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

2019 ANNUAL REPORT
April 1, 2019 thru March 31, 2020

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Funded By:

U.S. Department of Energy
Bonneville Power Administration
Environment, Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-3621
Project Number 1990-077-00
Contract Number 71866

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2019 Executive Summary
by

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This report presents results for year twenty-eight 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 accounted for a high percentage of mortality that juvenile salmonids experienced from piscivorous fish 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, and 1997, promotional activities and incentives were further improved based on the favorable

[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.*

response in 1994. Results of these and other lessons learned over the 28-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 Reports A & 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).

REPORT A

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

2019 Annual Report

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Funded by

U. S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
Portland, Oregon 97208-3621

Project No. 1990-077-00
Contract No. 00071866

March 2020

ACKNOWLEDGEMENTS

This project is funded by the Bonneville Power Administration (BPA) (project number 1990-077-00), John Skidmore, Project Manager, and David Roberts and Eric McOmie, COTRs (Contract DE-BI719-94BI24514). Steve Williams of the Pacific States Marine Fish Commission (PSMFC) administered this contract. We thank Mac Barr and his staff at the Oregon Department of Fish and Wildlife (ODFW) and Steve Williams and his staff at PSMFC for their cooperation in implementing this program during the 2019 season.

We are thankful to the City of Rainier for the use of the Rainier boat ramp; the City of Richland for the use of Columbia Point Park; the Cowlitz County Parks and Recreation Department for the use of the Willow Grove boat ramp; the Port of Bingen for the use of Bingen Marina; the Port of Camas/Washougal for the use of the Camas/Washougal boat ramp; the Port of Cascade Locks for the use of 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 and Chinook Landing Boat Ramps ; 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; Wally and Joanne Knouf for the use of Lyon’s Ferry Marina; and Mike and Monica Omstead for the use of Boyer Park.

We appreciate the efforts of Kyle Beckley, Josh Boston, Trina Byers, Shelby Carnright, Kevin Clawson, Nick Davids, Mark Flahaut, Bill Fleenor, Leif Fox, Roger Fox, Kevin Fryar, Anna Klundt, Eric Meyer, Jordan Miller, Emmy Thomson, Brittney Salter, Amber Santangelo, Ben Sorenson, Emily Splitgerber, John Paul Viviano, Robert Warrington, Dennis Werlau, Kodie Wight and Megan Wusterbarth for operating the 2019 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, Nancy Platt for her numerous phone survey interviews, and Dennis Werlau for producing our weekly field activity reports throughout the 2019 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, 2019. The objectives of this project were to (1) implement a recreational fishery that rewards recreational anglers for harvesting Northern Pikeminnow ≥ 228 mm (9 inches) total length (TL), (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 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 146,225 Northern Pikeminnow ≥ 228 mm fork length (FL) and 2,090 Northern Pikeminnow < 228 mm FL were harvested during the 2019 NPSRF season. There were a total of 2,717 different individual anglers who spent 20,286 angler days of effort participating in the NPSRF during the 2019 season. Catch per unit effort for combined returning and non-returning anglers was 7.2 fish/angler day. The Oregon Department of Fish and Wildlife (ODFW) estimated that the Northern Pikeminnow harvest activities from the 2019 NPSRF resulted in an overall exploitation rate of 15.4% (Anderson et al. 2020).

Anglers submitted 143 Northern Pikeminnow with external ODFW spaghetti or Floy tags, 141 of which also had an internal ODFW PIT tags (2 were missing their PIT tags but retained their external Floy tags). There were also 184 Northern Pikeminnow with ODFW PIT tags, but missing spaghetti or Floy tags (tag-loss). Additionally, 36 PIT tags from ingested juvenile salmonids were recovered from Northern Pikeminnow received during the 2019 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 Council 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 5.1 million reward sized Northern Pikeminnow and spent over 952,000 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 raised the base reward to $5 per fish and made it easier for anglers to reach the other two higher tier levels. The goal of this action was to grow the number of proficient individual anglers (Tier 2 and Tier 3 anglers), and to incentivize these anglers to expend additional effort. At the same time, the higher base reward and more attainable 2nd and 3rd tier levels could attract and recruit additional new anglers to the NPSRF. The 2019 NPSRF also continued to reward anglers an additional amount for returning Northern Pikeminnow with external tags (spaghetti or Floy type) and a lesser amount for fish with only PIT tags installed by the Oregon Department of Fish and Wildlife (ODFW) as part of the NPMP'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 2019 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 NPSRF 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 2019 NPSRF was conducted on the Columbia River from the mouth to the boat-restricted zone below Priest Rapids Dam, and on the Snake River from the mouth to the boat-restricted zone below Hells Canyon Dam (Figure 1). In addition, anglers were allowed to harvest (and submit for payment) Northern Pikeminnow caught in backwaters, sloughs, and up to 400 feet from the mouth of tributaries within this area. The NPSRF was fully implemented, with all stations operating during a regular season extending from May 1 through September 30, 2019.

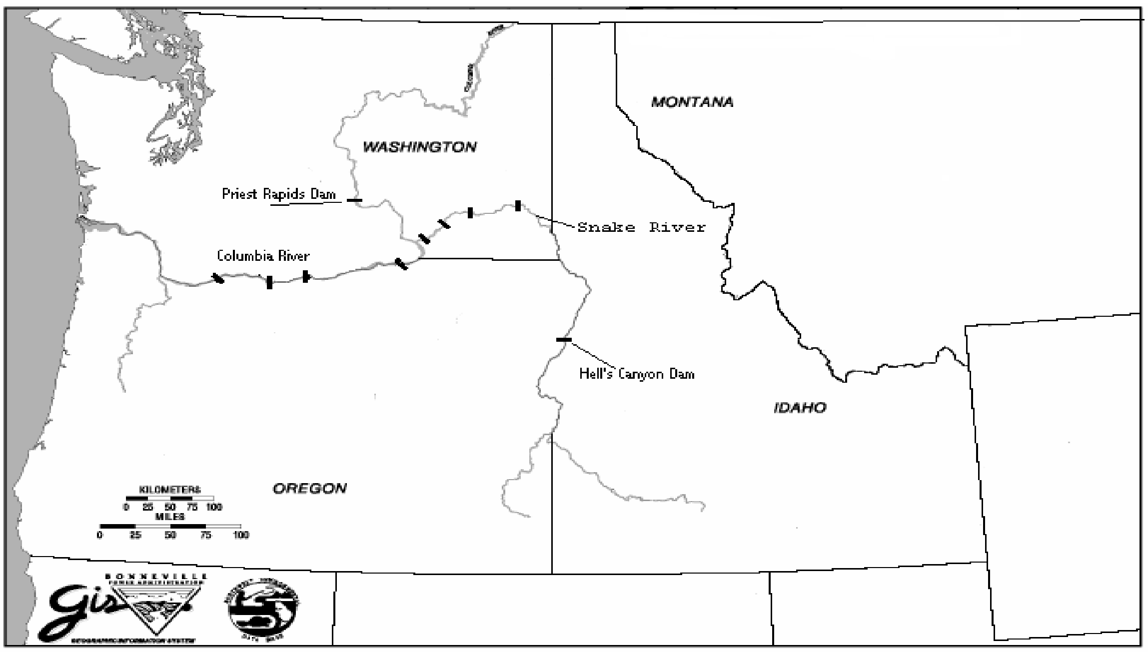
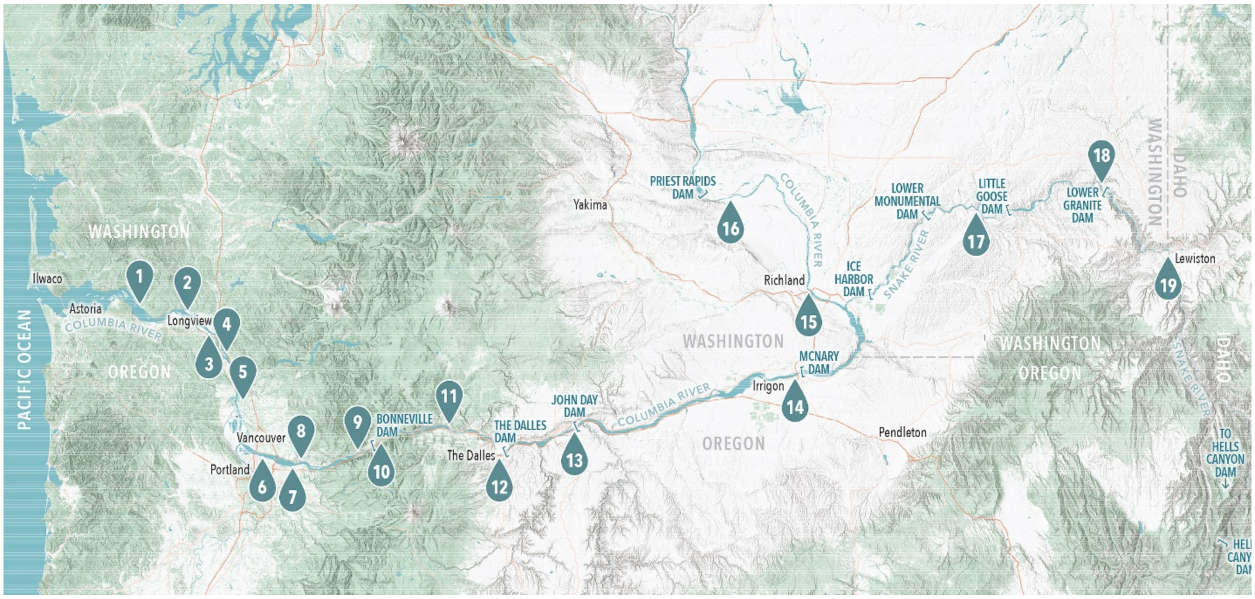


Figure 1. Northern Pikeminnow Sport-Reward Fishery Program Area

Registration Stations

Nineteen registration stations (Figure 2) were located along the Columbia and Snake Rivers within these boundaries 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 2 and 8.5 hours per day during the season. Technicians assisted in registering anglers, and in compiling data for 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 angling advice and Sport-Reward Fishery information to the public. Self-registration boxes were also located at each station so anglers could self-register when WDFW technicians were not present.



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

Figure 2. 2019 Northern Pikeminnow Sport-Reward Fishery registration stations and hours of operation

Reward System

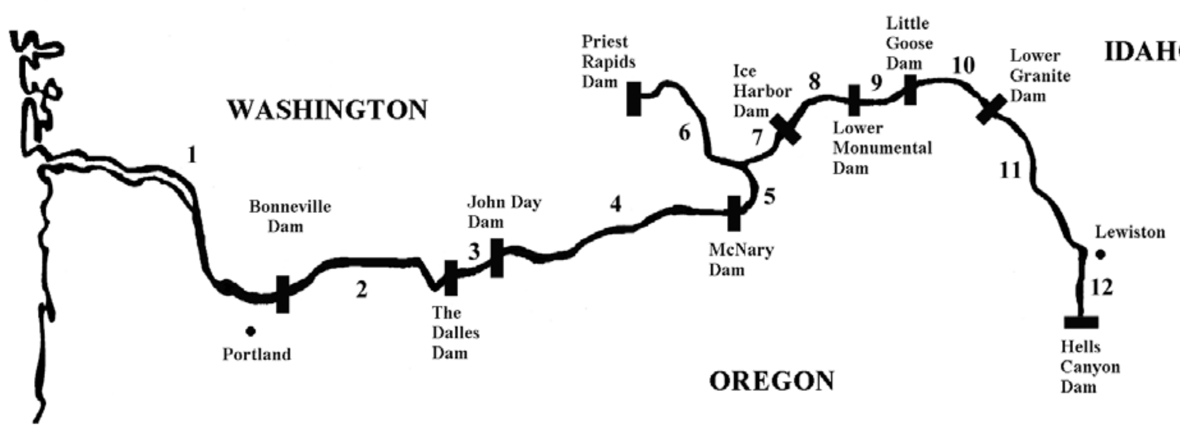
The 2019 NPSRF rewarded anglers for harvesting Northern Pikeminnow ≥ 228mm TL (9 inches TL) using a tiered reward system first implemented in 1995 (Hisata et al. 1996), which paid anglers a higher reward per fish once they had reached designated harvest levels over the course of the season. To receive payment, anglers returned their catch (daily) to the location where they had registered. WDFW technicians verified fish species (and that anglers had caught their fish in accordance with NPSRF Rules and Regulations) 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 2019 season was first developed in 1995 (Hisata et al. 1996), and reflected changes (to increase participation) that were made to the NPSRF's tiered reward system in 2015 (Winther et al. 2016). 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 external tag (spaghetti or Floy) used by ODFW for the biological evaluation of the NPMP. 2019 NPSRF anglers also continued to be paid $100 for each Northern Pikeminnow missing an external 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".



Fishing Locations:

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

Figure 3. Fishing Location codes used for the 2019 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 2019 per NPSRF protocol (Fox et al. 2000).

Northern Pikeminnow Handling Procedures

Biological Sampling

Technicians examined all fishes returned to registration stations and recorded basic biological data such as species and number of fish per species. Fork lengths and sex of Northern Pikeminnow as well as any other harvested fish species were recorded whenever possible. Technicians checked all Northern Pikeminnow for the presence of external tags (spaghetti, Floy, dart, etc.), fin-clip marks, and/or signs of tag-loss. All externally tagged Northern Pikeminnow had complete biological data collected whether the fish had a spaghetti tag as used by the NPMP since 1991, or with Floy type anchor tags used by ODFW on a trial basis in 2019. Data collected from externally tagged Northern Pikeminnow included Fork Length (FL), tag number, sex (determined by evisceration), and scale samples (if specified). Data from tagged Northern Pikeminnow were recorded both on corresponding tag voucher and on WDFW data form. The external tag was then removed from the Northern Pikeminnow and placed in a tag envelope, stapled to the tag voucher and then given to the angler to submit by mail to ODFW for verification. All tagged Northern Pikeminnow carcasses were then processed or labeled and frozen for data verification and/or PIT tag recovery at a later date.

PIT Tag Detection

All Northern Pikeminnow collected during the 2019 NPSRF were scanned for Passive Integrated Transponder (PIT) tags. PIT tags have been used by ODFW as a secondary mark in all Northern Pikeminnow fitted with external, spaghetti or Floy, tags (beginning in 2003) as part of the NPMP's biological evaluation activities (Takata and Koloszar 2004). Northern Pikeminnow harvested by anglers participating in the NPSRF have also been found to ingest juvenile salmonids that have been PIT tagged by other studies within the basin (Glaser et al. 2001). 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 entire 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 on site, or labeled and preserved for later dissection and PIT 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. Anglers were eligible for an additional $100 reward from PSMFC for "tag-loss" fish which were defined as Northern Pikeminnow missing external tags, but retaining ODFW PIT tags as part of the NPMP.

Northern Pikeminnow Processing

During biological sampling, all Northern Pikeminnow were either caudal clipped, or dissected to recover PIT tags as an anti-fraud measure to eliminate the possibility of previously processed Northern Pikeminnow being resubmitted for payment. As in recent years, all Northern Pikeminnow harvested in 2019 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

During the 2019 NPSRF, anglers harvested a total of 146,225 reward size Northern Pikeminnow (≥ 228 mm TL) over the course of a 23 week field season. Harvest was lower than mean 1991-2018 harvest of 177,033 fish and 34,048 fish lower than 2018 harvest (Hone et al. 2019) (Figure 4). The 2019 NPSRF harvest was estimated to equal an exploitation rate of 15.4% (Anderson et al. 2020). In addition to harvesting 146,225 reward size Northern Pikeminnow, anglers participating in the 2019 NPSRF also harvested 2,090 Northern Pikeminnow < 228 mm TL.

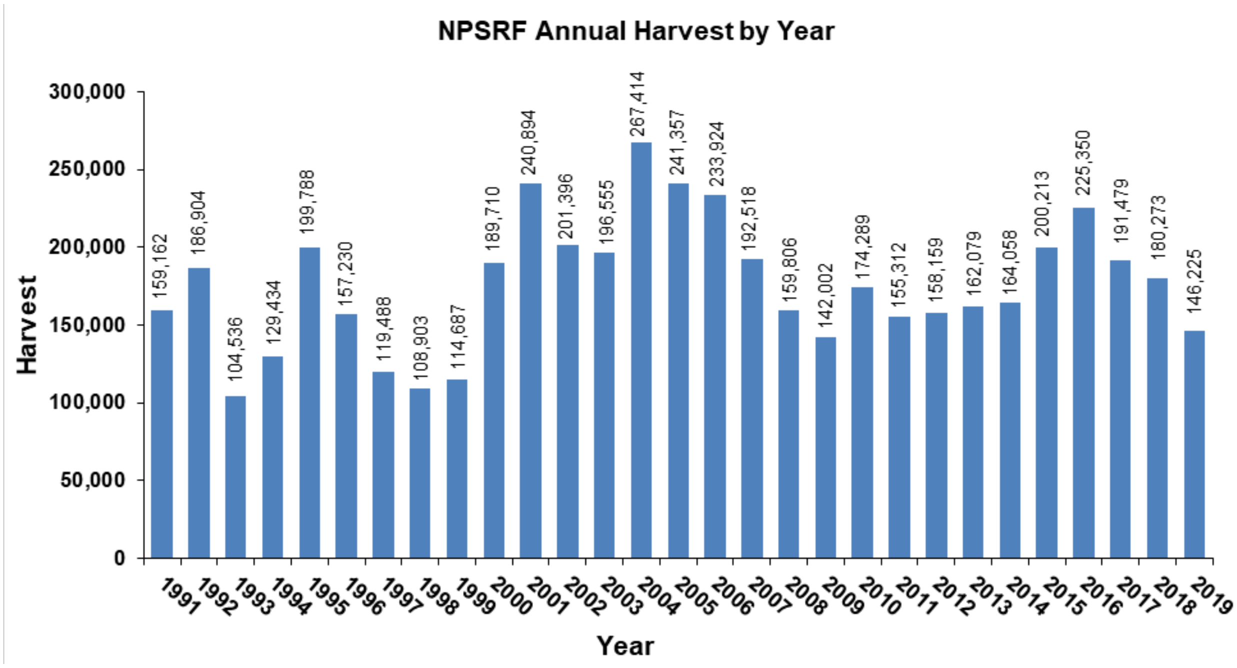


Figure 4. Annual harvest totals for the Northern Pikeminnow Sport-Reward Fishery

Harvest by Week

Peak weekly harvest was 9,273 Northern Pikeminnow and occurred in week 24 (Figure 5), two weeks earlier than in 2018 (Figure 6), and 1,681 fish less than in 2018 (10,954). Mean weekly harvest was lower in 2019 (6,358) than in 2018 (8,194) and was below 2018 weekly harvest for all but 2 weeks of the 23 week season (Hone et al. 2019). Harvest was well below 10,000 fish per week during the first critical 6 weeks of the season and never reached that point during the entire 2019 season. Without high early season harvest as the NPSRF usually experiences, it was likely that the seasonal harvest total would be below average. Peak harvest occurred in week 24, two weeks earlier the NPSRF's historical 1991-2018 peak in week 26 (Fox et al. 2000), followed by a second late-season peak in week 37 (Figure 7).

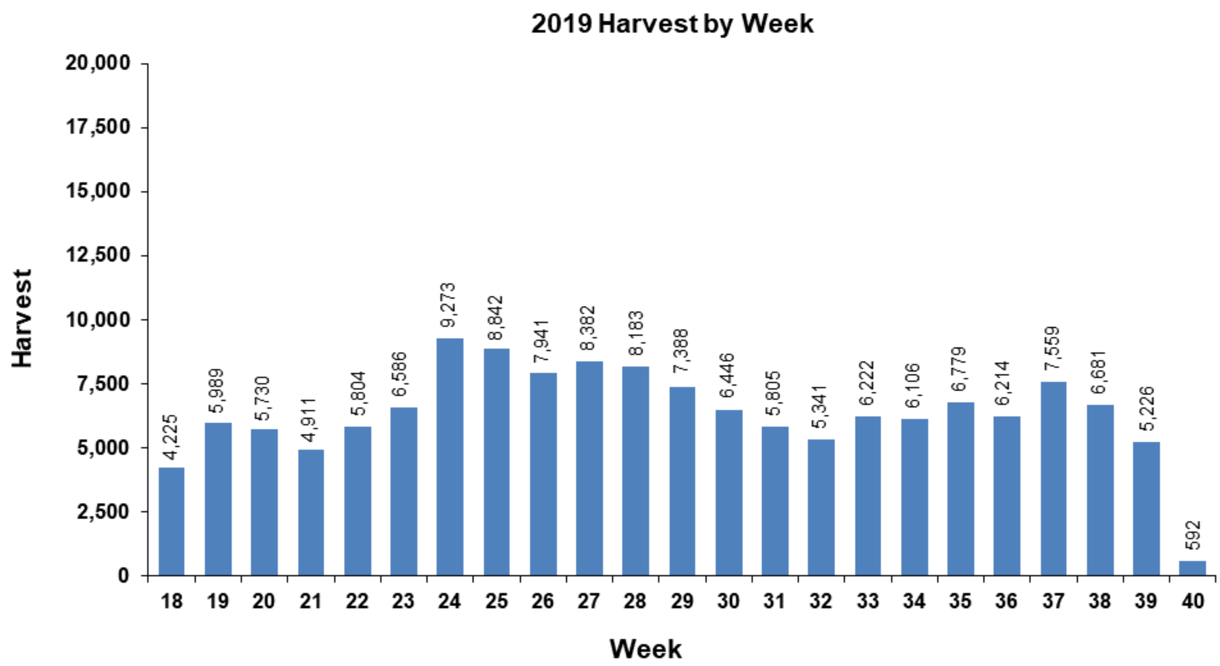


Figure 5. 2019 Weekly Northern Pikeminnow Sport-Reward Fishery harvest

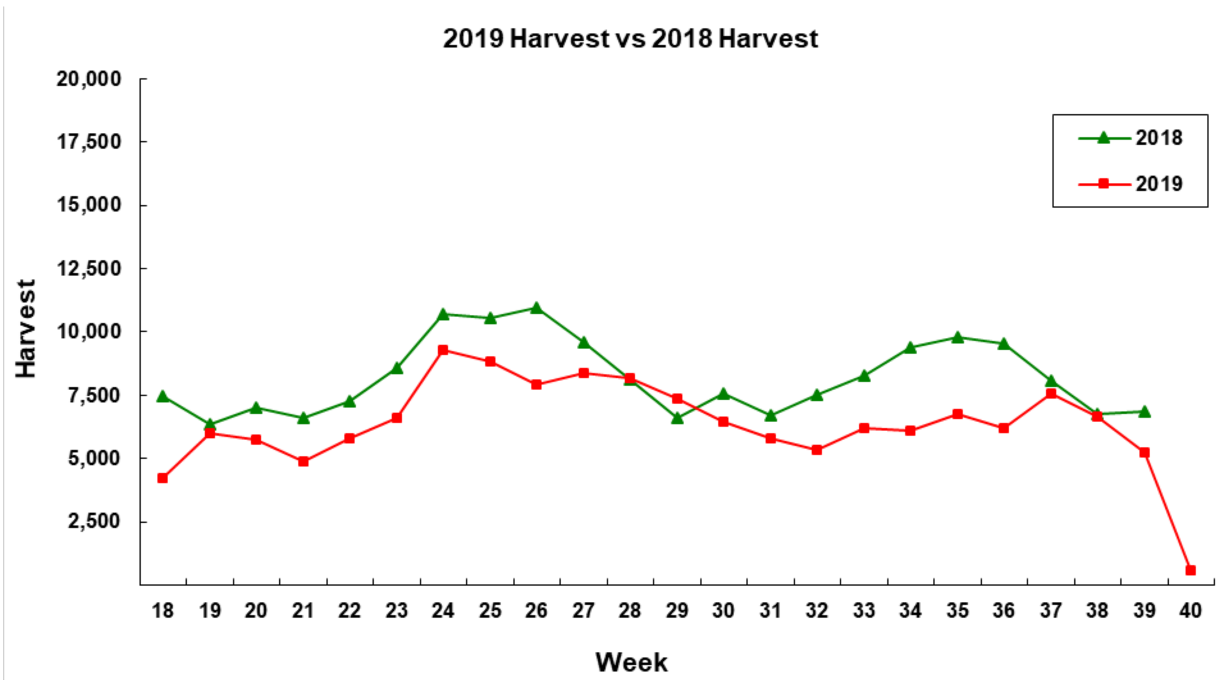


Figure 6. 2019 Weekly NPSRF harvest vs 2018 weekly harvest

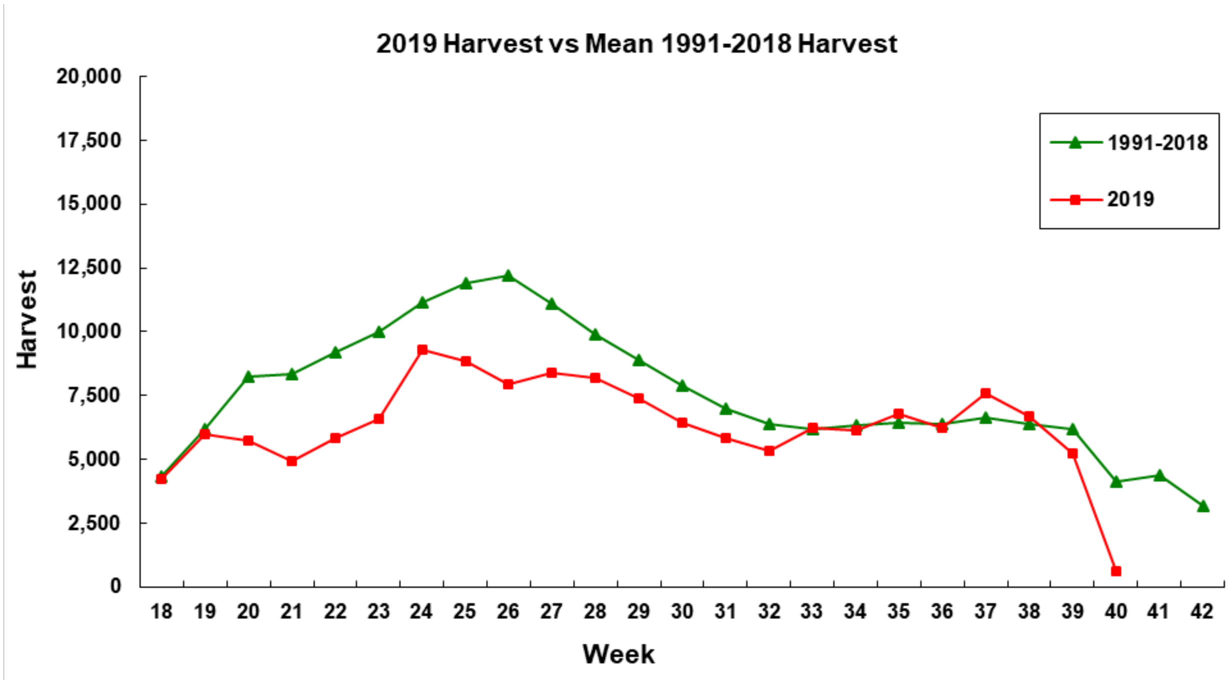


Figure 7. Comparison of 2019 NPSRF weekly harvest to 1991-2018 mean weekly harvest

Harvest by Fishing Location

The mean harvest by fishing location for the 2019 NPSRF was 12,185 Northern Pikeminnow (compared to 15,023 in 2018) and ranged from 90,287 reward size Northern Pikeminnow in fishing location 01 (Below Bonneville Dam) to only 10 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) increased to 61.75% of total NPSRF harvest (from 53.86% of NPSRF in 2018) and was the highest producing location again in 2019 as it has been for all but one of the preceding 28 seasons since the NPSRF began system wide implementation of the NPSRF in 1991 (Hone et al. 2019). Fishing location 02 (Bonneville Reservoir) had the most change from the previous year, dropping from 17.37% in 2018 to only 8.45% of the harvest in 2019. With the tremendous decline in harvest from fishing location 02, Little Goose Reservoir (Fishing Location 10) became the second highest producing area accounting for 14.75% of total 2019 NPSRF harvest.

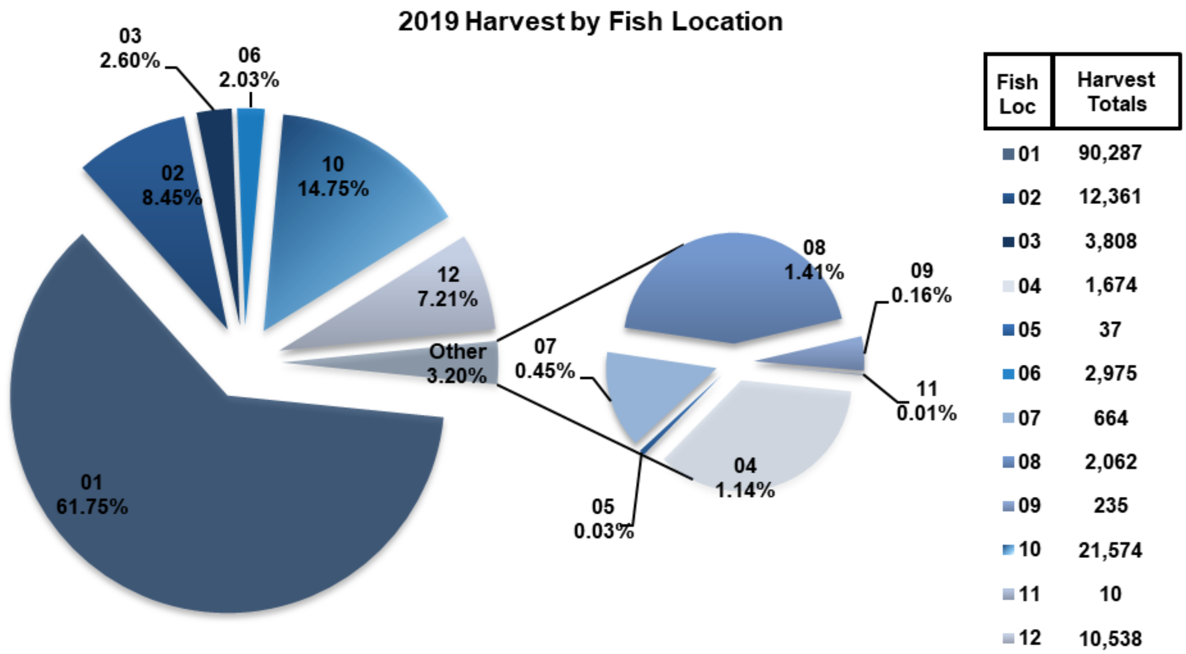


Figure 8. 2019 Northern Pikeminnow Sport-Reward Fishery harvest by fishing location*

*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 2019 was up from 2018 at 5 of the 19 registration stations, mostly in the lower river (Hone et al. 2019) downstream of Bonneville Dam. The Cathlamet registration station retained the title of the NPSRF's top producing station for a second consecutive season, where anglers harvested 27,329 Northern Pikeminnow, equaling 18.7% of total 2019 NPSRF harvest (Figure 9). The Boyer Park registration station finished with the second highest total of 21,004 Northern Pikeminnow (14.4% of total) harvested in 2019. The Dalles station, which is typically one of the top two stations, fell to fifth place in 2019 with harvest of 9,214 fish. The average harvest per registration station was 7,696 reward size Northern Pikeminnow, down from 9,488 per station in 2018 (Hone et al. 2019). The registration station with the smallest harvest was Vernita where anglers harvested only 565 Northern Pikeminnow during the 2019 season. The Cathlamet registration station also showed the largest increase in harvest during the 2019 NPSRF with 2,194 more reward size Northern Pikeminnow turned in than in 2018 (Hone et al. 2019).

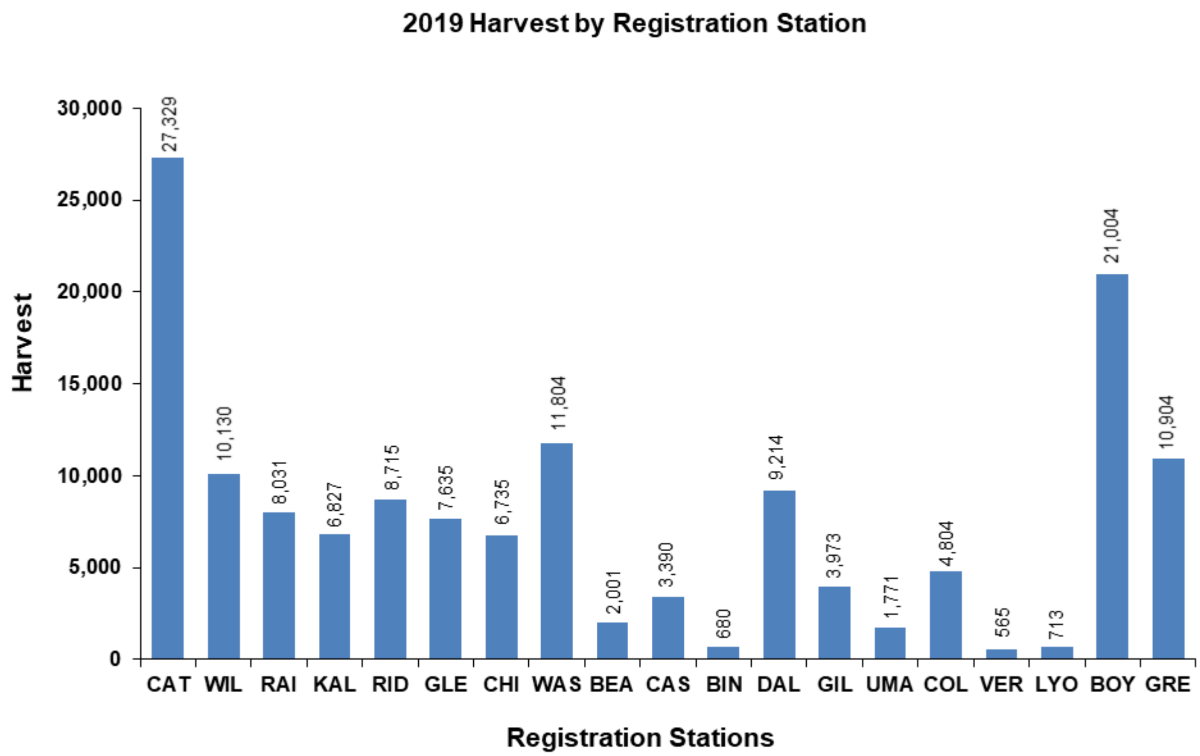


Figure 9. 2019 Northern Pikeminnow Sport-Reward Fishery harvest by registration station
CAT-Cathlamet, WIL-Willow Grove, RAI-Rainier, KAL-Kalama, RID-Ridgefield, GLE-Gleason, CHI-Chinook, WAS-Washougal, BEA-Beacon Rock, CAS-Cascade Locks, BIN-Bingen, DAL- The Dalles, GIL-Giles, UMA-Umatilla, COL-Columbia 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 2019 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 2019.

Salmon

Species	Caught	Harvest	Harvest Percent
Chinook (Juvenile)	74	0	0%
Trout (Unknown)	59	5	8.47%
Steelhead Juvenile (Hatchery)	45	0	0%
Steelhead Juvenile (Wild)	34	0	0%
Chinook (Adult)	27	10	37.04%
Steelhead Adult (Hatchery)	24	1	4.17%
Steelhead Adult (Wild)	23	0	0%
Chinook (Jack)	20	7	35%
Cutthroat (Unknown)	15	1	6.67%
Coho (Adult)	10	5	50%
Sockeye (Adult)	1	0	0%

Anglers reported that all juvenile salmonids caught during the 2019 NPSRF were released. Per NPSRF protocol, technicians recorded all juvenile steelhead caught by NPSRF anglers as "wild", (except those specifically reported as missing the adipose fin). Harvested adult salmonids that were caught incidentally during the 2019 NPSRF were only retained during legal salmonid fisheries. NPSRF protocol is to immediately 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 in 2019 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 2019

Non-Salmonid Species	Caught	Harvest	Harvest Percent
Northern Pikeminnow >228mm	146,226	146,225	99.99%
Peamouth	26,494	9,304	35.12%
Northern Pikeminnow <228mm	23,641	2,090	8.84%
Smallmouth Bass	12,430	778	6.26%
Yellow Perch	8,079	2,331	28.85%
Sculpin (unknown)	6,362	3,668	57.65%
Channel Catfish	1,883	270	14.34%
Sucker (unknown)	1,797	161	8.96%
Catfish (unknown)	1,768	272	15.38%
White Sturgeon	1,580	10	.63%
Walleye	986	459	46.55%
Bullhead (unknown)	733	144	19.65%
Chiselmouth	541	66	12.20%
Starry Flounder	282	39	13.83%
Carp	278	18	6.47%
American Shad	167	54	32.34%
Bluegill	156	5	3.21%
Largemouth Bass	49	2	4.08%
Crappie (unknown)	28	3	10.71%
Whitefish	4	2	50%
Pumpkinseed	3	0	0%
Sandroller	1	0	0%

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 2019, there were 5,997 non-returning angler days recorded and a total of 1,228 calls were completed to non-returning anglers (20.5% 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 2019 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 2019 NPSRF. Estimated totals are listed in columns 5 and 6 of Table 3.

Table 3. 2019 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	93	1	1.1%	454	5
Northern Pikeminnow $\geq$ 228 mm	13	12	92.3%	63	59
Trout (Unknown)	7	0	0%	34	0
Steelhead Juvenile	3	0	0%	15	0
Chinook Salmon (Adult)	2	2	100%	10	10

N=5,997 n=1,228

Fork Length Data

The length frequency distribution for harvested Northern Pikeminnow ($\geq$ 200 mm) from the 2019 NPSRF is presented in Figure 10. Fork length data from 106,682 Northern Pikeminnow $\geq$ 200 mm FL (73% of total harvest) were taken during the 2019 NPSRF. The mean fork length for all measured Northern Pikeminnow ($\geq$ 200 mm) in 2019 was 281.2 mm (SD= 61.03 mm), up from 272.6 in 2018 (Hone et al. 2019).

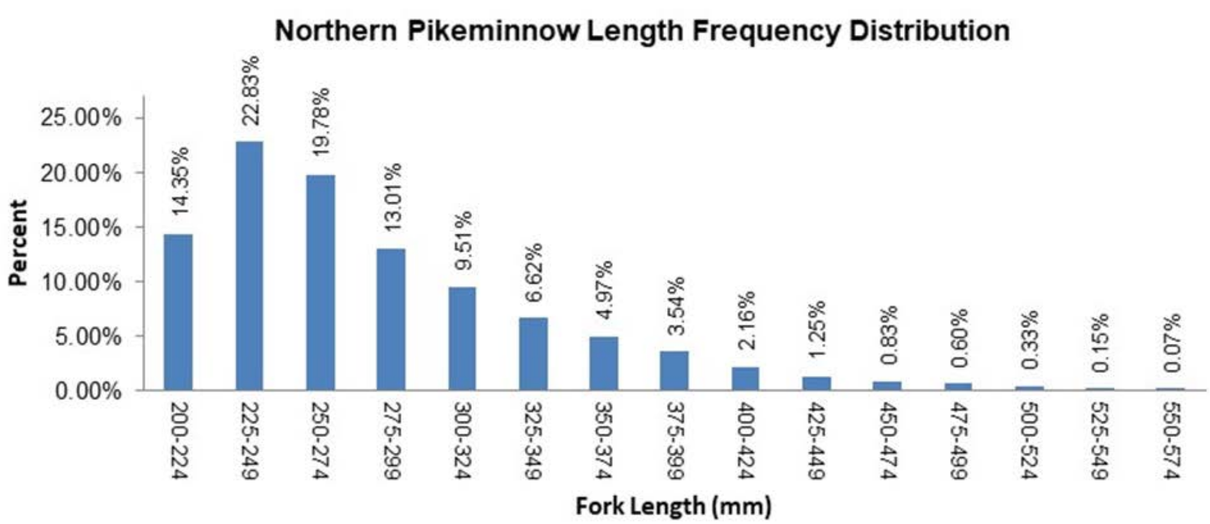


Figure 10. Length frequency distribution of Northern Pikeminnow $\geq$ 200 mm FL from 2019 NPSRF

Angler Effort

The 2019 NPSRF recorded total effort of 20,286 angler days spent during the season, a decrease of 3,693 angler days from 2018 (Hone et al. 2019) (Figure 11). When total effort is divided into returning and non-returning angler days, 14,289 angler days (70.4%) were recorded by returning anglers, and 5,997 angler days (29.6%) were spent by non-return anglers. The percentage of returning anglers in 2019 (70.4%) was lower than the 2018 (71.7%) season (Hone et al. 2019). In addition, 59% of total effort, and 84% of returning angler effort (11,934 angler days), was attributed to successful anglers who harvested at least one Northern Pikeminnow in 2019.

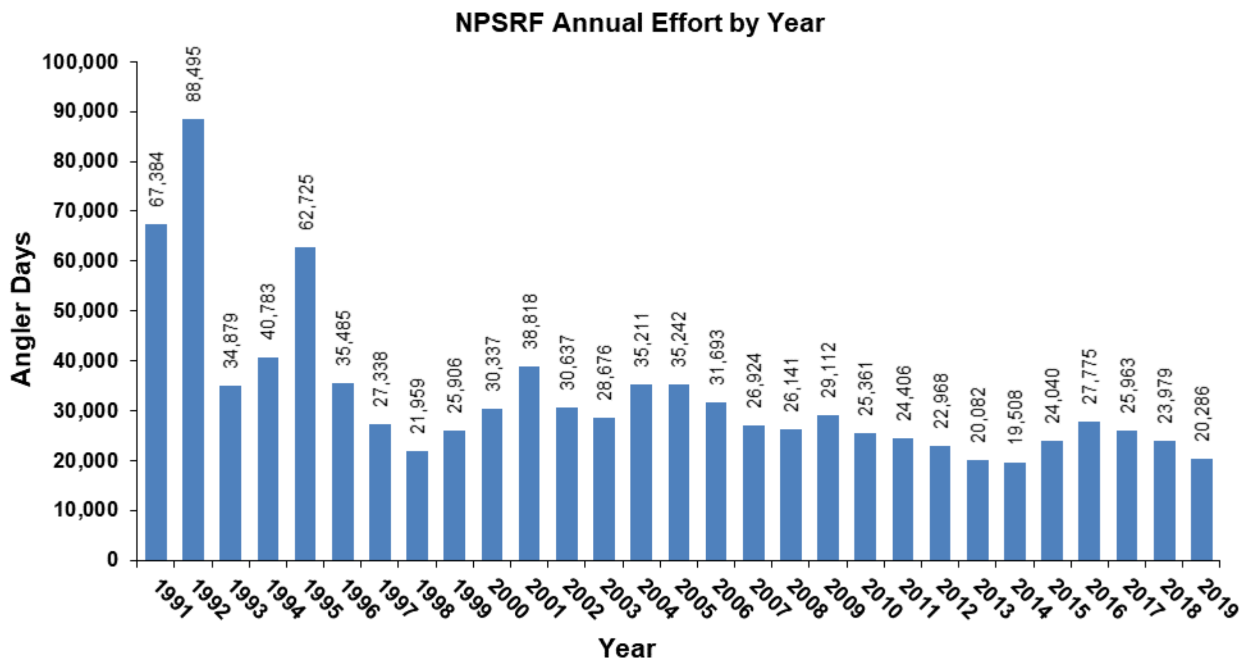


Figure 11. Annual Northern Pikeminnow Sport-Reward Fishery effort

Effort by Week

Mean weekly effort for the 2019 NPSRF was 882 angler days during the season, with the peak occurring in week 19, the first full week of the season (Figure 12). When we compare weekly effort totals for 2019 with the 2018 season, weekly effort totals from all weeks were down from those of 2018 (Hone et al. 2019) (Figure 13). Peak weekly effort in 2019 occurred five weeks earlier than 2019 peak harvest (week 24) (Figure 5). Overall, mean weekly effort decreased from 1,090 in 2018 to 882 in 2019 (Hone et al. 2019). Since the tier change in 2015, weekly effort totals have followed a pattern where peak effort occurs near the first full week of the season (Figure 14). This is different from historical 1991-2015 (Winther et al. 2016) pattern where peak effort typically occurred on the same week as peak harvest (Figure 14).

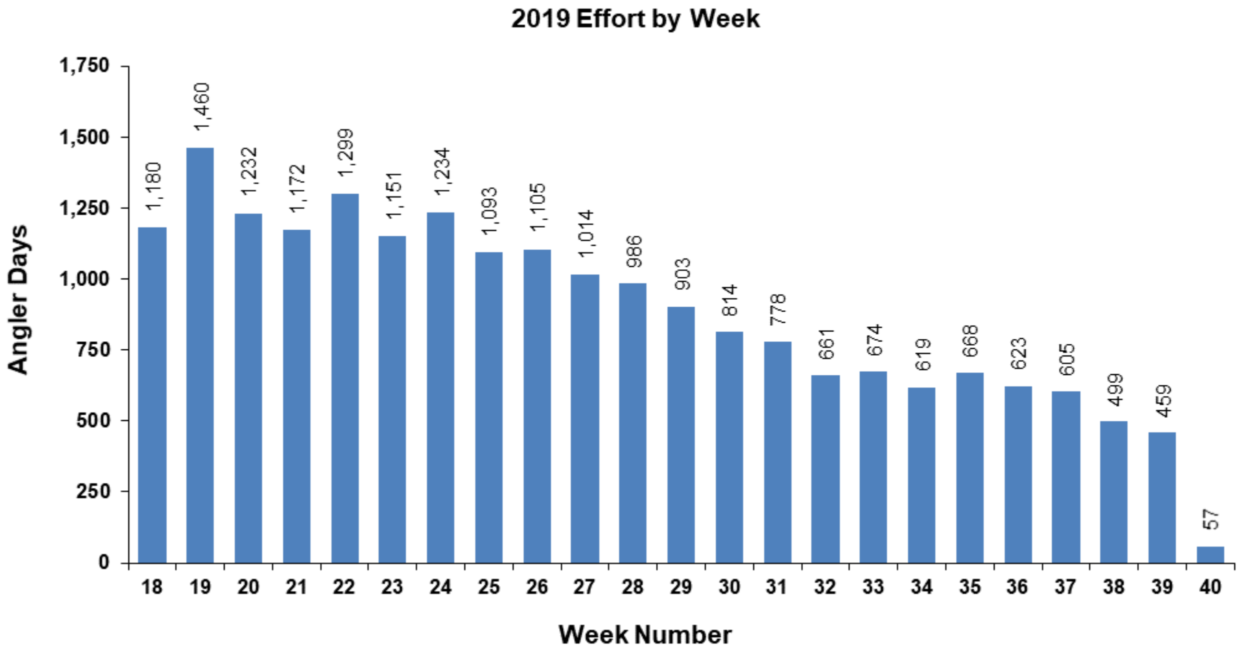


Figure 12. 2019 Weekly Northern Pikeminnow Sport-Reward Fishery angler effort

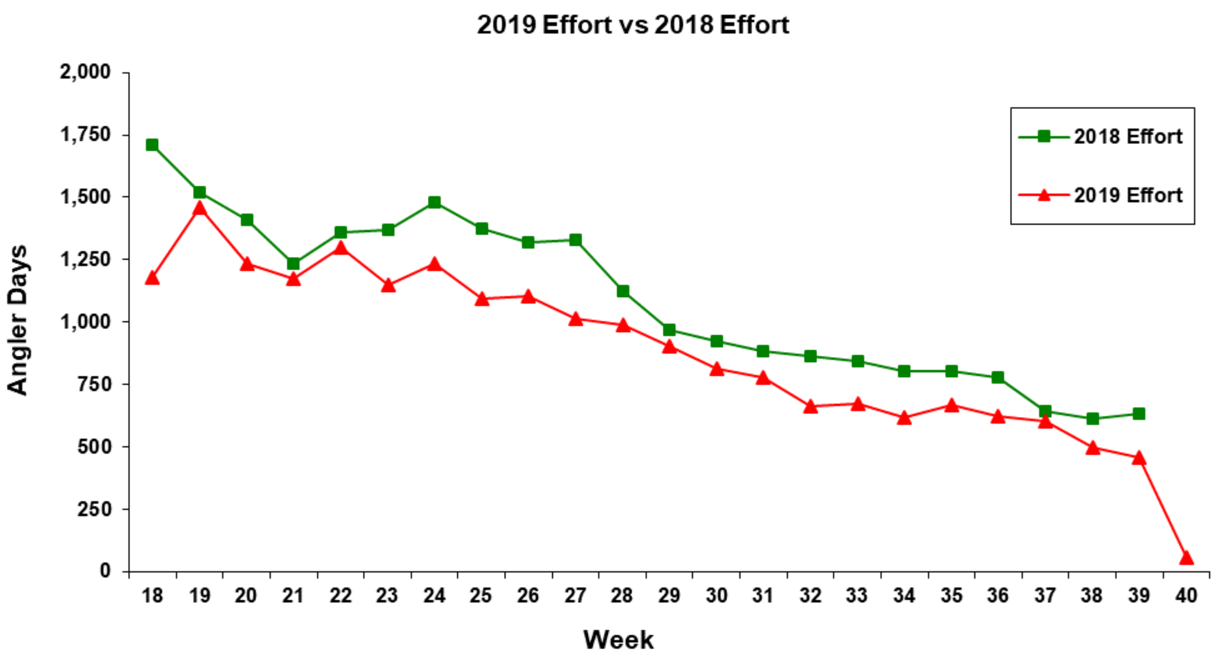


Figure 13. Effort 2019 Northern Pikeminnow Sport-Reward Fishery effort vs 2018 effort

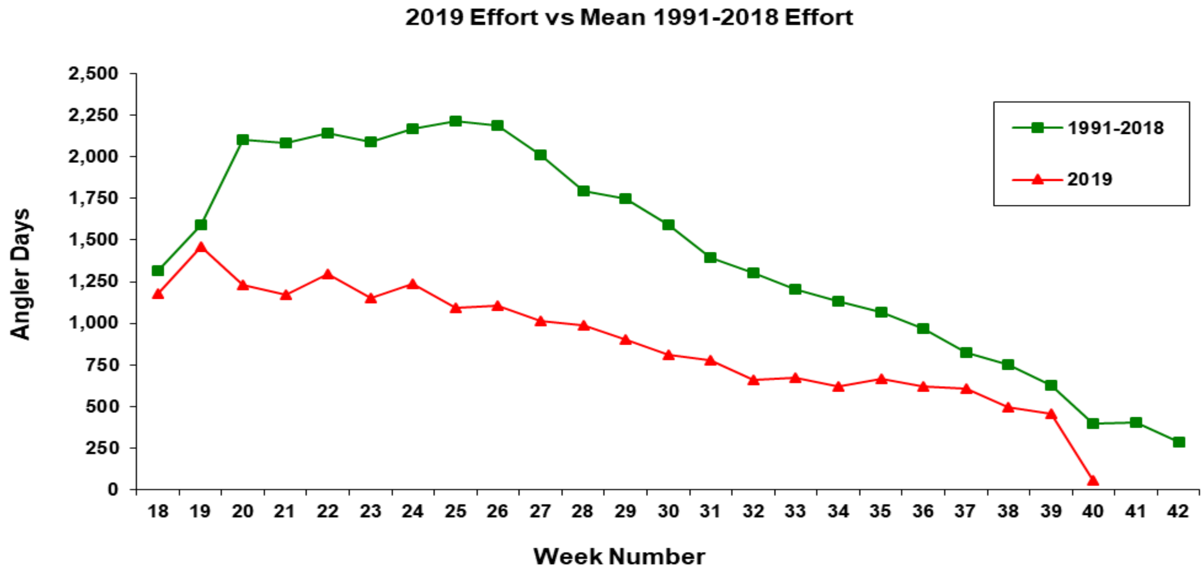


Figure 14. 2019 NPSRF weekly effort vs mean 1991-2018 effort

Effort by Fishing Location

Mean annual effort by fishing location for the 2019 NPSRF (returning anglers only) decreased from 1,432 angler days in 2018 (Hone et al. 2019) to 1,191 angler days in 2019. Effort totals ranged from 7,073 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). Only three of the 12 NPSRF fishing locations (07, 10, and 12) in the Snake River recorded an increase in angler effort in 2019.

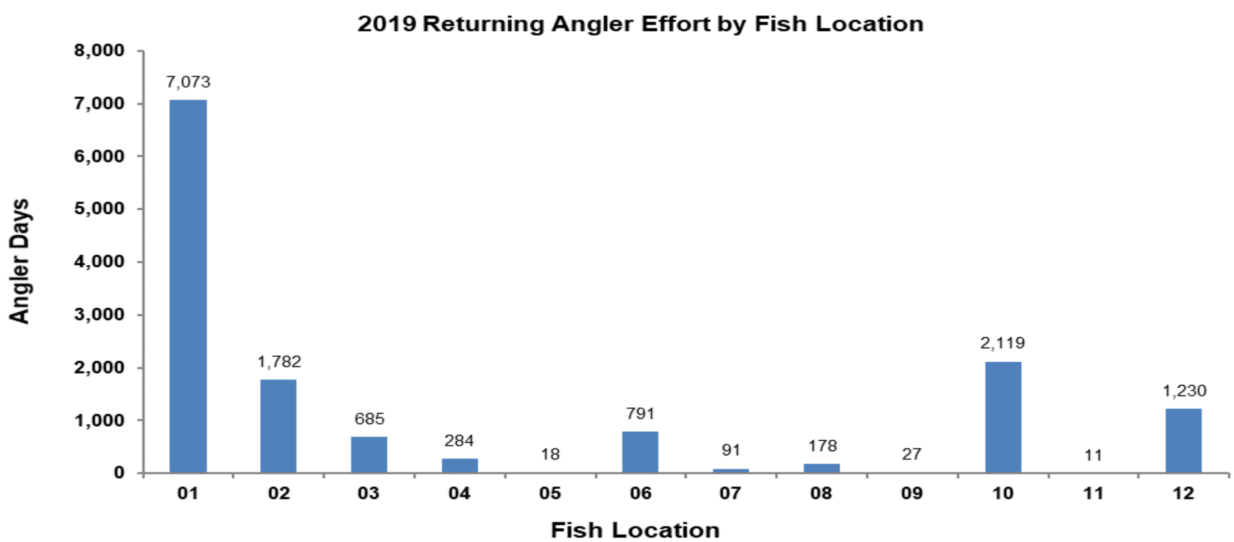


Figure 15. 2019 NPSRF angler effort by fishing location* (returning anglers only).

*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 2019 NPSRF was 1,068 angler days compared to 1,262 angler days in 2018 (Hone et al. 2019). Effort totals ranged from a high of 2,815 angler days at the Cathlamet station to a low of 86 angler days at the Lyon's Ferry station (Figure 16). Although effort decreased at 14 of the 19 registration stations, there were increases in angler effort at registration stations near the lower (Cathlamet) and upper ends of NPSRF boundaries in 2019.

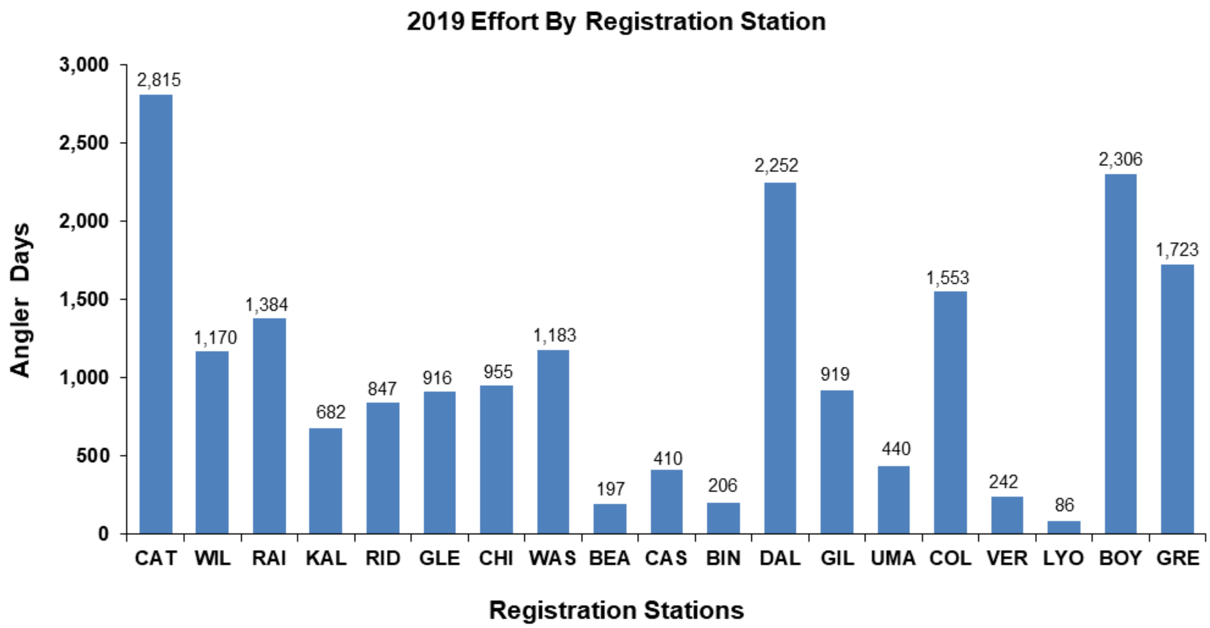


Figure 16. 2019 Northern Pikeminnow Sport-Reward Fishery angler effort by registration station
CAT-Cathlamet, WIL-Willow Grove, RAI-Rainier, KAL-Kalama, RID-Ridgefield, GLE-Gleason, CHI-Chinook, WAS-Washougal, BEA-Beacon Rock, CAS-Cascade Locks, BIN-Bingen, DAL-The Dalles, GIL-Giles, UMA-Umatilla, COL-Columbia Point, VER-Vernita, LYO-Lyon's Ferry, BOY-Boyer Park, GRE-Greenbelt.

Catch Per Angler Day (CPUE)

The 2019 NPSRF recorded an overall (returning + non-returning anglers) catch per unit of effort (CPUE or "catch rate") of 7.21 Northern Pikeminnow harvested per angler day during the season. This catch rate was down from the 2018 overall CPUE of 7.52 (Figure 17) and reaffirms accounts of poorer river conditions/angling success we received anecdotally from Pikeminnow anglers during 2019. Angler CPUE has trended upwards throughout the NPSRF's 29-year history and began climbing again in 2019 after falling for the past three seasons. Returning angler CPUE during the 2019 NPSRF was 10.23 Northern Pikeminnow per angler day, down slightly from the 2018 returning angler CPUE of 10.49 (Hone et al. 2019). The estimated CPUE for non-returning anglers was 0.01 reward size Northern Pikeminnow per angler day based on 2019 NPSRF phone survey results and has remained constant throughout recent NPSRF history.

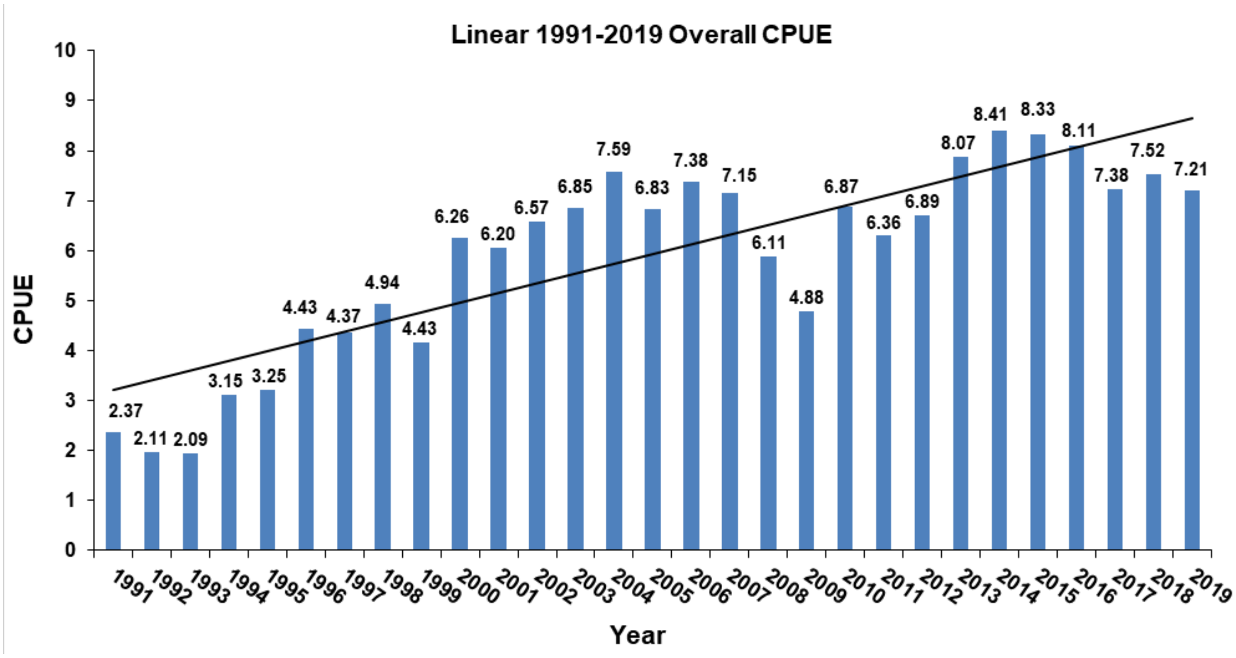


Figure 17. Annual NPSRF CPUE (returning + non-returning anglers) for the years 1991-2019

CPUE by Week

Mean angler CPUE by week for the 2019 NPSRF was 8.03 fish per angler day compared to 8.18 in 2018 (Hone et al. 2019) and ranged from a low of 3.58 in week 18 (May 1-5) to a peak of 13.39 in week 38 (September 16-22) (Figure 18). Weekly CPUE for the 2019 NPSRF followed a typical two-peak pattern where the first peak happened in week 28 near the historical Northern Pikeminnow spawning peak and then again late in the season (week 38) when favorable water and angling conditions were present in the lower Columbia and Snake rivers (Winther et al. 2011).

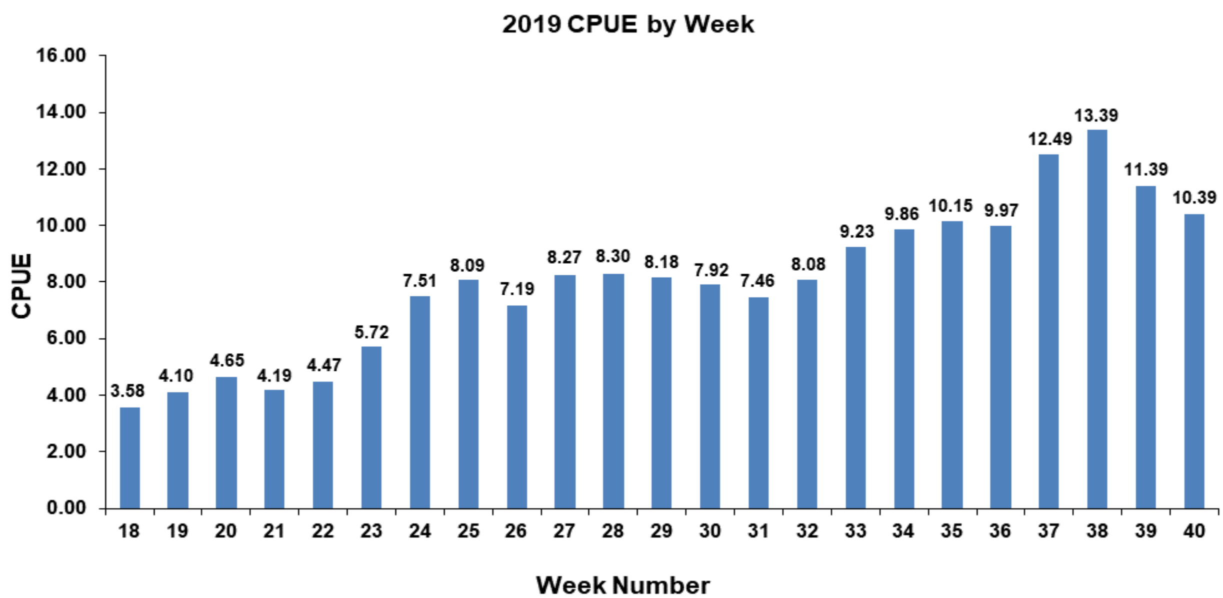


Figure 18. 2019 Northern Pikeminnow Sport-Reward Fishery angler CPUE by week

CPUE by Fishing Location

Angler success rates for the 2019 NPSRF (as indicated by CPUE), represent returning anglers only and varied by fishing location. Success rates ranged from a high of 12.77 Northern Pikeminnow per angler day in fishing location 01 (Below Bonneville Dam) to a low of .91 fish per angler per day in fishing location 11 (Lower Granite Dam to the Mouth of Clearwater River) (Figure 19). CPUE increased at four of the 12 fishing locations in 2019. The average CPUE by fishing location was 7.02 Northern Pikeminnow per angler day in 2019 compared to 7.77 in 2018 (Hone et al. 2019).

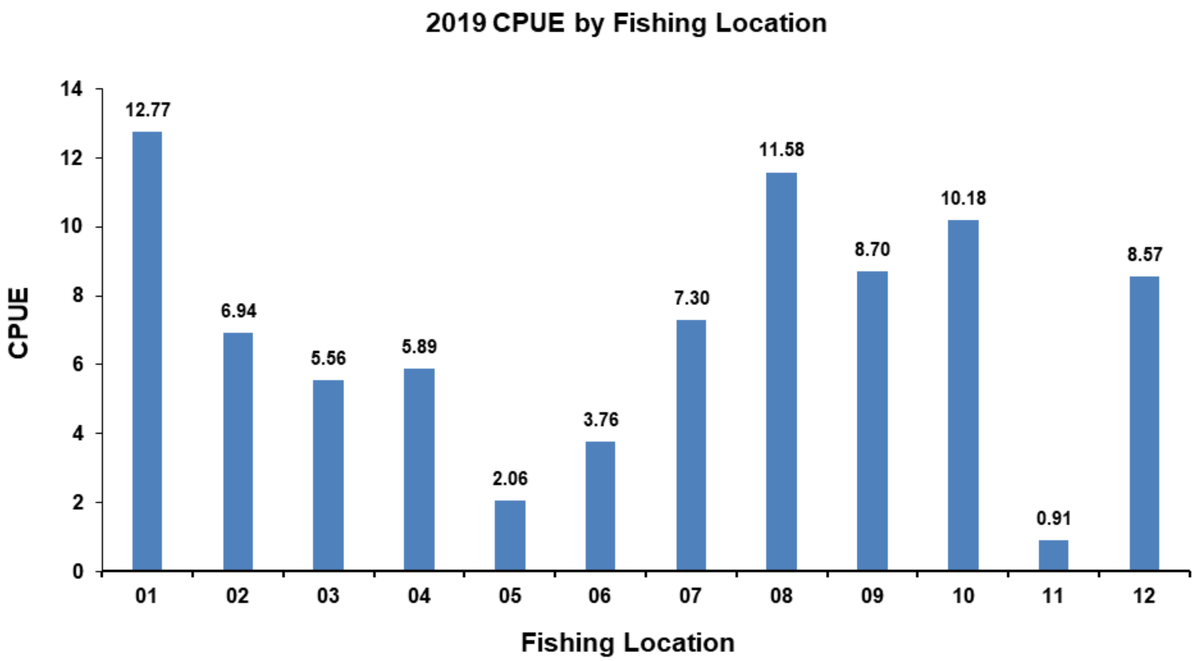


Figure 19. 2019 Northern Pikeminnow Sport-Reward Fishery angler CPUE by fishing location.*
*Fishing Location Codes for **Columbia River**; 01 = Below Bonneville Dam, 02 = Bonneville Reservoir, 03 = The Dalles Reservoir, 04 = John Day Reservoir, 05 = McNary Dam to the mouth of the Snake River, 06 = Mouth 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 2019 NPSRF was the Ridgefield station where anglers averaged 10.29 Northern Pikeminnow per angler day (Figure 20). The registration station with the lowest CPUE was the Vernita station with a CPUE of 2.33 Northern Pikeminnow per angler day. The station average for angler CPUE was 7.01 in 2019, down from 8.18 in 2018 (Hone et al. 2019). Angler CPUE by registration station increased at nine stations during the 2019 NPSRF season and almost all stations with increases were located below Bonneville Dam. With The Dalles station not having the exceptional harvest it has had for more than 10 years, anglers appeared to find the best angling success at stations below Bonneville Dam. The largest CPUE increase occurred at the Willow Grove station, where CPUE increased from 5.62 in 2018 (Hone et al. 2019) to 8.66 in 2019.

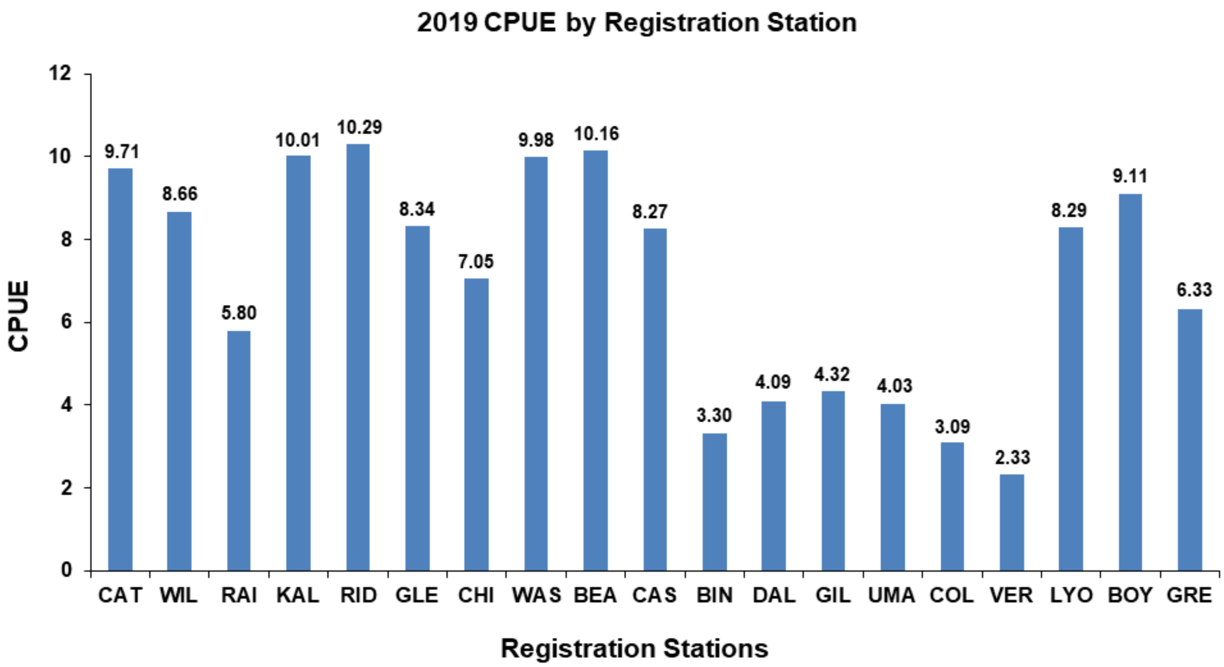


Figure 20. 2019 Northern Pikeminnow Sport-Reward Fishery angler CPUE by registration station
CAT-Cathlamet, WIL-Willow Grove, RAI-Rainier, KAL-Kalama, RID-Ridgefield, GLE-Gleason, CHI-Chinook, WAS-Washougal, BEA-Beacon Rock, CAS-Cascade Locks, BIN-Bingen, DAL-The Dalles, GIL-Giles, UMA-Umatilla, COL-Columbia Point, VER-Vernita, LYO-Lyon's Ferry, BOY-Boyer Park, GRE-Greenbelt.

Angler Totals

There were 2,717 separate anglers who participated in the 2019 NPSRF, a decrease of 331 participants from 2018. One thousand, eighty of these anglers (39.7% of total vs. 43.7% in 2018 were classified as successful, harvesting at least one reward size Northern Pikeminnow (for which a voucher was issued) during the 2019 season. Of the successful anglers, 74% (804 anglers) sent in their vouchers to PSMFC for payment (PSMFC 12/12/19 Sport-Reward Payment Summary) while 276 anglers (26%) did not. The average successful angler harvested 135 Northern Pikeminnow during the 2019 NPSRF compared to 139 in 2018 (Hone et al. 2019).

When we break down the 1,080 successful anglers by tier, 783 of these anglers (72.5%) harvested fewer than 25 Northern Pikeminnow and were classified as Tier 1 anglers (Figure 21). This is down from the 917 individual Tier 1 anglers in 2018. The number of Tier 2 anglers declined to 178 in 2019, down from 226 in 2018. The number of Tier 3 anglers (known as "highliners") decreased from 158 anglers in 2018 to 119 anglers in 2019 (Hone et al. 2019).

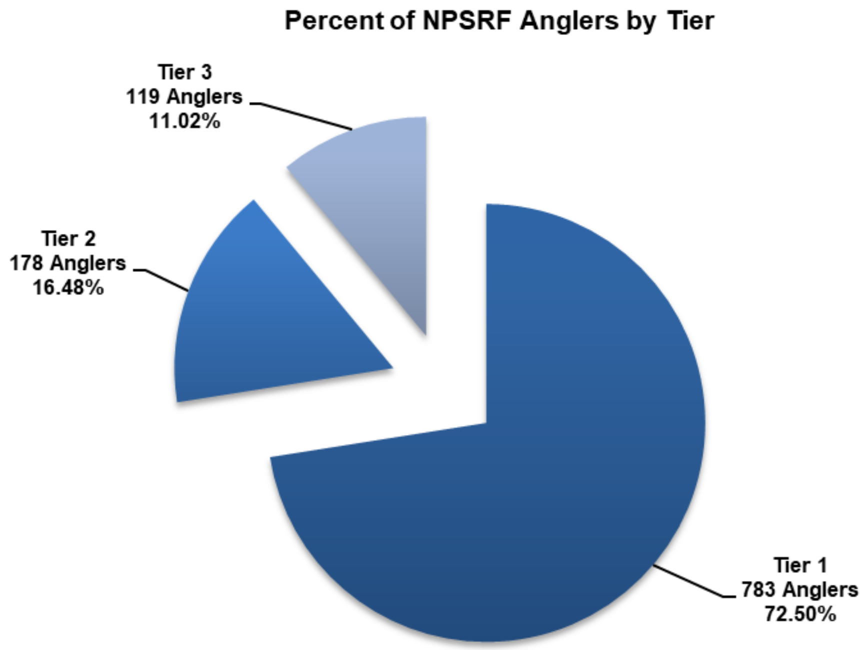


Figure 21. 2019 NPSRF anglers by tier (returning anglers) based on total harvest

The larger number, and higher percentage of individual anglers at Tiers 2 and 3, (as a component of all 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 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 has grown (from levels prior to 2015), the NPSRF continued to mostly recruit and maintain a similar numbers of Tier 1 anglers (which makes up the largest group of successful anglers) (Table 4). Despite a lower number of Tier 1 anglers in 2019, the gains in participation realized after the tier level adjustment in 2015, allowed the overall number of "successful anglers" to remain above 2010-14 levels.

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	1091	111	109	1311	3313	39.57
2011	1226	113	87	1426	3624	39.35
2012	1097	90	98	1285	3302	38.92
2013	941	97	92	1130	2618	43.16
2014	977	96	91	1164	2773	41.98
2010-2014 Mean	**1066**	**101**	**95**	**1263**	**3126**	**40.40**
2015	986	239	163	1388	3210	43.24
2016	1140	295	184	1619	3718	43.54
2017	1048	287	155	1490	3462	43.04
2018	917	226	158	1301	3048	42.68
2019	783	178	119	1080	2717	39.75
2015-2019 Mean	**975**	**245**	**156**	**1376**	**3231**	**42.59**

While Tier 1 anglers made up 72.5% of all successful NPSRF participants in 2019, (below the mean 2010-2014 level of 84.4%), they accounted for only 2.92% of total NPSRF harvest (4,270 Northern Pikeminnow) (Figure 22). Tier 2 anglers made up 16.48% of all successful anglers and harvested 9.57% of total NPSRF harvest (14,001 fish). Tier 3 anglers made up 4.4% of all participants (both returning and non-returning anglers), 11.02% of all successful anglers and accounted for 87.50% of total NPSRF harvest (127,954 fish).

Average annual harvest per angler was up for Tier 1, Tier 2 and Tier 3 anglers. Tier 1 anglers annual average harvest was up slightly from 5.40 fish per year in 2018 to 5.45 fish per year in 2019. Tier 2 anglers harvested an annual average of 78.66 fish per year in 2019, up from 77.33 fish per year in 2018. Average annual harvest for Tier 3 anglers increased to 1,075.24 fish per angler in 2019 compared to 999.02 fish per angler in 2018 (Hone et al. 2019).

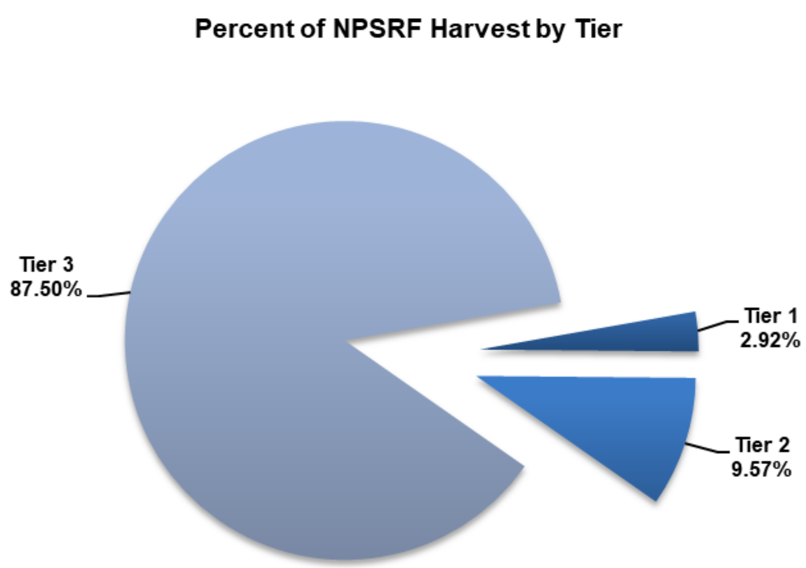


Figure 22. 2019 NPSRF harvest by angler tier (Tier 1 = ≤25, Tier 2 =26-200, Tier 3 = > 200)

The overall average NPSRF participant (returning + non-returning anglers) expended slightly less effort pursuing Northern Pikeminnow during the 2019 season than in 2018 (7.47 vs. 7.87 angling days of effort). When we look at successful anglers only, the average successful angler also slightly decreased their average annual effort spent to 16.21 angler days during the 2019 NPSRF compared to 16.27 days in 2018. When we break down successful angler effort by tier, only Tier 3 anglers spent more annual effort in 2019 than they did in 2018. Tier 1 anglers spent an average of 5 days, and Tier 2 anglers spent an average of 26 days fishing in both 2018 and 2019 (Figure 23). Tier 3 anglers averaged 72 days fishing in 2019, up from 67 days in 2018 (Hone et al. 2019).

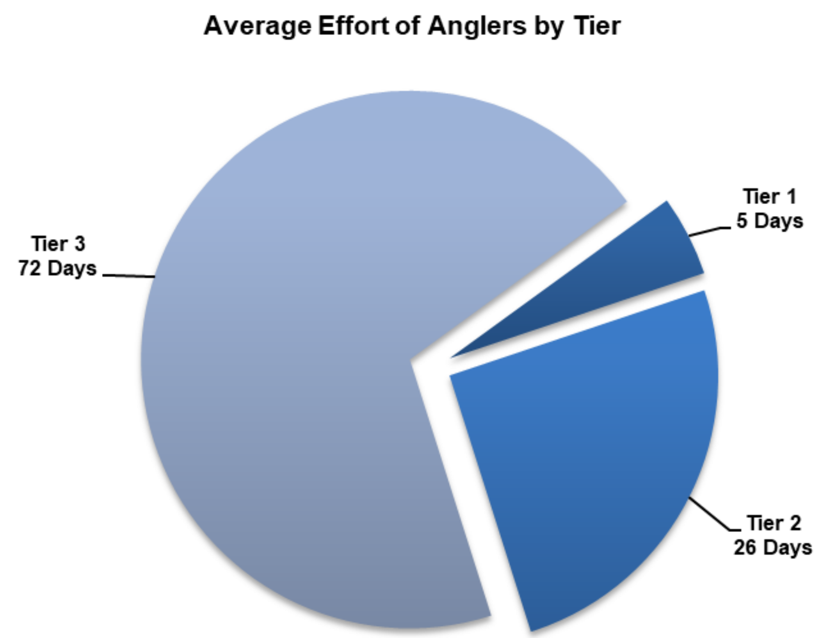


Figure 23. Average effort of 2019 NPSRF anglers by tier (Tier 1 = ≤ 25, Tier 2 = 26-200, Tier 3 = > 200)

When 2019 CPUE by tier is compared to 2018 there is a very slight decrease in CPUE at all three tiers, reflecting poorer fishing/river conditions in effect during the 2019 NPSRF. CPUE for anglers at Tier 1 decreased from 1.05 fish per angler day in 2018 to 1.01 in 2019 (Figure 24). CPUE for Tier 2 anglers decreased from 2.98 fish per angler day in 2018 to 2.97 in 2019. CPUE for Tier 3 anglers decreased from 14.93 fish per angler day in 2018 to 14.92 in 2019 (Hone et al. 2019).

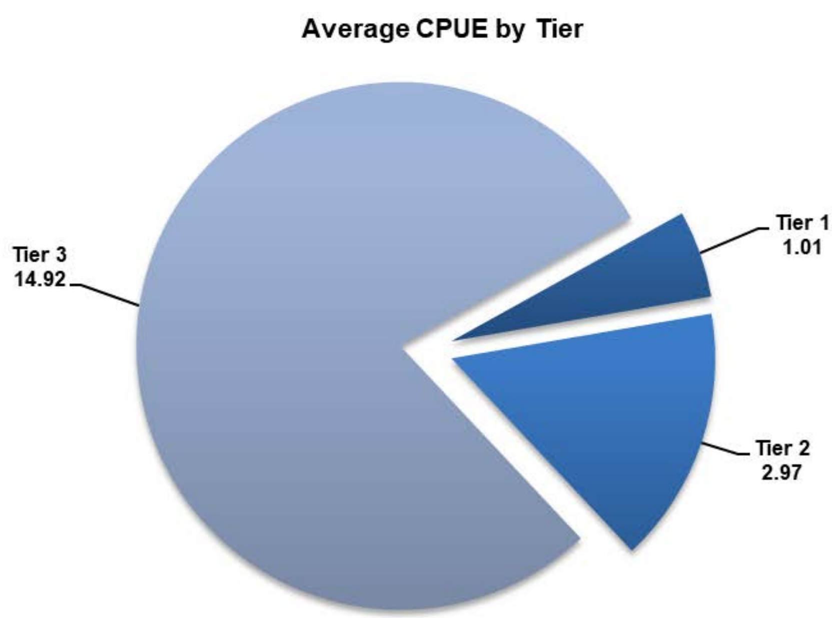


Figure 24. Average CPUE of 2019 NPSRF anglers by tier (Tier 1 = ≤25, Tier 2 =26-200, Tier 3 = > 200)

The top individual angler (based on number of fish caught) for the 2019 NPSRF harvested 6,482 Northern Pikeminnow, which also included 3 externally tagged Northern Pikeminnow and 2 tag-loss Northern Pikeminnow worth total earnings of $53,107 (PSMFC 12/12/2019 Sport-Reward Payment Summary). For the first time in 10 years, the top individual angler was different from the individual that had been the top angler for every NPSRF season since 2009. The 2019 top angler did catch 2,204 less reward sized Northern Pikeminnow than the top angler did in 2018, but still caught 1,832 more fish than the former top angler was able to catch in 2019. The CPUE for this year's top angler (51.4 fish per angler day) was down from the top angler in 2018 (64.8 fish per angler day) reflecting the poorer fishing/river conditions in effect in 2019 than during the 2018 NPSRF. The top angler for the 2019 season also spent 8 fewer days of effort (126 days) than the top angler did in 2018 (Hone et al. 2019). By comparison, the top angler in terms of participation (rather than harvest) for the 2019 NPSRF fished 151 days of the 153 available days (98.7% of available days) and harvested 2,331 Northern Pikeminnow.

Tag Recovery

Northern Pikeminnow Tags

Returning anglers harvested 143 Northern Pikeminnow tagged by ODFW with external spaghetti or Floy tags during the 2019 NPSRF compared to 198 external spaghetti tags harvested in 2018 (Hone et al., 2019). Tag recoveries peaked during week 19 (Figure 25), which was seven weeks earlier than peak tag recovery in 2018 week 26 (Hone et al. 2019). One hundred forty-one of the externally tagged Northern Pikeminnow recovered in the 2019 NPSRF, retained PIT tags added by ODFW as a secondary mark. WDFW technicians recovered an additional 184 Northern Pikeminnow, which retained ODFW PIT tags, but had lost the external tag (referred to as "tag-loss"). ODFW used WDFW's tag recovery data from the 2019 NPSRF (Spaghetti, Floy and/or PIT) to estimate a 15.4% exploitation rate for the NPMP in 2019 (Anderson et al. 2020).

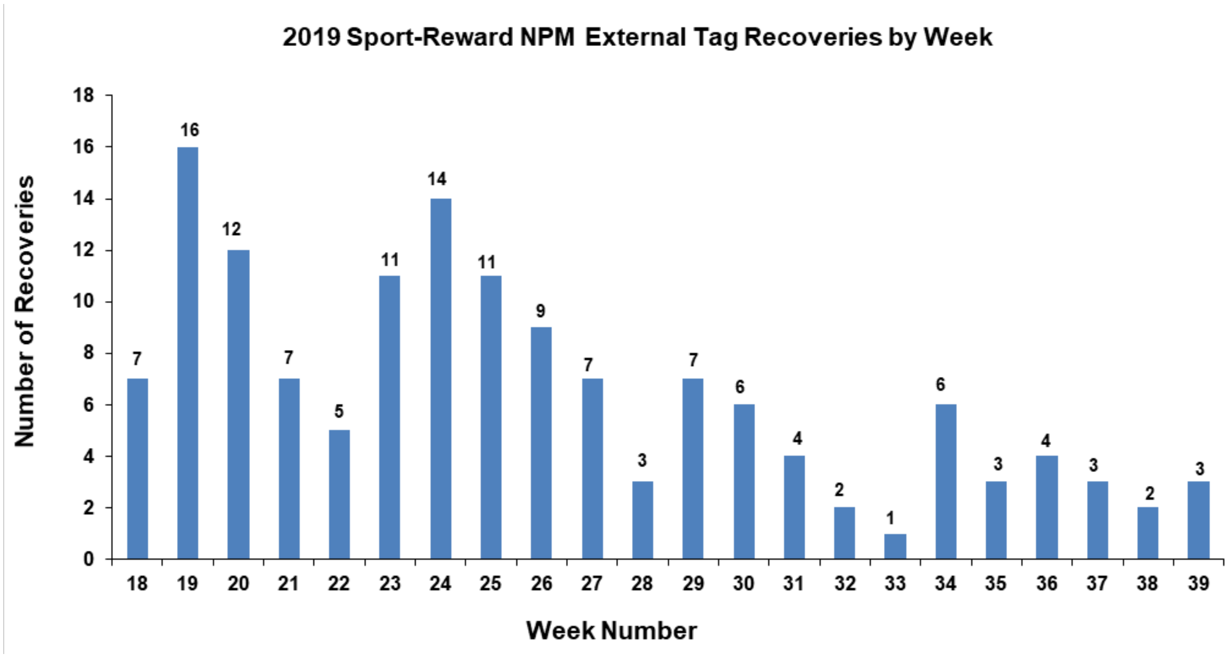


Figure 25. 2019 NPSRF external tag recoveries by week

Ingested PIT Tags

A total of 146,225 Northern Pikeminnow were individually scanned for the presence of PIT tags in 2019. This represents 100% of the total harvest of reward-size fish for the 2019 NPSRF (Northern Pikeminnow not qualifying for rewards were also scanned whenever possible). Technicians recovered a total of 36 PIT tags from consumed smolts that had been ingested by Northern Pikeminnow harvested during the 2019 NPSRF, an overall occurrence ratio of 1:4,062 compared to 1:6,934 in 2018. Total ingested PIT tag recoveries in 2019 was 10 recoveries higher than the previous year. While total harvest was lower in 2019 than in 2018, the rate of occurrence for ingested PIT tags increased from 1:6,934 in 2018 to 1:4,062 in 2019. PIT tag recoveries of salmonid smolts ingested by Northern Pikeminnow peaked during week 19 of the 2019 NPSRF (compared to weeks 18 and 25 in 2018) (Hone et al. 2019). The final ingested PIT tag recoveries for the 2019 NPSRF occurred during week 30 (July 22nd – July 28th) (Figure 26).

Ingested PIT tag recoveries by fishing location during the 2019 NPSRF showed that Northern Pikeminnow harvested from fishing location 02 (Bonneville Reservoir) and 08 (Ice Harbor Reservoir) consumed the largest number of PIT tagged juvenile salmonids (Figure 27).

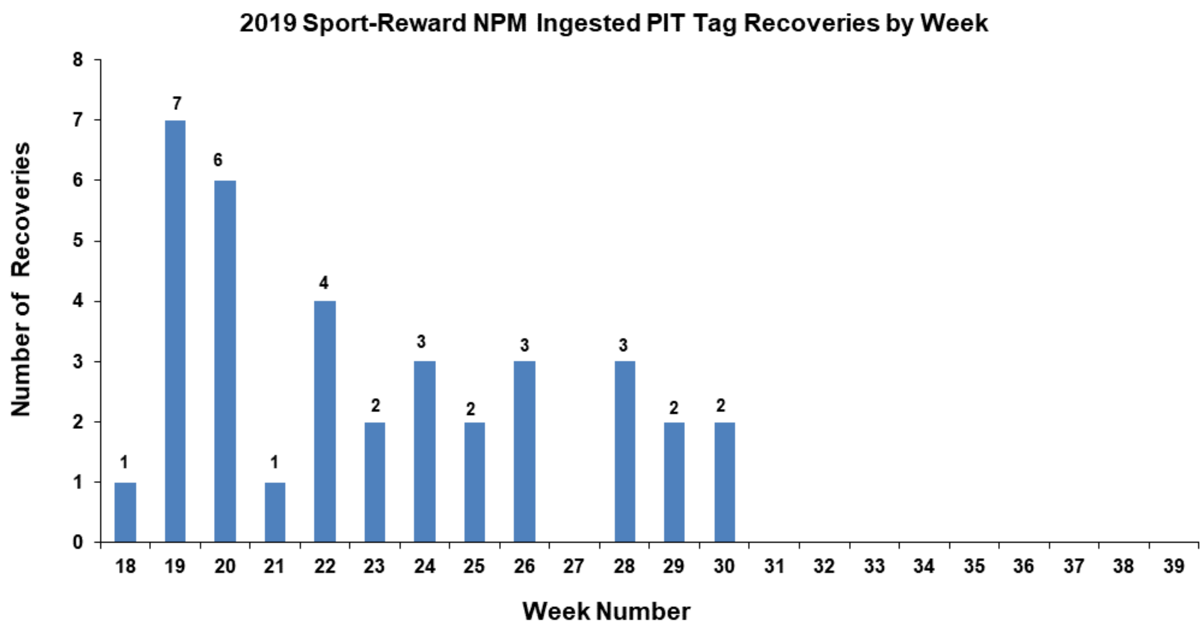


Figure 26. 2019 NPSRF ingested PIT Tag recoveries by week

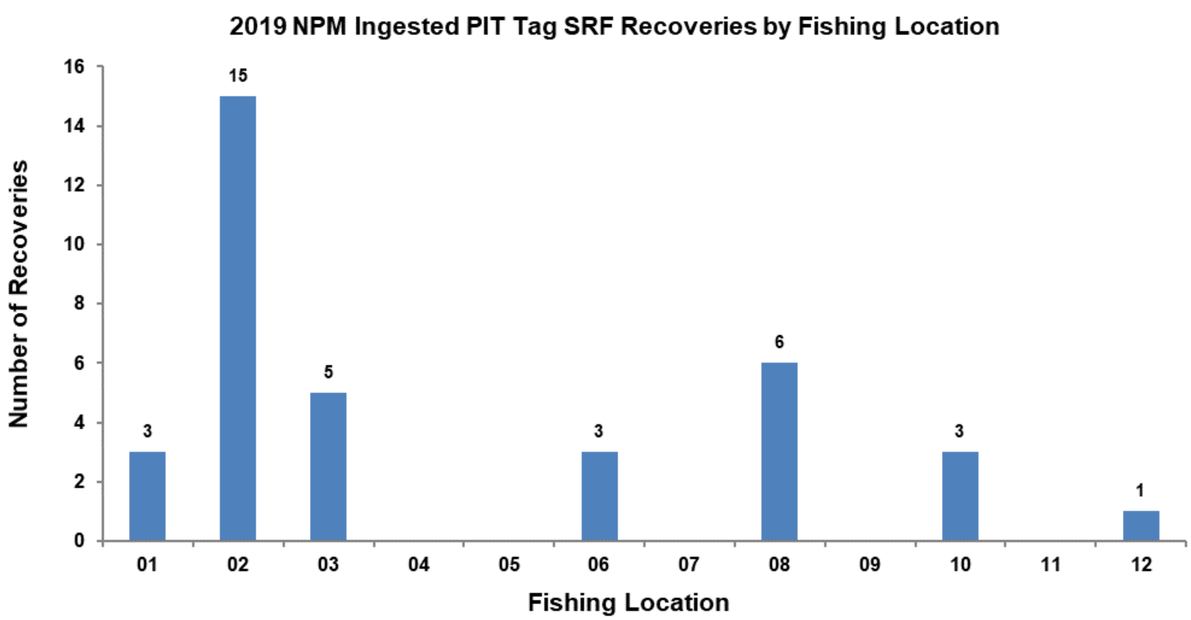


Figure 27. 2019 NPSRF ingested PIT Tag recoveries by fishing location*

*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 2019 NPSRF was obtained from PTAGIS and indicated that 23 of the 36 ingested PIT tag recoveries

(63.9%) were from Chinook smolts (Figure 28). Of the Chinook smolts, 22 (95.7%) of the 23 PIT tags indicated that the smolts were of hatchery origin and one of wild origin. PTAGIS queries further revealed that the Chinook PIT tag recoveries consisted of 10 Fall Chinook, 5 Spring Chinook, 7 Summer Chinook, and 1 unknown hatchery origin Chinook. Finally, PTAGIS queries revealed that the other 13 ingested PIT tag recoveries came from 7 Steelhead, 2 Sockeye, and 1 Coho, with 3 "orphan tags" (tag codes not entered into PTAGIS).

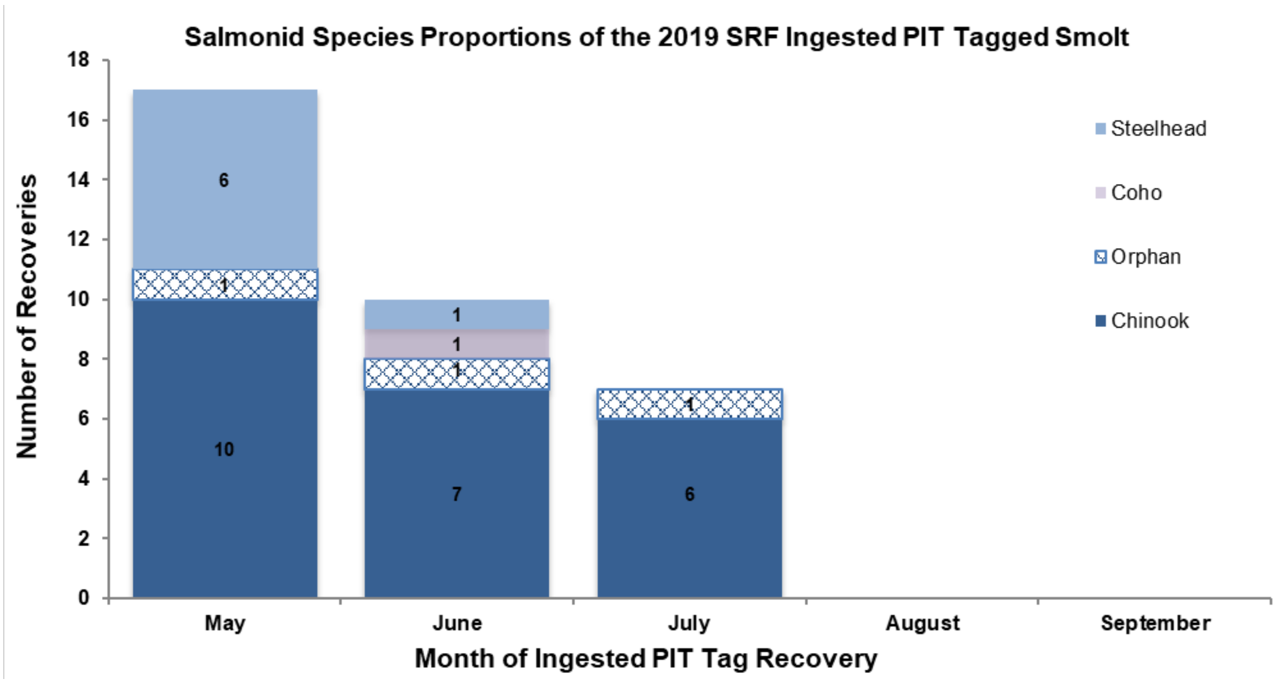


Figure 28. Recoveries of ingested Salmonid PIT Tags from the 2019 NPSRF

Analysis of PIT tag recovery data from the 2019 NPSRF continues to document actual Northern Pikeminnow predation on downstream migrating juvenile salmonids and identify possible predation "hotspots". 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 2019 NPSRF succeeded in reaching the NPMP's 10-20% exploitation goal for the twenty-second consecutive year, achieving an estimated exploitation rate of 15.4%. NPSRF harvest in 2019 was 34,048 fish lower than 2018 harvest and below mean 1991-2018 annual harvest of 177,033. Annual angler effort in 2019 decreased by 3,693 angler days from 2018, but was still higher than in 2014, prior to the tier modification. The number of individual anglers decreased by 331 anglers in 2019 from 2018. Early in the 2019 season, despite subpar angling for the second year in a row near the traditional early season hotspot of The Dalles, anglers were able to seek out and find decent harvest opportunities in the lower river from Ridgefield to Cathlamet. Later in the season, angling also picked up in the Snake River near Boyer Park and upriver at Greenbelt. CPUE decreased from 7.52 in 2018 to 7.21 in 2019 (Hone et al. 2019). Peak weekly harvest occurred during week 24 (June 10-16) and peak weekly effort occurred during the second week of the 2019 season (May 6-12). The Cathlamet registration station was the NPSRF's top station for harvest in 2019 (27,329 fish) for a second season in a row. The Cathlamet registration station also accounted for the most angler effort with 2,815 angler days of effort spent. We recovered 143 Northern Pikeminnow with external spaghetti or Floy tags implanted by ODFW as part of the NPMP's biological evaluation. Of those, 100 were spaghetti tags and 43 were the Floy tags. We recovered an additional 184 Northern Pikeminnow which were missing external tags but retained ODFW PIT tags (tag-loss). Mean fork length for Northern Pikeminnow harvested in the 2019 NPSRF was 281.2 mm, up from 272.6 mm in 2018 (Hone et al. 2019). Incidental catch consisted primarily of Peamouth, Smallmouth Bass, and Yellow Perch, and reflected similar angler harvest patterns as seen in previous NPSRF seasons.

For the 2019 NPSRF, there were several noteworthy occurrences. First of all, the 2019 NPSRF had a new individual as the top producing angler for the first time since 2009. The Cathlamet registration station was the number one station in terms of harvest for the second consecutive year and for only the second time in the 29 year history of the NPSRF.

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 increased to 1:4,062 in 2019 versus 1:6,934 in 2018 (Hone et al. 2019). Species composition of the 36 ingested PIT tags recovered from harvested Northern Pikeminnow showed that 23 were from Chinook smolts, 22 being of hatchery origin and 1 of wild origin, along with 7 Steelhead (2 of which were of wild origin), 1 Coho, 2 Sockeye and 3 "orphan tags" according to PTAGIS.

RECOMMENDATIONS

1.) Continue to use standardized season dates (May 1st-Sept 30th) for implementation of the 2019 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 2019 as an incentive designed to recruit new anglers to the 2020 NPSRF. Continue to utilize the Tier levels used in 2019 designed to incentivize current, proficient anglers to expend additional effort participating in the 2020 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 uses of internet and social media for advertising the NPSRF and furthering angler recruitment and education as a means to maintain or increase harvest.

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.) Continue to evaluate suitability of using Floy tags as external tags on Northern Pikeminnow compared to spaghetti tags. Monitor tag-loss and review results to determine if changes to tagged fish protocol should be made in 2021.

6.) Investigate the feasibility of using PIT tag scanners that can communicate with Ipad-type devices for PIT tag data collection.

7.) 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

2019 Annual Report

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March 2020

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 2019, the rewards paid to anglers were the same as in the 2018 season. Anglers were paid $5, $6, and $8 per fish for the three payment tiers (1-25 fish, 26-200 fish and 201-up) during the season. The rewards for a tagged fish were $500 per fish. One hundred forty-four thousand seven hundred thirty-seven 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 $1,066,031.

A total of 141 tagged fish (having an external spaghetti or floy tag) were paid at $500 each. The season total paid for tag rewards was $70,500. A total of 183 tag-loss fish (external tag missing but still possessing a verifiable pit tag) were paid a *bonus* reward of $100. The season total paid for tag-loss *bonus* was $18,300.

A total of 659 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 $6,590.

A total of 2,717 separate anglers registered to fish, of which 804 (30%) caught one or more fish and received payments during the season. The total value for all 144,878 Northern Pikeminnow submitted for payment in 2019 (including all coupons, tagged fish and tag-loss *bonus* payments) was $1,161,421.

INTRODUCTION

The **Northern Pikeminnow Sport Reward Program** was administered by PSMFC in 2019. 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.

THE 2019 SEASON

The 2019 season ran from May 1, 2019 through September 30, 2019.

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 (2014 – 2018) and to those who signed up for our mailing list at the various sportsmen's shows. The 2019 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 659 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 $6,590.

PARTICIPATION AND PAYMENT

A total of 1,080 anglers who registered were successful in catching one or more fish in 2019. Of those anglers; 804 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 2019 a total of 146,225 fish were harvested in the sport-reward fishery. Of this total, 144,878 fish were submitted for payment and paid prior to the 2019 payment deadline (To obtain payment, vouchers must have been received no later than November 15, 2019). In addition, any *received* vouchers with issues preventing payment (missing information, voiding of voucher for program violations, etc.) not resolved by November 15, 2019 became null and void.

TAGGED FISH AND PAYMENTS

Registered anglers caught and submitted a total of 141 tagged fish (showing an external spaghetti or floy 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 then the angler's responsibility to 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 $70,500.

TAG-LOSS BONUS PAYMENT

All tagged Northern Pikeminnow initially have both a spaghetti/floy 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/floy 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/floy 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 183 tag-loss fish qualified for and were paid the *bonus* reward of $100. The season total paid for tag-loss *bonus* was $18,300.

TOTAL ACCOUNTING

Total payments for the season of regular vouchers, *$10 bonus coupons,* tag vouchers and *tag-loss bonus* payments was $1,161,421.

All IRS Form 1099-MISC Statements were sent to the qualifying anglers for tax purposes in the fifth week of January 2020. Appropriate reports and copies were provided to the IRS by the end of February 2020.

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

2019 SPORT REWARD PAYMENTS SUMMARY

The following is a summary of all vouchers received and paid as of December 12, 2019

	Fish	Incentives	Reward
Fish paid @ tier 1 ($5 each):	10,511	-	$52,555
Fish paid @ tier 2 ($6 each):	30,166	-	$180,996
Fish paid @ tier 3 ($8 each):	104,060	-	$832,480
Tags paid (@ $500 each):	141	-	$70,500
Coupons issued (@ $10 each):	-	659	$6,590
Tag-loss issued (@ $100 each):	-	183	$18,300
Total:	144,878		$1,161,421

Anglers @ tier 1	*512*
Anglers @ tier 2	*173*
Anglers @ tier 3	*119*
Number of separate anglers	*804*

Anglers with 10 fish or less:	*403*
Anglers with 2 fish or less:	*205*

	Total Fish	$500 Tags	Tag Loss	Coup.	Total Reward
1.	6,482	3	$ 200	$ -	$ 53,107
2.	5,034	5	$ 500	$ 10	$ 42,817
3.	4,650	1	$ 400	$ 10	$ 37,677
4.	3,568	8	$ 500	$ 10	$ 32,565
5.	3,702	2	$ 200	$ 10	$ 30,385
6.	3,730	1	$ 300	$ 10	$ 30,220
7.	3,220	7	$ 500	$ 10	$ 29,289
8.	3,294	3	$ 400	$ 10	$ 27,813
9.	2,978	3	$ 100	$ 10	$ 24,985
10.	2,754	2	$ 300	$ 10	$ 22,901
11.	2,444	2	$ 300	$ 10	$ 20,421
12.	2,280	2	$ 100	$ 10	$ 18,909
13.	2,331	1	$ -	$ 10	$ 18,725
14.	2,235	1	$ 500	$ 10	$ 18,457
15.	2,096	4	$ -	$ 10	$ 18,327
16.	2,284	0	$ -	$ 10	$ 17,857
17.	2,022	0	$ 200	$ 10	$ 15,961
18.	1,948	1	$ 200	$ 10	$ 15,864
19.	1,878	1	$ 600	$ 10	$ 15,701
20.	1,884	1	$ 200	$ 10	$ 15,349
	60,814	48	$ 5,500	$ 190	$ 507,330

NORTHERN PIKEMINNOW
SPORT-REWARD FISHERY VOUCHER

2019 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 9

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 11/15/19.*****

[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

2019 TAG

LAST NAME | FIRST NAME | MI

ADDRESS

CITY | STATE | ZIP CODE

ANGLER TELEPHONE NUMBER — —

TAG VOUCHER #

MONTH DAY 2 0 1 9

DOCUMENT #

STATION | FISH LOC | EXTERNAL TAG # | TAG TYPE (S/F) | FORK LENGTH

PIT TAG #

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**

STAPLE TAG ENVELOPE HERE

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 11/15/19.*****

[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

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Funded by

U. S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
Portland, Oregon 97208-3621

Project No. 1990-077-00
Contract No. 78040

March 2020

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 suppress predation on out-migrating juvenile Pacific salmon and steelhead *Oncorhynchus* spp. During 2019, the Oregon Department of Fish and Wildlife evaluated the continued efficacy of the Northern Pikeminnow removal 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 on juvenile salmonids resulting from the targeted removal fisheries; 3) characterize population parameters of Northern Pikeminnow, Smallmouth Bass *Micropterus dolomieu,* and Walleye *Sander vitreus* in four Snake River reservoirs; and 4) assess evidence of possible intra- and inter-specific compensatory responses by Northern Pikeminnow, Smallmouth Bass, and Walleye related to the sustained removal of Northern Pikeminnow from the lower Columbia and Snake rivers. To quantify exploitation during 2019, we used standardized boat electrofishing to tag and release Northern Pikeminnow throughout the lower Columbia and Snake rivers. We used tags recovered in the NPMP Sport Reward Fishery 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 (FL) in the Sport Reward Fishery during 2019 was 15.4% (95% confidence interval, 11.0–19.8%). This value is within the NPMP targeted range of 10-20% and above the program average of 13.9%. Based on this level of exploitation, we estimate 2020 predation levels will be 29% (range: 13–42%) lower than pre-program levels. Assuming continuation of the current fishery structure, Northern Pikeminnow population structure, and mean rates of exploitation, model projections suggest predation on juvenile salmon will remain at a relatively stable reduced level and gradually decrease through 2023. Predation behavior by Northern Pikeminnow caught in the Dam Angling Fishery in Bonneville and The Dalles reservoirs was similar to previous years; the highest presence of juvenile salmonids, lampreys (family Petromyzontidae), and American Shad *Alosa sapidissima* in the diet of Northern Pikeminnow, likely coincided with their respective out-migration peaks. Abundance index estimates for 2019 in most areas of the Snake River reservoirs sampled indicate a continued decrease of Northern Pikeminnow greater than or equal to 250 mm FL since the early 1990s. Overall, we recorded highly variable abundance, consumption, and predation index values for the predators monitored in our study, which provides no obvious indication of a long-term compensatory response to the targeted removal of Northern Pikeminnow. However, substantial increases in Smallmouth Bass and modest increases in Walleye abundance observed in the lower Snake River reservoirs could reduce the benefit of removing Northern Pikeminnow as these fish also predate upon juvenile salmon and steelhead. Proportional size distribution of Northern Pikeminnow collected during Sport Reward Fishery evaluation continues to indicate a significant decrease since the early 1990s in The Dalles, John Day, and Lower Granite reservoirs. These results suggest that in these areas the program has been successful at restructuring the population via removal of larger fish. Given the dynamic nature of these systems (both biotic and abiotic), we encourage continued monitoring efforts to assess trends in piscivorous fish populations throughout the Columbia and Snake rivers to help elucidate potential local and system-wide effects.

INTRODUCTION

The Columbia and Snake rivers historically 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 further examine 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 investigate predator impacts on juvenile salmonids given that: (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 existing information (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; Vigg 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 explain 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 premise 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 the issue of predation on juvenile salmonids 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 (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 2019 in areas of the Columbia and Snake rivers and, wherever possible, evaluates temporal and spatial changes. Specific goals for this reporting period were to:

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

METHODS

ODFW researchers conducted sampling during 2019 using Smith-Root™ 18-EH model electrofishing boats equipped with a 5.0 or 7.5 generator powered pulsator electrofisher powered by either a Kohler Power Systems™ or Briggs and Stratton™ gas generator. When engaged, the electrofishing unit applies pulsed direct current at a rate of 60 pulses/s to maximize capture efficiency with minimal injury to fish. The boats contain anodes suspended from two boom arms extending forward from the bow and each supports a single array composed of six electrodes. Electrodes hanging from the boat hull function as the cathodes. We set electrofishing controls 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 electrical current during all electrofishing events was 3–4 A. We standardized all controls across boats with minor adjustments to the duty cycle to achieve the targeted output. We utilized electrofishing protocols to minimize fish exposure to electric current yet induce uncontrolled swimming toward the anode (electrotaxis) and avoid intense muscle contraction to the point of becoming stiff (tetany). Additionally, we developed and implemented protocols to reduce interactions with species listed under the U.S. Endangered Species Act to guide sampling efforts.

Sport Reward Fishery Evaluation and Predation Reduction Estimates

Field Procedures

We tagged Northern Pikeminnow and estimated exploitation rates with tag recovery data from the Sport Reward Fishery (SRF). We used boat electrofishing to collect Northern Pikeminnow 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). We conducted four sampling events within each 1.61 river kilometer (1 river mile), consisting of 900 seconds (s) of boat electrofishing effort. We sampled along shallow shoreline areas because the effective range of boat electrofishing tends to be limited to a maximum depth of approximately 3 m. We sampled from 3 April to 28 June 2019 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 daytime sampling was necessary to navigate safely. We were unable to sample 34 rkm in John Day Reservoir and 19 rkm in the Snake River due to equipment malfunction or weather related constraints. We adjusted sampling plans to ensure un-sampled areas occurred only in locations where tagging rates were historically low. Ideally, all tagging activities would conclude before the Sport Reward and Dam Angling fisheries began, but that was unachievable due to time constraints and the extent of the sampling area. We tagged all fish captured downstream of The Dalles Dam (rkm 307) prior to the start of the fisheries (1 May 2019). Upstream of The Dalles Dam, we tagged the majority of Northern Pikeminnow concurrent with fishery activities.

We tagged and released Northern Pikeminnow ≥ 200 mm fork length (FL) with uniquely numbered Floy® FT-4 lock-on external loop tags or, for the first time beginning 2019, Floy® FD-94 external T-bar anchor tags. We tagged approximately half of target sized Northern Pikeminnow (≥ 200 mm FL) with T-bar anchor tags and half with locking loop tags to evaluate tag retention and post-release survival of tagged fish by tag type. We inserted each loop tag between the pterygiophores below the midpoint of the dorsal fin. We inserted each T-bar anchor tag between the pterygiophores below the dorsal fin on the left side of the fish. We also marked all externally tagged fish with an internal 134.2 MHz passive integrated transponder (PIT) tag injected into the dorsal sinus cavity. During Northern Pikeminnow tagging operations, we also opportunistically captured, measured, and weighed Walleye in an attempt to gain some understanding of their populations in these areas and supplement data collected during biological evaluation activities (see below).

Working with the Washington Department of Fish and Wildlife (WDFW), we obtained tag recovery information from the SRF and the Dam Angling Fishery (DAF). The SRF occurred daily from 1 May to 30 September 2019 (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 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 externally 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 retained a functioning PIT tag internally). Given this, we assumed 100% of the Northern Pikeminnow marked with an external and/or an internal PIT tag harvested by participating anglers were submitted to a check station for reward payment during the season.

The DAF operated from 2 May to 25 September 2019 (see Report D for details) in the powerhouse tailraces of The Dalles and John Day dams and used a team of anglers with hook-and-line fishing gear to remove Northern Pikeminnow. During 2019 at The Dalles Dam, angling did not occur in the outflow below the ice/trash sluiceway as it has in the past because of United States Army Corps of Engineers voiced safety concerns. WDFW personnel examined all fish for the presence of external loop and internal PIT tags. We accounted for tagged Northern Pikeminnow removed in the DAF when estimating exploitation rates for the SRF.

Data Analysis

We quantified the proportion of the Northern Pikeminnow population removed during program fisheries 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, we calculated rates of exploitation for three size-classes: 1) ≥ 200 mm FL (all tagged fish), 2) 200–249 mm FL, and 3) ≥ 250 mm FL. We used the subset of fish ≥ 250 mm FL for long-term temporal comparisons.

To account for the introduction of a known bias into area-specific estimates of annual exploitation, we applied two different models: one for areas where we tagged Northern Pikeminnow 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, we estimated rates of exploitation 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 2019 exploitation rates.

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

$$u_j \pm \frac{z \times \sqrt{R_j}}{M_j}, \tag{2}$$

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, we treated each week as a separate sampling period according to the function:

$$u_{weekly_j} = \frac{R_{ij}}{M_{ij}}, \tag{3}$$

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 SRF.

To account for the positive bias associated with insufficient mixing, we excluded the few fish that anglers 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 uncertain 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:

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

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. The model assumes removal of Northern Pikeminnow through completion of the SRF in the current year will reduce predation on out-migrating juvenile salmon in spring and summer of the following year. We applied a ten-year mean age-structure (based on catch curves) for a pre-program baseline and assumed constant recruitment. Since its development, we revised the model to include FL increments derived from annual mark-recapture growth observations rather than growth estimates obtained from length and age data. With these inputs, the model predicts changes in potential predation that are directly related to removals, if all other variables remain constant. We estimate the potential predation during 2020 based on observed exploitation rates from 2019 and predict three future predation rates (maximum, median, and minimum) using the mean level of exploitation observed during contemporary program rules (2001; 2004–2019). Additional model documentation is described in Friesen and Ward (1999).

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 lower Snake River reservoirs during 2019. We conducted early morning (0200–1200 hours) sampling during spring (7–21 May 2019) and summer (18 June–2 July 2019) in the areas of Ice Harbor (forebay, rkm 16-23; mid-reservoir, rkm 28-39; and Lower Monumental Dam tailrace, rkm 60-67), Lower Monumental (forebay, rkm 67-72; mid-reservoir, rkm 92-100; and Little Goose Dam tailrace, rkm 105-112), Little Goose (forebay, rkm 112-120; mid-reservoir, rkm 128-136; and Lower Granite Dam tailrace, rkm 165-172), and Lower Granite (upper-reservoir, rkm 219-228) reservoirs. Our objective in analyzing the diets of predatory fishes in relation to salmonid consumption is to perform field sampling during peak smolt outmigration. We sampled randomly selected fixed-site transects, approximately 500 m long, in each reservoir area along both shores of the river. Effort at each transect consisted of a 900-second boat electrofishing period with continuous output of approximately 3-4 A.

We recorded catch and biological data for all Northern Pikeminnow, Smallmouth Bass, and Walleye collected. We measured FL (nearest mm) and mass (nearest 10 g) for all fish collected. We removed scale samples from 25 fish per 25 mm FL increment for all three species in all four areas. We sacrificed all untagged Northern Pikeminnow greater than or equal to 200 mm FL and collected diet samples (whole digestive tracts) for subsequent analyses in the laboratory. We removed digestive tracts by securing both ends with hemostats, removing extra tissue, and placing whole in individual sample bags. Whenever possible, we recorded sex and stage of maturity for each sacrificed fish. We collected diet samples from Smallmouth Bass and Walleye greater than or equal to 200 mm FL by a non-lethal gastric lavage method using a modified Seaburg sampler (Seaburg 1957). We flushed contents from the foregut of each fish into a 425-µm sieve and then transferred the diet contents into individual sample bags. For all species, we stored diet samples on ice while in the field and transferred to a freezer until processing in the laboratory.

Using the protocol described above, we also collected diet samples from Northern Pikeminnow captured during the 2019 DAF in Bonneville and The Dalles reservoirs. We collected diets from a representative subsample of catches at each dam weekly from 3 May–29 August 2019, generally three days per week with a target of 15 fish per day at each dam. In addition, we collected morphometric measurements (FL and mass), sex, and stage of maturity data for each fish sampled.

Laboratory Procedures

We examined the contents of diets from Northern Pikeminnow, Smallmouth Bass, and Walleye collected during biological evaluation field activities, and Northern Pikeminnow collected from the DAF to quantify relative consumption of juvenile salmon. Due to the large number of Smallmouth Bass diets collected, in the laboratory we selected a random subsample of 150 diet samples per reservoir within each season, divided equally among reservoir areas or days of sampling. Similarly, we sub-sampled Northern Pikeminnow diets collected from the DAF to ensure that we processed 36 diets from each dam per field sampling week when samples were available. We processed all Northern Pikeminnow and Walleye diet samples collected during 2019 biological evaluation field activities.

We thawed frozen field samples in the laboratory and sorted the diet contents into general prey categories (i.e., fish, crayfish, other crustaceans, insects and other invertebrates, and miscellaneous). We noted parasitic invertebrates (e.g., tapeworms and nematodes) found in the diet samples in our dataset comments, but did not weigh or categorize them as prey items or include them in our prey consumption calculations. We weighed (blotted wet mass) diet material to the nearest 0.01 g according to prey category. For Smallmouth Bass and Walleye, we returned portions of diet samples containing fish to the original sample bags for chemical digestion. To ensure complete recovery of diagnostic structures from Northern Pikeminnow diet samples, we chemically digested the entire digestive tract along with possible fish parts. To chemically digest soft tissues, we added 20 ml of a solution of pancreatin (20 g/L) and sodium sulfide nonahydrate (Na_2O_9S; 10 g/L) in tap water — to each sample. Next, we placed sample bags in a desiccating oven at approximately 48°C for 24 h. After removal from the oven, we added a 20 ml solution of sodium hydroxide (lye, NaOH) mixed at 30g/L with tap water to dissolve remaining fatty materials. Then, we poured the contents of each bag into a 425 µm sieve and rinsed with tap water. In rare cases, we recorded the presence of fish during the initial sorting and weighing, but did not find any bones after chemical digestion. When this occurred, we assumed that those bones were lost, and therefore we assumed one unidentified fish was present in the sample. We included diet samples of fishes that did not contain any diet items (empty) in all statistical analyses.

We examined bones remaining after chemical digestion to identify prey fish to the lowest possible taxon (typically family) using stereoscopic dissecting microscopes and standard keys (Hansel et al. 1988, Frost 2000, and Parrish et al. 2006). We enumerated paired structures to arrive at minimum counts of a given prey taxon in a diet sample, but we could only evaluate presence/absence for certain prey items. For example, if we only encountered ventral scutes of American Shad *Alosa sapidissima* in a diet sample, we assumed one American Shad had been consumed because the total number of scutes associated with an individual fish is ambiguous. The same assumption was made for instances in which we encountered lamina of lampreys (family Petromyzontidae) in diet samples. Further, for samples where only fish vertebrae were observed, we were able to distinguish between salmonid and other fish prey, but could only conclude that at least one juvenile salmonid had been consumed if salmonid vertebrae were present. Given these constraints, in addition to comparing the relative size and quality of diagnostic bones encountered, we enumerated the total numbers of prey fish in samples as necessarily conservative. Lastly, to calibrate identification accuracy among analysts, we re-analyzed a minimum of 10% of all samples at random by a second reviewer.

Data Analysis

Following the methods of Ward et al. (1995), we calculated seasonal abundance index values for each predator species by calculating the mean catch per 900 s of boat electrofishing by season and area, then multiplying by the surface area (ha) of the 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 diet 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 are correlated with consumption rates for Northern Pikeminnow (Ward et al. 1995) and Smallmouth Bass (Ward and Zimmerman 1999). Therefore, the abundance and consumption indices provide a means to characterize relative predation impacts. We calculated consumption index values 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 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. 2007) to characterize variation in size structure for Northern Pikeminnow to three groups; those sampled during fishery evaluation, biological evaluation, and from the DAF. We also applied models describing PSD for Walleye populations sampled during both fishery and biological evaluation and Smallmouth Bass sampled during biological evaluation using the formula:

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

where

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

We calculated proportional size distribution of preferred-length fish (PSD – P) for Smallmouth Bass and Walleye (Gabelhouse 1984; Guy et al. 2007) sampled during fishery and 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). We took stock, quality, and preferred minimum length categories from the literature (Anderson 1980; and Gabelhouse 1984) and converted them to FL measurements using a species specific model for Smallmouth Bass ($FL_{SMB} = TL_{SMB} /1.040$). The published stock-length measurement is smaller than our target size (200 mm FL) for Smallmouth Bass and to remove any bias in our data from variation in sampling procedures among years, we chose to use our target size as minimum stock-length for PSD and PSD – P analyses. Thus, stock, quality, and preferred minimum FL categories for Smallmouth Bass were 200, 269, and 337 mm, respectively. Similarly, using published categories (Anderson 1980; Gabelhouse 1984) and the species-specific model for Walleye ($FL_{WAL}= TL_{WAL}/1.060$), we calculated these categories as 236, 358, 481 mm FL, respectively. We calculated annual PSD and PSD – P values 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; Wege and Anderson 1978) to compare the condition of Northern Pikeminnow, Smallmouth Bass, and Walleye over time. We used 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) 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. However, field sampling methodologies precluded diagnosis of sex for Smallmouth Bass and Walleye as they were not euthanized. Therefore, calculations of W_r for

Smallmouth Bass and Walleye are for both sexes combined. Additionally, we only included fishes that met minimum target sizes (250 mm FL for Northern Pikeminnow and 200 mm FL for Smallmouth Bass and Walleye) in our samples. Similar to 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).

We assessed temporal monotonic trends in PSD and median W_r for Northern Pikeminnow, Smallmouth Bass, and Walleye by applying a non-parametric Mann-Kendall test (Mann 1945). Similarly, we also analyzed PSD – P with this method for Smallmouth Bass and Walleye. A monotonic trend means that the variable consistently increases or decreases through time, although the trend may be non-linear. We used spline interpolation to account for data gaps, when present. However, because there was a large gap in length data in the DAF (1997–2005 in Bonneville Reservoir and 1996–2006 in The Dalles Reservoir), we did not interpolate data for this large data gap. Instead, we treated them as two different time series; data collected before 1997 as "early" and data collected after 2005 as "late." We then used a non-parametric a Mann-Whitney U test to compare PSD values between early and late years for each reservoir. Lastly, to help visualize trends, we fit locally weighted scatterplot smoothing (LOWESS) curves to the data. We conducted all analyses in the R programming environment using the 'Kendall' (McLeod 2011) and, where necessary, the 'boot' or 'tsboot' (Fox and Weisberg 2011) packages. We considered all tests significant at $\alpha < 0.05$.

RESULTS

Sport Reward Fishery Evaluation and Predation Reduction Estimates

We tagged and released 1,161Northern Pikeminnow greater than or equal to 200 mm FL throughout the lower Columbia and Snake rivers during 2019 (Table 1). We also recaptured 12 Northern Pikeminnow greater or equal to 200 mm FL that were tagged in previous years. These previously marked fish are accounted for in the current annual exploitation calculations and are therefore considered “tagged” or in-year marked fish for 2019 estimates. For 2019, 45% of the in-year marked fish were from 200 to 249 mm FL and 55% were 250 mm FL and greater. SRF recaptures of Northern Pikeminnow greater than or equal to 250 mm FL accounted for 58% of the recovered fish tagged during 2019. Overall, SRF anglers recaptured 170 of the 1,173 in-year marked fish and three fish were recaptured in the DAF. One fish marked in Lower Granite reservoir was recaptured within the same week it was tagged and therefore not included in our calculations of exploitation to avoid violating mark-recapture assumptions (i.e., incomplete mixing). Fish tagged in 2019 and subsequently recaptured in the SRF were at large from 7 to 165 days (mean = 66.5 d; SE = 3.1).

Of the 1,161 new tags deployed in 2019, 54% were T-bar anchor tags and 46% were lock-loop tags. Of the tagged fish recaptured in the SRF, 69% were marked with a T-bar tag and 31% were marked with a lock-loop tag. For Northern Pikeminnow 200 to 249 mm FL, the SRF recaptured 7% of those initially marked with a lock-loop tags and 19% of those initially marked with T-bar anchor tags. Tag loss rates for T-bar anchor tags was 65% and 3.7% for lock-loop tags. As tagged fish contained an internal PIT tag even if the external tag is lost to the environment, we were able to identify these “tag loss fish” as being initially marked.

System-wide exploitation of Northern Pikeminnow greater than or equal to 200 mm FL during the SRF in 2019 was 17.3%, which was greater than the 12.9% average since 2000 when the minimum FL eligible for reward was reduced from 250 to 200 mm (Table 2). Tag returns in 2019 were sufficient ($n \geq 4$) to calculate area-specific exploitation estimates for all sampling areas with the exception of The Dalles, John Day, and Ice Harbor reservoirs, which was consistent with results from previous years. Tagged fish were released in Ice Harbor reservoir for the third time since 1992, but only nine fish were tagged there in 2019 and none of these were recaptured in the SRF. For areas where we could calculate exploitation rates, values varied from 9.5 to 30.4% for Northern Pikeminnow greater than or equal to 200 mm FL (Table 2). Within the 200–249 mm FL size class, area specific exploitation estimates ranged from 9.9% to 29.9% while the system wide estimate of 19.4% was well above average (7.4%) and exceeded those of the other size classes (Table 3). In all areas where we could calculate exploitation for this smaller size class in 2019, estimates were above average and 2-3 times higher than previous values. The 2019 system-wide exploitation rate for Northern Pikeminnow greater than or equal to 250 mm FL was 15.4% (confidence interval 11.0–19.8%). While this year’s exploitation estimate was down compared to the prior two years, it was above the program average of 13.9% since 1991 (Figure 2). Area-specific exploitation rates of fish greater than or equal to 250 mm FL were 15.8% for the Columbia River below Bonneville Dam, 8.0% for Bonneville Reservoir, 16.5% for McNary Reservoir, and 19.7% for Lower Granite Reservoir (Table 4).

The model-estimated median reduction of predation on juvenile salmonids relative to pre-program levels for 2019 was 29% (range: 12–42%) and for 2020 will remain 29% (range: 13–42%; 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 at relatively stable suppressed levels and gradually decrease, further reducing predation, through 2023.

Biological Evaluation

We conducted 317 electrofishing runs during 2019 in the sampling areas of Ice Harbor, Little Goose, Lower Monumental, and Lower Granite reservoirs to collect fishes for biological evaluation. Our electrofishing effort in 2019 was consistent with previous sampling events in those areas. In prior years, sampling events were conducted in the boat-restricted zones directly adjacent to dams in many reservoirs. However, we have not had access to those areas in recent years, including 2019, and therefore do not report those observations in this report. Our sampling objective to observe predatory behavior during peak smolt outmigration continues. In 2019, our spring biological evaluation sampling coincided with a peak of yearling Chinook salmon passage and regular passage of Steelhead and subyearling Chinook salmon at Lower Granite Dam (Figure 4). Timing of summer sampling did not correspond with peak out migration of any smolt species, however passage of out migrating subyearling Chinook salmon was occurring at the time.

Northern Pikeminnow encounters were lower than previous years in all reservoirs and only captured in the tailrace areas of Ice Harbor and Little Goose reservoirs and upriver of Lower Granite Dam during 2019 (Catch per Unit Effort [CPUE] range: 0.00 to 0.17 fish/900 s; Table 5). Smallmouth Bass were encountered at higher levels compared to the other species across all sampling sites and seasons in the lower Snake River reservoirs in 2019. CPUE within reservoirs varied for Smallmouth Bass, with the greatest catch rates occurring in tailrace area of Lower Monumental Reservoir (spring 17.0 fish/900 s; summer 11.0 fish/900 s), the forebay of Little Goose Reservoir (summer 8.15 fish/900 s), and upriver of Lower Granite Dam (spring 10.9 fish/900 s). Walleye catch rates were consistently low in Little Goose (only one individual caught in 2019) and Lower Granite (no individuals caught since biological evaluation started in 1991; Table 5) reservoirs. For Ice Harbor and Lower Monumental reservoirs, Walleye were more prevalent in the tailraces (range 0.17 to 1.29 fish/900 s), somewhat abundant in mid-reservoir (range 0.00 to 0.56 fish/900 s), and uncommonly encountered in forebays (range 0.00 to 0.07 fish/900 s; Table 5).

Abundance index values for Northern Pikeminnow in 2019 were 0.0 in most locations and subsequently below average for all sampling areas and seasons with the exception of the Ice Harbor tailrace area in summer (Table 6). While abundance index values for Smallmouth Bass have fluctuated over time, the 2019 values were above average in nearly all areas and seasons with exceptions in the Little Goose tailrace area in spring and Lower Monumental mid area in summer (Table 7). In some areas such as Ice Harbor Reservoir, spring 2019 abundance index values in the mid and tailrace areas are relatively similar to baseline values from spring 1991. For other areas such as Lower Monumental and Lower Granite reservoirs, spring abundance index values have greatly increased over the time series. From 1991 to 2019, Smallmouth Bass spring abundance values increased 13.1 times upriver of Lower Granite Dam (0.70 to 9.15), with summer in Lower Monumental tailrace a close second at a 9.71 fold increase (0.96 to 9.32). However, not all areas increased when compared to baseline levels (such as Little Goose tailrace both seasons, mid reservoir of Little Goose in spring, or mid reservoir of Ice Harbor). Walleye are not abundant in the lower Snake River reservoirs, but when considering their abundance index values over time, they have increased over baseline levels in several areas of Ice Harbor and Lower Monumental reservoirs (Table 8). Standard error values are nearly equal to Walleye abundance index values in many areas, which makes their current abundance difficult to interpret, yet that variability emphasizes the importance of continued monitoring of these species in the lower Snake River reservoirs.

We examined the diets from 40 Northern Pikeminnow collected from the four lower Snake River reservoirs (Table 9). The majority of Northern Pikeminnow captured, regardless of season or reservoir, contained food items. Prey fish were abundant in diets, and salmonids were found in the majority of diet samples in Lower Granite Reservoir in the spring ($\widehat{p}$ = 0.70; Table 9). The proportion of Northern Pikeminnow diets that contained salmonids during spring upriver of Lower Granite Dam in 2019 increased greatly over what we observed in 2016, when 45% of Northern Pikeminnow diets containing salmonids (Carpenter et al. 2017). The timing of the salmonid out-migration is relatively similar for both years and all of the other areas have similar proportion of diets containing salmonids (Carpenter et al. 2017, Figure 4, and Table 9). All of the 1,157 Smallmouth Bass diets sampled in 2019 contained food items and relatively few of those fish consumed salmonids (Table 9). Though relative values varied by area, Smallmouth Bass diets were primarily comprised of other crustacea (such as abundant, non-native Siberian prawn) in the spring and crayfish or insects/invertebrates in the summer. Like other species sampled, the vast majority of Walleye diets contained food items. Salmonids were found in around a third of diets in the spring (Ice Harbor $\widehat{p}$ = 0.37; Lower Monumental $\widehat{p}$ = 0.35), whereas they were not present in summer samples. Other crustacea and non-salmonid fishes were relatively important items in Walleye diets during both seasons. For all three species, seasonality (spring vs. summer) presumably has the largest effect on prey availability and it appears these predators are consuming prey that are abundant, in contrast to having a preference for certain prey items.

For Northern Pikeminnow diet samples that contained fish, the main fish groups observed were unidentified fishes in Ice Harbor Reservoir ($\widehat{p}$ = 0.50), and salmonids in Little Goose ($\widehat{p}$ = 0.09) and Lower Granite reservoirs ($\widehat{p}$ = 0.54; Table 10). In Little Goose Reservoir, the proportion of Northern Pikeminnow diet samples that contained sunfishes (family Centrarchidae; $\widehat{p}$ = 0.09) was the same as salmonids (Table 10). Salmonids in the diets of Smallmouth Bass were most abundant in Lower Granite Reservoir and to a lesser extent in Little Goose Reservoir, though unidentified fishes, unidentified non-salmonids, and Sand Rollers *Percopsis transmontana* were just as prevalent in the diets in Little Goose Reservoir. One quarter of Walleye in Ice Harbor and Lower Monumental reservoirs consumed salmonid fishes, which is higher than all other species in any area with the exception of Northern Pikeminnow in Lower Granite reservoir. While sampling diets in the spring, we recovered PIT tags from two hatchery fall Chinook Salmon in Lower Granite reservoir; one in a Northern Pikeminnow diet, the other in a Smallmouth Bass diet.

Consistent with results from the past ten years, we were not able to estimate consumption index and subsequently, predation index values for Northern Pikeminnow greater than 249 mm FL due to insufficient sample sizes throughout the lower Snake River reservoirs in 2019 ($n \leq 5$). We considered combining areas within the reservoirs for a given season to be able to calculate values for these indices, however, sample sizes when combined in this manner are still not adequate for analyses. To effectively monitor these changes in the future, we will likely need to adjust sampling protocols or adjust analyses of these data to account for the insufficient sample sizes.

Consumption index values for Smallmouth Bass in 2019 were relatively similar to values for 2016 with few exceptions (Table 11). Large increases in consumption index values were observed in Little Goose tailrace during both seasons and mid reservoir of Little Goose and upriver of Lower Granite Dam in the summer. Generally, predation index values for Smallmouth Bass in 2019 were relatively similar to or less than values from 2016 (Table 12). When 2019 results were compared to baseline values from 1991 for spring, predation index values increased substantially in Ice Harbor tailrace, Lower Monumental mid-reservoir and tailrace, Little Goose forebay and mid-reservoir, and upriver of Lower Granite Dam. Large increases were also observed in summer predation index values in Lower Monumental forebay and tailrace, Little Goose forebay and mid-reservoir, and upriver of Lower Granite Dam. Little Goose mid-reservoir was the highest value we calculated for 2019, however, higher values were calculated in this area in summer of 2013 and spring 2016. These observed changes were likely due to increases in abundance index values rather than great increases in consumption of salmonids as the trends of Table 7 (abundance index) roughly track to Table 12 (predation index), rather than Table 11 (consumption index).

From data collected during tagging for the 2019 SRF evaluation, we calculated PSD for Northern Pikeminnow below Bonneville Dam and Bonneville, McNary, and Lower Granite reservoirs (Figure 5). Sample sizes in other reservoirs were too small ($n \leq 19$) to calculate PSD for 2019. Below Bonneville Dam there was a large decrease in PSD from 2018 to 2019. Conversely, there was a large increase in PSD from 2018 to 2019 in McNary Reservoir, where PSD has increased over the last three years. Since 1991, Northern Pikeminnow PSD decreased, increased, and then decreased again for Bonneville, The Dalles and John Day reservoirs (Figure 5). There were significant monotonic decreases in PSD in The Dalles (Mann-Kendall $\tau = -0.38$, $P = 0.03$), John Day (Mann-Kendall $\tau = -0.71$, $P = 0.04$), and Lower Granite reservoirs (Mann-Kendall $\tau = -0.43$, $P < 0.01$; Figure 4). There were no significant monotonic trends in PSD below Bonneville Dam (Mann-Kendall $\tau = -0.04$, $P = 0.79$), or in Bonneville (Mann-Kendall $\tau = -0.16$, $P = 0.23$) or McNary (Mann-Kendall $\tau = -0.27$, $P = 0.05$; Figure 5) reservoirs. Unfortunately, during biological evaluation sampling in 2019, we did not catch enough target sized (greater or equal to 250 mm FL) Northern Pikeminnow to calculate PSD for any of the Snake River reservoirs, as has been the case since 1999 ($n \leq 19$).

During the 2019 SRF evaluation, we captured the most Walleye in The Dalles Reservoir (n = 233), followed by McNary Reservoir (n = 106), Ice Harbor Reservoir (n = 66), and Bonneville (n = 50) and John Day (n = 50) reservoirs (Figure 6). We captured the least Walleye below Bonneville Dam (n = 18). A pulse of Walleye that are 150–250 mm FL is present below Bonneville Dam and in The Dalles, John Day, McNary, and Ice Harbor reservoirs. This pulse is not present in Bonneville Reservoir; however, there is a strong pulse of larger Walleye in the 500–600 mm FL range. Size distribution is similar across John Day and McNary reservoirs. In Little Goose and Lower Granite Reservoirs, we observed few Walleye during past SRF evaluations and observed none during the 2019 SRF evaluation.

Through our opportunistic sampling of Walleye during the 2019 SRF evaluation, we calculated Walleye PSD and PSD – P values for five of the eight areas sampled (Bonneville, The Dalles, John Day, McNary, and Ice Harbor reservoirs; Table 13). Data from Little Goose and Lower Granite Reservoir are not presented here as sample sizes have never been great enough to calculate PSD or PSD – P ($n \leq 19$) over the time series. In Bonneville Reservoir, Walleye PSD was greater in 2019 than 2018 (Table 13). Walleye PSD in The Dalles and Ice Harbor reservoirs decreased in 2019 from 2018. PSD was relatively similar to last year in John Day and McNary reservoirs. Walleye in Bonneville Reservoir had the greatest PSD in 2019, at 94%, and Walleye in The Dalles Reservoir had the lowest PSD at 68%. For 2019, PSD – P increased in all reservoirs upstream of Bonneville Dam compared to 2018, although PSD – P was similar in 2018 and 2019 in Ice Harbor Reservoir. Walleye in Bonneville Reservoir had the greatest PSD – P in 2019 at 73%, and Ice Harbor Reservoir had the lowest at 15%. The Dalles, John Day and McNary reservoirs all had decreasing trends in PSD across the time series, however, none of these trends were significant (Figure 7). Distribution of the preferred size category of Walleye also decreased overtime in these reservoirs and in McNary Reservoir it was statistically significant (Mann-Kendall τ = -0.40, P = 0.04; Figure 8). However, Walleye PSD – P has shown an increasing trend in these reservoirs in the last two years.

From data collected during biological evaluation, we collected sufficient Walleye in Ice Harbor Reservoir to calculate Walleye PSD and PSD – P for the first time, at 100% and 42%, respectively (Table 14). The only other estimate of PSD and PSD – P we have calculated was Lower Monumental Reservoir in 2007 when PSD was 35% and PSD-P was 6%. For all Snake River reservoirs, too few samples are obtained within a year to calculate and few data points over the time series making the detection of trends impossible.

Smallmouth Bass PSD increased in Ice Harbor, Lower Monumental, and Lower Granite reservoirs and decreased in Little Goose Reservoir since our last visit in 2016 (Table 15). PSD – P was the same in 2019 as in 2016 for Ice Harbor and Lower Monumental reservoirs, reduced in Little Goose Reservoir, and greater in Lower Granite Reservoir. There were no significant monotonic trends of Smallmouth Bass PSD (Figure 9). When considering Lower Monumental Reservoir PSD – P over time, we have observed a significant decrease over time (Mann-Kendall τ = -0.60, P = 0.02; Figure 10). The trends of PSD – P over the time series from the other reservoirs were non-significant, though Ice Harbor and Lower Granite reservoirs appear to generally decrease.

We did not capture enough male or female target sized Northern Pikeminnow in Ice Harbor Reservoir over the entire time series to assess trends in W_r. In 2019, we were unable to produce an estimate again due to low samples. Similarly, we did not capture any target sized male or female Northern Pikeminnow in Lower Monumental Reservoir in 2019, however prior data show there were no significant monotonic trends in W_r from 1990 through 2016 for both female and male Northern Pikeminnow (Carpenter et al. 2017). In Little Goose Reservoir, we only captured one male and one female target sized Northern Pikeminnow in 2019 and there were no significant monotonic trends in W_r over time for either females (Mann-Kendall τ = -0.20, P = 0.47) or males (Mann-Kendall τ = 0.21, P = 0.54; Figure 11). In Lower Granite Reservoir, we captured three target sized Northern Pikeminnow in 2019, which were all female. Again, there were no statistically significant monotonic trends in Northern Pikeminnow W_r over time for either females (Mann-Kendall $\tau = 0.02$, $P = 1.00$) or males (Mann-Kendall $\tau = 0.29$, $P = 0.39$; Figure 12).

The 2019 median W_r value for Smallmouth Bass was the same for Ice Harbor and Little Goose reservoirs at 91% (Figure 13). Lower Monumental and Lower Granite reservoirs had larger W_r values, both at 94%. There were no significant monotonic trends over time for Ice Harbor (Mann-Kendall $\tau = 0.24$, $P = 0.55$), Lower Monumental (Mann-Kendall $\tau = 0.27$, $P = 0.28$), Little Goose (Mann-Kendall $\tau = 0.02$, $P = 1.00$), or Lower Granite (Mann-Kendall $\tau = 0.31$, $P = 0.21$) reservoirs. Throughout the time series, W_r of Smallmouth Bass remains relatively consistent over time and among all of the Snake River reservoirs.

Median W_r of Walleye was larger in Lower Monumental Reservoir (95%) than Ice Harbor Reservoir (89%) in 2019 (Figure 14). There are not enough data points over the time series for Ice Harbor to analyze a monotonic trend, although the difference in W_r among the data points appears negligible. Additionally, there was not a significant monotonic trend for W_r over time in Lower Monumental Reservoir (Mann-Kendall $\tau = -0.47$, $P = 0.26$).

In 2019, we collected 900 Northern Pikeminnow diet samples from fish harvested in the DAF from the angler accessible areas in the powerhouse tailraces of The Dalles (fishing in Bonneville Reservoir) and John Day (fishing in The Dalles Reservoir) dams. These fish ranged in size from 247 to 598 mm FL in Bonneville Reservoir (mean = 369 mm; SE 2.60) and from 290 to 582 mm FL in The Dalles Reservoir (mean = 381 mm; SE 2.26). In both reservoirs, large proportions of the diets of Northern Pikeminnow examined contained food (Bonneville $\hat{p} = 0.82$; The Dalles $\hat{p} = 0.77$; Table 16). For the entire sampling season, invertebrates that were not identified as crayfish (other invertebrates) were observed in larger proportions of diet samples from Bonneville ($\hat{p} = 0.50$) and The Dalles ($\hat{p} = 0.54$) reservoirs than all of the other prey categories, including fish, though fish were nearly as prevalent in Bonneville diets ($\hat{p} = 0.49$). A large proportion of the "other invertebrates" prey category consisted of non-native prawns and amphipods. Fish were the second most abundant diet item in Bonneville ($\hat{p} = 0.49$) and in The Dalles ($\hat{p} = 0.38$) reservoirs. *We observed one Banded Killifish (Fundulus diaphenus) in the diet samples from The Dalles Reservoir for the first time.* In Bonneville Reservoir, the proportion of lamprey found in 2019 DAF diet samples ($\hat{p} = 0.24$) was greater than in 2018 ($\hat{p} = 0.05$), which was much less than the average proportion for all other years ($\hat{p} = 0.25$). In The Dalles Reservoir, the proportion of lamprey found in 2019 DAF diet samples ($\hat{p} = 0.16$), was higher than the past few years and close to the mean proportion for the time series ($\hat{p} = 0.19$).

In Bonneville Reservoir, lampreys were encountered in the greatest proportion of Northern Pikeminnow diet samples during week 20 ($\hat{p} = 0.71$; Figure 15). The proportion of lampreys encountered then dropped sharply during week 22 ($\hat{p} = 0.36$) and again during week 28 ($\hat{p} = 0.09$), where it remained low through the rest of the DAF season. Salmon and steelhead were encountered in the greatest proportion of Northern Pikeminnow diet samples during week 21 ($\hat{p} = 0.27$) and 26 ($\hat{p} = 0.23$). Juvenile salmon and steelhead were observed infrequently during all other weeks, except week 20 ($\hat{p} = 0.14$) and 23 ($\hat{p} = 0.14$). American Shad in the diet were encountered at relatively low rates until week 32 in Bonneville Reservoir.

In The Dalles Reservoir, lampreys were encountered in the greatest proportion of Northern Pikeminnow diet samples during week 18 ($\hat{p} = 0.50$), dropped off during week 19 ($\hat{p} = 0.35$), and again during week 26 ($\hat{p}$ = 0.06), where it continued to remain low through the rest of the season (Figure 15). For salmon and steelhead, they were consumed in the greatest proportion of Northern Pikeminnow diet samples during weeks 29 ($\hat{p}$ = 0.33) and 30 ($\hat{p}$ = 0.33). They were present in less than 10% of Northern Pikeminnow diet samples during weeks 21–24 and 31–32. In week 31, American Shad was the most frequent taxon observed in diet samples through the end of the season.

The weekly juvenile salmon consumption index for Northern Pikeminnow removed from Bonneville Reservoir in 2019 was the greatest during week 26 (Figure 16). For The Dalles Reservoir, week 30 was the peak of the juvenile salmon weekly consumption index. These peaks in the consumption index for Northern Pikeminnow captured at the two damns generally correspond with the outmigration of subyearling Chinook salmon at John Day Dam. Our sampling of Northern Pikeminnow diets occurred after the peak outmigration for steelhead and an early peak for yearling salmon, however, much of the yearling salmon out-migration coincided with our DAF sampling.

PSD of Northern Pikeminnow captured in both Bonneville (W = 79, $P < 0.001$) and The Dalles (W = 64, $P = 0.029$) reservoirs during the DAF was significantly greater during the early years (1990–1996) of sampling than during the later years (2006–2019; Figure 17). The trends between the two reservoirs in later years appears to follow the same general shape with a small increase over the past two years. There was no significant monotonic trend over time for *Wr* of either female (Mann-Kendall τ = -0.19, $P = 0.38$) or male (Mann-Kendall τ = -0.03, $P = 0.91$) Northern Pikeminnow captured in Bonneville Reservoir (Figure 18). Additionally, there was no significant *Wr* monotonic trend overtime for either female (Mann-Kendall τ = 0.15, $P = 0.50$) or male (Mann-Kendall τ = 0.03, $P = 0.95$) Northern Pikeminnow captured in The Dalles Reservoir (Figure 19). The size distribution of the population and relative body size of Northern Pikeminnow appear to be relatively healthy in both reservoirs.

DISCUSSION

The 2019 SRF system wide exploitation rate of Northern Pikeminnow ≥ 250 mm FL was 15.4% and the 95% confidence bounds of the estimate were11.0% to 19.8% (Table 4 and Figure 2). Both were well centered within the management goal of 10-20% exploitation. This targeted range has been hypothesized to produce predation reduction values of up to 50% compared to pre-program predation levels (Rieman and Beamesderfer 1990). This year's modeled estimates for 2020 show a range of 13% to 42% with a median value of 29% predation reduction (Figure 3). The 2019 system-wide exploitation rate of Northern Pikeminnow ≥ 250 mm FL is higher than the average since 1991 (13.9%, Table 4), which suggests that the removal program was relatively successful this year.

Where area-specific tag recoveries of Northern Pikeminnow ≥ 200 mm FL were sufficient, exploitation estimates were highest in Little Goose Reservoir followed by McNary Reservoir and subsequently below Bonneville Dam (Table 2). The exploitation rate for Little Goose reservoir is considerably higher compared to recent years. Annual patterns of exploitation among areas typically show the highest rates in McNary and Bonneville reservoirs and downstream of Bonneville Dam. This could be a result of the proximity of these reservoirs to the Portland/Vancouver metropolitan and Tri-Cities (Washington) areas (Carpenter et al. 2019). This year's highest exploitation rate in the relatively remote Little Goose Reservoir (an estimate more than five times greater than the previous observation; Table 2) may be the result of strong recruitment to the fishery and the subsequent removal of a highly abundant smaller size class. This hypothesis is supported by the fact that ODFW tagged 161 Northern Pikeminnow 200–249 mm FL and the SRF recaptured 42 of those fish in 2019, while in 2018 we tagged 59 fish in this size class and the SRF recaptured 3. The inter-relationship of both ecological factors and anthropogenic factors as influential variables on annual exploitation rates continues to evolve and supports the need for continuing evaluation of the NPMP.

In previous years of fishery implementation, estimates for exploitation of Northern Pikeminnow 200–250 mm FL have typically been lower than other size classes or unable to be calculated due to low tag returns (Table 3). Yet, this size class represents a substantial component of the catches in the SRF fishery (e.g., 48% of the total catch in 2018, Hone et al. 2019). We hypothesized that post-release mortality due to tagging injuries associated with the traditional lock loop tag could be a major factor in these observations, especially for 200–250 mm FL sized Northern Pikeminnow. Therefore, we tested an alternative tag type, the T-bar anchor tag in 2019. Subsequently, we observed large increases in the 2019 exploitation estimate of this size class across all areas. This change may reflect a lower post-release mortality in association with the fish marked with the less invasive T-bar tag. The tradeoff is that tag retention for the T-bar anchor tags was lower during our initial trial (65% tag loss). We attribute the high incidence of tag loss for T-bar anchor tags to improper training and tag placement, which we plan to correct. We intend to conduct the same method of using both types in 2020 and will reevaluate the relative success of each. However, it appears that use of an alternative to the lock loop tag may increase the post-release survival of Northern Pikeminnow, especially for the 200–250 mm FL size class, and improve our ability to estimate exploitation rates.

Median modelled reductions in Northern Pikeminnow predation rates have generally remained around 30% with some variability since 1997 (Figure 3). Projected levels of reduced predation relative to preprogram levels suggest a very modest reduction in predation during future years, if exploitation rates continue at average levels and natural mortality is constant. Given that we achieved the target exploitation rate and a median model estimate shows a 29% reduction in predation, it appears that the 2019 implementation of the NPMP was successful based on these metrics. However, continued annual promotion and occasional changes to incentives to ensure sport reward anglers participate are likely needed to achieve the target exploitation rates and predation reduction goals.

The NPMP requires continuing monitoring of the system-wide catch from the SRF and the DAF to evaluate the success of the ongoing removal efforts. From our biological evaluation, the primary indicator of a compensatory response is whether the level of predation changes within Northern Pikeminnow populations and how it compares with other fish predators of salmon and steelhead, particularly Smallmouth Bass and Walleye. Changes in the abundance of the predator populations, their rates of consumption of juvenile salmonids or both can influence changes in the predation index. If we observe changes in predation, we could describe potential explanatory mechanisms by variations in recruitment to reproductive or predatory size, condition factor of individuals, and changes in diet including prey composition and capacity (proportion full stomachs, distribution of vertebrates, invertebrates, and fish species consumed, etc.).

Overall, the design of our biological evaluation sampling in the lower Snake River captures a snapshot of the populations of interest as a result of sampling only one day in a particular site for a given season with the exception of the area upriver of Lower Granite Dam which has two days of sampling per season at a single site for the reservoir. If this lone sampling event occurs on a day with less than favorable electrofishing conditions (e.g., windy, low water clarity) whether observation of low abundance of the target species are reflecting population changes or simply low encounters could remain unknown. In other areas we sample, such as Bonneville or The Dalles reservoirs, the sampling for a season occurs over two days, which can buffer against sampling events in less favorable conditions. Even with additional days in other reservoirs, we often do not meet minimum sample sizes for the calculation of metrics for Northern Pikeminnow such as consumption index or PSD, which suggests a need to modify the sampling design or analyses used to evaluate the population. When researchers collected baseline data for this study, there were three organizations working collaboratively in the field to collect samples. In our current era of biological evaluation, the field effort consists of only two vessels and six weeks of allotted time. In our sampling, we often only catch Northern Pikeminnow and Walleye during our first few early morning electrofishing events. Therefore, capturing more of these species would require additional vessels sampling simultaneously or additional days of sampling. For the 2020 season, we have modified our sampling plan to have an additional boat during biological evaluation in order to increase our ability to encounter these species. Furthermore, large gaps in data (currently three years planned between sampling events) creates a situation where reaching meaningful conclusions regarding changes over time is precluded by a lack of calculated values. Moving toward a biological evaluation of an area where we believe predation to be greatest (e.g., below Bonneville Dam and Bonneville Reservoir) with surveys repeating annually, may be in our best interest. Ultimately, gathering empirical information on interactions between the three primary fish predators and their potential effects on depressed salmon and steelhead populations requires regional investment to ensure the efficacy of predator management efforts.

Abundance metrics (CPUE and abundance index) are difficult to interpret for Northern Pikeminnow, especially in the lower Snake River reservoirs where we encountered few fish in 2019. Though these metrics are scalable (the number of fish caught in a 900 s run, a minimum of three runs for a reservoir area in a year to obtain a mean value), it follows that additional sampling could allow for better precision. As mentioned above, these metrics are dependent on the ability to repeatedly sample to reduce uncertainty in our estimates. Our low abundance estimates may be a result of the sustained removals of Northern Pikeminnow in the lower Snake River reservoirs. We catch Smallmouth Bass frequently in the lower Snake River reservoirs, which suggests that our capture technique and sampling protocol are sufficient to estimate abundance. This would lead us to believe that the NPMP is effective in reducing the population of predatory sized Northern Pikeminnow in the lower Snake River. However, supporting evidence of rates of area specific exploitation from fisheries evaluation are not available for all reservoirs due to low tag returns. For the continued success of program implementation, it is critical that we monitor these populations and avoid over exploitation of the native species. Therefore, we may need to explore alternative forms of analysis.

The frequency of occurrence of salmonids in the diets of the predators studied appeared to be similar to our observations during 2016 sampling in the lower Snake River reservoirs. Upriver of Lower Granite Dam, 70% of Northern Pikeminnow consumed salmonids in the spring. Though the sample size was small (n = 10), this frequency of occurrence is much higher than any other strata (species, season, and reservoir combination) observed in 2019. Summer consumption of salmonids was relatively low for all species (Northern Pikeminnow in Little Goose Reservoir was the greatest at $\hat{p}$ = 0.07) and the vast majority of diets sampled contained food items. This may reflect a change in the food web composition as salmonids begin out-migration or are released in the spring and few are present this far up the river system during the summer. Vigg et al. (1991) found water temperature to be the most influential individual variable regulating consumption rates. While this information suggests consumption rates of juvenile salmonids would be greater in the summer when the river is warmer, consumption and predation indices will remain low if salmon are not present. Given this conclusion, it could be important to focus summer biological evaluation lower in the river system where salmon and steelhead are typically more abundant during this time.

A consumption index for Walleye has not been created. An alternative could be to consider a new metric (such as mean number of salmonids per predator) where we can easily compare relative impacts among species to better explore changes in salmonid predation. As with current metrics, sufficient sample sizes would be required to reliably compare numbers. Further, we would want to ensure that collecting sufficient sample sizes for a new metric is regularly achievable. In the event that we change how we evaluate diets, we retain the problem of insufficient sample sizes to evaluate other population parameters such as PSD. A combination of these diet and population metrics are useful in elucidating trends when evaluating these piscivorous predators.

In light of limited sample sizes for Northern Pikeminnow and the lack of a model for consumption index for Walleye, a comparison of the seasonal CPUE by species and area (Table 8) multiplied by the proportion of diets that contained salmonids (Table 12) could give us a rough estimate of salmonid predation across species and areas. Though salmonid consumption remains low for Smallmouth Bass compared to Northern Pikeminnow, they could have had the greatest predatory impact on salmon in the lower Snake River reservoirs based on their comparatively high abundance (CPUE) in 2019 (Table 5). The product of CPUE and proportion of diets containing one or more salmonids is greatest for Smallmouth Bass in any area or season with the exception of spring in the Ice Harbor tailrace, which is much higher for Walleye. Although this rough metric does not take into account the number of salmonids consumed by individual fish of each species, it can give an alternative view of predation in the reservoirs of the lower Snake River. A similar approach produces the same result when we compare abundance index values (Tables 9-11) with salmonid predation by season and area, though Walleye have a predatory impact similar to Smallmouth Bass in some areas of Lower Monumental Reservoir.

Smallmouth Bass may have the greatest predatory impact of all of the piscivores monitored based on abundance and the proportion of diets containing salmonids in 2019. Despite this, it is unclear if this is a response to the targeted removals of Northern Pikeminnow. There are several environmental factors such as flow, water temperature, and nutrient availability that could result in conditions for favorable recruitment or survival for Smallmouth Bass, leading to an increase in their abundance. Additionally, trends in populations could be a reflection of quality and availability of habitat in the reservoir for a specific species. We would expect in reservoir areas with quality physical habitat that the population would increase given favorable environmental conditions, compared to poor habitat where we would not expect a population boom even with favorable conditions. This highlights not only the need for continued biological evaluation in the Columbia and lower Snake river systems, but also a modification of how we evaluate predation in these areas. Habitat quality may be an important new variable to account for when assessing drivers of variation in relative abundance. Our results have the potential to be useful and inform fisheries management actions outside the scope of the NPMP. For example, both ODFW and WDFW removed maximum daily allowable catch limits on Smallmouth Bass and Walleye in 2016. Our monitoring observations do not yet inform whether that management action has reduced the predatory impact of either species. Coordination and comparison with the results of other study efforts in the lower Snake River could inform potential changes. For example, Erhardt et al. (2018) evaluated Smallmouth Bass abundance and predation behavior in the lower Snake River reservoirs. Those observations are short term and how they can be compared to long term NPMP observations are still to be investigated.

We observed a significant decrease in PSD for Northern Pikeminnow in The Dalles, John Day, and Lower Granite reservoirs (Figure 5), indicating that the SRF is successful in restructuring the size distribution of the population of Northern Pikeminnow by reducing the number of larger, more predatory fish. Interestingly, while last year's report found a significant decreasing trend in PSD in McNary Reservoir, the trend was not significant with the addition of this year's data. PSD has increased in McNary reservoir over the last three years suggesting an increasing abundance of larger sized fish, or a decrease in smaller Northern Pikeminnow. Both may be at play as exploitation of the smaller size class has increased recently (Table 3) while the larger fish may not be effectively being removed as rates of exploitation for Northern Pikeminnow ≥ 250 mm FL have decreased over the last two years in this reservoir (Table 4).

The distribution of FL for Walleye collected during Northern Pikeminnow fishery evaluation in 2019, suggests successful reproduction occurred in 2018, given that age-1 Walleye are typically 200–250 mm FL (Figure 6; Tinus and Beamesderfer 1994). Simultaneously, we observed no significant trends in PSD for Walleye in The Dalles, John Day, and McNary reservoirs (Figure 7) and a significant decrease in PSD – P in McNary Reservoir (Figure 8). These estimates of PSD in all reservoirs, however, were greater than values suggested for balanced populations (PSD 30–60%; Anderson and Weithman 1978). These trends could indicate there is no compensatory response by Walleye to Northern Pikeminnow removals in terms of size structure. However, there has been an increase in PSD and PSD – P in the past two years. This finding substantiates the need for continued monitoring and suggests larger Walleye remain in these reservoirs and are not regularly removed by fishing or have low natural mortality. This result is surprising given that recent successful years of reproduction would skew data towards smaller sized fish (Figure 6). However, we would potentially not observe a lower estimate of PSD or PSD – P as smaller age-1 Walleye could fall below the stock size (236 mm FL) for the calculation. In addition, there are other factors, such as fishing pressure, food availability, and temperature which can affect the size distribution of Walleye and may have a greater influence than Northern Pikeminnow removals. Climate change effects to seasonal water temperatures and flow levels could influence population dynamics like these (ISAB 2007).

The Removal fishery led by WDFW from the tailrace decks at the powerhouses of The Dalles and John Day dams continue to remove substantial numbers of predatory size Northern Pikeminnow from Bonneville and The Dalles reservoirs in concert with the SRF. The DAF takes place in two areas of the Columbia River system accessible only by authorized agencies and therefore presents a unique opportunity to suppress predation. Our observations from analyses of these diet samples since 2006 show consistent annual predatory impacts to juvenile salmon and steelhead. Additionally, the Northern Pikeminnow at these locations prey consistently on lampreys, also a regional taxon of conservation concern (ODFW 2020). Northern Pikeminnow primarily consume lampreys early in the DAF season (mid-May through mid-June), salmonids in the middle of the season (mid-June through July) and American Shad in August at the end of the season (Figure 15). These data, coupled with what we know about the out-migration timing of the aforementioned prey species suggests that Northern Pikeminnow are not preferentially feeding on any one prey item, rather they opportunistically eat prey that are most available in the discharge through the power turbines during certain times of the year. We observed that the salmonid consumption index for Northern Pikeminnow in Bonneville and The Dalles reservoirs was greatest during weeks 26 and 30, respectively (Figure 16). Furthermore, the pattern of juvenile salmonid passage index at John Day Dam suggests that subyearling Chinook Salmon are the primary salmonid available to Northern Pikeminnow when consumption is the greatest. Therefore, subyearling Chinook Salmon may be the most vulnerable salmonid prey in the tailrace areas of these two dams.

The PSD for Northern Pikeminnow at the two dams suggests the NPMP has successfully restructured the size distribution of individuals in the populations of Northern Pikeminnow towards smaller fish in The Dalles Dam and John Day Dam tailraces. PSD at both dams was relatively high in the early 1990s when the Dam Angling fishery began (Figure 17). Although a gap in data exists from 1996 through 2006, PSD from both dams after 2006 remains lower than it was in the early 1990s (Figure 17). This suggests that the Dam Angling fishery was initially successful in decreasing the size-structure of Northern Pikeminnow at the two dams and is currently maintaining them at relatively low values. In contrast, our condition factor (W_r) data suggests that there has been little change in the body condition of Northern Pikeminnow at the two dams (Figures 18 and 19), indicating the fisheries have a negligible influence on this metric.

We do not have substantial evidence to indicate inter- or intra-specific compensation by remaining Northern Pikeminnow, Smallmouth Bass, or Walleye. However, observed increases in the abundance of Smallmouth Bass in the lower Snake River reservoirs suggest that their predatory impact has substantially increased since program design and implementation. The variation of observations across reservoirs suggest each Snake River reservoir has unique characteristics (e.g., species composition, environment, fishing pressure). Trends were not consistent within species or among metrics. Those mixed and sometimes conflicting signals make drawing definitive conclusions difficult, but indicate continued monitoring to add to the time series is essential. Beamesderfer et al. (1996) predicted that because of the low exploitation rate the NPMP exerts on Northern Pikeminnow, it restructures the size distribution of the population, as opposed to reducing the abundance of individuals, and thus removals may never reach a level to cause a compensatory response within the native Northern Pikeminnow population or the other non-native predators. Sources of variability in the metrics developed from the empirical observations annually, seasonally, and by location used for biological evaluation are uncertain. Variability of interpretation can result from the sampling design and varying predator and prey behavior coinciding with changing environmental conditions, changes to the operation and configuration of the Federal Columbia River Power System (FCRPS), hatchery production practices, changes to lower Snake River smolt collection and transportation practices, other factors – and the sustained removal of larger Northern Pikeminnow. Cause and effect relationships of interactions within and between fish predator populations resulting from the NPMP remain unclear. However, if predation by other fish predators increases concurrent to removing Northern Pikeminnow, the success of suppressing predation by Northern Pikeminnow and mitigating for the salmon losses caused by the FCRPS could be diminished.

Whether out-migrating juvenile salmon and steelhead that survive predation by Northern Pikeminnow also survive to return as reproductive adults is dependent on survival of salmon and steelhead at later life stages, which is not monitored by the NPMP. Continued regional evaluation of the combined predatory impacts from fish, colonial piscivorous birds, and marine mammals in the ocean and Columbia River estuary will be important to adaptively manage the negative impacts to depressed populations of Columbia Basin salmon and steelhead (ISAB 2016). The NPMP does not evaluate any changes in life cycle ecology of the predator species when they are themselves are prey as eggs, larvae, or fry before they are large enough to prey on salmon. Clearly the altered Columbia Basin environment and the relationships among predators and prey are inherently complex (ISAB 2011). Coordination through the Northwest Power and Conservation Council Fish and Wildlife amendment process with input from the Independent Scientific Advisory Board will be essential as the NPMP continues to evolve in this context.

ACKNOWLEDGEMENTS

We are grateful to those who worked long hours in the field to collect the data presented in this report, particularly Katherine Carey, Parker Chambliss, Torrey Gorra, Kevin Kirkley, James Morrill, Karah Roof, and Jason Westlund. We had additional help with data and in the laboratory from Ruth Hannevig, Katie Jenkins, and Eric Tinus. We thank the following individuals for their cooperation and assistance: Ken Frisby, Lisa Chambers (ODFW, The Dalles Screen Shop), and Terry Blessing (ODFW, Irrigon Hatchery) for providing boat storage facilities; Eric Winther, Ruthanna Shirley, and other WDFW staff for providing PIT tag recovery and loop tag loss information; Scott Mengis (WDFW) and his Dam Angling Fishery colleagues for assistance obtaining diet samples at The Dalles and John Day dams; and Erin Kovalchuk, Tammy Mackey, Ida Royer, Andrew Traylor, Eric Grosvenor, Miro Zyndol, Ron Twiner, Jeff Randall, Robert Kampert, Ryan Schlattment, David James, and many others of the U.S. Army Corps of Engineers for coordination of access to project boat-restricted zones and powerhouse sampling sites. We thank our colleagues Art Martin and Eric Tinus for helpful comments on earlier versions of this report.

This project is funded by the Bonneville Power Administration (project number 1990-077-00) under the direction of Contracting Officer's Technical Representative Eric McOmie. Art Martin of ODFW and Steve Williams of Pacific States Marine Fisheries Commission administered the contract.

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TABLES

Table 1. Numbers of Northern Pikeminnow tagged and recaptured[a] in the Sport Reward Fishery during 2019 by location and size class.

	200–249 mm FL		≥ 250 mm FL		Combined	
Reach/Reservoir	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recaptured
Below Bonneville	223	26	422	62	645	88
Bonneville	19	4	130	12	149	16
The Dalles	4	0	7	0	11	0
John Day	2	0	3	0	5	0
McNary	44	4	43	5	87	9
Ice Harbor	7	0	2	0	9	0
Little Goose	161	42	9	3	170	45
Lower Granite	63	6	34	6	97	12
Combined	523	82	650	88	1,173	170

[a] Fish that were recaptured the same week in which they were tagged are not included in this table or in calculations of exploitation to avoid violating mark-recapture assumptions (i.e., incomplete mixing). There was one fish recaptured in the same week it was tagged in 2019 in Lower Granite Reservoir.

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
2018	10.1	16.8	*a*	*a*	18.3	*a*	5.5	5.5	12.6
2019	13.6	9.5	*a*	*a*	15.9	*a*	30.4	13.2	17.3
mean (SE)	13.8 (0.9)	10.4 (0.7)	14.2 (3.5)	*b*	11.8 (1.3)	*b*	14.8 (3)	13.7 (4.3)	12.9 (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 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	9.7	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
2018	3.5	*a*	*a*	*a*	10.6	*a*	*a*	*a*	4.5
2019	11.7	21.1	*a*	*a*	13.0	*a*	29.9	9.9	19.4
mean (SE)	7.2 (1.5)	9 (1.9)	*b*	*b*	8.1 (1.2)	*b*	12 (3.4)	6.2 (2.4)	7.4 (1)

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
2018	13.8	18.3	*a*	*a*	18.1	*a*	*a*	16.9	16.8
2019	14.7	7.8	*a*	*a*	16.5	*a*	*a*	19.7	15.4
mean (SE)	13.8 (0.8)	10.1 (0.8)	14.2 (1.8)	3.1 (0.2)	14.9 (1.3)	7.7 (0.8)	13.4 (3.2)	14 (1.2)	13.9 (0.7)

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

Table 5. 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 lower Snake River reservoirs during spring and summer 2019. FB = forebay, Mid = mid-reservoir, and Rkm = river kilometer.

Species,	Ice Harbor			Lower Monumental			Little Goose			Lower Granite
Season	FB	Mid	TR	FB	Mid	TR	FB	Mid	TR	Rkm 222—228
Northern Pikeminnow,										
Spring	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)	0.08 (0.06)
Summer	0.00 (0.00)	0.00 (0.00)	0.17 (0.11)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.14 (0.10)	0.03 (0.03)
Smallmouth Bass,										
Spring	2.52 (0.64)	2.68 (0.73)	5.57 (1.98)	2.46 (0.80)	5.17 (1.14)	17.0 (3.03)	5.30 (0.98)	1.38 (0.67)	0.75 (0.22)	10.9 (2.19)
Summer	3.28 (0.74)	4.05 (0.99)	8.08 (1.78)	4.04 (0.49)	3.64 (0.86)	11.0 (2.03)	8.15 (0.99)	5.92 (0.97)	1.78 (0.59)	4.54 (0.73)
Walleye,										
Spring	0.00 (0.00)	0.12 (0.09)	1.29 (0.42)	0.07 (0.07)	0.56 (0.27)	1.00 (0.84)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Summer	0.00 (0.00)	0.00 (0.00)	0.67 (0.33)	0.00 (0.00)	0.29 (0.17)	0.17 (0.17)	0.00 (0.00)	0.00 (0.00)	0.07 (0.07)	0.00 (0.00)

Table 6. 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 lower Snake River reservoirs, 1991–2019. FB = forebay, Mid = mid-reservoir, TR = tailrace, and Rkm = river kilometer.

Season,	Ice Harbor			Lower Monumental			Little Goose			Lower Granite
Year	FB	Mid	TR	FB	Mid	TR	FB	Mid	TR	Rkm 222—228
Spring,										
1991	0.11 (0.08)	1.35 (0.51)	0.44 (0.11)	0.33 (0.09)	3.51 (1.22)	1.97 (0.68)	0.74 (0.27)	2.46 (1.03)	1.44 (0.50)	2.66 (0.49)
1994	—	—	—	—	—	0.40 (0.15)	—	—	0.44 (0.16)	0.93 (0.18)
1995	—	—	—	—	—	0.08 (0.06)	—	—	0.06 (0.04)	0.29 (0.07)
1996	—	—	—	—	—	0.21 (0.14)	—	—	0.25 (0.12)	0.47 (0.10)
1999	—	—	—	—	—	0.00 (0.00)	—	—	0.11 (0.05)	0.32 (0.09)
2004	—	—	—	—	—	0.00 (0.00)	—	—	0.10 (0.06)	0.04 (0.03)
2007	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.05 (0.05)	0.13 (0.13)	0.00 (0.00)	0.07 (0.07)	0.00 (0.00)	0.00 (0.00)	0.19 (0.06)
2010	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.38 (0.32)	0.05 (0.05)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.03 (0.02)
2013	0.00 (0.00)	0.00 (0.00)	0.03 (0.03)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.17 (0.07)
2016	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)	0.20 (0.20)	0.00 (0.00)	0.18 (0.07)
2019	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)	0.07 (0.05)
mean (SE)	0.02 (0.02)	0.22 (0.22)	0.08 (0.07)	0.06 (0.05)	0.67 (0.57)	0.25 (0.18)	0.14 (0.12)	0.44 (0.40)	0.22 (0.13)	0.49 (0.23)
Summer,										
1991	0.00 (0.00)	0.20 (0.20)	0.13 (0.06)	0.37 (0.15)	1.76 (1.00)	0.17 (0.09)	0.17 (0.09)	1.19 (0.79)	0.24 (0.11)	0.71 (0.19)
1994	—	—	—	—	—	0.17 (0.10)	—	—	0.02 (0.02)	0.07 (0.03)
1995	—	—	—	—	—	0.09 (0.06)	—	—	0.00 (0.00)	0.08 (0.05)
1996	—	—	—	—	—	0.11 (0.07)	—	—	0.02 (0.02)	0.05 (0.03)
1999	—	—	—	—	—	—	—	—	0.18 (0.09)	0.04 (0.04)
2004	—	—	—	—	—	0.09 (0.09)	—	—	0.16 (0.09)	0.07 (0.04)
2007	0.08 (0.08)	0.00 (0.00)	0.24 (0.14)	0.00 (0.00)	0.32 (0.16)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.02 (0.02)	0.00 (0.00)
2010	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.25 (0.12)	0.07 (0.07)	0.00 (0.00)	0.00 (0.00)	0.09 (0.04)	0.23 (0.08)
2013	—	—	—	—	0.32 (0.16)	0.08 (0.06)	—	0.00 (0.00)	0.02 (0.02)	0.03 (0.03)
2014	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	—	—	—	—	—	—	—
2016	—	—	—	—	0.15 (0.11)	0.00 (0.00)	0.07 (0.07)	0.00 (0.00)	0.11 (0.05)	0.00 (0.00)
2019	0.00 (0.00)	0.00 (0.00)	0.11 (0.08)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.06 (0.04)	0.03 (0.03)
mean (SE)	0.02 (0.02)	0.04 (0.04)	0.10 (0.04)	0.09 (0.09)	0.47 (0.26)	0.08 (0.02)	0.05 (0.03)	0.20 (0.20)	0.09 (0.02)	0.12 (0.06)

Note: dashes (—) = no sampling conducted.

Table 7. 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 lower Snake River reservoirs, 1991–2019. FB = forebay, Mid = mid-reservoir, TR = tailrace, and Rkm = river kilometer.

Season,	Ice Harbor			Lower Monumental			Little Goose			Lower Granite
Year	FB	Mid	TR	FB	Mid	TR	FB	Mid	TR	Rkm 222—228
Spring,										
1991	1.65 (0.61)	11.3 (1.77)	2.74 (0.36)	1.56 (0.37)	3.79 (0.81)	3.26 (0.93)	2.40 (0.67)	11.8 (2.81)	1.08 (0.55)	0.70 (0.22)
1994	—	—	—	—	—	1.65 (0.41)	—	—	2.17 (0.41)	4.68 (0.93)
1995	—	—	—	—	—	0.89 (0.27)	—	—	1.52 (0.51)	1.68 (0.36)
1996	—	—	—	—	—	0.64 (0.45)	—	—	1.11 (0.43)	1.74 (0.37)
1999	—	—	—	—	—	2.70 (0.78)	—	—	0.80 (0.15)	1.42 (0.30)
2004	—	—	—	—	—	0.00 (0.00)	—	—	0.00 (0.00)	1.54 (0.51)
2007	1.78 (0.72)	6.45 (2.62)	3.83 (0.99)	2.65 (0.69)	5.36 (1.97)	5.03 (1.02)	6.76 (1.37)	5.89 (1.29)	0.42 (0.11)	3.78 (0.76)
2010	1.07 (0.45)	8.85 (1.91)	3.43 (0.96)	1.66 (0.49)	6.40 (1.40)	4.07 (0.92)	3.09 (1.16)	11.3 (4.41)	0.16 (0.06)	1.38 (0.39)
2013	3.81 (0.91)	3.99 (1.41)	2.52 (0.78)	1.71 (0.38)	5.72 (1.72)	10.01 (1.67)	4.71 (1.19)	15.4 (4.59)	0.71 (0.19)	6.45 (1.15)
2016	5.63 (1.31)	15.8 (2.75)	5.90 (1.30)	4.70 (0.86)	11.9 (2.57)	16.77 (3.64)	3.97 (0.94)	13.3 (4.21)	0.73 (0.18)	4.40 (0.69)
2019	3.60 (0.92)	9.62 (2.63)	3.75 (1.33)	2.56 (0.83)	7.93 (1.74)	14.41 (2.57)	7.84 (1.45)	5.10 (2.45)	0.33 (0.10)	9.15 (1.84)
mean (SE)	2.92 (0.71)	9.33 (1.66)	3.69 (0.49)	2.47 (0.49)	6.85 (1.15)	5.40 (1.74)	4.80 (0.86)	10.5 (1.68)	0.82 (0.19)	3.36 (0.80)
Summer,										
1991	0.71 (0.29)	5.18 (2.01)	1.21 (0.35)	0.89 (0.27)	1.68 (0.47)	0.96 (0.31)	4.50 (0.60)	9.93 (2.76)	1.75 (0.52)	3.72 (0.69)
1994	—	—	—	—	—	2.25 (0.39)	—	—	0.93 (0.16)	1.10 (0.21)
1995	—	—	—	—	—	0.85 (0.24)	—	—	0.82 (0.23)	1.68 (0.32)
1996	—	—	—	—	—	1.06 (0.35)	—	—	0.35 (0.09)	0.46 (0.10)
1999	—	—	—	—	—	—	—	—	0.00 (0.00)	0.00 (0.00)
2004	—	—	—	—	—	8.99 (1.45)	—	—	0.47 (0.13)	2.00 (0.61)
2007	5.03 (1.22)	11.2 (1.87)	3.73 (0.81)	3.79 (0.64)	3.38 (0.78)	4.52 (0.79)	6.35 (1.18)	9.51 (2.35)	0.38 (0.18)	2.77 (0.72)
2010	3.78 (1.17)	8.33 (1.68)	2.80 (0.38)	3.31 (0.58)	6.48 (1.32)	13.1 (2.00)	3.12 (0.74)	11.7 (3.83)	0.67 (0.29)	3.24 (0.45)
2013	—	—	—	—	7.11 (1.14)	7.34 (1.23)	—	24.9 (5.42)	0.48 (0.16)	4.38 (0.81)
2014	2.14 (0.71)	1.79 (0.70)	1.29 (0.44)	—	—	—	—	—	—	—
2016	—	—	—	—	9.40 (1.46)	15.9 (1.95)	13.9 (2.00)	14.0 (2.63)	0.64 (0.26)	2.15 (0.70)
2019	4.69 (1.05)	14.5 (3.54)	5.43 (1.20)	4.21 (0.51)	5.57 (1.32)	9.32 (1.73)	12.1 (1.46)	21.8 (3.59)	0.79 (0.26)	3.82 (0.62)
mean (SE)	3.27 (0.81)	8.21 (2.23)	2.89 (0.79)	3.05 (0.74)	5.60 (1.12)	6.44 (1.71)	7.98 (2.12)	15.3 (2.66)	0.66 (0.13)	2.30 (0.43)

Note: dashes (—) = no sampling conducted.

Table 8. 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 lower Snake River reservoirs, 1991–2019. FB = forebay, Mid = mid-reservoir, TR = tailrace, and Rkm = river kilometer.

Season,	Ice Harbor			Lower Monumental			Little Goose			Lower Granite
Year	FB	Mid	TR	FB	Mid	TR	FB	Mid	TR	Rkm 222—228
Spring,										
1991	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
1994	—	—	—	—	—	0.00 (0.00)	—	—	0.00 (0.00)	0.00 (0.00)
1995	—	—	—	—	—	0.00 (0.00)	—	—	0.00 (0.00)	0.00 (0.00)
1996	—	—	—	—	—	0.00 (0.00)	—	—	0.00 (0.00)	0.00 (0.00)
1999	—	—	—	—	—	0.08 (0.08)	—	—	0.00 (0.00)	0.00 (0.00)
2004	—	—	—	—	—	0.00 (0.00)	—	—	0.00 (0.00)	0.00 (0.00)
2007	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.89 (0.35)	0.35 (0.20)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2010	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.05 (0.05)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2013	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.29 (0.23)	0.16 (0.16)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2016	0.08 (0.08)	0.36 (0.36)	0.28 (0.15)	0.00 (0.00)	3.02 (1.32)	1.45 (0.95)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2019	0.00 (0.00)	0.45 (0.31)	0.86 (0.29)	0.07 (0.07)	0.86 (0.42)	0.85 (0.71)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
mean (SE)	0.01 (0.01)	0.13 (0.09)	0.19 (0.14)	0.01 (0.01)	0.84 (0.46)	0.27 (0.14)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Summer,										
1991	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)	0.00 (0.00)
1994	—	—	—	—	—	0.00 (0.00)	—	—	0.00 (0.00)	0.00 (0.00)
1995	—	—	—	—	—	0.00 (0.00)	—	—	0.00 (0.00)	0.00 (0.00)
1996	—	—	—	—	—	0.00 (0.00)	—	—	0.00 (0.00)	0.00 (0.00)
1999	—	—	—	—	—	—	—	—	0.00 (0.00)	0.00 (0.00)
2004	—	—	—	—	—	0.00 (0.00)	—	—	0.00 (0.00)	0.00 (0.00)
2007	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.32 (0.16)	0.59 (0.26)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2010	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.25 (0.20)	0.14 (0.14)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2013	—	—	—	—	0.32 (0.18)	0.17 (0.17)	—	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2014	0.00 (0.00)	0.00 (0.00)	0.06 (0.06)	—	—	—	—	—	—	—
2016	—	—	—	—	0.38 (0.27)	0.11 (0.07)	0.00 (0.00)	0.00 (0.00)	0.04 (0.04)	0.00 (0.00)
2019	0.00 (0.00)	0.00 (0.00)	0.45 (0.22)	0.00 (0.00)	0.45 (0.25)	0.14 (0.14)	0.00 (0.00)	0.00 (0.00)	0.03 (0.03)	0.00 (0.00)
mean (SE)	0.00 (0.00)	0.00 (0.00)	0.10 (0.09)	0.00 (0.00)	0.29 (0.06)	0.12 (0.06)	0.00 (0.00)	0.00 (0.00)	0.01 (0.00)	0.00 (0.00)

Note: dashes (—) = no sampling conducted.

Table 9. Number (n) of Northern Pikeminnow, Smallmouth Bass, and Walleye (≥ 200 mm FL) diets examined during biological evaluation in the lower Snake River reservoirs during spring and summer 2019 and proportion of samples containing specific prey items (cray = crayfish, crust = all crustacea not identified at crayfish, sal = salmon or steelhead, lam = lamprey).

Season,	Northern Pikeminnow								Smallmouth Bass								Walleye							
Area	n	$\hat{p}_{food}$	$\hat{p}_{fish}$	$\hat{p}_{cray}$	$\hat{p}_{crust}$	$\hat{p}_{insect}$	$\hat{p}_{sal}$	$\hat{p}_{lam}$	n	$\hat{p}_{food}$	$\hat{p}_{fish}$	$\hat{p}_{cray}$	$\hat{p}_{crust}$	$\hat{p}_{insect}$	$\hat{p}_{sal}$	$\hat{p}_{lam}$	n	$\hat{p}_{food}$	$\hat{p}_{fish}$	$\hat{p}_{cray}$	$\hat{p}_{crust}$	$\hat{p}_{insect}$	$\hat{p}_{sal}$	$\hat{p}_{lam}$
Spring																								
Ice Harbor	1	1.00	0.00	0.00	0.00	0.00	0.00	0.00	152	0.99	0.28	0.45	0.54	0.18	0.02	0.01	19	0.95	0.37	0.11	0.37	0.16	0.37	0.00
Lower Monumental	1	1.00	0.00	1.00	0.00	0.00	0.00	0.00	150	1.00	0.21	0.39	0.61	0.19	0.04	0.01	23	1.00	0.39	0.04	0.70	0.13	0.35	0.00
Little Goose	8	0.75	0.50	0.00	0.13	0.13	0.13	0.00	110	1.00	0.33	0.37	0.68	0.28	0.08	0.00	0	—	—	—	—	—	—	—
Lower Granite	10	0.90	0.80	0.20	0.10	0.50	0.70	0.00	152	0.99	0.65	0.19	0.35	0.28	0.09	0.00	0	—	—	—	—	—	—	—
All	20	0.85	0.60	0.15	0.10	0.30	0.40	0.00	564	1.00	0.37	0.35	0.53	0.23	0.05	0.00	42	0.98	0.38	0.07	0.55	0.14	0.36	0.00
Summer																								
Ice Harbor	3	1.00	0.67	1.00	0.00	0.33	0.00	0.00	152	1.00	0.27	0.66	0.39	0.40	0.01	0.00	8	1.00	0.25	0.13	0.50	0.25	0.00	0.00
Lower Monumental	0	—	—	—	—	—	—	—	150	1.00	0.17	0.63	0.46	0.45	0.03	0.01	7	1.00	0.43	0.57	0.57	0.00	0.00	0.00
Little Goose	14	1.00	0.14	0.64	0.00	0.79	0.07	0.00	150	1.00	0.21	0.48	0.45	0.62	0.03	0.00	1	1.00	1.00	0.00	0.00	0.00	0.00	0.00
Lower Granite	3	0.33	0.00	0.00	0.00	0.33	0.00	0.00	141	0.99	0.59	0.36	0.10	0.67	0.05	0.00	0	—	—	—	—	—	—	—
All	20	0.90	0.20	0.60	0.00	0.65	0.05	0.00	593	1.00	0.31	0.54	0.35	0.53	0.03	0.00	16	1.00	0.38	0.31	0.50	0.13	0.00	0.00

Table 10. Proportion of diet samples containing specific prey fish families collected from Northern Pikeminnow, Smallmouth Bass, and Walleye during spring and summer biological evaluation in the lower Snake River reservoirs, 2019.

	Northern Pikeminnow				Smallmouth Bass				Walleye			
Common name (Family)	Ice Harbor (*n* = 4)	Lower Monumental (*n* = 1)	Little Goose (*n* = 22)	Lower Granite (*n* = 13)	Ice Harbor (*n* = 304)	Lower Monumental (*n* = 300)	Little Goose (*n* = 260)	Lower Granite (*n* = 293)	Ice Harbor (*n* = 27)	Lower Monumental (*n* = 30)	Little Goose (*n* = 1)	Lower Granite (*n* = 0)
lampreys (Petromyzontidae)	—	—	—	—	—	0.01	—	—	—	—	—	—
suckers (Catostomidae)	—	—	—	—	—	—	0.01	0.04	—	0.03	—	—
minnows (Cyprinidae)	—	—	0.05	—	—	—	—	0.02	—	—	1.00	—
catfish (Ictaluridae)	—	—	—	—	0.05	0.03	0.02	0.01	—	—	—	—
salmon and trout (Salmonidae)	—	—	0.09	0.54	0.02	0.04	0.05	0.07	0.26	0.27	—	—
Sand Roller (Percopsidae)	—	—	—	—	—	—	0.05	0.26	—	—	—	—
sunfishes (Centrarchidae)	—	—	0.09	0.08	0.02	0.03	0.02	0.03	—	0.03	—	—
sculpins (Cottidae)	—	—	—	—	0.06	0.03	0.02	0.01	0.04	—	—	—
unidentified non-salmonidae	—	—	—	—	0.07	0.03	0.05	0.05	—	—	—	—
unidentified	0.50	—	0.05	—	0.07	0.04	0.07	0.20	0.04	0.03	—	—

Note: Multiple fish taxa may be represented in the diet samples of some individual fish. Sample sizes (*n*) listed below each reservoir, dashes (—) = fish family not present in diets.

Table 11. Annual consumption index values for Smallmouth Bass (≥ 200 mm FL) captured during biological evaluation in the lower Snake River reservoirs by season, 1991–2019. Mean and SE were calculated for each location across the time series. FB = forebay, Mid = mid-reservoir, TR = tailrace, and Rkm = river kilometer.

Season,	Ice Harbor			Lower Monumental			Little Goose			Lower Granite
Year	FB	Mid	TR	FB	Mid	TR	FB	Mid	TR	Rkm 222-228
Spring										
1991	0.00	0.01	0.00	0.08	0.00	0.00	0.03	0.01	0.02	0.11
1994	—	—	—	—	—	0.07	—	—	0.09	0.17
1995	—	—	—	—	—	0.00	—	—	0.00	0.08
1996	—	—	—	—	—	0.00	—	—	0.02	0.02
1999	—	—	—	—	—	0.01	—	—	0.02	0.06
2004	—	—	—	—	—	*a*	—	—	*a*	0.10
2007	0.07	0.04	0.01	0.07	0.04	0.03	0.08	0.07	0.00	0.08
2010	0.05	0.00	0.03	0.08	0.01	0.01	0.03	0.02	0.00	0.14
2013	0.00	0.03	0.05	0.05	0.04	0.02	0.08	0.10	0.05	0.09
2016	0.04	0.04	0.04	0.13	0.09	0.00	0.08	0.18	0.00	0.08
2019	0.00	0.00	0.04	0.04	0.04	0.02	0.05	0.14	0.10	0.08
mean (SE)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)
Summer										
1991	—	—	—	—	—	—	—	—	—	—
1994	—	—	—	—	—	*a*	—	—	*a*	—
1995	—	—	—	—	—	0.00	—	—	0.00	0.00
1996	—	—	—	—	—	0.00	—	—	0.00	0.00
1999	—	—	—	—	—	—	—	—	*a*	*a*
2004	—	—	—	—	—	*a*	—	—	*a*	0.08
2007	0.05	0.05	0.01	0.00	0.00	0.00	0.05	0.00	0.12	0.19
2010	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.05	0.05	0.11
2013	—	—	—	—	0.06	0.00	—	0.08	0.00	0.20
2014	0.00	*a*	0.00	—	—	—	—	—	—	—
2016	—	—	—	—	0.00	0.00	0.06	0.00	0.00	0.00
2019	0.04	0.00	0.03	0.15	0.00	0.03	0.06	0.07	0.07	0.11
mean (SE)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)

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

Table 12. Annual predation index values for Smallmouth Bass (≥ 200 mm FL) captured during biological evaluation in the lower Snake River reservoirs by season, 1991–2019. Mean and SE were calculated for each location across the time series. FB = forebay, Mid = mid-reservoir, TR = tailrace, and Rkm = river kilometer.

Season,	Ice Harbor			Lower Monumental			Little Goose			Lower Granite
Year	FB	Mid	TR	FB	Mid	TR	FB	Mid	TR	Rkm 222-228
Spring										
1991	0.00	0.11	0.00	0.12	0.00	0.00	0.10	0.12	0.02	0.08
1994	—	—	—	—	—	0.11	—	—	0.19	0.80
1995	—	—	—	—	—	0.00	—	—	0.00	0.13
1996	—	—	—	—	—	0.00	—	—	0.02	0.03
1999	—	—	—	—	—	0.04	—	—	0.02	0.09
2004	—	—	—	—	—	*a*	—	—	*a*	0.15
2007	0.12	0.26	0.04	0.19	0.21	0.16	0.54	0.42	0.00	0.30
2010	0.05	0.00	0.10	0.13	0.06	0.06	0.09	0.23	0.00	0.19
2013	0.00	0.12	0.13	0.09	0.23	0.19	0.39	1.55	0.04	0.58
2016	0.22	0.59	0.24	0.59	1.04	0.00	0.32	2.34	0.00	0.35
2019	0.00	0.00	0.14	0.11	0.33	0.26	0.36	0.74	0.03	0.70
mean (SE)	0.1 (0.0)	0.2 (0.1)	0.1 (0.0)	0.2 (0.1)	0.3 (0.2)	0.1 (0.0)	0.3 (0.1)	0.9 (0.4)	0.0 (0.0)	0.3 (0.1)
Summer										
1991	—	—	—	—	—	—	—	—	—	—
1994	—	—	—	—	—	*a*	—	—	*a*	—
1995	—	—	—	—	—	0.00	—	—	0.00	0.00
1996	—	—	—	—	—	0.00	—	—	0.00	0.00
1999	—	—	—	—	—	—	—	—	*a*	*a*
2004	—	—	—	—	—	*a*	—	—	*a*	0.16
2007	0.25	0.56	0.04	0.00	0.00	0.00	0.32	0.00	0.05	0.53
2010	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.59	0.03	0.36
2013	—	—	—	—	0.43	0.00	—	2.01	0.00	0.88
2014	0.00	*a*	0.00	—	—	—	—	—	—	—
2016	—	—	—	—	0.00	0.00	0.84	0.00	0.00	0.00
2019	0.18	0.00	0.14	0.65	0.00	0.31	0.71	1.57	0.06	0.40
mean (SE)	0.1 (0.1)	0.2 (0.2)	0.0 (0.0)	0.2 (0.2)	0.1 (0.1)	0.0 (0.0)	0.5 (0.2)	0.8 (0.4)	0.0 (0.0)	0.3 (0.1)

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

Table 13. Number of stock-length (n_s) Walleye opportunistically sampled during fisheries evaluation, proportional size distribution (PSD, %), and proportional size distribution of preferred-length fish (PSD – P, %) by location. Mean and SE were calculated for each location across the time series.

	Below Bonneville			Bonneville			The Dalles			John Day			McNary			Ice Harbor		
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
1992	0	*a*	*a*	0	*a*	*a*	0	*a*	*a*	0	*a*	*a*	0	*a*	*a*	0	*a*	*a*
1993	3	*a*	*a*	1	*a*	*a*	14	*a*	*a*	4	*a*	*a*	0	*a*	*a*	—	—	—
1994	1	*a*	*a*	9	*a*	*a*	4	*a*	*a*	11	*a*	*a*	2	*a*	*a*	—	—	—
1995	9	*a*	*a*	17	*a*	*a*	14	*a*	*a*	12	*a*	*a*	11	*a*	*a*	—	—	—
1996	28	62	36	0	*a*	*a*	18	*a*	*a*	26	97	85	17	*a*	*a*	—	—	—
1997	17	*a*	*a*	6	*a*	*a*	93	63	10	23	97	39	15	*a*	*a*	—	—	—
1998	4	*a*	*a*	8	*a*	*a*	23	78	30	18	*a*	*a*	43	96	79	—	—	—
1999	3	*a*	*a*	2	*a*	*a*	16	*a*	*a*	33	68	52	14	*a*	*a*	—	—	—
2000	9	*a*	*a*	1	*a*	*a*	18	*a*	*a*	15	*a*	*a*	24	100	71	—	—	—
2001	13	*a*	*a*	4	*a*	*a*	15	*a*	*a*	19	*a*	*a*	17	*a*	*a*	—	—	—
2002	15	*a*	*a*	2	*a*	*a*	45	90	31	45	60	36	19	*a*	*a*	—	—	—
2003	18	*a*	*a*	2	*a*	*a*	31	73	19	129	73	16	36	84	58	—	—	—
2004	6	*a*	*a*	3	*a*	*a*	2	*a*	*a*	22	70	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	—	—	—
2007	0	*a*	*a*	1	*a*	*a*	22	64	45	50	82	32	33	100	88	—	—	—
2008	10	*a*	*a*	2	*a*	*a*	29	69	17	49	58	20	73	59	52	—	—	—
2009	6	*a*	*a*	11	*a*	*a*	11	*a*	*a*	48	52	23	20	95	50	—	—	—
2010	20	75	0	2	*a*	*a*	15	*a*	*a*	37	32	5	68	71	47	—	—	—
2011	14	*a*	*a*	29	83	17	68	57	6	171	51	6	90	83	50	—	—	—
2012	6	*a*	*a*	21	100	24	47	49	9	53	81	9	98	66	55	—	—	—
2013	2	*a*	*a*	1	*a*	*a*	9	*a*	*a*	85	55	29	101	75	59	—	—	—
2014	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2015	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2016	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2017	4	*a*	*a*	131	79	2	276	45	3	214	24	10	243	66	32	31	52	16
2018	11	*a*	*a*	59	88	29	121	85	13	164	85	26	343	83	40	74	81	12
2019	15	*a*	*a*	48	94	73	133	68	28	41	80	56	89	84	63	20	70	15
mean (SE)	9 (1)	*b*	*b*	15 (6)	89 (4)	29 (12)	44 (12)	71 (4)	22 (4)	57 (11)	65 (5)	28 (5)	58 (16)	84 (4)	62 (5)	31 (16)	68 (9)	14 (1)

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

Table 14. Number of stock-length (n_s) Walleye, proportional size distribution (PSD, %), and proportional size distribution of preferred-length fish (PSD – P, %) collected during biological evaluation in the lower Snake River reservoirs, 1991–2019. Mean and SE were calculated across the time series.

	Ice Harbor			Lower Monumental			Little Goose			Lower Granite		
Year	n_s	PSD (%)	PSD – P (%)	n_s	PSD (%)	PSD – P (%)	n_s	PSD (%)	PSD – P (%)	n_s	PSD (%)	PSD – P (%)
1991	0	*a*	*a*	0	*a*	*a*	0	*a*	*a*	0	*a*	*a*
1994	—	—	—	0	*a*	*a*	0	*a*	*a*	0	*a*	*a*
1995	—	—	—	0	*a*	*a*	0	*a*	*a*	0	*a*	*a*
1996	—	—	—	0	*a*	*a*	0	*a*	*a*	0	*a*	*a*
1999	—	—	—	1	*a*	*a*	0	*a*	*a*	0	*a*	*a*
2004	—	—	—	0	*a*	*a*	0	*a*	*a*	0	*a*	*a*
2007	0	*a*	*a*	31	35	6	0	*a*	*a*	0	*a*	*a*
2010	0	*a*	*a*	6	*a*	*a*	0	*a*	*a*	0	*a*	*a*
2013	0	*a*	*a*	15	*a*	*a*	0	*a*	*a*	0	*a*	*a*
2014	1	*a*	*a*	—	—	—	—	—	—	—	—	—
2016	4	*a*	*a*	9	*a*	*a*	2	*a*	*a*	0	*a*	*a*
2019	26	100	42	16	*a*	*a*	1	*a*	*a*	0	*a*	*a*
mean (SE)	4 (4)	*b*	*b*	7 (3)	*b*	*b*	0 (0)	*b*	*b*	0 (0)	*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 15. Number of stock-length (n_s) Smallmouth Bass, proportional size distribution (PSD, %), and proportional size distribution of preferred-length fish (PSD – P, %) collected during biological evaluation in the lower Snake River reservoirs, 1991–2019. Mean and SE were calculated across the time series.

	Ice Harbor			Lower Monumental			Little Goose			Lower Granite		
Year	n_s	PSD (%)	PSD – P (%)	n_s	PSD (%)	PSD – P (%)	n_s	PSD (%)	PSD – P (%)	n_s	PSD (%)	PSD – P (%)
1991	348	27	4	297	24	4	391	28	5	157	13	5
1994	—	—	—	90	16	2	95	8	1	269	14	4
1995	—	—	—	39	18	3	85	19	6	178	26	9
1996	—	—	—	26	15	0	50	22	4	111	34	13
1999	—	—	—	35	69	3	30	70	0	71	44	7
2004	—	—	—	191	20	2	17	*a*	*a*	152	25	3
2007	414	21	6	427	18	3	315	30	8	374	20	4
2010	335	22	4	572	10	1	214	24	7	245	29	11
2013	156	34	4	588	27	1	277	30	6	427	15	4
2014	50	58	16	—	—	—	—	—	—	—	—	—
2016	330	14	3	946	9	1	454	26	6	211	9	1
2019	362	28	3	596	22	1	379	14	1	403	13	4
mean (SE)	285 (50)	29 (5)	6 (2)	346 (92)	23 (5)	2 (0)	210 (49)	27 (5)	4 (1)	236 (36)	22 (3)	6 (1)

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

Table 16. Number (n) of Northern Pikeminnow diets examined from Dam Angling Fishery catch from Bonneville (tailraces of The Dalles Dam) and The Dalles (tailrace of John Day Dams) reservoirs and proportions containing specific prey items (cray = crayfish, other invert = all invertebrates not identified as crayfish, sal = salmon or steelhead, lam = lamprey, ash = American Shad).

Reservoir, Year	n	$\hat{p}_{food}$	$\hat{p}_{fish}$	$\hat{p}_{cray}$	$\hat{p}_{other\ invert}$	$\hat{p}_{sal}$	$\hat{p}_{lam}$	$\hat{p}_{ash}$	$\hat{p}_{other\ fishes}$
Bonneville,									
2006	129	0.36	0.21	0.08	0.04	0.04	0.17	0.00	0.05
2007	340	0.61	0.40	0.04	0.22	0.13	0.31	0.00	0.06
2008	209	0.63	0.44	0.04	0.33	0.11	0.31	0.00	0.12
2009	223	0.70	0.64	0.06	0.19	0.09	0.50	0.01	0.14
2010	395	0.62	0.49	0.06	0.14	0.16	0.18	0.15	0.18
2011	329	0.66	0.44	0.07	0.19	0.36	0.09	0.00	0.08
2012	275	0.77	0.57	0.09	0.19	0.15	0.18	0.00	0.00
2013	216	0.77	0.43	0.12	0.34	0.17	0.22	0.04	0.06
2014	489	0.58	0.46	0.07	0.13	0.19	0.47	0.19	0.42
2015	474	0.75	0.53	0.13	0.29	0.07	0.53	0.21	0.15
2016	463	0.73	0.37	0.03	0.44	0.07	0.14	0.13	0.08
2017	415	0.76	0.53	0.03	0.35	0.14	0.18	0.17	0.14
2018	346	0.72	0.46	0.04	0.36	0.06	0.05	0.29	0.15
2019	383	0.82	0.49	0.03	0.50	0.07	0.24	0.13	0.12
The Dalles,									
2007	453	0.58	0.37	0.02	0.27	0.13	0.08	0.11	0.21
2008	64	0.81	0.36	0.03	0.69	0.09	0.23	0.00	0.08
2009	224	0.61	0.56	0.08	0.31	0.11	0.40	0.00	0.14
2010	382	0.55	0.29	0.07	0.34	0.16	0.10	0.02	0.07
2011	283	0.70	0.22	0.06	0.56	0.15	0.07	0.00	0.02
2012	479	0.77	0.39	0.13	0.48	0.15	0.12	0.04	0.00
2013	447	0.78	0.47	0.22	0.34	0.23	0.16	0.09	0.05
2014	363	0.72	0.44	0.31	0.27	0.18	0.46	0.14	0.36
2015	337	0.79	0.45	0.24	0.37	0.14	0.45	0.12	0.16
2016	426	0.73	0.31	0.04	0.57	0.14	0.04	0.06	0.07
2017	329	0.61	0.30	0.05	0.48	0.11	0.07	0.09	0.08
2018	473	0.75	0.30	0.04	0.57	0.13	0.09	0.06	0.04
2019	410	0.77	0.38	0.06	0.54	0.14	0.16	0.06	0.06

FIGURES

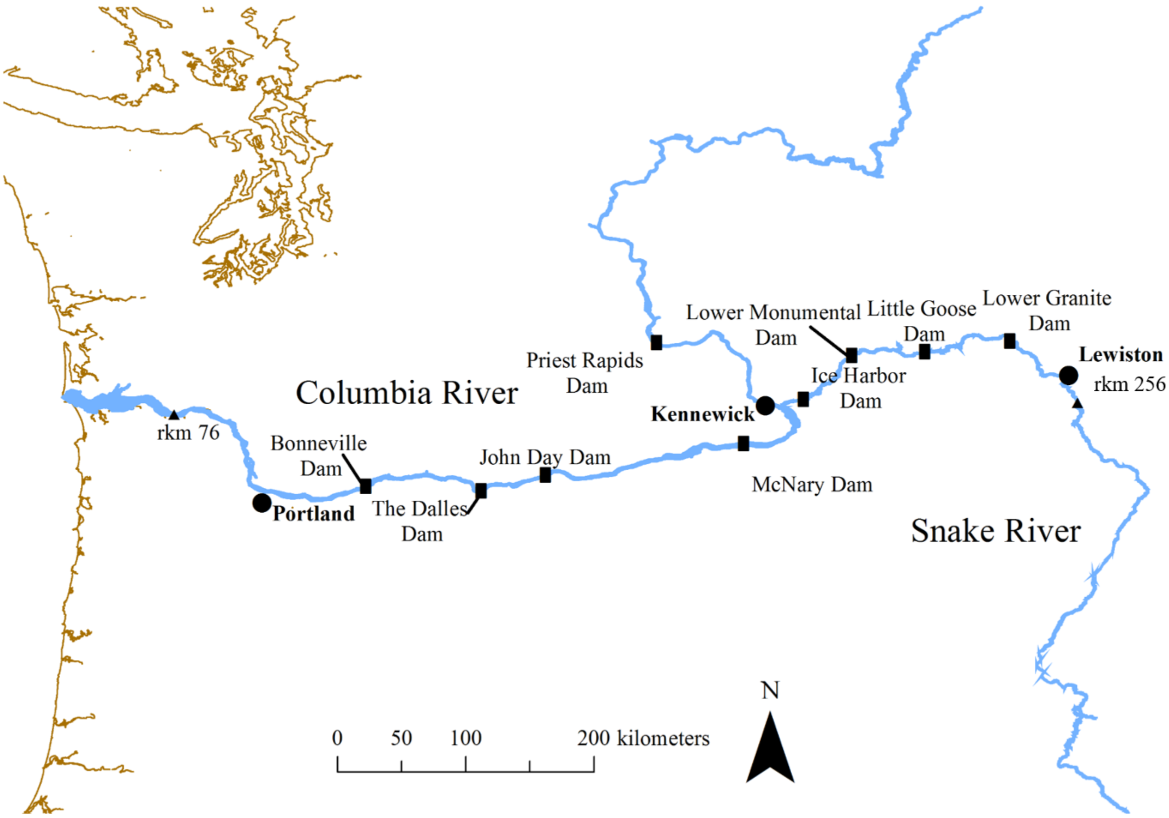

Figure 1. Study area in the Columbia and Snake rivers.

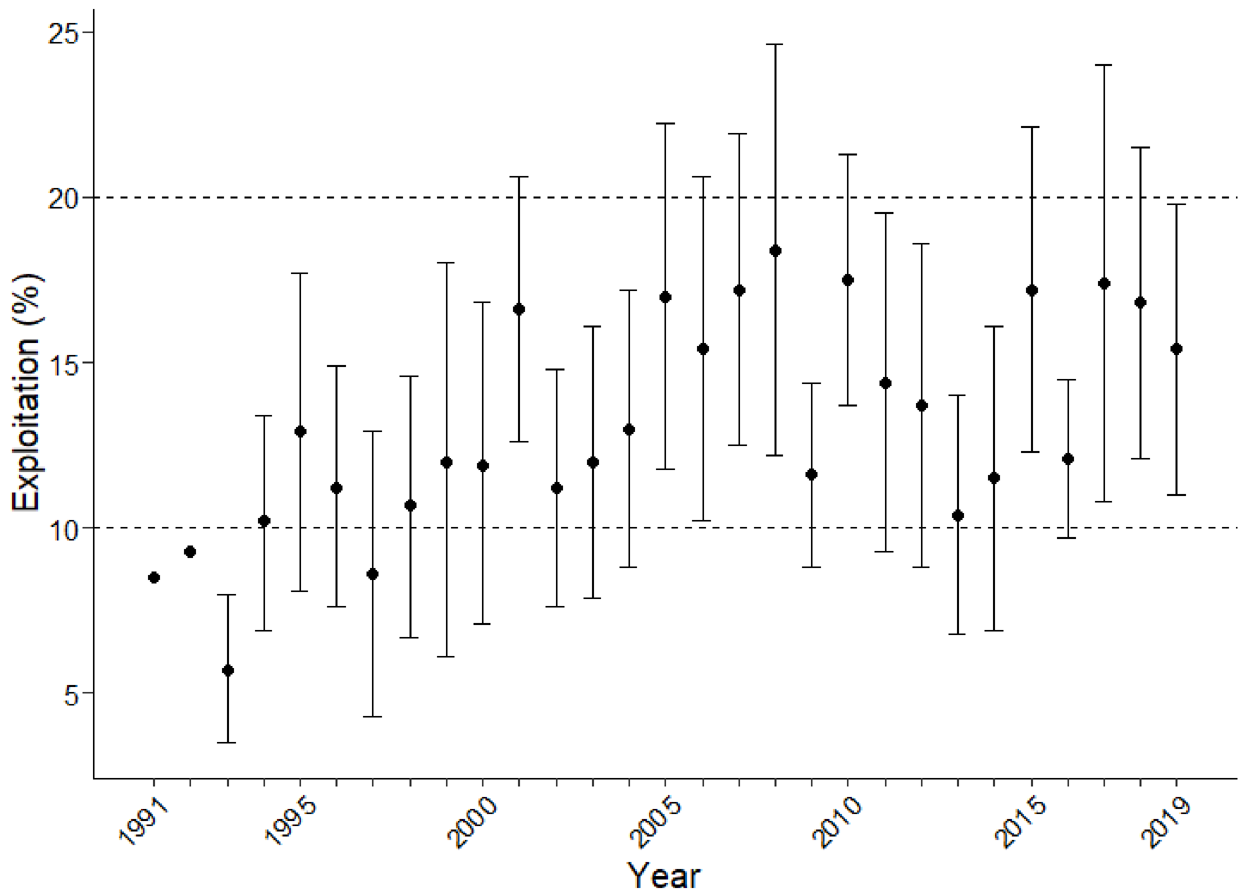

Figure 2. System-wide exploitation rates of Northern Pikeminnow (≥ 250 mm FL) in the Sport Reward Fishery, 1991–2019. Error bars represent 95% confidence intervals, though variation was not estimated for the years 1991–1992. Target exploitation is 10–20% (dashed lines).

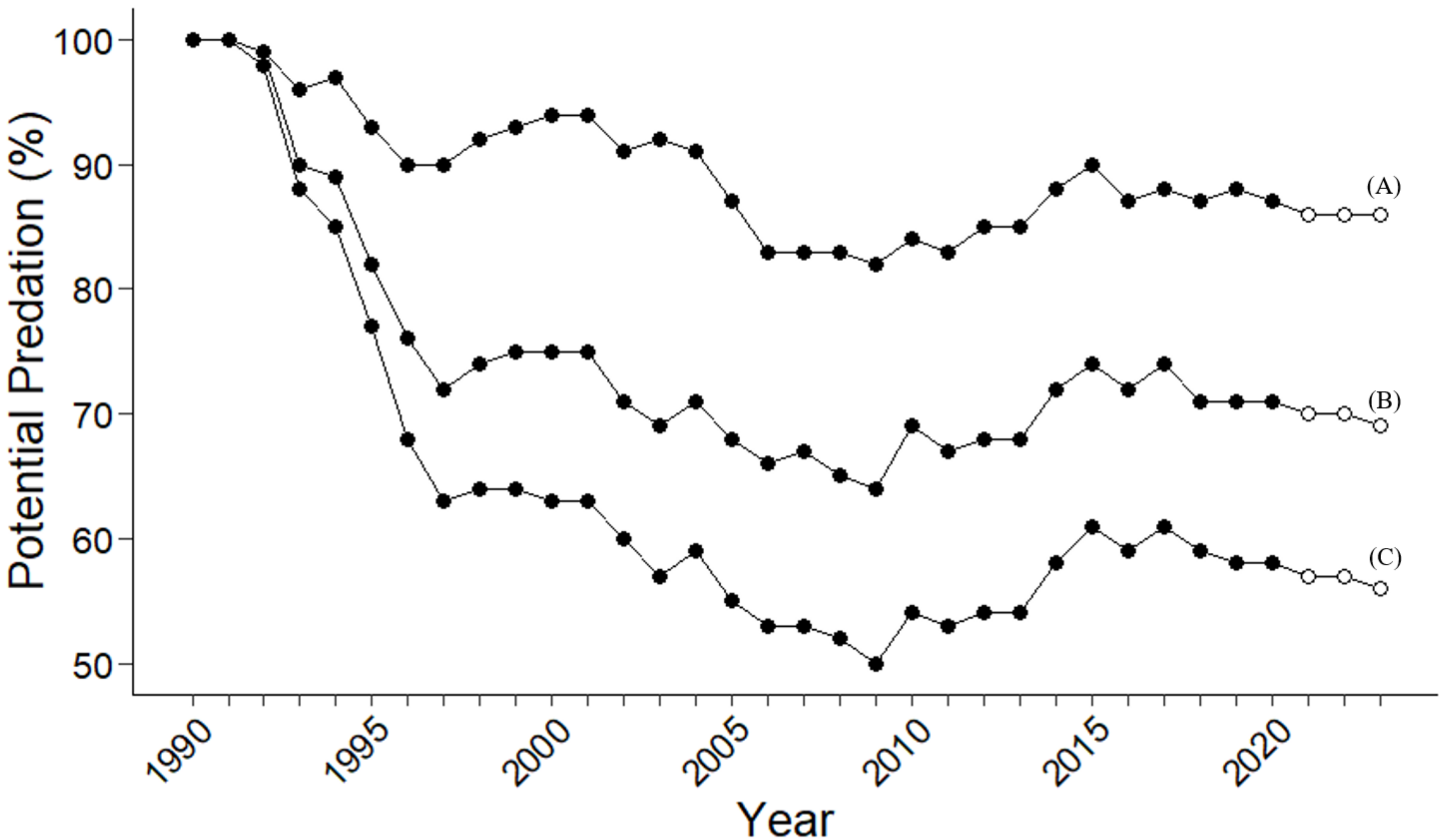

Figure 3. Estimates of (A) maximum, (B) median, and (C) minimum annual levels of potential predation by Northern Pikeminnow on juvenile salmon relative to predation levels before implementation of the Northern Pikeminnow Management Program. For the years 1991–2020, model estimates (filled circles) are based on exploitation rates from the previous year. Model forecast predictions after 2020 (open circles) are based on average exploitation estimates from years with similar fishery structure (2001, 2004–2019).

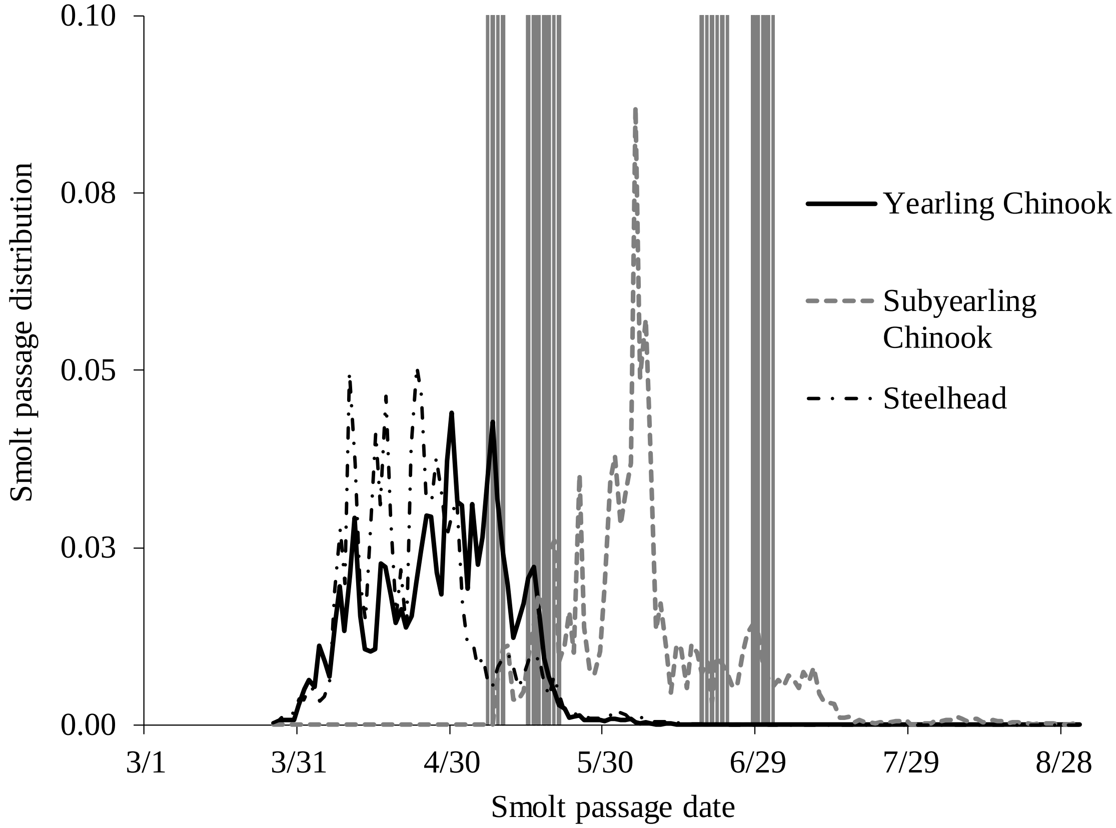

Figure 4. Periods of biological evaluation (vertical bars) in the lower Snake River reservoirs and juvenile salmon and steelhead daily passage frequency through Lower Granite Dam, March–August 2019 (Source: Fish Passage Center, unpublished data).

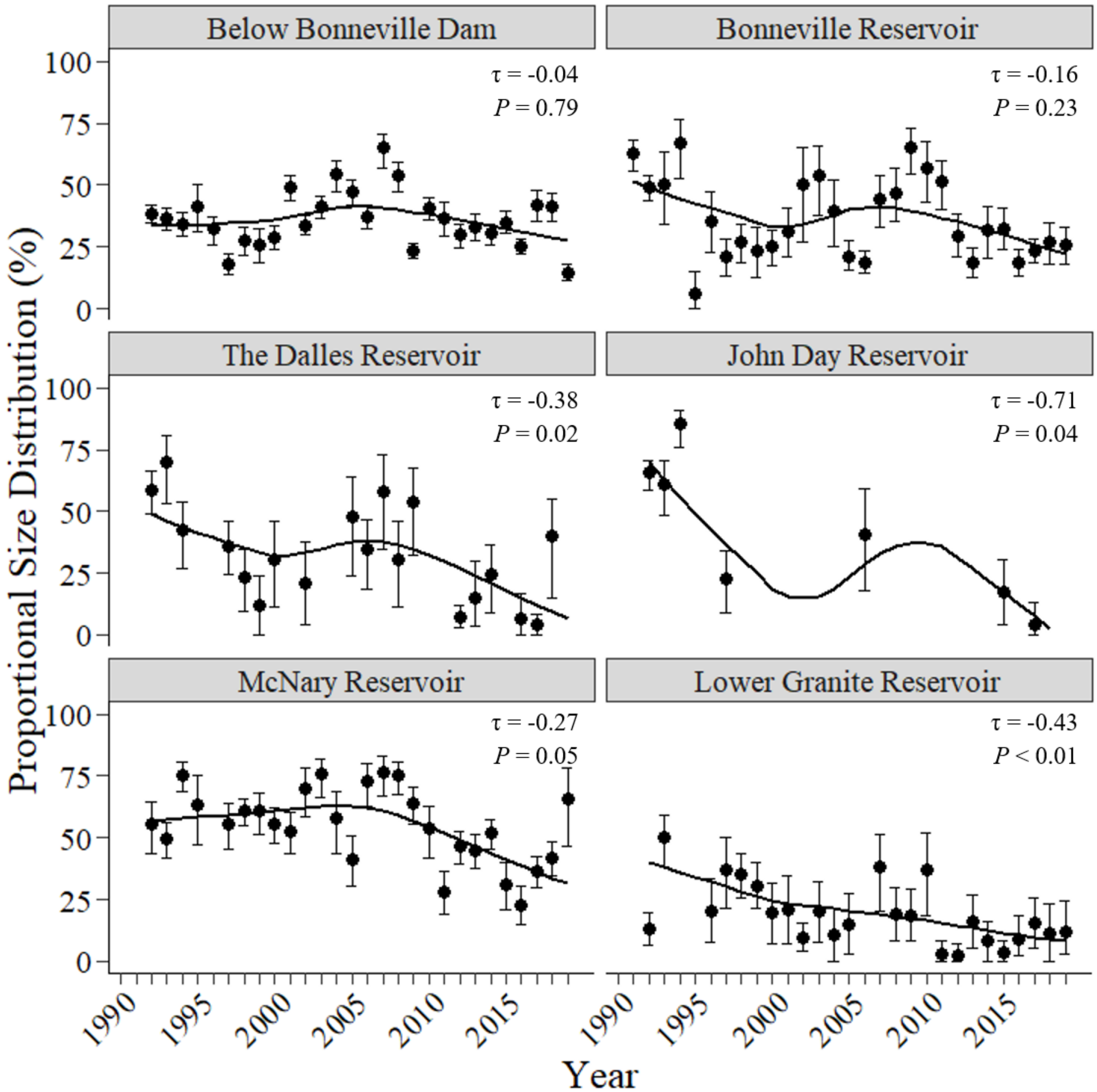

Figure 5. Estimates of proportional size distribution (PSD, %) for Northern Pikeminnow collected during fishery evaluation in the Columbia and lower Snake rivers, 1991–2019. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years without data indicate sample sizes were insufficient for analysis ($n_s \leq 19$).

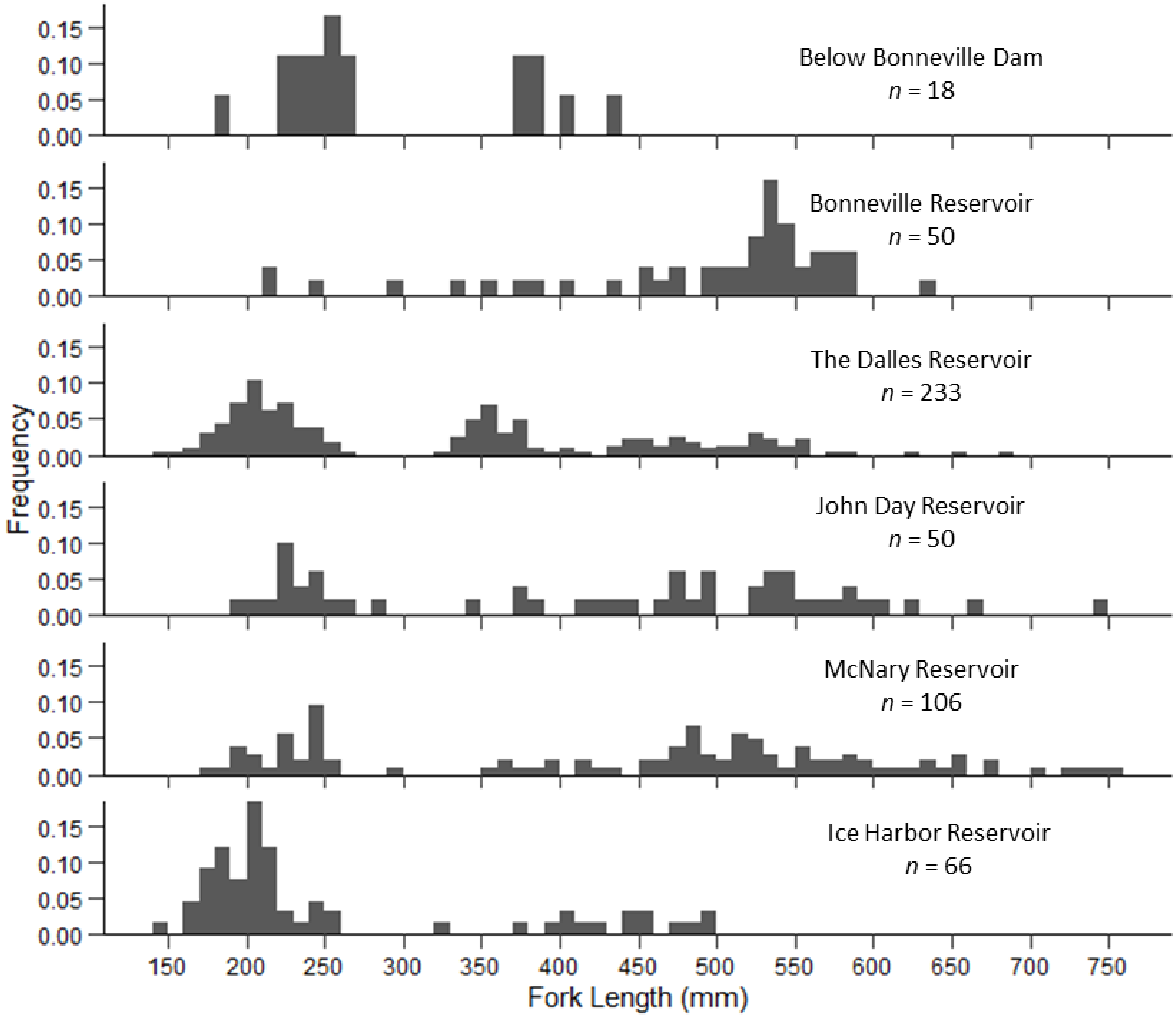

Figure 6. Length-frequency histogram of Walleye observed opportunistically during fishery evaluation in the Columbia and lower Snake River reservoirs in 2019. Fork length size bins are 10 mm.

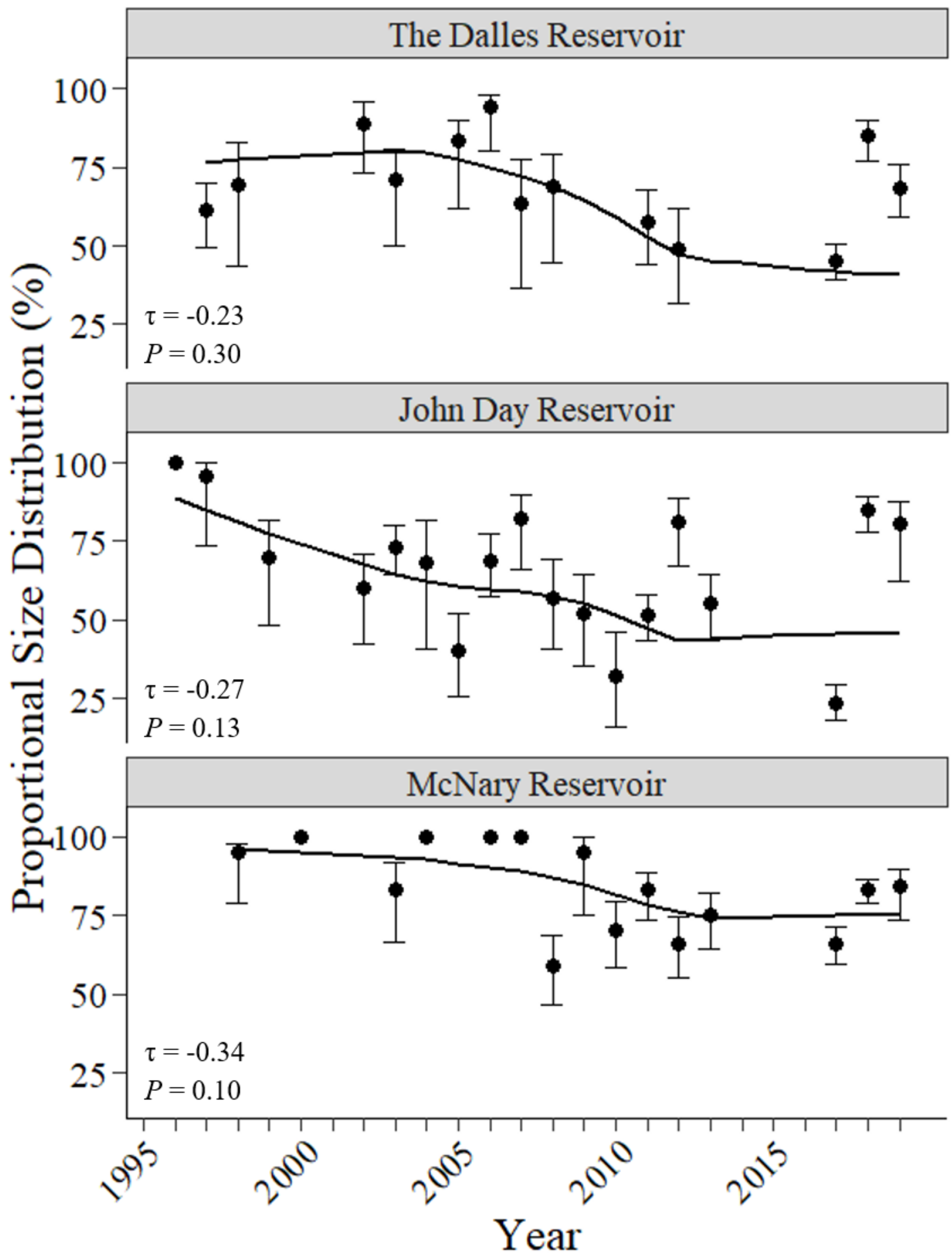

Figure 7. Estimates of proportional size distribution (PSD, %) of Walleye collected during fishery evaluation in The Dalles, John Day, and McNary reservoirs, 1996–2019. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years without data indicate no sampling or sample sizes were insufficient for analysis ($n_s \leq 19$).

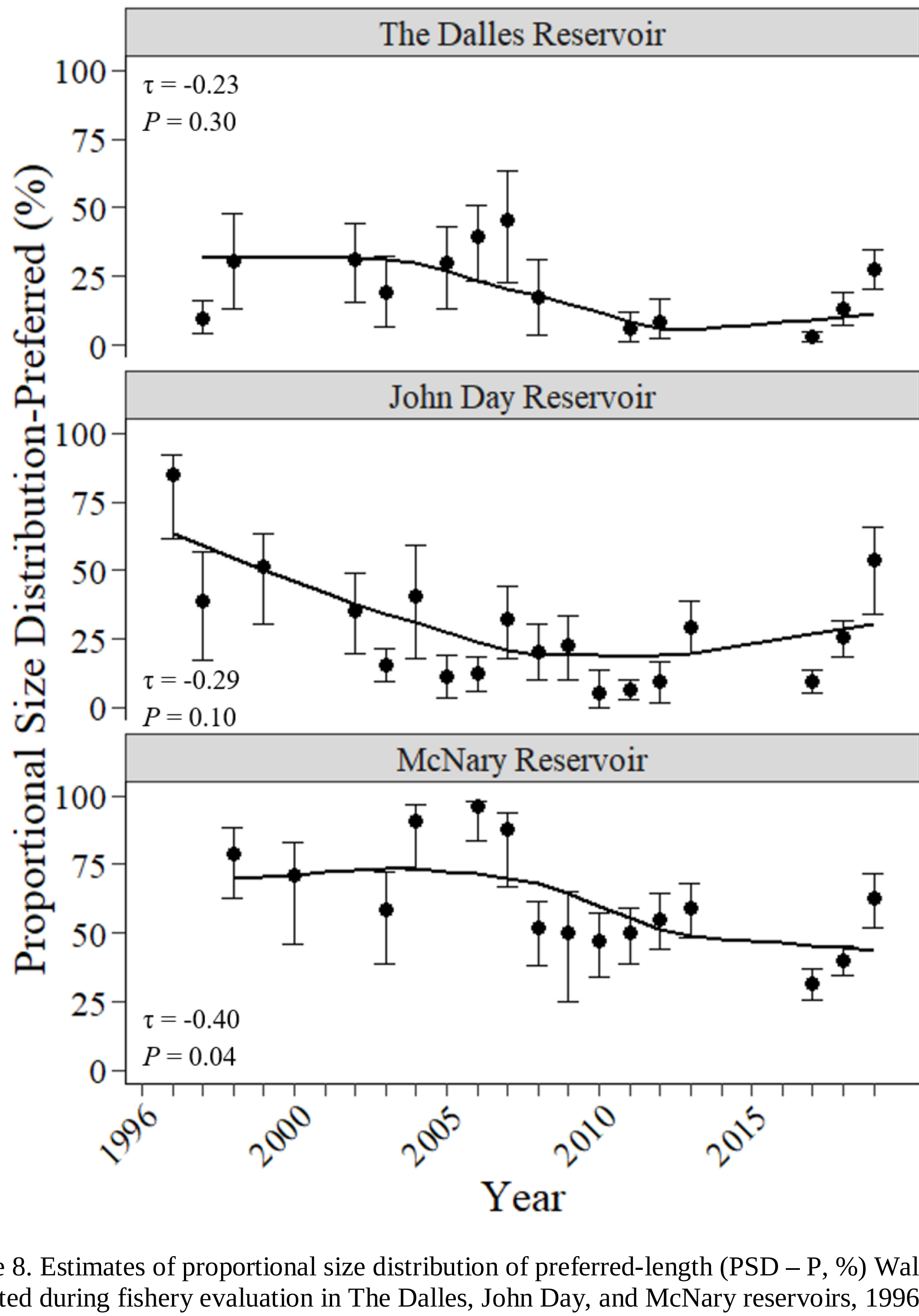

Figure 8. Estimates of proportional size distribution of preferred-length (PSD – P, %) Walleye collected during fishery evaluation in The Dalles, John Day, and McNary reservoirs, 1996–2019. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years without data indicate no sampling or sample sizes were insufficient for analysis ($n_s \leq 19$).

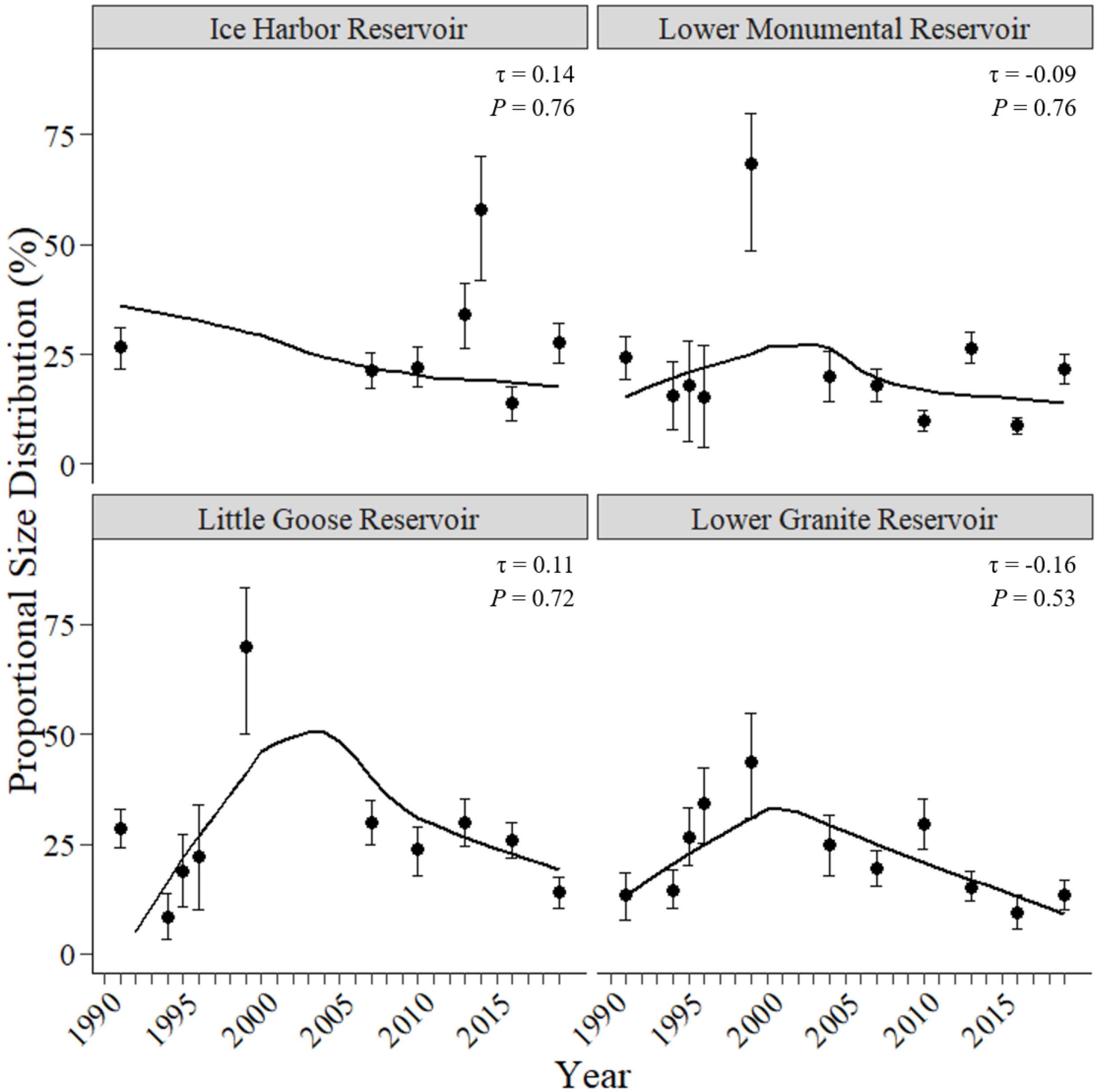

Figure 9. Estimates of proportional size distribution (PSD, %) of Smallmouth Bass collected during biological evaluation in Ice Harbor, Lower Monumental, Little Goose, and Lower Granite reservoirs, 1991–2019. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years without data indicate sampling was not conducted or sample sizes were insufficient for analysis ($n_s \leq 19$).

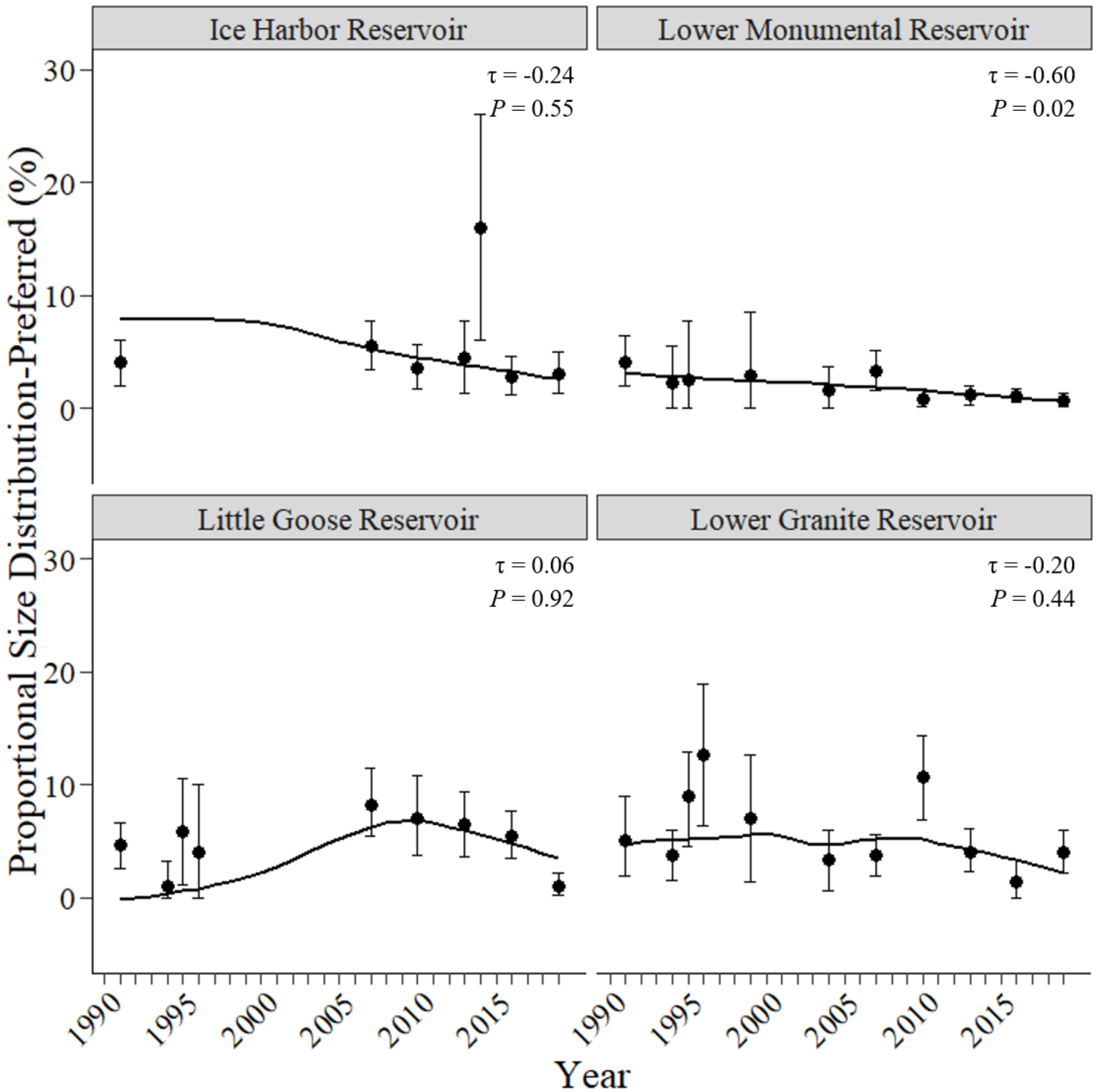

Figure 10. Estimates of proportional size distribution of preferred-length (PSD – P, %) Smallmouth Bass collected during biological evaluation in Ice Harbor, Lower Monumental, Little Goose, and Lower Granite reservoirs, 1991–2019. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years without data indicate sampling was not conducted or sample sizes were insufficient for analysis ($n_s \leq 19$).

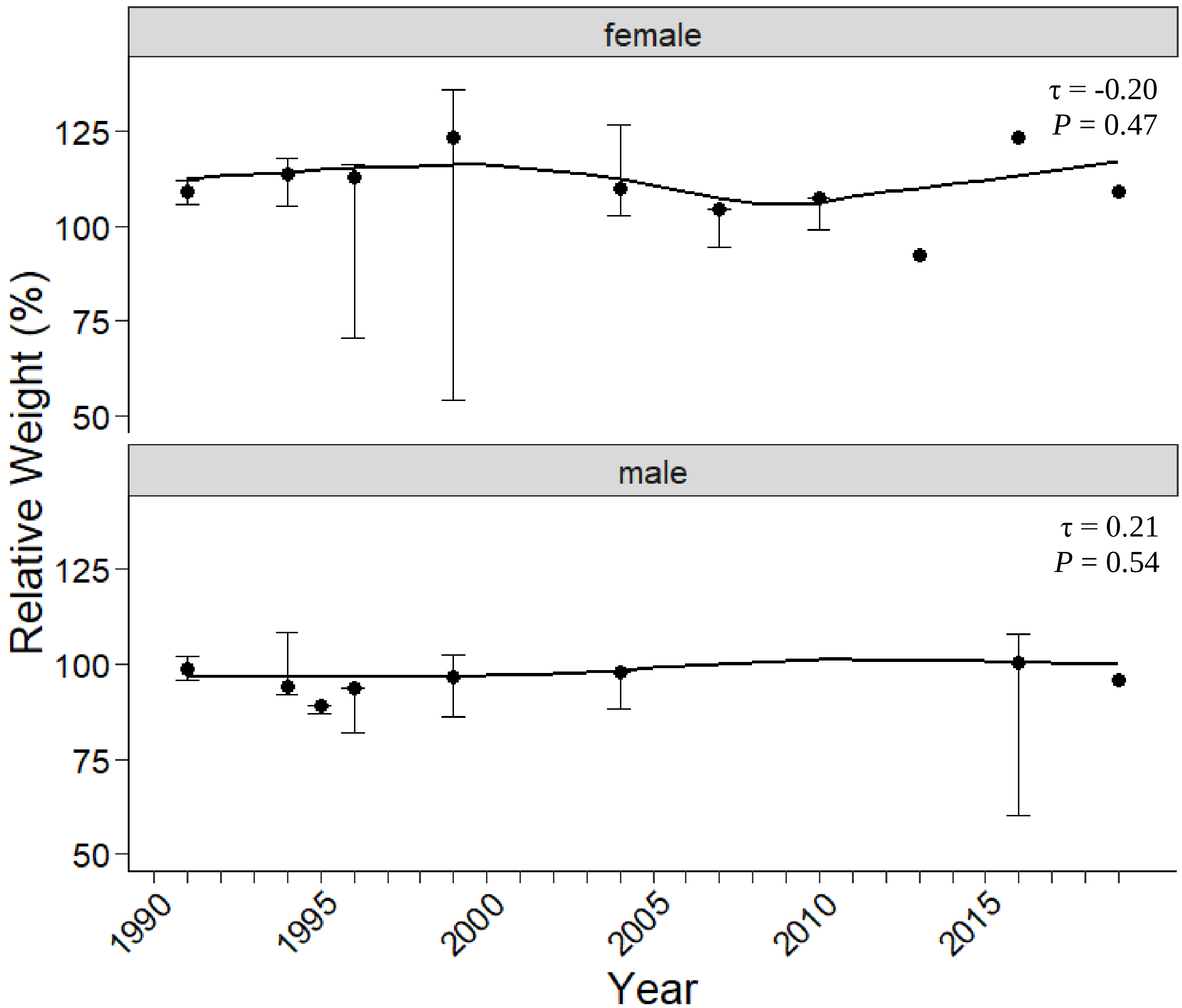

Figure 11. Median relative weight (W_r, %) of female and male Northern Pikeminnow collected during biological evaluation in Little Goose Reservoir, 1991–2019. Error bars represent 95% bootstrap (percentile) confidence intervals. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years without data indicate that sampling was not conducted or no fish were collected. Years without error bars indicate that only one fish was collected and confidence intervals were not calculated.

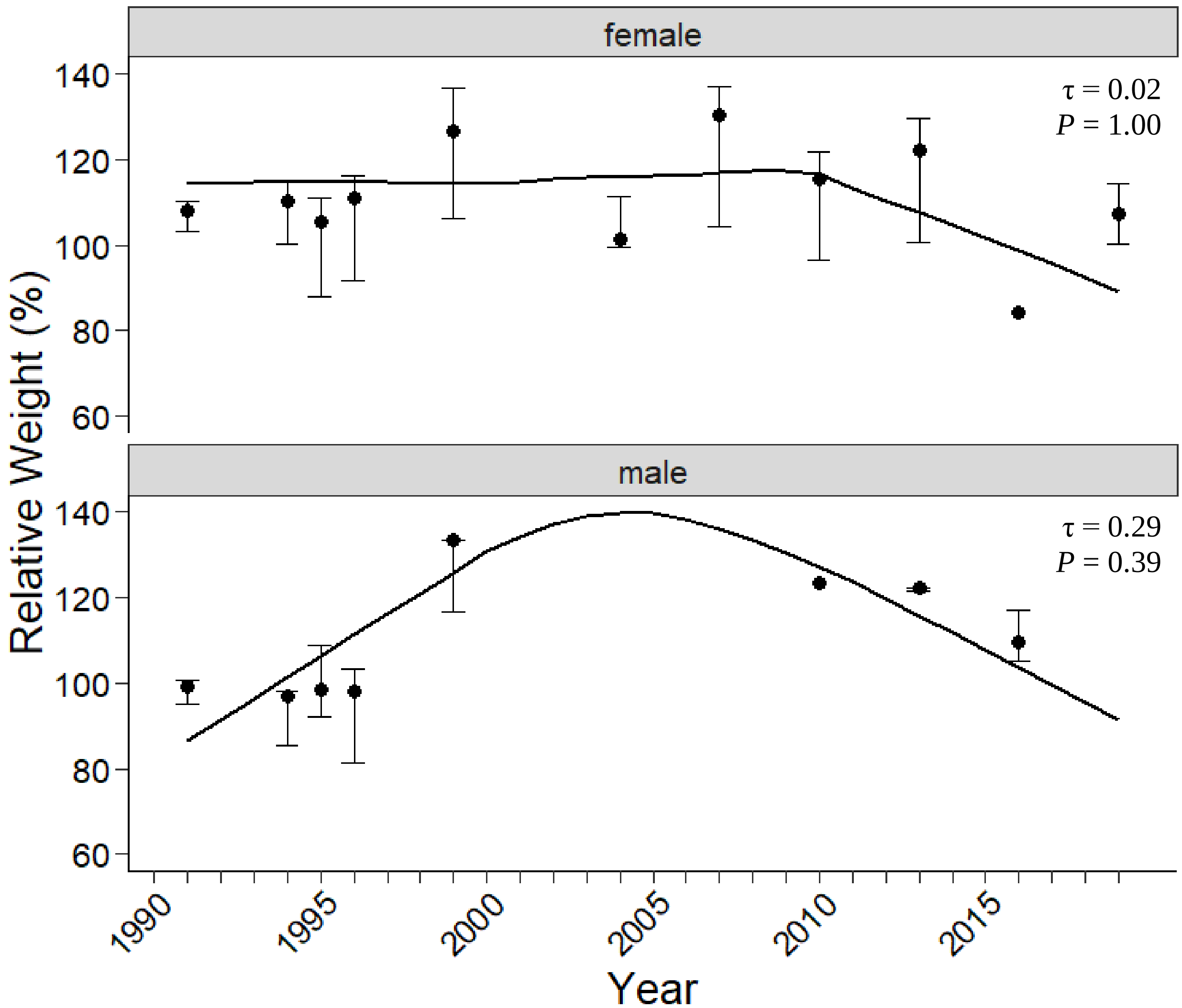

Figure 12. Median relative weight (W_r, %) of female and male Northern Pikeminnow collected during biological evaluation in Lower Granite Reservoir, 1991–2019. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years without data indicate that sampling was not conducted or no fish were collected. Years without error bars indicate that only one fish was collected and confidence intervals were not calculated.

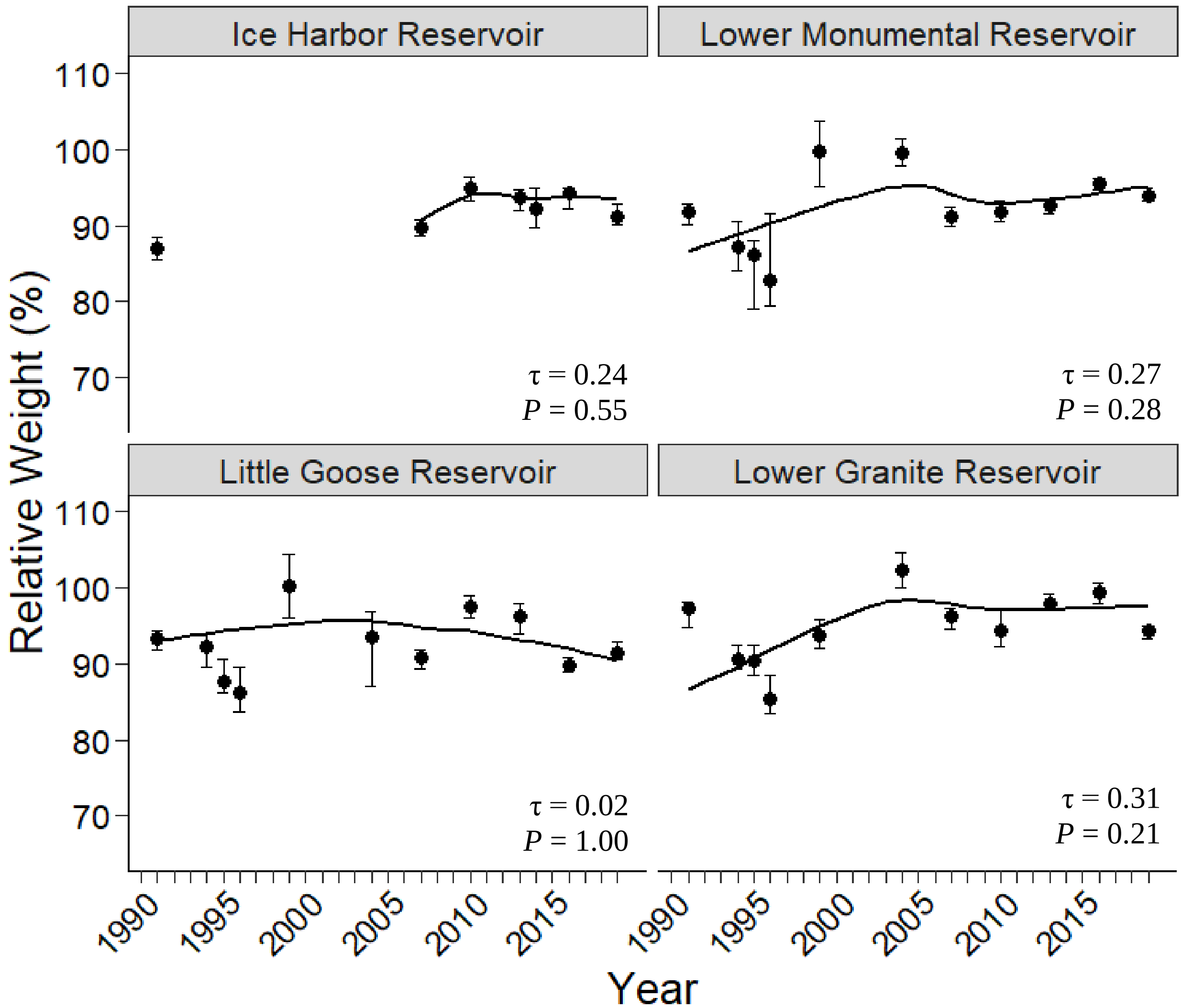

Figure 13. Median relative weight (W_r, %) of Smallmouth Bass collected during biological evaluation in the lower Snake River reservoirs, 1991–2019. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. In Ice Harbor Reservoir, only data from 2007-2019 are used for the curve as a large gap in data prohibited fitting the entire dataset with a LOWESS curve. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years without data indicate that sampling was not conducted or no fish were collected.

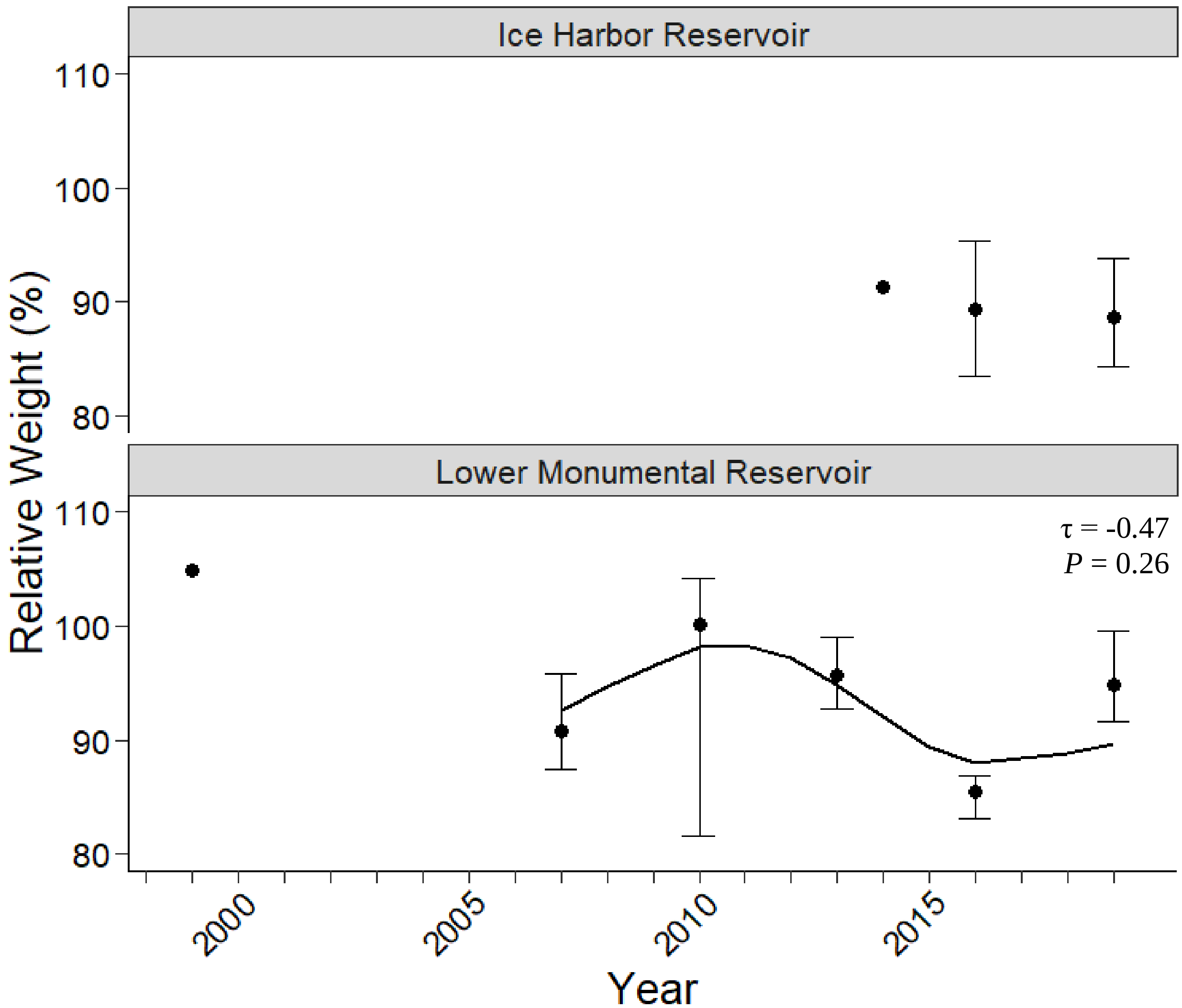

Figure 14. Median relative weight (W_r, %) of Walleye collected during biological evaluation in Ice Harbor and Lower Monumental reservoirs, 1999–2019. Error bars represent 95% bootstrap (percentile) confidence intervals. Data for Lower Monumental Reservoir are fit with a LOWESS curve. Results from a Mann-Kendall test of monotonic trend are presented for Lower Monumental Reservoir. Limited data for Ice Harbor reservoir prohibited further analyses. Years without data indicate that sampling was not conducted or no fish were collected. Years without error bars indicate that only one fish was collected and confidence intervals were not calculated.

Figure 15. Proportion of all Northern Pikeminnow diet samples containing prey fish collected during the Dam Angling Fishery from the powerhouse tailraces of Bonneville (fishing from The Dalles Dam) and The Dalles (fishing from John Day Dam) reservoirs May–August 2019 (statistical week 18–34). Multiple fish groups may be represented in individual Northern Pikeminnow diets.

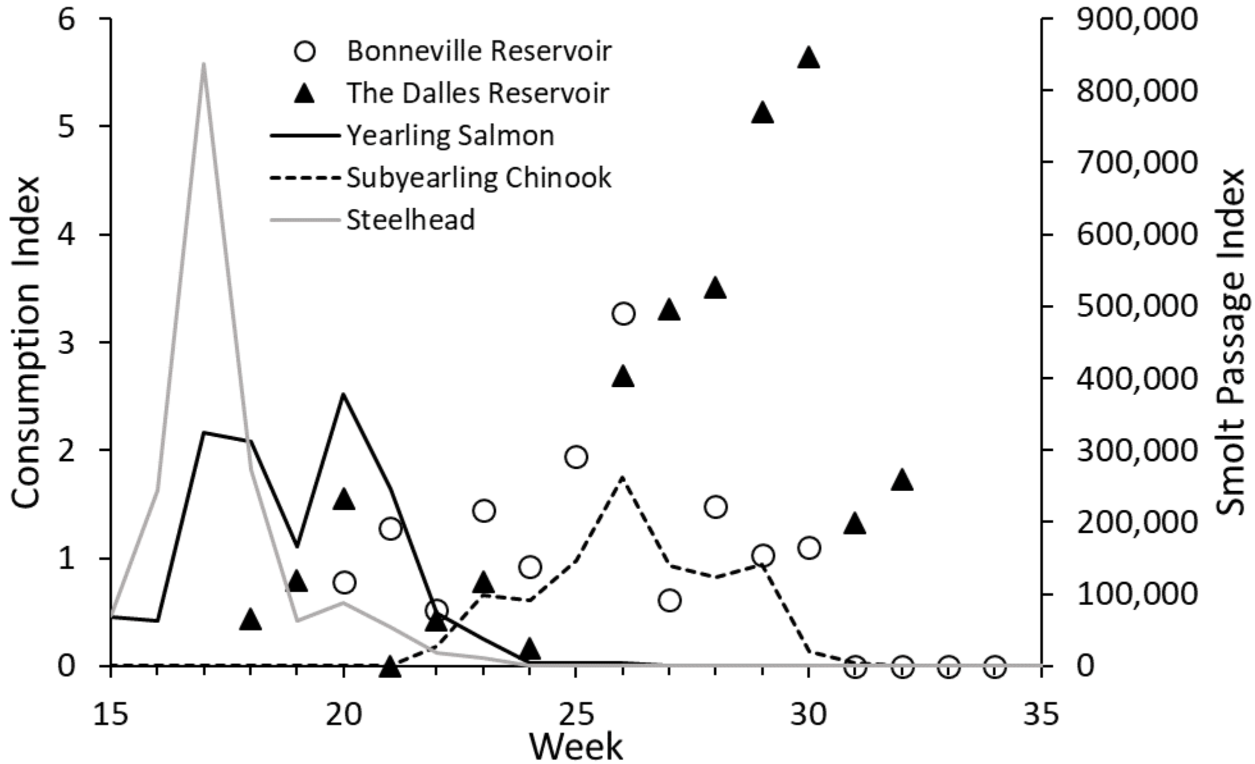

Figure 16. Mean weekly juvenile salmon consumption index for Northern Pikeminnow captured from the Dam Angling Fishery in Bonneville (open circles) and The Dalles (filled triangles) reservoirs compared to the weekly smolt passage index at John Day Dam, 2019. Smolt passage data are summarized from Fish Passage Center (unpublished data).

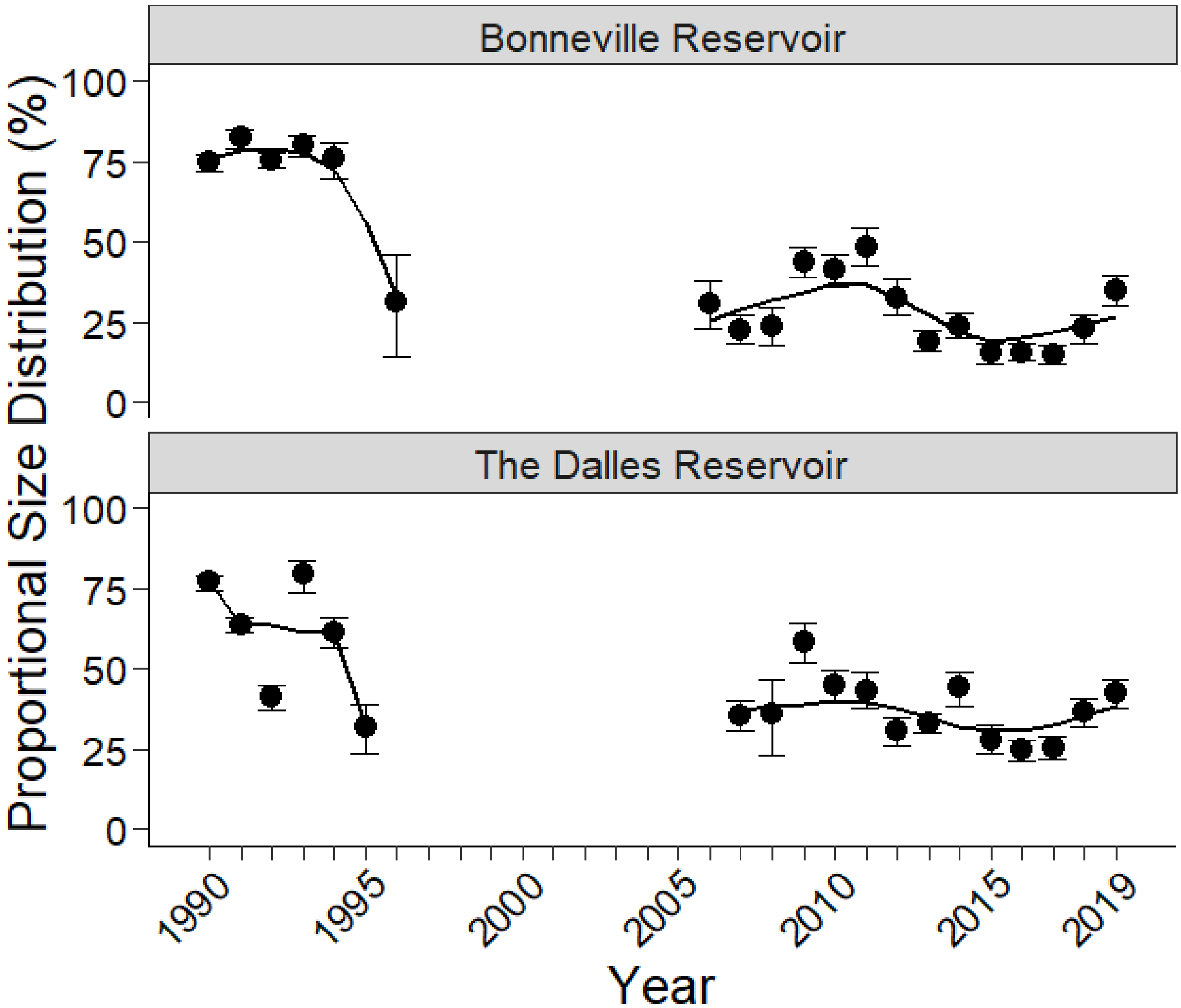

Figure 17. Estimates of proportional size distribution (PSD, %) of Northern Pikeminnow sampled in Bonneville and The Dalles reservoirs during the Dam Angling Fishery, 1990–2019. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves for two different time series: early (1990–1996) and late (2006–2019), due to the large data gap between them. Years without data indicate sampling was not conducted or sample sizes were insufficient for analyses ($n_s \leq 19$).

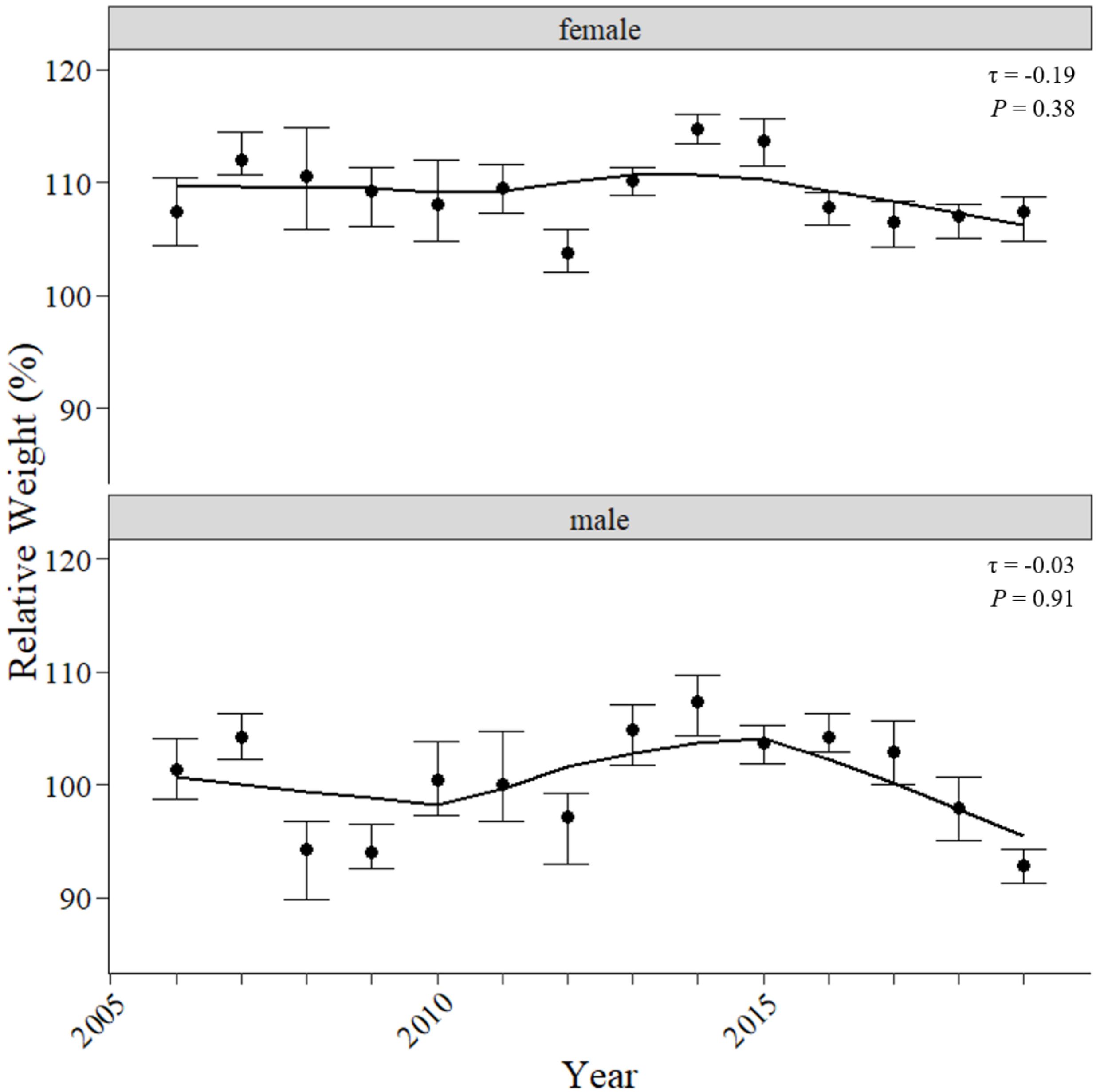

Figure 18. Median relative weight (*Wr*, %) for Northern Pikeminnow collected in Bonneville Reservoir during the Dam Angling Fishery, 2006–2019. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each reservoir.

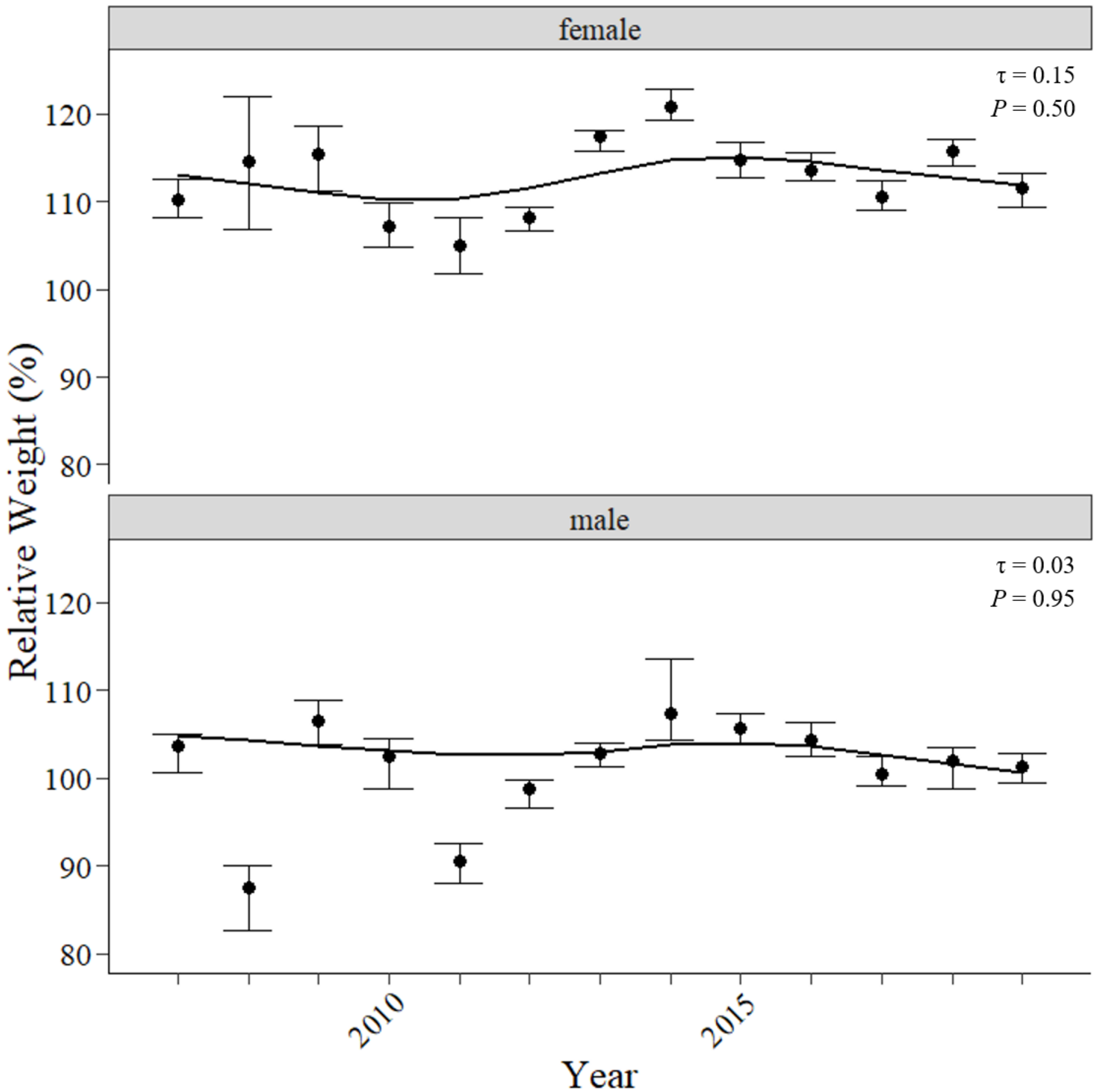

Figure 19. Median relative weight (*Wr*, %) for Northern Pikeminnow collected in The Dalles Reservoir during the Dam Angling Fishery, 2007–2019. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each reservoir.

REPORT D

Northern Pikeminnow Dam Angling on the Columbia River

2019 Annual Report

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Funded by

U. S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
Portland, Oregon 97208-3621

Project No. 1990-077-00
Contract No. 00071866

March 2020

ACKNOWLEDGEMENTS

This project is funded by the Bonneville Power Administration (BPA) as part of the Northern Pikeminnow Management Program (project number 1990-077-00), John Skidmore, Environment, Fish & Wildlife Manager and Eric McOmie and David Roberts as Project COTRs. Steve Williams of Pacific States Marine Fisheries Commission (PSMFC) administered the contract. We would like to thank Tammy Mackey, Erin Kovalchuk, Robert Cordie, Jeffrey Randall, Miroslaw Zyndol and Eric Grosvenor at the US Army Corps of Engineers (USACE), Mac Barr and his staff at the Oregon Department of Fish and Wildlife (ODFW); and Steve Williams and his staff at PSMFC for their assistance and coordination in implementing this project in 2019.

We appreciate the efforts of Scott Mengis as the Pikeminnow Dam Angling crew leader, along with Kyle Beckley, Cole Shirley and John Paul Viviano who served as our 2019 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 2019 season.

ABSTRACT

We are reporting on the 2019 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 22 weeks from May 2nd through September 25th 2019. The objectives of this project 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 Dam Angler CPUE in order to maximize harvest of Northern Pikeminnow, (3) collect, compile and report data on Dam 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 2019 Dam Angling crew.

A Dam Angling crew of four anglers harvested 4,125 Northern Pikeminnow during the 2019 season. Of those, 2,231 Northern Pikeminnow were harvested at The Dalles Dam and 1,894 were harvested at the John Day Dam. The crew fished a total of 1,380.9 hours during the 22 week fishery, averaging 188 fish per week and for a combined overall average catch per angler hour (CPUE) of 3.0 Northern Pikeminnow. At The Dalles Dam, the crew averaged 3.6 fish per angler hour, and cumulatively 38 Northern Pikeminnow per day. At the John Day Dam, the crew averaged 2.5 fish per angler hour with a cumulative crew total of 30 fish per day.

Based on the success of the WDFW Dam Angling Crew in implementing the Dam Angling component of the NPMP from 2010-18, the 2019 Dam Angling crew continued to use back bouncing soft plastic lures with rod and reel 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 2019 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 also contracted to conduct the Dam Angling component of the NPMP and 2019 marked the tenth 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 2019.

The objectives of the 2019 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 Dam 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 or Floy tags, fin-clips or signs of tag-loss from these fishes for use in coordination with other predation studies, and (5) collect relevant biological data on all Northern Pikeminnow and other fishes caught by the 2019 Dam Angling crew.

METHODS

Project Area

In 2019, 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 2019 were planned for approximately 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 deck (Figure 2). At the John Day Dam, the crew fished exclusively along the turbine deck (Figure 3).

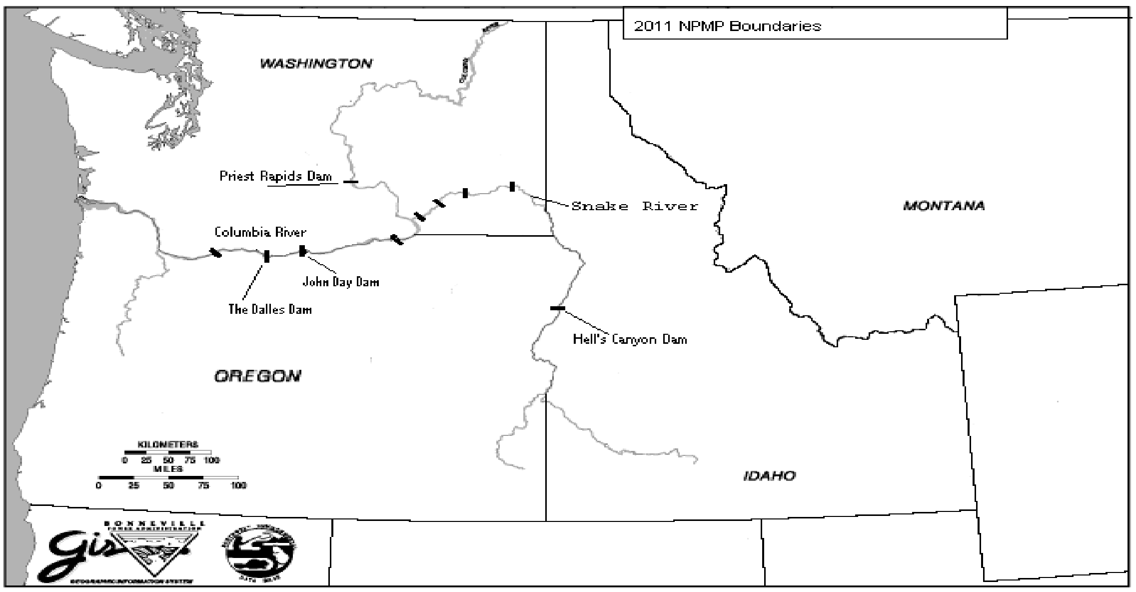

Figure 1. Northern Pikeminnow Management Program boundaries, including 2019 Dam Angling sites.

Figure 2. Angling locations for 2019 Dam Angling at The Dalles Dam

Figure 3. Angling locations for 2019 Dam Angling 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 2019, WDFW used a Dam Angling Strategy (DAS) 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 2019 Dam Angler CPUE goal remained set at 2.0 fish/angler hour as established in our original 2011 DAS (Dunlap et al. 2012).

The Dam Angling Crew

The four member Dam Angling crew typically worked four ten hour days a week, (usually Tuesday - Friday) during the 2019 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 Lexa_HD 300 or Shimano TranX 300 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.

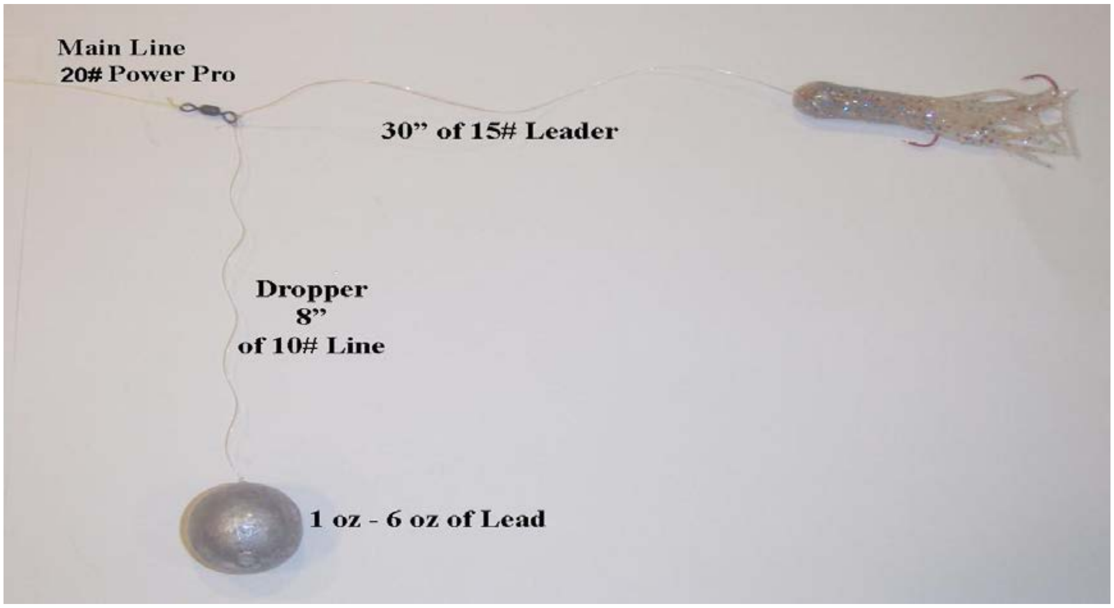

Figure 5. Example of typical rigging used by 2019 NPMP Dam Anglers

Figure 6. Examples of soft plastic tube lures used by 2019 NPMP Dam Angling Crew.

Data Collection

Creel data were recorded onto data sheets for each individual angler and 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, Floy, etc.), fin-clip marks, and signs of tag-loss. Complete biological data were collected from all externally tagged Northern Pikeminnow including FL, tag number, sex (determined by evisceration), and scale samples if specified. Spaghetti or Floy tagged Northern Pikeminnow carcasses were then labeled and preserved for later data verification and/or tag recovery. External tags from harvested Northern Pikeminnow along with biological data were recorded on 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 utilization in NPMP exploitation estimates.

PIT Tag Detection

All Northern Pikeminnow collected by Dam Anglers during 2019 were also scanned for Passive Integrated Transponder (PIT) tags. PIT tags have been used by ODFW as a secondary mark in all Northern Pikeminnow fitted with external spaghetti or Floy type tags (beginning in 2003) as part of the NPMP's biological evaluation activities (Takata and Koloszar 2004). Northern Pikeminnow harvested by anglers participating in the NPSRF have also been found to ingest juvenile salmonids which have been PIT tagged by other studies within the basin (Glaser et al. 2001). 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, entered into the PIT Tag Information System (PTAGIS) and provided to ODFW as requested.

Northern Pikeminnow Processing

During biological sampling, all Northern Pikeminnow were caudal clipped as an anti-fraud measure to reduce the possibility of previously processed Northern Pikeminnow being submitted 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

2019 Dam Angling Season

The 2019 Dam Angling Season took place from May 2nd through September 25th. River conditions were challenging and harvest was low during the first five weeks of the season (weeks 18-22) as reflected in Figure 7. Harvest did not really start to take off until runoff receded in week 23, and then remained good through week 31. Late season angling was also challenging, as Northern Pikeminnow in large numbers once again could not be consistently found. Total harvest for The Dalles and John Day dams combined was 4,125 Northern Pikeminnow in 1,380.9 angling hours, with a combined CPUE of 3.0 fish per angler hour. The Dam Angling crew exceeded the CPUE goal of 2.0 fish/angler hour (for the first time during the 2019 season) in week 22 and remained above it through week 30 during the 2019 season (Figure 8). Per our DAS protocol (Dunlap et al. 2012), weeks with CPUE under the 2.0 fish/angler hour goal (outside core harvest weeks 23-30) were typically due to the Dam Angling crew deploying only limited crews (< 50% effort) for "prospecting" purposes to locate and/or determine if catchable numbers of fish were present and/or available.

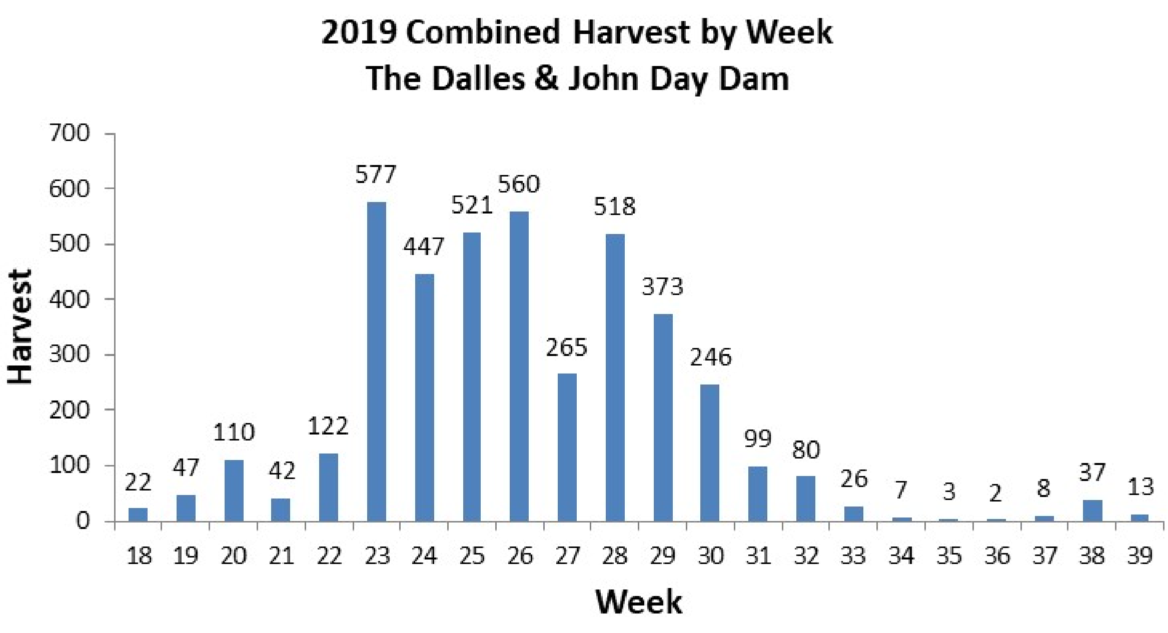

Figure 7. 2019 Weekly harvest of The Dalles (TD) and John Day (JD) Dams combined

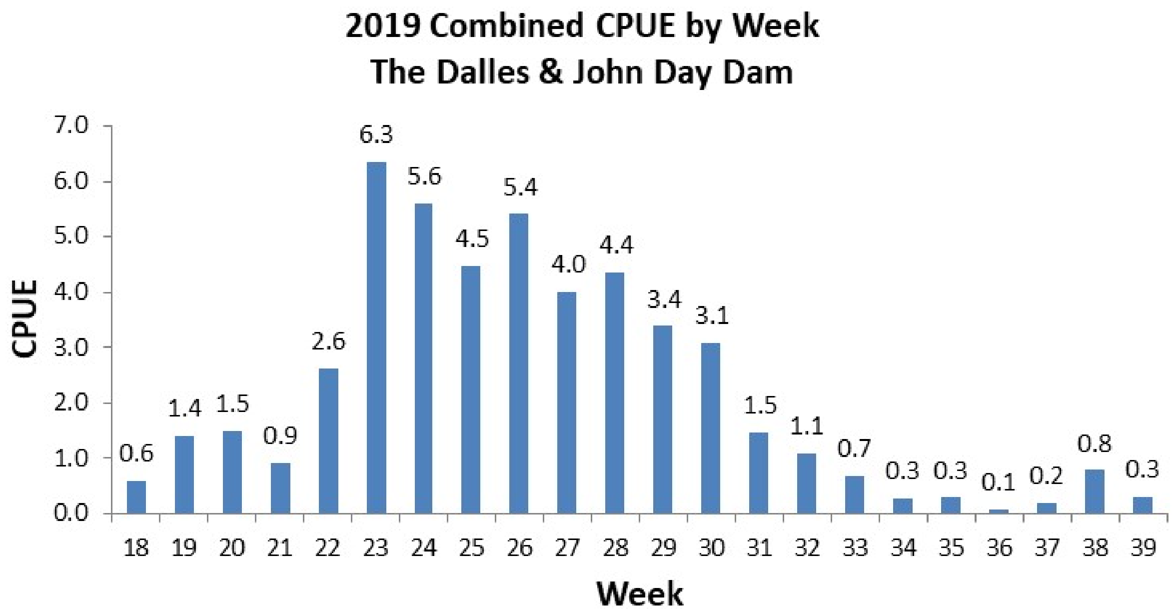

Figure 8. 2019 Weekly CPUE (fish/angler hour) of The Dalles (TD) and John Day (JD) Dams combined

Angling Gear and Technique

The 2019 Dam Angling crew primarily targeted fishing areas and fishing times at each dam that had been productive in the past (Dunlap et al. 2019). Our top producing lure in 2019 was the 3.75" Gitzit tube (a soft plastic lure) in Smoke/Black Copper Glitter color. This size and color lures were back bounced off the turbine decks and accounted for 2,194 harvested Northern Pikeminnow. A list of the top 5 most productive soft plastic lures used by the Dam Angling crew in 2019 is presented in Table 1.

Table 1. Top 5 Northern Pikeminnow Lures used by 2019 WDFW Dam Angling Crew

Northern Pikeminnow Lures

Brand/style	Size	Color	# N. Pikeminnow Caught
Canyon/ tube bait	3.75"	Smoke/Black Copper Glitter	2,194
Gitzit/ tube bait	3.50"	Pearl/Black Smoke Purple	530
Gitzit/ tube bait	3.50"	Smoke Sparkle	317
Canyon/ tube bait	3.75"	Pearl White/Black Back	303
Canyon/ tube bait	2.50"	Smoke/Black Copper Glitter	256

Angling Times

Time of day continued to make a difference in harvest success during the 2019 season. Dam Angler catch data from previous seasons had indicated that morning hours prior to noon were consistently the most productive times for harvesting Northern Pikeminnow (Dunlap et al. 2019). Results for the 2019 season indicated that 58% of the Dam Angler harvest of Northern Pikeminnow occurred prior to noon (Table 2). Evening hours also continued to be productive at The Dalles Dam in 2019 with 42% of harvest occurring after noon) (Table 3).

Table 2. Combined 2019 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 (rounded)
4:30 a.m. – 6:00 a.m.	385	9%
6:00 a.m. – 7:00 a.m.	407	10%
7:00 a.m. – 8:00 a.m.	382	9%
8:00 a.m. – 9:00 a.m.	305	7%
9:00 a.m. – 10:00 a.m.	331	8%
10:00 a.m. – 11:00 a.m.	294	7%
11:00 a.m. – 12:00 p.m.	280	7%
12:00 p.m. – 1:00 p.m.	197	5%
1:00 p.m. – 6:00 p.m.	155	4%
6:00 p.m. – 7:00 p.m.	81	2%
7:00 p.m. – 8:00 p.m.	161	4%
8:00 p.m. – 9:00 p.m.	217	5%
9:00 p.m. – 10:00 p.m.	222	5%
10:00 p.m. – 11:00 p.m.	302	7%
11:00 p.m. – 12:00 a.m.	248	6%
12:00 a.m. – 1:00 a.m.	154	4%
1:00 a.m. – 4:00 a.m.	4	0%

Table 3. 2019 WDFW Dam Angler hourly Northern Pikeminnow Harvest comparison (TD vs JD, rounded)

	The Dalles Dam		John Day Dam	
Time of day	**Harvest**	**% of Harvest**	**Harvest**	**% of Harvest**
4:30 a.m. – 6:00 a.m.	254	11%	131	7%
6:00 a.m. – 7:00 a.m.	205	9%	202	11%
7:00 a.m. – 8:00 a.m.	165	7%	217	11%
8:00 a.m. – 9:00 a.m.	107	5%	198	10%
9:00 a.m. – 10:00 a.m.	114	5%	217	11%
10:00 a.m. – 11:00 a.m.	107	5%	187	10%
11:00 a.m. – 12:00 p.m.	96	4%	184	10%
12:00 p.m. – 1:00 p.m.	86	4%	111	6%
1:00 p.m. – 6:00 p.m.	33	1%	122	6%
6:00 p.m. – 7:00 p.m.	20	1%	61	3%
7:00 p.m. – 8:00 p.m.	82	4%	79	4%
8:00 p.m. – 9:00 p.m.	110	5%	107	6%
9:00 p.m. – 10:00 p.m.	167	7%	55	3%
10:00 p.m. – 11:00 p.m.	294	13%	8	0%
11:00 p.m. – 12:00 a.m.	240	11%	8	0%
12:00 a.m. – 1:00 a.m.	147	7%	7	0%
1:00 a.m. – 4:00 a.m.	4	0%	0	0%
Total	2,231	100%	1,894	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 2019. All incidentally caught fish species were released in 2019. Incidental species most often caught were Walleye *Sander vitreus and* Smallmouth Bass *Micropterus dolomieue*. The Dam Angling crew continued to observe 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. 2019 WDFW Dam Angler incidental catch by project

Incidental Catch

Species	The Dalles Dam	John Day Dam
Smallmouth Bass	98	583
Walleye	6	100
Sculpin	4	18
American Shad	26	39
Channel Catfish	2	18
White Sturgeon	0	14
Peamouth	0	4
Carp	1	0
Sucker	0	2

Tag Recovery

All Northern Pikeminnow harvested by Dam Anglers in 2019 were visually examined for the presence of external spaghetti or Floy tags and 100% were individually scanned with PIT tag readers for the presence of PIT tags. Four Northern Pikeminnow retaining both ODFW spaghetti and PIT tags were recovered by the Dam Angling crew in 2019 (Figure 9), which was two more than that in 2018 (Dunlap et al. 2019). In addition, there were a total of 11 Northern Pikeminnow recovered that had lost the spaghetti or Floy ODFW 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 (Anderson et al. 2020). The 2019 Dam Angling crew also recovered Northern Pikeminnow with 3 PIT tags from ingested juvenile salmonids (one hatchery Chinook, one wild Chinook, and one wild Steelhead) at The Dalles Dam. There were no recoveries of PIT tags from ingested salmonids at the John Day Dam (Figure 10). There were two less total recoveries of ingested salmonids from Northern Pikeminnow than in 2018 (Dunlap et al. 2019). The overall occurrence rate for ingested PIT tagged salmonids recovered from Northern Pikeminnow caught by Dam Anglers in 2019 was 1:1,625 Northern Pikeminnow, compared to 1:975 for the Dam Angling crew in 2018 (Dunlap et al. 2019) and 1:4,062 for the 2019 NPSRF (Hone et al. 2020).

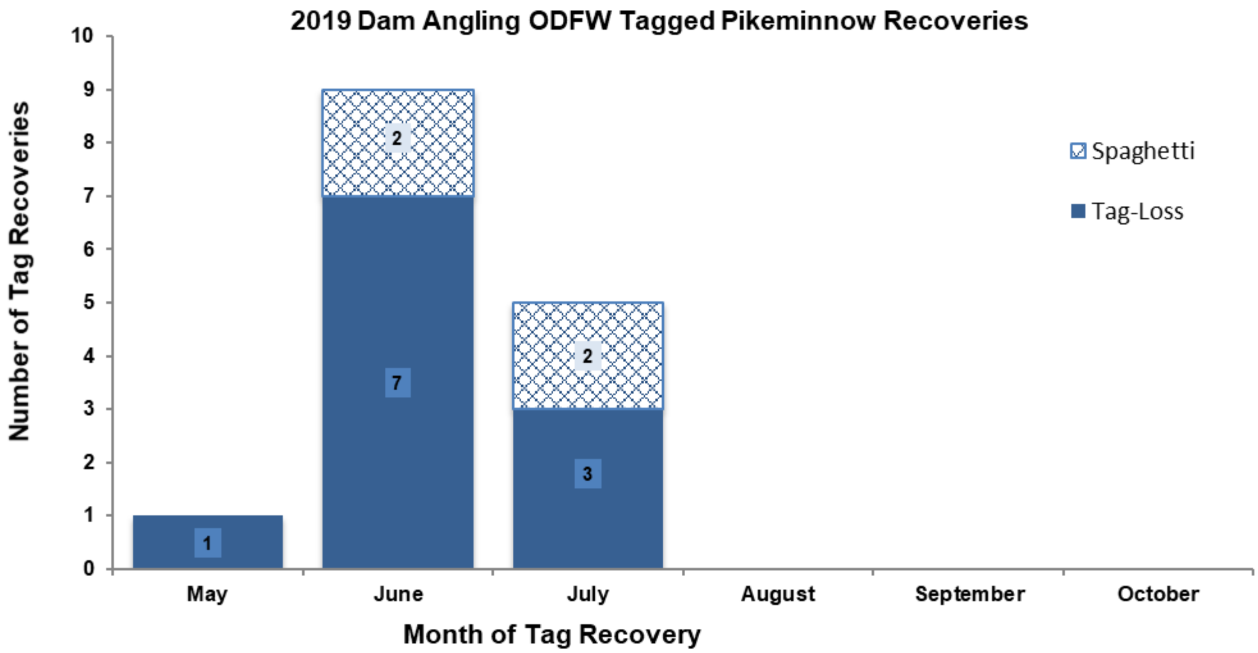

Figure 9. Recoveries of Spaghetti Tagged and Tag-Loss fish from 2019 Dam Angling

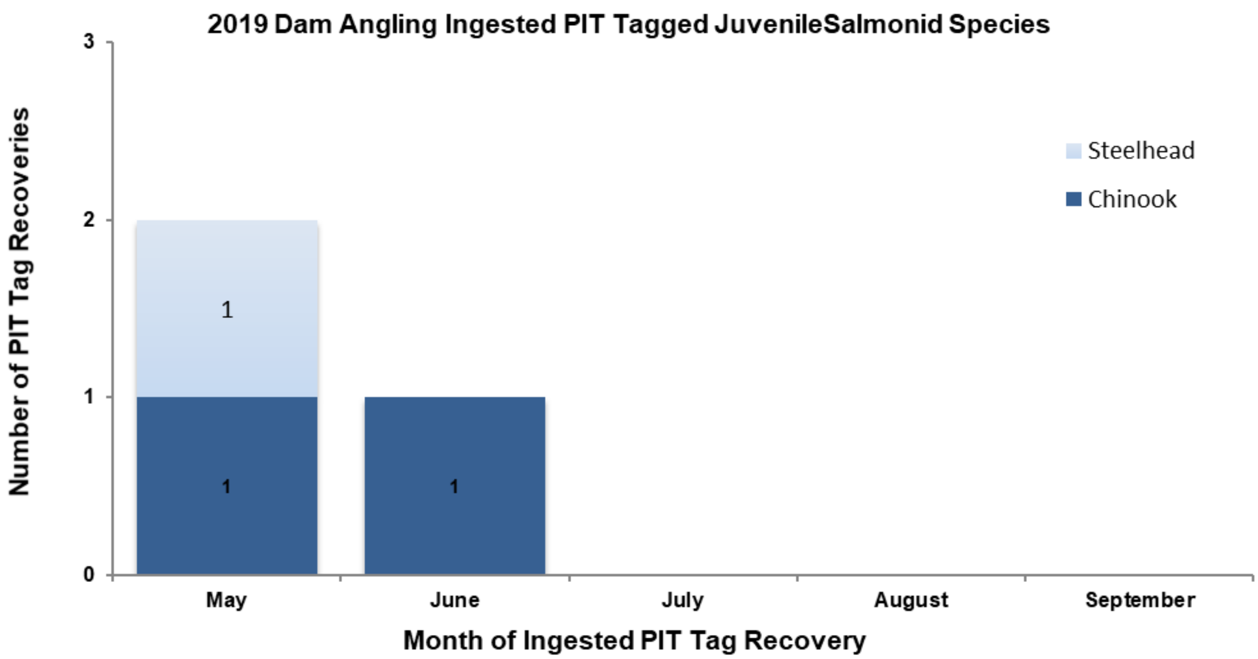

Figure 10. Recoveries of ingested salmonid PIT Tags from 2019 Dam Angling

The Dalles Dam

Harvest

The Dam Angling crew harvested 2,231 Northern Pikeminnow in 21 weeks of Dam Angling at The Dalles Dam in 2019. Weekly harvest for the Dam Angling crew averaged 106 fish per week and ranged from peak harvest of 521 Northern Pikeminnow in week 25 (June 17 – June 23) to 0 fish in weeks 36 & 39 (no effort was spent during week 38) (Figure 11). River outflows during the first 6 weeks of 2019 (Figure 12) were somewhat challenging, very good from weeks 24-30, and then challenging again from weeks 31-39. Overall harvest at The Dalles Dam was 20% higher than in 2018 (Dunlap et al. 2019) and peak harvest for Dam Angling occurred in week 25, one week later than in the 2019 NPSRF (Hone et al. 2020).

The 2,231 Northern Pikeminnow harvested at The Dalles Dam in 2019 included four spaghetti tagged Northern Pikeminnow and three tag-loss Northern Pikeminnow from ODFW's biological evaluation of the NPMP. The 2019 Dam Angling crew also recovered three Northern Pikeminnow from The Dalles Dam with ingested juvenile salmonids with PIT tags.

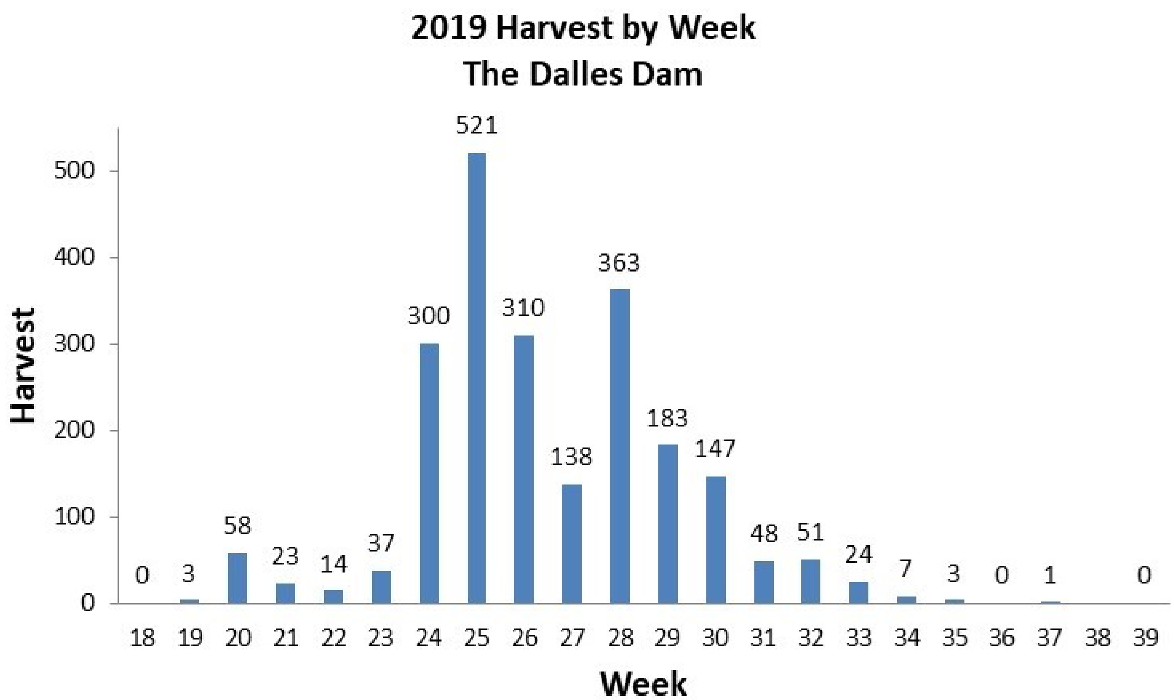

Figure 11. 2019 Weekly Dam Angler harvest of Northern Pikeminnow at The Dalles Dam

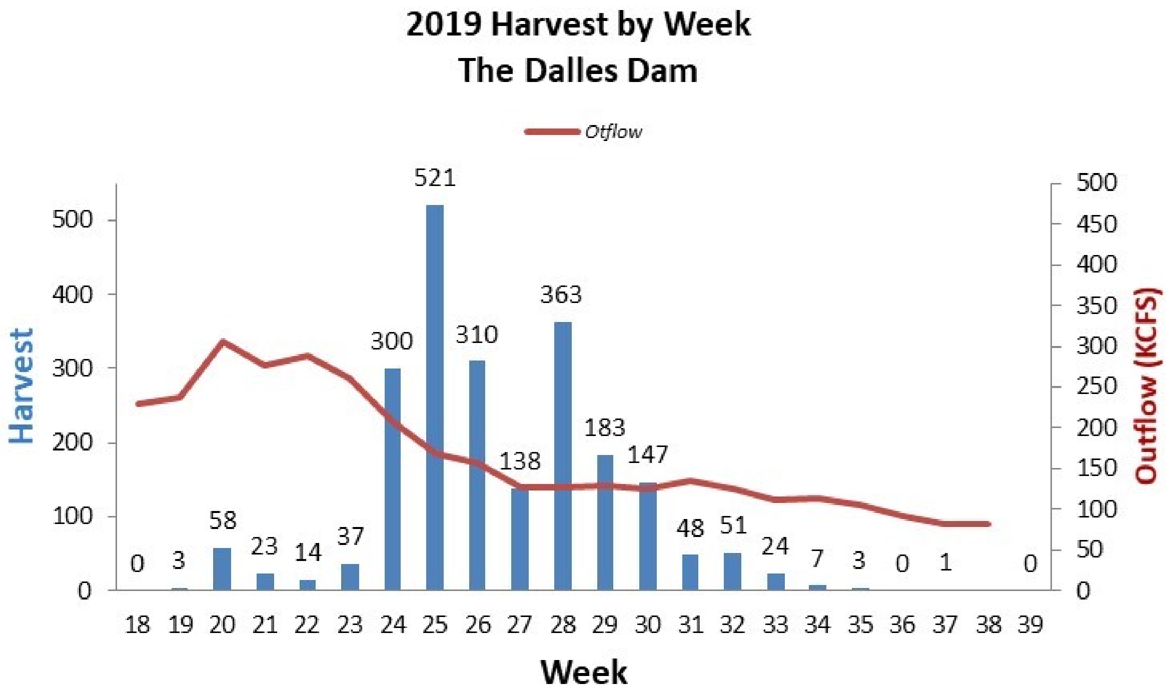

Figure 12. 2019 Weekly Northern Pikeminnow harvest compared to outflow

As was the case in past Dam Angling seasons, certain areas and/or turbines at The Dalles Dam were better producers than others in 2019. The angling between Turbine #7 (T7) and Turbine #14 (T4) accounted for 40% of total harvest at The Dalles Dam in 2019, down from 47% in 2018 (Dunlap et al. 2019) (Figure 13). The area between the Fishway (F) and Turbine 4 (T4) accounted for 58% of total harvest. Due to USACE policy, the 2019 Dam Angling crew was not allowed to fish the rock shore above the ice trash sluiceway which historically contributes 25% of the total Northern Pikeminnow harvest for The Dalles Dam (Dunlap et al. 2018).

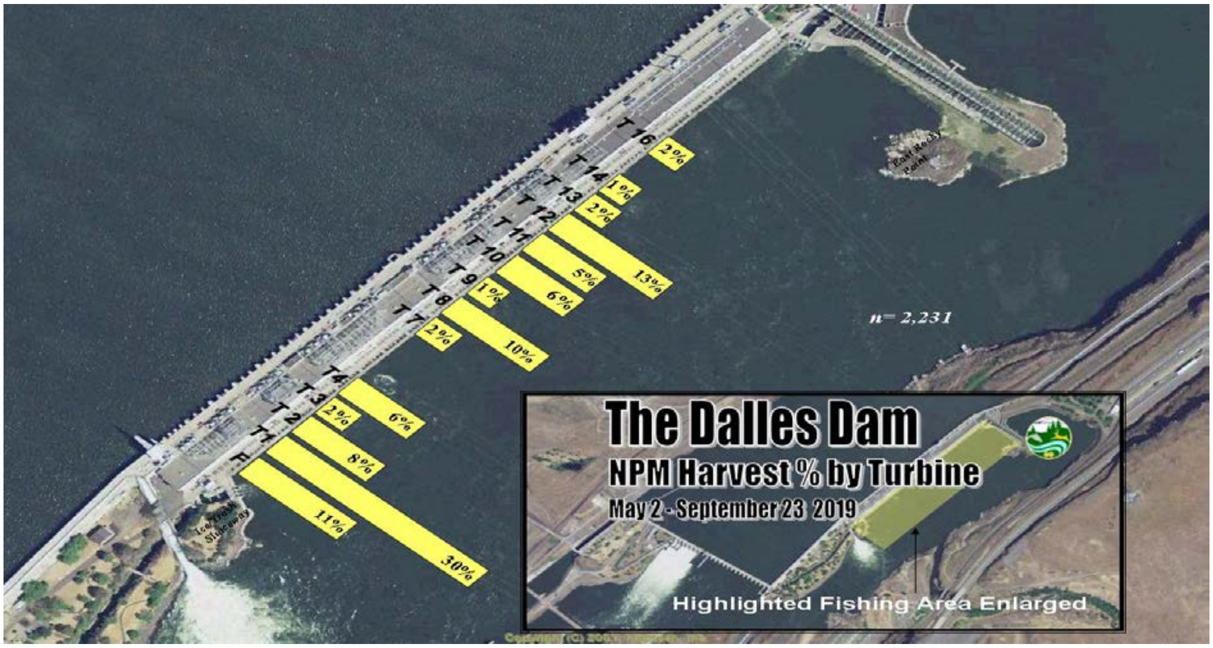

Figure 13. 2019 Overall percent of Northern Pikeminnow harvest by area (T=turbine #, F = fishway)

The Dalles Dam NPM Harvest % by Turbine

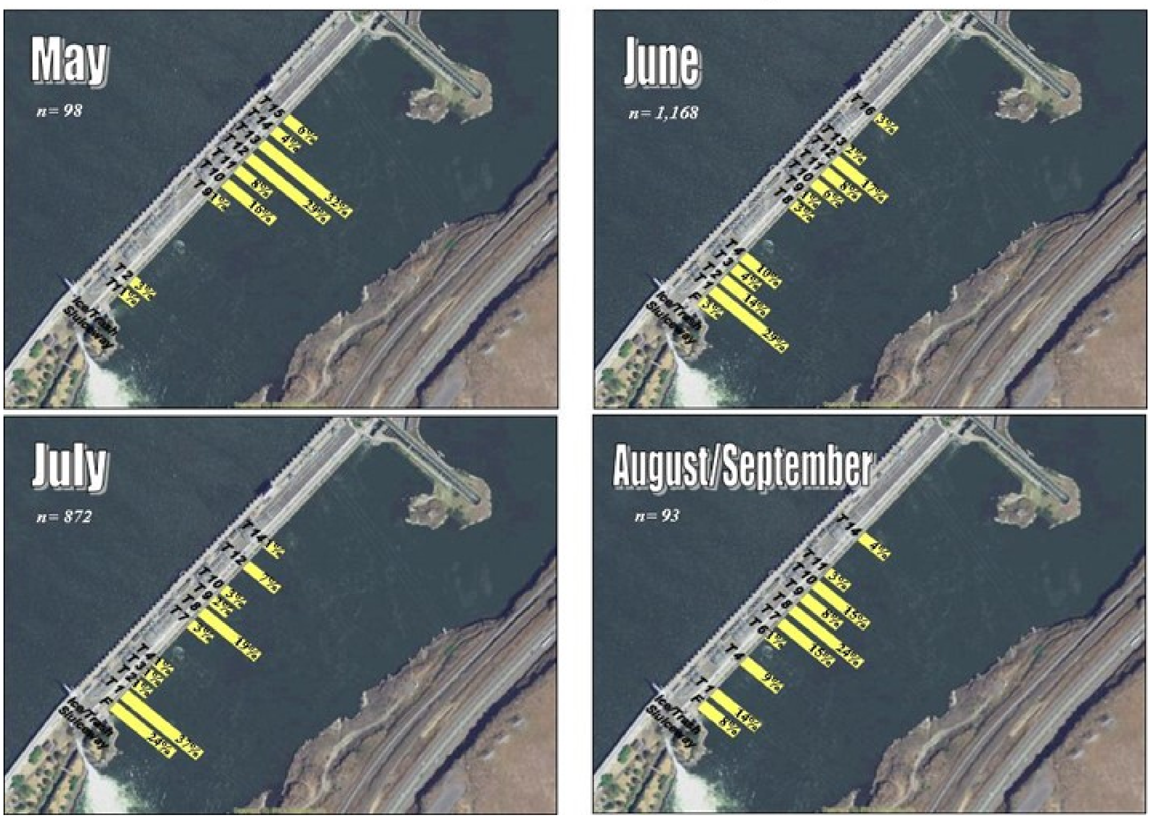

Figure 14. 2019 Monthly harvest percent (*rounded) by area at The Dalles Dam (T=turbine#, F = fishway)

When we look at Northern Pikeminnow harvest at The Dalles Dam during the 2019 Dam Angling season, our harvest data showed some variability in productivity over the course of the May-September Dam Angling season (Figure 14). In general, 2019 data shows the highest concentrations of Northern Pikeminnow were harvested near Turbine 1 (T1) in June and July, then more scattered harvest during the rest of the season.

Incidental Catch

While the Dam Angling crew did not target fish species other than Northern Pikeminnow in 2019, they did catch 98 Smallmouth Bass and 6 Walleye at The Dalles Dam in 2019 (Figure 15). The 6 Walleye caught in 2019 were half the Walleye caught in 2018 (12), a smaller percentage of the 66 Walleye caught in 2017 and the 55 Walleye caught in 2016 (Figure 15). This may have partially been due to the recent USACE policy change which prohibited the 2019 Dam Angling crew from fishing the area between the Fishway and the Ice Trash Sluice Way where Walleye are more apt to be caught. Turbine 12 and the Turbine 1/ Fishway locations had the highest catches of Smallmouth Bass (Figure 16) and all Smallmouth Bass and Walleye caught were scanned for PIT tags and released. No PIT tags from ingested salmonids were recovered from Smallmouth Bass or Walleye at The Dalles Dam in 2019.

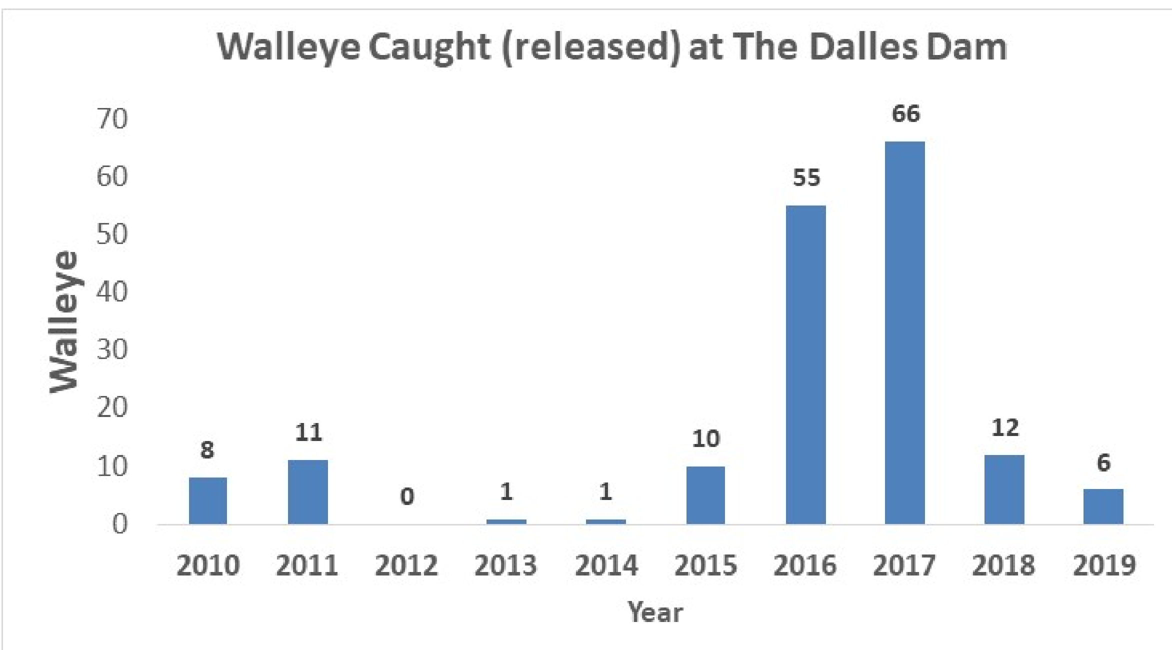

Figure 15. 2019 Annual Dam Angler catch of Walleye at The Dalles Dam

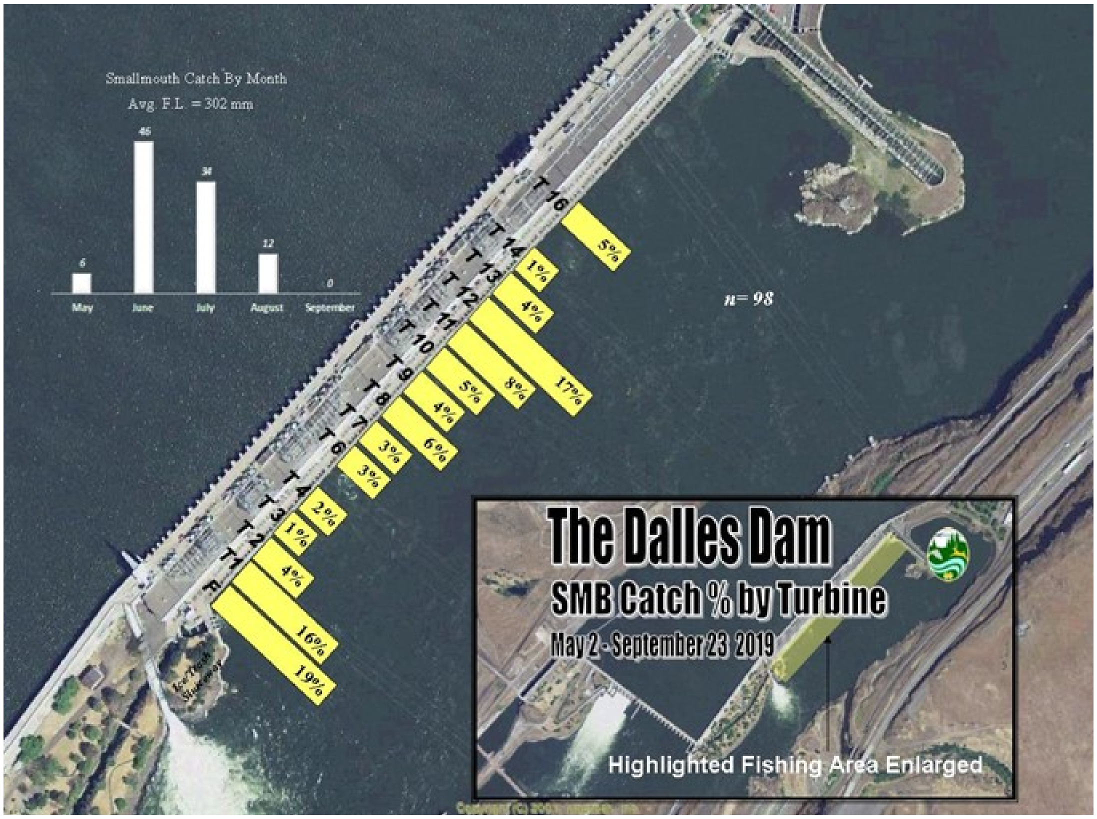

Figure 16. 2019 Incidental catch of Smallmouth Bass (*rounded) by Dam Angling Crew at The Dalles Dam

Effort

Total angler hours of effort at The Dalles Dam decreased to 620.4 hours in 2019 from 700.8 hours in the 2018 Dam Angling season (Dunlap et al. 2019). The Dam Angling crew fished 59 days at The Dalles Dam over 21 weeks and spent 45% of total Dam Angling effort at The Dalles Dam in 2019.

CPUE

The Dam Angling crew harvested 2,231 Northern Pikeminnow in 620.4 angler hours at The Dalles Dam in 2019 for an overall average CPUE of 3.6 fish/angler hour, up from 2.5 in 2018 (Dunlap et al. 2019). Peak weekly CPUE at The Dalles Dam occurred during week 24 (Figure 17). Unfortunately, **c**hallenging river conditions early and late in the 2019 season resulted in overall CPUE at The Dalles Dam exceeding the 2.0 fish/angler hour goal for only 8 of the 21 weeks fished (no effort was spent in week 38).

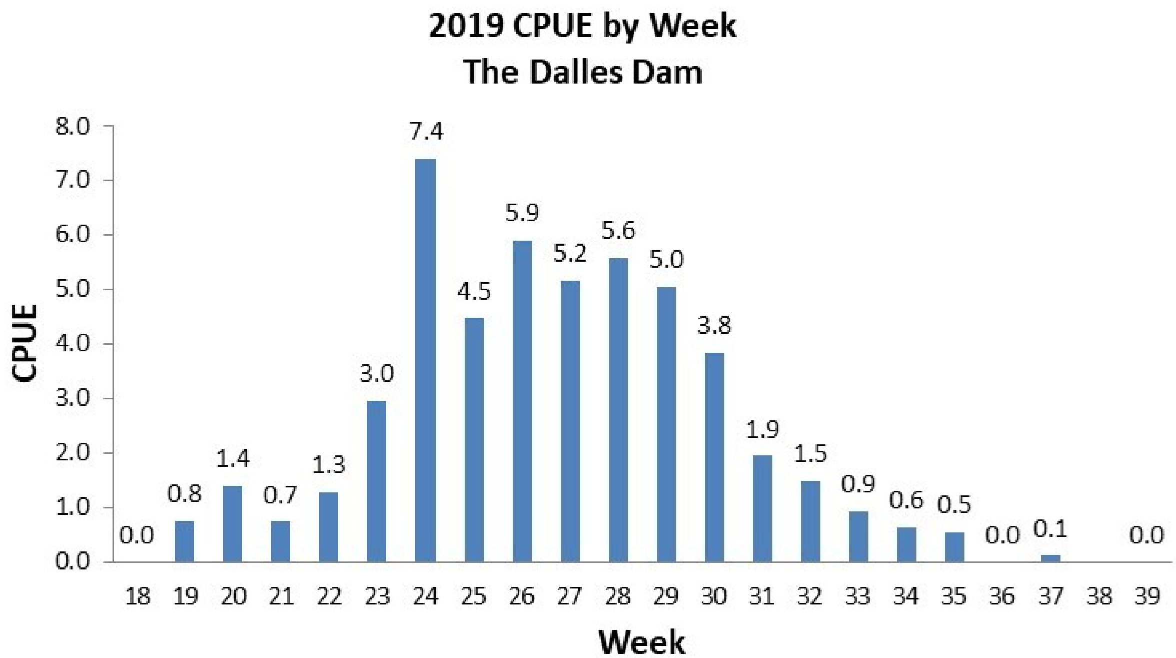

Figure 17. 2019 Weekly Dam Angler CPUE at The Dalles Dam

Fork Length Data

Fork lengths were recorded from 2,231 (100%) Northern Pikeminnow harvested by the Dam Angling crew at The Dalles Dam during the 2019 Season. The length frequency distribution of Northern Pikeminnow harvested at The Dalles Dam in 2019 is presented in Figure 18. Mean fork length for Northern Pikeminnow caught by the Dam Angling crew at The Dalles Dam in 2019 was 373 mm (SD=55.2), up from 355 mm in 2018 (Dunlap et al. 2019). By comparison, the mean fork length for the 2019 NPSRF was 281 (Hone et al. 2020).

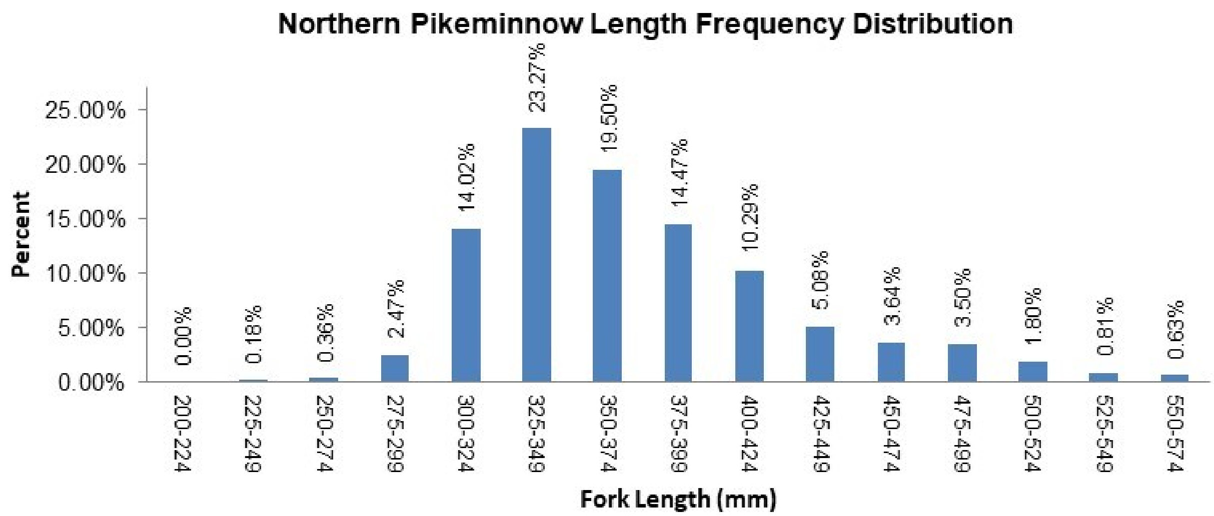

Figure 18. Northern Pikeminnow length frequency distribution at The Dalles Dam in 2019

John Day Dam

Harvest

The Dam Angling crew harvested 1,894 Northern Pikeminnow over 21 weeks at the John Day Dam in 2019. Weekly harvest averaged 86 fish per week and ranged from zero fish in weeks 34 and 35 (no effort in week 25) to a peak of 540 in week 23 (June 3 – June 9) (Figure 19). Peak weekly harvest at the John Day Dam occurred in week 23 which was six weeks earlier than in 2018 (Dunlap et al. 2019) and 1 week later than the week 24 peak for the 2019 Sport Reward Fishery (Hone et al. 2020). The 1,894 harvested Northern Pikeminnow included no external tags, but did include eight tag-loss Northern Pikeminnow from ODFW's biological evaluation of the NPMP (Anderson, E.S et al. 2020). We recovered no/0 PIT tags from juvenile salmonids ingested by a Northern Pikeminnow at the John Day Dam in 2019.

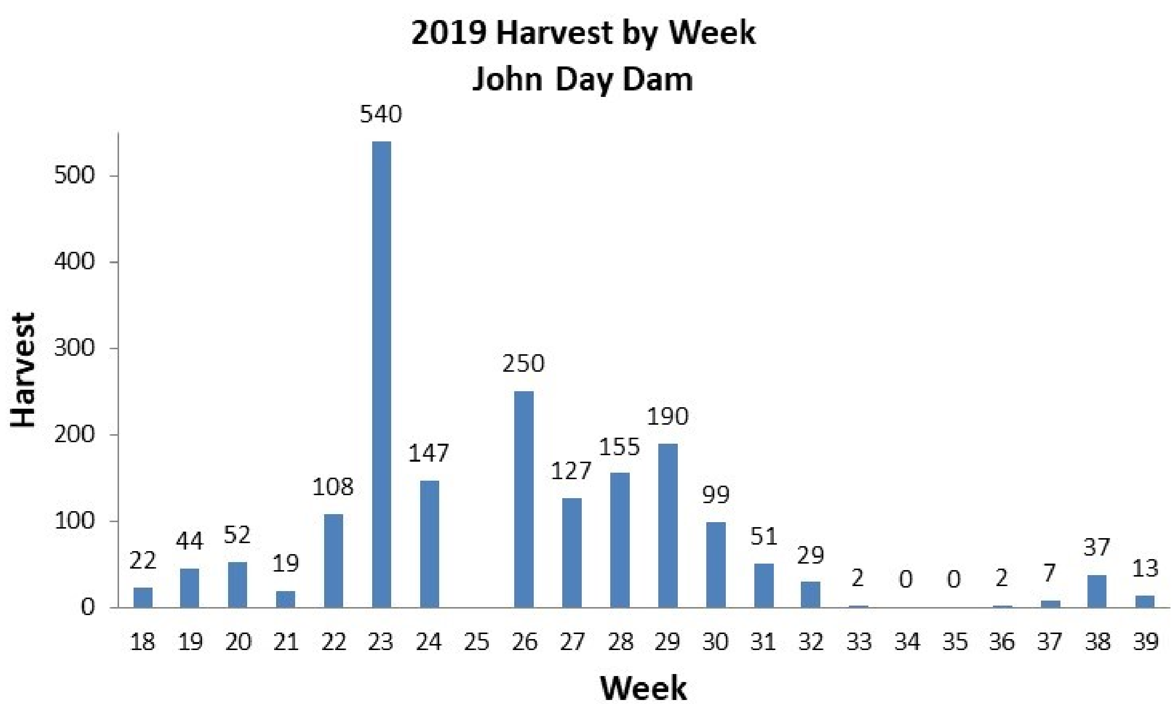

Figure 19. 2019 Weekly Dam Angler harvest of Northern Pikeminnow at the John Day Dam

Average outflow at the John Day Dam during the peak Dam Angler harvest week of 2019 (week 23) was 275 kcfs (Figure 20), and certain turbines at the John Day Dam created water flow conditions more favorable for harvesting Northern Pikeminnow than others (Dunlap et al. 2019). Turbine #8 (T8) was the single best producing area at the John Day Dam in 2019 accounting for 26% of the total Northern Pikeminnow harvest (Figure 21). Harvest of Northern Pikeminnow peaked during week 23 in June and was best between T13 and T8 with 76% of total (Figure 22).

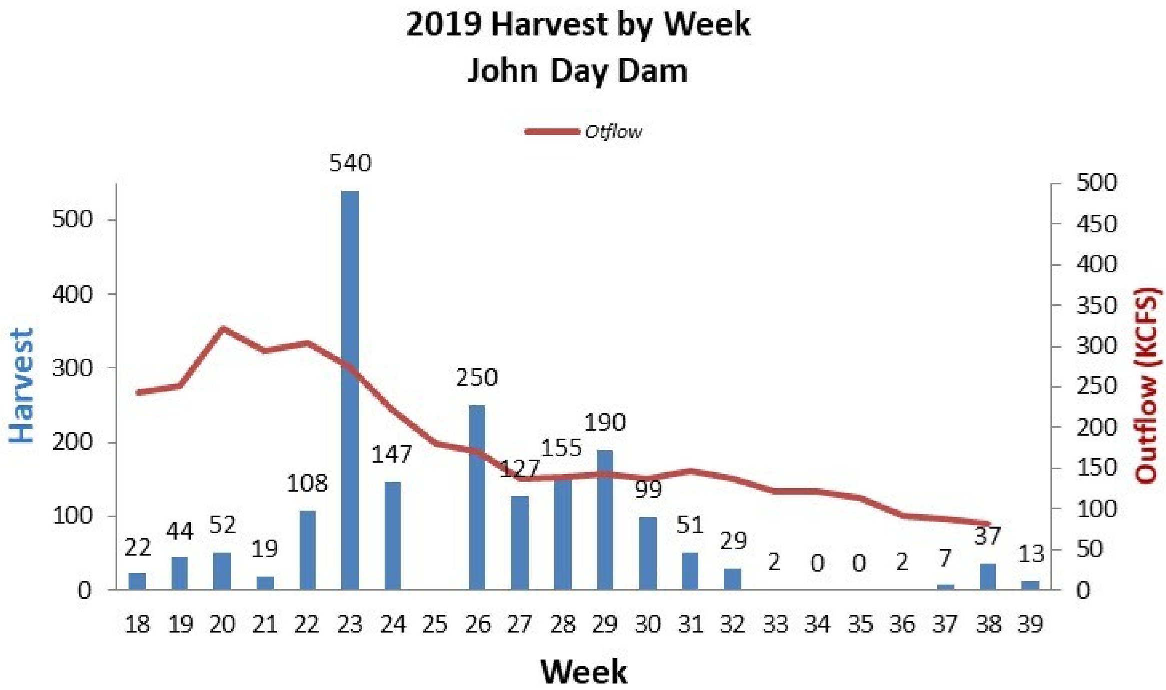

Figure 20. 2019 Weekly Dam Angler harvest of Northern Pikeminnow at the John Day Dam vs outflow

Figure 21. 2019 Overall percent of Northern Pikeminnow harvest by area (T=turbine#)

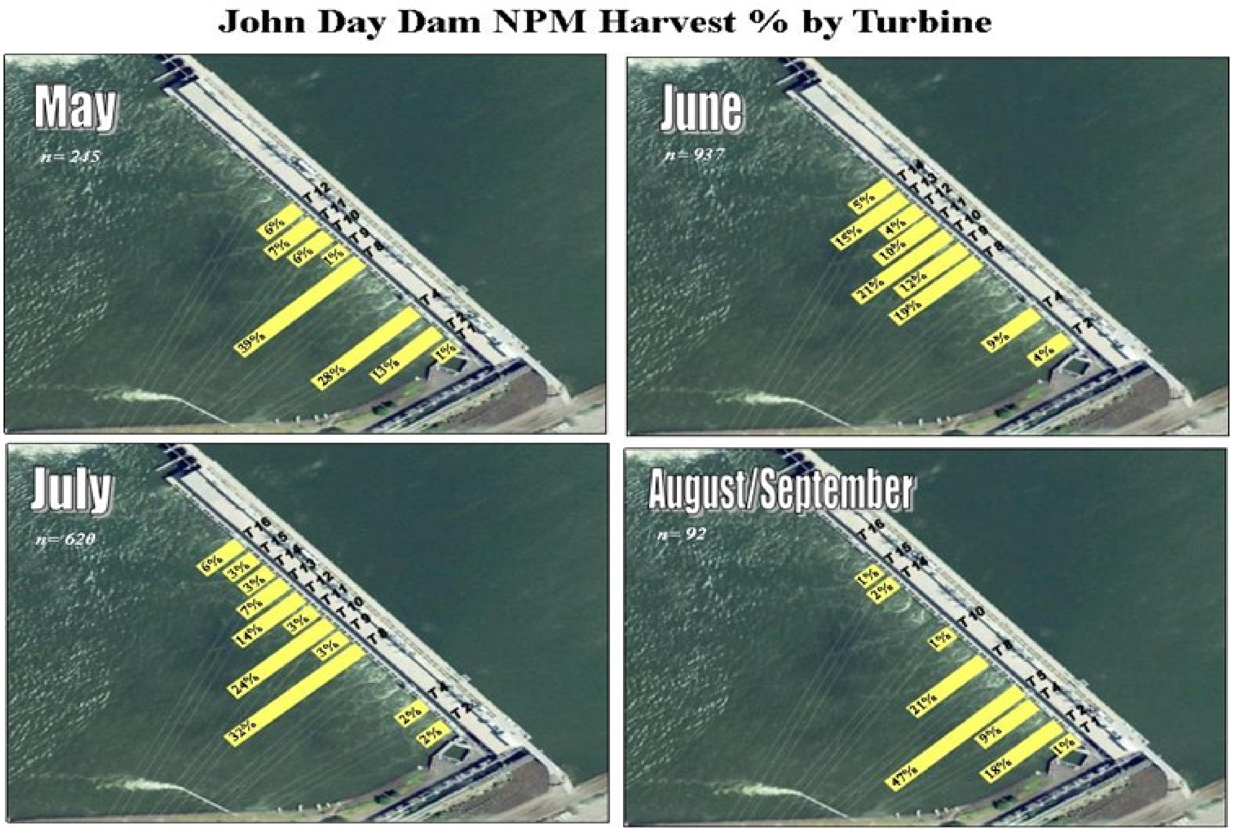

Figure 22. 2019 Monthly percent (*rounded) of Northern Pikeminnow harvest by area (T=turbine#)

Incidental Catch

The Dam Angling crew did not target fish species other than Northern Pikeminnow, but did catch and release 100 Walleye at the John Day Dam in 2019. (Figure 23). The Dam Angling crew also caught and released 583 Smallmouth Bass (smb) at the John Day Dam in 2019. All Walleye and Smallmouth Bass were scanned for PIT tags from ingested salmonids and one PIT tag was found from an ingested juvenile salmonid recovered from one of the Smallmouth Bass. There were no recoveries from Walleye. Through PTAGIS queries, we were able to determine that this PIT tag was from a Wild Summer Chinook.

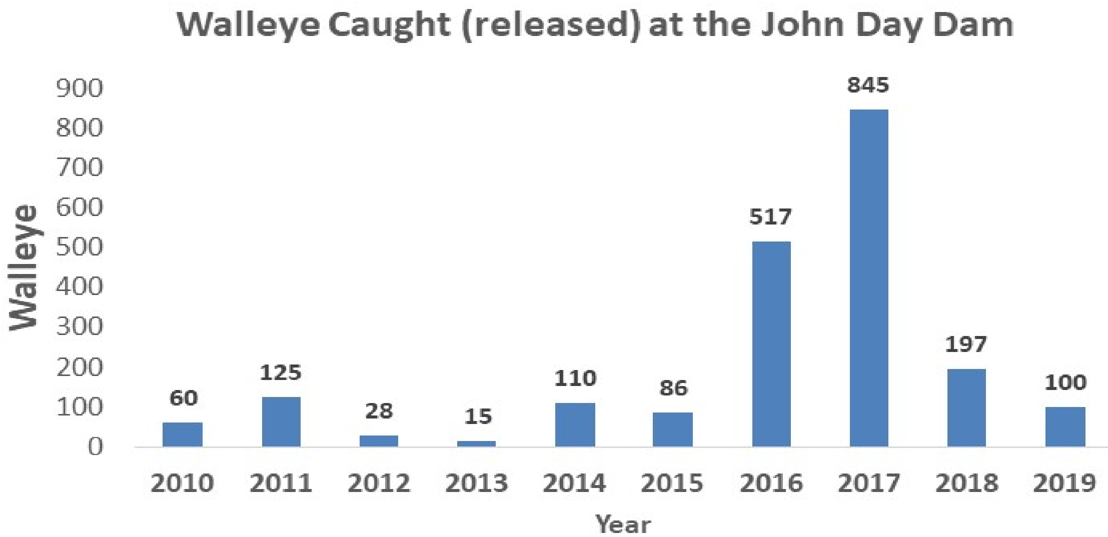

Figure 23. 2019 Annual Dam Angler catch of Walleye at the John Day Dam

Effort

Total effort at the John Day Dam was 760.5 angler hours in 2019, down from 1,199.25 hours in 2018 (Dunlap et al. 2019). The crew averaged a combined 36.2 angler hours of effort per week and 12 angler hours of effort per day at the John Day Dam in 2019. The Dam Angling crew spent 55% of total Dam Angling effort (63 days over 21 weeks) at the John Day Dam in 2019.

CPUE

The Dam Angling crew harvested 1,894 Northern Pikeminnow in 760.5 angler hours at the John Day Dam in 2019 for an overall average CPUE of 2.5 fish/angler hour, slightly down from the 2.6 CPUE in 2018 (Dunlap et al. 2019). Peak weekly CPUE at the John Day Dam occurred during week 23 and there was no effort spent at the John Day Dam in week 25 (Figure 24). Peak weekly CPUE at the John Day Dam occurred 1 week earlier than at The Dalles Dam and the overall CPUE goal of 2.0 fish/angler hour was met or exceeded 8 of the 21 weeks fished.

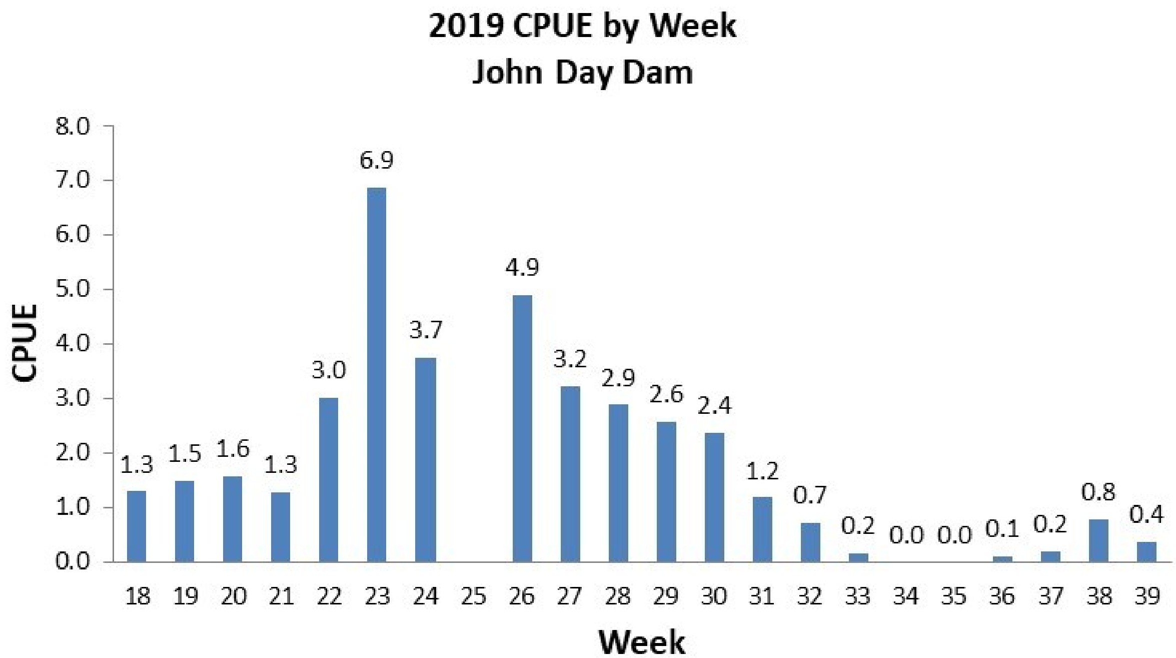

Figure 24. 2019 Weekly Dam Angling CPUE at John Day Dam

Fork Length Data

Fork lengths were recorded from 1,894 Northern Pikeminnow (100% of harvest) at the John Day Dam during the 2019 Dam Angling Season. The length frequency distribution of harvested Northern Pikeminnow from the John Day Dam in 2019 is presented in Figure 25. Mean fork length for Northern Pikeminnow from the John Day Dam in 2019 was 379 mm (SD=48.1) compared to 373 mm in 2018 (Dunlap et al. 2019). By comparison, 2019 mean FL for The Dalles Dam was 373 mm (SD=55.2) and for the 2019 NPSRF was 281 mm (Hone et al. 2020).

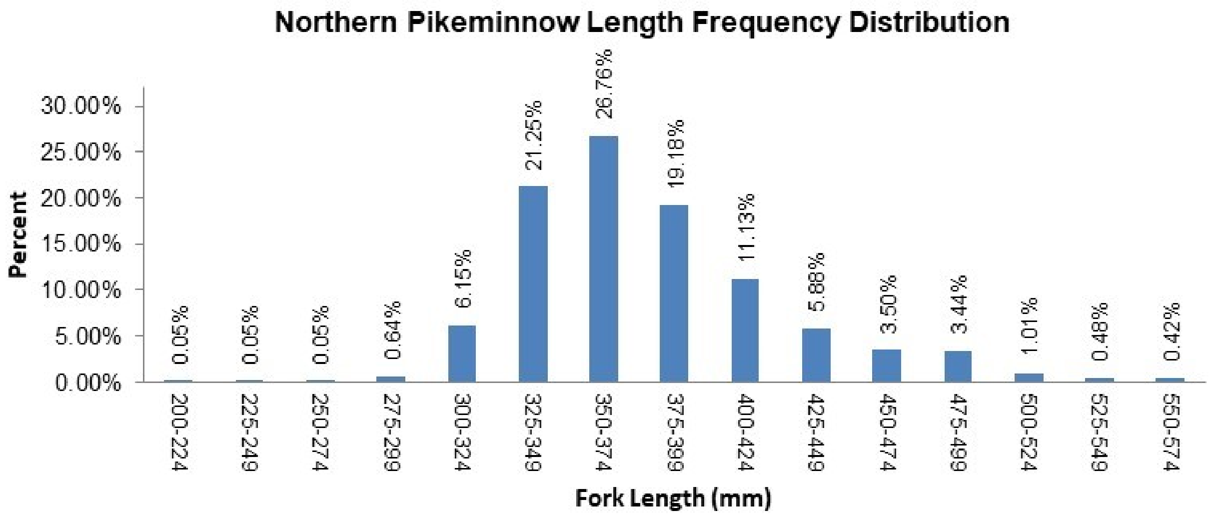

Figure 25. Northern Pikeminnow length frequency distribution at the John Day Dam in 2019

SUMMARY

The 2019 Dam Angling crew harvested 4,125 Northern Pikeminnow at The Dalles and John Day Dams, with 2,231 coming from The Dalles Dam and 1,894 from the John Day Dam. Overall harvest was lower than 2018 although higher at The Dalles Dam in 2019 (Dunlap et al. 2019). Dam Angling was conducted for a 22 week season implemented from May 2nd through September 25th 2019.

During the 2019 season, the Dam Angling crew spent 55% of their effort fishing at the John Day Dam and exceeded the 2.0 CPUE goal for 9 of the 22 weeks of the 2019 Dam Angling season. Angling hours prior to 1:00 pm continued to be the most productive harvest times and the top producing lure for 2019 was the 3.75” Gitzit tube in Smoke/Black Copper Glitter color.

Fork length data for Northern Pikeminnow harvested by the 2019 Dam Angling Crew at both The Dalles and John Day dams showed that they were considerably larger than the mean fork length of Northern Pikeminnow harvested in the NPSRF (373 mm at The Dalles Dam and 379 mm at the John Day Dam compared to 281 mm in the 2019 NPSRF (Hone et al. 2020). The Dam Angling Crew recovered four spaghetti tagged Northern Pikeminnow and 11 tag-loss Northern Pikeminnow during 2019. There were also three PIT tags from salmonids ingested by harvested Northern Pikeminnow. The overall occurrence rate for ingested PIT tags from Northern Pikeminnow caught by the 2019 Dam Angling crew was 1:1,625. We also recovered one PIT tag from a juvenile salmonid ingested by a Smallmouth Bass incidentally caught by the Dam Angling Crew at the John Day Dam.

While targeting only Northern Pikeminnow, the 2019 Dam Angling crew incidentally caught a combined total of 681 Smallmouth Bass, 106 Walleye, 65 American Shad, 22 Sculpin, and 20 Channel Catfish between the two projects.

RECOMMENDATIONS FOR 2020

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 2020 Dam Angling activities to conduct the standard May-September Dam Angling season with a focus on maximizing effort during peak harvest weeks.

3.) Continue to utilize the 2.0 CPUE goal to determine and allocate Dam Angler effort between projects in order to maximize harvest of Northern Pikeminnow.

4.) Continue to improve data collection in the areas of scanning other incidentally caught predator fishes for PIT tags, and in scanning and enumerating juvenile lamprey regurgitated by Northern Pikeminnow caught by Dam Anglers in 2020.

5.) Continue using HPR PIT tag scanners for scanning all incidentally caught fishes.

6.) Continue to investigate and further develop Northern Pikeminnow angling techniques in 2020 (such as "heavying up" effort) in order to improve Dam Angler CPUE and/or allow exploitation of Northern Pikeminnow in areas not currently fishable.

7.) Implement and investigate the feasibility of retaining carcasses of non-native predator fishes and recording data as done with other Columbia River research projects.

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APPENDIX A
Top 5 lures used by 2019 Dam Angler

Type- Canyon Plastic 3 3/4" Original Gitzit Tube

Color- Smoke/Black & Copper Glitter

Type- Gitzit Incorporated 3.5" Injected Molded Tube

Color– Pearl/Black Smoke Purple Sparkle

Type- Gitzit Incorporated 3.5" The Original Fat Gitzit

Color- Smoke Sparkle

Type- Canyon Plastic 3 3/4" Original Gitzit Tube

Color– Pearl White/Black Back

Type- Canyon Plastic 2 1/2" Mini Gitzit Tube

Color- Smoke/Black & Copper Glitter