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

2021 ANNUAL REPORT
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Prepared by:

Eric Winther
Grant Waltz
Allan Martin

Pacific States Marine Fisheries Commission
Washington Dept. of Fish and Wildlife
Oregon Dept. of Fish and Wildlife

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2021 Executive Summary
by

Allan Martin

This report presents results for year thirty-one in the basin-wide Northern Pikeminnow Sport Reward Program (NPMSRP), designed to harvest Northern Pikeminnow[1] (Ptychocheilus oregonensis) in the Columbia and Snake Rivers. In 2020, the start of the NPMSRP season was delayed due to the COVID-19 pandemic. To compensate for the previous season's delay, the 2021 season started two weeks early on April 19. In an effort to boost exploitation and angler participation adversely affected by the continuation of the pandemic, the season was later extended to October 17. The continued decline of participation and catch and it's resulting effect on exploitation prompted a proposal to increase the tier rates for 2022. The proposal to change the tier rate rewards from $5, $6 and $8 per fish to $6, $8, and $10 per fish was accepted for implementation during the 2022 season. To further increase angler participation, an online registration application was developed for use in 2022. This application will allow anglers to register to fish without the need to drive to a check station and fill out a registration form prior to fishing.

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

[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.*

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 response in 1994. Results of these and other lessons learned over the 32-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

2021 Annual Report

Prepared by

Eric C. Winther
Paul V. Dunlap
Ruthanna M. Shirley
Dennis M. Werlau
Diana M. Murillo
John D. Hone

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

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We are thankful to the City of Rainier for the use of the Rainier boat ramp; the City of Richland for the use of Columbia Point Park; the Cowlitz County Parks and Recreation Department for the use of the Willow Grove boat ramp; the Port of Bingen for the use of Bingen Marina; the Port of Camas/Washougal for the use of the Camas/Washougal boat ramp; the Port of Cascade Locks for the use of the Cascade Locks Marine Park; the Port of Cathlamet for the use of the Cathlamet Marina; the Port of Kalama for the use of the Kalama Marina; the Port of Ridgefield for the use of the Ridgefield boat ramp; the Port of The Dalles for the use of The Dalles Boat Basin; the Port of Umatilla for the use of the Umatilla Marina; the Portland Metro Regional Parks Department for the use of the M. James Gleason and Chinook Landing Boat Ramps; The Scapoose Bay Marina; the U.S. Army Corps of Engineers for the use of Giles French Park, Windust Park and the Greenbelt Boat Ramp; the Washington Department of Transportation for the use of the Vernita Bridge Rest Area; 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, Addie Donohue, Mark Flahaut, Bill Fleenor, Leif Fox, Roger Fox, Summer Henrickson, Anna Klundt, McKaden Manderbach, Eric Meyer, Jordan Miller, Brittney Salter, Amber Santangelo, Emily Splitgerber, John Paul Viviano, Bec Missildine, Rudy Busch, Joel Benner, Andrew Vaughn, and Dennis Werlau for operating the 2021 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 Vert for her numerous phone survey interviews, and Dennis Werlau for producing our weekly field activity reports throughout the 2021 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 October 17, 2021 (the Columbia Point station opened 4/19/21). 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 89,542 Northern Pikeminnow ≥ 228 mm fork length (FL) and 2,408 Northern Pikeminnow < 228 mm FL were harvested during the 2021 NPSRF season. There were 1,608 individual anglers who spent 11,553 angler days of effort participating in the NPSRF during the 2021 season. Catch per unit effort for combined returning and non-returning anglers was 7.75 fish/angler day. The Oregon Department of Fish and Wildlife (ODFW) estimated that the Northern Pikeminnow harvest activities from the 2021 NPSRF resulted in an overall exploitation rate of 12.9% (Waltz et al. 2022).

Anglers submitted 75 Northern Pikeminnow with external ODFW spaghetti or Floy tags, all of which had an internal ODFW PIT tag. There were also 99 Northern Pikeminnow with ODFW PIT tags, but missing spaghetti or Floy tags (tag-loss). Additionally, 45 PIT tags from ingested juvenile salmonids were recovered from Northern Pikeminnow received during the 2021 NPSRF.

Peamouth *Mylocheilus caurinus*, Smallmouth Bass *Micropterus dolomieue*, and Sculpin *Cottoidea* 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 was low and continued to remain well 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 ($\geq$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 nearly 5.3 million reward sized Northern Pikeminnow and spent over 979,000 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).

A tiered angler reward system developed in 1995 (Hisata et al. 1996) was used to pay anglers increasingly higher rewards per fish based on achieving designated harvest levels. Rewards tiers were a base reward of $5 per fish for the first 25 eligible fish turned in. Fish from #26-200 were paid $6 per fish, and all eligible fish >200 were paid at $8 per fish. Anglers continued to be rewarded 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 start of the 2021 NPSRF returned to May 1st*, 2021 and the season was extended at limited stations through October 17th, 2021 (the Columbia Point station opened 4/19/21 on a trial basis).

The objectives of the 2021 NPSRF were to (1) implement a public fishery that rewards recreational anglers for harvesting Northern Pikeminnow $\geq$ 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 from this segment of NPSRF participants.

METHODS OF OPERATION

Fishery Operation

Boundaries and Season

The 2021 NPSRF started for most stations* on May 1st (Columbia Point opened on April 19th), and 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 as done since 1991 (Figure 1). The 2021 NPSRF also resurrected "Satellite stations, which operated for varying portions of the usual 5-month NPSRF season. 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 2021 season was also extended at limited stations through October 17, 2021.

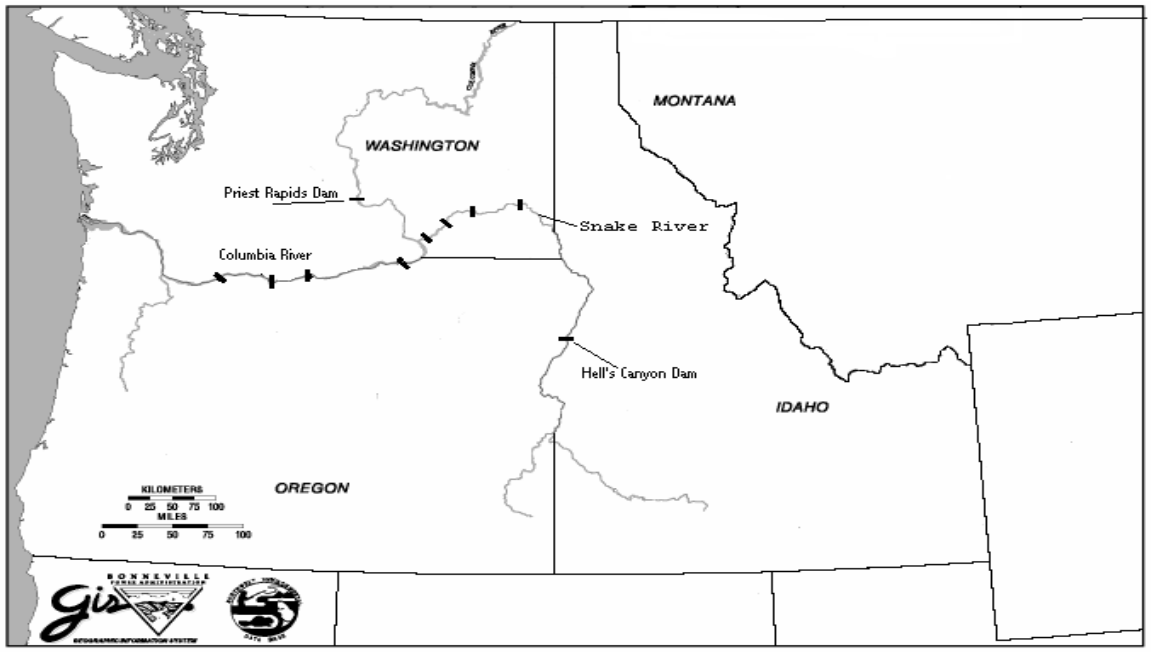
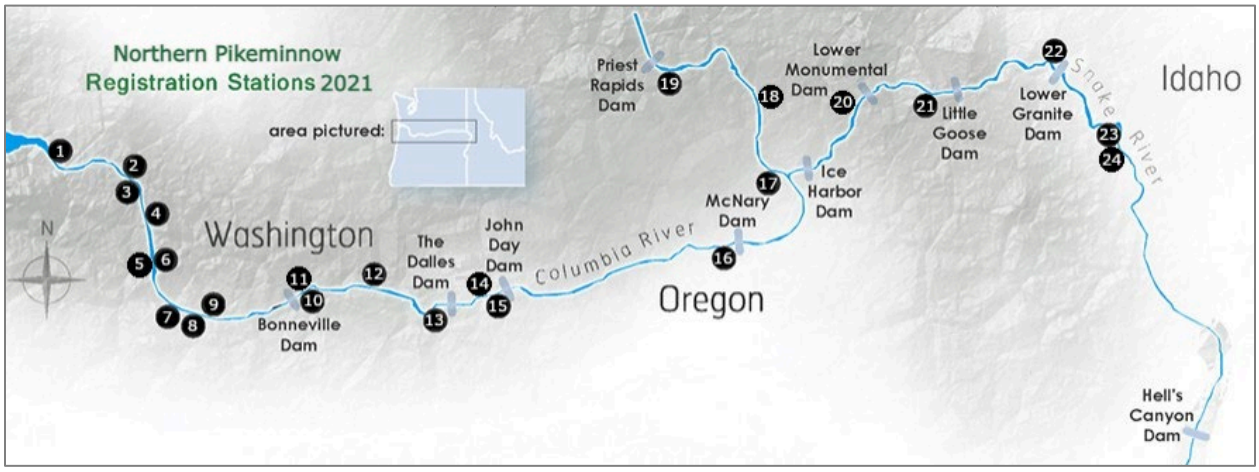


Figure 1. Northern Pikeminnow Sport-Reward Fishery Program Area

Registration Stations

Twenty-four 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 4.5 hours per day during the season. In addition, "satellite stations" were again used in 2021 at select locations for portions of the 5-month season to take advantage of short-term Pikeminnow harvest opportunities near them. 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- 1:15 pm)
2.Willow Grove (2.00 pm - 4:00 pm)
3.Rainier Marina (11:15 am - 1:00 pm)
4.Kalama (1:30 pm - 4:30 pm)
5.Scappoose Bay (8:30 am - 10:30 am) [5/1-8/15]
6.Ridgefield Marina (8:00 - 10:30 am)
7.Gleason Boat Ramp (1:00 pm - 3:30 pm)
8.Chinook Landing (8:30 am - 12:30 pm)
9.Washougal (11:30 pm - 3:30 pm)
10.Cascade Locks (2:00 pm - 5:00 pm)
11.Stevenson (9:00 am -12:00 pm) [7/12-10/17]
12.Bingen (8:30 am - 12:00 pm) [5/1-7/25]
13.The Dalles (8:30 am - 1:00 pm)
14.Maryhill (11:00 am - 1:00 pm) [7/19-10/3]
15.Giles French (1:00 pm - 5:00 pm)
16.Umatilla (9:30 am - 1:00 pm)
17.Columbia Point (2:00 pm - 6:00 pm)
18.Ringold (2:00 pm - 5:30 pm) [8/2-10/3]
19.Vernita (10:00 am - 1:00 pm) [8/2-10/17]
20.Windust (1:00 pm - 5:00 pm) [5/31-8/1]
21.Lyon's Ferry (10:00 am - 12:00 pm) [5/31-8/1]
22.Boyer Park (12:30 pm - 3:30 pm)
23.Greenbelt (9:30 am - 11:00 am)
24.Swallow's Park (5:00 pm - 6:30 pm)

Figure 2. 2021 Northern Pikeminnow Sport-Reward Fishery registration stations and hours of operation

Reward System

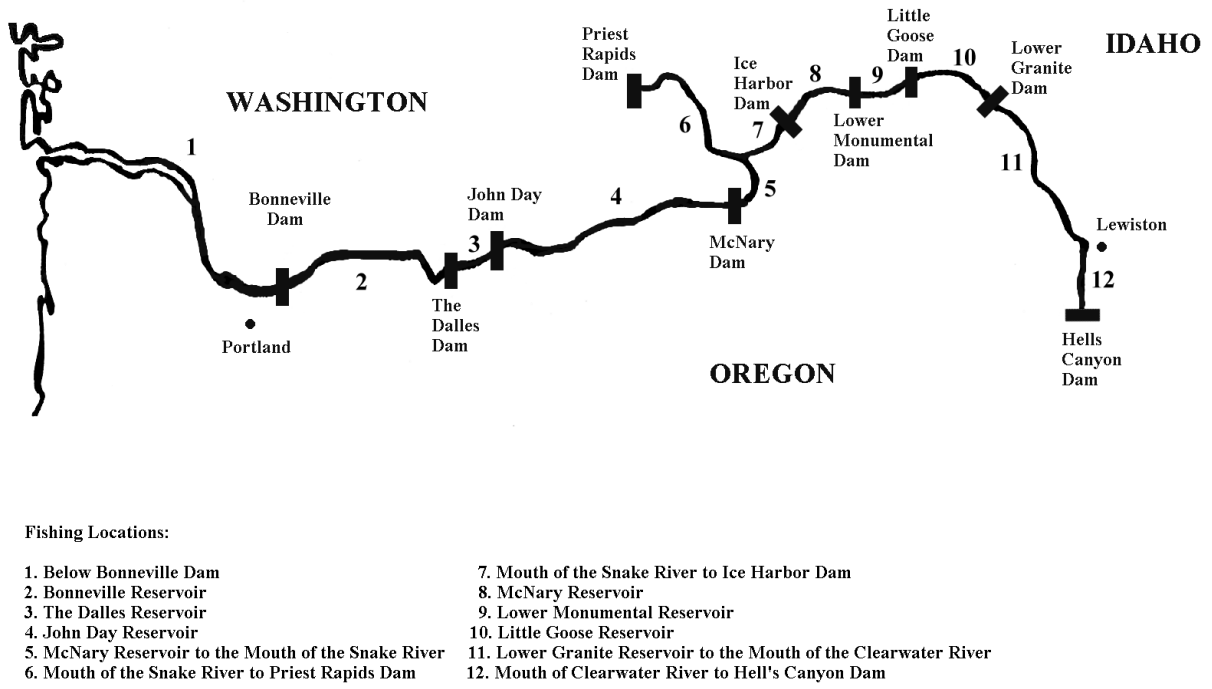
The 2021 NPSRF rewarded anglers for harvesting Northern Pikeminnow ≥ 228mm TL (9 inches TL) using a tiered reward system first implemented in 1995 (Hisata et al. 1996), which paid anglers a higher reward per fish once they had reached designated harvest levels over the course of the season. To receive 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 2021 season reflected changes (to increase participation) that were last 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. 2021 NPSRF anglers were also paid $100 for each Northern Pikeminnow missing an external tag, but retaining the ODFW PIT tag (referred to as "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 2021 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 from each station 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 also not collected in 2021 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 from 2019-21. 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 2021 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 dissection and PIT tag recovery. All tag 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, Pacific States Marine Fisheries Commission 2021) 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. 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 2021 NPSRF, anglers harvested a total of 89,542 reward size Northern Pikeminnow (≥ 228 mm TL) over the course of a 26 week field season. The 2021 season began with a single station (Columbia Point) opening 4/19/21 and also included a 17 day season extension at limited stations through October 17th. Harvest was the lowest ever recorded in the 31 years the NPSRF has been fully implemented. Harvest was well below mean 1991-2020 harvest of 167,938 fish and 13,393 fish lower than the previous historic low harvest in 2020 (Hone et al. 2021) (Figure 4). The 2021 NPSRF harvest was estimated to equal an exploitation rate of 12.9% (Waltz et al. 2022). In addition to harvesting 89,542 reward size Northern Pikeminnow, anglers participating in the 2021 NPSRF also harvested 2,408 Northern Pikeminnow < 228 mm TL.

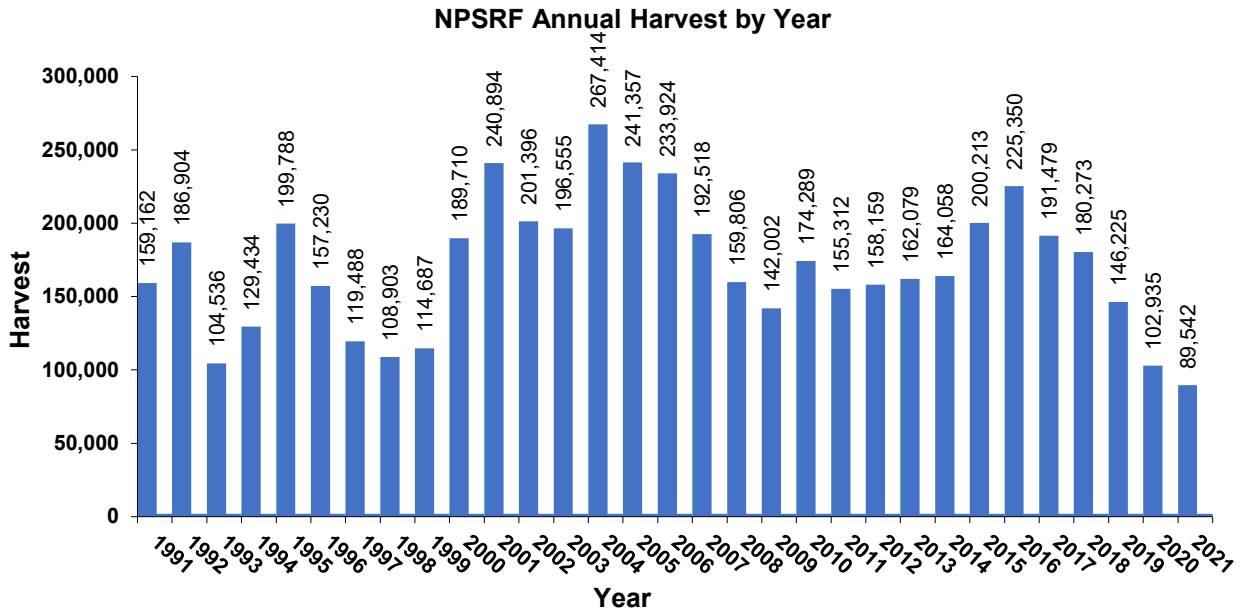


Figure 4. Annual harvest totals for the Northern Pikeminnow Sport-Reward Fishery

Harvest by Week

Peak weekly harvest was 6,356 Northern Pikeminnow and occurred in week 39, which was the first time peak NPSRF harvest has occurred outside the typical week 24-26 period (Figure 5). Peak harvest for 2021 occurred 15 weeks later (Figure 6) than in 2020 and was also 13 weeks later the NPSRF's historical 1991-2019 peak in week 26 (Fox et al. 2000), which normally coincides with peak Pikeminnow spawning activity (Figure 7). Mean weekly harvest was lower in 2021 (3,444) than in 2020 (4,679) and total weekly harvest was below 2020 weekly harvest for 24 of the 26 weeks of the season (Hone et al. 2021). The far-reaching effects of the COVID-19 pandemic were

likely a major factor in continuing to negatively affect angler participation and result in 2021 harvest again being the NPSRF's lowest to date (for the second consecutive season).

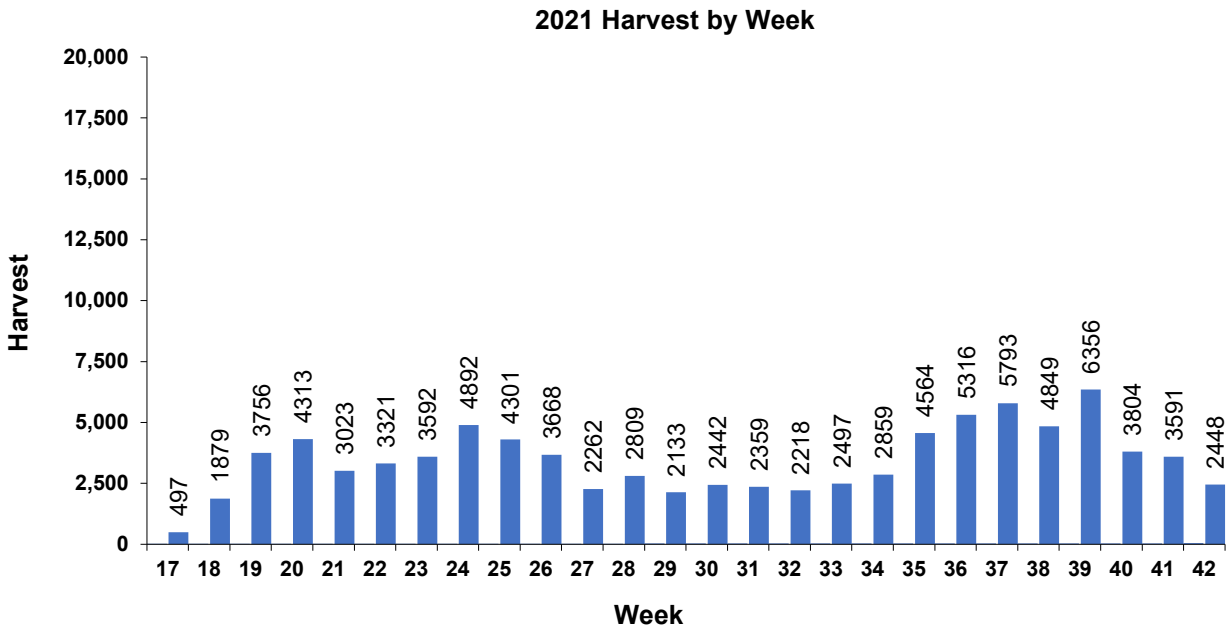


Figure 5. 2021 Weekly Northern Pikeminnow Sport-Reward Fishery harvest

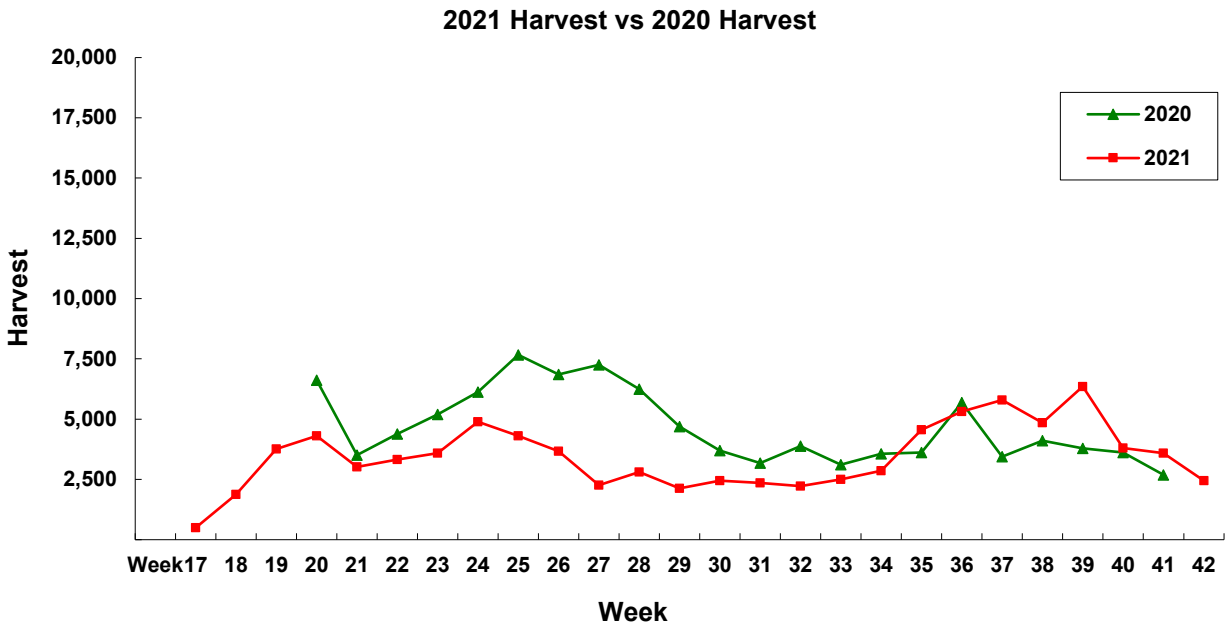


Figure 6. 2021 Weekly NPSRF harvest vs 2020 weekly harvest

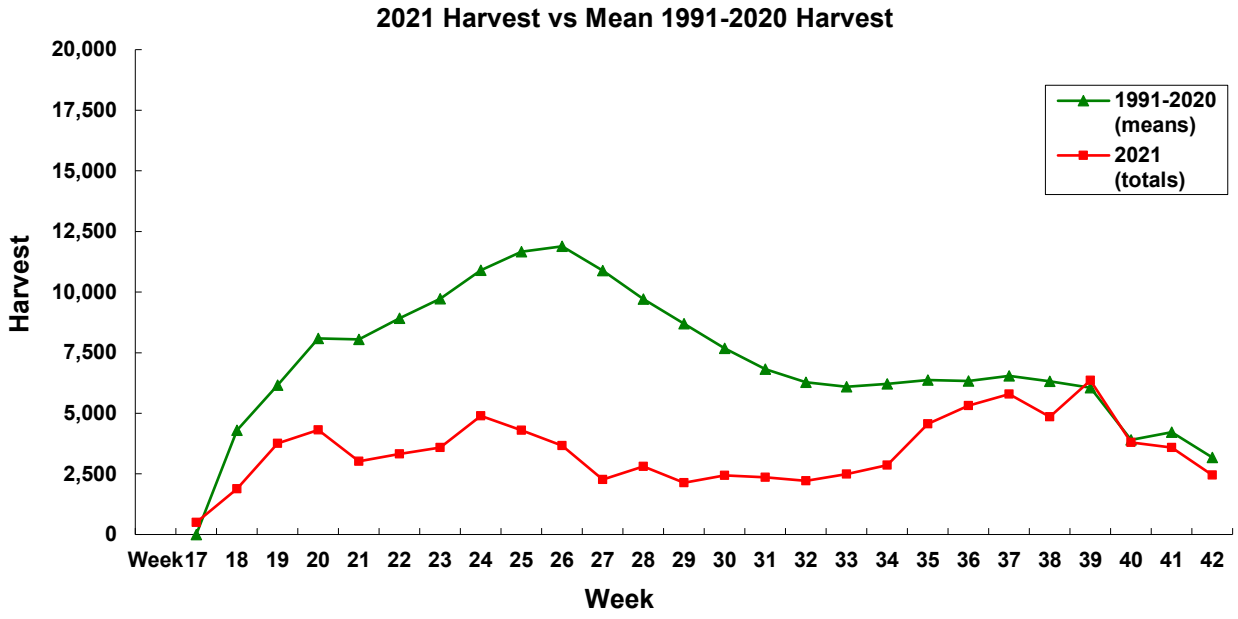


Figure 7. Comparison of 2021 NPSRF weekly harvest to 1991-2020 mean weekly harvest

Harvest by Fishing Location

The mean harvest by fishing location for the 2021 NPSRF was 7,462 Northern Pikeminnow (compared to 8,578 in 2020) and ranged from 37,938 reward size Northern Pikeminnow in fishing location 01 (Below Bonneville Dam) to only 29 Northern Pikeminnow from fishing location 5 (McNary Dam to the mouth of the Snake River) (Figure 8). Harvest from fishing location 01 (the Columbia River below Bonneville Dam) decreased from 51.08% of total NPSRF harvest in 2020 to 42.37% of total NPSRF harvest in 2021, although it continued to be the highest producing location in 2021, as it has been for all but one of the preceding 30 NPSRF seasons (Hone et al. 2021). Bonneville Reservoir (Fishing Location 02 was the second highest producing fish location area accounting for 19.53% of total 2021 NPSRF harvest.

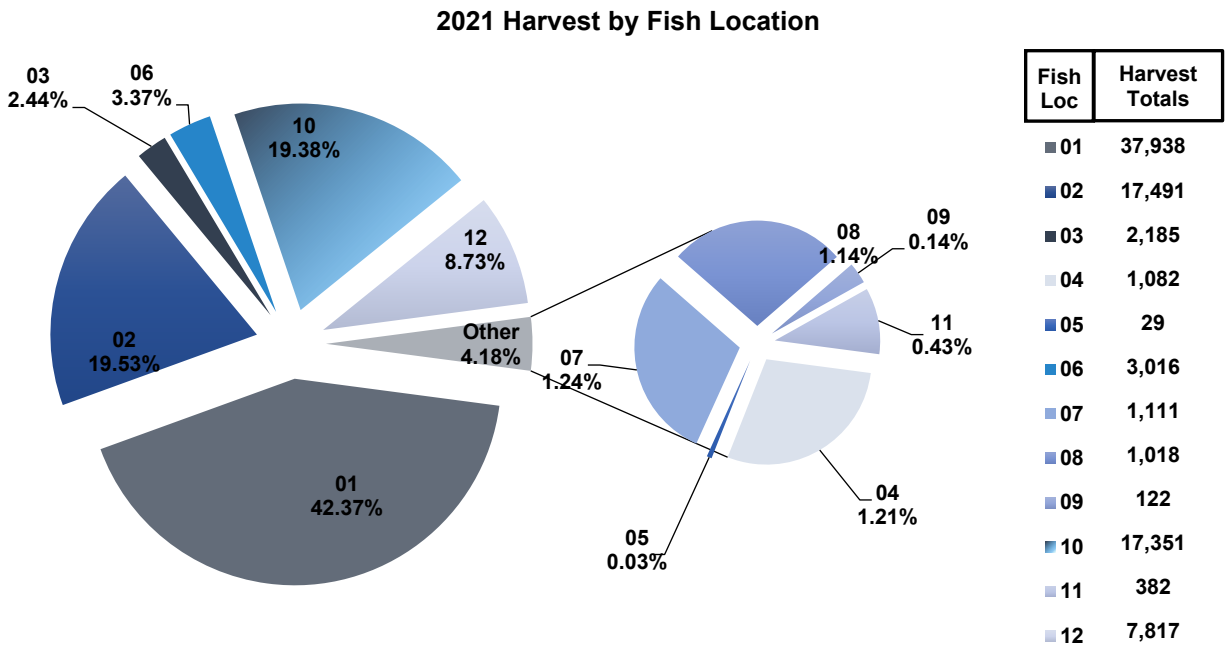


Figure 8. 2021 Northern Pikeminnow Sport-Reward Fishery harvest by fishing location*
*Fishing Location Codes for **Columbia River**; 01 = Below Bonneville Dam, 02 = Bonneville Reservoir, 03 = The Dalles Reservoir, 04 = John Day Reservoir, 05 = McNary Dam to the mouth of the Snake River, 06 = Mouth of 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 2021 was down from 2020 at 13 of the 18 registration stations used in 2020 (there were 6 additional "satellite" stations added in 2021). The Boyer Park registration station regained the title of the NPSRF's top producing station in 2021, where anglers harvested 17,086 Northern Pikeminnow, equaling 19.1% of total NPSRF harvest (Figure 9). The average harvest per registration station was 3,731 reward size Northern Pikeminnow, down from 5,719 per station in 2020 (Hone et al. 2021), although this average included the 6 "satellite" stations which were not open for the entire May through September NPSRF season.

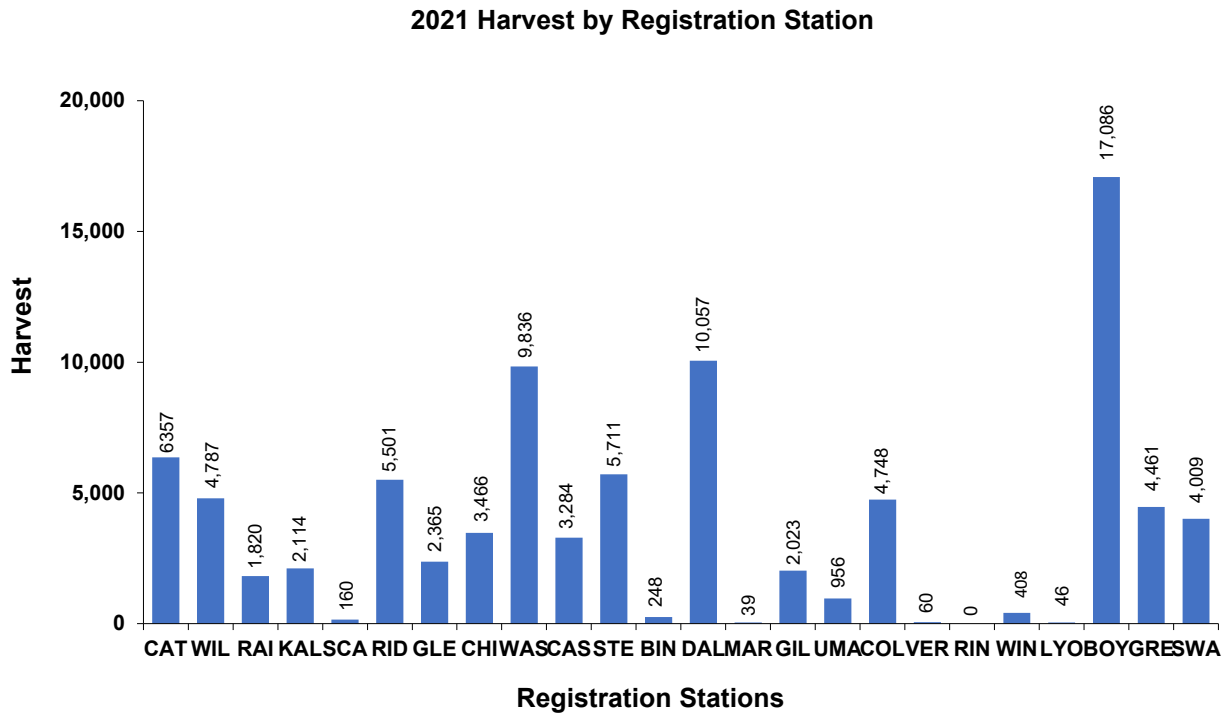


Figure 9. 2021 Northern Pikeminnow Sport-Reward Fishery harvest by registration station
CAT-Cathlamet, WIL-Willow Grove, RAI-Rainier, KAL-Kalama, SCA-Scappoose Bay, RID-Ridgefield, GLE-Gleason, CHI-Chinook, WAS-Washougal, CAS-Cascade Locks, STE-Stevenson, BIN-Bingen, DAL- The Dalles, MAR-Maryhill, GIL-Giles, UMA-Umatilla, COL-Columbia Point, VER-Vernita, RIN-Ringold, WIN-Windust, LYO-Lyon's Ferry, BOY-Boyer Park, GRE-Greenbelt, SWA-Swallows.

Harvest by Species/ Incidental Catch

Returning anglers

In addition to catching Northern Pikeminnow, returning anglers participating in the 2021 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 2021.

Salmonids

Species	Caught	Harvest	Harvest Percent
Steelhead Juvenile (Wild)	261	0	0%
Trout (Unknown)	26	3	12%
Steelhead Juvenile (Hatchery)	43	0	0%
Chinook (Adult)	4	2	50%
Chinook (Jack)	10	2	20%
Steelhead Adult (Wild)	10	0	0%
Cutthroat (Unknown)	12	1	8%
Chinook (Juvenile)	65	0	0%
Steelhead Adult (Hatchery)	15	1	7%
Sockeye (Adult)	1	1	100%
Coho (Adult)	8	1	13%

Anglers reported that all juvenile salmonids caught during the 2021 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 caught incidentally during the 2021 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 2021 were most often Peamouth, Smallmouth Bass, and Sculpin (Table 2).

Table 2. Catch and harvest of non-Salmonids by returning anglers targeting Northern Pikeminnow in 2021

Non-Salmonids

Species	Caught	Harvest	Harvest Percent
Northern Pikeminnow >228mm	89,545	89,540	99.99%
Northern Pikeminnow <228mm	26,276	2,408	9.16%
Peamouth	10,532	4,371	41.50%
Smallmouth Bass	7,444	604	8.11%
Sculpin (unknown)	4,092	2,771	67.72%
Yellow Perch	2,689	962	35.78%
Channel Catfish	916	100	10.92%
White Sturgeon	752	11	1.46%
Sucker (unknown)	602	89	14.78%
Walleye	673	352	52.30%
Catfish (unknown)	713	67	9.40%
Bullhead (unknown)	318	20	6.29%
Chiselmouth	287	48	16.72%
Carp	131	10	7.63%
Starry Flounder	68	9	13.24%
Bluegill	25	1	4.00%
American Shad	62	19	30.65%
Largemouth Bass	36	2	5.56%
Crappie (unknown)	7	0	0%
Pumpkinseed	1	0	0%
Sandroller	4	1	25.00%

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 24 stations in order to determine and record their catch and/or harvest of reward sized Northern Pikeminnow and other incidentally caught fish species. In 2021, there were 2,997 non-returning angler days recorded and a total of 500 calls were completed to non-returning anglers (16.7% 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 2021 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 2021 NPSRF. Estimated totals are listed in columns 5 and 6 of Table 3.

Table 3. 2021 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	75	9	12.00%	450	54
Northern Pikeminnow ≥ 228 mm	17	15	88.24%	102	90
Trout (Unknown)	4	0	0%	24	0
Steelhead Juvenile	1	0	0%	6	0
Chinook Salmon (Adult)	2	0	0%	12	0

Fork Length Data

The length frequency distribution for harvested Northern Pikeminnow (≥ 200 mm) from the 2021 NPSRF is presented in Figure 10. Fork length data from 68,207 Northern Pikeminnow ≥ 200 mm FL (76% of total harvest) were taken during the 2021 NPSRF. The mean fork length for all measured Northern Pikeminnow (≥ 200 mm) in 2021 was 277.7 mm (SD= 66.93 mm), down from 289.9 in 2020 (Hone et al. 2021).

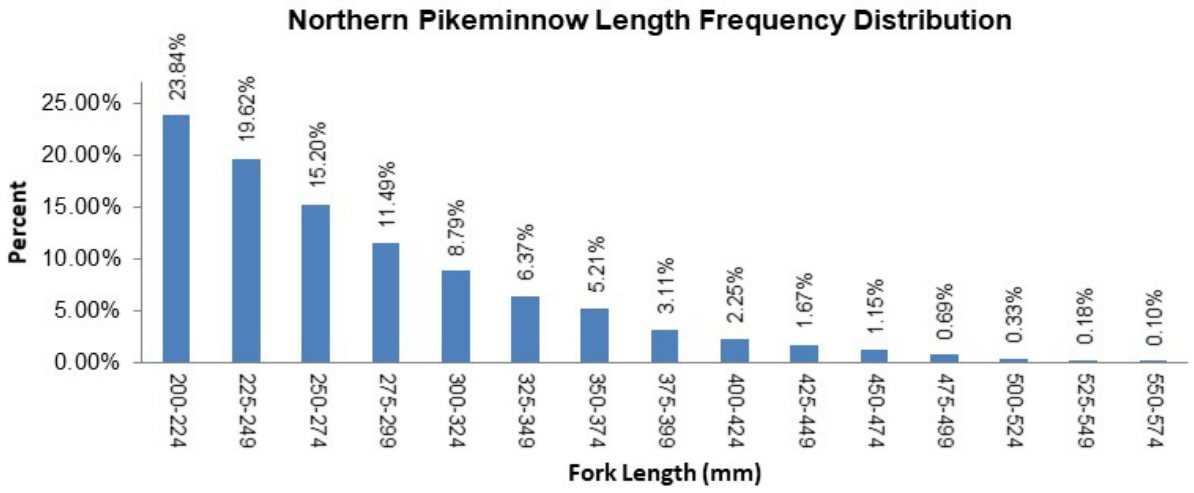


Figure 10. Length frequency distribution of Northern Pikeminnow ≥ 200 mm FL from 2021 NPSRF. n=68,207

Angler Effort

The 2021 NPSRF recorded total effort of 11,553 angler days spent during the season, a decrease of 4,429 angler days from 2020 (Hone et al. 2021) (Figure 11). The ongoing COVID-19 pandemic continued to have residual negative effects on angler participation in 2021 according to anecdotal angler accounts. When total effort is divided into returning and non-returning angler days, 8,556 angler days (74%) were recorded by returning anglers, and 2,997 angler days (26%) were spent by non-return anglers. The percentage of returning anglers in 2021 increased from 69.3% in 2020 (Hone et al. 2021). In addition, 61% of total effort, and 85% of returning angler effort (7,269 angler days), was attributed to successful anglers who harvested at least one Northern Pikeminnow in 2021.

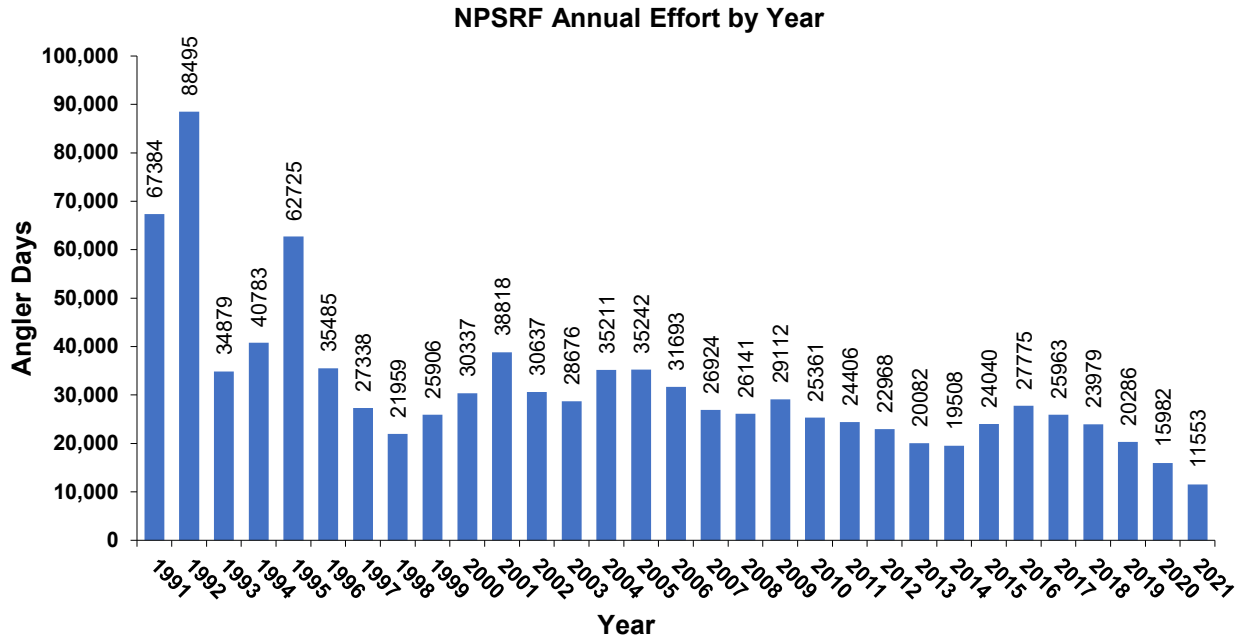


Figure 11. Annual Northern Pikeminnow Sport-Reward Fishery effort

Effort by Week

Mean weekly effort for the 2021 NPSRF was 444 angler days during the season, with the peak occurring in week 20, the first full week of the season (Figure 12). When we compare weekly effort totals for 2021 with the 2020 season, weekly effort totals from all but one week were below those of 2020 (Hone et al. 2021) (Figure 13). Overall, mean weekly effort decreased from 726 in 2020 to 444 in 2021 (Hone et al. 2021). Weekly effort totals continue to follow a recent pattern where peak effort occurs at or near the start of the season (Figure 14). This is different from prior historical effort data from 1991-2015 (Winther et al. 2016) where peak effort typically occurred on the same week as peak harvest (Figure 14).

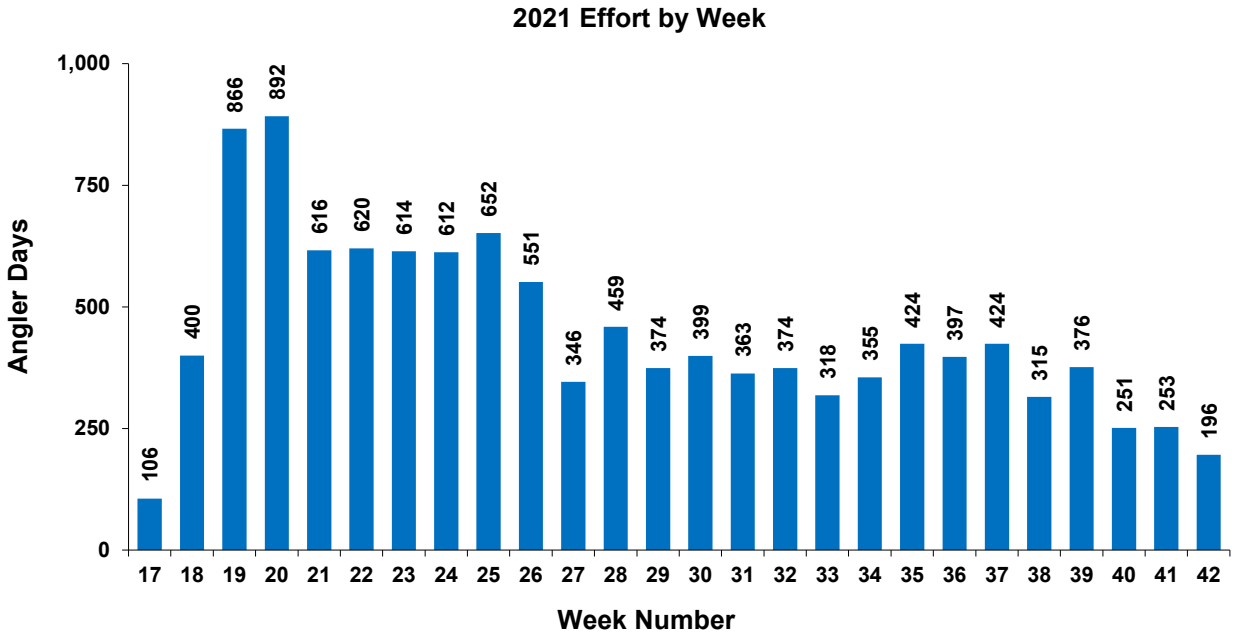


Figure 12. 2021 Weekly Northern Pikeminnow Sport-Reward Fishery angler effort

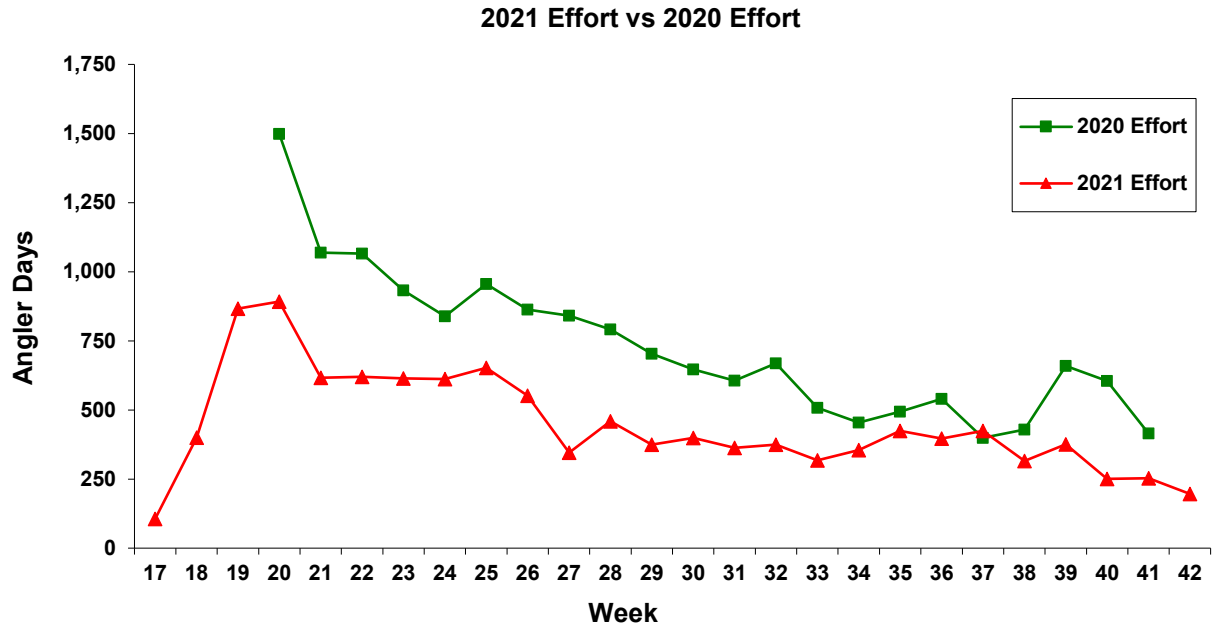


Figure 13. Effort 2021 Northern Pikeminnow Sport-Reward Fishery effort vs 2020 effort

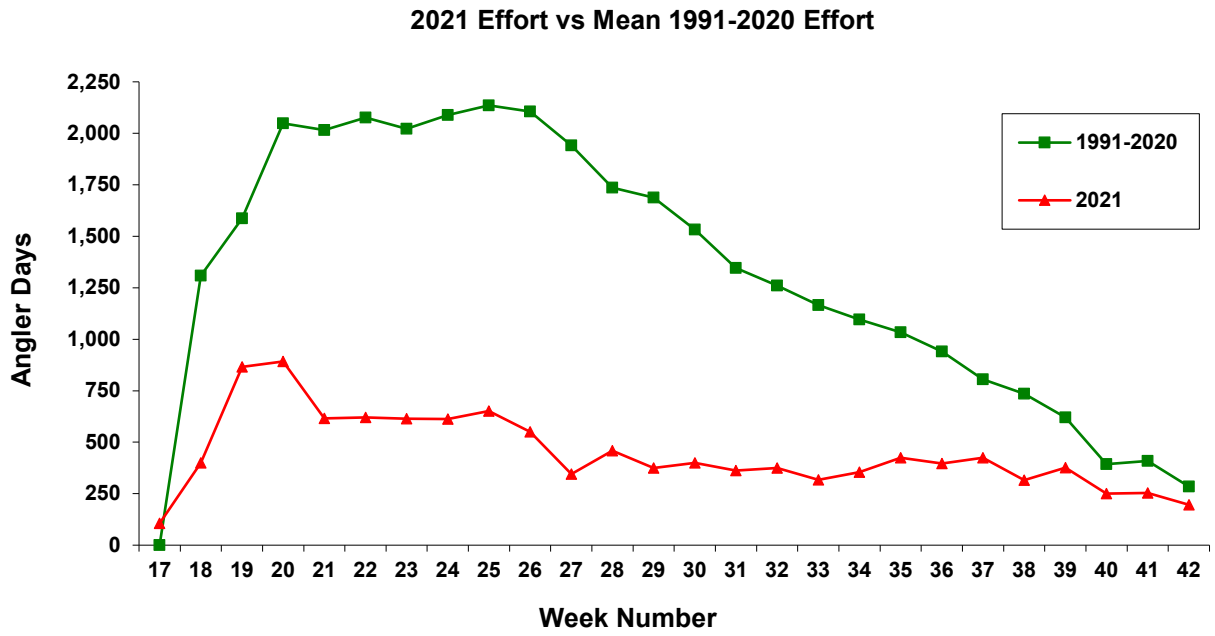


Figure 14. 2021 NPSRF weekly effort vs mean 1991-2020 effort

Effort by Fishing Location

Mean annual effort by fishing location for the 2021 NPSRF (returning anglers only) increased from 922 angler days in 2020 (Hone et al. 2021) to 963 angler days in 2021. Effort totals ranged from 3,204 angler days spent in fishing location 01 (below Bonneville dam) to only 3 angler days spent in fishing location 05 (McNary Dam to the mouth of the Snake River) (Figure 15). Only Locations 06, 09, and 11 recorded an increase in angler effort in 2021.

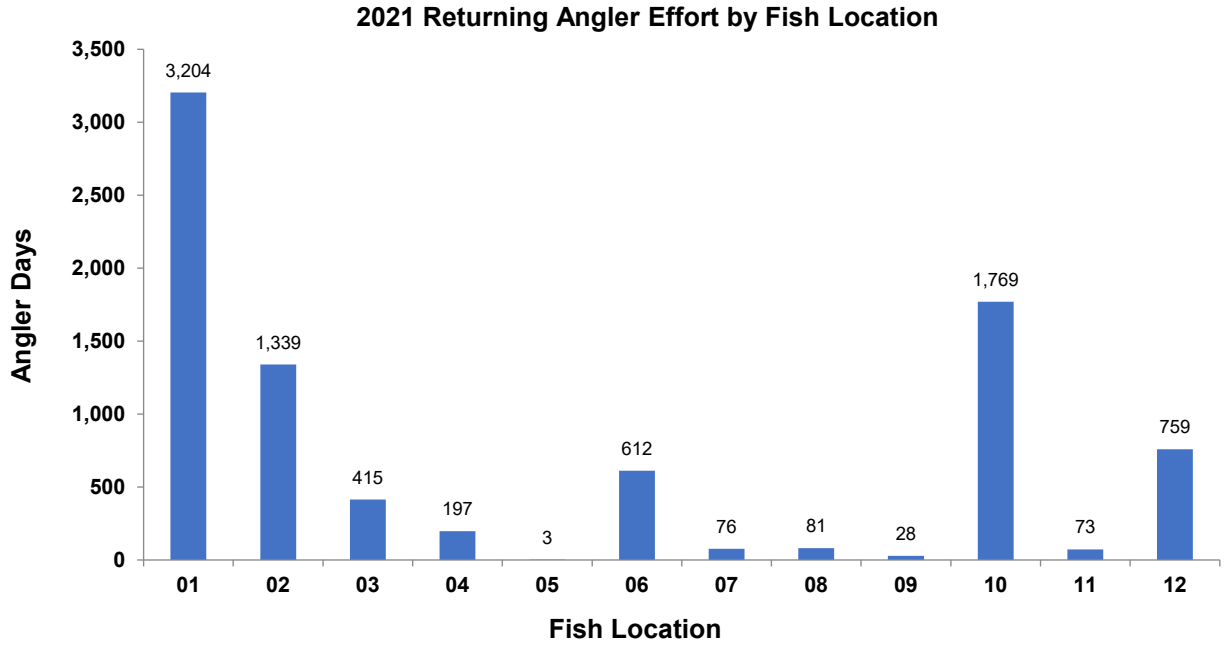


Figure 15. 2021 NPSRF angler effort by fishing location* (returning anglers only).
*Fishing Location Codes for **Columbia River**; 01 = Below Bonneville Dam, 02 = Bonneville Reservoir, 03 = The Dalles Reservoir, 04 = John Day Reservoir, 05 = McNary Dam to the mouth of the Snake River, 06 = Mouth of the 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 2021 NPSRF was 481 angler days compared to 888 angler days in 2020 (Hone et al. 2021). Effort totals ranged from a high of 1,845 angler days at the Boyer station to only 2 angler days at the Ringold station (Figure 16). Some of the reduction in mean effort per station in 2021 may be attributed to the 2021 NPSRF using six Satellite stations which were not open for the entire May through September season.

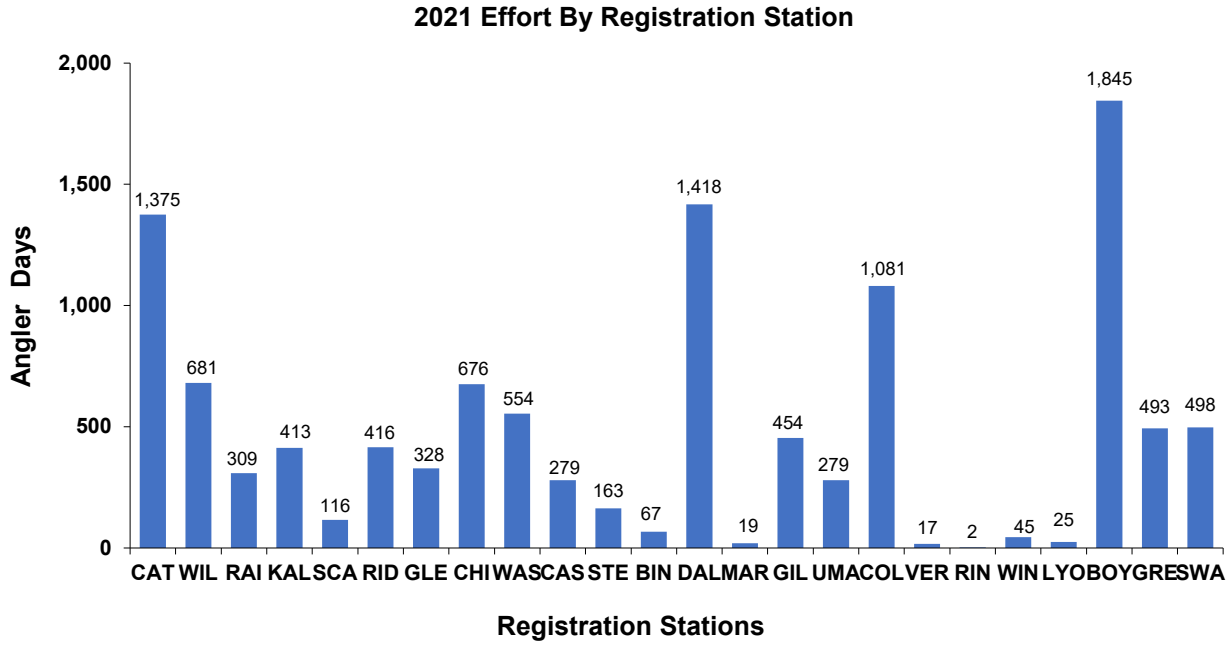


Figure 16. 2021 Northern Pikeminnow Sport-Reward Fishery angler effort by registration station
CAT-Cathlamet, WIL-Willow Grove, RAI-Rainier, KAL-Kalama, SCA-Scappoose Bay, RID-Ridgefield, GLE-Gleason, CHI-Chinook, WAS-Washougal, BEA-Beacon Rock, CAS-Cascade Locks, STE-Stevenson, BIN-Bingen, DAL-The Dalles, MAR-Maryhill, GIL-Giles, UMA-Umatilla, COL-Columbia Point, VER-Vernita, RIN-Ringold, WIN-Windust, LYO-Lyon's Ferry, BOY-Boyer Park, GRE-Greenbelt, SWA-Swallows.

Catch Per Angler Day (CPUE)

The 2021 NPSRF recorded an overall (returning + non-returning anglers) catch per unit of effort (CPUE or "catch rate") of 7.75 Northern Pikeminnow harvested per angler per day during the season. This catch rate was up from the 2020 overall CPUE of 6.44 (Figure 17) and since angler CPUE was higher for all anglers regardless of angler Tier level, it indicates that angling conditions throughout the NPSRF area were generally more favorable during 2021 than in 2020. Angler CPUE has generally trended upwards throughout the NPSRF's 31-year history, and although CPUE declined each of the previous 2 years, CPUE in 2021 resumed the NPSRF's historical

upward trend. Returning angler CPUE during the 2021 NPSRF was 12.32 Northern Pikeminnow per angler day, up from the 2020 returning angler CPUE of 9.30 (Hone et al. 2021). The estimated CPUE for non-returning anglers was estimated to be 0.02 reward size Northern Pikeminnow per angler day based on 2021 NPSRF phone survey results and has remained constant throughout the 31-year NPSRF history.

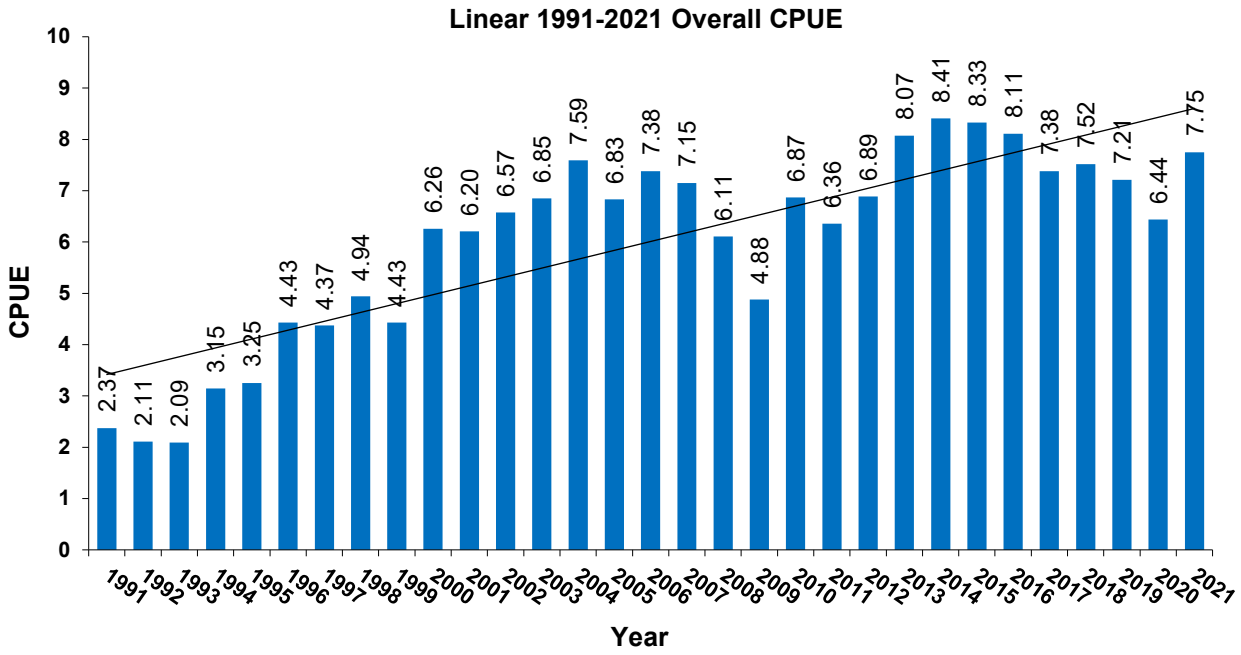


Figure 17. Annual NPSRF CPUE (returning + non-returning anglers) for the years 1991-2021

CPUE by Week

Mean angler CPUE by week for the 2021 NPSRF was 8.49 fish per angler day compared to 6.77 in 2020 (Hone et al. 2021) and ranged from a low of 4.34 in week 19 (May 10-16) to a peak of 16.9 in week 39 (September 27-October 3) (Figure 18). Weekly CPUE for the 2021 NPSRF followed a typical two-peak pattern with the first peak in week 24 near the historical Northern Pikeminnow spawning peak and then again late in the season (week 39) when favorable late-season water and angling conditions are typically present in the lower Columbia and Snake rivers (Winther et al. 2011).

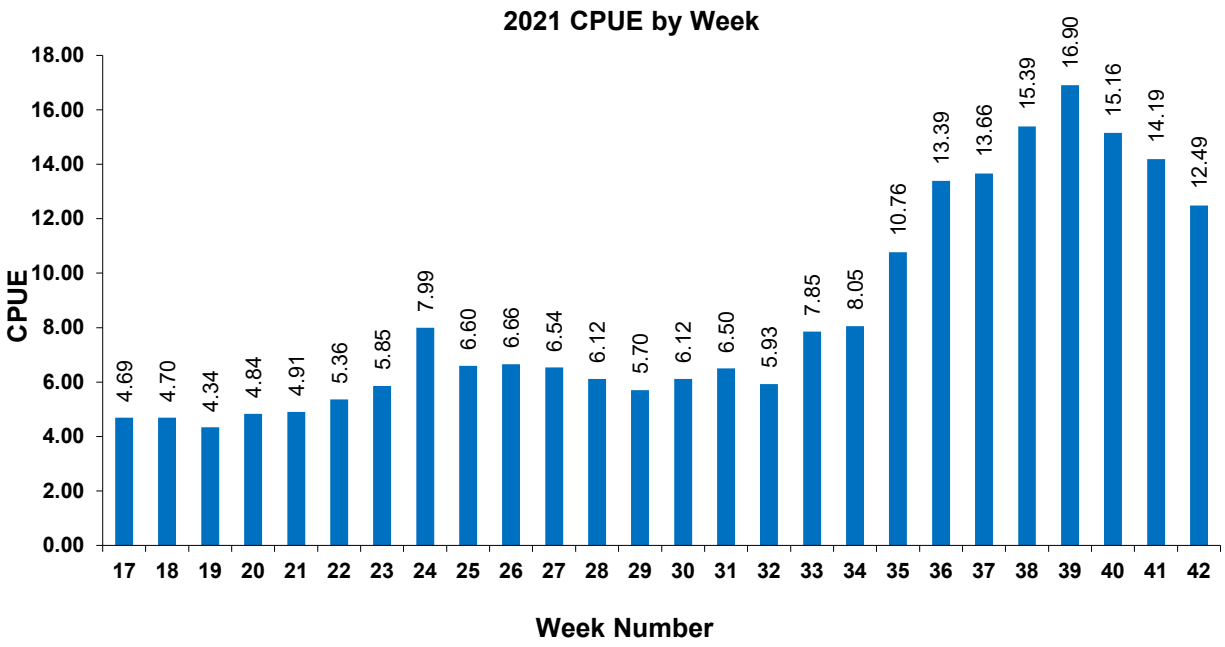


Figure 18. 2021 Northern Pikeminnow Sport-Reward Fishery angler CPUE by week

CPUE by Fishing Location

Angler success rates for the 2021 NPSRF (as indicated by CPUE), are represented by returning angler data only and varied by fishing location. Success rates ranged from a high of 14.62 Northern Pikeminnow per angler day in fishing location 07 (Mouth of Snake River to Ice Harbor Dam) to a low of 4.36 fish per angler per day in fishing location 09 (Lower Monumental Reservoir) (Figure 19). CPUE increased at six of the 12 fishing locations in 2021. The average CPUE by fishing location (returning anglers only) was 8.93 Northern Pikeminnow per angler day in 2021 compared to 8.10 in 2020 (Hone et al. 2021).

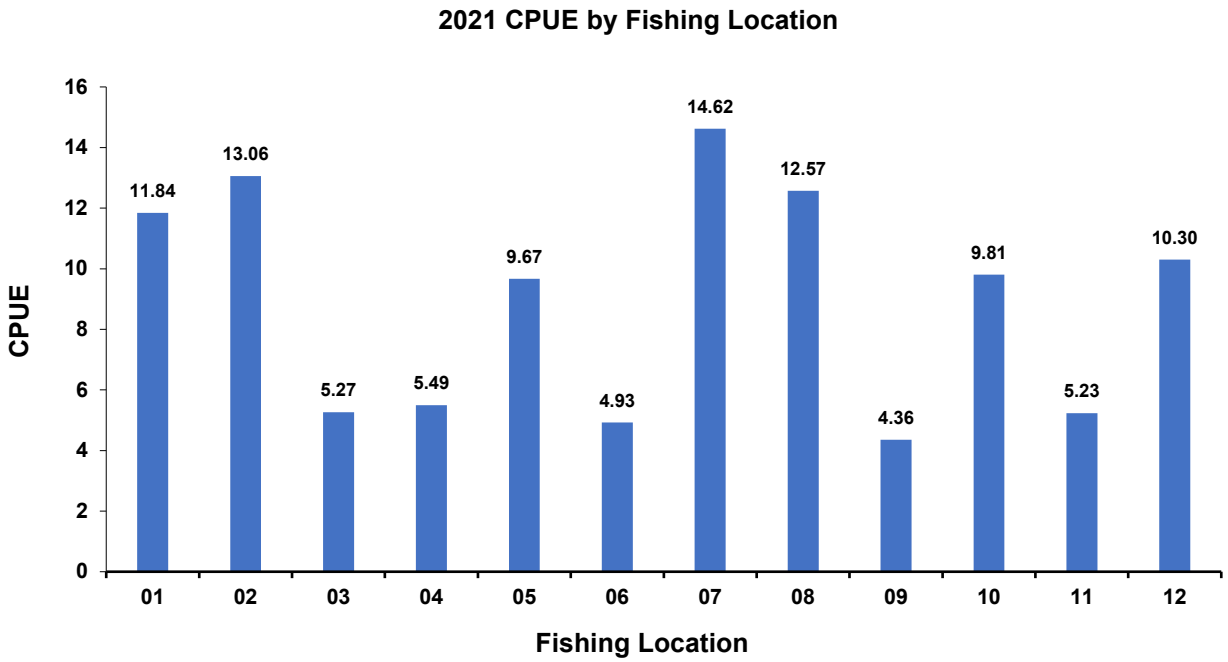


Figure 19. 2021 Northern Pikeminnow Sport-Reward Fishery angler CPUE by fishing location.*
*Fishing Location Codes for **Columbia River**; 01 = Below Bonneville Dam, 02 = Bonneville Reservoir, 03 = The Dalles Reservoir, 04 = John Day Reservoir, 05 = McNary Dam to the mouth of the Snake River, 06 = Mouth 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 2021 NPSRF was the Stevenson station where anglers averaged 35.04 Northern Pikeminnow per angler day (Figure 20). The registration station with the lowest CPUE was the Scappoose Bay Marina station with a CPUE of 1.38 Northern Pikeminnow per angler day (the Ringold station received zero fish during limited operations). The station average for angler CPUE was 7.50 in 2021, up from 5.90 in 2020 (Hone et al. 2021). Angler CPUE by registration station increased at 11 of the 24 stations operated during the 2021 NPSRF season (as well as at 5 of the 6 new satellite stations utilized in 2021). The largest CPUE increase occurred at the new Stevenson station, where CPUE was more than twice the level of the 13.5 CPUE at the NPSRF's top CPUE station from the previous year in 2020 (Washougal) (Hone et al. 2021).

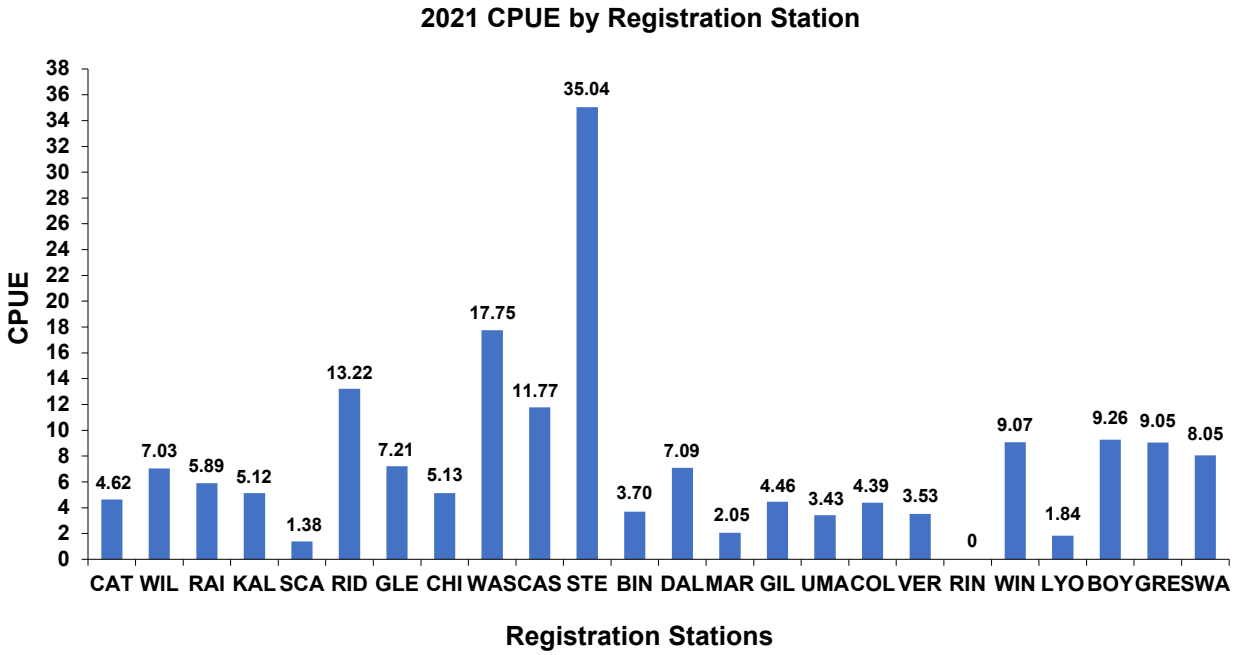


Figure 20. 2021 Northern Pikeminnow Sport-Reward Fishery angler CPUE by registration station
CAT-Cathlamet, WIL-Willow Grove, RAI-Rainier, KAL-Kalama, SCA-Scappoose Bay, RID-Ridgefield, GLE-Gleason, CHI-Chinook, WAS-Washougal, CAS-Cascade Locks, STE-Stevenson, BIN-Bingen, DAL-The Dalles, MAR-Maryhill, GIL-Giles, UMA-Umatilla, COL-Columbia Point, VER-Vernita, RIN-Ringold, WIN-Windust, LYO-Lyon's Ferry, BOY-Boyer Park, GRE-Greenbelt, SWA-Swallows Park.

Angler Totals

There were 1,608 separate anglers who participated in the 2021 NPSRF, a decrease of 825 participants from 2020. Six hundred forty-five of these anglers (40% of total vs. 36.3% in 2020 were classified as successful, harvesting at least one reward size Northern Pikeminnow (for which a voucher was issued) during the 2021 season. Of the successful anglers, 73% (472 anglers) sent in their vouchers to PSMFC for payment (PSMFC 12/7/21 Sport-Reward Payment Summary) while 173 anglers (27%) did not. The average successful angler harvested 138 Northern Pikeminnow during the 2021 NPSRF, compared to 117 fish per angler in 2020 (Hone et al. 2021).

When we break down the 645 successful anglers by tier, 450 of these anglers (70%) harvested fewer than 25 Northern Pikeminnow in 2021 and were classified as Tier 1 anglers (Figure 21). This percentage is up slightly from the 633 individual Tier 1 anglers in 2020. The number of Tier 2 anglers declined to 115 (18%) in 2021, down from 149 in 2020. The number of Tier 3 anglers (known as "highliners") decreased from 100 anglers in 2020 to 80 anglers (12%) in 2021 (Hone et al. 2021).

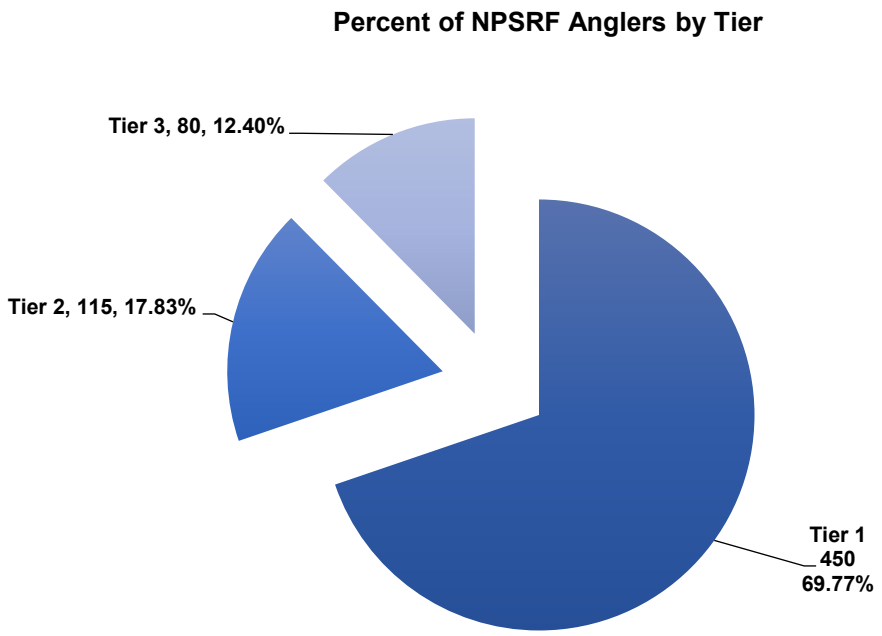


Figure 21. 2021 NPSRF anglers by tier (returning anglers) based on total harvest

Despite lower angler participation for the second consecutive year, the NPSRF continued to see a relatively high number of individual anglers at Tiers 2 and 3, as a component of successful anglers. This was especially important in achieving NPSRF harvest and exploitation objectives in 2021 since Tier 2 and Tier 3 anglers have a much higher CPUE than Tier 1 anglers (Hisata et al. 1996), and thus are responsible for maintaining an adequate level of overall NPSRF harvest. With continuing COVID-19 issues in effect in 2021, it is not surprising that Tier 1 anglers (usually new anglers), which make up the largest group of SRF anglers, were down since they are the anglers most likely to need additional fishing guidance that was still not as available to them in 2021 as it was pre-Covid.

While Tier 1 anglers made up 70% of all successful NPSRF participants in 2021, they accounted for only 2.9% of total NPSRF harvest (2,601 Northern Pikeminnow) (Figure 22). Tier 2 anglers made up 18% of all successful anglers and harvested 10% of total NPSRF harvest (8,917 fish). Tier 3 anglers made up 5% of all participants (returning and non-returning anglers combined), and 12% of all successful anglers, accounting for 87.1% of total NPSRF harvest (78,024 fish).

Average annual harvest per angler was up slightly for Tier 1 anglers and significantly for Tier 3 anglers, while down slightly for Tier 2 anglers. Tier 1 anglers annual average harvest was 5.78 fish per year in 2021, up from 5.45 fish per year in 2021. Tier 2 anglers harvested an annual average of 77.54 fish per year in 2021, down from 78.40 fish per year in 2021. Average annual harvest for Tier 3 anglers increased to 975.3 fish per angler/year in 2020 compared to 879.28 fish per angler/year in 2021 (Hone et al. 2021).

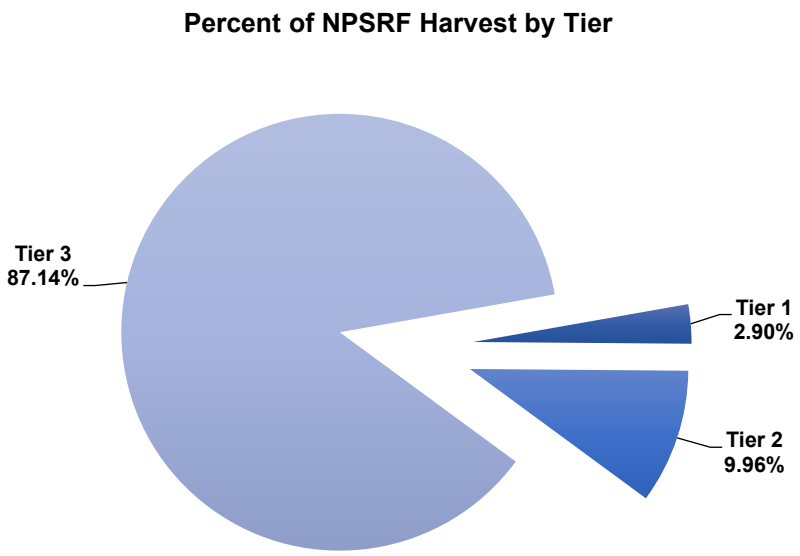


Figure 22. 2021 NPSRF harvest by angler tier (Tier 1 = ≤25, Tier 2 =26-200, Tier 3 = > 200)

The overall average NPSRF participant (returning + non-returning anglers) expended more effort pursuing Northern Pikeminnow during the 2021 season than in 2020 (7.18 vs. 6.56 angling days of effort). When we look at successful anglers only, the average successful angler decreased their average annual effort spent to 13.27 angler days during the 2021 NPSRF compared to 15.38 days in 2020. When we break down average successful angler effort by tier, only Tier 3 anglers spent more average annual effort in 2021 than they did in 2020. Tier 1 anglers spent an average of 5 days in both 2020 and 2021 (Figure 23). Tier 2 anglers spent an average of 21 days fishing in 2021 compared to 25 in 2020. Tier 3 anglers averaged 67 days fishing in 2021, up from 66 days in 2020 (Hone et al. 2021).

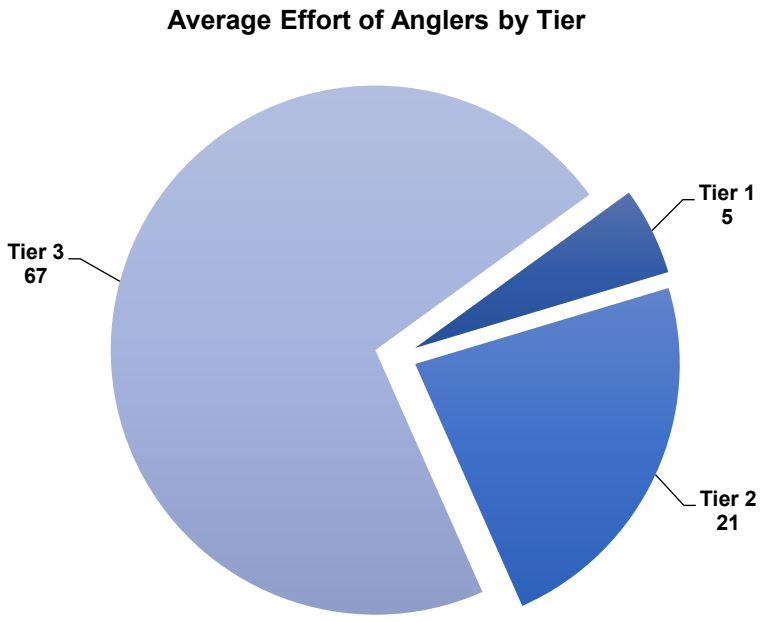


Figure 23. Average effort of 2021 NPSRF anglers by tier (Tier 1 = ≤25, Tier 2 = 26-200, Tier 3 = > 200)

When 2021 CPUE by tier is compared to 2020 there were increases in angler CPUE recorded at all three Tier levels. CPUE for anglers at Tier 1 increased from 1.05 fish per angler day in 2020 to 1.16 in 2021 (Figure 24). CPUE for Tier 2 anglers increased from 3.12 fish per angler day in 2020 to 3.62 in 2021. CPUE for Tier 3 anglers increased from 13.26 fish per angler day in 2020 to 14.63 in 2021 (Hone et al. 2021).

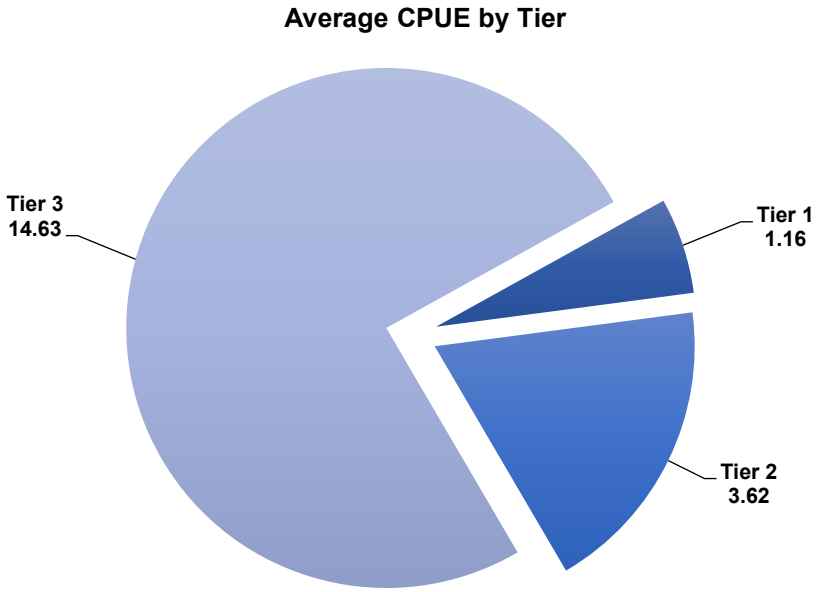


Figure 24. Average CPUE of 2021 NPSRF anglers by tier (Tier 1 = ≤25, Tier 2 =26-200, Tier 3 = > 200)

The top individual angler (based on number of fish caught) for the 2021 NPSRF harvested 7,185 reward sized Northern Pikeminnow, which includes 7 externally tagged Northern Pikeminnow and 5 tag-loss Northern Pikeminnow worth a total earnings of $61,009 (PSMFC 12/7/2021 Sport-Reward Payment Summary). The 2021 top angler caught 1,606 more reward sized Northern Pikeminnow in 2021 than the top angler did in 2020 (Hone et al 2021). The CPUE for this year's top angler (55.7 fish per angler day) was up from the top angler's CPUE in 2020 (46.9 fish per angler day) reflecting better fishing (CPUE)/river conditions seen for all anglers at all Tiers in 2021. The top angler for 2021 spent 129 days of effort compared to 119 days of effort in 2020 (Hone et al. 2021). By comparison, the top angler in terms of participation (rather than harvest) for the 2021 NPSRF fished 165 days of the 170 available days (97.1% of available days) and harvested 1,900 Northern Pikeminnow.

Tag Recovery

Northern Pikeminnow Tags

Returning anglers harvested 75 Northern Pikeminnow tagged by ODFW with external spaghetti or Floy tags during the 2021 NPSRF compared to 111 external spaghetti/Floy tags harvested in 2020 (Hone et al., 2021). Tag recoveries peaked during week 20, which was four weeks earlier than peak tag recovery in 2020 week 25 (and week 27) (Hone et al. 2021). All 75 externally tagged Northern Pikeminnow recovered in the 2021 NPSRF, retained PIT tags added by ODFW as a secondary mark. WDFW technicians recovered an additional 99 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 2021 NPSRF (Spaghetti/Floy and/or PIT) to estimate a 12.9% exploitation rate for the NPMP in 2021 (Waltz et al. 2022).

Ingested PIT Tags

A total of 89,542 Northern Pikeminnow were individually scanned for the presence of PIT tags in 2021. This represents 100% of the total harvest of reward-size fish for the 2021 NPSRF (Northern Pikeminnow not qualifying for rewards were also scanned whenever possible). Technicians recovered a total of 45 PIT tags from consumed smolts that had been ingested by Northern Pikeminnow harvested during the 2021 NPSRF, an overall occurrence ratio of 1:1,990 compared to 1:4,902 in 2020. Total ingested PIT tag recoveries in 2021 was 24 more recoveries than the previous year. While the rate of occurrence for ingested PIT tags was nearly three times higher in 2021 than it was in 2020, it was attained with harvest of 13,393 less fish (Hone et al. 2021). PIT tag recoveries of salmonid smolts ingested by Northern Pikeminnow peaked during week 20 of the 2021 NPSRF (compared to week 23 in 2020).

Species composition of PIT tagged smolts ingested by Northern Pikeminnow harvested in the 2021 NPSRF was obtained from PTAGIS and continued to indicate that the majority (40 of 45) ingested PIT tag recoveries (89%) were from Chinook smolts. Of the Chinook smolts, 34 of the 40 PIT tags (85%) indicated that the smolts hatchery origin chinook, while six were of wild origin. PTAGIS queries further revealed that there were also 2 PIT tag recoveries from hatchery Steelhead and 2 from hatchery summer Sockeye. Finally, PTAGIS queries indicated that the other 1 ingested PIT tag recovery came from a Wild Summer Steelhead.

Analysis of PIT tag recovery data from the 2021 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 2021 season was even more challenging than the Covid-19 affected 2020 NPSRF season. Prior to 2021, the 2020 season had been the NPSRF's most difficult and lowest harvest season in the program's 30-year history. Given the continuing COVID-19 pandemic and all the uncertainty surrounding it, it was noteworthy that the 2021 season was not only able to start for most stations on the traditional May 1st date, but the Columbia Point station started 11 days earlier on 4/19/21 and the season was also extended at select stations for 17 days late into October. Despite the continued Covid-related uncertainties present during the 2021 NPSRF, the program once again succeeded in achieving the NPMP's 10-20% exploitation goal for the twenty-fourth consecutive year, with exploitation estimated to be 12.9% for the 2021 NPSRF. Harvest for the 2021 NPSRF was 13,393 fish lower than 2020 harvest and well below mean 1991-2020 annual harvest of 165,488. Annual angler effort in 2021 once again decreased by 4,429 angler days from 2020. The number of individual anglers decreased by 825 anglers from 2020, with 62% of that number coming from Tier 1 anglers. CPUE increased from 6.44 in 2020 to 7.75 in 2021 (Hone et al. 2021). Peak weekly harvest occurred during week 39 (Sept 27 – Oct 3) which was the first time it had occurred outside the historical June peak, while peak weekly effort occurred during week 20, the fourth week of the 2021 season. The Boyer Park registration station was the NPSRF's top station for harvest in 2021 (17,086 fish), as well as the most angler effort with 1,845 angler days of effort spent. We recovered 75 Northern Pikeminnow with external spaghetti or Floy tags implanted by ODFW as part of the NPMP's biological evaluation. We recovered an additional 99 Northern Pikeminnow which were missing external tags but retained ODFW PIT tags (tag-loss). Mean fork length for Northern Pikeminnow harvested in the 2021 NPSRF was 277.7 mm, down from 289.9 mm in 2020 (Hone et al. 2020). Incidental catch consisted primarily of Peamouth, Smallmouth Bass, and Sculpin as seen in recent NPSRF seasons.

For the 2021 NPSRF, the most noteworthy occurrence was that we were again able to implement a full NPSRF season in the midst of the COVID-19 global pandemic. Secondarily, the NPSRF was able to demonstrate adaptive management during the season by resurrecting the Satellite station concept from earlier NPSRF years as a way to be more efficient by sharing time at slow stations by offering new NPSRF satellite stations at supplemental locations (which would not normally have stations) during periods of good angling opportunity, for minimal additional cost to 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 1:1,990 in 2021 versus 1:4,902 in 2020, and species composition of the 45 ingested PIT tags recovered from harvested Northern Pikeminnow indicated most continued to come from Chinook smolts, with most of them being of hatchery origin according to PTAGIS. There were also 6 Chinook and 1 Steelhead of wild origin, along with 2 hatchery Sockeye smolts according to PTAGIS.

RECOMMENDATIONS

1.) Continue to evaluate whether the use of "standardized season dates (May 1st-Sept 30th) is appropriate at all registration stations during implementation of the 2022 NPSRF. Identify feasibility of opening a limited number of stations for shorter duration seasons where high harvest opportunities are available during limited time periods during the season (such as prior to May 1st). Early, and/or limited openings (as the NPSRF did in the 1990's) may enhance angler harvest opportunities, increase program efficiency, and improve exploitation estimates for select program areas by operating the SRF during dates when larger numbers of predatory Northern Pikeminnow are better available to anglers while incurring minimal additional cost to the NPSRF.

2.) Review angler incentives such as the $5, $6, $8 reward levels used in 2021 with the option of increasing angler rewards as a means of arresting continued declines in angler effort and designed to recruit new anglers to the 2022 NPSRF.

a) Review NPSRF station times and routes for efficiencies which may allow adding additional stations or provide additional angler opportunities for participation. Consider continuing the "satellite" station concept first used in the 1994 SRF for limited times and durations as a means to increase SRF efficiency and angler outreach at minimal additional cost to the NPSRF.
b) Initiate development and NPSRF ability to use online angler registration for 2022 NPSRF.
c) Continue to expand use of angler clinics (post Covid), coupons, and sport shows as tools to recruit new anglers and promote NPSRF awareness.
d) Continue to develop video content for use in improving angler education, NPMP awareness through the use of Facebook, Instagram and other online/ social media as a means to maintain or increase NPM 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. Investigate the feasibility of using PIT tag scanners to communicate with Ipad type devices for data collection.

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 2022.

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

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REPORT B

Northern Pikeminnow Sport-Reward Payments

2021 Annual Report

Prepared by

Allan Martin

Pacific States Marine Fisheries Commission
205 S.E. Spokane St. Suite 100
Portland, OR 97202

May 2022

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 2021, the tier rewards paid to anglers were the same as in the 2020 season. Unlike 2020, there were no late season increases to the dollar amount paid to eligible or verified specially-tagged Northern Pikeminnow. All vouchers issued from April 19 through October 17, 2021 were paid at $5, $6, and $8 per fish for the three payment tiers (1-25 fish, 26-200 fish and 201-up). The rewards for tagged fish were $500 per fish.

A total of 88,645 fish were paid at the standard payment tiers (excluding coupon amounts, tagged fish and tag-loss bonus payments). The season total reward paid for these fish was $649,217.

A combined total of 74 tagged fish (having an external spaghetti or floy tag) were paid in 2021. The season total paid for tag rewards was $37,000.

A total of 96 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 $9,600.

A total of 405 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 $4,050.

A total of 1,608 separate anglers registered to fish, of which 472 (29%) caught one or more fish and received payments during the season. The total value for all 88,719 Northern Pikeminnow submitted for payment in 2021 (including all coupons, tagged fish and tag-loss *bonus* payments) was $699,867.

INTRODUCTION

The **Northern Pikeminnow Sport Reward Program** was again administered by PSMFC in 2021. 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), and is funded by the Bonneville Power Administration (BPA). 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, contractual, fiscal and administrative oversight for all segments of the Program and processed all reward vouchers for the sport-reward anglers.

THE 2021 SEASON

The 2021 Northern Pikeminnow Sport-Reward Fishery started April 19, earlier than the normal May 1 startup, to mitigate for the delayed opening last season. In 2020, stay at home orders issued

in March by governors in Washington and Oregon closed or limited fishing and limited access to some recreational facilities, including boat ramps. Washington's limited re-opening of many outdoor recreational activities (including opening most fishing seasons and allowing day-use of many boat ramps) allowed the Pikeminnow Sport-Reward Fishery to open on May 11, 2020.

PSMFC maintained an accounting system during the season to determine the appropriate reward amount due each angler for particular fish. From April 19 thru October 17, 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.

Throughout the season catch and effort remained substantially lower than average. In an effort to increase the final catch and effort for the season, the decision was made to extend the end date from September 30 to October 17. From September 27 through October 17, an additional 702 hours of angler effort resulted in 9,844 more Northern Pikeminnow removed from the system.

ONE-TIME $10 BONUS COUPON

Prior to the opening of the season, "coupon" postcards were mailed to anglers in the pikeminnow database who participated in the program within the past 5 years (2016 – 2020) and to those who signed up for our mailing list at the various sportsmen's shows. The 2021 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 405 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 $4,050.

PARTICIPATION AND PAYMENT

A total of 645 anglers who registered were successful in catching one or more fish in 2021. Of those anglers; 472 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 2021 a total of 89,542 fish were harvested in the sport-reward fishery. Of this total, 88,719 (99%) fish were submitted for payment and paid prior to the 2021 payment deadline. To obtain payment, vouchers must have been received no later than November 15, 2021. In addition, any *received* vouchers with issues preventing payment (missing information, voiding of voucher for program violations, etc.) that had not been resolved by November 15, 2021 became null and void.

TAGGED FISH AND PAYMENTS

Registered anglers caught and submitted a total of 74 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 $37,000.

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. 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 96 tag-loss fish qualified for and were paid the *bonus* reward of $100. The season total paid for tag-loss *bonus* was $9,600.

TOTAL ACCOUNTING

Total payments for the season of regular vouchers, *$10 bonus coupons,* tag vouchers and *tag-loss bonus* payments were $699,867.

All IRS Form 1099-MISC Statements were sent to the qualifying anglers for tax purposes from January 15 to January 31, 2022. Appropriate reports and copies were provided to the IRS on January 15, 2022.

A summary of the catch and rewards paid, including information on the "top 20" anglers, is provided in Table 1. For further information contact Allan Martin, PSMFC, Field Programs Administrator at (503) 595-3100 or email at DMartin@psmfc.org.

2021 SPORT REWARD PAYMENTS SUMMARY

The following is a summary of all vouchers received and paid in 2021

	Fish	Incentives	Reward
Fish paid @ tier 1 ($5 each):	6,685	-	$33,425
Fish paid @ tier 2 ($6 each):	19,944	-	$119,664
Fish paid @ tier 3 ($8 each):	62,016	-	$496,128
Tags paid (@ $500 each):	74	-	$37,000
Coupons issued (@ $10 each):	-	405	$4,050
Tag-loss issued (@ $100 each):	-	96	$9,600
Total:	88,719		$699,867

Anglers @ tier 1	*280*
Anglers @ tier 2	*112*
Anglers @ tier 3	*80*
Number of separate anglers	*472*

Anglers with 10 fish or less:	*214*
Anglers with 2 fish or less:	*104*

	Total Fish	$500 Tags	Tag Loss	Coup.	Total Reward
1.	7,185	7	$ 900	$ 10	$ 61,409
2.	4,288	5	$ 100	$ 10	$ 36,449
3.	4,020	3	$ 700	$ 10	$ 33,921
4.	3,814	0	$ 200	$ -	$ 30,287
5.	2,667	2	$ 400	$ 10	$ 22,305
6.	2,597	1	$ 400	$ 10	$ 21,256
7.	2,056	0	$ 400	$ -	$ 16,423
8.	1,931	2	$ 400	$ 10	$ 16,419
9.	1,901	1	$ 200	$ 10	$ 15,488
10.	1,968	0	$ 100	$ -	$ 15,419
11.	1,751	2	$ -	$ 10	$ 14,577
12.	1,714	1	$ 200	$ 10	$ 13,992
13.	1,713	1	$ 200	$ 10	$ 13,981
14.	1,647	2	$ 100	$ 10	$ 13,851
15.	1,641	0	$ 100	$ 10	$ 12,813
16.	1,457	1	$ 200	$ -	$ 12,017
17.	1,529	0	$ 100	$ 10	$ 11,996
18.	1,477	1	$ 200	$ 10	$ 11,926
19.	1,277	1	$ 100	$ 10	$ 10,395
20.	1,230	1	$ 200	$ 10	$ 10,120
	47,863	31	$ 5,200	$ 160	$ 395,044

NORTHERN PIKEMINNOW SPORT-REWARD FISHERY VOUCHER

2021 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 | DOCUMENT # | STATION

2021

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 11/15/21.
[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

2021 TAG

LAST NAME | FIRST NAME | MI

ADDRESS

CITY | STATE | ZIP CODE

ANGLER TELEPHONE NUMBER – –

TAG VOUCHER #

MONTH | DAY | 2021

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 11/15/21.

[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 RULES AND REGULATIONS

Anglers participating in the Northern Pikeminnow Sport-Reward Fishery must adhere to each of the following rules:

1) Present a valid fishing license and picture identification upon request by any authorized program representative.

2) Adhere to all applicable state fishing regulations for the area in which you fish. Contact your local state fishery agency for license requirements and current fishing regulations.

3) Register in person at one of the designated registration stations each day prior to fishing. Anglers may register during times when stations are unstaffed by using the station's self-registration box. Anglers may not register at multiple stations simultaneously.

4) Provide true and accurate information to authorized program representatives regarding the taking, possession, delivery, transportation, sale, transfer or any other use of fish caught while participating in the Northern Pikeminnow Sport-Reward Fishery.

5) Comply with the directions of authorized program personnel related to the collection of sampling data and angler participation in the Northern Pikeminnow Sport-Reward Fishery.

6) Mail in all reward vouchers within 30 days of the end of each year's fishery. To obtain payment, vouchers must be received no later than Nov. 15, 2021. Any issues preventing payment (missing information, voiding of voucher for program violations, etc.) must be resolved by Nov. 15, 2021 or the voucher becomes null and void.

7) Fish must have been caught in the mainstem Columbia River from the mouth up to the restricted zone below Priest Rapids Dam, or in the Snake River from the mouth up to the restricted zone below Hells Canyon Dam. The "mainstem" includes backwaters, sloughs, and up tributaries 400 feet from the tributary mouths. "Tributary mouth" is as defined by state fishing regulations.

8) Fish must be returned to the same registration station where the angler registered. They must be returned on the same calendar day stamped on the angler's registration form before that station closes for that day, and they must have been caught subsequent to that day's registration time.

9) Fish must have a total length greater than or equal to 9 inches. Fish less than 9 inches total length are not eligible for reward payment.

10) All fish to be redeemed for reward payment must have been personally caught solely by the angler submitting them for reward payment.

11) Fish must be alive or in fresh condition. Fish that are or were frozen, or that are in otherwise poor condition, will not be accepted for payment. Technicians have the authority to determine whether Northern Pikeminnow submitted for payment meet these standards.

12) Violation of any of the above rules may result in disqualification from the Northern Pikeminnow Sport-Reward Fishery.

Report C

System-wide Predator Control Program: Fisheries and Biological Evaluation

Prepared by

Grant T. Waltz
Kevin J. Rybacki
Charles M. Barr
Andrea L. Carpenter
Kelsey R. Anderson
Elijah B. Lamb
Parker E. Chambliss

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

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ABSTRACT

Since 1990, the Northern Pikeminnow Management Program (NPMP) has applied targeted 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 2021, the Oregon Department of Fish and Wildlife (ODFW) evaluated the continued efficacy of the Northern Pikeminnow removal program and assessed potential outcomes of the fisheries through a combination of field activities, laboratory work, and data analyses. This report augments historical information with current data and seeks to: 1) estimate rates of targeted fisheries exploitation of Northern Pikeminnow and the concomitant reduction in juvenile salmonid predation; 2) characterize population parameters of Northern Pikeminnow, Smallmouth Bass *Micropterus dolomieu*, and Walleye *Sander vitreus* in the tailrace area below Bonneville Dam and in Bonneville Reservoir; and 3) assess evidence of possible intra- and inter-specific compensatory responses by Northern Pikeminnow, Smallmouth Bass, and Walleye related to the sustained removal of Northern Pikeminnow from the lower Columbia and Snake rivers. To quantify exploitation during 2021, standardized boat electrofishing was used to collect, tag, and release Northern Pikeminnow throughout the lower Columbia and Snake rivers. Tags recovered in the NPMP Sport Reward Fishery were used to calculate exploitation rates for Northern Pikeminnow in the area covered by program implementation. Analyses of recaptures indicated that system-wide exploitation of Northern Pikeminnow greater than or equal to 250 mm FL during 2021 was 12.9% (± 5.2, 95% confidence interval). Based on this level of exploitation, modeled results predict that predation in 2022 will be reduced by 31% (range: 10–44%), relative to pre-program levels. These metrics suggest that NPMP continues to be successful to reduce predation on juvenile salmonids. For the predatory species monitored, the indices of abundance, consumption, and predation continue to be variable across time and space, complicating efforts to distinguish meaningful trends. In 2021, there was some evidence of compensation in predation by Smallmouth Bass relative to Northern Pikeminnow. Smallmouth Bass indices of abundance, consumption, and predation were all elevated in 2021 relative to the historic mean, while the same indices for Northern Pikeminnow were lower than the historic mean. These general trends occurred in both biological monitoring sites from the tailrace area below the Bonneville Dam and within the Bonneville Reservoir. In contrast, the predatory impact of Walleye seems unlikely to have increased since the program began based on 2021 results in these areas. Walleye continue to be captured infrequently relative to the other target predators. Although very few Walleye stomach samples were obtained, the frequency of occurrence of salmonids in the diet was the greatest of all species monitored, suggesting the strong potential for the predatory impact of this species to increase, should its abundance increase.

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 many different factors, including habitat degradation and overexploitation (Nehlsen et al. 1991; Wismar et al. 1994), hydroelectric and flood control activities (Raymond 1988) predation on out-migrating juveniles was also identified as a significant factor in adult salmon returns (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, especially by resident fishes, may constrain juvenile salmon survival in the Columbia River Basin. 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 on 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, the native Northern Pikeminnow was the most abundant and dominant predator on juvenile salmon, accounting for the majority of 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 answer these questions, indices were developed to allow rapid assessment of predation by Northern Pikeminnow throughout the system. From 1991 through 1993, researchers applied these indices to data collected in the lower Columbia River reservoirs (1990 and 1993), the Columbia River downstream of Bonneville Dam (1991), and lower Snake River reservoirs (1992) to characterize abundance, consumption, and predation (Ward et al. 1995). Results from these evaluations showed temporally variable predation by Northern Pikeminnow on juvenile salmonids was problematic in areas throughout the lower Columbia and Snake River reservoirs. Work was conducted to examine management strategies that could decrease predation on juvenile salmonids based on the premise that persistent exploitation of Northern Pikeminnow (i.e., 10–20% per year) could lead to 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. The Oregon Department of Fish and Wildlife (ODFW) is responsible for Objective 2 through standardized monitoring techniques in the Columbia and

Snake rivers. This sampling has been ongoing at monitoring locations since the early 1990s. The data collected through these monitoring efforts have been used 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. Additionally, ODFW in collaboration with the Washington Department of Fish and Wildlife (WDFW) and the Pacific States Marine Fisheries Commission (PSMFC) has monitored the population of the native predator, Northern Pikeminnow, for signs of significant population declines related to the predation control program. There are two current Northern Pikeminnow predator removal strategies being incorporated by NPMP, both managed by WDFW. The first involves a reward based recreational angler fishery, known as the Sport Reward Fishery (SRF). The second involves WDFW staff directly removing Northern Pikeminnow from areas with high concentrations of these predators below the powerhouse turbine outflows in the tailrace of The Dalles Dam and the John Day Dam, known as the Dam Angling Fishery (DAF). More details on SRF and DAF removal fisheries can be found in reports A and D, respectively.

ODFW evaluates the efficacy of the predator removal efforts and fish population parameters through a combination of field and laboratory studies incorporating data obtained throughout the Columbia and Snake rivers in the states of Oregon, Washington, and Idaho (Fig. 1). Broadly, ODFW incorporates analyses to estimate Northern Pikeminnow exploitation from SRF and DAF, salmonid predation reduction incorporating data from estimates of exploitation, and curation of long-term data to assess predator population trends. ODFW relies on data collected through independent activities within the Agency as well as biological samples acquired through SRF and DAF. ODFW field activities span two field studies. The first field study was designed to tag Northern Pikeminnow to incentivize the SRF and inform a mark/recapture based estimate of exploitation from SRF and DAF (fisheries evaluation). The second field study was designed to obtain fisheries independent assessments of abundance and provide predator digestive material used to estimate prey consumption for Northern Pikeminnow, Smallmouth Bass, and Walleye (biological evaluation). Laboratory techniques were incorporated to quantify gut contents used to inform indices of consumption and predation as well as to address the question of predator compensation due to continued exploitation of Northern Pikeminnow.

This report augments historical information with data collected during 2021 in areas of the Columbia and Snake rivers and, wherever possible, evaluated spatiotemporal changes of fish population parameters and their relation to reductions in juvenile salmonid predation from SRF and DAF activities. 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 the tailrace area below Bonneville Dam and in Bonneville Reservoir; and
(3) Assess evidence of possible intra- and inter-specific compensatory responses by Northern Pikeminnow, Smallmouth Bass, and Walleye related to the sustained removal of Northern Pikeminnow from the Columbia and lower Snake rivers.

METHODS

COVID-19 continued to impact our operations in 2021. Staff followed social distancing requirements when possible and mitigated exposure in other ways when social distancing was not possible. Operations occurred in reduced staff densities in office, field, and laboratory work environments. Staff may have been exposed to or contracted COVID-19, necessitating time away from work. COVID-19 restrictions also impacted our operations less directly, generally making travel, sourcing repairs, hiring, and other heretofore routine tasks more complicated as the world continued to adjust to COVID-19 related restrictions. In addition to COVID-19 related issues, NPMP operations were also adjusted because of excessive heat in the summer of 2021. These incidents led to necessary modifications of work schedules. In total, 2021 was a dynamic year further compounding the logistical challenges already associated with monitoring and evaluating the effects of focused predator removal through the Northern Pikeminnow Management Program.

Sport Reward Fishery Evaluation and Predation Reduction Estimates

Field Procedures

Boat electrofishing was used to collect and tag Northern Pikeminnow in the Columbia River from river kilometer (rkm) 76 (near Clatskanie, Oregon) upstream to rkm 620 (near Vernita boat launch), and in the Snake River from rkm 113 (Little Goose Dam) to rkm 251 (near Asotin, WA) upstream of Lower Granite Dam (Fig. 1). Sampling consisted of four 900 s electrofishing transects within each 1.61 river kilometer. ODFW researchers conducted sampling during 2021 using Smith-Root™ 18-EH model electrofishing boats equipped with a 5.0 or 7.5 generator powered pulsator electrofisher powered by a Kohler Power Systems™ gas generator and one Smith-Root electrofishing boat equipped with an Apex™ electrofisher powered by an air-cooled Honda 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 fishes. 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. Electrofishing controls were set according to federal guidelines for waters containing ESA listed salmonids 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. All controls were standardized across boats with minor adjustments to the duty cycle and/or voltage to achieve the targeted output. Electrofishing protocols were followed 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, protocols were developed and implemented to reduce interactions with species listed under the U.S. Endangered Species Act to guide sampling efforts.

Sampling occurred along shallow shoreline areas as the effective range of boat electrofishing was limited to an approximate maximum depth of 3 m. The timing of sampling ranged from 17 March to 24 June 2021 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. Three rkm in Bonneville Reservoir, two rkm

in Dalles Reservoir, and six rkm in the Snake River were dropped from sampling due to equipment malfunction or weather-related constraints. When weather or other reasons required, sampling was strategically adjusted to eliminate sampling areas with historically low rates of tag deployment. 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. All fish captured downstream of The Dalles Dam (rkm 307) were tagged prior to the start of the fisheries (1 May 2021). Upstream of The Dalles Dam, Northern Pikeminnow were tagged concurrent with the fisheries.

Northern Pikeminnow ≥ 200 mm fork length (FL) were tagged with uniquely numbered Floy® FT-4 lock-on external loop tags or Floy® FD-94 external T-bar anchor tags and released. A target tag ratio was established where half of target sized Northern Pikeminnow (≥ 200 mm FL) were tagged 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 for the third year in a row. Tag type was assigned haphazardly so that tag types were evenly distributed across all sizes of fish within a given area or reservoir. Loop tags were inserted between the pterygiophores below the midpoint of the dorsal fin (Fig. 2). T-bar anchor tags were inserted between the pterygiophores below the dorsal fin on the left side of the fish (Fig. 2). All externally tagged fish were also implanted with an internal 134.2 MHz passive integrated transponder (PIT) tag injected into the dorsal sinus cavity (Fig. 2). During Northern Pikeminnow tagging operations, Walleye were also captured, measured, and weighed to gain better understanding of their populations in these areas and to supplement data collected during biological evaluation activities (see below).

Working with WDFW, tag recovery information was obtained from the SRF and DAF (Report D). The SRF occurred daily from 1 May to 17 October 2021 (Report A). Participating anglers received payment for all harvested Northern Pikeminnow ≥228 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 2021 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). It was 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 7 May to 7 October 2021 (Report D) 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. WDFW personnel examined all fish for the presence of external tags (loop and T-bar) and PIT tags. Tagged Northern Pikeminnow removed in the DAF were accounted for when estimating exploitation rates for the SRF.

Data Analysis

Sport Reward Fishery Exploitation

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

To account for the introduction of a known bias into area-specific estimates of annual exploitation, two different models were applied; one for areas where Northern Pikeminnow were tagged prior to the beginning of the Sport Reward Fishery, and a second for areas where tagging occurred concurrent with the fishery (Styer 2003). Under each of these scenarios, estimated rates of exploitation were calculated 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, the rate of exploitation (u) of the population was calculated 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 with a cash reward and since that time, a correction for tag retention has not been applied to exploitation estimates.

Confidence intervals (95%) were calculated 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, each week was treated 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, fish that anglers recaptured during the same week they were tagged were excluded 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, a multiple sample approach was applied as follows:

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

where

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

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

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

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.

Predation Reduction

Indirect measures of predation reduction were incorporated to evaluate the efficacy of Northern Pikeminnow removals (Beamesderfer et al. 1996) due to numerous confounding factors that limit the ability to measure success in terms of increased number of juvenile salmonids reaching the estuary or returning as adults. A model based on Friesen and Ward (1999) was incorporated to estimate current predation on juvenile salmon relative to predation before the implementation of the program. The model was designed to estimate the effects of the NPMP if all other factors were held constant (river and ocean conditions, number of migrating juvenile salmonids, passage conditions/mortality at dams, etc.). The model also assumed no compensation by non-native predators, and remaining Northern Pikeminnow, which were assessed through the biological evaluation. The model estimated 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 and recruitment, (4) area- and size-specific abundance estimates, and (5) area- and size-specific estimates of seasonal consumption of juvenile salmon by Northern Pikeminnow (Friesen and Ward 1999). The details for these components were:

1. Northern Pikeminnow population size (length) structure before SRF and DAF removals were simulated using length frequency distributions in each reservoir (Parker et al. 1995; Knutsen and Ward 1999).

2. Area specific exploitation rates were calculated as described above, for the area below Bonneville Reservoir, the pooled Columbia River reservoirs and the pooled Snake River reservoirs. Relationships between exploitation and length of Northern Pikeminnow were used to estimate age-specific exploitation rates (Friesen and Ward 1999). Age increments were changed to 15 mm FL increments based on measured annual growth from mark recapture information (Weaver et. al 2008).

3. Linear regression on a growth curve, constructed from adjusted age frequencies (Ricker 1975), was used to estimate natural mortality (0.611 for area below Bonneville Reservoir, 0.62 for impounded Columbia and Snake River reservoirs) and mean index of recruitment to age five or 240 mm FL (Friesen and Ward 1999).

4. Area specific size structure was adjusted over time for exploitation and natural mortality using equation 6:

$$A_{h+j} = A_{h-1,j-1}\left(1 - E_{(h-1,j-1)}(1 - M)\right), \quad (6)$$

where

A_{h+j} = abundance index for size-j fish in year j,

$A_{h-1,j-1}$ = abundance index of fish size h -1 in year j –1,

$E_{h-1,j-1}$ = exploitation rate of fish size h –1 in year j –1, and

M = annual natural mortality rate.

5. Consumption information from 1990 to 1996 was collected and the consumption index as calculated below in equation (7) was converted to consumption rates:

$$C = -0.077 + 0.618(CI) \quad (7)$$

where

C = number of juvenile salmonids per Northern Pikeminnow per day

CI = consumption index

Separate size and area specific consumption rates were calculated for the area below Bonneville Dam, the combined Columbia River reservoirs, and the combined Snake River reservoirs.

Using these five model components, consumption rates for each size class were multiplied by the abundance index and the number of days in each season (Spring 91, Summer 62) to get a loss index by season and area. Summing loss by season and area estimated the total loss for the year for all areas contained within the NPMP. Relative predation was calculated by subtracting the overall loss index in the current year and divide it by the 1990 overall loss index and multiply by 100.

PSD, Fishery Evaluation and DAF

Rates of exploitation of Northern Pikeminnow increase with increasing fish size (Zimmerman et al. 1995). A model describing proportional size distribution (PSD; Anderson 1980; Guy et al. 2007) was fit to characterize variation in size structure for Northern Pikeminnow to three groups; those sampled during fishery evaluation, biological evaluation, and from the DAF. Models describing PSD for Walleye populations sampled during both fishery and biological evaluation and Smallmouth Bass sampled during biological evaluation were applied using the equation 8:

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

where

FQ_i = number of fish ≥ quality-length for species *i*, and

FS_i = number of fish ≥ stock-length for species *i*.

Proportional Size Distribution, preferred length (PSD-P), Fishery Evaluation and DAF

Proportional size distribution of preferred-length fish (PSD-P) was calculated for Smallmouth Bass and Walleye (Gabelhouse 1984; Guy et al. 2007) sampled during fishery and biological evaluation using equation 9:

$$PSD - P_i = 100 \times \frac{FP_i}{FS_i}, \quad (9)$$

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). Stock, quality, and preferred minimum length categories were collected from the literature (Anderson 1980; 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, our target size was used as the 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 ($FL_{WAL} = TL_{WAL}/1.060$), these categories were calculated as 236, 358, 481 mm FL, respectively. Annual PSD and PSD – P values were calculated only when sample sizes exceeded 19 stock-length fish in an area. To characterize uncertainty surrounding PSD and PSD – P values, a non-parametric bootstrap approach using the 'boot' package (Fox and Weisberg 2011) in the R programming environment (R Core Team 2021) was used to calculate 95% confidence intervals. Temporal monotonic trends were calculated for PSD of Northern Pikeminnow and PSD and PSD-P of Walleye by applying a non-parametric Mann-Kendall test (Mann 1945). All analyses were conducted in the R programming environment using the 'Kendall' (McLeod 2011)

and, where necessary, the 'boot' or 'tsboot' (Fox and Weisberg 2011) packages. Significant differences were assessed at $\alpha \leq 0.05$.

Relative Weight (W_r), DAF

Relative weight (W_r; Wege and Anderson 1978) was calculated to compare the condition of Northern Pikeminnow over time. Length-specific standard weights predicted by a length-mass regression model ($\log_{10}[W_s]=a'+b\cdot\log_{10}[L]$) were used for Northern Pikeminnow (Parker et al. 1995 to calculate W_r according to equation (10):

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

where

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

To account for sexual dimorphism, male and female W_r values were calculated separately for Northern Pikeminnow. Additionally, these analyses only included fishes that met minimum target sizes, 250 mm FL for Northern Pikeminnow. Annual median W_r values were calculated only when sample sizes exceeded four target sized fish in a given reservoir and by sex for Northern Pikeminnow. 95% confidence intervals were estimated for median W_r values using a non-parametric bootstrap approach (Fox and Weisberg 2011; R Core Team 2021).

Temporal monotonic trends in median W_r were assessed for Northern Pikeminnow by applying a non-parametric Mann-Kendall test (Mann 1945). Spline interpolation was used to account for data gaps, when present. Last, to help visualize trends, locally weighted scatterplot smoothing (LOWESS) curves were fit to the data. All analyses were conducted in the R programming environment using the 'Kendall' (McLeod 2011) and, where necessary, the 'boot' or 'tsboot' (Fox and Weisberg 2011) packages. Significant differences were assessed at $\alpha \leq 0.05$.

DAF Consumption Index (DAF-CI)

Consumption indices provide a proxy of the number of juvenile salmon eaten per day by an average predator and previous work has demonstrated that the output values are correlated with consumption rates for Northern Pikeminnow (Ward et al. 1995). An index of consumption for DAF fish (DAF-CI) was calculated for each week of DAF using the model of Ward et al. (1995) for Northern Pikeminnow (CI_{NPM}) using the equation 11:

$$\boldsymbol{CI_{\mathrm{NPM}} = 0.0209 \times T^{1.60} \times W^{0.27} \times (S \times GW^{-0.61})}, \tag{11}$$

where

T = mean water temperature per week stratum (ºC),

W = mean predator mass (g),

S = mean number of juvenile salmon per predator, and

GW = mean diet mass (g) per predator.

Water temperature data were downloaded from the Columbia River Operational Hydrometeorological Management System. CI-DAF was calculated when sample sizes exceeded five fish, per week, per dam.

Biological Evaluation

Field Procedures

Standardized boat electrofishing techniques were used to evaluate Northern Pikeminnow, Smallmouth Bass, and Walleye population parameters below Bonneville Dam and in Bonneville Reservoir during 2021 (Ward et al. 1995; Zimmerman and Ward 1999). Sampling was conducted in the early morning (0200–1000 hours) during spring (11 May–28 May 2021) in the tailrace area below Bonneville Dam (rkm 225-233) and in Bonneville Reservoir (forebay, rkm 234-239; mid-reservoir, rkm 273-281; and tailrace, rkm 302-305). The objective was to analyze predatory fish diets focusing on salmonid consumption. The timing of this work was selected to correspond with peak smolt outmigration. Sampling locations were randomly selected fixed-site transects, approximately 500 m long, in each area along all shorelines of the river. Effort at each transect consisted of a 900-second boat electrofishing period with continuous output of approximately 3-4 A. Temperature (nearest 0.1°C) and minimum/maximum observed depth were recorded for each transect (nearest 0.1').

Species, FL (nearest mm), and mass (nearest 10 g) were recorded for all Northern Pikeminnow, Smallmouth Bass, and Walleye ≥200 mm. Target-sized Northern Pikeminnow that were not previously tagged were sacrificed and the digestive tract was extracted for digestive tract content analysis in the laboratory. To remove NPM digestive tracts, an incision was made along the ventral midline from the pectoral fins to the vent. The digestive tract was removed by securing both ends with hemostats, removing extra tissue, and placing the complete digestive tract into individual Whirl-Pak bags. Digestive tracts were squeezed with forceps from one end to the other to extract the contents and water was added to reduce post-collection digestion. Sex and stage of maturity were assessed by examining the gonads and scoring maturity from 0-4 with '0' representing a juvenile fish and '4' representing a mature fish that had recently spawned (spawned-out). Diet samples were collected from target-sized Smallmouth Bass and Walleye by a non-lethal gastric lavage method using a modified Seaburg sampler (Seaburg 1957). Gut contents were flushed from the foregut of each fish into a 425 μm sieve and then transferred into individual sample bags. For all species, diet samples were stored on ice while in the field and transferred to a freezer until processing.

Using the protocol described above, diet samples were also collected from Northern Pikeminnow captured during the 2021 DAF in Bonneville and The Dalles reservoirs. Diets were collected from a representative subsample of catches at each dam weekly from 11 May–5 August 2021, generally two days per week with a target of 20 fish per day at each dam. In addition, FL, mass, sex, and stage of maturity were recorded for each fish sampled. Sampling was halted in August due to extreme air temperatures and thereafter catch numbers were not sufficient for data collection.

Laboratory Procedures

Contents of diets from Northern Pikeminnow, Smallmouth Bass, and Walleye collected during biological evaluation field activities, and Northern Pikeminnow collected from the DAF were examined to quantify relative consumption of juvenile salmonids. Due to the large number of Smallmouth Bass diets collected, in the laboratory a random subsample of 120 diets was selected for each sampling area in the Bonneville reservoir. All Northern Pikeminnow and Walleye gut contents collected in the field during 2021 were processed in the laboratory.

Frozen field samples were thawed in the laboratory and sorted the diet contents into general prey categories (i.e., fish, crayfish, other crustaceans, insects, other invertebrates, vegetation, miscellaneous). Parasitic invertebrates (e.g., tapeworms, nematodes, parasitic copepods) found in the diet samples were noted in our dataset comments, but they were not weighed, categorized as prey items, or included in the prey consumption calculations. Diet items were blotted with a paper towel to remove excess moisture and weighed to the nearest 0.01 g according to prey category. For Smallmouth Bass and Walleye, portions of diet samples containing fish were returned to the original sample bags for chemical digestion. To ensure complete recovery of diagnostic structures from Northern Pikeminnow diet samples, the entire digestive tract was chemically digested along with possible fish parts. To chemically digest soft tissues, a 20 ml of solution of pancreatin (20 g/L) and sodium sulfide nonahydrate (Na_2O_9S; 10 g/L) in tap water was added to each sample. Next, sample bags were placed in a desiccating oven at approximately 48°C for 24 h. After removal from the oven, a 20 ml solution of sodium hydroxide (lye, NaOH) mixed at 30g/L with tap water was added to dissolve remaining fatty materials and the sample was agitated. Contents of each sample bag were then poured into a 425 µm sieve and rinsed with tap water. In rare cases, the presence of fish was recorded during the initial sorting and weighing but no bones were found after chemical digestion. When this occurred, those bones were assumed lost, and therefore one unidentified fish was counted present in the sample (unless the taxa was identified during the preprocessing stage). Diet samples of fishes that did not contain any diet items (empty) were included in all statistical analyses.

Bones from prey items, post chemical digestion, were identified to the lowest possible taxon (typically family) using stereoscopic dissecting microscopes at 6.1x-55x magnification with 10x eyepieces and standard keys (Hansel et al. 1988, Frost 2000, and Parrish et al. 2006). Paired structures were enumerated to arrive at minimum counts of a given prey taxon in a diet sample, but presence/absence could be determined for certain prey items. For example, if ventral scutes of American Shad *Alosa sapidissima* were the only diet item present in a sample, it was assumed that 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 where lamina of lampreys (family Petromyzontidae) were present in diet samples. For samples where fish

vertebrae were observed, it was possible to distinguish between salmonid and other fish prey; however, it was impossible to determine the exact number of juvenile salmon consumed. In these cases, it was assumed that one juvenile salmon was consumed to avoid arbitrarily inflating the count. Given these constraints diet data represent a conservative enumeration of prey fish within diet samples. Lastly, to calibrate identification accuracy among analysts, 10% of all samples were re-analyzed at random by a second reviewer.

Data Analysis

Biological Evaluation Abundance Index (AI)

Catch per unit effort (CPUE) was found to be the strongest index of abundance to correlate with mark recapture population estimates (Ward et al, 1995). Following the methods of Ward et al. (1995), seasonal abundance index values were calculated for each predator species using the mean CPUE of boat electrofishing (900 s) by season and area, the surface area (ha) of the specific sampling locations in each river area, divided by 1,000 for scale using the equation 12:

$$AI_i = D_i \times \frac{S_i}{1{,}000}, \quad (12)$$

where:

AI_i = abundance index for area *i*

D_i = density in area *i* as determined by mean CPUE and

S_i = surface size (hectares of area *i*)

Biological Evaluation Consumption Index (CI)

Consumption indices provide a proxy of the number of juvenile salmon eaten per day by an average predator and previous work has demonstrated that the output values are correlated with consumption rates for Northern Pikeminnow (Ward et al. 1995) and Smallmouth Bass (Ward and Zimmerman 1999). An index of consumption (CI) was calculated using the models of Ward et al. (1995) and Ward and Zimmerman (1999) for Northern Pikeminnow (CI_{NPM}) and Smallmouth Bass (CI_{SMB}) using the equations 11 and 13:

$$CI_{\mathrm{SMB}} = 0.0407 \times e^{(0.15)(T)} \times W^{0.23} \times (S \times GW^{-0.29}), \quad (13)$$

where

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

Water temperature data were either collected in the field (boat electrofishing) or downloaded from the Columbia River Operational Hydrometeorological Management System (DAF collected fish). CI was calculated when sample sizes exceeded five fish for a given species, season, and sampling area.

Biological Evaluation Predation Index (PI)

To quantify compensatory responses to removals, a predation index (PI) was developed to describe changes in the relative magnitude of predation on juvenile salmonids by Northern Pikeminnow (Ward et al, 1995) and Smallmouth Bass (Ward and Zimmerman, 1999). Currently, no comparable model exists to evaluate Walleye consumption and predation. Seasonal-and location-specific PI estimates were generated for Northern Pikeminnow and Smallmouth Bass using the product of seasonal AI and CI values (Ward et al. 1995) using equation 14:

$$PI_i = AI_i \times CI_i, \quad (14)$$

where

PI_i = predation index for area *i.*

AI_i = abundance index in area *i,*

CI_i = consumption index in area *i.*

Proportional Size Distribution (PSD)

PSD was calculated for Northern Pikeminnow, Smallmouth Bass, and Walleye caught during biological evaluation using equation 8.

Proportional Size Distribution, preferred length (PSD-P)

PSD-P was calculated for Smallmouth Bass and Walleye (Gabelhouse 1984; Guy et al. 2007) sampled during biological evaluation using equation 9.

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). Stock, quality, and preferred minimum length categories were collected from the literature (Anderson 1980; 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 was smaller

than the target size (200 mm FL) for Smallmouth Bass from this study and to remove any bias in these data from variation in sampling procedures among years, the target size was used as the 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 ($FL_{WAL} = TL_{WAL}/1.060$), these categories were calculated as 236, 358, 481 mm FL, respectively. Annual PSD and PSD – P values were calculated only when sample sizes exceeded 19 stock-length fish in an area. To characterize uncertainty surrounding PSD and PSD – P values, a non-parametric bootstrap approach using the 'boot' package (Fox and Weisberg 2011) in the R programming environment (R Core Team 2021, Canty et al. 2021) was used to calculate 95% confidence intervals.

Relative Weight (W_r)

Relative weight (W_r; Wege and Anderson 1978) was calculated to compare the condition (within species) of Northern Pikeminnow, Smallmouth Bass, and Walleye over time. Length-specific standard weights predicted by a length-mass regression model ($\log_{10}[W_s] = a' + b \cdot \log_{10}[L]$) were used 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 equation (10).

To account for sexual dimorphism, male and female W_r values were calculated separately for Northern Pikeminnow. However, field sampling methodologies precluded diagnosis of sex for Smallmouth Bass and Walleye as they were not sacrificed. Therefore, calculations of W_r for Smallmouth Bass and Walleye were for both sexes combined. Additionally, these analyses only included fishes that met minimum target sizes (250 mm FL for Northern Pikeminnow and 200 mm FL for Smallmouth Bass and Walleye). Annual median W_r values were calculated only when sample sizes exceeded four target sized fish in a given reservoir and by sex for Northern Pikeminnow. 95% confidence intervals were estimated for median W_r values using a non-parametric bootstrap approach (Fox and Weisberg 2011; R Core Team 2021).

Temporal monotonic trends in PSD were assessed for Northern Pikeminnow and Walleye and median W_r for Northern Pikeminnow, Smallmouth Bass, and Walleye by applying a non-parametric Mann-Kendall test (Mann 1945). Similarly, PSD – P was also analyzed with this method for Walleye. Spline interpolation was used to account for data gaps, when present. Due to a large gap in length data for Northern Pikeminnow in the DAF (1997–2005 in Bonneville Reservoir and 1996–2006 in The Dalles Reservoir), data for this large data gap were not interpolated. Instead, the two periods were treated as separate time series; data collected before 1997 as "early" and data collected after 2005 as "late". A non-parametric Mann-Whitney U test was used to compare PSD values between early and late years for each reservoir. Last, to help visualize trends, locally weighted scatterplot smoothing (LOWESS) curves were fit to the data. All analyses were conducted in the R programming environment using the 'Kendall' (McLeod 2011) and, where necessary, the 'boot' or 'tsboot' (Fox and Weisberg 2011) packages. Significant differences were assessed at $\alpha \leq 0.05$.

RESULTS

Sport Reward Fishery Evaluation and Predation Reduction Estimates

A total of 577 Northern Pikeminnow ≥ 200 mm FL were marked throughout the Columbia and lower Snake rivers during 2021, of which 392 were ≥ 250 mm FL (Table 1). While boat electrofishing for tagging purposes, 10 Northern Pikeminnow ≥ 200 mm FL that were tagged in previous years were recaptured. These previously tagged fish were accounted for in annual exploitation calculations and were included as in-year marked or handled fish for 2021 estimates. Overall, 65 of the fish marked in 2021 were recovered in SRF and none in DAF. Two fish marked in McNary Reservoir and one fish marked in Little Goose Reservoir were recaptured within the same week they were tagged. They were excluded from recapture totals and the calculations of exploitation to avoid violating mark-recapture assumptions (i.e., incomplete mixing). Three fish that were tagged in Bonneville Reservoir and recovered in a different area were also excluded from calculations of exploitation. Fish tagged in 2021 and subsequently recaptured in the SRF were at large from 5 to 183 days (mean = 62.4 d; SE = 6.8). Sport Reward Fishery recaptures greater than or equal to 250 mm FL accounted for 75% of all 2021 tag recoveries (Table 1).

Sport Reward Fishery Exploitation

Of the 577 new tags deployed in 2021, 246 (43%) were T-bar anchor tags and 331 (57%) were lock-loop tags. T-bar anchor tagged fish were recaptured at a 13.0% rate and lock-loop tagged fish were recaptured at a 10.0% rate. Tagged fish in the 200-249 mm FL size class were recaptured at a similar rate for both T-anchor bar tags (9.5%) and lock-loop tags (8.9%). The tag loss rate for T-bar anchor tags deployed in 2021 was 19% and 9% for lock-loop tags.

The system-wide exploitation rate for Northern Pikeminnow ≥ 250 mm FL during the Sport Reward Fishery was estimated at 12.9% (±5.2; 95% confidence interval; Table 2). This estimate was within the targeted exploitation range of 10-20% (Fig. 3). Tag returns were sufficient (n ≥ 4) to calculate area-specific exploitation rates of fish ≥ 250 mm FL for the Columbia River downstream of Bonneville Dam (11.8%) and for Bonneville Reservoir (5.6%) (Table 2). System-wide exploitation of Northern Pikeminnow ≥ 200 mm FL was 12.3% (±5.5; 95% confidence interval) and tag returns were sufficient to calculate area-specific exploitation estimates for the Columbia River downstream of Bonneville Dam, and in Bonneville and McNary reservoirs (Table 3). For Northern Pikeminnow within the 200–249 mm FL size class, system-wide exploitation was estimated to be 10.9% (±8.6; 95% confidence interval) (Table 4). Area-specific rates of exploitation for this size class was estimated for Bonneville and McNary reservoirs.

Sport Reward Fishery Predation Reduction

The model-estimated median reduction of predation on juvenile salmonids relative to pre-program levels for 2021 was 34% (range: 12–46%) and for 2022 will be 31% (range: 10–44%; Fig. 4). 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 suppressed levels through 2025 with an estimated median reduction near 31% (Fig. 4).

PSD, Northern Pikeminnow

Northern Pikeminnow PSD significantly decreased over time in McNary reservoir (Mann-Kendall $\tau = -0.36$, $P = 0.01$; Fig. 5). There was not a significant monotonic trend in PSD below Bonneville Dam or in the Bonneville Reservoir. Sufficient data were not collected in Snake River reservoirs and The Dalles Reservoir to calculate PSD for 2021 ($n < 20$).

PSD/PSD-P, Walleye

There was not a significant monotonic trend in Walleye PSD in McNary and The Dalles reservoirs (Figure 6). There was a significant monotonic decrease in Walleye PSD-P across the time series for McNary reservoir (Mann-Kendall $\tau = -0.44$, $P = 0.02$; Fig. 7).

Dam Angling Fishery

During the 2021 DAF season, 672 Northern Pikeminnow diet samples were collected from fish harvested at the angler accessible areas in the powerhouse tailraces of Bonneville reservoir (fishing from the Dalles Dam) and The Dalles reservoir (fishing from the John Day Dam). These fish ranged in size from 218-574 mm FL. In both reservoirs, large proportions of the diets of target sized Northern Pikeminnow contained food and the most prevalent diet item was fish (Table 5). In Bonneville Reservoir, salmonid proportions were 0.18 for 2021 DAF fish, which was above the long-term average of 0.13. In The Dalles Reservoir, the proportion of salmonids increased (0.20) from the mean proportion of the time series (0.15). The proportions of "other fishes" for both Bonneville Reservoir (0.19) and The Dalles Reservoir (0.07) consisted of sculpin (*Cottidae* spp.), unknown Centrarchidae, Mountain Whitefish, and unknown species (non-salmonid and unidentified). Northern Pikeminnow, catfish (*Ictaluridae* spp.), and sucker (*Catostomidae* spp.) were found only in diets of 2021 DAF fish from Bonneville Reservoir. Other invertebrates not identified as crayfish were the second most abundant diet item in both reservoirs (Bonneville 0.34; The Dalles 0.40). A large proportion of the "other invertebrates" prey category consisted of non-native prawns and amphipods.

In Bonneville Reservoir, the proportion of lampreys (*Petromyzontidae* spp.) encountered in the 2021 DAF diet samples increased until reaching the peak (0.55) at week 23 and then decreased over the rest of the sampling time series (Fig. 8). Salmon and steelhead were encountered in the greatest proportion (0.65) of diet samples in week 19 and decreased over the rest of the DAF season, although they remained prevalent. American Shad were first encountered in the diet samples in week 29 and increased sharply to 0.67 in week 31. The sample size for week 30 was insufficient for analyses.

In The Dalles Reservoir, lampreys were encountered in the greatest proportion of DAF diet samples (0.63) in week 24 and then decreased throughout the rest of the sampling time series. Salmon and steelhead proportions increased and reached a peak in week 26 (0.42) and then steadily declined. American Shad was the most frequent taxon observed in diet samples through

the end of the season, with a peak in week 31 appearing in 73% of samples. Sampling collection for DAF fish was halted in August due to extreme air temperatures and poor air quality. Sampling did not occur after week 31 at either sampling site.

The 2021 weekly juvenile salmonid consumption index for Northern Pikeminnow removed during DAF at Bonneville and The Dalles reservoirs was the greatest during week 26 (Fig. 9). There was also peak in CI early in the DAF season in the Bonneville Reservoir during week 19 that was associated with an increase in yearling salmon (Fig. 9).

PSD of Northern Pikeminnow in Bonneville Reservoir during the DAF was significantly greater during the early years (1990-1996) of sampling than during the later years (2006-2021) ($W=89$, $P < 0.01$; Fig. 10). There was no significant difference in PSD at The Dalles Reservoir during the early years relative to the later years. The PSD trends between the two reservoirs in the later years have followed an upward trend since 2018. There was no significant monotonic trend for *Wr* for either female or male DAF Northern Pikeminnow captured in either Bonneville or The Dalles reservoirs (Figs. 11 and 12).

Biological Evaluation

Field staff conducted 239 electrofishing runs during spring 2021 below Bonneville Dam and in Bonneville Reservoir to collect fishes for biological evaluation. Due to time and budget constraints, total effort had been reduced to only include a spring index season. Sampling was optimized for logistical efficiency by distributing effort between sampling areas based on the number of diet samples needed to meet minimum sample sizes in an attempt to fill data gaps where sample sizes have not historically been met. This was in contrast to prior sampling plans which attempted to distribute an equal amount of effort between all sampling areas. As a result of the 2021 sampling plan, 36% of our sampling transects were concentrated on the mid-reservoir section of Bonneville. Due to limited time and poor catch rates in recent years, the boat-restricted zones adjacent to Bonneville Dam were not sampled. The timing of our annual biological evaluation field work was planned to coincide with predicted peak juvenile salmon out migrations. Spring sampling in 2021 overlapped with peak yearling salmon outmigration at Bonneville Dam (Fig. 13).

Diet Composition

Detailed results of the diet assessments are found in Table 6 but relevant trends are listed here. Diets were examined from 355 Northern Pikeminnow, 425 Smallmouth Bass, and eight Walleye at one site below Bonneville Dam and three sites in Bonneville Reservoir. Food items were present in the majority of digestive tracts assessed during biological evaluation (76% - 100%, Table 6). Diet composition varied within and between species by capture reservoir. Fish were more frequently found in diet samples for all species below Bonneville Dam. Diet composition in the Bonneville reservoir included increased proportions of other diet items (e.g., crayfish and

other crustaceans), relative to the area below Bonneville Dam. Salmonids were present in diets for all three species and in both sampling reservoirs. Walleye had the greatest average proportion of salmonids (0.25), followed by Smallmouth Bass (0.15), and Northern Pikeminnow (0.03). Additionally, the proportion of salmonids in diet samples was greatest below Bonneville Dam for all three species relative to the Bonneville Reservoir. Lampreys were found in relatively high proportions in Northern Pikeminnow below Bonneville Dam (0.17) and infrequently in Northern Pikeminnow (0.01) in the Bonneville Reservoir. Lampreys were not found in the diets of Walleye in either reservoir or in the diets of Smallmouth Bass in Bonneville reservoir. Of note, only two diet samples were collected from Walleye below Bonneville Dam for this assessment.

AI, Northern Pikeminnow

Northern Pikeminnow AI trended lower than the series mean from 1990 – 2021 in all areas (Table 7). In Bonneville Reservoir, all three sub-areas had a lower index of abundance when compared to the last evaluation in 2017. In both Bonneville mid-reservoir and tailrace sub-areas, AI for Northern Pikeminnow in 2021 was the lowest on record. In the tailrace area below Bonneville Dam, AI increased and was the highest since 1999.

AI, Smallmouth Bass

Smallmouth Bass AI trended above the mean of the time series for all areas (Table 8). Since the last spring evaluation, Smallmouth Bass AI increased in all areas except for the mid-reservoir which, although the high was lower than the record high in 2017. Increases in Smallmouth Bass AI were also documented over the 30 years since our initial estimate in 1990, with substantial increases occurring in Bonneville mid-reservoir.

AI, Walleye

In total, only eight Walleye were captured among all areas sampled in 2021 and none were captured in the forebay. AI for Walleye decreased in all areas where Walleye were detected compared to the 2017 index and were lower in all areas with regards to the series mean (Table 9).

CI, Northern Pikeminnow

Northern Pikeminnow 2021 CI values were calculated below Bonneville Dam and in Bonneville Reservoir forebay and tailrace. Not enough samples were collected to calculate CI for Northern Pikeminnow in Bonneville Reservoir mid-reservoir (Table 10). Northern Pikeminnow CI, when calculable, trended below the mean of the time series in each area (Table 10). In the tailrace area below Bonneville Dam, there was a decrease in the spring CI value (0.29) compared to 2017 (2.07). CI for Northern Pikeminnow in the Bonneville Reservoir tailrace was 0.00 due to a lack of salmonids in the diet samples collected from Northern Pikeminnow in this sub-area of the reservoir.

CI, Smallmouth Bass

Smallmouth Bass CI was similar across all sample areas below Bonneville Dam and in the Bonneville Reservoir (Table 11). Smallmouth Bass CI in 2021 trended higher than the mean for the time series and was the highest it has been throughout the course of this work (Table 11).

PI, Northern Pikeminnow

The 2021 PI for Northern Pikeminnow trended lower than the mean of the time series in all areas sampled in spring of 2021(Table 12).

PI, Smallmouth Bass

PI below Bonneville Dam and in the Bonneville Reservoir were the highest observed in the time series (Table 13). Due to the large AI of Smallmouth Bass in the Bonneville mid-reservoir, the corresponding PI was greatest among areas at 4.86 (Table 13).

PSD, Northern Pikeminnow

Northern Pikeminnow PSD, calculated during biological evaluation field studies, below Bonneville Dam was 48%, compared to 20% in Bonneville Reservoir (Fig. 14). There was a significant positive monotonic trend below Bonneville Dam (Mann-Kendall $\tau = 0.37$, $P = 0.05$). There was not a significant monotonic trend in the Bonneville Reservoir (Bonneville Reservoir Mann-Kendall $\tau = -0.33$, $P = 0.11$).

PSD, Smallmouth Bass

Smallmouth Bass PSD, calculated from biological evaluation field studies, dropped from recent years below Bonneville Dam (24%) and in Bonneville Reservoir (45%; Fig. 15). Smallmouth Bass PSD below Bonneville Dam was below the average for the time series (mean = 37%; SE 3) and also in Bonneville Reservoir (mean = 51%; SE 2; Table 13). With respect to trends over time, below Bonneville Dam demonstrated no significant trend and a steadily increasing trend was observed in Bonneville Reservoir. PSD-P below Bonneville Dam was 3%, compared to 22% in Bonneville Reservoir, with variable trends over time for both reservoirs (Fig. 16).

PSD, Walleye

No PSD or PSD-P values were calculated in 2021 in either reservoir for Walleye due to sample size constraints ($n < 20$) during biological evaluation field studies. Only one stock-length (≤ 236 mm FL) Walleye was caught below Bonneville Dam, and only six were caught in Bonneville Reservoir during biological evaluation field studies. These results were consistent with past data where there were only enough Walleye samples to calculate PSD and PSD-P once in 15 sampling years for each reservoir.

W_r, Northern Pikeminnow

Median W_r of female Northern Pikeminnow below Bonneville Dam was not significantly different (Mann-Kendall $\tau = 0.32$, $P = 0.10$; Fig. 17). Median W_r for male Northern Pikeminnow

below Bonneville Dam was lower than females at 103%, which was higher than recent, previous observations. Analyses of the trends over time showed a significant increasing monotonic trend for male Northern Pikeminnow below Bonneville Dam (Mann-Kendall $\tau = 0.50$, $P = 0.01$). In Bonneville Reservoir, female W_r decreased from previous years to 98% (Fig. 18). There were no monotonic trends in W_r for either sex in Bonneville Reservoir (female Mann-Kendall $\tau = -0.01$, $P = 1.00$; male Mann-Kendall $\tau = 0.05$, $P = 0.83$).

W_r Smallmouth Bass

The 2021 median W_r value for Smallmouth Bass collected below Bonneville Dam (101%) was higher than in Bonneville Reservoir (96%; Fig. 19). Annual median W_r values below Bonneville Dam have varied over time and did not show significant increasing or decreasing trends (Mann-Kendall $\tau = -0.19$, $P = 0.38$). Smallmouth Bass W_r in Bonneville Reservoir has remained nearly constant over time and shows no significant monotonic trend (Mann-Kendall $\tau = -0.16$, $P = 0.43$).

W_r Walleye

Calculating median W_r of Walleye below Bonneville Dam in 2021 was impossible due to sample size constraints ($n<5$) during biological evaluation. Alternatively, median W_r of Walleye was relatively similar below Bonneville Dam (96%) and in Bonneville Reservoir (94%), with overlapping confidence intervals (Fig. 20). The large confidence intervals were due to limited sample sizes. Trends in Walleye body condition over time from either reservoir were not significant.

DISCUSSION

Overview

NPMP was tasked with reducing the predation on juvenile salmonids as they migrate through the hydropower systems of the Columbia and Snake rivers. NPMP was a multi-agency collaboration incorporating a sport reward and dam fisheries managed by WDFW which promoted focused removals of Northern Pikeminnow. These removal efforts were paired with requisite biological monitoring of the Northern Pikeminnow targeted by these removal activities as well as evaluation into the efficacy of the Northern Pikeminnow removal efforts on the reduction in predation to juvenile salmonids conducted by ODFW. NPMP program administration and contract management was led by PSMFC.

Sport Reward Fishery Exploitation

The 2021 Sport Reward Fishery system wide exploitation rate of Northern Pikeminnow ≥ 250 mm FL was 12.9% (±5.2, 95% C.I.) which marked the 24th consecutive year that the target of 10 – 20% exploitation was achieved. The point estimate was in the lower end of the exploitation management goal and trended below the mean of the exploitation time series. Despite reaching this goal system-wide, there were insufficient tag returns in 2021 to calculate area-specific estimates of exploitation in The Dalles, Little Goose, and Lower Granite reservoirs. Due to the lack of sufficient data available and time and budget constraints, ODFW discontinued tagging efforts in John Day Reservoir following the 2019 season. Reasons for low recaptures resulting in a subsequent inability to estimate exploitation included but were not limited to; an inability to place sufficient initial marks in a reservoir, a lack of angler effort, a lack of angler success in an area, or other unaccounted for processes. Going forward, NPMP will continue to adapt and make project management decisions to optimize resources to meet project objectives within a constrained budget.

Predation Reduction

The target predation reduction was met in 2021 at a median, system wide reduction of 31%. The variability associated with this predation reduction estimate was indicative of uncertainty associated with the numerous indices that were integrated into the predation reduction model. Despite this uncertainty, the predation reduction estimates were comparable to previous years and as expected with the measured level of exploitation. The exploitation estimate coupled with the estimated predation reduction value suggest that the removal program continued to be successful. These findings were designed to be presented in conjunction with biological evaluation of additional fisheries metrics, allowing NPMP to further assess whether long-term exploitation of Northern Pikeminnow contributed to predatory compensation with non-native piscivores and native Northern Pikeminnow. The biological evaluation metrics also provide a means to monitor for a chronic decline in the Northern Pikeminnow population.

Fishery Evaluation Trends

Aside from some initial research in 1990 and 1993, there were no recent biological evaluations in McNary Reservoir, despite ESA listed salmonids present above the dam and populations of predator fish in the reservoir. Therefore, fisheries dependent data were utilized for McNary Reservoir in lieu of the biological evaluation used in other areas monitored by the NPMP. Fisheries evaluation sampling techniques were less standardized than fisheries independent biological evaluation data. The fishery evaluation data showed a significant monotonic decrease for Northern Pikeminnow PSD in McNary Reservoir. Walleye also demonstrated a significant decrease in PSD-P and a non-significant decreasing trend in PSD in McNary Reservoir. This trend in PSD for Northern Pikeminnow may be cause for concern as it indicated a truncation of the larger end of the size frequency distribution, potentially related to fishing or a compensatory response due to Walleye competition. Unfortunately, NPMP was unable to collect additional biological evaluation information that could be used to further elucidate potential explanations for declines in PSD. These results warrant consideration for additional resources and focus to initiate a biological evaluation in McNary Reservoir to characterize population parameters for all predators and monitor for evidence of a compensatory response to SRF removals. These results were not further discussed at this time as other areas have similar metrics available from biological evaluation field studies.

DAF

Northern Pikeminnow removed in the DAF appeared to be feeding regularly in the powerhouse tailrace areas of Bonneville and The Dalles reservoirs. Additionally, around 20% of the diet composition of DAF caught Northern Pikeminnow was salmonids. These proportions were calculated from Northern Pikeminnow collected from 11 May– 5 August 2021. During this time, there were documented pulses of out-migrating juvenile salmonids associated with increases in the proportions of juvenile salmonids in the diet of Northern Pikeminnow. Additionally, there was intra-annual variation in the diet composition with noticeable shifts in diet from digestive tracts composed predominantly of lampreys and juvenile salmonids in late spring/early summer transitioning to American Shad in mid/late summer. These data suggest that Northern Pikeminnow feeding in the powerhouse tailrace areas may be influenced by prey availability. These results were notable for the potential differential level of juvenile salmonid predation concentrated at the powerhouse tailrace areas in relation to other areas of these reservoirs. Relative to the timing of the biological evaluation, sampling of Northern Pikeminnow diet composition in the powerhouse tailrace areas occurred over a longer temporal scale, bracketing not only pulses of out-migrating salmonids but other species as well. Despite this, the proportions of salmonids in Northern Pikeminnow diets for powerhouse tailrace caught fish (DAF) were consistently higher than in Northern Pikeminnow assessed throughout the non-powerhouse tailrace areas in this study, including the tailrace areas directly downstream of the powerhouses.

A direct comparison of digestive tract contents between Northern Pikeminnow caught in the tailrace area below Bonneville Dam and in Bonneville Reservoir during the biological evaluation

relative to those caught by DAF was not possible due to differences in sample design and timing of sampling. However, there was evidence that diet composition differed over numerous seasons from Northern Pikeminnow caught in the powerhouse tailrace areas relative to the areas sampled outside of the powerhouse tailrace during biological evaluation. This was consistent with initial research where consumption of juvenile salmonids by Northern Pikeminnow was high in the tailrace boat restricted zones, particularly in The Dalles and John Day reservoirs (Ward et al 1995). With these results, it's reasonable to hypothesize that Northern Pikeminnow caught in the powerhouse tailrace areas consistently predate on more juvenile salmonids, per individual, than Northern Pikeminnow caught throughout the rest of these two areas. Additionally, the timing of DAF sampling bracketed the outmigration of several salmonid species or sub-species as well as other taxa of conservation concern, like lampreys. The continuation of diet composition analyses from DAF caught Northern Pikeminnow may be valuable to track trends in the predation of numerous taxa traveling through the powerhouse tailraces, several of which may be threatened or endangered. The significance of this work is elevated in the context of high proportions of salmonids in digestive tracts of Northern Pikeminnow caught in the boat restricted zones in previous years. Sampling in these areas, through the biological evaluation component, have since been eliminated from the study design due to budget cuts, safety and logistical concerns, and restrictions to access. Therefore, DAF diet composition data provide one mechanism to fill in data gaps surrounding potentially important Northern Pikeminnow feeding areas adjacent to the powerhouse tailrace areas. These data are useful in augmenting the understanding of the predator/prey dynamics between Northern Pikeminnow, juvenile salmonids, lampreys, and numerous other prey taxa. In addition, the removal of Northern Pikeminnow from the powerhouse tailrace areas via DAF mitigates for the direct impact of the Federal Columbia River Power System through a means that is inaccessible to anglers participating in the SRF.

PSD for Northern Pikeminnow in the Bonneville Reservoir powerhouse tailrace (The Dalles Dam), caught through DAF, was significantly lower during the more recent sampling time period (2006 – 2021) relative to the older time period (1990 – 1995). This may indicate a fishing signal from DAF, which began actively removing Northern Pikeminnow in 1990. The Dalles Reservoir tailrace (John Day Dam) did not have a significant difference in PSD for late relative to early time periods. However, in both DAF areas, there was a similar pattern where PSD was depressed in 2006, relative to 1990 - 1995 but then began to increase in 2018 and increased through 2021. While DAF may have initially depressed PSD in these powerhouse tailrace areas, increasing PSD since 2018 suggest Northern Pikeminnow population dynamics have changed recently. The abundance of larger Northern Pikeminnow were increasing relative to smaller Northern Pikeminnow. This could indicate an ontogenetic shift from a smaller or younger cohort elsewhere in the reservoir growing large enough to inhabit these powerhouse tailrace areas. There was some support for this process as there were a limited number of fish tagged outside of the powerhouse tailrace areas that were recaptured in DAF (WDFW personal communication). This suggests movement of some Northern Pikeminnow into the powerhouse tailrace areas and may compliment previous radio telemetry work demonstrating Northern Pikeminnow movement into and out of powerhouse tailrace areas (Fahler et al. 1988, Martinelli and Shiveli 1997). However, DAF caught fish were not tagged and therefore this study did not generate data about the movement of Northern Pikeminnow from the powerhouse tailrace areas to other areas of the reservoir. Future biological evaluation of Bonneville and The Dalles Reservoirs will be conducted through 2025 and may help to further elucidate trends in PSD across the sub-areas of each reservoir and between Northern Pikeminnow and Smallmouth Bass.

Northern Pikeminnow relative weight was not different in either powerhouse tailrace for males or females. This result would suggest that while the proportion of larger Northern Pikeminnow has increased in these areas (e.g., PSD) the condition of individual Northern Pikeminnow has not significantly changed. This result may not be surprising given that several hundred to thousands of Northern Pikeminnow were removed from the powerhouse tailrace areas each year through DAF thereby possibly reducing the intraspecies competition from, presumably, food rich areas of these hydropower reservoirs. However, if these powerhouse tailrace areas were prime feeding areas, increasing competition from other predators may change the present predator/prey dynamics potentially impacting when or how much food Northern Pikeminnow were able to access from the powerhouse tailrace areas.

Biological Evaluation

In addition to modeling the predation reduction due to the NPMP SRF and DAF, fishery metrics were measured for three predatory species: Northern Pikeminnow, Smallmouth Bass, and Walleye. These data were collected independently of the SRF and DAF and were designed to test for indications of a compensatory predatory response among these three species due to focused Northern Pikeminnow removals and monitor for signs of Northern Pikeminnow overfishing. The primary indicator of a compensatory response was whether the level of predation changed within Northern Pikeminnow populations and how it compared with other fish predators of salmon and steelhead, particularly non-native Smallmouth Bass and Walleye. Changes in the abundance of the predators or trends in the consumption of juvenile salmonids can provide additional evidence of a compensatory response to Northern Pikeminnow removals.

There were indications of a compensatory response in Smallmouth Bass relative to Northern Pikeminnow below Bonneville Dam and in Bonneville Reservoir. Smallmouth Bass PI was the highest recorded for the tailrace area below Bonneville Dam and Bonneville Reservoir during 30 years of NPMP. Congruent with the increase in Smallmouth Bass PI was a broad decline in Northern Pikeminnow PI, particularly below Bonneville Dam where PI in 2021 was below the mean of the timeseries and among the lowest ever recorded. Northern Pikeminnow PI in the Bonneville Reservoir was also below the mean for the timeseries though it has historically been lower than area below Bonneville Dam. NPMP did not incorporate PI for Walleye due to a lack of a model for prey consumption needed to develop a CI. PI was informed by the indices of abundance and consumption for Northern Pikeminnow and Smallmouth Bass. Patterns in these indices provided additional information about how predator populations and interspecies interactions might be changing.

Northern Pikeminnow AI broadly declined in 2021 relative to the historic mean from 1990 - 2020, both below Bonneville Dam and in Bonneville Reservoir. Within the tailrace area below Bonneville Dam, Northern Pikeminnow AI increased relative to the time period 2004 – 2017 suggesting that the Northern Pikeminnow population could be cyclical and potentially influenced by environmental parameters (e.g., water temperature, food availability, high/low water year). Northern Pikeminnow AI in the Bonneville Reservoir sub-areas was, with two exceptions, lower than any other in the historical dataset. This trend warrants additional monitoring as it's possible the Northern Pikeminnow population was cyclical as it appears to be in the tailrace area below

Bonneville Dam or that other ecological processes were affecting the Northern Pikeminnow population in Bonneville Reservoir. Alternatively, this decline in AI could continue, approaching or reaching zero in the sub-areas of Bonneville Reservoir. In contrast, Smallmouth Bass AI in 2021 were some of the highest in the historic dataset, above the historic mean in both areas. This result suggests Smallmouth Bass populations may be increasing while Northern Pikeminnow populations, particularly in Bonneville Reservoir, may be decreasing beyond the point that the abundance of Northern Pikeminnow can be monitored as represented by AI. Walleye AI continued to be low in all areas monitored in 2021 suggesting low relative predatory impacts.

CI followed similar trends to those observed with AI in both species. Broadly, Northern Pikeminnow CI trended below the historic mean of the timeseries for all monitoring areas. CI could not be calculated for Northern Pikeminnow from Bonneville mid-reservoir and no Northern Pikeminnow digestive tracts contained salmonids from the Bonneville Reservoir tailrace. In contrast, CI trended above the mean of the timeseries for Smallmouth Bass. This was the first time the sample size of Smallmouth Bass diets containing salmonids was great enough to calculate CI above 0.00 from the tailrace area below Bonneville Dam and all monitoring areas within the Bonneville Reservoir. In addition, the 2021 CI for Smallmouth Bass was the greatest for the time series from the tailrace area below Bonneville Dam and within Bonneville Reservoir. At the time of this report, no CI had been developed for Walleye. As with AI, trends in CI should continue to be monitored between these two species as the implications for the management of juvenile salmonid predation may need to change to account for a compensatory shift in predation. The increase in Smallmouth Bass CI and PI provided evidence for such a potential shift to elevated levels of juvenile salmonid predation by Smallmouth Bass.

The interpretations from these indices were complicated by the fact that the Columbia and Snake river reservoirs were assessed on a multi-year rotating schedule that has varied spatially and temporally throughout the history of the project. This schedule rotation left gaps in the data leading to a coarser temporal scale used to assess trends in AI, CI, and PI. The coarser temporal scale of data could miss important high or low index years leading to misinterpretations of the long-term trends present in the data. The low Northern Pikeminnow and high Smallmouth Bass AI, CI, and PI observed in 2021 were broadly consistent over this timeframe and not from a single anomalously low or high year in a series of relatively constant years. The rotating index scheduling was driven by the incorporation of rapid assessment methods necessary to generate management actionable data through chronic flat funding for this program. The results presented here support the difficulty in assessing fish predator populations with limited data and means for assessment.

Two additional fisheries metrics were calculated for these three species, independent of SRF and DAF, for the tailrace area below Bonneville Dam and the Bonneville Reservoir. These metrics were PSD and W_r which provided additional information about the size frequency distribution and body condition of these species. These metrics can be used to assess for further signs of compensation among predator species, potentially related to Northern Pikeminnow removal, as well as to monitor for signs of overfishing of Northern Pikeminnow. Significant increases in PSD were present for Northern Pikeminnow below Bonneville Dam, indicating an increase in

quality size individuals (> 380 mm) relative to stock size individuals (> 250 mm) and not suggestive of overfishing of large Northern Pikeminnow. However, there was evidence that SRF anglers target smaller Northern Pikeminnow (Report A) and an increasing PSD could indicate a truncation of smaller Northern Pikeminnow in the length frequency distribution. Alternatively, an increasing PSD could indicate a depressed level of Northern Pikeminnow recruitment or decreased survival of smaller size classes from non-SRF related influences. There was no change in PSD for Northern Pikeminnow in the Bonneville Reservoir. Smallmouth Bass PSD and PSD-P were not significantly different in the tailrace area below Bonneville Dam but PSD-P did significantly increase in Bonneville Reservoir. This result could be related to growth from increased consumption of juvenile salmonids as indicated by CI. There may be additional ecological processes occurring that could explain the significant increase in Smallmouth Bass PSD-P that were not accounted for in this study. It should be noted that the patterns in PSD between Northern Pikeminnow and Smallmouth Bass in the tailrace area below Bonneville Dam and Bonneville Reservoir could be indicative of a compensatory response between these two species. Increasingly large Northern Pikeminnow, as represented by a significantly increasing PSD in the area below Bonneville Dam, could be truncating the upper end of the Smallmouth Bass size frequency distribution in the tailrace area below Bonneville Dam. Increasingly larger Smallmouth Bass could have had a similar effect on Northern Pikeminnow in Bonneville Reservoir. There may also be additional direct or indirect interspecies competition dynamics or differential preferences in habitat between Northern Pikeminnow and Smallmouth Bass that were not captured by these data. The drivers of such mechanisms would be speculatory at this time but the pattern in PSD is worth tracking over time, particularly in combination with other fisheries metrics monitored by NPMP.

W_r for male Northern Pikeminnow significantly increased in the area below Bonneville Dam. This result suggests an improvement in male Northern Pikeminnow body condition, potentially indicative of intra-specific competition or other life history differences between male and female Northern Pikeminnow. It was difficult to speculate about the cause of this in the absence of other significant changes in W_r for female Northern Pikeminnow or some signal in Smallmouth Bass. There were no significant differences in W_r for female Northern Pikeminnow or Smallmouth Bass in either of the monitoring areas.

Walleye did not appear to be contributing to a significant level of predation of juvenile salmonids below Bonneville Dam and in the Bonneville Reservoir. There were only two Walleye captured below Bonneville Dam and six captured in the Bonneville Reservoir during biological evaluation and monitoring in 2021. Walleye have historically been less abundant in these areas of the river so these results are not abnormal. However, when present, Walleye had consistently high proportions of juvenile salmonids in their digestive tracts among all areas monitored in the Columbia and Snake rivers. For this reason, it would be prudent to continue to monitor Walleye in these areas given the indications of ongoing shifts in the predator/prey dynamics among Northern Pikeminnow, Smallmouth Bass, and juvenile salmonids.

Taken in aggregate, the fisheries independent indices of abundance, consumption, and predation suggest a long-term decline in Northern Pikeminnow populations and a reduction in their

predatory impact on juvenile salmonids in the area below Bonneville Dam and the Bonneville Reservoir. These changes were potentially being compensated for by increased abundance and predation of juvenile salmonids by Smallmouth Bass in the same areas. However, there was not strong evidence that this compensatory response was paired with significant declines in Northern Pikeminnow size distribution or a reduction in body condition. This finding could support that Northern Pikeminnow populations were robust enough to withstand long-term exploitation by SRF and DAF while simultaneously shifting their diet, habitat preference, or other modifications to their behavior to compensate for increased competition from Smallmouth Bass. Alternatively, reductions in overall abundance, as indicated by AI, may reduce the intraspecies Northern Pikeminnow competition, leading to stable body condition, as measured by W_r. The complex interactions present in this system necessitate ongoing biological monitoring in order to provide accurate management relevant information. Continued evidence of compensatory responses to removals could justify a need to augment the current study design to include investigations into the predator/prey dynamics occurring in areas where compensation is suspected. In the absence of long-term, scientifically rigorous data, state and federal resource managers will not be able to accurately assess the effects of long-term fishing pressure, subsequent reduction in predation on juvenile salmonids, and changes to the multi-species predator/prey dynamics in this highly modified river system. It is important that ODFW adapts and continues to monitor these areas through biological evaluation to assure a viable population of the native predator persists.

The rapid assessment methods incorporated into this report provided cost effective methods to biologically monitor and evaluate the effect of recreational sport reward fishing for Northern Pikeminnow. While these methods were not spatially or temporally exhaustive, they did provide an additional year of scientifically robust data that was used to augment the existing 30 years of historical data. In doing so, NPMP was able to address the efficacy of the sport reward fishery to exploit 10 – 20% of the Northern Pikeminnow population, estimate the concomitant juvenile salmonid predation reduction, monitor for predator compensation, and provide a safeguard against overexploiting a native fish predator. These methods provided evidence that there may be a compensatory response in Smallmouth Bass, potentially due to the removal of Northern Pikeminnow in the tailrace area below Bonneville Dam and Bonneville Reservoir. This potential compensatory response needs to be monitored carefully as continuing to remove one predator, only to have the reductions to juvenile salmonid predation negated by predation from another predator, counteracts the essence of the efforts of NPMP. There were many factors that influenced the predatory impact of piscivorous fishes on ESA listed salmonids. In the effort to elucidate the relationships among these factors, NPMP has and will continue adapting the research methods to provide management actionable information about the predation of juvenile salmonids in the Columbia and Snake rivers.

Future Perspectives

The NPMP is based on an adaptive management framework which implicitly calls for updates to project operation as data inform management strategies (NMFS 2020) and based on input from an independent scientific review panel (ISRP 2019). To continually improve the relevance and

utility of the data collected by NPMP, there are several priority project areas that will be evaluated for potential modification for the 2022 season and beyond. These priority areas nest within a broader plan to address recommendations presented by ISRP in 2019.

First, to address concerns about incidental electrofishing interactions with juvenile salmonids during Northern Pikeminnow sampling activities, alternative gear types and shifts in the field season schedule will be evaluated for potential incorporation into NPMP biological evaluation and monitoring. Second, the analytical methods employed here may benefit from recent advances in computing power such that it's prudent to assess the costs and benefits of a model-driven (e.g., Cormack Jolly Seber, Brownie band recovery) approach to estimate Northern Pikeminnow abundance and rates of exploitation. Third, NPMP has obtained commercially available side-scan sonar units that may allow for relatively cost-effective acquisition and incorporation of habitat data during biological evaluation and monitoring efforts. Habitat data like depth, rugosity, and hardness may be used to better understand observed trends in Northern Pikeminnow, Smallmouth Bass, and Walleye occupancy and abundance, that may have implications in the NPMP efforts to better understand predation on juvenile salmonids. Fourth, NPMP will assess the potential to eliminate the external tag (mark) and only using the internal PIT tags during the 2022 field season. This change would be justified by previous NPMP work suggesting elevated survival, via recapture rate of external tag loss (with PIT tag retention), particularly in smaller fish (200-249 mm FL).

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TABLES

Table 1. Numbers of Northern Pikeminnow marked and recaptured[a] in the Sport Reward Fishery during 2021 by location and size class.

	200–249 mm FL		≥ 250 mm FL		Combined	
Reach/Reservoir	Marked	Recaptured	Marked	Recaptured	Marked	Recaptured
Below Bonneville	42	3	246	29	288	32
Bonneville	57	6	71	4	128	10
The Dalles	3	0	6	0	9	0
McNary	38	5	66	10	104	15
Little Goose	13	1	3	0	16	1
Lower Granite	22	0	10	1	32	1
Combined	175	15	402	44	577	59

[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). In 2021 this included 2 fish from McNary Reservoir and 1 fish from Little Goose Reservoir. Fish that were recaptured in a different area than they were marked were also excluded in calculations of exploitation. In 2021 this included 3 fish marked in Bonneville Reservoir.

Table 2. 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	Little Goose	Lower Granite	All areas
1991	7.6	10.9	23.6	2.8	5.3	2.4	20.0	8.5
1992	11.4	4.0	6.2	3.4	5.6	11.9	15.0	9.3
1993	6.0	2.1	7.0	2.4	15.9	3.3	12.5	6.8
1994	13.6	2.2	9.8	3.2	14.0	6.1	8.7	10.9
1995	16.1	3.5	14.9	*a*	22.4	2.9	6.4	13.4
1996	12.7	6.1	15.5	*a*	18.2	8.9	11.7	12.1
1997	7.8	8.0	5.8	*a*	16.5	*a*	15.5	8.9
1998	8.2	7.8	12.8	*a*	13.6	*a*	12.1	11.1
1999	9.6	13.9	16.1	3.7	15.9	*a*	6.1	12.5
2000	10.0	16.3	*a*	*a*	9.7	*a*	8.7	11.9
2001	16.2	8.5	*a*	*a*	26.0	—	*a*	16.2
2002	12.6	6.0	*a*	*a*	7.7	—	14.3	12.3
2003	13.6	16.7	*a*	*a*	8.2	—	*a*	13.0
2004	20.1	9.3	*a*	*a*	*a*	—	23.8	18.5
2005	23.1	8.2	18.0	*a*	13.0	—	*a*	19.0
2006	15.6	13.7	25.3	*a*	11.2	26.3	*a*	17.1
2007	19.4	11.1	*a*	*a*	7.5	*a*	17.3	17.8
2008	22.2	10.5	15.0	*a*	16.8	21.7	9.2	19.5
2009	11.3	15.9	*a*	*a*	11.6	25.8	*a*	12.8
2010	19.8	13.1	*a*	*a*	*a*	*a*	*a*	18.8
2011	14.5	10.4	*a*	*a*	17.8	*a*	*a*	15.6
2012	17.4	13.5	*a*	*a*	17.6	*a*	*a*	15.9
2013	9.6	11.2	*a*	*a*	26.5	*a*	11.4	10.8
2014	9.2	6.9	*a*	*a*	17.9	*a*	11.3	11.5
2015	16.7	14.3	*a*	*a*	*a*	*a*	24.4	17.2
2016	11.6	8.9	*a*	*a*	4.6	24.8	14.4	12.1
2017	16.3	14.8	*a*	*a*	28.1	*a*	*a*	17.4
2018	13.8	18.3	*a*	*a*	18.1	*a*	16.9	16.8
2019	14.7	7.8	*a*	*a*	16.5	*a*	19.7	15.4
2020	19.0	10.1	—	—	*a*	*a*	*a*	17.8
2021	11.8	5.6	*a*	—	19.7	*a*	*a*	12.9
mean (SE)	13.9 (0.8)	10 (0.8)	14.2 (1.8)	3.1 (0.2)	15 (1.2)	13.4 (3.2)	14 (1.2)	14 (0.6)

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

Table 3. 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	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	13.6	*a*	15.0
2018	10.1	16.8	*a*	*a*	18.3	5.5	5.5	12.6
2019	13.6	9.5	*a*	*a*	15.9	30.4	13.2	17.3
2020	16.3	8.7	—	—	*a*	15.0	5.3	15.2
2021	11.1	7.8	*a*	—	18.1	*a*	*a*	12.3
mean (SE)	13.8 (0.9)	10.2 (0.6)	14.2 (3.5)	*b*	12.1 (1.3)	14.8 (2.7)	13.1 (4.1)	13 (0.6)

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 (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	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	10.6	*a*	8.7
2018	3.5	*a*	*a*	*a*	10.6	*a*	*a*	4.5
2019	11.7	21.1	*a*	*a*	13.0	29.9	9.9	19.4
2020	*a*	7.9	—	—	*a*	*a*	*a*	8.4
2021	*a*	10.5	*a*	—	*15.4*	*a*	*a*	10.9
mean (SE)	7.2 (1.5)	9.1 (1.5)	*b*	*b*	8.9 (1.3)	12 (3.4)	6.2 (2.4)	7.6 (0.9)

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 5. Number (*n*) of Northern Pikeminnow diets examined from Dam Angling Fishery catch from Bonneville (tailrace of The Dalles Dam) and The Dalles (tailrace of John Day Dam) 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
2020	336	0.69	0.49	0.03	0.26	0.16	0.26	0.07	0.13
2021	327	0.78	0.55	0.04	0.34	0.18	0.23	0.03	0.19
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
2020	549	0.70	0.48	0.04	0.39	0.13	0.19	0.19	0.03
2021	317	0.67	0.45	0.06	0.40	0.20	0.20	0.08	0.07

Table 6. Number (*n*) of Northern Pikeminnow, Smallmouth Bass, and Walleye (≥ 200 mm FL) diets examined during biological evaluation below Bonneville Dam and in Bonneville Reservoir during spring 2021 and proportion of samples containing specific prey items (cray = crayfish, crust = all crustacea not identified as crayfish, sal = salmon or steelhead, lam = lamprey).

Season,	Northern Pikeminnow							
Area	n	$\hat{p}_{food}$	$\hat{p}_{fish}$	$\hat{p}_{cray}$	$\hat{p}_{crust}$	$\hat{p}_{insect}$	$\hat{p}_{sal}$	$\hat{p}_{lam}$
Spring,								
Below Bonneville Dam	78	0.76	0.44	0.35	0.05	0.03	0.10	0.17
Bonneville	277	0.90	0.14	0.11	0.56	0.16	0.01	0.01
All	355	0.87	0.21	0.16	0.45	0.13	0.03	0.04
	Smallmouth Bass							
	n	$\hat{p}_{food}$	$\hat{p}_{fish}$	$\hat{p}_{cray}$	$\hat{p}_{crust}$	$\hat{p}_{insect}$	$\hat{p}_{sal}$	$\hat{p}_{lam}$
Spring,								
Below Bonneville Dam	65	0.89	0.74	0.37	0.22	0.15	0.15	0.00
Bonneville	360	0.92	0.43	0.48	0.49	0.24	0.14	0.02
All	425	0.92	0.47	0.46	0.44	0.23	0.15	0.02
	Walleye							
	n	$\hat{p}_{food}$	$\hat{p}_{fish}$	$\hat{p}_{cray}$	$\hat{p}_{crust}$	$\hat{p}_{insect}$	$\hat{p}_{sal}$	$\hat{p}_{lam}$
Spring,								
Below Bonneville Dam	2	1.00	1.00	0.00	0.00	0.00	0.50	0.00
Bonneville	6	0.83	0.67	0.17	0.17	0.17	0.17	0.00
All	8	0.88	0.75	0.13	0.13	0.13	0.25	0.00

Table 7. Spring abundance index values (mean catch per 900-s boat electrofishing scaled to surface area [ha] divided by 1,000; and SE) for Northern Pikeminnow (≥ 250 mm FL) below Bonneville Dam and in Bonneville Reservoir, 1990–2021. FB = forebay, Mid = mid-reservoir, and TR = tailrace.

	Below Bonneville Dam					Bonneville Reservoir		
Season, Year	Rkm 116–121	Rkm 173–181	Rkm 188–194	TR	TR/BRZ	FB	Mid	TR
Spring,								
1990	—	—	—	2.54 (0.78)	2.08 (0.71)	4.11 (0.70)	22.44 (4.36)	0.66 (0.17)
1991	—	—	—	3.22 (1.32)	4.12 (1.33)	0.23 (0.10)	4.18 (1.39)	0.35 (0.14)
1992	21.82 (5.86)	35.56 (9.38)	32.68 (17.37)	1.47 (0.58)	4.18 (1.65)	—	—	—
1993	—	—	—	7.22 (4.10)	3.44 (1.04)	1.29 (0.58)	7.81 (3.49)	1.15 (0.52)
1994	—	—	—	—	—	1.70 (0.39)	6.81 (1.72)	0.80 (0.28)
1995	19.64 (3.78)	29.29 (6.24)	17.34 (5.12)	2.43 (0.68)	0.92 (0.44)	2.51 (0.44)	9.87 (2.77)	0.40 (0.11)
1996	19.04 (7.06)	28.41 (8.19)	20.87 (4.97)	1.58 (0.76)	0.58 (0.32)	1.39 (0.41)	5.64 (1.75)	0.89 (0.35)
1999	13.83 (3.85)	12.55 (3.06)	12.65 (3.33)	1.51 (0.58)	—	0.58 (0.16)	3.25 (1.33)	1.44 (1.01)
2004	17.79 (7.93)	8.54 (3.35)	16.46 (5.43)	0.97 (0.19)	3.61 (1.1)	0.66 (0.17)	—	1.34 (0.81)
2005	15.83 (3.43)	11.39 (3.88)	10.52 (2.11)	0.79 (0.17)	2.07 (0.86)	0.34 (0.11)	4.11 (1.60)	0.23 (0.15)
2008	19.82 (5.16)	10.42 (2.88)	5.26 (2.14)	1.03 (0.33)	2.15 (0.46)	0.22 (0.11)	0.69 (0.47)	0.32 (0.18)
2011	6.61 (2.68)	4.13 (1.6)	3.61 (2.45)	0.39 (0.11)	0.25 (0.16)	0.15 (0.08)	3.00 (1.99)	0.29 (0.13)
2014	13.16 (8.01)	1.05 (1.05)	4.12 (2.32)	0.25 (0.08)	0.00 (0.00)	0.03 (0.03)	1.40 (0.57)	0.22 (0.13)
2017	19.09 (6.29)	3.69 (1.43)	2.45 (0.91)	0.59 (0.17)	0.00 (0.00)	0.23 (0.12)	3.06 (1.74)	0.28 (0.11)
2021	—	—	—	1.12 (0.23)	—	0.16 (0.05)	0.08 (0.08)	0.15 (0.06)
mean (SE)	16.66(1.42)	14.5 (3.48)	12.59 (3.02)	1.79 (0.48)	1.95(0.46)	0.97 (0.31)	5.56 (1.61)	0.61 (0.12)

Note: dashes (—) = no sampling conducted.

Table 8. Spring abundance index values (mean catch per 900-s boat electrofishing scaled to surface area [ha] divided by 1,000; and SE) for Smallmouth Bass (≥ 200 mm FL) below Bonneville Dam and in Bonneville Reservoir, 1990–2021. FB = forebay, Mid = mid-reservoir, and TR = tailrace.

	Below Bonneville Dam					Bonneville Reservoir		
Season, Year	Rkm 116–121	Rkm 173–181	Rkm 188–194	TR	TR/BRZ	FB	Mid	TR
Spring,								
1990	—	—	—	0.06 (0.06)	0.13 (0.09)	0.05 (0.05)	6.94 (3.25)	1.46 (0.78)
1991	—	—	—	0.14 (0.14)	0.00 (0.00)	0.06 (0.06)	1.09 (0.79)	1.77 (1.01)
1992	0.00 (0.00)	0.04 (0.01)	0.01 (0.00)	0.11 (0.11)	0.27 (0.21)	—	—	—
1993	—	—	—	0.00 (0.00)	0.32 (0.26)	0.43 (0.23)	4.49 (3.04)	3.51 (1.00)
1994	—	—	—	—	—	0.15 (0.07)	9.61 (2.47)	2.22 (0.48)
1995	1.4 (1.4)	49.16 (15.1)	23.52 (6.33)	1.29 (0.54)	0.71 (0.44)	0.36 (0.14)	11.77 (3.23)	1.89 (0.37)
1996	0.00 (0.00)	17.74 (6.07)	6.96 (3.94)	0.06 (0.06)	0.36 (0.36)	0.41 (0.15)	7.83 (2.40)	3.39 (0.62)
1999	0.00 (0.00)	2.64 (1.33)	1.15 (0.79)	0.20 (0.10)	—	0.24 (0.13)	1.80 (0.89)	1.50 (0.32)
2004	0.00 (0.00)	19.49 (6.64)	9.43 (4.81)	0.93 (0.23)	0.63 (0.23)	0.57 (0.14)	—	2.23 (0.71)
2005	1.97 (1.44)	6.25 (2.26)	11.58 (3.13)	0.52 (0.14)	0.51 (0.16)	0.98 (0.20)	8.37 (3.06)	1.30 (0.23)
2008	3.3 (2.13)	17.24 (4.58)	14.16 (6.15)	0.91 (0.26)	0.9 (0.23)	1.89 (0.53)	4.40 (1.82)	2.57 (0.39)
2011	0.00 (0.00)	8.33 (3.33)	0.00 (0.00)	0.08 (0.04)	0.25 (0.1)	0.37 (0.11)	17.21 (2.81)	1.93 (0.39)
2014	0.00 (0.00)	1.04 (1.04)	3.12 (1.63)	0.11 (0.06)	0.11 (0.06)	0.38 (0.13)	10.87 (2.59)	2.26 (0.35)
2017	0.00 (0.00)	7.38 (3.58)	2.85 (0.96)	0.11 (0.05)	0.04 (0.04)	1.74 (0.41)	33.60 (6.15)	1.71 (0.27)
2021	—	—	—	0.98 (0.20)	—	2.15 (0.32)	23.07 (2.98)	2.28 (0.31)
mean (SE)	0.67 (0.37)	13.55 (4.45)	7.49 (2.33)	0.39 (0.12)	0.35 (0.08)	0.70 (0.19)	10.85 (2.53)	2.15 (0.18)

Note: dashes (—) = no sampling conducted.

Table 9. Spring abundance index values (mean catch per 900-s boat electrofishing scaled to surface area [ha] divided by 1,000; and SE) for Walleye (≥ 200 mm FL) below Bonneville Dam and in Bonneville Reservoir, 1990–2021. FB = forebay, Mid = mid-reservoir, and TR = tailrace.

	Below Bonneville Dam					Bonneville Reservoir		
Season, Year	Rkm 116–121	Rkm 173–181	Rkm 188–194	TR	TR/BRZ	FB	Mid	TR
Spring,								
1990	—	—	—	0.00 (0.00)	0.04 (0.04)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
1991	—	—	—	0.35 (0.22)	0.14 (0.07)	0.00 (0.00)	0.00 (0.00)	0.18 (0.13)
1992	0.00 (0.00)	0.00 (0.00)	0.02 (0.00)	0.23 (0.15)	0.05 (0.05)	—	—	—
1993	—	—	—	0.10 (0.10)	0 (0)	0.00 (0.00)	0.00 (0.00)	0.13 (0.09)
1994	—	—	—	—	—	0.02 (0.02)	1.00 (0.59)	0.11 (0.08)
1995	0.00 (0.00)	4.18 (4.18)	0.00 (0.00)	0.49 (0.30)	0.11 (0.11)	0.00 (0.00)	0.76 (0.52)	0.11 (0.08)
1996	0.00 (0.00)	0.66 (0.66)	0.00 (0.00)	0.17 (0.12)	0.36 (0.26)	0.00 (0.00)	0.94 (0.52)	0.18 (0.07)
1999	0.00 (0.00)	0.00 (0.00)	0.01 (0.00)	0.13 (0.09)	—	0.00 (0.00)	0.36 (0.36)	0.03 (0.03)
2004	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.25 (0.10)	0.00 (0.00)	0.00 (0.00)	—	0.13 (0.09)
2005	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.07 (0.04)	0.03 (0.03)	0.00 (0.00)	0.00 (0.00)	0.02 (0.02)
2008	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.02 (0.02)	0.03 (0.03)	0.00 (0.00)	0.34 (0.34)	0.06 (0.05)
2011	0.00 (0.00)	1.04 (0.72)	0.01 (0.00)	0.16 (0.06)	0.00 (0.00)	0.00 (0.00)	0.30 (0.21)	0.41 (0.20)
2014	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.16 (0.07)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2017	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.03 (0.03)	0.00 (0.00)	0.00 (0.00)	1.25 (1.02)	0.19 (0.13)
2021	—	—	—	0.03 (0.02)	—	0.00 (0.00)	0.25 (0.14)	0.06 (0.03)
mean (SE)	0.00 (0.00)	0.59 (0.42)	0.16 (0.32)	0.16 (0.04)	0.06 (0.03)	0.00 (0.00)	0.40 (0.12)	0.12 (0.03)

Note: dashes (—) = no sampling conducted

Table 10. Annual spring consumption index values for Northern Pikeminnow (≥ 250 mm FL) captured during biological evaluation below Bonneville Dam and in Bonneville Reservoir, 1990–2021. Mean and SE were calculated for each location across the time series. FB = forebay, Mid = mid-reservoir, and TR = tailrace.

	Below Bonneville Dam					Bonneville Reservoir		
Season, Year	Rkm 116–121	Rkm 173–181	Rkm 188–194	TR	TR/BRZ	FB	Mid	TR
Spring,								
1990	—	—	—	1.28	2.34	0.06	0.00	0.32
1992	0.81	1.97	2.16	0.91	1.41	—	—	—
1993	—	—	—	0.53	0.82	0.46	0.00	0.00
1994	—	—	—	—	—	0.04	0.25	0.00
1995	0.54	0.34	1.03	0.91	1.76	0.45	0.00	0.23
1996	0.37	0.07	0.41	0.37	0.60	0.00	0.12	0.00
1999	0.77	0.44	0.42	0.14	—	0.00	0.59	0.16
2004	0.17	0.31	0.11	0.26	0.97	0.52	—	0.00
2005	0.17	0.00	0.54	0.42	1.58	0.28	*a*	1.47
2008	0.79	0.98	0.00	1.02	0.94	1.31	*a*	0.64
2011	0.57	0.58	*a*	0.71	1.00	0.00	0.00	0.49
2014	0.27	*a*	*a*	1.31	*a*	*a*	0.00	0.29
2017	2.47	*a*	2.97	2.07	*a*	0.00	0.00	1.78
2021	—	—	—	0.29	—	0.26	*a*	0.00
mean (SE)	0.69 (0.21)	0.59 (0.22)	0.95 (0.38)	0.79 (0.15)	1.27 (0.18)	0.28 (0.11)	0.11 (0.07)	0.41 (0.16)

Note: *a* = no consumption index calculated ($n < 6$), dashes (—) = no sampling conducted.

Table 11. Annual spring consumption index values for Smallmouth Bass (≥ 200 mm FL) captured during biological evaluation below Bonneville Dam and in Bonneville Reservoir, 1990–2021. Mean and SE were calculated for each location across the time series. FB = forebay, Mid = mid-reservoir, and TR = tailrace.

	Below Bonneville Dam					Bonneville Reservoir		
Season, Year	Rkm 116–121	Rkm 173–181	Rkm 188–194	TR	TR/BRZ	FB	Mid	TR
Spring,								
1990	—	—	—	*a*	0.38	*a*	*a*	0.00
1992	*a*	0.08	*a*	*a*	*a*	—	—	—
1993	—	—	—	*a*	0.11	*a*	*a*	0.00
1994	—	—	—	—	—	*a*	0.00	0.00
1995	*a*	0.05	0.00	0.00	0.00	0.08	0.03	0.00
1996	*a*	0.00	0.00	*a*	*a*	0.00	0.00	0.00
1999	*a*	0.00	*a*	*a*	—	0.00	*a*	0.01
2004	*a*	0.00	0.23	0.00	0.00	0.00	—	0.00
2005	*a*	0.34	0.05	0.00	0.00	0.10	0.00	0.03
2008	*a*	0.04	0.04	0.02	0.00	0.05	0.00	0.02
2011	*a*	0.07	*a*	*a*	0.12	0.11	0.04	0.00
2014	*a*	*a*	*a*	*a*	*a*	0.00	0.06	0.05
2017	*a*	0.11	0.19	*a*	*a*	0.04	0.09	0.01
2021	—	—	—	0.20	—	0.17	0.21	0.21
mean (SE)	*b*	0.08 (0.04)	0.09 (0.04)	0.04 (0.04)	0.09 (0.05)	0.06 (0.02)	0.05 (0.02)	0.03 (0.02)

Note: *a* = no consumption index calculated ($n < 6$), dashes (—) = no sampling conducted, b = no mean calculated (n< 3).

Table 12. Annual spring predation index values for Northern Pikeminnow (≥ 250 mm FL) captured during biological evaluation below Bonneville Dam and in Bonneville Reservoir, 1990–2021. Mean and SE were calculated for each location across the time series. FB = forebay, Mid = mid-reservoir, and TR = tailrace.

	Below Bonneville Dam					Bonneville Reservoir		
Season, Year	Rkm 116–121	Rkm 173–181	Rkm 188–194	TR	TR/BRZ	FB	Mid	TR
Spring,								
1990	—	—	—	3.26	4.88	0.23	0.00	0.21
1992	22.63	37.54	34.84	1.34	5.79	—	—	—
1993	—	—	—	3.86	3.41	0.60	0.00	0.00
1994	—	—	—	—	—	0.08	1.69	0.00
1995	10.67	10.07	17.78	2.20	0.00	1.12	0.00	0.09
1996	6.98	2.11	8.47	0.59	0.55	0.00	0.66	0.00
1999	10.62	5.48	5.30	0.21	—	0.00	1.91	0.23
2004	3.02	2.68	1.89	0.25	0.00	0.34	—	0.00
2005	2.76	0.00	5.64	0.33	5.69	0.10	*a*	0.33
2008	15.57	10.20	0.00	1.05	1.93	0.28	*a*	0.20
2011	3.75	2.40	*a*	0.28	2.15	0.00	0.00	0.14
2014	3.57	*a*	*a*	0.32	*a*	*a*	0.00	0.06
2017	47.15	*a*	7.26	1.22	*a*	0.00	0.00	0.49
2021	—	—	—	0.32	—	0.04	*a*	0.00
mean (SE)	12.67 (4.33)	8.81 (4.31)	10.15 (4)	1.17 (0.34)	2.71 (0.78)	0.23 (0.1)	0.47 (0.26)	0.14 (0.04)

Note: *a* = no predation index calculated ($n_{fish} < 6$ or $n_{runs} < 3$), dashes (—) = no sampling conducted.

Table 13. Annual spring predation index values for Smallmouth Bass (≥ 200 mm FL) captured during biological evaluation below Bonneville Dam and in Bonneville Reservoir, 1990–2021. Mean and SE were calculated for each location across the time series. FB = forebay, Mid = mid-reservoir, and TR = tailrace.

	Below Bonneville Dam					Bonneville Reservoir		
Season, Year	Rkm 116–121	Rkm 173–181	Rkm 188–194	TR	TR/BRZ	FB	Mid	TR
Spring,								
1990	—	—	—	*a*	1.05	*a*	*a*	0.00
1992	*a*	0.47	*a*	*a*	*a*	—	—	—
1993	—	—	—	*a*	0.77	*a*	*a*	0.00
1994	—	—	—	—	—	*a*	0.00	0.00
1995	*a*	2.59	0.00	0.00	0.00	0.03	0.39	0.00
1996	*a*	0.00	0.00	*a*	*a*	0.00	0.00	0.00
1999	*a*	0.00	*a*	*a*	—	0.00	*a*	0.02
2004	*a*	0.00	2.16	0.00	0.00	0.00	—	0.00
2005	*a*	2.14	0.63	0.00	0.00	0.10	0.00	0.04
2008	*a*	0.76	0.53	0.02	0.00	0.09	0.00	0.06
2011	*a*	0.59	*a*	*a*	0.03	0.04	0.73	0.00
2014	*a*	*a*	*a*	*a*	*a*	0.00	0.63	0.12
2017	*a*	0.82	0.55	*a*	*a*	0.08	2.92	0.02
2021	—	—	—	0.20	—	0.37	4.86	0.48
mean (SE)	*b*	0.82 (0.31)	0.64 (0.32)	0.04 (0.04)	0.26 (0.17)	0.07 (0.04)	1.06 (0.57)	0.06 (0.04)

Note: *a* = no predation index calculated ($n_{fish} < 6$ or $n_{runs} < 3$), dashes (—) = no sampling conducted, *b* = no mean calculated ($n < 3$)

FIGURES

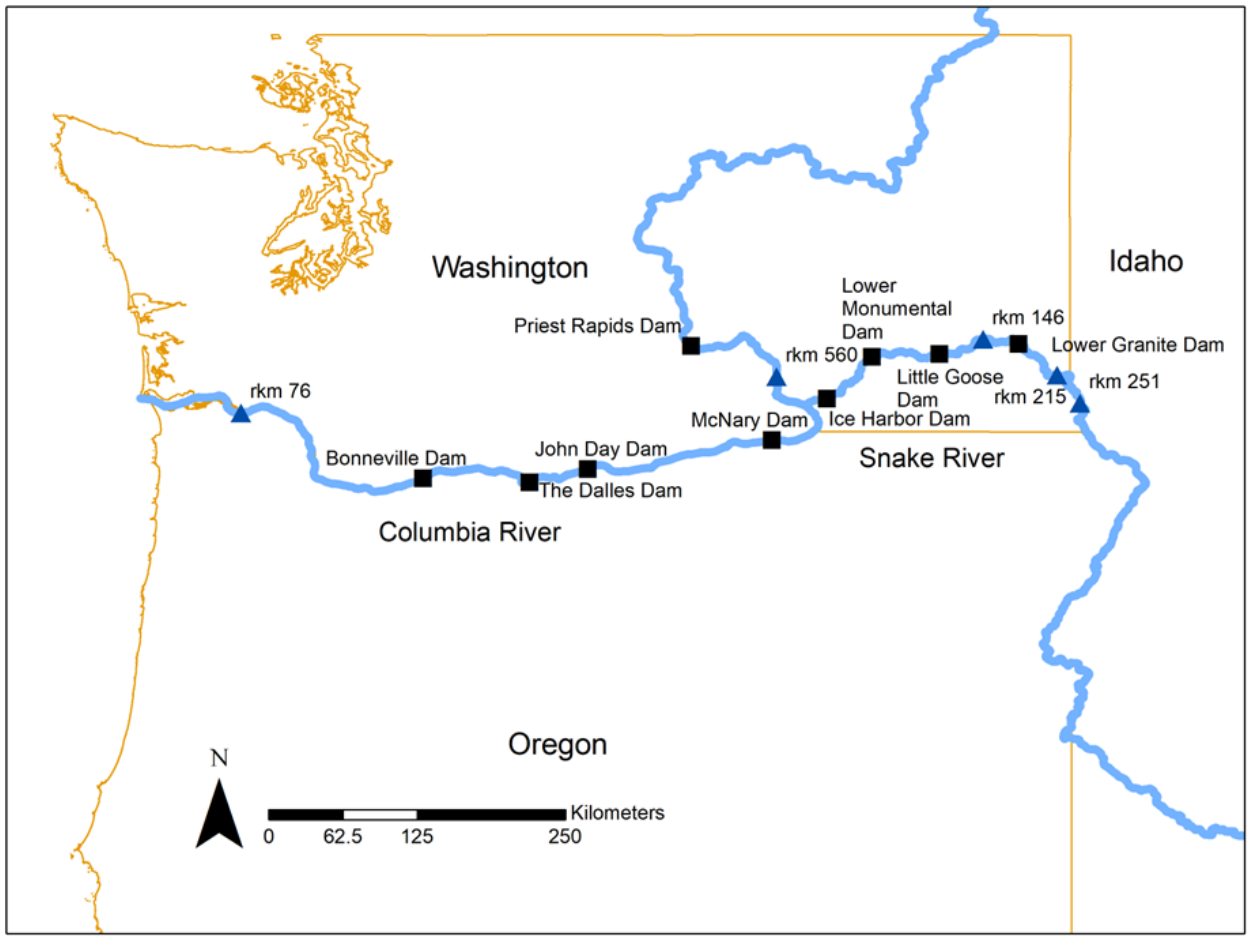

Figure 1. Study area in the Columbia and Snake rivers.

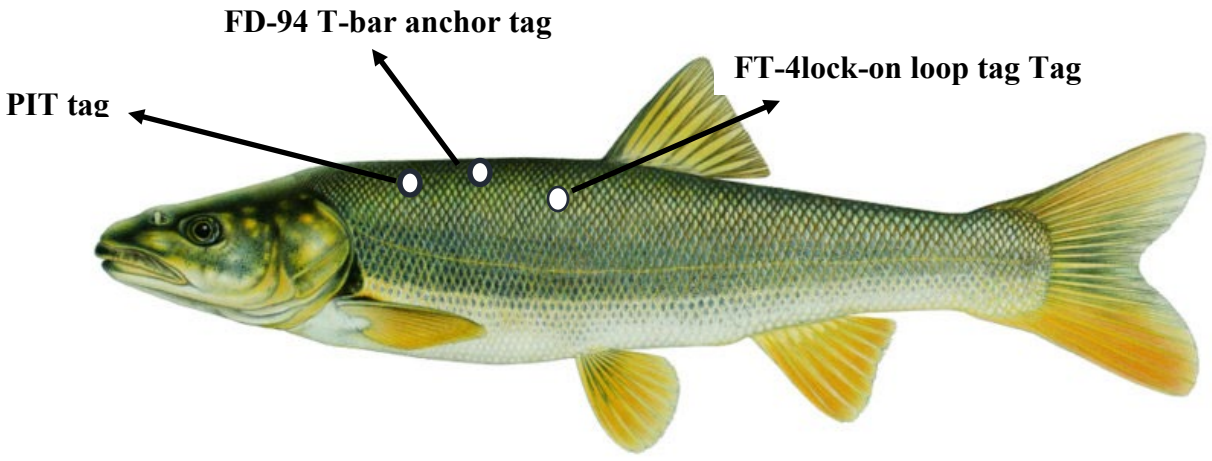

Figure 2. Tag placements areas for Floy® FT4-lock-loop, Floy® FD-94 T-bar anchor, and 134.2 MHz passive integrated transponder (PIT) tags for marked Northern Pikeminnow.

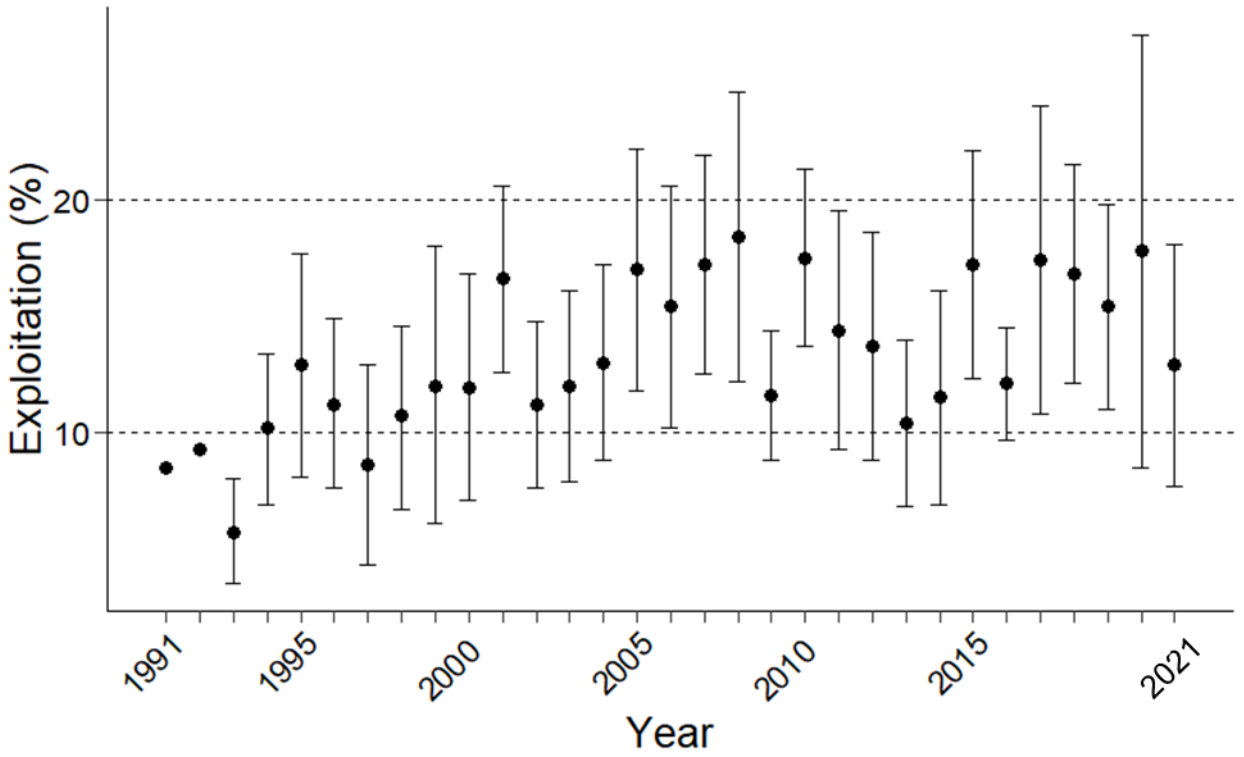

Figure 3. System-wide exploitation rates of Northern Pikeminnow (≥ 250 mm FL) in the Sport Reward Fishery, 1991–2021. Error bars represent 95% confidence intervals, though variation was not estimated for the years 1991–1992. Target exploitation is 10–20% (dashed lines).

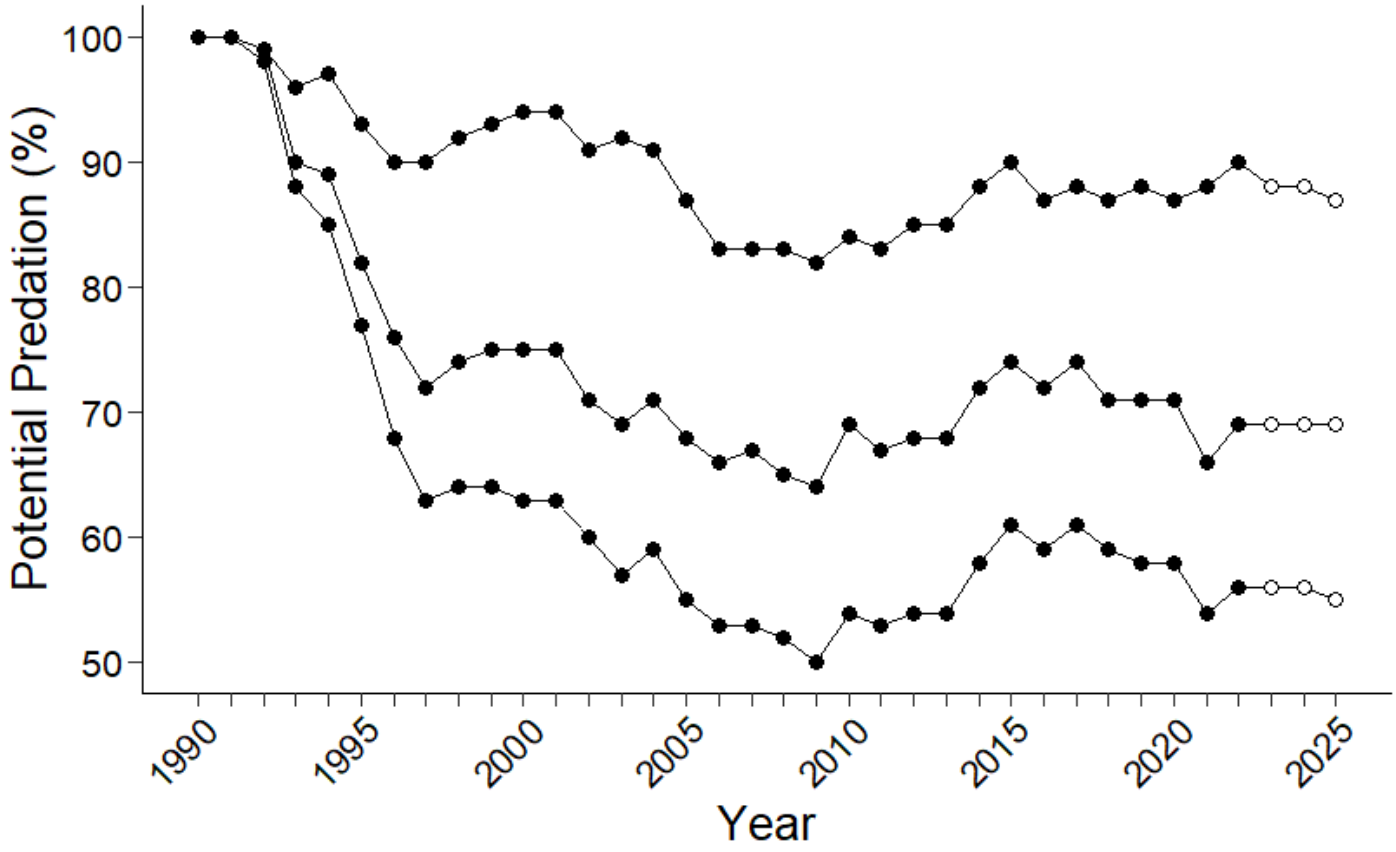

Figure 4. Estimates of (A) maximum, (B) median, and (C) minimum annual levels of potential predation by Northern Pikeminnow on juvenile salmon relative to predation levels before implementation of the Northern Pikeminnow Management Program. For the years 1991–2022, model estimates (filled circles) are based on exploitation rates from the previous year. Model forecast predictions after 2022 (open circles) are based on average exploitation estimates from years with similar fishery structure (2001, 2004–2021).

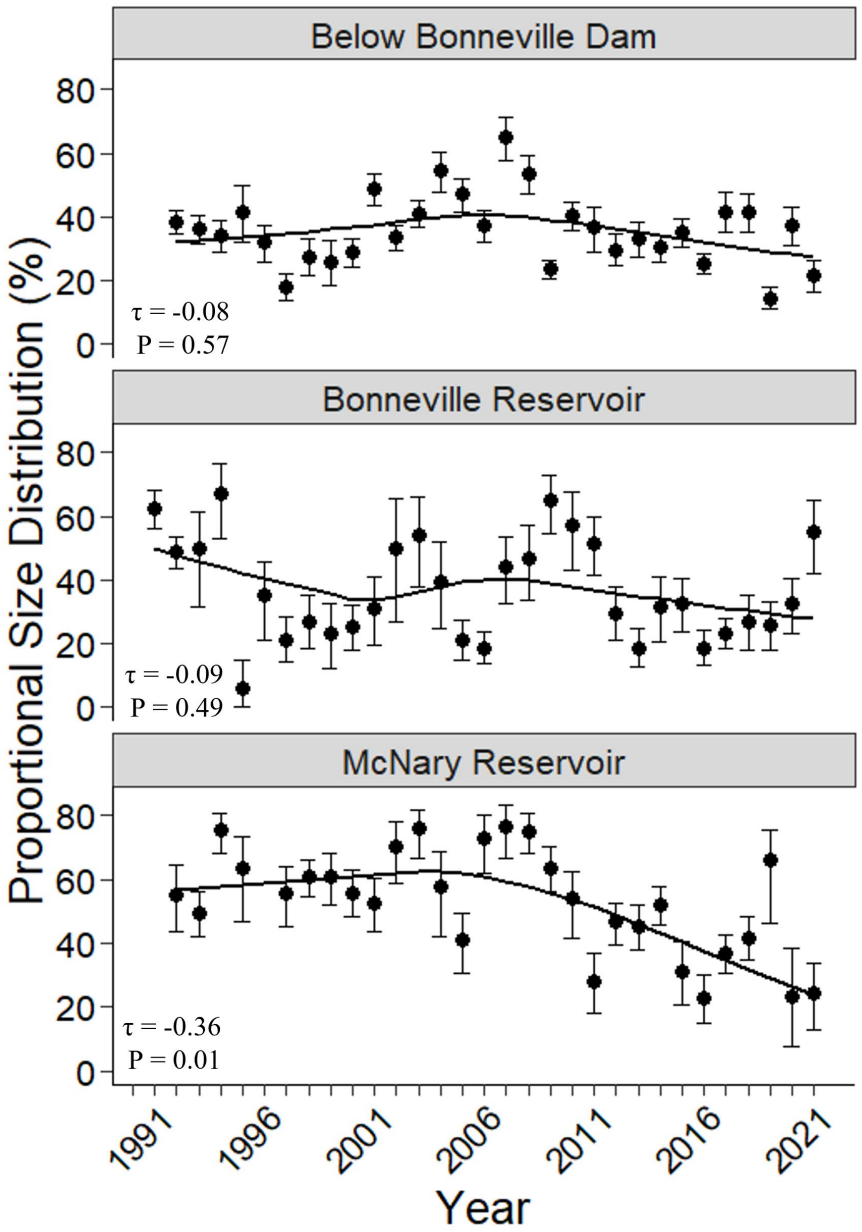

Figure 5. Estimates of proportional size distribution (PSD, %) for Northern Pikeminnow collected during fishery evaluation in the Columbia River, 1991–2021. **Estimates for other areas sampled in 2021 but did not have sufficient sample sizes were not included. Error bars represent 95% bootstrap confidence 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 ($n_s < 20$).**

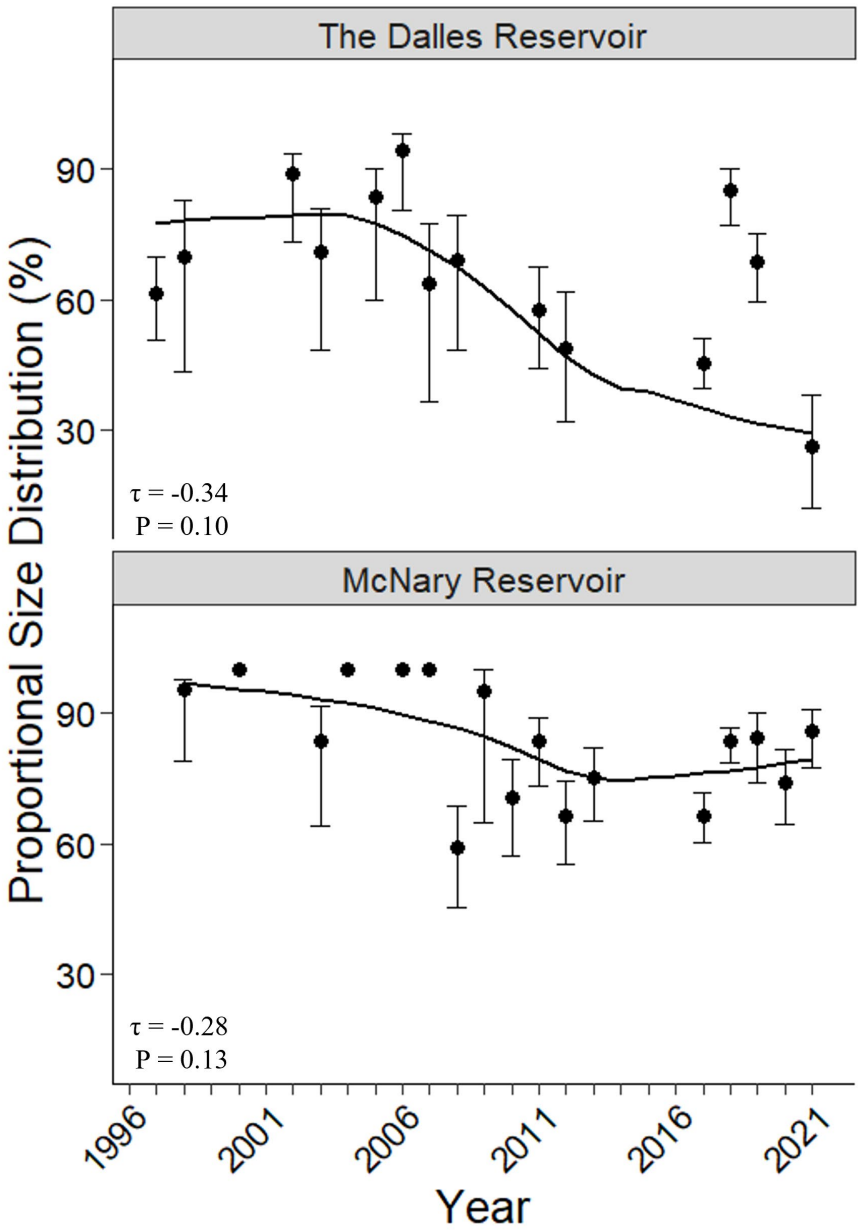

Figure 6. Estimates of proportional size distribution (PSD, %) of Walleye collected during fishery evaluation in The Dalles Reservoir and McNary Reservoir, 1998–2021. **Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years without data indicate no sampling or sample sizes were insufficient for analysis (n_s < 20).**

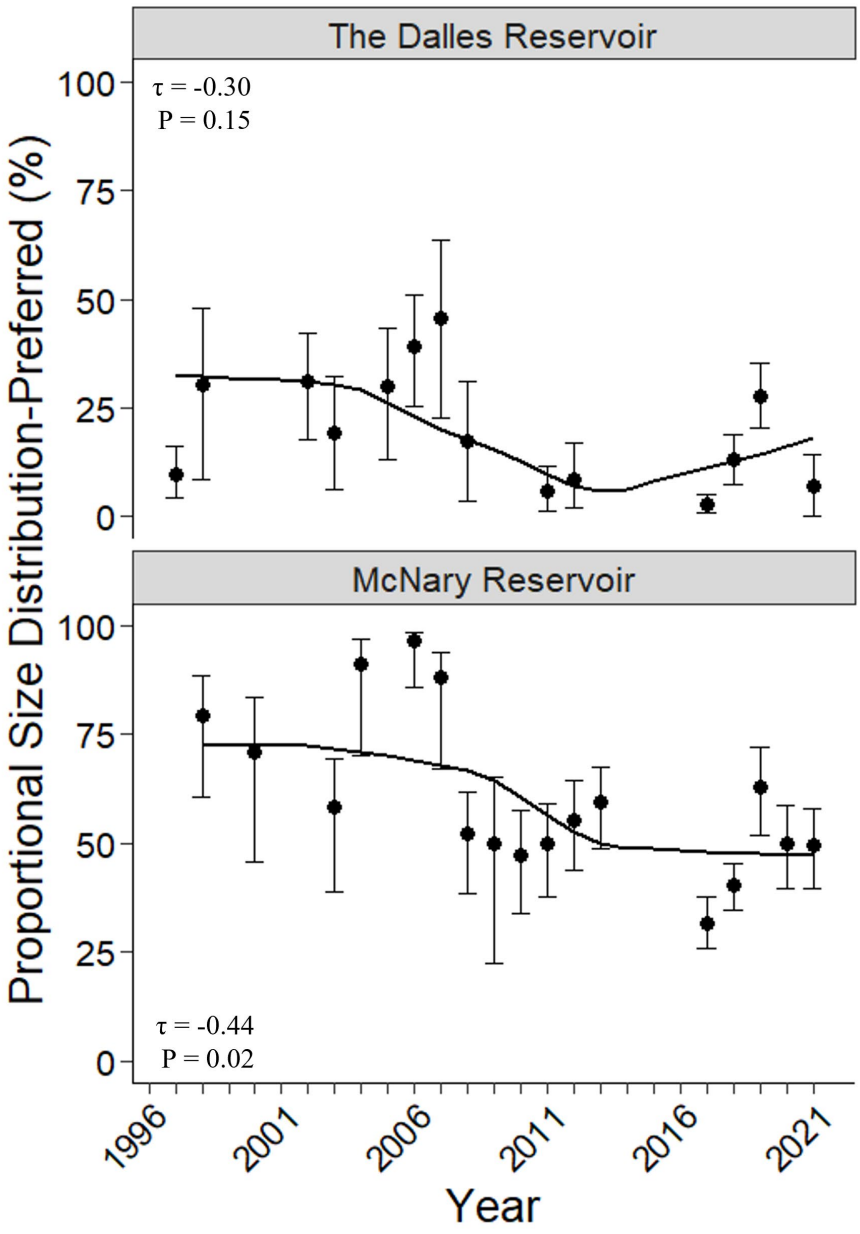

Figure 7. Estimates of proportional size distribution of preferred-length (PSD – P, %) Walleye collected during fishery evaluation in The Dalles Reservoir and McNary Reservoir, 1998–2021. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall 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 < 20).

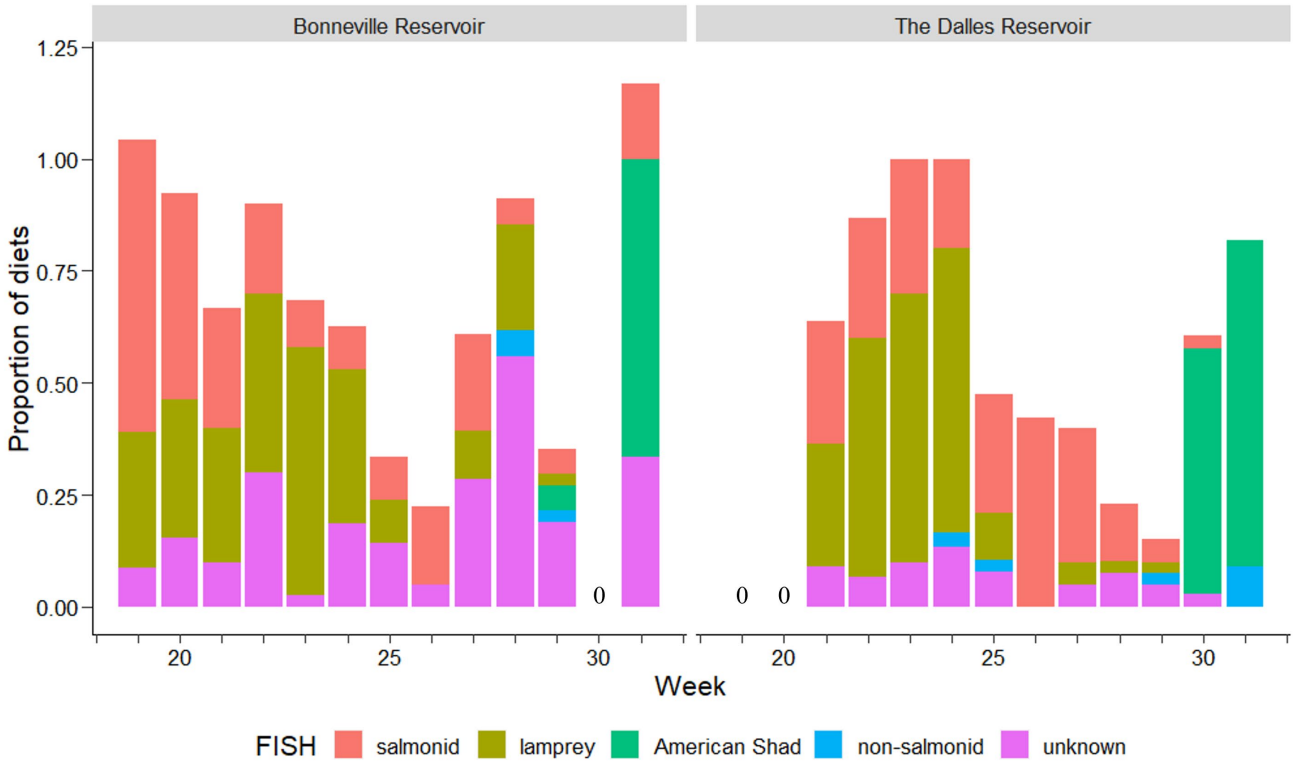

Figure 8. Proportion of all Northern Pikeminnow diet samples containing prey fish collected during the Dam Angling Fishery from the powerhouse tailraces of Bonneville (fishing from The Dalles Dam) and The Dalles (fishing from John Day Dam) reservoirs, May–August 2021 (statistical week 19–32). All Northern Pikeminnow diet samples collected, including empty and diets that did not contain fish, were included in this analysis. Multiple fish groups may be represented in individual Northern Pikeminnow diets. Note: due to Weeks without data (represented with zeros above the x-axis) indicate that sampling was not conducted, or sample sizes were insufficient for analyses (n < 6).

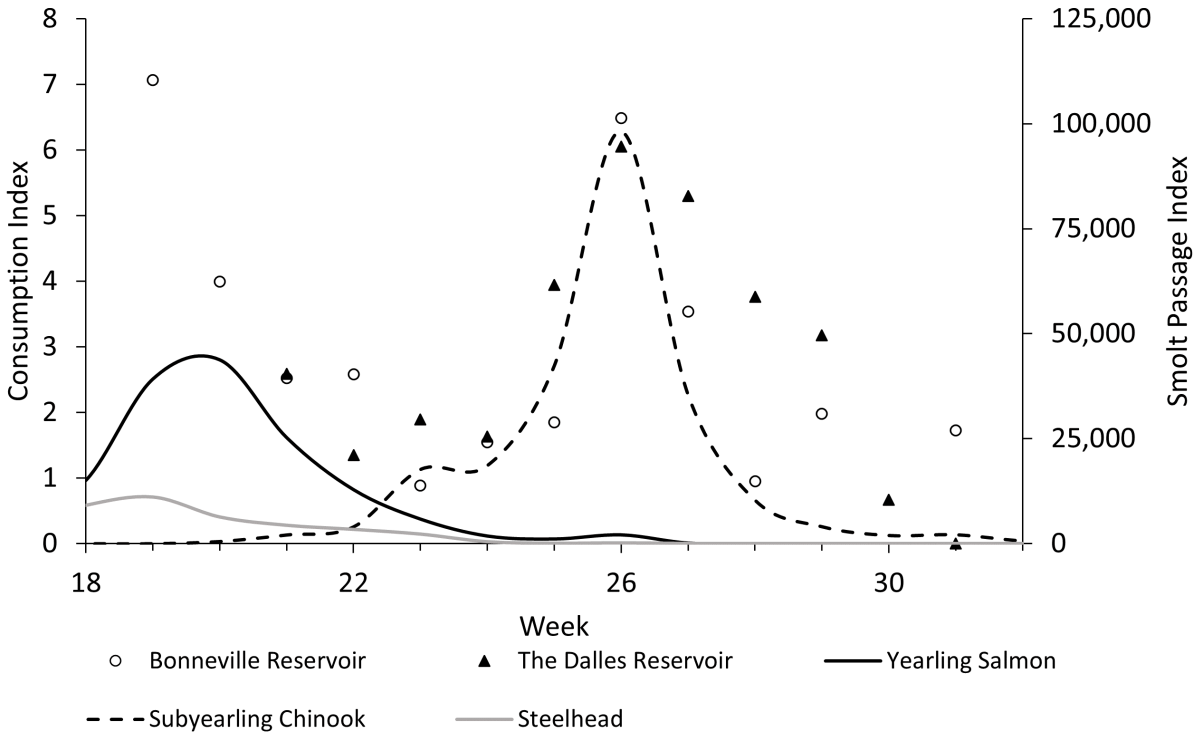

Figure 9. Mean weekly juvenile salmon consumption index for Northern Pikeminnow captured from the Dam Angling Fishery (DAF) in Bonneville (open circles) and The Dalles (filled triangles) reservoirs compared to the weekly smolt passage index at John Day Dam, 2021. Smolt passage data are summarized from Fish Passage Center (unpublished data). DAF sampling were conducted from Weeks 19-31. Weeks without data indicate that sampling was not conducted or sample sizes were insufficient for analyses (n < 6).

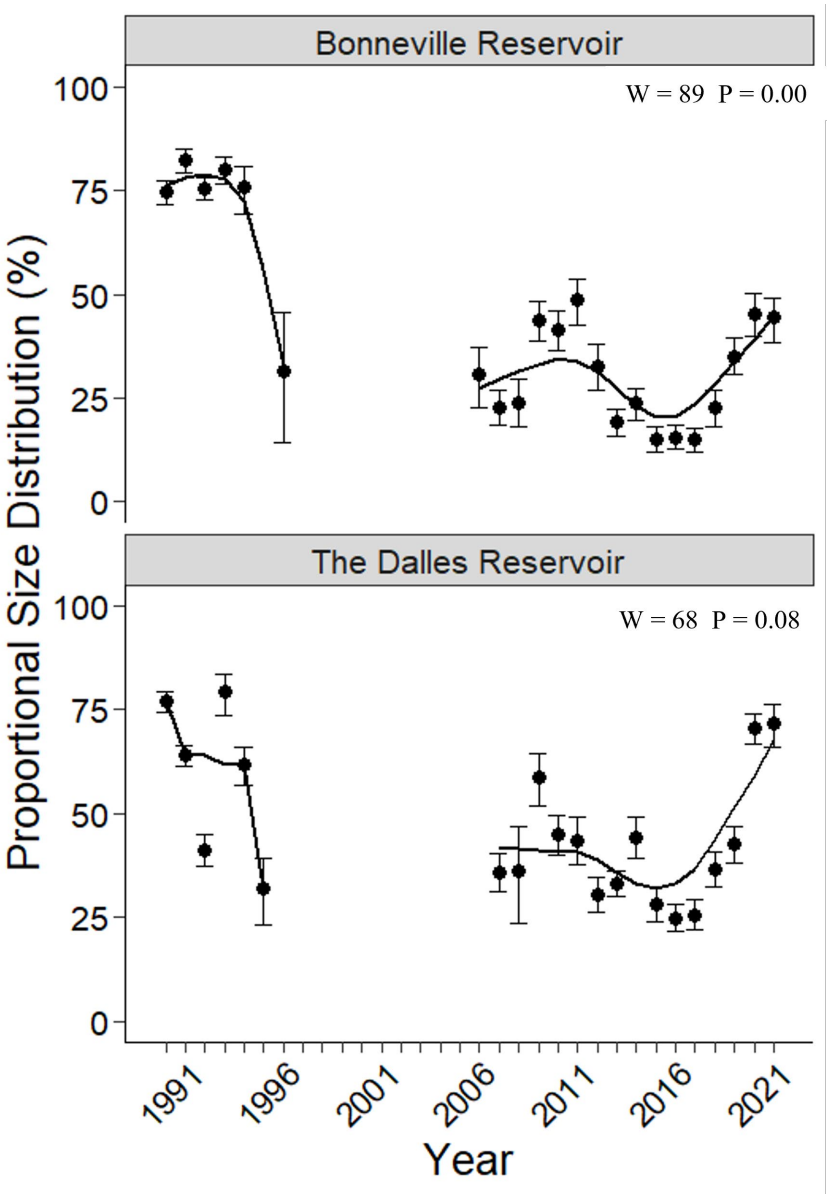

Figure 10. Estimates of proportional size distribution (PSD, %) of Northern Pikeminnow sampled in Bonneville and The Dalles reservoirs during the Dam Angling Fishery, 1990–2021. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves for two different time series: early (1990–1996) and late (2006–2021), 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 < 20).

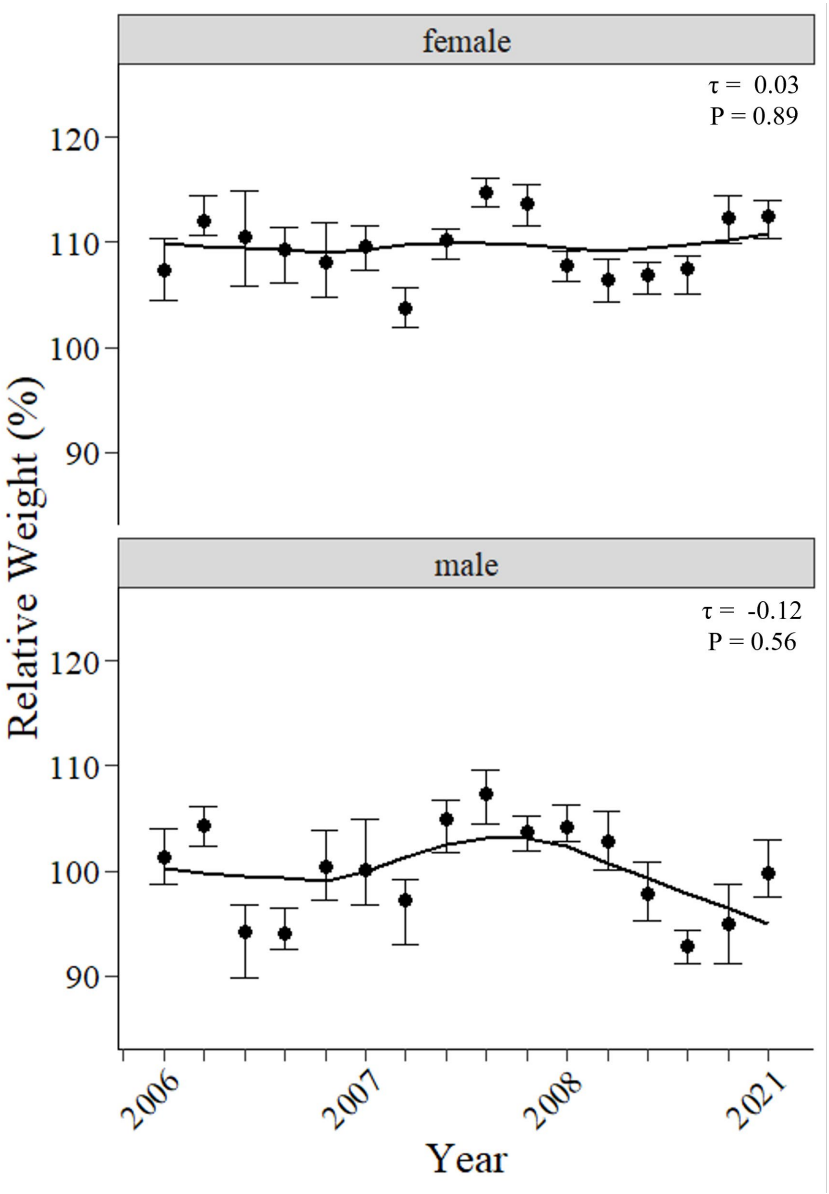

Figure 11. Median relative weight (*Wr*, %) for female and male Northern Pikeminnow collected in Bonneville Reservoir during the Dam Angling Fishery, 2006–2021. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each reservoir.

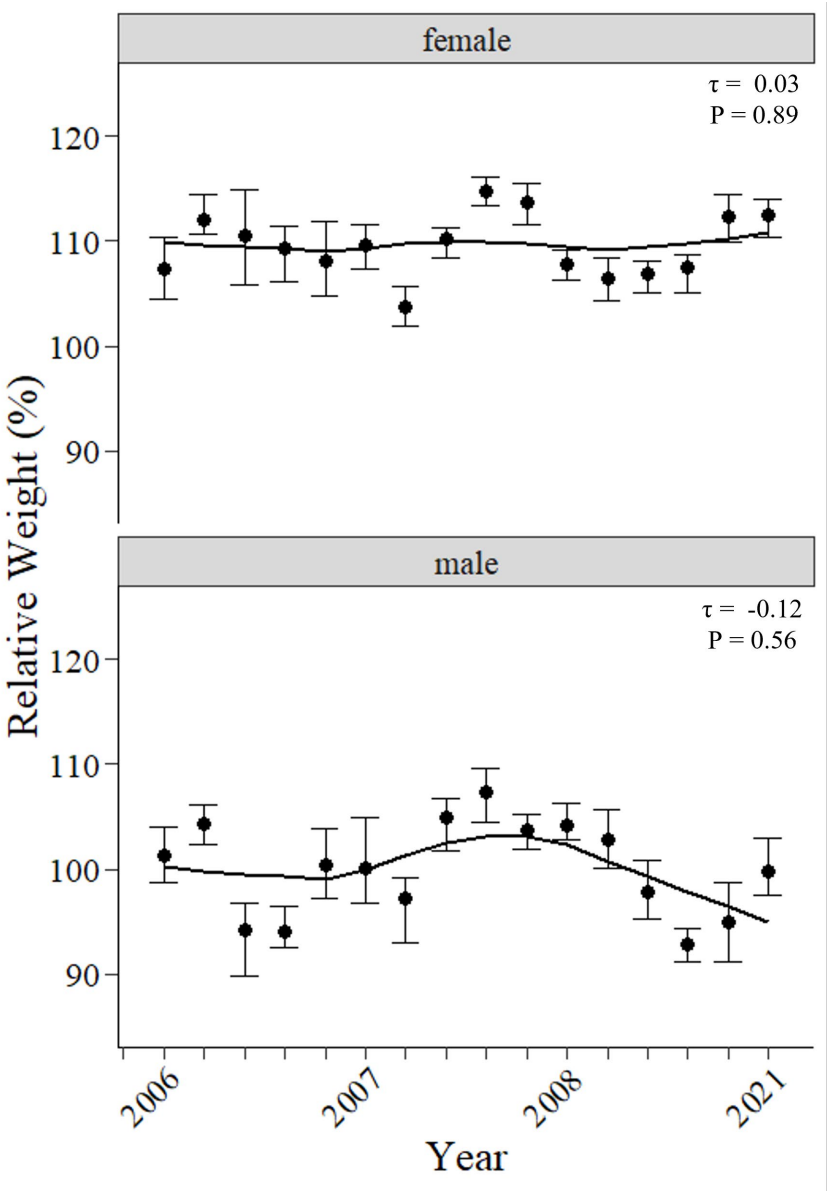

Figure 12. Median relative weight (*Wr*, %) for female and male Northern Pikeminnow collected in The Dalles Reservoir during the Dam Angling Fishery, 2007–2021. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each reservoir.

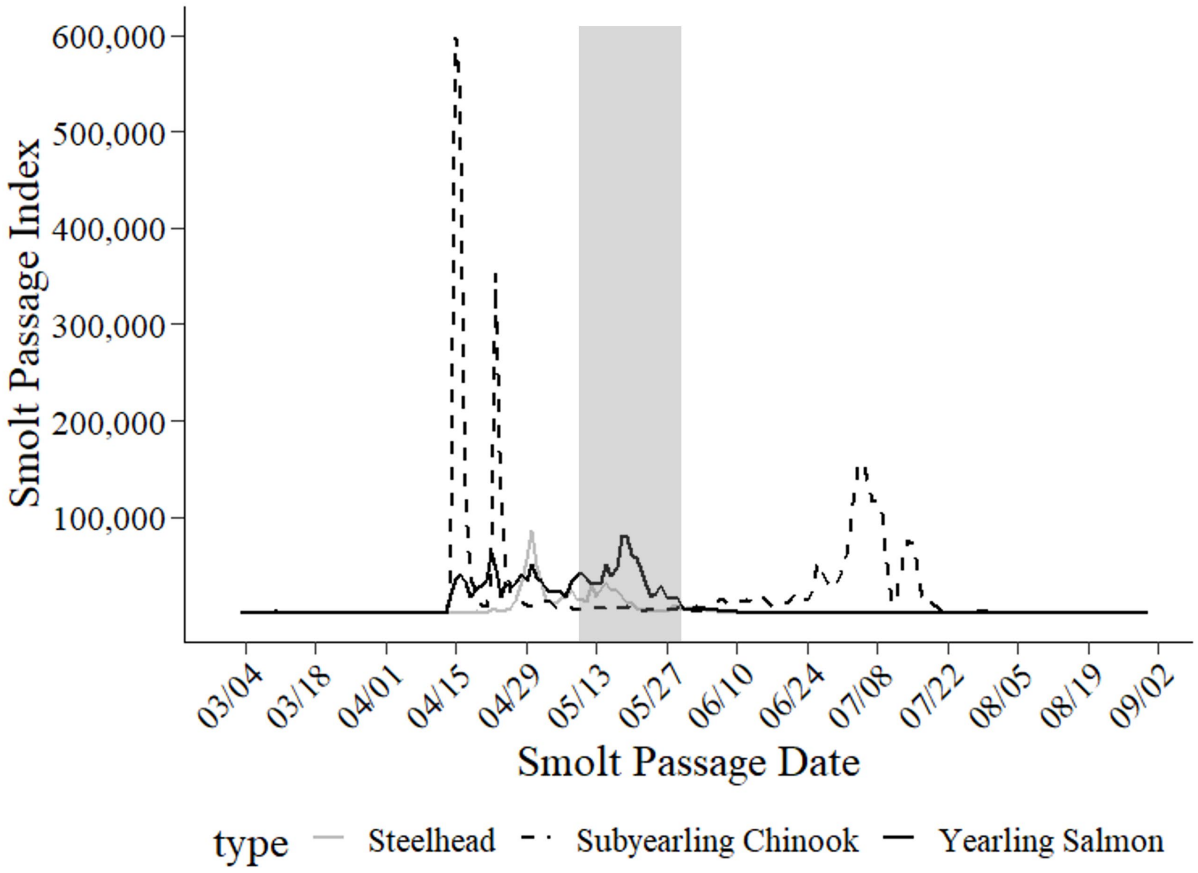

Figure 13. Period of biological evaluation (vertical bar) below Bonneville Dam and in Bonneville Reservoir and juvenile salmon and steelhead daily passage index through Bonneville Dam, March–September 2021 (Source: Fish Passage Center, unpublished data)

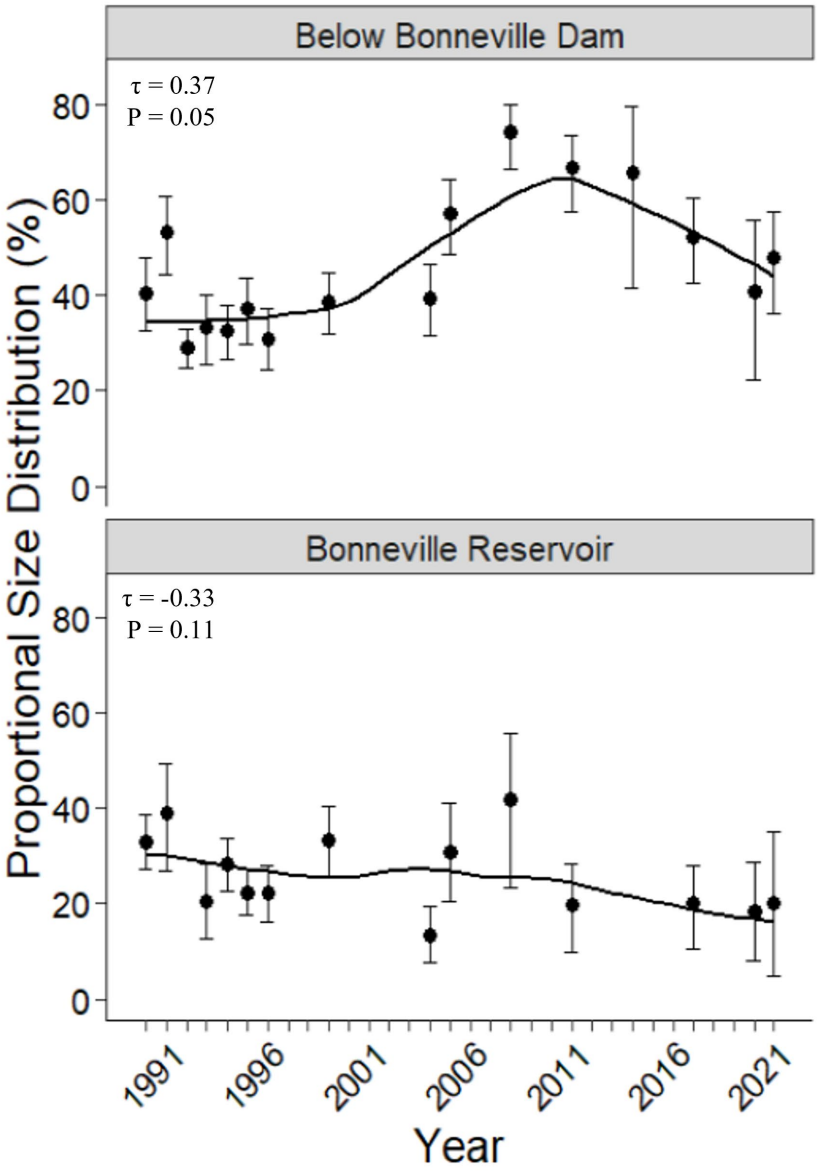

Figure 14. Estimates of proportional size distribution (PSD, %) of Northern Pikeminnow collected during biological evaluation below Bonneville Dam and in Bonneville Reservoir, 1990–2021. Error bars represent 95% bootstrap confidence intervals. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Data are fit with LOWESS curves. Years without data indicate sampling was not conducted or sample sizes were insufficient for analysis ($n_s < 20$).

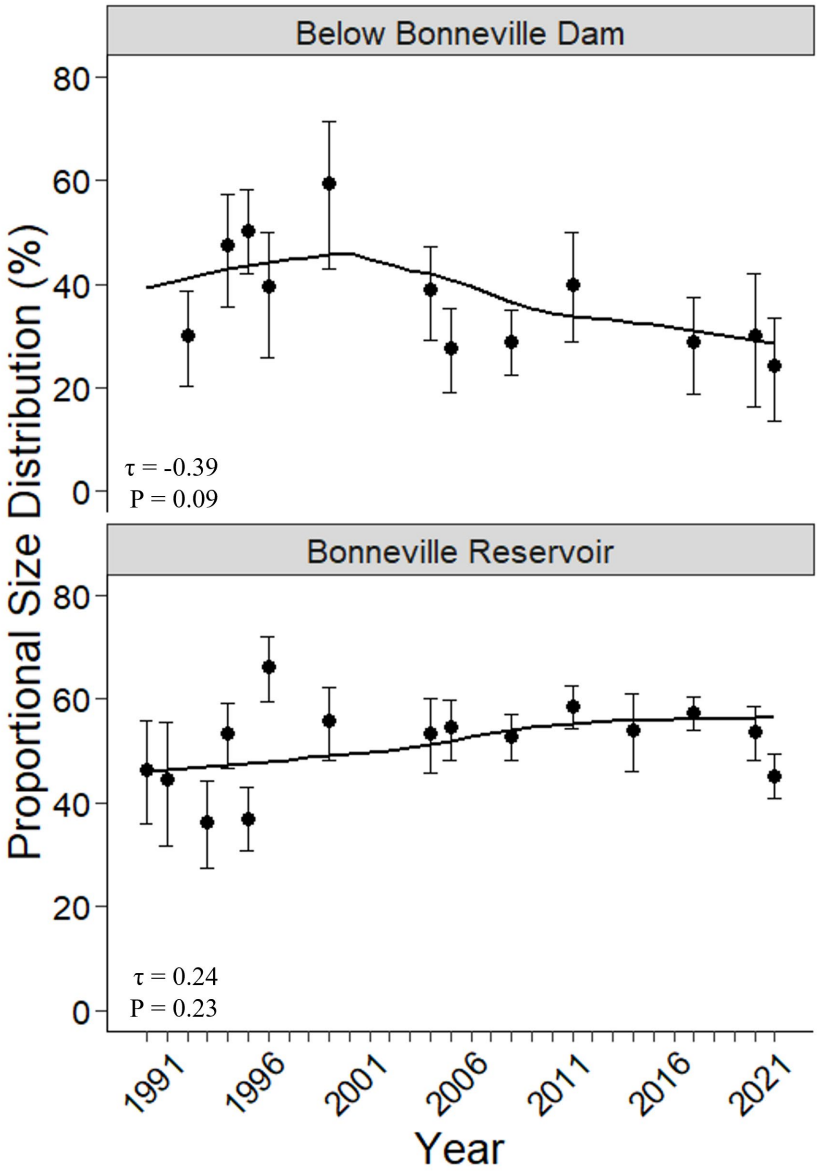

Figure 15. Estimates of proportional size distribution (PSD, %) of Smallmouth Bass collected during biological evaluation below Bonneville Dam and in Bonneville Reservoir, 1990–2021. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Years without data indicate sampling was not conducted or sample sizes were insufficient for analysis (n_s < 20).

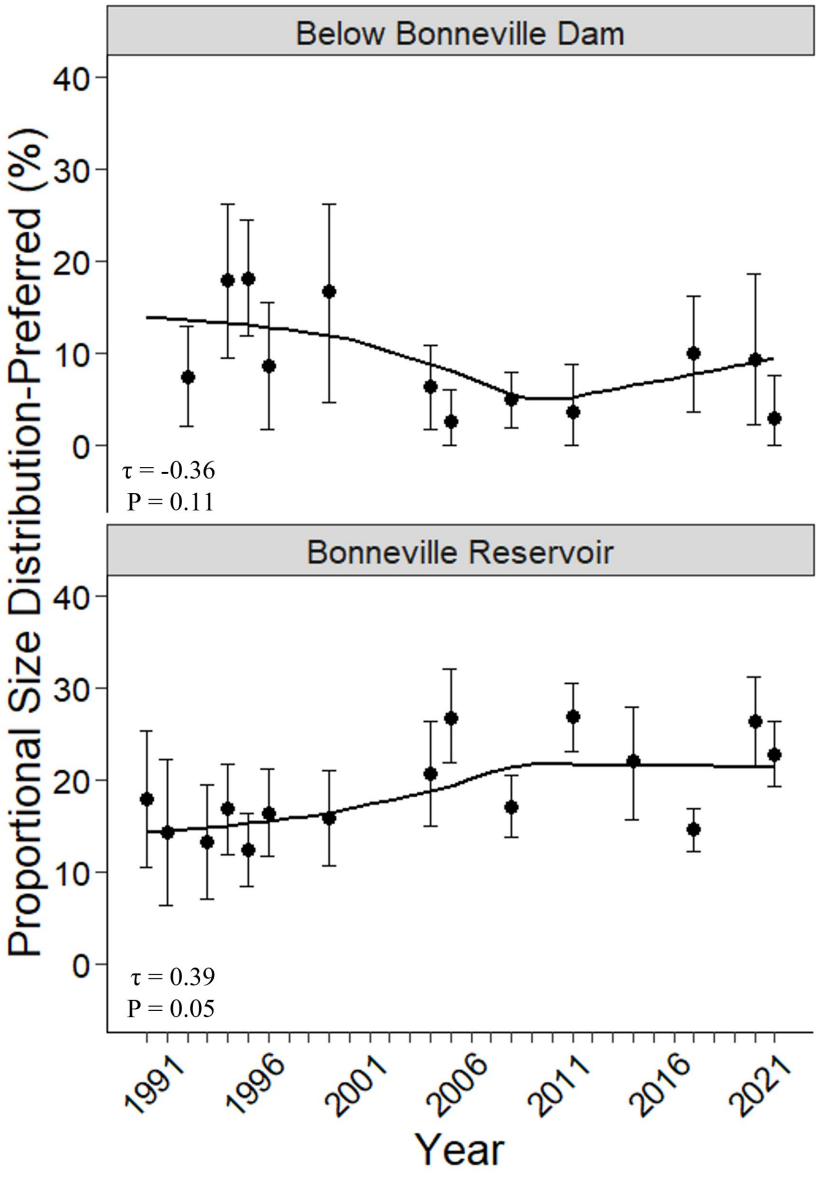

Figure 16. Estimates of proportional size distribution of preferred-length (PSD – P, %) Smallmouth Bass collected during biological evaluation below Bonneville Dam and in Bonneville Reservoir, 1990–2021. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Years without data indicate sampling was not conducted or sample sizes were insufficient for analysis ($n_s < 20$).

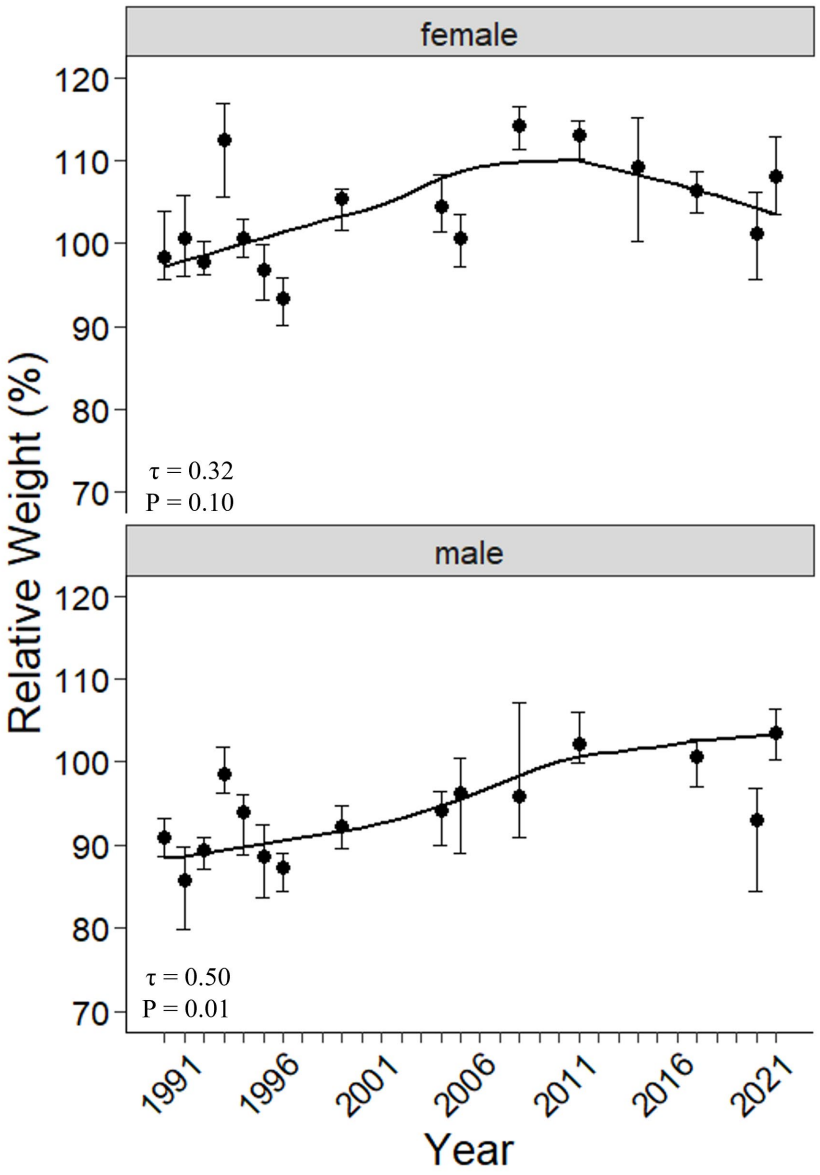

Figure 17. Median relative weight (W_r, %) of female and male Northern Pikeminnow collected during biological evaluation below Bonneville Dam, 1990–2021. Error bars represent 95% bootstrap (percentile) confidence intervals. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years without data indicate that sampling was not conducted or sample sizes were insufficient for analyses (n < 5).

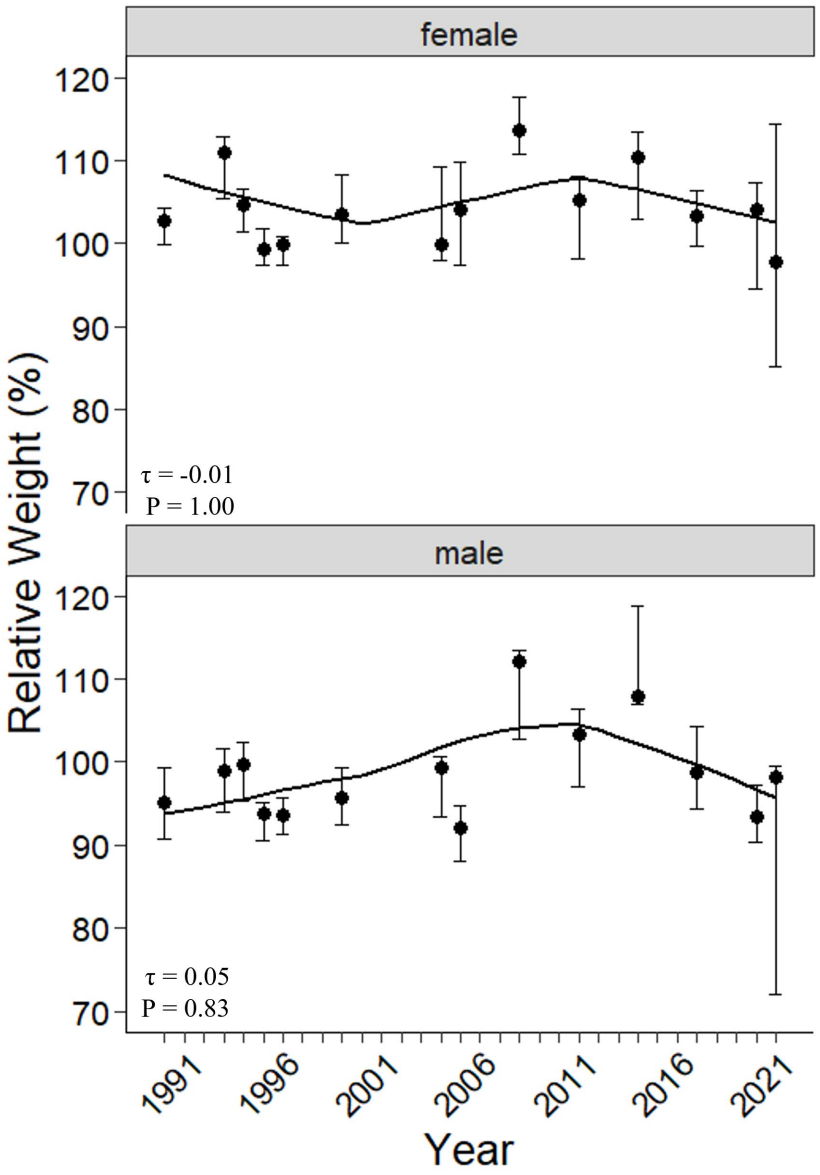

Figure 18. Median relative weight (W_r, %) of female and male Northern Pikeminnow collected during biological evaluation in Bonneville Reservoir, 1990–2021. **Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years without data indicate that sampling was not conducted or sample sizes were insufficient for analyses (n < 5).**

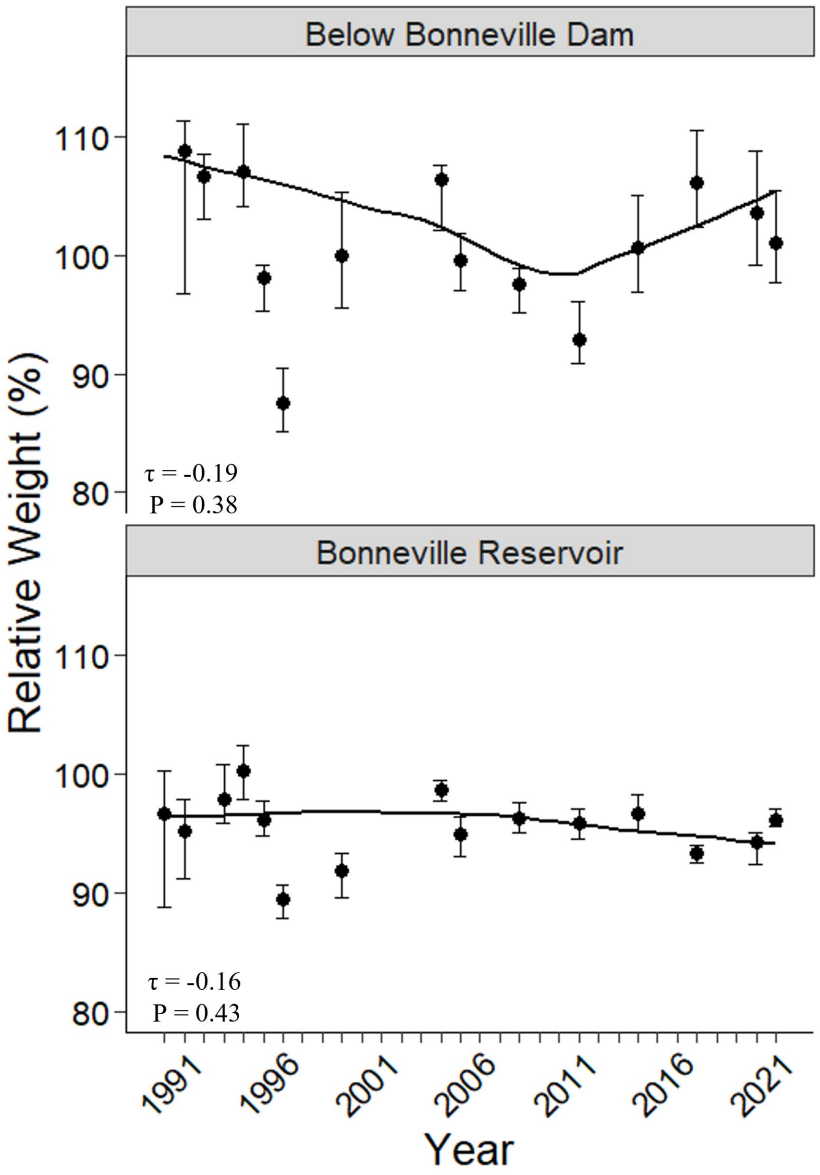

Figure 19. Median relative weight (W_r, %) of Smallmouth Bass collected during biological evaluation below Bonneville Dam and in Bonneville Reservoir, 1990–2021. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years without data indicate that sampling was not conducted or sample sizes were insufficient for analyses (n < 5).

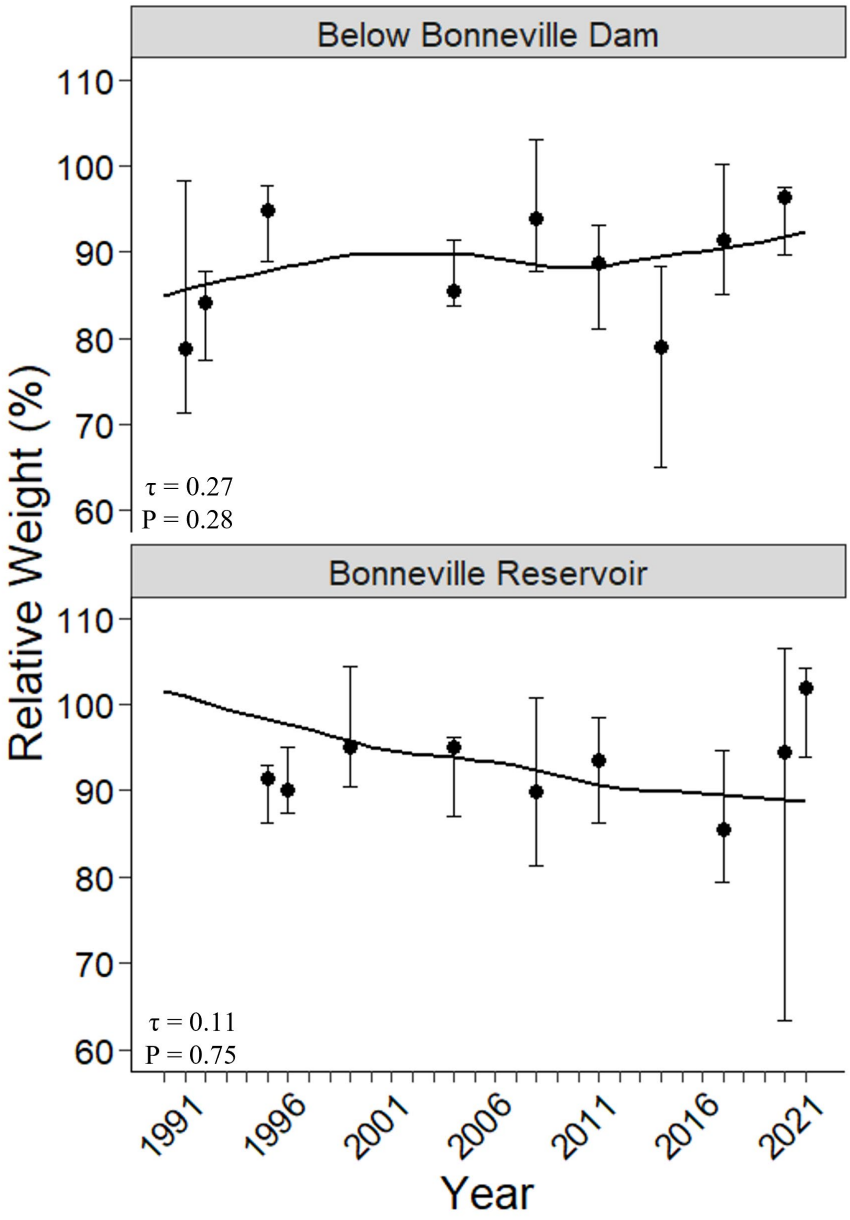

Figure 20. Median relative weight (W_r, %) of Walleye collected during biological evaluation below Bonneville Dam and in Bonneville Reservoir, 1990–2021. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time series. Years without data indicate that sampling was not conducted or sample sizes were insufficient for analyses (n < 5).

REPORT D

Northern Pikeminnow Dam Angling on the Columbia River

2021 Annual Report

Prepared by

Paul V. Dunlap
Eric C. Winther
Ruthanna M. Shirley
John D. Hone

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

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We appreciate the efforts of Scott Mengis as the Pikeminnow Dam Angling crew leader, along with Kyle Beckley, Gregor Pierce, Kevin Kumagai and John Paul Viviano who served as our 2021 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 2021 season.

ABSTRACT

We are reporting on the 2021 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 20 weeks from May 7th through October 7th, 2021. 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 data 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 2021 Dam Angling crew.

A Dam Angling crew of four anglers harvested a total of 2,660 Northern Pikeminnow during the 2021 season. Of those, 1,391 Northern Pikeminnow were harvested at The Dalles Dam and 1,269 were harvested at the John Day Dam. The crew fished a total of 1,464.7 hours during the 20 week fishery, averaging 133 fish per week for a combined overall average catch per angler hour (CPUE) of 1.8 Northern Pikeminnow. At The Dalles Dam, the crew averaged 2.0 fish per angler hour, and cumulatively 23 Northern Pikeminnow per day. At the John Day Dam, the crew averaged 1.6 fish per angler hour with a cumulative crew total of 19 fish per day.

Based on the previous success of the WDFW Dam Angling Crew in implementing the Dam Angling component of the NPMP from 2010-20, the 2021 crew continued to use back bouncing soft plastic lures with rod and reel as the primary angling method for harvesting Northern Pikeminnow from the turbine decks of The Dalles and John Day dams. Incidental species most frequently caught and released by the Dam Angling crew in 2021 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 $\geq$ 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 $\geq$275 mm FL within the program area (Vigg and Burley 1989). The primary component of the NPMP is the Northern Pikeminnow Sport-Reward Fishery (NPSRF) implemented by the Washington Department of Fish and Wildlife (WDFW) (Burley et al. 1992). Beginning in 2010, WDFW was also contracted to conduct the Dam Angling component of the NPMP (Hone et al. 2011) and 2021 marked the 12th 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 2021.

The objectives of the 2021 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 2021 Dam Angling crew.

METHODS

Project Area

In 2021, as a continuing supplemental component to the NPMP, Northern Pikeminnow hook-and-line 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 2021 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).

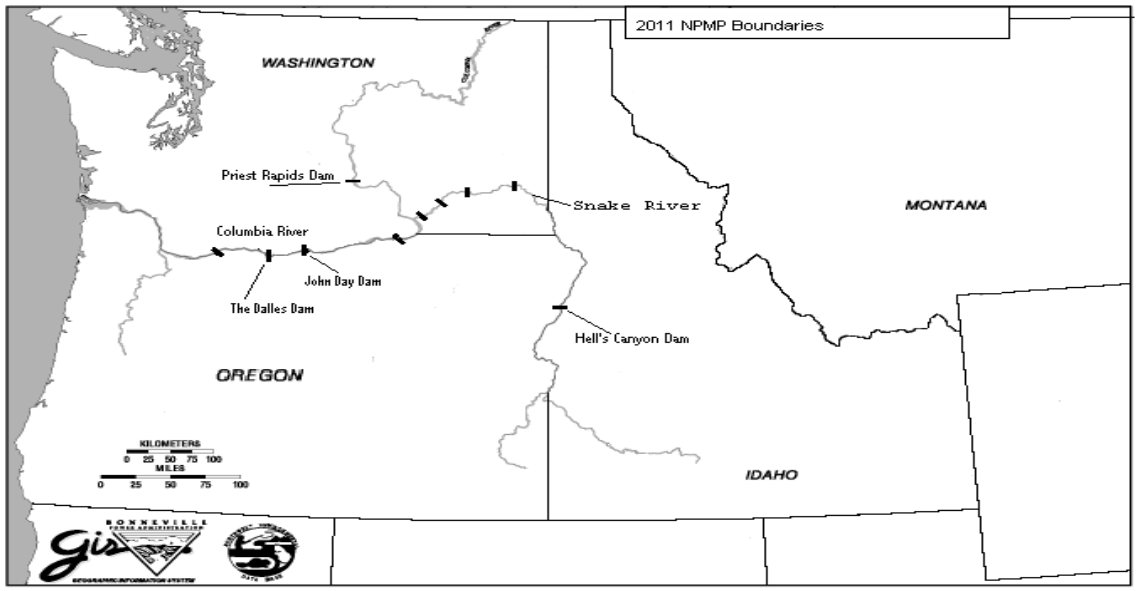

Figure 1. Northern Pikeminnow Management Program boundaries, including 2021 Dam Angling sites.

Figure 2. Angling locations for 2021 Dam Angling at The Dalles Dam

Figure 3. Angling locations for 2021 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 2021, the WDFW Dam Angling crew continued to use WDFW's Dam Angling Strategy (DAS) established in 2011 (Dunlap et al. 2012), which maintained full scale angling activities when CPUE was $\geq$ 2.0 fish/angler hour, and reduced scale angling activities when CPUE fell below 2.0 fish/angler hour.

The Dam Angling Crew

The four member Dam Angling crew generally worked four ten hour days a week, (usually Tuesday - Friday) during the 2021 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 either 15# or 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 2-6 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.

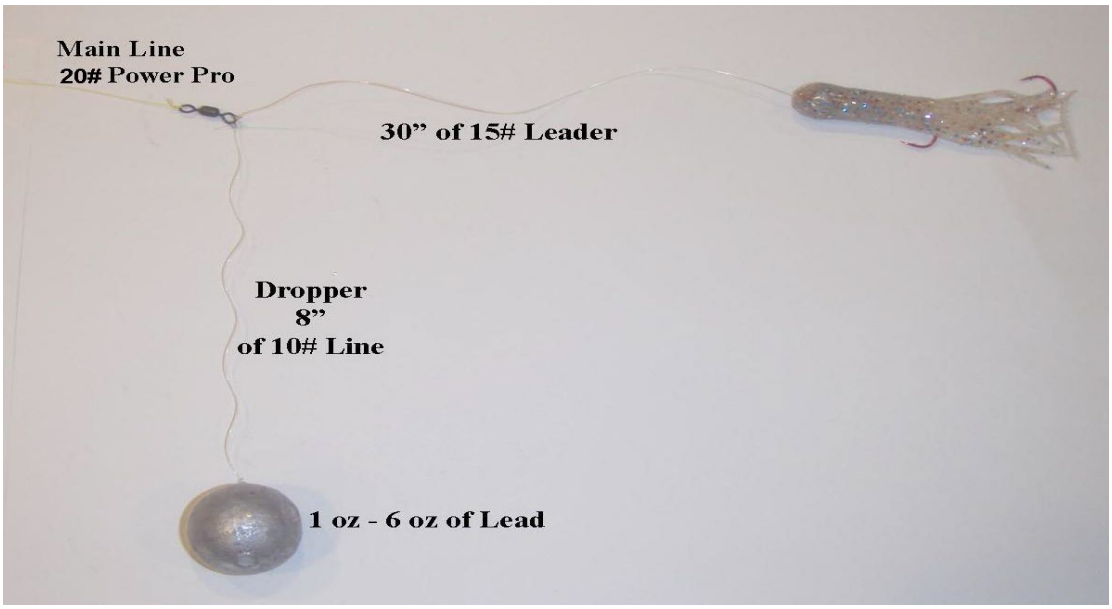

Figure 5. Example of typical rigging used by 2021 NPMP Dam Anglers

Figure 6. Examples of soft plastic tube lures used by 2021 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 2021 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

2021 Dam Angling Season

The 2021 Dam Angling Season took place from May 7th through October 7th. Total harvest for The Dalles and John Day dams combined was 2,660 Northern Pikeminnow in 1,464.7 angling hours, with a combined CPUE of 1.8 fish per angler hour. The Dam Angling crew exceeded the CPUE goal of 2.0 fish/angler hour (for the first time during the 2021 season) in week 23 and results were mixed through the core harvest period ending in week 31(Figure 8). Per DAS protocol (Dunlap et al. 2012), weeks when CPUE was under the 2.0 fish/angler hour goal (outside core harvest weeks 23-31) were typically due to the Dam Angling crew deploying limited crews (< 50% effort) for "prospecting" purposes to locate and/or determine if catchable numbers of fish were present and/or available.

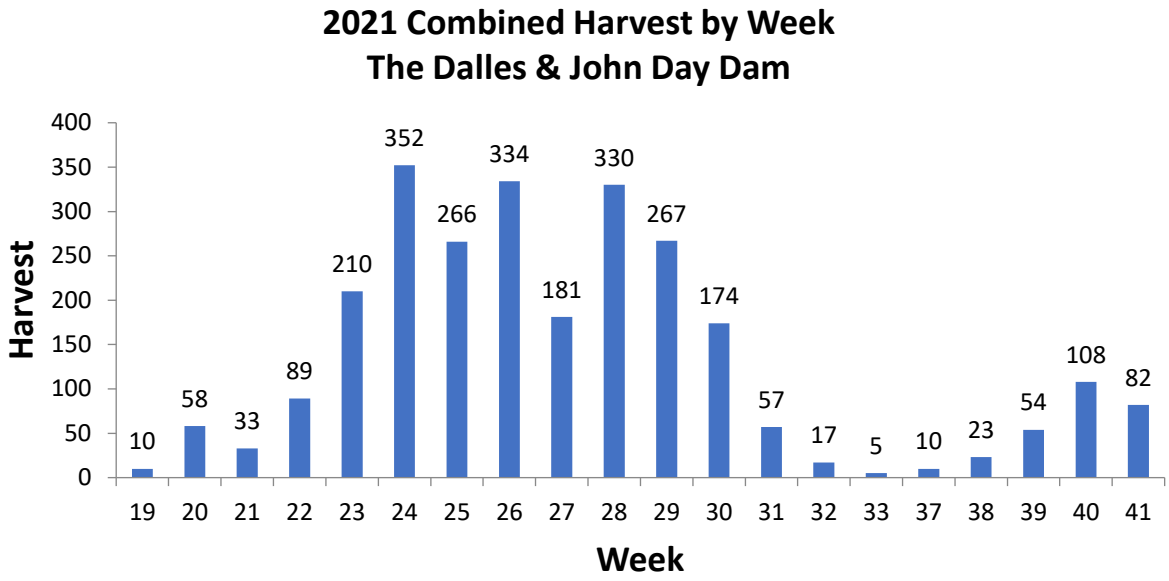

Figure 7. 2021 Weekly harvest of The Dalles (TD) and John Day (JD) Dams combined

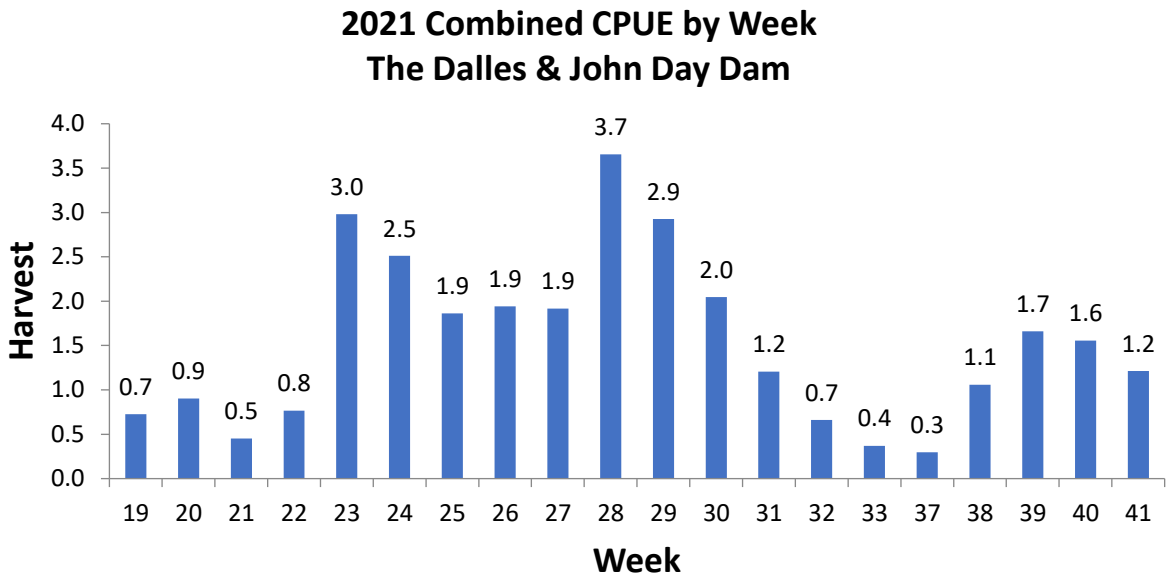

Figure 8. 2021 Weekly CPUE (fish/angler hour) of The Dalles (TD) and John Day (JD) Dams combined

Angling Gear and Technique

The 2021 Dam Angling crew primarily targeted fishing areas and fishing times at each dam that had been productive in past years. Our top producing lure in 2021 was the 3.75" Gitzit tube (a soft plastic lure) in Smoke/Black Copper Glitter color.

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 2021. All incidentally caught fish species were released in 2021. 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 1. 2021 WDFW Dam Angler incidental catch by project

Incidental Catch

Species	The Dalles Dam	John Day Dam
Smallmouth Bass	211	761
Walleye	15	297
Sculpin	30	21
American Shad	26	23
Channel Catfish	0	18
White Sturgeon	0	9
Peamouth	0	4
Whitefish	0	1
Sucker	0	9

The Dalles Dam

Harvest

The Dam Angling crew harvested 1,391 Northern Pikeminnow in 18 weeks of Dam Angling at The Dalles Dam in 2021. Weekly harvest for the Dam Angling crew averaged 77 fish per week (no effort was spent during weeks 34 - 36) (Figure 9).

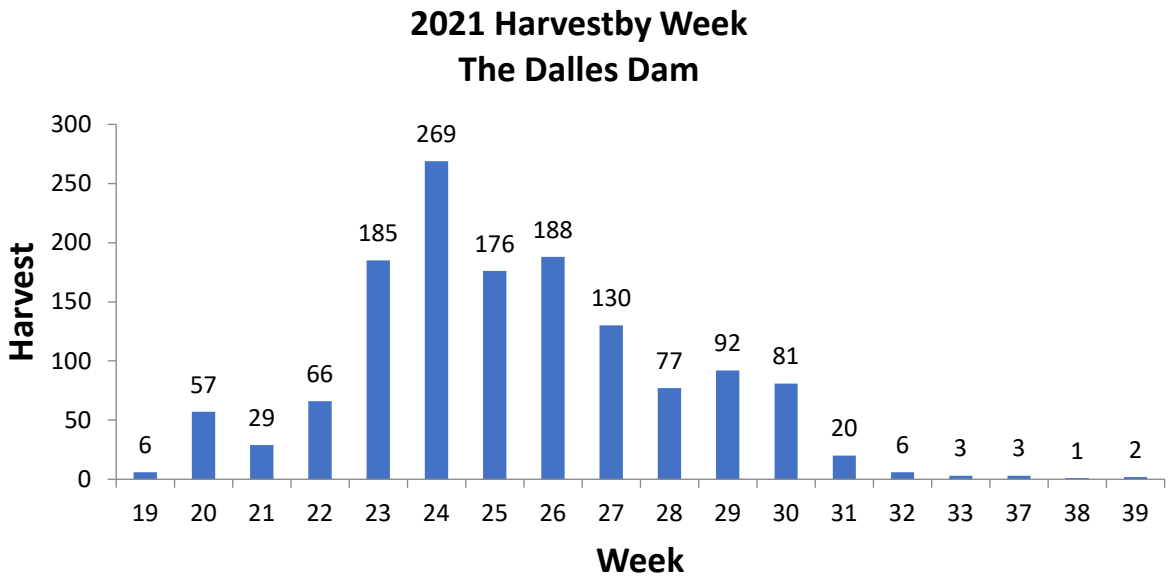

Figure 9. 2021 Weekly Dam Angler harvest of Northern Pikeminnow at The Dalles Dam

Effort

Total effort at The Dalles Dam was 679.25 angler hours in 2021. The Dam Angling crew fished 61 days at The Dalles Dam over 18 weeks and spent 46% of total Dam Angling effort at The Dalles Dam in 2021.

CPUE

The Dam Angling crew harvested 1,391 Northern Pikeminnow in 679.25 angler hours at The Dalles Dam in 2021 for an overall average CPUE of 2.05 fish/angler hour (Figure 10).

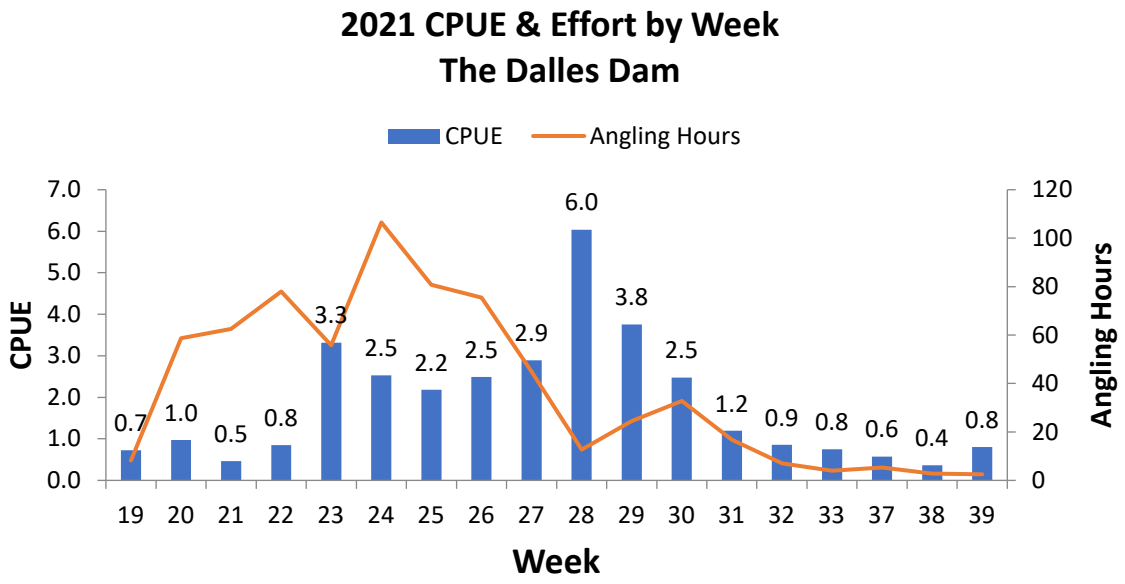

Figure 10. 2021 Weekly Dam Angler CPUE and Effort at The Dalles Dam

Fork Length Data

Fork lengths were recorded from 1,317 (95%) Northern Pikeminnow harvested by the Dam Angling crew at The Dalles Dam during the 2021 Season. The length frequency distribution of Northern Pikeminnow harvested at The Dalles Dam in 2021 is presented in Figure 11. Mean fork length for Northern Pikeminnow caught by the Dam Angling crew at The Dalles Dam in 2021 was 367 mm. By comparison, the mean fork length for the 2021 NPSRF was 278 mm (Winther et al. 2022).

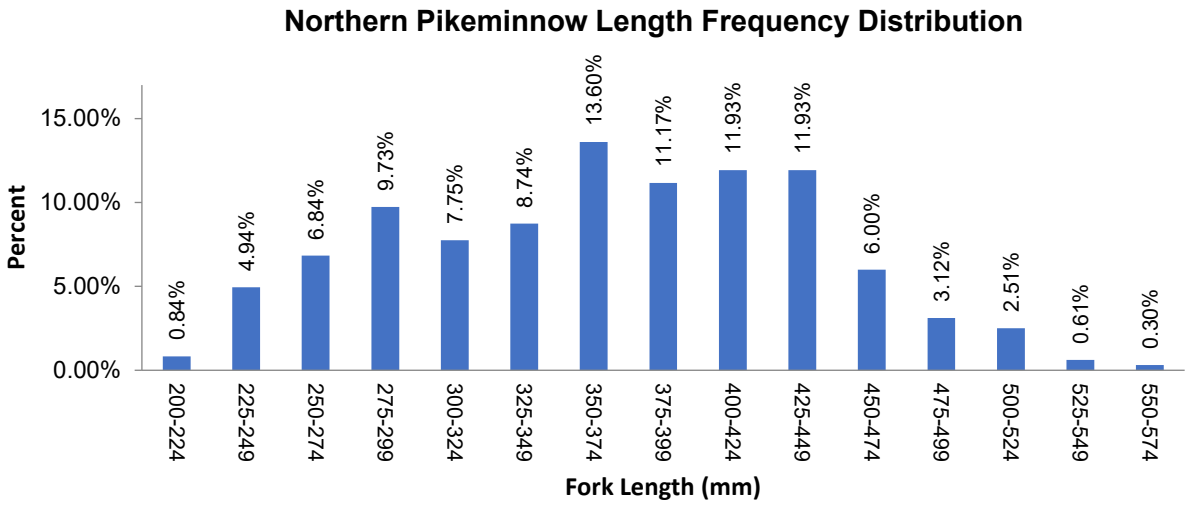

Figure 11. Northern Pikeminnow length frequency distribution at The Dalles Dam in 2021

John Day Dam

Harvest

The Dam Angling crew harvested 1,269 Northern Pikeminnow over 20 weeks at the John Day Dam in 2021. Peak weekly harvest at the John Day Dam occurred in week 28 (Figure 12).

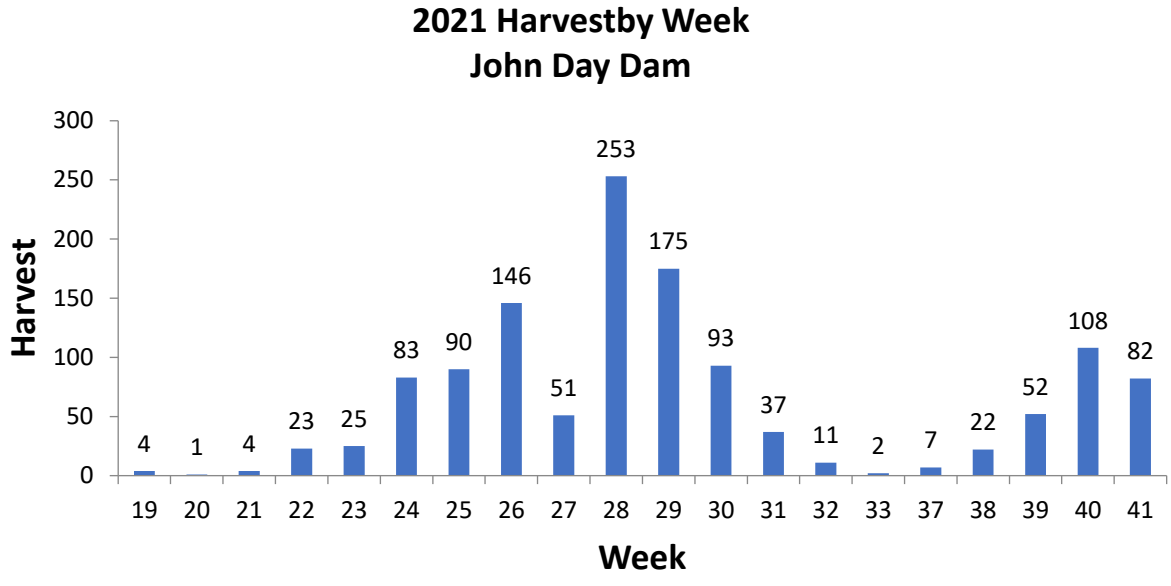

Figure 12. 2021 Weekly Dam Angler harvest of Northern Pikeminnow at the John Day Dam

Effort

Total effort at the John Day Dam was 785.5 angler hours in 2021. The Dam Angling crew fished 66 days at John Day Dam over 20 weeks and spent 54% of total Dam Angling effort at the John Day Dam in 2021.

CPUE

The Dam Angling crew harvested 1,269 Northern Pikeminnow in 785.5 angler hours at the John Day Dam in 2021 for an overall average CPUE of 1.62 fish/angler hour. Peak weekly CPUE at the John Day Dam occurred during week 28 and there was no effort spent at the John Day Dam in weeks 34-36 (Figure 13).

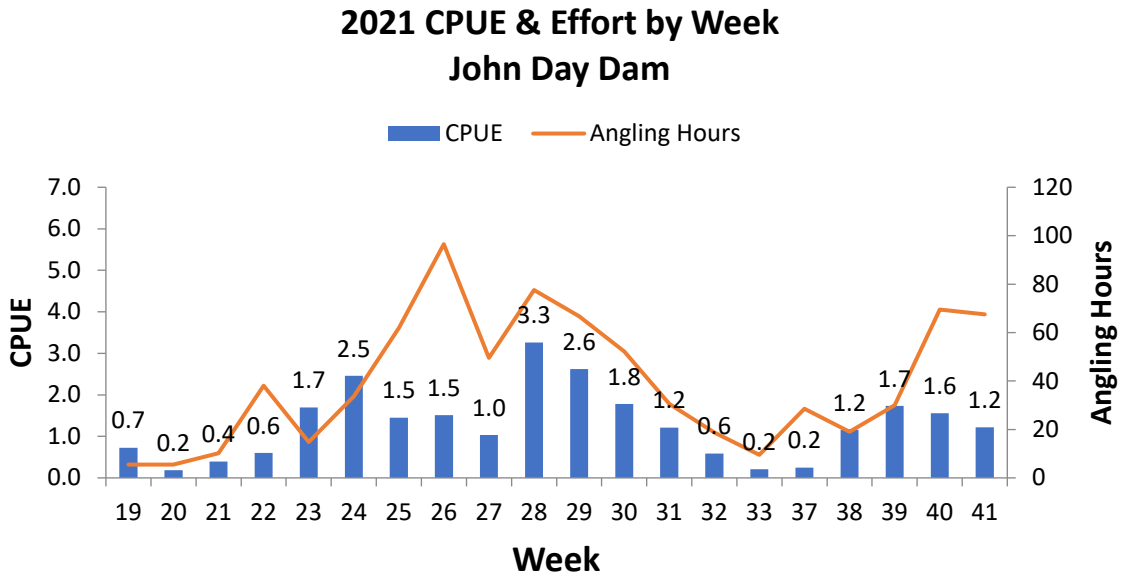

Figure 13. 2021 Weekly Dam Angling CPUE at John Day Dam

Fork Length Data

Fork lengths were recorded from 1,266 (99%) Northern Pikeminnow harvested by the Dam Angling crew at the John Day Dam during the 2021 Season. The length frequency distribution of harvested Northern Pikeminnow from the John Day Dam in 2021 is presented in Figure 14. Mean fork length for Northern Pikeminnow from the John Day Dam in 2021 was 416 mm. By comparison, the mean fork length for the 2021 NPSRF was 278 mm (Winther et al. 2022).

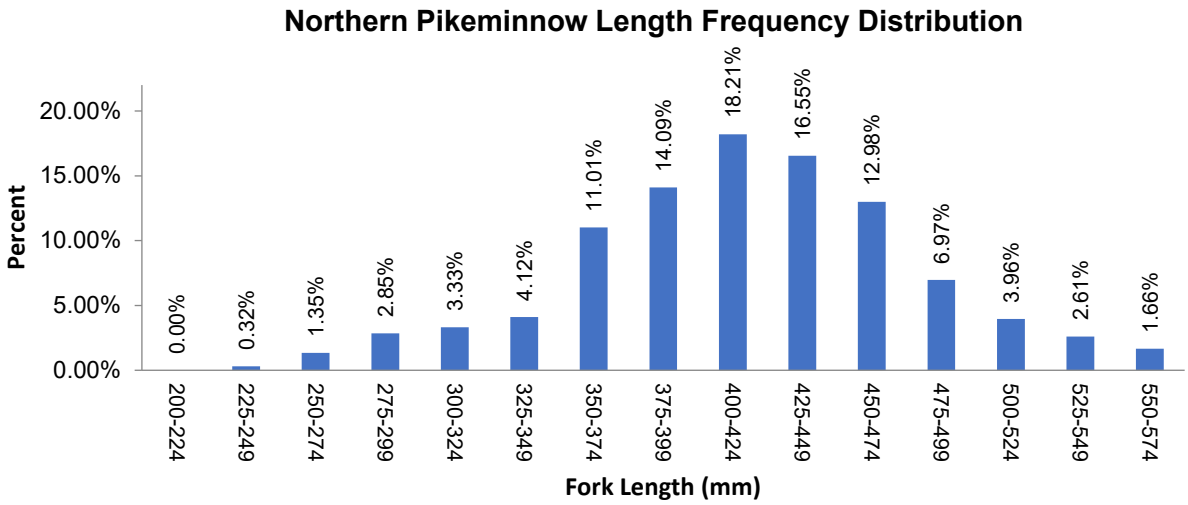

Figure 14. Northern Pikeminnow length frequency distribution at the John Day Dam in 2021

SUMMARY

During the 2021 season, the Dam Angling crew spent 54% of their effort fishing at the John Day Dam and 46% of their effort at The Dalles Dam.

Mean Fork lengths for Northern Pikeminnow harvested by the 2021 Dam Angling Crew at The Dalles and John Day dams were considerably larger than the mean fork length for the NPSRF (367 mm at The Dalles Dam, 416 mm at John Day, and 278 mm from the 2021 NPSRF).

While targeting Northern Pikeminnow, the 2021 Dam Angling crew incidentally caught a combined total of 972 Smallmouth Bass, 312 Walleye, 49 American Shad, 51 Sculpin, and 18 Channel Catfish between the two projects.

RECOMMENDATIONS FOR 2022

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

2.) Continue to investigate conducting Pikeminnow Dam Angling at other Columbia and Snake River dams as funding and resources allow, or during non-peak times at TD and JD dams. Offer Dam Angler assistance to other research projects wishing to obtain Northern Pikeminnow and other fishes from BRZ areas to determine project feasibility and/or as a possible step to adding additional dams to the DA project.

3.) Plan for 2022 Dam Angling activities to occur during the standard May-September Dam Angling season with a focus on maximizing Dam Angler effort during peak CPUE weeks.

4.) Continue to utilize the 2.0 CPUE goal (DAS) to allocate Dam Angler effort between projects in order to maximize Dam Angler harvest of Northern Pikeminnow.

5.) Continue to improve data collection in the areas of scanning other incidentally caught predator fishes for PIT tags, and in scanning and enumerating juvenile lamprey regurgitated by Northern Pikeminnow caught by Dam Anglers in 2022.

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

7.) Continue to investigate and further develop Northern Pikeminnow angling techniques in 2022 such as finding additional exploitation opportunities of Northern Pikeminnow in areas not previously fished or currently fishable.

8.) 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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