeted fishing areas and fishing times at each dam that had been productive in the past (Winther et al. 2017). Back bouncing soft plastic lures off the turbine decks, our top producing lure in 2017 was the 3.75" Gitzit tube in Smoke/Black Copper Glitter color, which accounted for 1,401 harvested Northern Pikeminnow. A list of the top 5 most productive soft plastic lures used by the Dam Angling crew in 2017 is presented in Table 1.

Table 1. Top 5 Northern Pikeminnow Lures used by 2017 WDFW Dam Angling Crew

Northern Pikeminnow Lures

Brand/style	Size	Color	# N. Pikeminnow Caught
Gitzit/ tube bait	3.75"	Smoke/Black Copper Glitter	1,401
Gitzit/ tube bait	3.75"	Smoke/Black Red Glitter	1,375
Gitzit/ tube bait	2.50"	Mini Smoke/Black Red Glitter	391
Gitzit/ tube bait	3.75"	Grey Shad	380
Gitzit/ tube bait	3.75"	Rainbow Trout	253

Angling Times

Time of day continued to make a difference in harvest success during the 2017 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 (Winther et al. 2017). Results for the 2017 season indicated that the best catch hours seemed to shift slightly later in the morning although most Dam Angler harvest of Northern Pikeminnow (67%) continued to occur prior to 1:00 pm (Table 2).

Table 2. Combined 2017 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. - 6:00 a.m.	338	6%
6:00 a.m. - 7:00 a.m.	422	8%
7:00 a.m. - 8:00 a.m.	458	9%
8:00 a.m. - 9:00 a.m.	468	9%
9:00 a.m. - 10:00 a.m.	475	9%
10:00 a.m. - 11:00 a.m.	457	9%
11:00 a.m. - 12:00 p.m.	538	10%
12:00 p.m. - 1:00 p.m.	361	7%
1:00 p.m. - 6:00 p.m.	198	4%
6:00 p.m. - 7:00 p.m.	184	4%
7:00 p.m. - 8:00 p.m.	224	4%
8:00 p.m. - 9:00 p.m.	268	5%
9:00 p.m. - 10:00 p.m.	230	4%
10:00 p.m. - 11:00 p.m.	161	3%
11:00 p.m. - 12:00 a.m.	175	3%
12:00 a.m. - 1:00 a.m.	218	4%
1:00 a.m. - 2 a.m.	73	1%

Table 3. 2017 WDFW Dam Angler Hourly Northern Pikeminnow Harvest Comparison (TD vs JD)

Time of day	The Dalles Dam		John Day Dam	
	Harvest	% of Harvest	Harvest	% of Harvest
4:30 a.m. - 6:00 a.m.	98	6%	240	7%
6:00 a.m. - 7:00 a.m.	116	7%	306	9%
7:00 a.m. - 8:00 a.m.	129	7%	329	9%
8:00 a.m. - 9:00 a.m.	134	8%	334	10%
9:00 a.m. - 10:00 a.m.	137	8%	338	10%
10:00 a.m. - 11:00 a.m.	107	6%	350	10%
11:00 a.m. - 12:00 p.m.	118	7%	420	12%
12:00 p.m. - 1:00 p.m.	81	5%	280	8%
1:00 p.m. - 6:00 p.m.	26	1%	172	5%
6:00 p.m. - 7:00 p.m.	13	1%	171	5%
7:00 p.m. - 8:00 p.m.	38	2%	186	5%
8:00 p.m. - 9:00 p.m.	70	4%	198	6%
9:00 p.m. - 10:00 p.m.	111	6%	119	3%
10:00 p.m. - 11:00 p.m.	142	8%	19	1%
11:00 p.m. - 12:00 a.m.	165	9%	10	0.3%
12:00 a.m. - 1:00 a.m.	218	12%	0	0%
1:00 a.m. - 2:00 a.m.	73	4%	0	0%
Total	1,776	100%	3,472	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 2017. All incidentally caught fish species were released. Incidental species most often caught were Walleye *Sander vitreus and* Smallmouth Bass *Micropterus dolomieue*. 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. 2017 WDFW Dam Angler Incidental Catch by Project

Incidental Catch

Species	**The Dalles Dam**	**John Day Dam**
Walleye	66	846
Smallmouth Bass	139	491
Sculpin	12	5
American Shad	12	89
Channel Catfish	2	6
White Sturgeon	1	6
Peamouth	1	3
Yellow Perch	2	0
Carp	2	0
Chinook (adult)	1	0

Tag Recovery

All Northern Pikeminnow harvested by Dam Anglers in 2017 were visually examined for the presence of external spaghetti tags and 100% were individually scanned with PIT tag readers for the presence of PIT tags. Two Northern Pikeminnow retaining both the external ODFW spaghetti tags and ODFW secondary mark PIT tags were recovered by the Dam Angling crew in 2017 (Figure 9) (compared to 4 Spaghetti tags recovered in 2016) (Winther et al. 2017). In addition, there were a total of 13 Northern Pikeminnow recovered that had lost spaghetti tags, but retained PIT tags (tag-loss) implanted by ODFW as a secondary tag mark as part of ODFW's biological evaluation of the NPMP (Carpenter et al. 2018). This is more than double the number of tag-loss recovered in 2016 (Winther et al. 2017). The 2017 Dam Angling crew also recovered 6 PIT tags from juvenile salmonids ingested by Northern Pikeminnow at The Dalles and John Day dams (Figure 10). This was also double the number of ingested recoveries from Northern Pikeminnow in 2016 (Winther et al. 2017). The overall occurrence rate for ingested PIT tagged fishes recovered from Northern Pikeminnow caught by Dam Anglers in 2017 was 1:875 Northern Pikeminnow, compared to 1:2,054 for the Dam Angling crew in 2016 (Winther et al. 2017) and 1:7,659 for the 2017 NPSRF (Shirley et al. 2018).

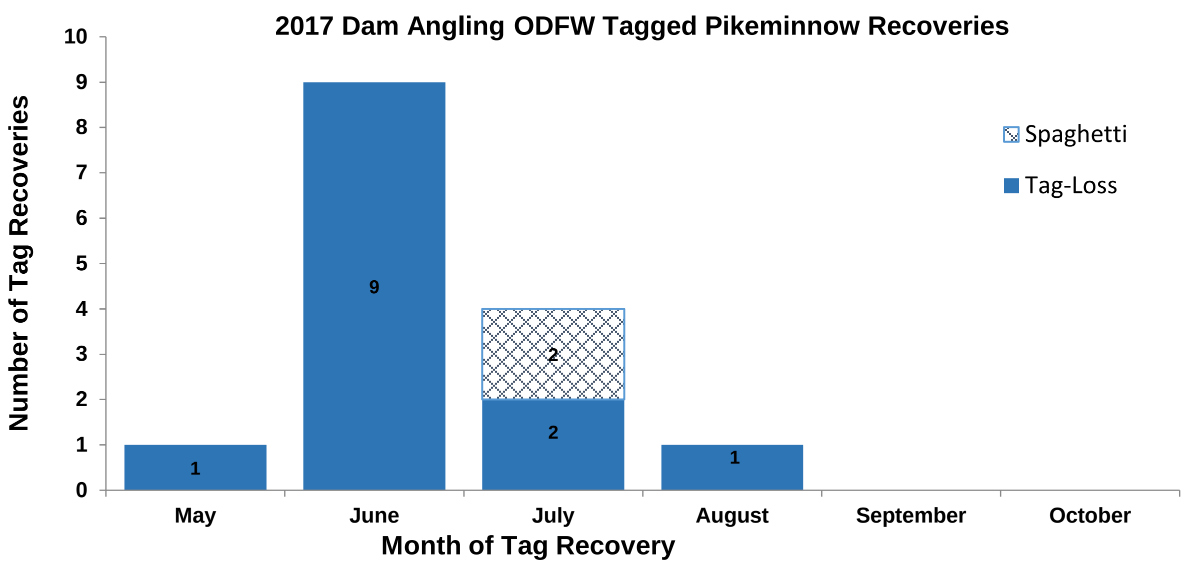

Figure 9. Recoveries of Spaghetti Tag and Tag-Loss Recoveries From the 2017 Dam Angling

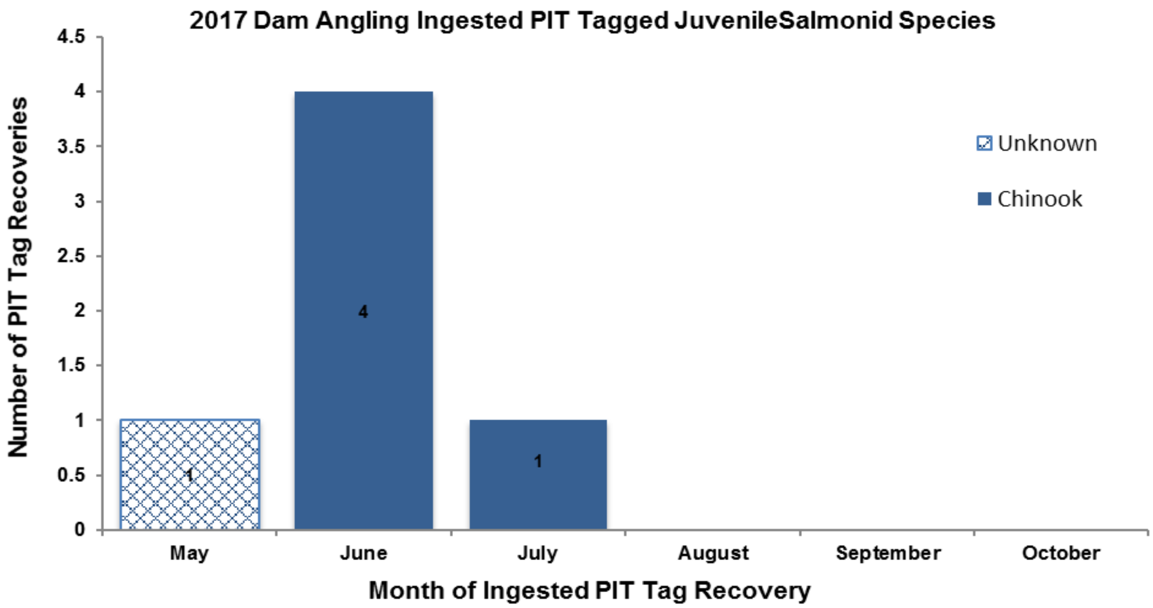

Figure 10. Recoveries of Ingested Salmonid PIT Tags From the 2017 Dam Angling

The Dalles Dam

Harvest

The Dam Angling crew harvested 1,776 Northern Pikeminnow in 23 weeks at The Dalles Dam in 2017. Weekly harvest for the Dam Angling crew averaged 77 fish per week and ranged from peak harvest of 249 Northern Pikeminnow in week 29 (July 17 – July 23) to only 2 fish in week 40 (Figure 11). River outflows during the first 6 weeks of 2017 (Figure 12) were higher than in 2016 and harvest was down 3,064 fish from 2016 (Winther et al. 2017). Peak weekly harvest decreased 42% from 2016 and occurred six weeks later than in 2016. Peak harvest for Dam Angling was also four weeks later than for the 2017 NPSRF (Shirley et al. 2018).

The 1,776 Northern Pikeminnow harvested at The Dalles Dam in 2017 included one spaghetti tagged and three tag-loss Northern Pikeminnow which were from ODFW's biological evaluation of the NPMP. The 2017 Dam Angling crew also recovered five Northern Pikeminnow that had ingested juvenile salmonids containing PIT tags

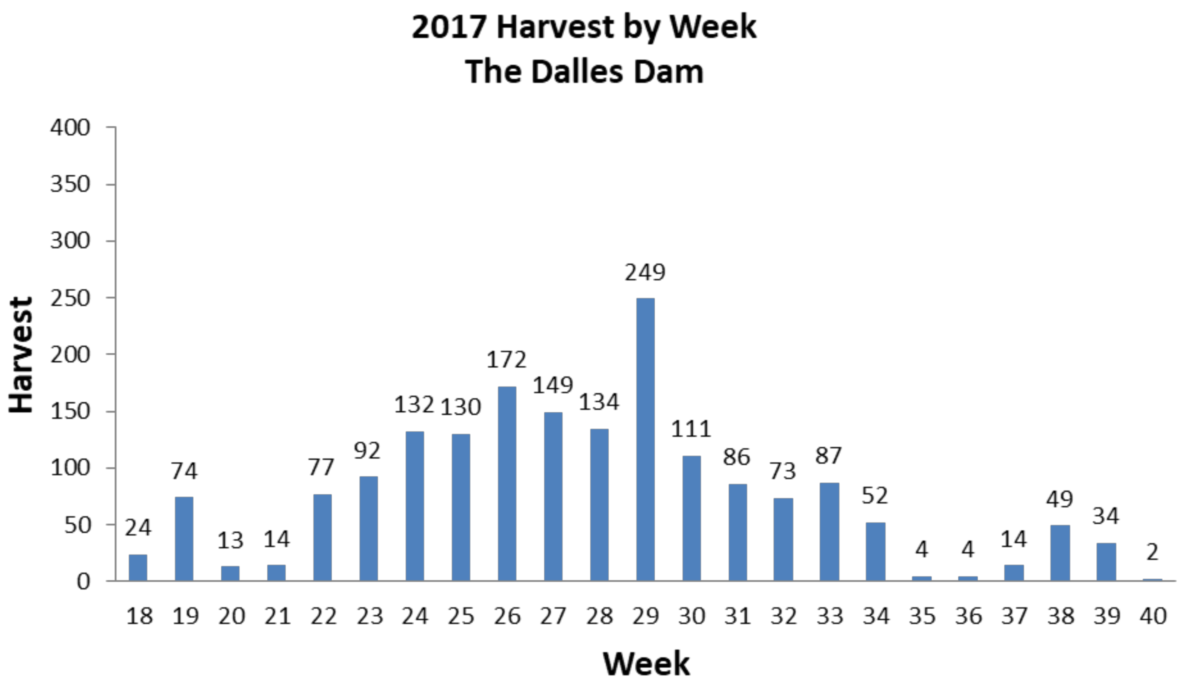

Figure 11. 2017 Weekly Dam Angler Harvest of Northern Pikeminnow at The Dalles Dam

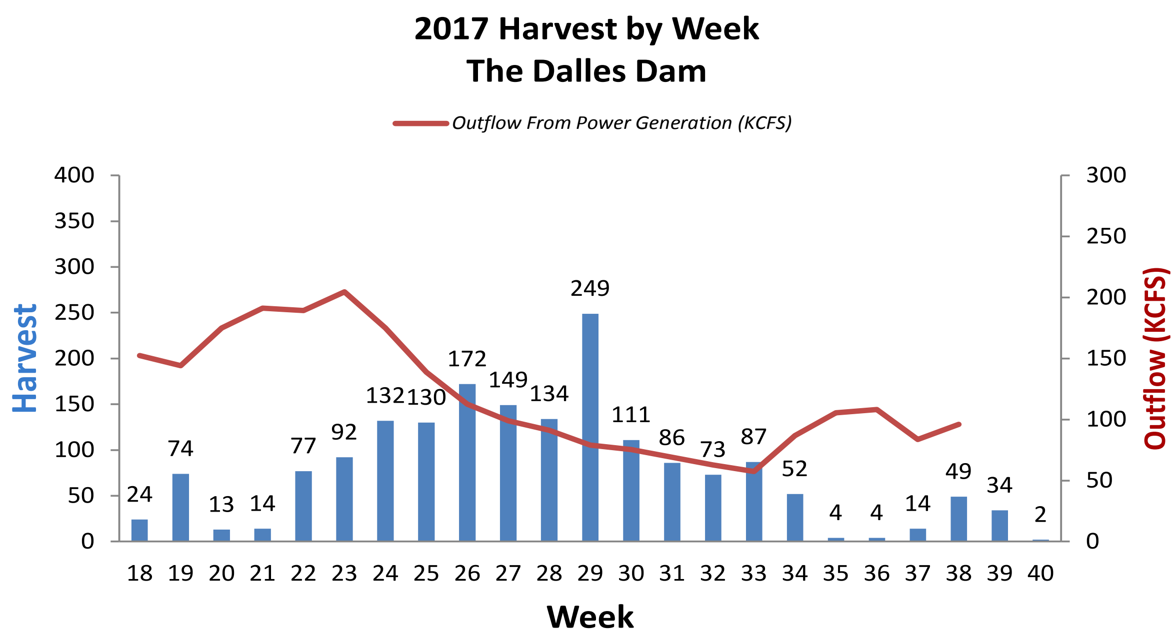

Figure 12. 2017 Weekly Northern Pikeminnow Harvest Compared to Outflow

As was the case in past Dam Angling seasons, certain areas and/or turbines at The Dalles Dam produced better harvest than others in 2017. The angling areas between Turbine #7 (T7) and Turbine #14 (T4) accounted for 61% of total harvest at The Dalles Dam in 2017, up from 34% in 2016 (Winther et al. 2017) (Figure 13). Turbine #8 (T8) and the rock shore above the ice trash sluiceway were the two best angling locations.

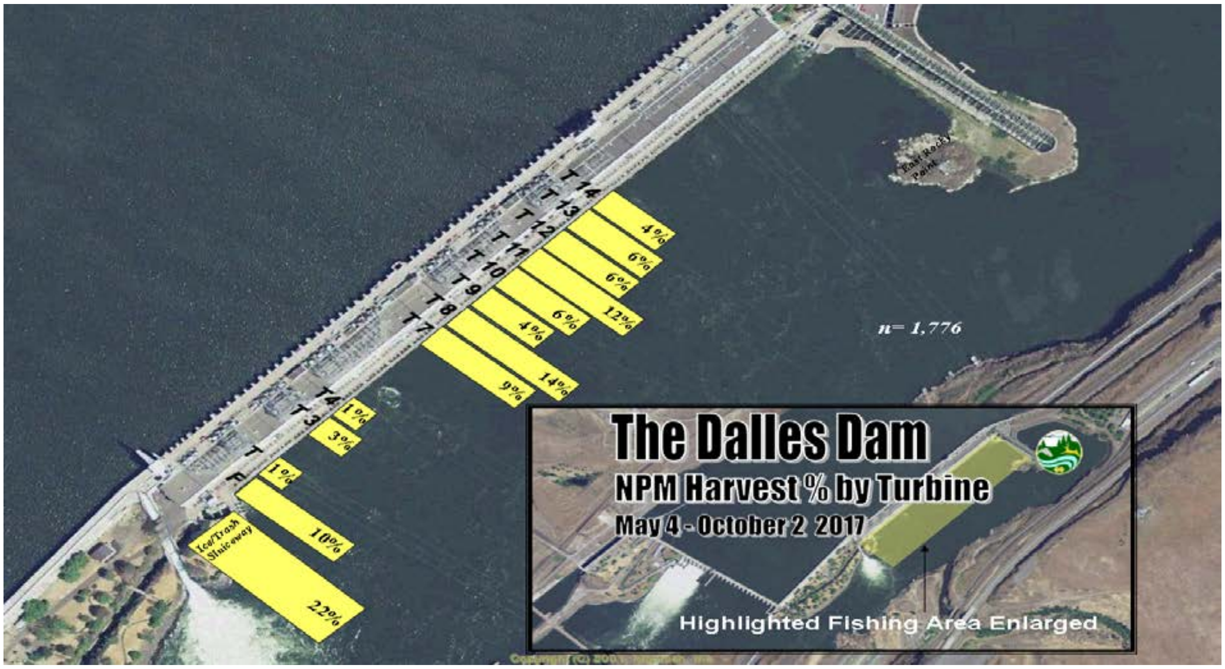

Figure 13. 2017 Overall Percent of Northern Pikeminnow Harvest by Area (T=turbine #, F = fishway)

The Dalles Dam NPM Harvest % by Turbine

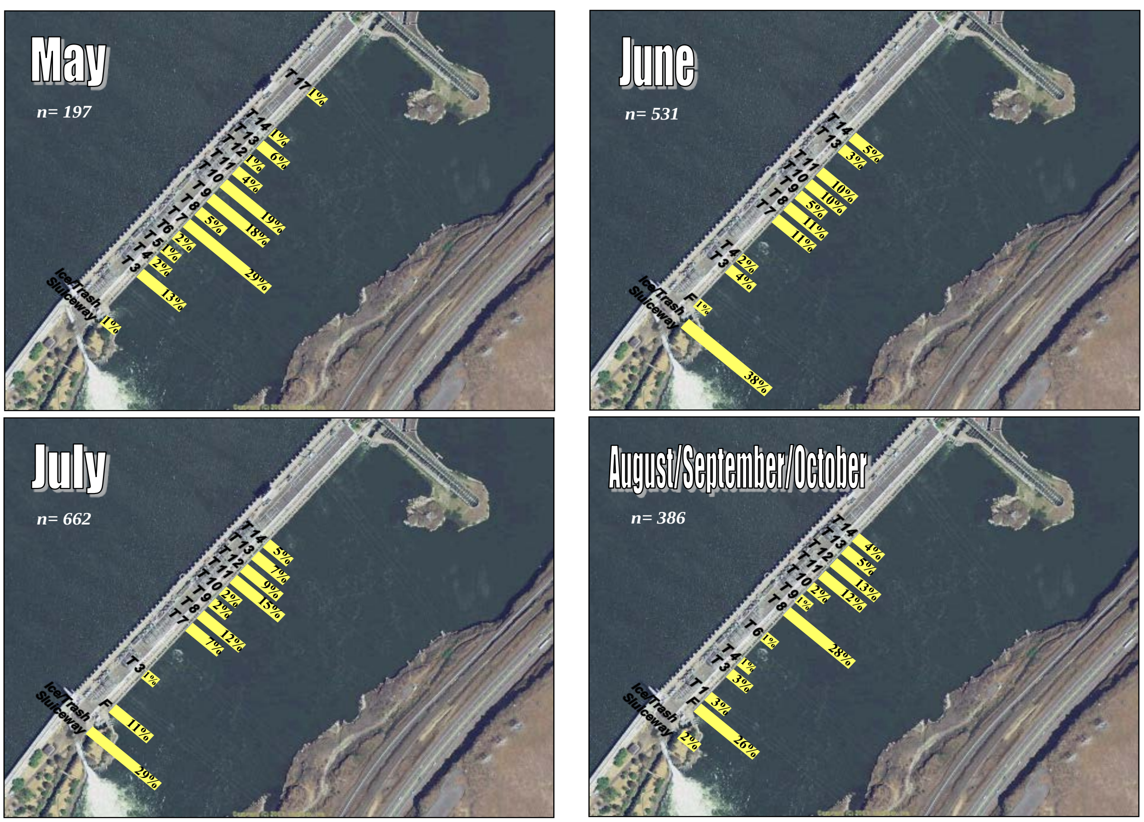

Figure 14. 2017 Monthly Harvest Percent (*rounded) by Area at The Dalles Dam (T=turbine#, F = fishway)

When we look at Northern Pikeminnow harvest at The Dalles Dam over the course of the 2017 Dam Angling season, our harvest data showed some variation in where the best harvest areas were over the course of the May through September Dam Angling season (Figure 14). In general, 2017 data shows high harvest concentrations near the ice/trash sluiceway in June and July, then more scattered throughout the rest of the season.

Incidental Catch

While the Dam Angling crew did not target other fish species in their angling activities during 2017, they did catch 139 Smallmouth Bass at The Dalles Dam in 2017, compared to 356 in 2016 (Winther et al. 2017). During the past two Dam Angling seasons, we have also recorded a substantial increase in Walleye catch at The Dalles Dam with 66 Walleye caught in 2017 and 55 caught in 2016. Prior to that, Dam Angling crews had only caught a combined total of 31 walleye at The Dalles Dam from 2010 – 2014 (Figure 15). Most Walleye were caught near the Ice/Trash sluiceway and Turbine #8 (T8) (Figure 16). As in past seasons, all Smallmouth Bass and Walleye were scanned for PIT tags and released, but no PIT tags from ingested salmonids were recovered at The Dalles Dam in 2017.

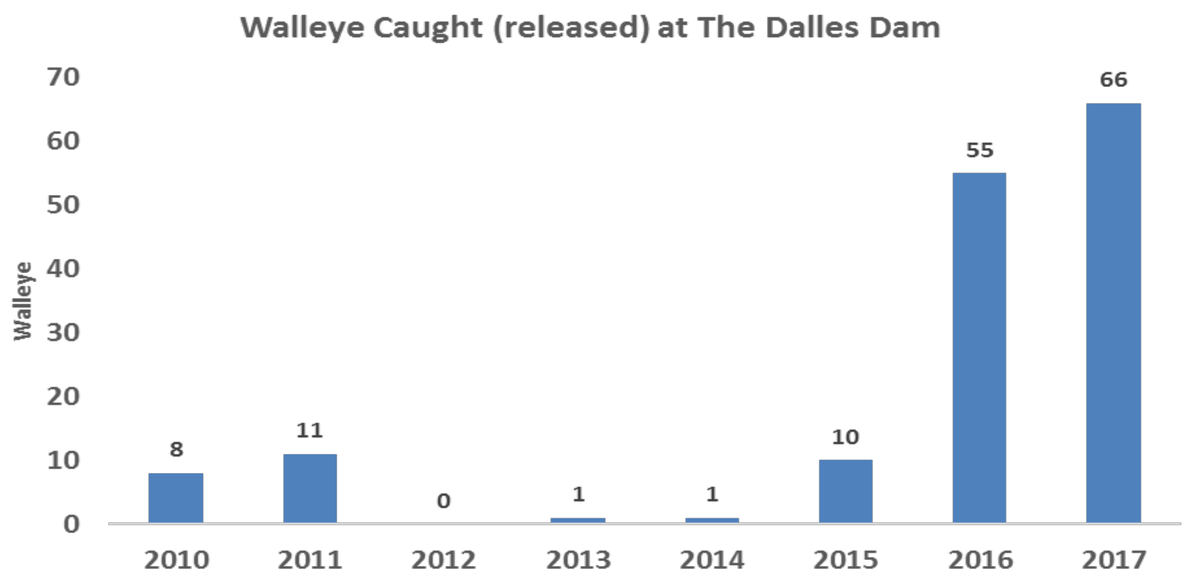

Figure 15. 2017 Annual Dam Angler Catch of Walleye at The Dalles Dam

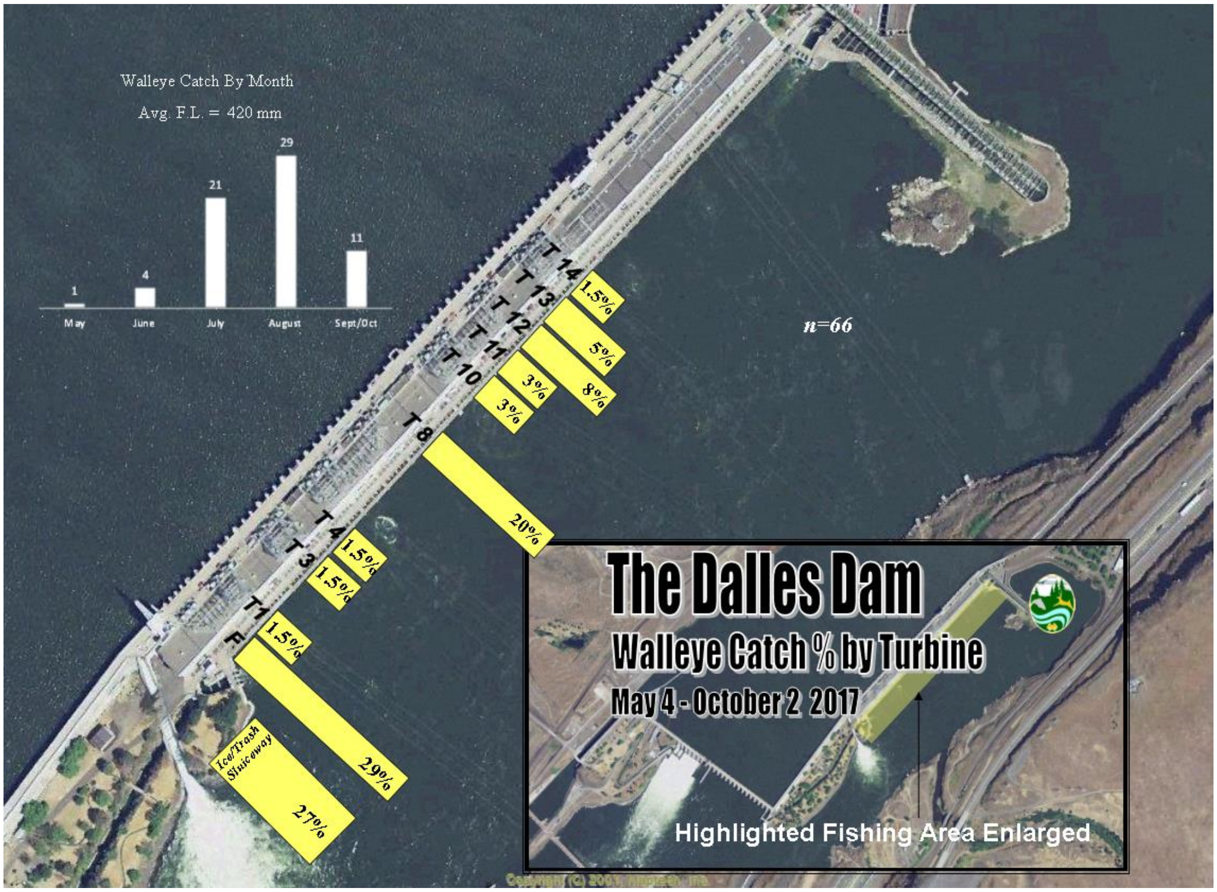

Figure 16. 2017 Incidental Catch of Walleye (*rounded) by Dam Angling Crew at The Dalles Dam

Effort

Total angler hours of effort at The Dalles Dam increased to 778.5 hours in 2017 from 712.25 hours in the 2016 Dam Angling season (Winther et al. 2017). The Dam Angling crew fished 60 days at The Dalles Dam over 23 weeks and spent 43% of total Dam Angling effort at The Dalles Dam in 2017.

CPUE

The Dam Angling crew harvested 1,776 Northern Pikeminnow in 778.50 angler hours at The Dalles Dam in 2017 for an overall average CPUE of 2.3 fish/angler hour, down from 4.3 in 2016 (Winther et al. 2017). Peak weekly CPUE at The Dalles Dam occurred during week 25 (Figure 17). Challenging river conditions in 2017 resulted in overall CPUE at The Dalles Dam exceeding the 2.0 fish/angler hour goal for only 10 of the 23 weeks fished.

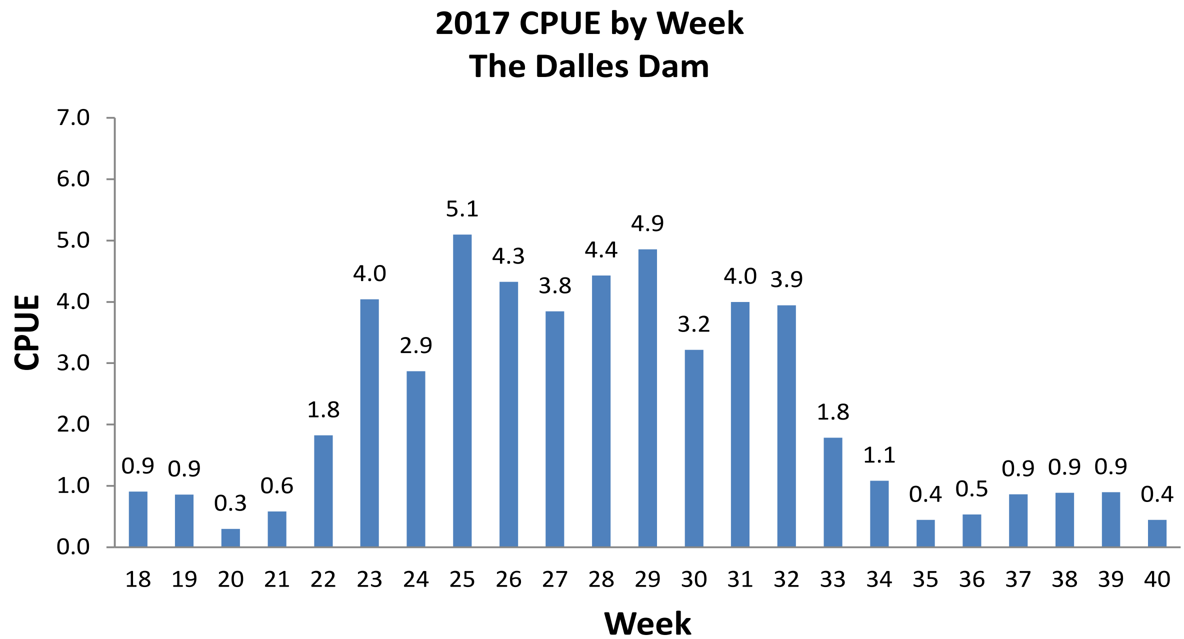

Figure 17. 2017 Weekly Dam Angler CPUE at The Dalles Dam

Fork Length Data

Fork lengths were recorded from 1,776 (100%) Northern Pikeminnow harvested by the Dam Angling crew at The Dalles Dam during the 2017 Season. The length frequency distribution of Northern Pikeminnow harvested at The Dalles Dam in 2017 is presented in Figure 18. Mean fork length for Northern Pikeminnow caught by the Dam Angling Crew at The Dalles Dam in 2017 was 332 mm (SD=54.6), up from 313 mm in 2016 (Winther et al. 2017). By comparison, the mean fork length for the 2017 NPSRF was 279.8 mm (Shirley et al. 2018).

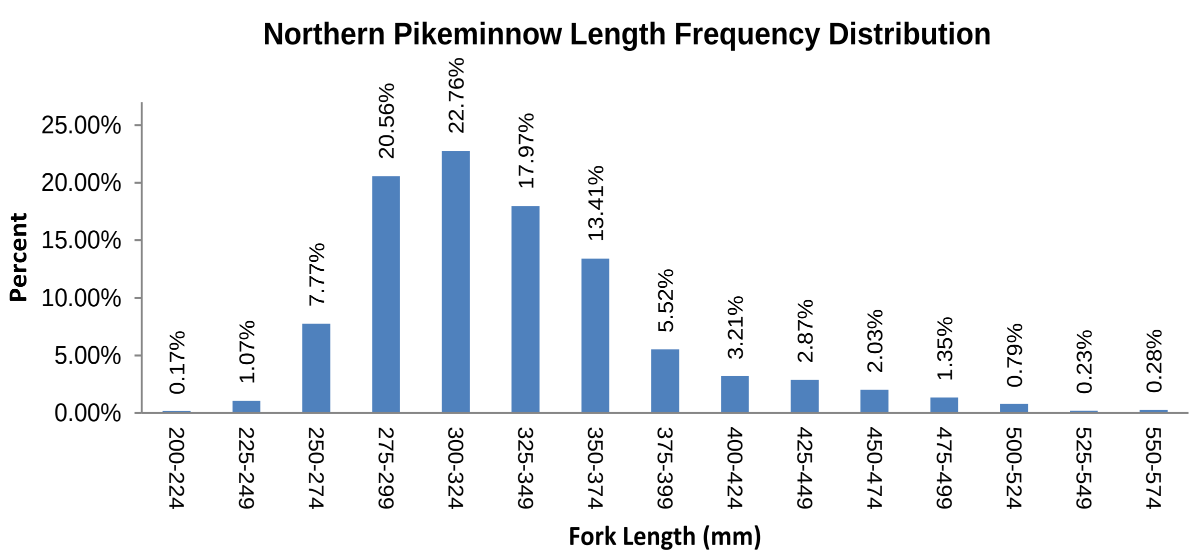

Figure 18. Northern Pikeminnow Length Frequency Distribution at The Dalles Dam in 2017

John Day Dam

Harvest

The Dam Angling crew harvested a total of 3,472 Northern Pikeminnow over 22 weeks at the John Day Dam in 2017, second only to the record 2014 harvest of 4,250 fish in 2014 (Dunlap et al. 2015). Weekly harvest averaged 158 fish per week and ranged from zero fish in weeks 34 and 38 to a peak of 492 in week 30 (July 24 – July 30) (Figure 19). Peak weekly harvest at the John Day Dam occurred in week 30 which was three weeks later than in 2016 (Winther et al. 2017) and 5 weeks later than the week 25 peak for the 2017 Sport Reward Fishery (Shirley et al. 2018). The 3,472 harvested Northern Pikeminnow included one spaghetti tagged and 10 tag loss Northern Pikeminnow which were part of ODFW's biological evaluation of the NPMP (Carpenter et al. 2018). We also recovered one PIT tag from a juvenile salmonid ingested by a Northern Pikeminnow at the John Day Dam in 2017.

Unlike the 2017 NPSRF season, Dam Angling harvest at the John Day Dam peaked (week 30) well after the week 25 peak of the NPSRF (Shirley et al. 2018). Average outflows at the John Day Dam during the best harvest weeks of 2017 (weeks 30-32) averaged 101 kcfs (Figure 20).

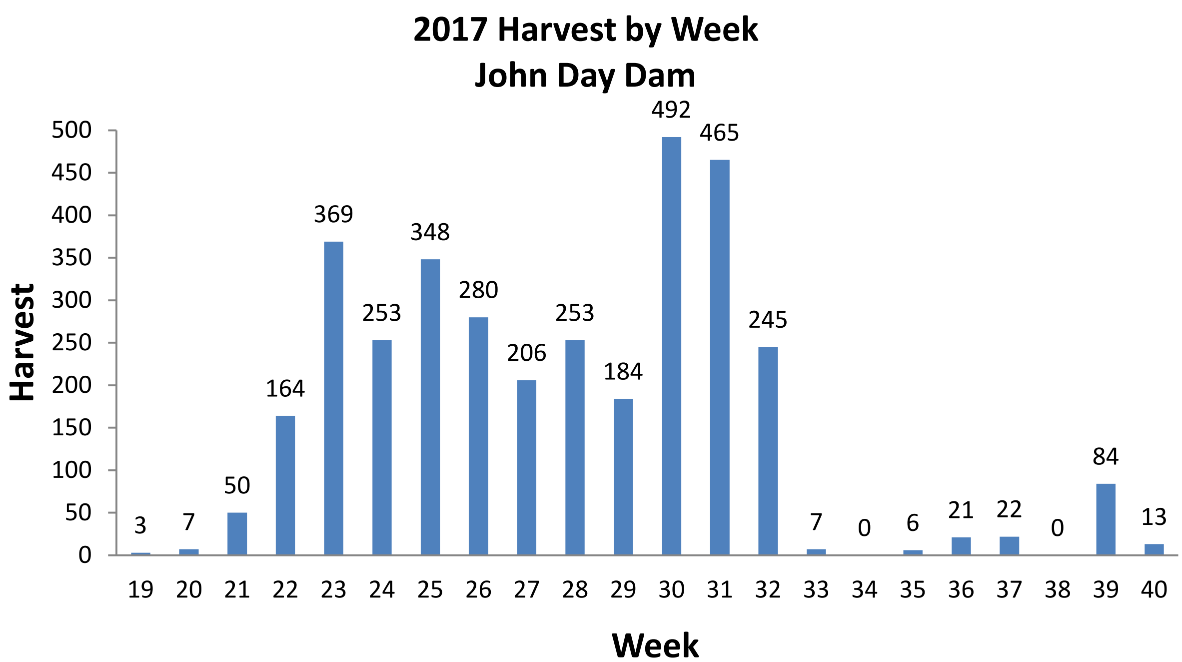

Figure 19. 2017 Weekly Dam Angler Harvest of Northern Pikeminnow at the John Day Dam

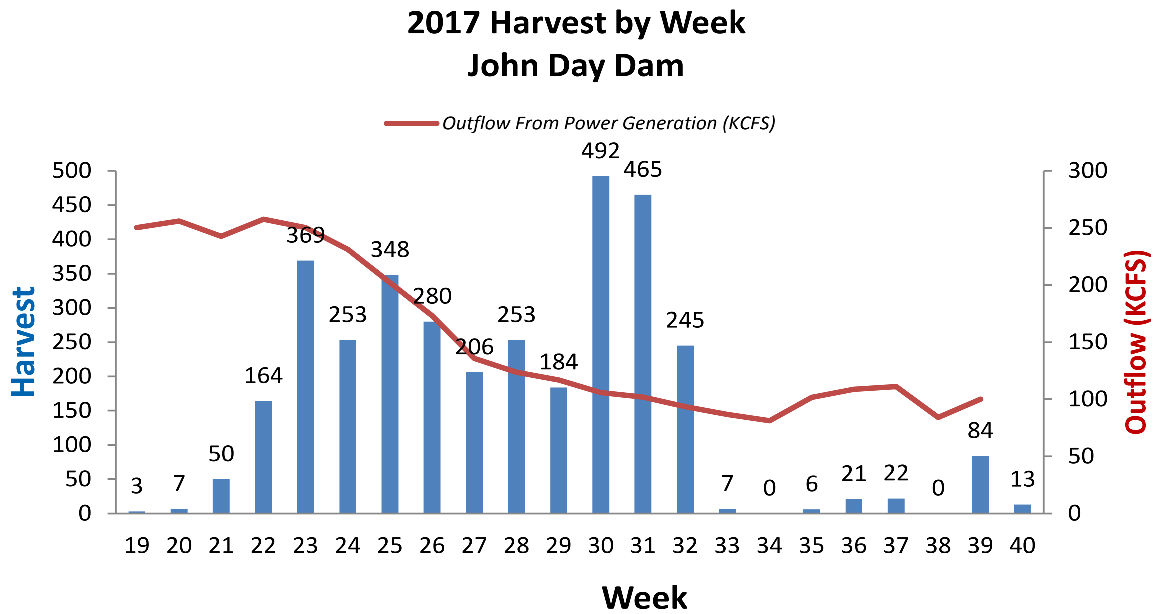

Figure 20. 2017 Weekly Dam Angler Harvest of Northern Pikeminnow at the John Day Dam vs Outflow

As seen in previous Dam Angling seasons, certain turbines at the John Day Dam created water flow conditions that were more favorable for harvesting Northern Pikeminnow than others (Winther et al. 2017). Turbine #7 (T7) was the single best producing area at the John Day Dam in 2017 with 18% of the total harvest (Figure 21), although our data also shows that harvest was spread over a wider range of turbines in 2017 than 2016. T5 had been the best producing location in 2016 with 33% of the total harvest (Winther et al. 2017).

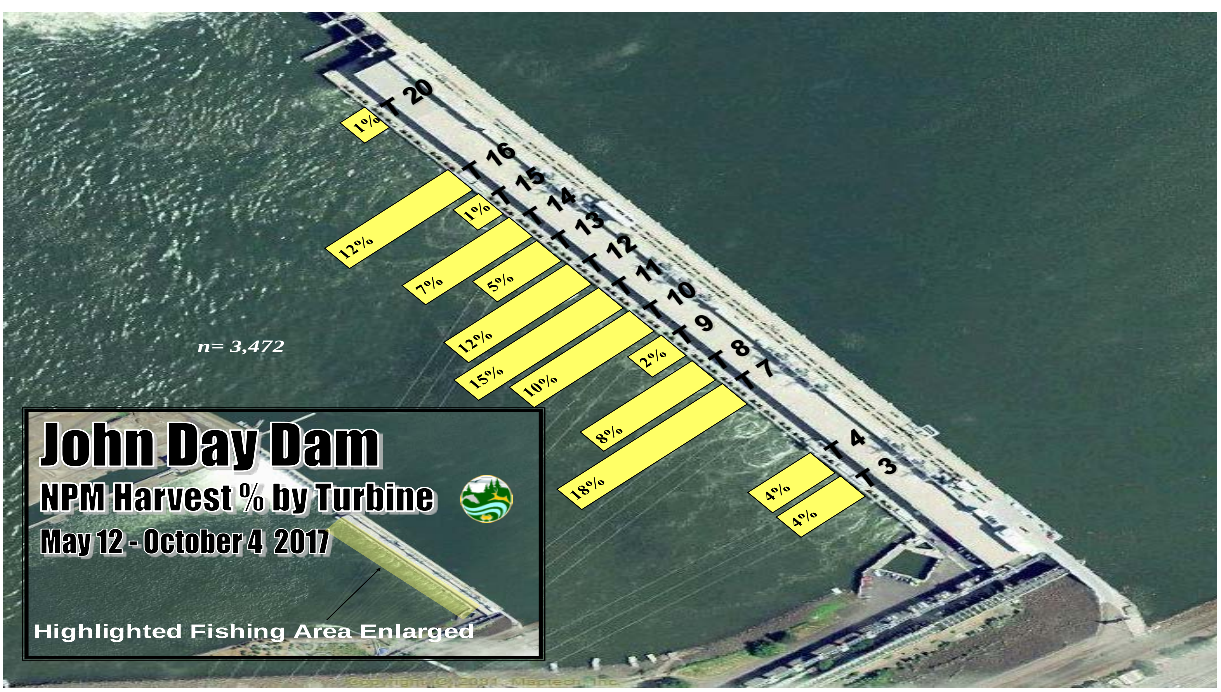

Figure 21. 2017 Overall Percent of Northern Pikeminnow Harvest by Area (T=turbine#)

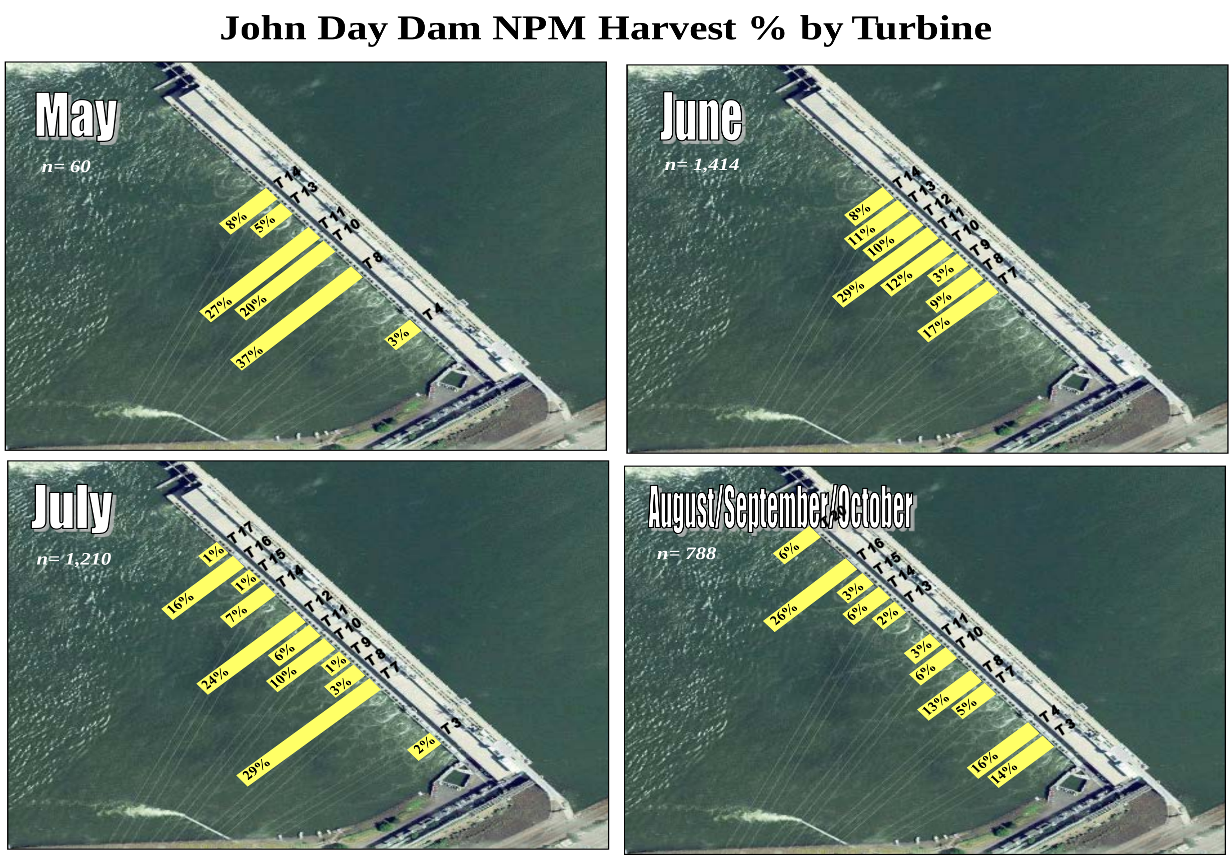

Figure 22. 2017 Monthly Percent (*rounded) of Northern Pikeminnow Harvest by Area (T=turbine#)

Incidental Catch

While the Dam Angling crew did not target fish species other than Northern Pikeminnow in their angling activities, the Dam Angling crew did catch and release 846 Walleye at the John Day Dam in 2017. The past two Dam Angling seasons have really seen a substantial increase in Walleye catch at the John Day Dam with 846 Walleye caught in 2017 and 517 caught in 2016 compared to a total of 338 Walleye caught at the John Day Dam from 2010 – 2014 (Figure 23). Of the 846 Walleye, two had positive PIT tag readings from ingested juvenile salmonids. Through PTAGIS queries, we were able to determine that those PIT tags were from 1-Hatchery Fall Chinook and 1-Wild Summer Chinook. The Dam Angling crew also caught and released 491 Smallmouth Bass (smb) at the John Day Dam in 2017.

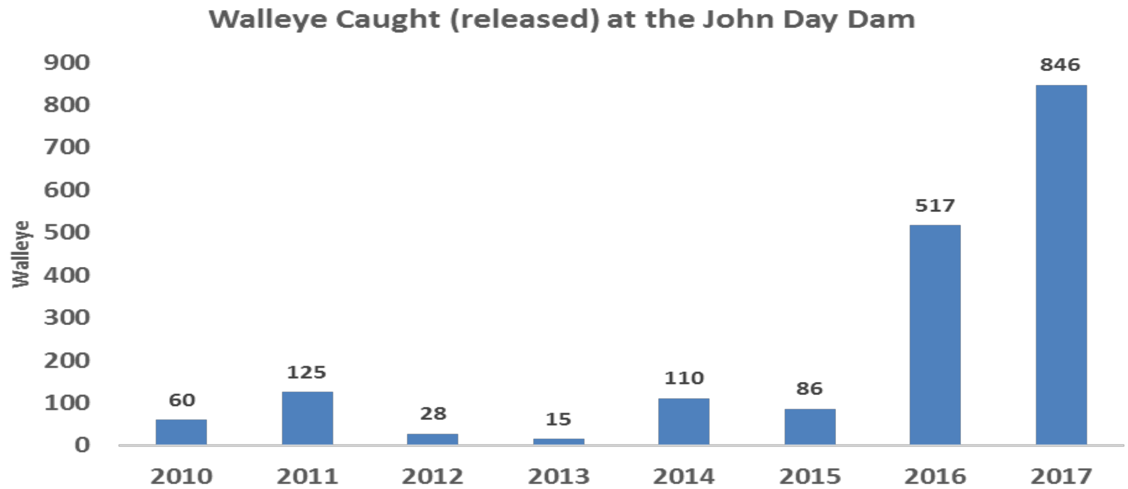

Figure 23. 2017 Annual Dam Angler Catch of Walleye at the John Day Dam

Effort

Total effort at the John Day Dam was 1,042.50 angler hours in 2017, up from 799.25 hours in 2016 (Winther et al. 2017). The crew averaged a combined 47.4 angler hours of effort per week and 15.6 angler hours of effort per day at the John Day Dam in 2017. The Dam Angling crew spent 57% of total effort (67 days over 22 weeks) at the John Day Dam in 2017.

CPUE

The Dam Angling crew harvested 3,472 Northern Pikeminnow in 1,042.50 angler hours at the John Day Dam in 2017 for an overall average CPUE of 3.3 fish/angler hour, down from 3.9 in 2016 (Winther et al. 2017). Peak weekly CPUE at the John Day Dam occurred during week 30 (Figure 24), five weeks later than at The Dalles Dam. The Dam Angling crew met or exceeded the overall CPUE goal of 2.0 fish/angler hour at the John Day Dam for 12 of the 22 weeks fished.

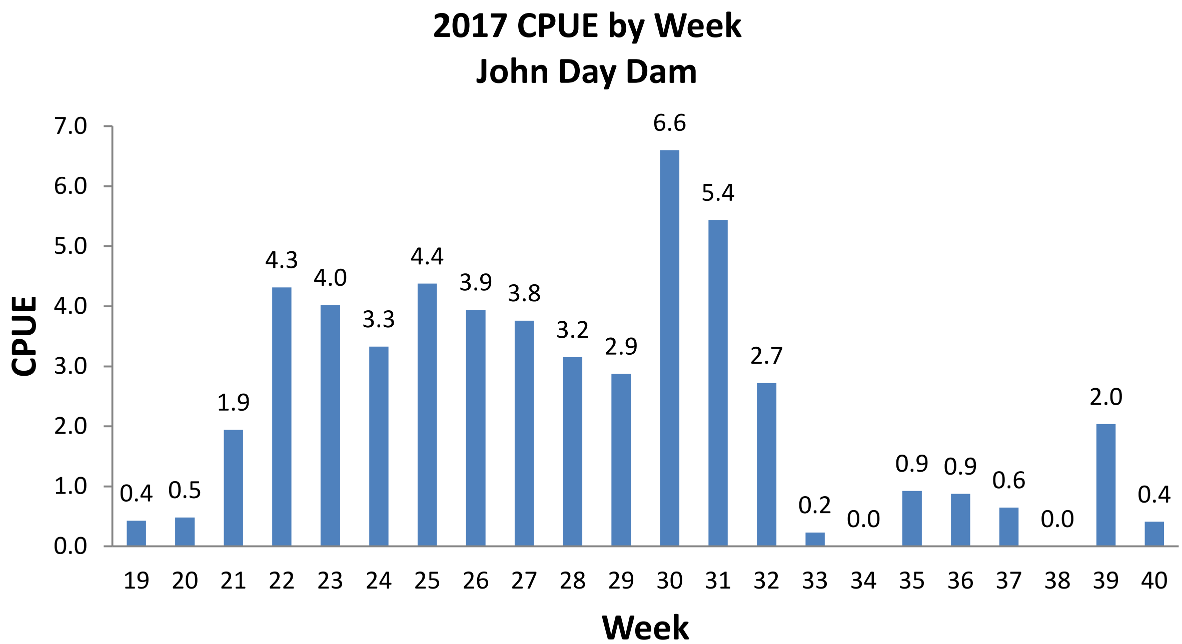

Figure 24. 2017 Weekly Dam Angling CPUE at John Day Dam

Fork Length Data

Fork lengths were recorded from 3,472 Northern Pikeminnow (100% of harvest) at the John Day Dam during the 2017 Dam Angling Season. The length frequency distribution of harvested Northern Pikeminnow from the John Day Dam in 2017 is presented in Figure 25. Mean fork lengths for Northern Pikeminnow from the John Day Dam in 2017 was 362 mm (SD=59.2) compared to 343 mm in 2016 (Winther et al. 2017). By comparison, the mean fork length for the 2017 NPSRF was 279.8 mm (Shirley et al. 2018).

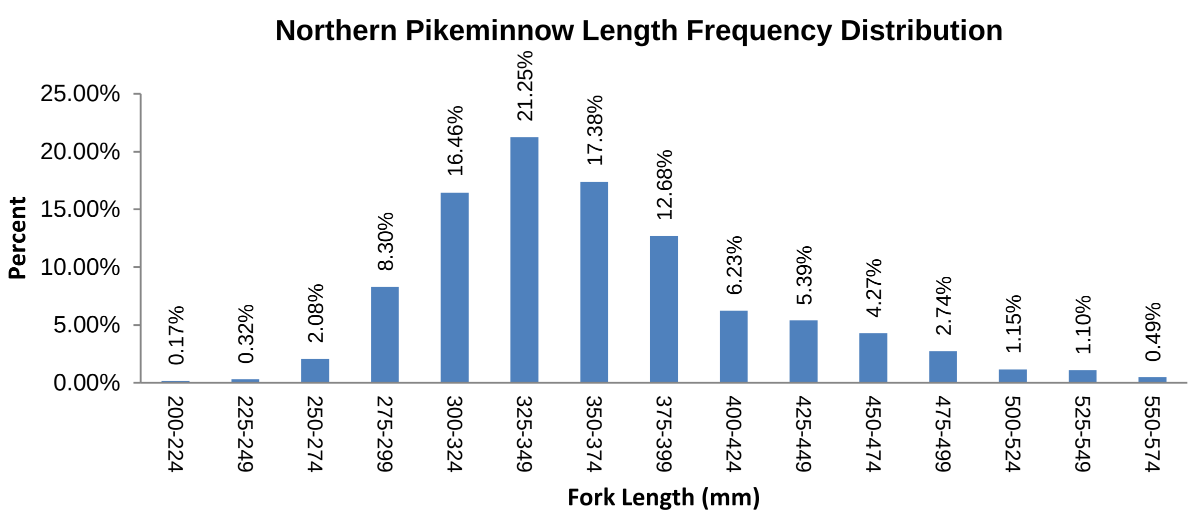

Figure 25. Northern Pikeminnow Length Frequency Distribution at the John Day Dam in 2017

SUMMARY

The 2017 Dam Angling crew harvested a total of 5,248 Northern Pikeminnow at The Dalles and John Day Dams, with 1,776 coming from The Dalles Dam and 3,472 from the John Day Dam. The Fishery operated over the course of 23 weeks between May 4th and October 4th, 2017. Harvest at the John Day Dam was the second highest to date, behind only 2014 (4,250).

During the 2017 season, the Dam Angling crew spent slightly more than half their time fishing at the John Day Dam (57%) and exceeded the 2.0 CPUE goal for 11 weeks of the 23 week season. Angling prior to 1:00 pm was the most productive time and the top producing lure for 2017 was the 3.75"Gitzit tube in Smoke/Black Copper Glitter color.

Fork length data for Northern Pikeminnow harvested by the 2017 Dam Angling crew continued to show that 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 NPSRF (332 mm at The Dalles Dam, 362 mm John Day Dam and 279.8 mm in the NPSRF. The 2017 Dam Angling crew also recovered 2 spaghetti tagged Northern Pikeminnow, 13 tag-loss Northern Pikeminnow, and 6 PIT tags from fishes ingested by Northern Pikeminnow. The overall occurrence rate for ingested PIT tags from Northern Pikeminnow caught by the 2017 Dam Angling crew was 1:875. There were also two PIT tags recovered from juvenile salmonids that had been ingested by Walleye that were incidentally caught by Dam Anglers at the John Day Dam.

While targeting only Northern Pikeminnow, the 2017 Dam Angling crew also incidentally caught a total of 912 Walleye, 630 Smallmouth Bass, 101 American Shad, 17 Sculpin, and 8 Channel Catfish between the two projects.

RECOMMENDATIONS FOR 2018

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 2018 Dam Angling activities to conduct the standard May-September Dam Angling season.

3.) Prepare a plan to initiate 2018 Dam Angling activities in April if low water conditions are present to take advantage of expected good angling conditions.

4.) Continue to utilize and/or 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.

5.) 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 2018.

6.) Fully incorporate use of HPR PIT tag scanners for scanning all incidentally caught fishes.

7.) Continue to investigate and further develop Northern Pikeminnow angling techniques in 2018 that will improve Dam Angler CPUE and/or allow exploitation of Northern Pikeminnow in areas not currently fishable.

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

9.) 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 2017 Dam Angler crew