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

2023 ANNUAL REPORT
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2023 Executive Summary
by

Allan Martin

This report presents results for year thirty-three in the basin-wide Northern Pikeminnow Sport-Reward Fishery (SRF), designed to harvest Northern Pikeminnow[1] (Ptychocheilus oregonensis;) in the Columbia and Snake Rivers. A new online registration application was available for anglers to use and was well received. The season started May 1 and ended September 30. During the five-month season, anglers earned tier rewards at the rate of $6 each for the first 25 qualifying Northern Pikeminnow vouchered, $8 each for 26-200 fish and $10 each for 201 fish and greater. In addition to the tier rates, anglers earned incentives for two categories of tagged fish. A Northern Pikeminnow with an external tag was worth $500, while the detection of a program-verified internal tag without the presence of an external tag was worth $200.

Prior to 2022, Oregon Department of Fish and Wildlife's (ODFW) tagging for biological evaluation involved both an external tag and an internal PIT tag. To reduce handling and post-tagging mortality, ODFW began a PIT tag only protocol for biological assessment of the fishery in 2022. During the season, Program partners decided to continue tagging some of the northern pikeminnow population with external tags for promotional purposes. This promotion only tagging was accomplished by Washington Department of Fish and Wildlife (WDFW) on an opportunistic basis.

The third annual Adaptive Management Committee (AMC) meeting was held June 14. During the meeting, a number of topics including funding prioritization, tagging for program evaluation and promotional purposes, results of increased monetary incentives in 2022 on angler participation and updates on topics covered during the previous AMC. The committee agreed to allocate funds to retrofitting boats used for program evaluation and to further development of the mobile registration application. Both ODFW and WDFW committed to continuing to tag Northern Pikeminnow in 2024. The increased monetary incentives in 2022 had a positive impact in regard to overall catch. Total catch increased 56% from 89,542 in 2021 to 140,121 in 2022. The updates from the previous AMC mostly focused on the program's on-going response to the Northwest Power and Conservation Council's recommendations stemming from the 2019 Independent Scientific Review Panel's program review and the 2020 Columbia River System Biological Opinion direction to evaluate alternative sampling strategies to reduce incidental take.

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

[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.*

eight Columbia River and Snake River reservoirs. Modeling simulations based on work in John Day Reservoir from 1982 through 1988 indicated that, if predator-size Northern Pikeminnow were exploited at a 10-20% rate, the resulting restructuring of their population could reduce their predation on juvenile salmonids by as much as 40%.

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

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

In 1994, we investigated the use of trapnets and gillnets at specific locations where concentrations of Northern Pikeminnow were known or suspected to occur during the spring season (*i.e.*, March through early June). In addition, we initiated a concerted effort to increase public participation in the sport-reward fishery through a series of promotional and incentive activities. In 1995, 1996, and 1997, promotional activities and incentives were further improved based on the favorable 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

2023 Annual Report

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We are thankful to the City of Rainier for the use of the Rainier boat ramp; the City of Richland for the use of Columbia Point Park; the Cowlitz County Parks and Recreation Department for the use of the Willow Grove boat ramp; the Port of Bingen for the use of Bingen Marina; the Port of Camas/Washougal for the use of the Camas/Washougal boat ramp; the Port of Cascade Locks for the use of the Cascade Locks Marine Park; the Port of Cathlamet for the use of the Cathlamet Marina; the Port of Kalama for the use of the Kalama Marina; the Port of Ridgefield for the use of the Ridgefield boat ramp; the Port of The Dalles for the use of The Dalles Boat Basin; the Port of Umatilla for the use of the Umatilla Marina; the Portland Metro Regional Parks Department for the use of the M. James Gleason and Chinook Landing Boat Ramps ; the U.S. Army Corps of Engineers for the use of the Giles French, Hood Park, Windust Park, Swallows Park, and 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 Amber Santangelo, Anna Klundt, Leif Fox, Kyle Beckley, Eric Meyer, Garrett Morrison, Beck Missildine, Jordan Cornell, MaKenzie Pool, Rose Carr, Cooper Sargent, Randi Richards, Jessy Cox, Taylor Ah Mook Sang, Lacey Oltmann, Ben Veysey, Gary Griffith, Blair Peters, Devan Reid, Breanne Rea, Wick Bouton, and James Bruce for operating the 2023 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 throughout the program area, Nancy Vert for her numerous phone survey interviews, and Dennis Werlau for producing our weekly field activity reports throughout the 2023 season.

ABSTRACT

We are reporting on the progress of the Northern Pikeminnow Sport-Reward Fishery (NPSRF) implemented by the Washington Department of Fish and Wildlife (WDFW) on the Columbia and Snake Rivers from May 1 through September 30, 2023. 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, 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 156,513 Northern Pikeminnow ≥ 228 mm fork length (FL) and 3,525 Northern Pikeminnow < 228 mm TL were harvested during the 2023 NPSRF season. There were a total of 1,553 different individual anglers who spent 12,040 angler days of effort participating in the NPSRF during the 2023 season. Catch per unit effort for combined returning and non-returning anglers was 13.00 fish/angler day. The Oregon Department of Fish and Wildlife (ODFW) estimated that the Northern Pikeminnow harvest activities from the 2023 NPSRF resulted in an overall exploitation rate of 9.2% (Waltz et al. 2024).

Anglers submitted 14 Northern Pikeminnow with external spaghetti or Floy tags, 11 of these also retained an internal ODFW PIT tag. There were also 71 Northern Pikeminnow with ODFW PIT tags, but missing spaghetti or Floy tags (tag-loss). Additionally, 24 PIT tags from ingested juvenile salmonids were recovered from Northern Pikeminnow received during the 2023 NPSRF (1 PIT tag was also recovered from a juvenile lamprey).

Peamouth *Mylocheilus caurinus*, Smallmouth Bass *Micropteris dolomieui*, and Sculpin *Cottoidea Spp*, were the fish species most frequently caught by NPSRF anglers targeting Northern Pikeminnow. The incidental catch of salmonids *Oncorhynchus* spp, by participating anglers targeting Northern Pikeminnow continued to remain below established limits for the Northern Pikeminnow Management Program (NPMP).

INTRODUCTION

Mortality of juvenile salmonids *Oncorhynchus* spp. migrating through the Columbia River system is a major concern of the Columbia Basin Fish and Wildlife Program, and predation is an important component of mortality (Northwest Power Planning Council 1987a). Northern Pikeminnow *Ptychocheilus oregonensis*, formerly known as Northern Squawfish (Nelson et al. 1998), are the primary piscine predator of juvenile salmonids in the Lower Columbia and Snake River Systems (Rieman et al. 1991). Rieman and Beamesderfer (1990) predicted that predation on juvenile salmonids could be reduced by up to 50% with a sustained exploitation rate of 10-20% on Northern Pikeminnow ≥ 275 mm TL (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 TL 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 TL (9 inches total length) in response to recommendations contained in a Council review of NPMP justification, performance, and cost-effectiveness (Hankin and Richards 2000). Beginning in 1991, the Washington Department of Fish and Wildlife (WDFW) was contracted to conduct the NPSRF component of the NPMP (Burley et al. 1992). The NPSRF enlists recreational anglers to harvest reward sized (≥9" total length) Northern Pikeminnow from within program boundaries on the Columbia and Snake Rivers using a monetary reward system. Since 1991, NPSRF anglers have harvested over 5.5 million reward sized Northern Pikeminnow and spent over 1 million 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).

Reward levels included a base reward of $6 per fish for the first 25, $8 per fish for #26-200, and $10 per fish for each fish above 200. 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 objectives of the 2023 NPSRF were to (1) implement a public fishery that rewards recreational anglers for harvesting Northern Pikeminnow ≥ 228 mm (9 inches) total length, (2) collect, compile, and report data on angler participation, catch rates and harvest of Northern Pikeminnow and other fish species during the season, (3) examine collected Northern Pikeminnow for the presence of external tags, fin-clips, and signs of tag loss, (4) collect biological data on Northern Pikeminnow and other fish species returned to registration stations, (5) scan Northern Pikeminnow for the presence of Passive Integrated Transponder (PIT) tags implanted into Northern Pikeminnow by ODFW as secondary tags, and/or from Northern Pikeminnow containing consumed salmonids with PIT tags, and (6) survey non-returning NPSRF participants targeting Northern Pikeminnow in order to obtain catch and harvest data on Northern Pikeminnow and other salmonid species from this segment of NPSRF participants.

METHODS OF OPERATION

Fishery Operation

Boundaries and Season

The 2023 NPSRF season opened on May 1st 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). In addition, anglers were allowed to harvest (and submit for payment) Northern Pikeminnow caught in backwaters, sloughs, and up to 400 feet from the mouth of tributaries within this area.

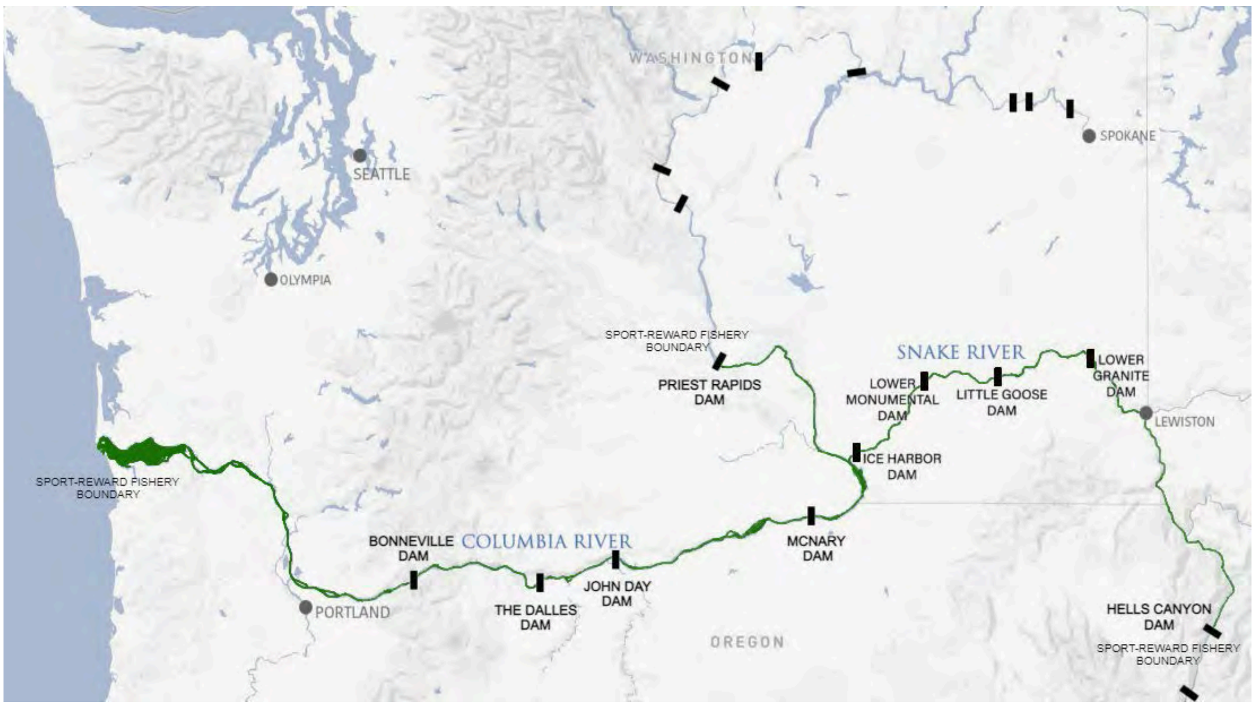


Figure 1. Northern Pikeminnow Sport-Reward Fishery Program Area

Registration Stations

Twenty-two 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 usually between 2 and 5 hours per day during the season. Technicians assisted in registering anglers, and in compiling data for registered anglers participating in the NPSRF, collected angler creel information, issued pay vouchers to anglers returning with eligible Northern Pikeminnow, recorded biological data, scanned Northern Pikeminnow for the presence of PIT tags, and provided angling advice and Sport-Reward Fishery information to the public. Self-registration boxes were also located at each station so anglers could self-register when WDFW technicians were not present.

Smart phone registration application

New for the 2023 NPSRF season, Pikeminnow anglers had an additional option for registering to participate in the SRF. A smart phone application (App) was created and developed by WDFW and made available to the public to download for free through one of the App Stores (Apple) or Google Play (Android). Phone app registration allowed anglers to register for participation in the 2023 NPSRF without going to the physical registration station and registering on paper. The intent was that the addition of this phone App option would lead to increased angler effort by making the registration process quicker and more convenient. Additional functionality can be added in future years to allow for electronic angler exit interviews, tag recovery capture, and biological data collection.

1. Cathlamet Marina 8:30 am -12:30 pm
2. Willow Grove 1:00 pm - 4:00 pm
3. Rainier Marina 8:00 am – 12:00 pm
4. Kalama Marina 12:30 pm – 4:30 pm
5. Ridgefield Marina 7:30 am – 11:00 am
6. Gleason Boat Ramp 12:30 pm – 4:00 pm
7. Chinook Landing 8:00 am – 12:00 pm
8. Washougal 12:00 pm – 4:00 pm
9. Stevenson 10:30 am – 1:30 pm
10. Cascade Locks 2:00 pm – 4:00 pm
11. Bingen 8:00 am – 10:00 am
12. The Dalles 11:30 am – 4:30 pm
13. Giles French 8:00 am – 11:00 am
14. Umatilla 10:00 am – 1:00 pm
15. Columbia Point 2:00 pm – 6:00 pm
16. Vernita 10:00 am – 1:30 pm
17. Hood Park 3:00 pm – 6:00 pm
18. Windust Park 2:00 pm – 5:30 pm
19. Lyon’s Ferry Marina 10:00am – 1:00pm
20. Boyer Park 12:30 pm – 3:30 pm
21. Greenbelt 9:30 am – 11:00 am
22. Swallow’s Park 5:00 pm – 6:30pm

Figure 2. 2023 Northern Pikeminnow Sport-Reward Fishery registration stations and hours of operation

Reward System

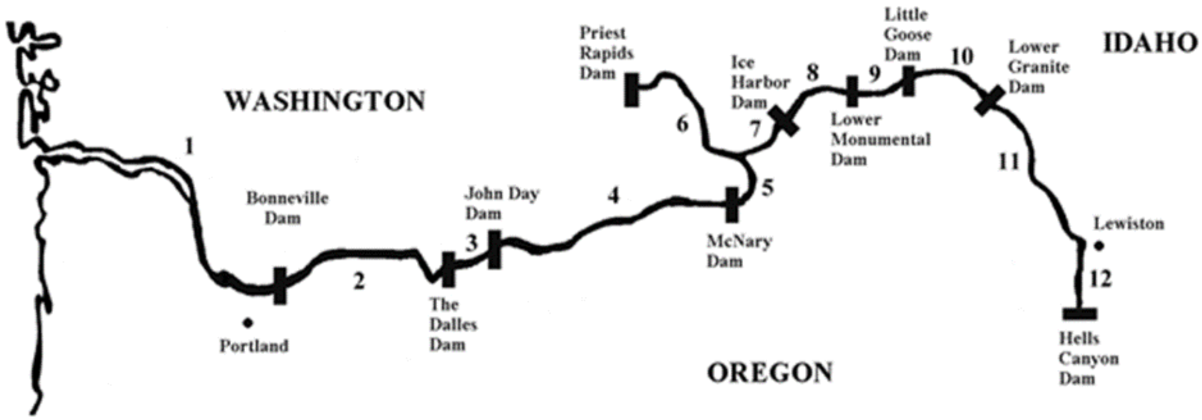
The 2023 NPSRF rewarded anglers for harvesting Northern Pikeminnow > 228mm TL (9 inches TL) using a tiered reward system first implemented in 1995 (Hisata et al. 1996), which paid anglers a higher reward per fish once they had reached designated harvest levels over the course of the season. To receive 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 2023 season was originally developed and implemented in 1995 (Hisata et al. 1996), and reflects multiple changes to the rewards and/or tier levels in an effort to address periods of declining participation. The tiered reward system paid anglers higher rewards per fish based on achieving designated harvest levels. Tier 1 paid anglers $6 each for their first 25 Northern Pikeminnow, Tier 2 paid anglers $8 each for fish numbers 26-200, and Tier 3 paid anglers $10 each for all fish over 200.

Although ODFW discontinued externally tagging Northern Pikeminnow in 2022, anglers continued to be paid $500 for each Northern Pikeminnow retaining a valid external tag (spaghetti or Floy) used by ODFW for the biological evaluation of the NPMP (prior to 2022), or tagged by WDFW as a new promotional activity in 2022 and 2023. NPSRF anglers were paid $200 for each Northern Pikeminnow without an external tag but retaining an ODFW PIT tag (formerly referred to as tag-loss) since external tags were not used by ODFW in 2023.

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 Dam 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. Ice Harbor Reservoir
9. Lower Monumental Reservoir
10. Little Goose Reservoir
11. Lower Granite Dam 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 2023 Northern Pikeminnow Sport-Reward Fishery

Returning Anglers

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

Non-Returning Anglers

Non-returning angler data were compiled from the pool of anglers who had registered for the NPSRF and targeted Northern Pikeminnow, but did not return to a registration station to participate in an exit interview. WDFW surveyed a minimum of 20% of the NPSRF's non-returning anglers using a telephone survey in order to obtain creel data from that segment of the NPSRF's participants. To obtain the 20% sample, non-returning anglers were randomly selected from each registration station for each week. A technician called anglers from each random sample until the 20% sample was attained. Non-returning anglers were surveyed with the same exit interview questions used for returning anglers. Anglers were asked: "did you specifically fish for Northern Pikeminnow at any time during your fishing trip?" With a "Yes" response, anglers were asked to report the number and species of adult and/or juvenile salmonids, and the number of reward size Northern Pikeminnow that were caught and harvested/released while they targeted Northern Pikeminnow. Angler catch and harvest data were not collected from non-returning anglers who did not target Northern Pikeminnow on their fishing trip. Non-returning angler catch and harvest data for non-salmonid species were not collected in 2023 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 2023 NPSRF were scanned for Passive Integrated Transponder (PIT) tags. PIT tags (prior to 2022) had been used by ODFW as a secondary mark in all Northern Pikeminnow fitted with external, spaghetti or Floy, tags as part of the NPMP's biological evaluation activities (Takata and Koloszar 2004). Beginning in 2022, ODFW discontinued use of external Floy or Spaghetti tags and exclusively used PIT tags for conducting the biological evaluation of the NPMP. Northern Pikeminnow harvested by anglers participating in the NPSRF have also been found to ingest juvenile salmonids that have been PIT tagged by other studies within the basin (Glaser et al. 2001). WDFW technicians were required to scan 100% of all Northern Pikeminnow returned to registration stations for PIT tags using PIT tag "readers". Northern Pikeminnow submitted for payment to the NPSRF were scanned using Biomark portable transceivers (model #HPR.PLUS.04V1) to record information from PIT tag detections for submission to the Columbia Basin PIT tag information System (PTAGIS). Scanning began on the first day of the NPSRF season and continued at all stations throughout the entire season. Technicians individually scanned all reward sized Northern Pikeminnow for PIT tag presence, and complete biological data were recorded from all Northern Pikeminnow with positive readings. All PIT tagged Northern Pikeminnow were processed on site, or labeled and preserved for later dissection and PIT tag recovery. All data were verified by WDFW tag lead biologist after recovery of PIT tags and all PIT tag recovery data were provided to ODFW and the PIT Tag Information System (PTAGIS 2023) on a regular basis. Anglers were eligible for an additional $200 reward from PSMFC for ODFW PIT tagged (formerly "tag-loss") fish which were defined as Northern Pikeminnow with no external tags, but retaining ODFW PIT tags used as part of the NPMP biological evaluation.

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 2023 NPSRF, anglers harvested a total of 156,513 reward size Northern Pikeminnow (≥ 228 mm TL) over the course of a 22-week field season. Harvest was below mean 1991-2022 harvest of 169,867 fish, but 16,392 fish more than the 2022 harvest (Werlau et al. 2023) (Figure 4). The 2023 NPSRF harvest was estimated to equal an exploitation rate of 9.2% (Waltz et al. 2024). In addition to harvesting 156,513 reward size Northern Pikeminnow, anglers participating in the 2023 NPSRF also harvested 3,525 Northern Pikeminnow < 228 mm TL.

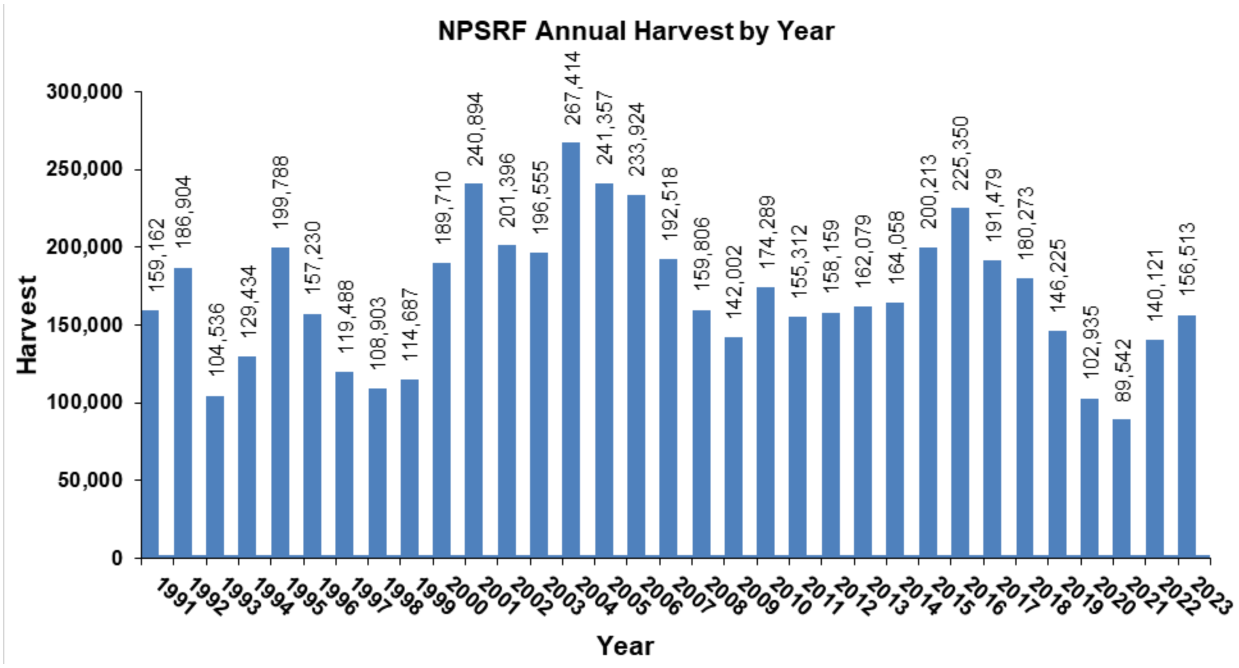


Figure 4. Annual harvest totals for the Northern Pikeminnow Sport-Reward Fishery

Harvest by Week

Peak weekly harvest in 2023 was 9,911 fish in week 20 (Figure 5) and was 1,490 fish higher than the peak harvest week in 2022 (8,421) (Figure 6). Mean weekly harvest was higher in 2023 (7,114) than in 2022 (6,092) and total weekly harvest was above 2022 weekly harvest for 17 of the 22 weeks of the season (Werlau et al. 2023). The 2023 NPSRF once again did not achieve weekly harvest of > 10,000 fish per week during the critical first 6 weeks of the season and weekly harvest remained below historical weekly average harvest for 12 of the 22 weeks of the 2023 season (Figure 7). Typically, high NPSRF weekly harvest levels (>10,000/week) early in the season, facilitates overall season harvest total above the NPSRF historical season average (169,867).

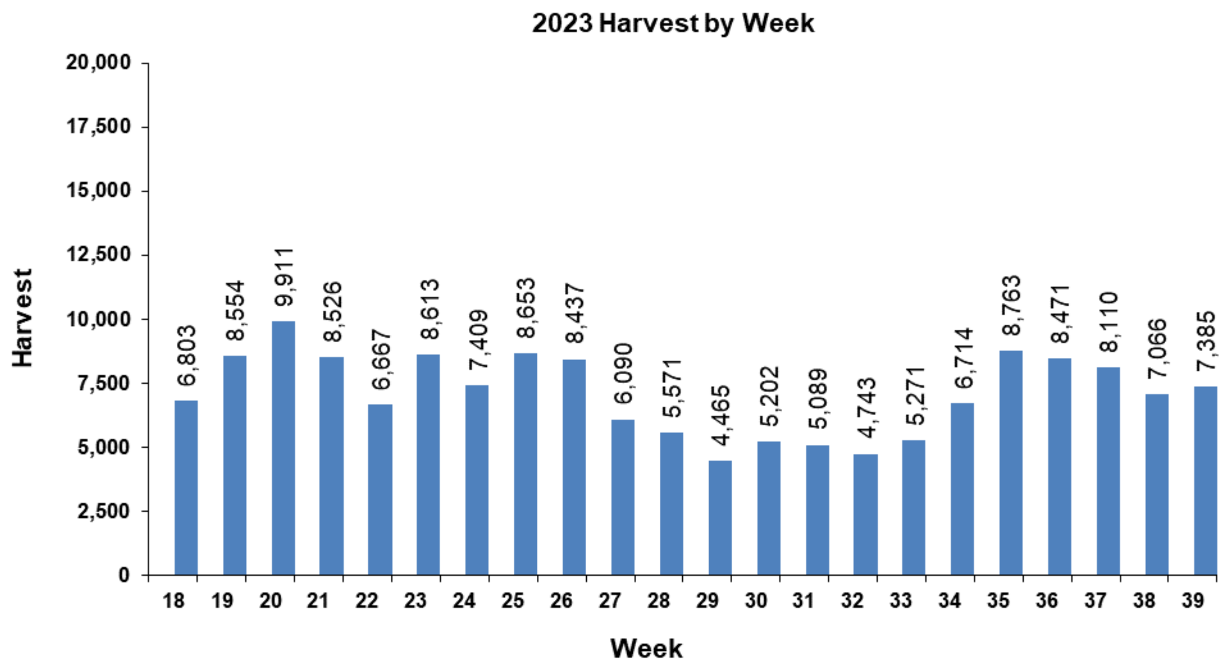


Figure 5. 2023 Weekly Northern Pikeminnow Sport-Reward Fishery harvest

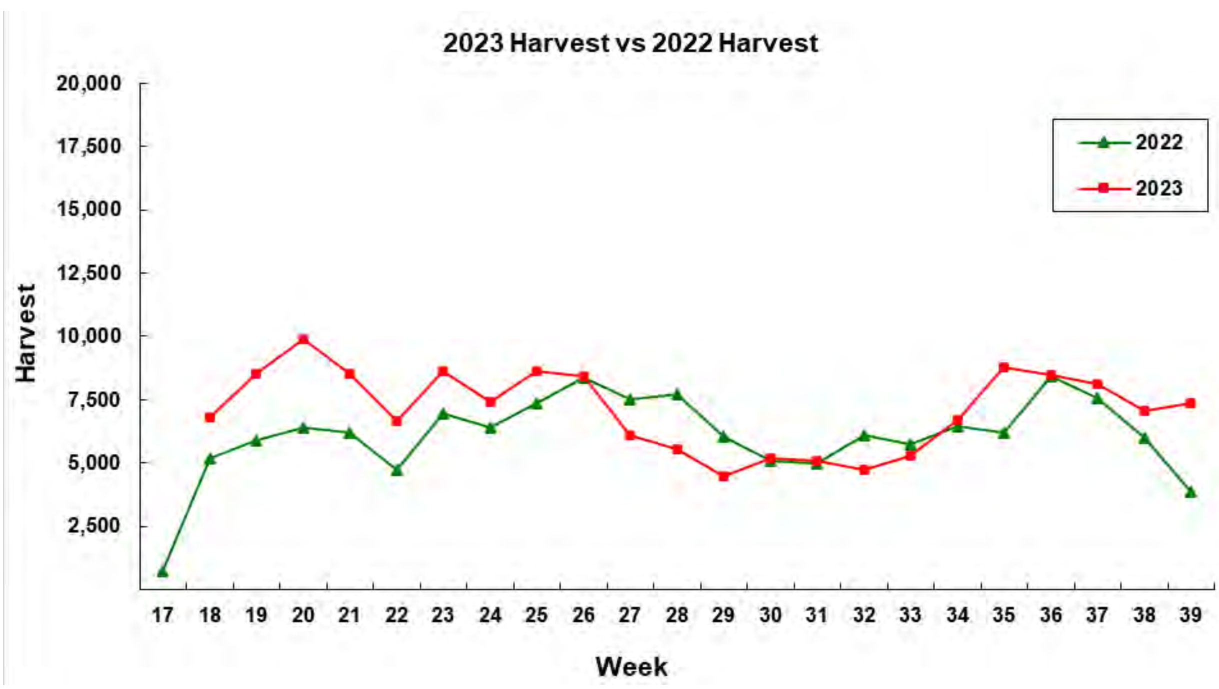


Figure 6. 2023 Weekly NPSRF harvest vs 2022 weekly harvest

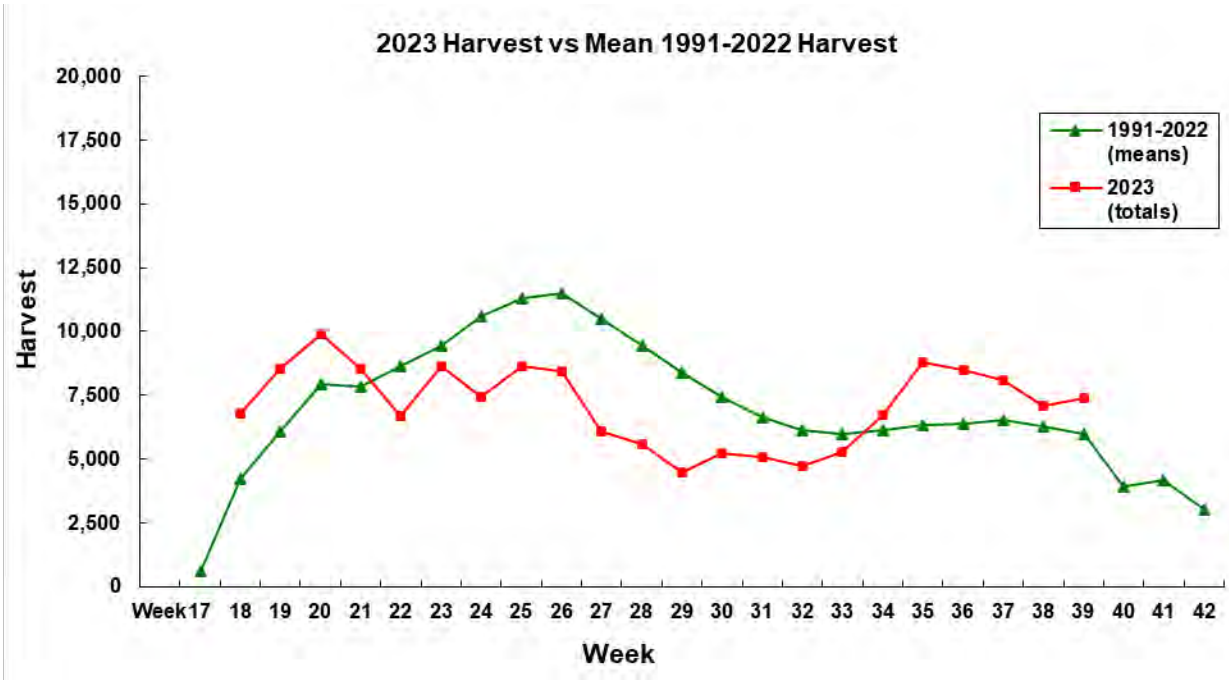


Figure 7. Comparison of 2023 NPSRF weekly harvest to 1991-22 mean weekly harvest

Harvest by Fishing Location

The mean harvest by fishing location for the 2023 NPSRF was 13,043 Northern Pikeminnow (compared to 11,677 in 2022) and ranged from 63,336 reward size Northern Pikeminnow in fishing location 01 (Below Bonneville Dam) to 0 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 44.5% of total NPSRF harvest in 2022 to 40.5% of total NPSRF harvest in 2023. Fishing location 01 remained the highest producing location in 2023, as it has been for all but one of the preceding 32 NPSRF seasons (Werlau et al. 2023). Bonneville Reservoir (Fishing Location 02) remained the second highest producing area accounting for 31.9% of total 2023 NPSRF harvest.

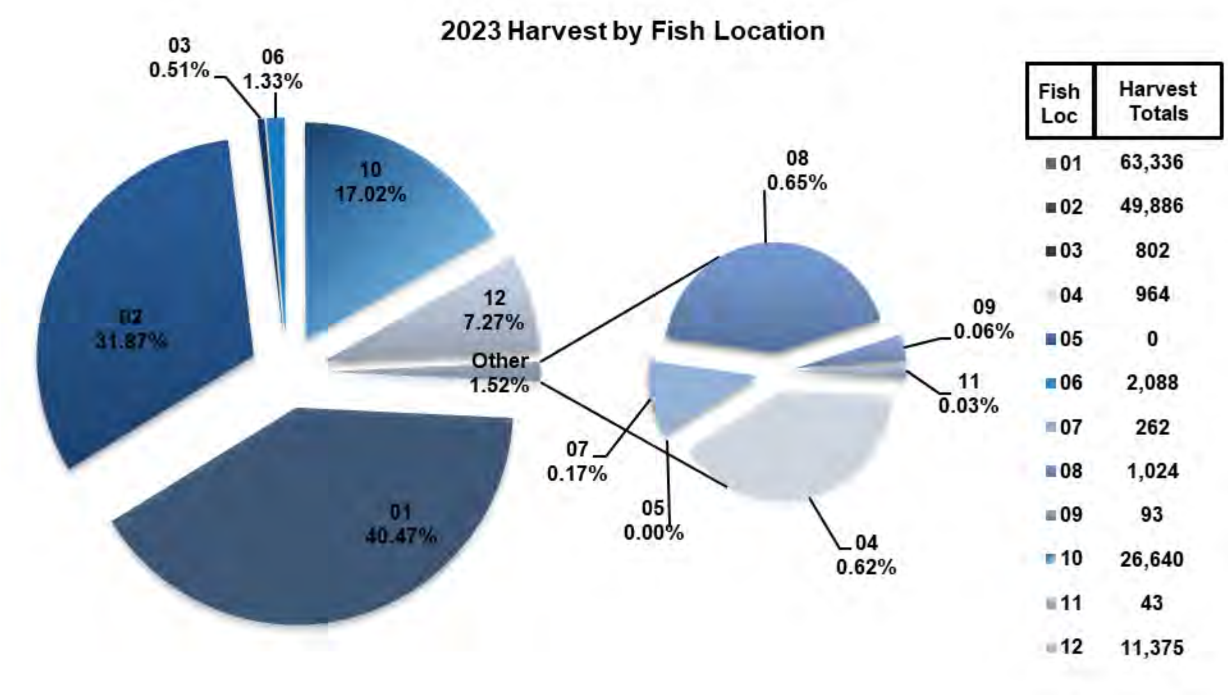


Figure 8. 2023 Northern Pikeminnow Sport-Reward Fishery harvest by fishing location*

*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 2023 was higher than in 2022 at 10 of the 22 registration stations. The Boyer Park registration station was once again the NPSRF's top producing station in 2023, where anglers harvested 26,051 Northern Pikeminnow, equaling 16.6% of total NPSRF harvest (Figure 9). The Washougal registration station finished with the second highest total of 25,885 Northern Pikeminnow (16.5% of total) harvested in 2023. The Dalles station finished third with 22,789 harvested fish. The average harvest per registration station was 7,114 reward size Northern Pikeminnow, up from 7,006 per station in 2022 (Werlau et al. 2023). The registration station with the smallest harvest was Vernita where anglers harvested only 57 Northern Pikeminnow during the 2023 season.

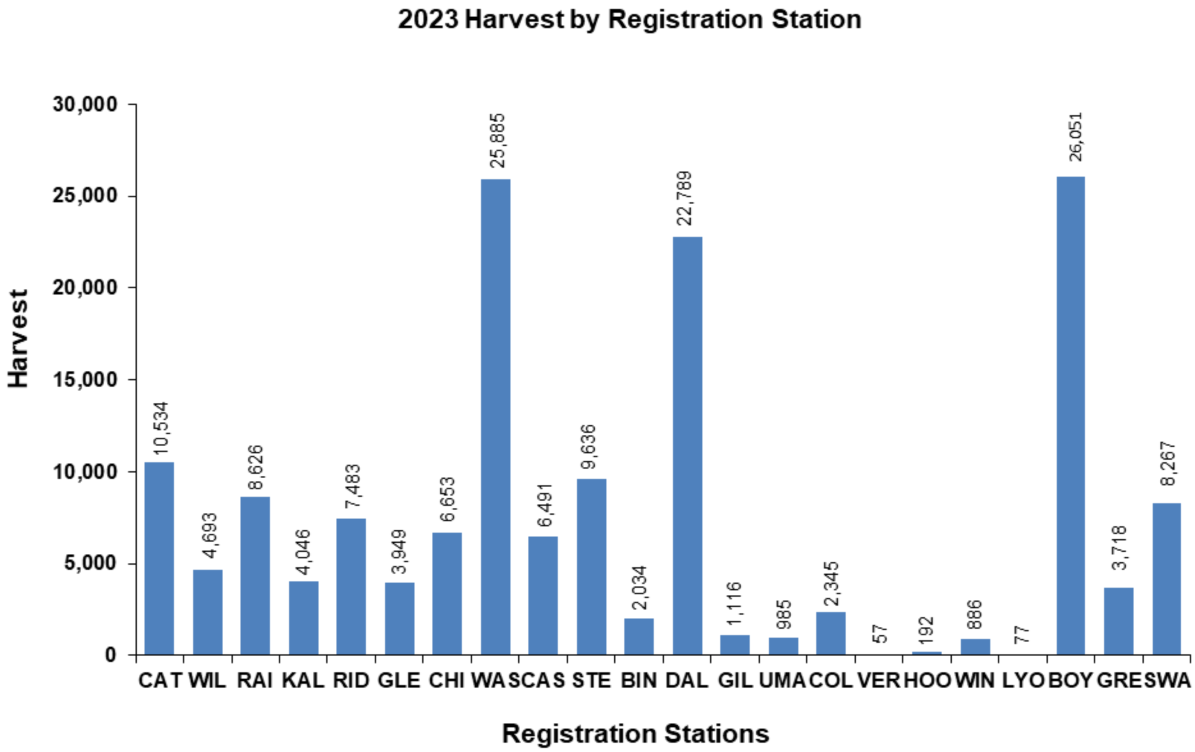


Figure 9. 2023 Northern Pikeminnow Sport-Reward Fishery harvest by registration station
CAT-Cathlamet, WIL-Willow Grove, RAI-Rainier, KAL-Kalama, RID-Ridgefield, GLE-Gleason, CHI-Chinook, WAS-Washougal, CAS-Cascade Locks, STE-Stevenson, BIN-Bingen, DAL- The Dalles, GIL-Giles, UMA-Umatilla, COL-Columbia Point, VER-Vernita, HOO-Hood Park, WIN-Windust, LYO-Lyons 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 2023 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 2023

Salmon

Species	Caught	Harvest	Harvest Percent
Chinook(Juvenile)	67	0	0%
Cutthroat(Unknown)	55	0	0%
Trout(Unknown)	30	0	0%
Steelhead Juvenile (Hatchery)	26	0	0%
Chinook (Adult)	8	0	0%
Steelhead Juvenile (Wild)	7	0	0%
Steelhead Adult (Hatchery)	4	2	50%
Steelhead Adult (Wild)	4	0	0%
Chinook (Jack)	3	0	0%

Anglers reported that all juvenile salmonids caught during the 2023 NPSRF were released. Per NPSRF protocol, technicians recorded all juvenile steelhead caught by NPSRF anglers as "wild", (except those specifically reported as missing an adipose fin). Harvested adult salmonids that were caught incidentally during the 2023 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 2023 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 2023

Non-Salmonid Species	Caught	Harvest	Harvest Percent
Northern Pikeminnow >228mm	156,513	156,513	100%
Northern Pikeminnow <228mm	38,010	3,525	9.27%
Peamouth	21,145	7,627	36.07%
Smallmouth Bass	14,528	1,418	9.76%
Sculpin (unknown)	6,079	3,624	59.62%
Walleye	2,569	1,733	67.46%
Channel Catfish	2,409	220	9.13%
Yellow Perch	1,642	465	28.32%
Sucker (unknown)	1,318	177	13.43%
White Sturgeon	1,157	0	0%
Catfish (unknown)	509	74	14.54%
Chiselmouth	493	118	23.94%
Bullhead (unknown)	393	39	9.92%
Carp	214	40	18.69%
American Shad	177	37	20.90%
Bluegill	90	4	4.44%
Starry Flounder	38	2	5.26%
Largemouth Bass	26	2	7.69%
Sandroller	14	0	0%
Whitefish	10	2	20%
Crappie (unknown)	5	0	0%
Pumpkinseed	4	0	0%

Non-Returning Anglers Catch and Harvest Estimates

As in past years, telephone interviews were conducted to randomly survey non-returning participants at each of the NPSRF's 22 stations in order to determine and record their catch and/or harvest of reward sized Northern Pikeminnow and other incidentally caught salmonid species. In 2023, there were 2,947 non-returning angler days recorded and a total of 597 calls were completed to non-returning anglers (20.3% 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 2023 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 2023 NPSRF. Estimated totals are listed in columns 5 and 6 of Table 3 (there were no salmonids caught by surveyed non-returning anglers in 2023).

Table 3. 2023 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	51	3	5.9%	251	15
Northern Pikeminnow ≥ 228 mm	9	6	66.7%	44	30

N=2,947 n=597

Fork Length Data

The length frequency distribution for harvested Northern Pikeminnow (≥ 200 mm) from the 2023 NPSRF is presented in Figure 10. Fork length data from 92,565 Northern Pikeminnow ≥ 200 mm FL (59.1% of total harvest) were taken during the 2023 NPSRF. The mean fork length for all measured Northern Pikeminnow (≥ 200 mm) in 2023 was 263 mm (SD= 54.63 mm), which is the same as in 2022 (Werlau et al. 2023).

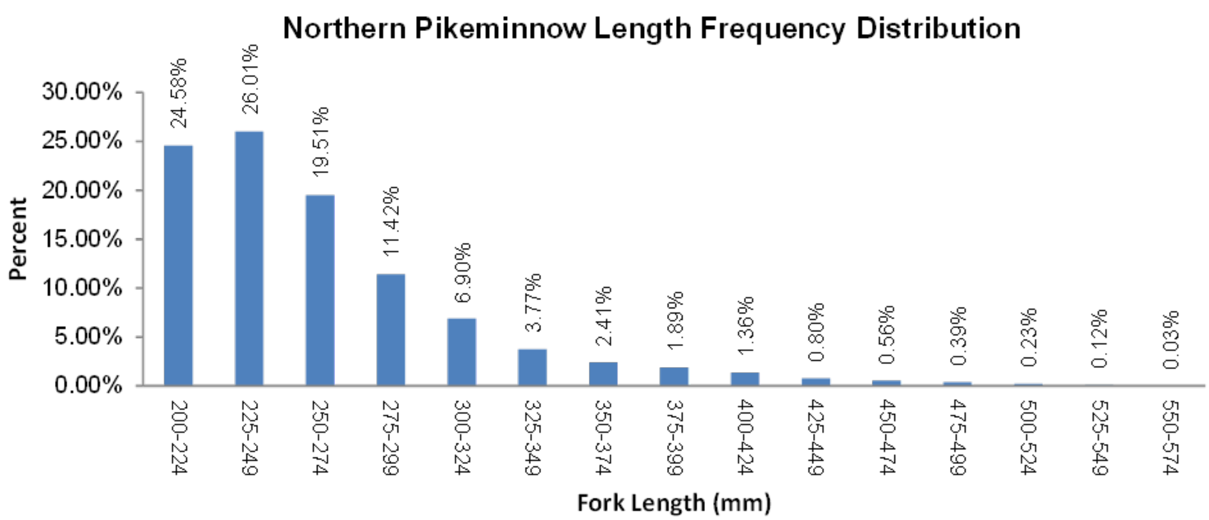


Figure 10. Length frequency distribution of Northern Pikeminnow > 200 mm FL from 2023 NPSRF. n=92,565

Angler Effort

The 2023 NPSRF recorded total effort of 12,040 angler days spent during the season, an increase of 1,479 angler days from 2022 (Werlau et al. 2023) (Figure 11). When total effort is divided into returning and non-returning angler days, 9,093 angler days (75.5%) were recorded by returning anglers, and 2,947 angler days (24.5%) were spent by non-return anglers. The percentage of returning anglers in 2023 (75.5%) was lower than the 2022 (78.6%) season (Werlau et al. 2023). Seventy-point one percent (70.1%) of total effort, and 92.8% of returning angler effort (8,438 angler days, 92.8%), was attributed to successful anglers who harvested at least one Northern Pikeminnow in 2023. In addition, 27.2% of angler registrations in 2023 were made using the new Pikeminnow phone App to register, compared to 72.8% of angler registrations which used paper.

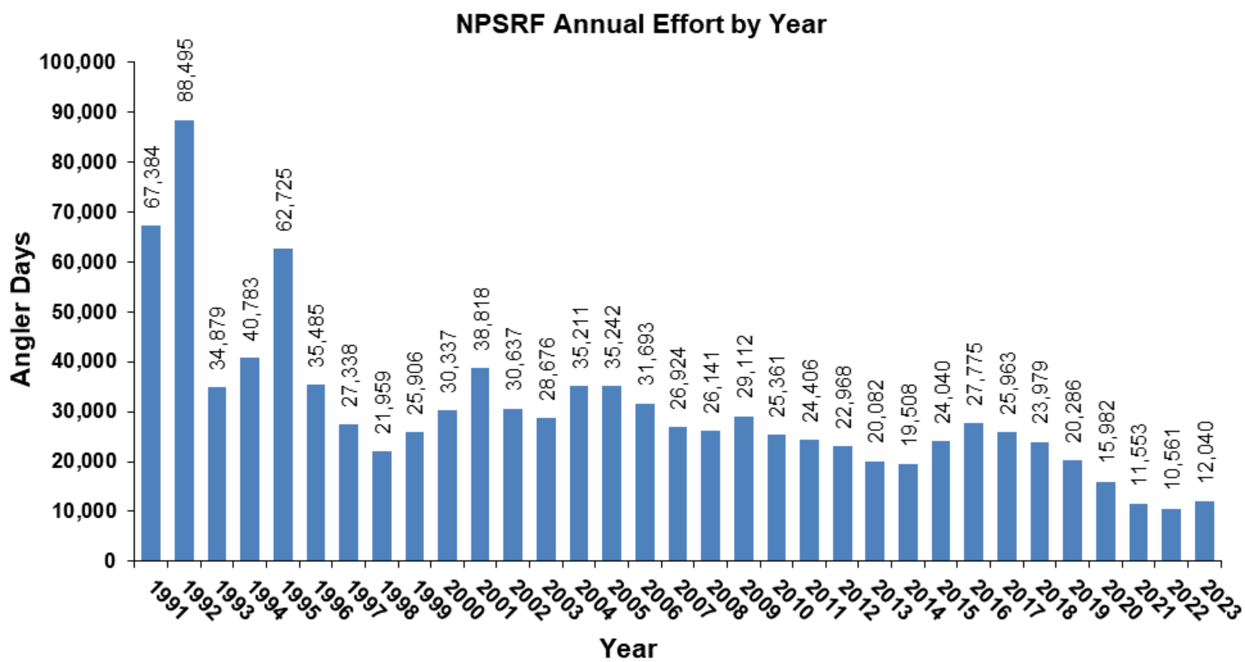


Figure 11. Annual Northern Pikeminnow Sport-Reward Fishery effort

Effort by Week

Mean weekly effort for the 2023 NPSRF was 547 angler days during the season, with the peak occurring in week 20 (Figure 12). Overall, mean weekly effort increased from 459 in 2022 (Werlau et al. 2023) and when we compare weekly effort totals between years, weekly effort totals for 19 of the 22 weeks in 2023 were up from those of 2022 (Werlau et al. 2023) (Figure 13). Peak weekly effort in 2023 occurred one week earlier than in 2022 and weekly effort totals continued to follow the pattern seen since 2015, where peak effort occurs near the first full week of the season (Figure 14). This pattern is different from the historical 1991-2015 (Winther et al. 2016) pattern for effort where the peak typically occurred around the same week as peak harvest and is likely the result of lowering angler tier levels, which incentivizes anglers to reach higher tier levels earlier in the season as a way to maximize their reward total.

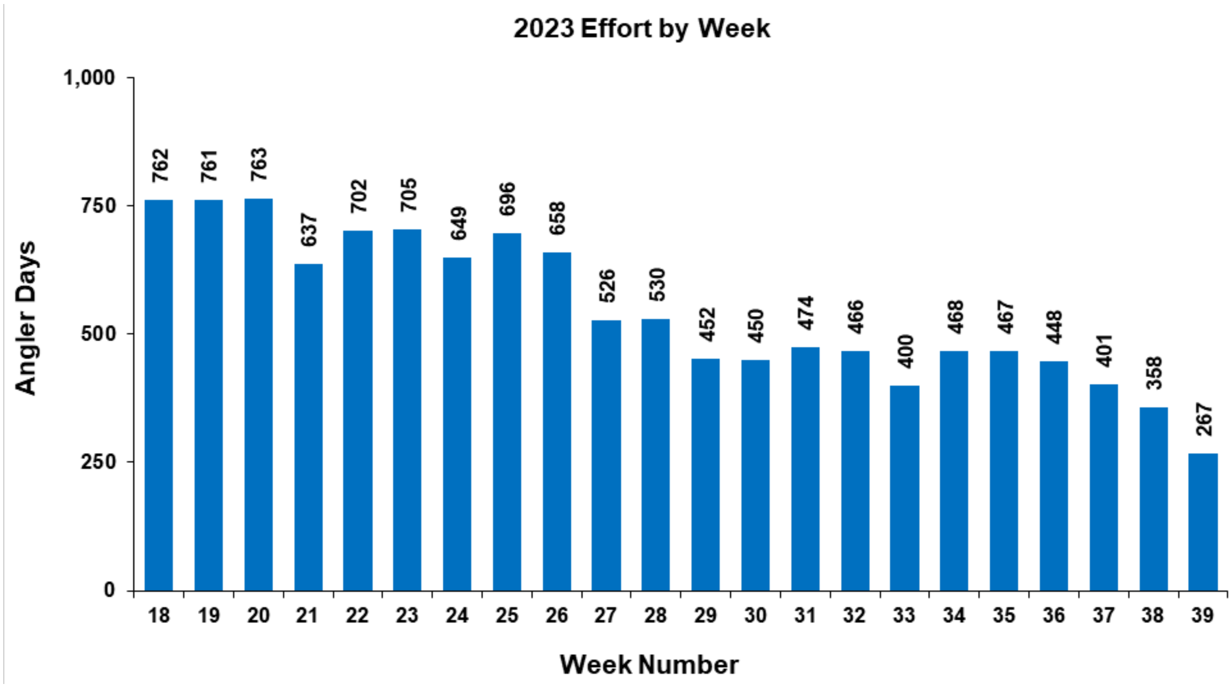


Figure 12. 2023 Weekly Northern Pikeminnow Sport-Reward Fishery angler effort

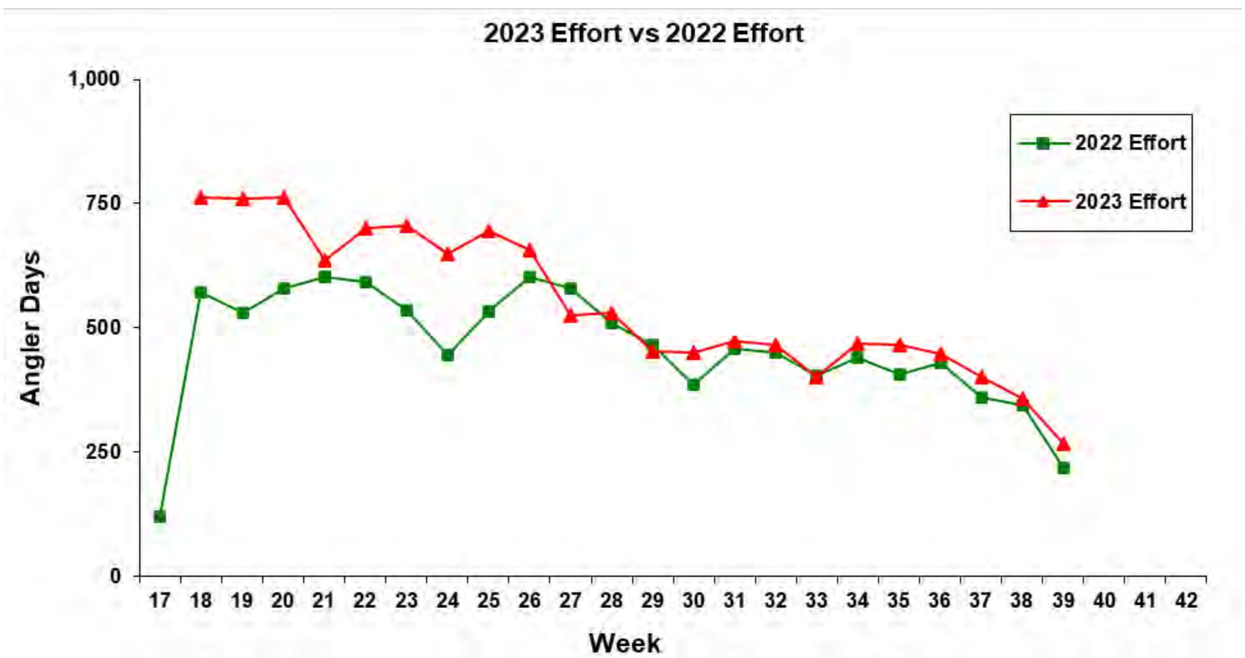


Figure 13. Effort 2023 Northern Pikeminnow Sport-Reward Fishery effort vs 2022 effort

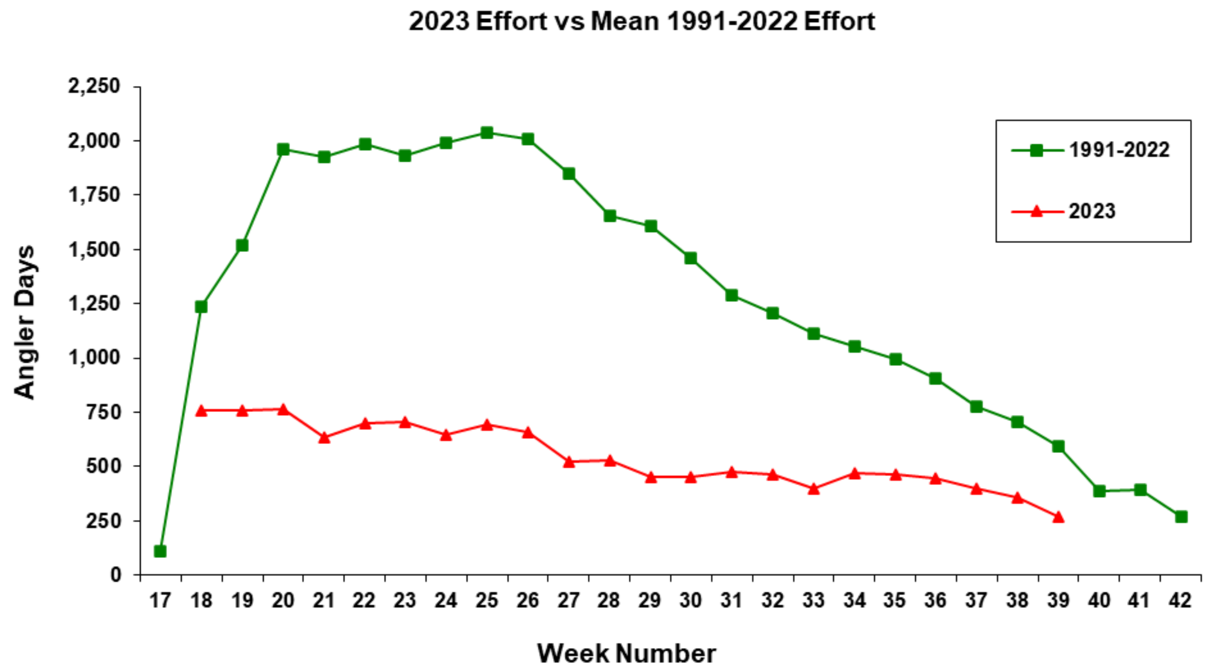


Figure 14. 2023 NPSRF weekly effort vs mean 1991-2022 effort

Effort by Fishing Location

Mean annual effort by fishing location for the 2023 NPSRF increased from 880 angler days in 2022 (Werlau et al. 2023) to 1,003 angler days in 2023. Effort totals ranged from 4,012 angler days spent in fishing location 01 (below Bonneville Dam) to 0 angler day spent in fishing location 05 on the Columbia River (McNary Dam to the Mouth of the Snake River) (Figure 15). Five of the 12 NPSRF fishing locations recorded an increase in angler effort (from 2022) in 2023.

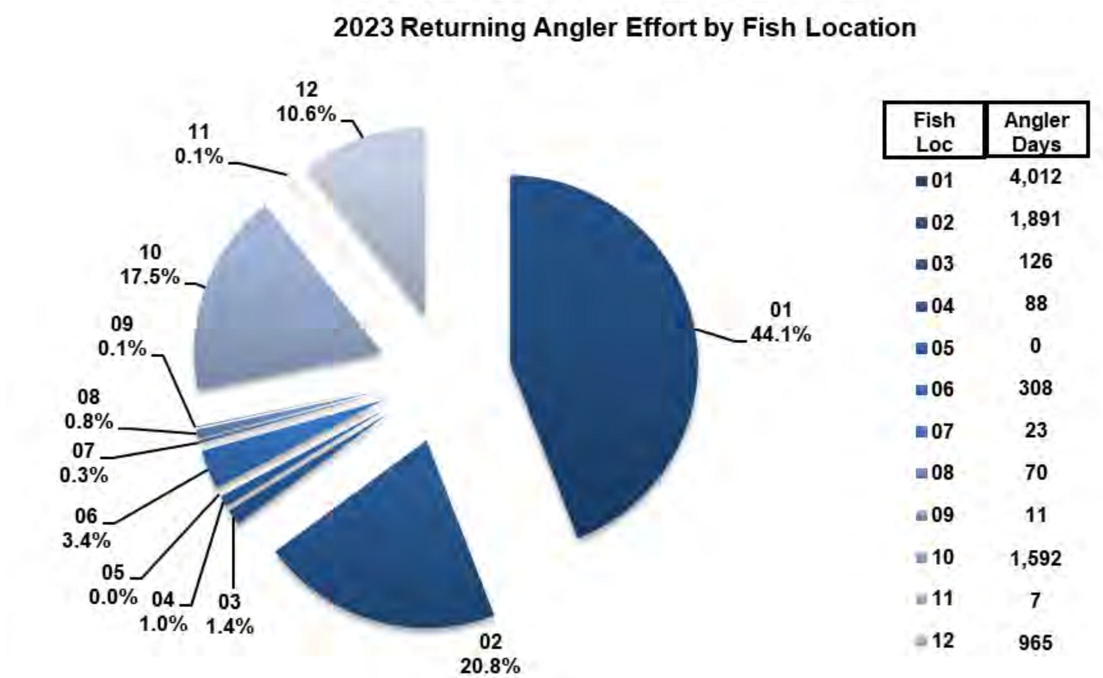


Figure 15. 2023 NPSRF angler effort by fishing location* (returning anglers only)
*Fishing Location Codes for **Columbia River**; 01 = Below Bonneville Dam, 02 = Bonneville Reservoir, 03 = The Dalles Reservoir, 04 = John Day Reservoir, 05 = McNary Dam to the mouth of the Snake River, 06 = Mouth of the 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 2023 NPSRF was 547 angler days compared to 528 angler days in 2022 (Werlau et al. 2023). Effort totals ranged from a high of 1,750 angler days at the Boyer Park station to a low of 22 angler days at the Lyon's Ferry station (Figure 16). Effort increased at 17 of the 22 registration stations with notable increases in angler effort at the Cathlamet, Willow Grove, and Rainier registration stations in 2023.

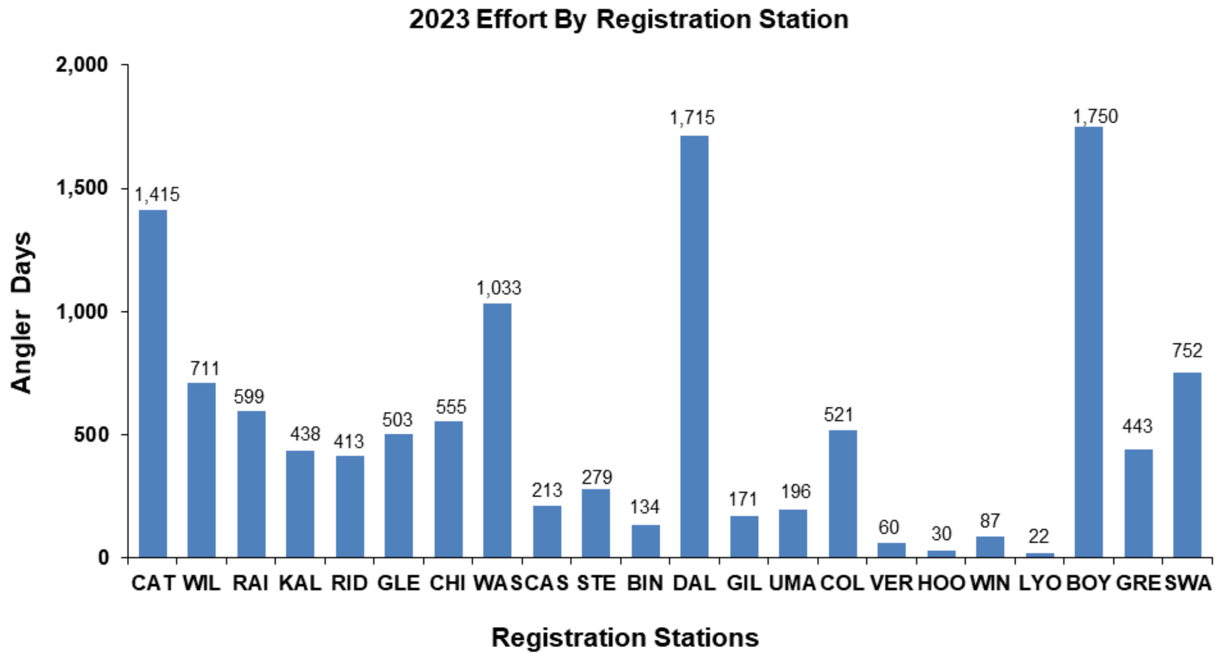


Figure 16. 2023 Northern Pikeminnow Sport-Reward Fishery angler effort by registration station
CAT-Cathlamet, WIL-Willow Grove, RAI-Rainier, KAL-Kalama, RID-Ridgefield, GLE-Gleason, CHI-Chinook, WAS-Washougal, CAS-Cascade Locks, STE-Stevenson, BIN-Bingen, DAL-The Dalles, GIL-Giles, UMA-Umatilla, COL-Columbia Point, VER-Vernita, HOO-Hood Park, WIN-Windust, LYO-Lyon's Ferry, BOY-Boyer Park, GRE-Greenbelt, SWA-Swallows.

Catch Per Angler Day (CPUE)

The 2023 NPSRF recorded an overall (returning + non-returning anglers) catch per unit of effort (CPUE or "catch rate") of 13.00 Northern Pikeminnow harvested per angler day during the season. This catch rate was slightly less than the 2022 overall CPUE of 13.27 (Figure 17), indicating that angling conditions throughout the NPSRF area during the 2023 season were similar to that of the 2022 season. Angler CPUE continued the upward trend seen throughout the NPSRF's 33-year history and was the second highest in NPSRF history. Returning angler CPUE during the 2023 NPSRF was 17.21 Northern Pikeminnow per angler day, up from the 2022 returning angler CPUE of 16.87 (Werlau et al. 2023). The estimated CPUE for non-returning anglers was 0.09 reward size Northern Pikeminnow per angler day based on 2023 NPSRF phone survey results and that level has remained constant throughout recent NPSRF history.

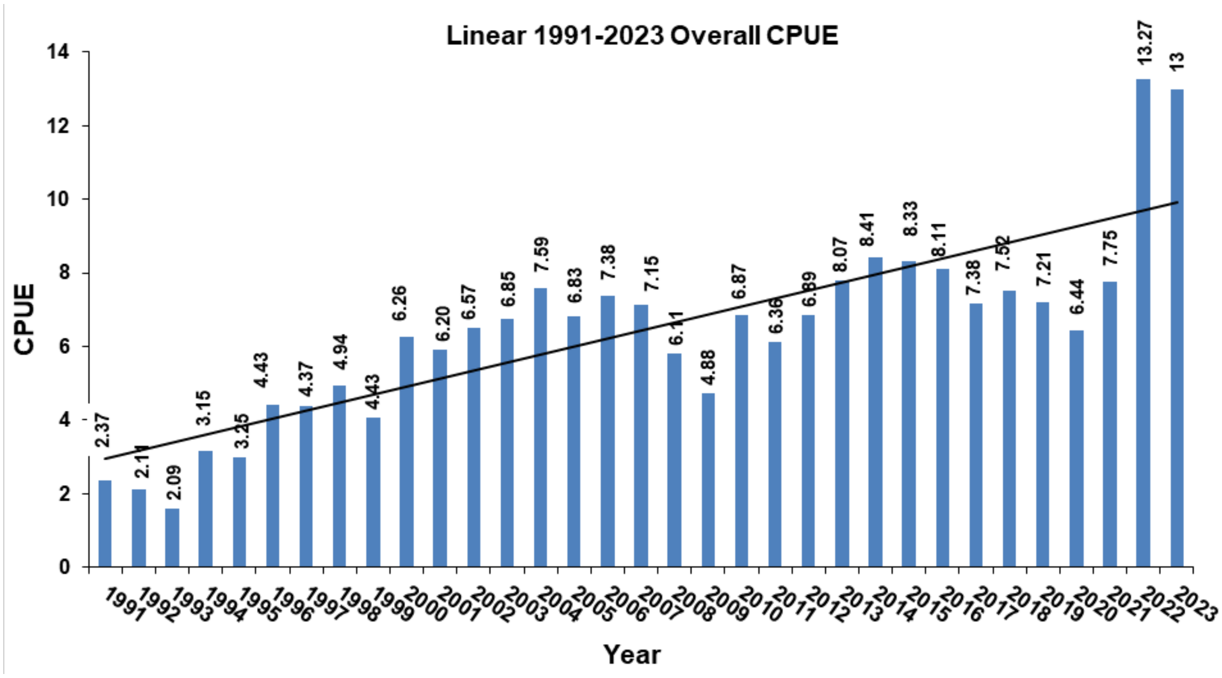


Figure 17. Annual NPSRF CPUE (returning + non-returning anglers) for the years 1991-2023

CPUE by Week

Mean angler CPUE by week for the 2023 NPSRF was 13.74 fish per angler day compared to 13.48 in 2022 (Werlau et al. 2023) and ranged from a low of 9.50 (week 18 was not a full week) in week 22 (May 29-June4) to a peak of 27.66 in week 39 (September 25-30) (Figure 18). Weekly CPUE for the 2023 NPSRF followed a typical two-peak pattern with the first peak in week 21 and then again late in the season (week 39) when favorable water and angling conditions were present in the lower Columbia and Snake rivers (Winther et al. 2011).

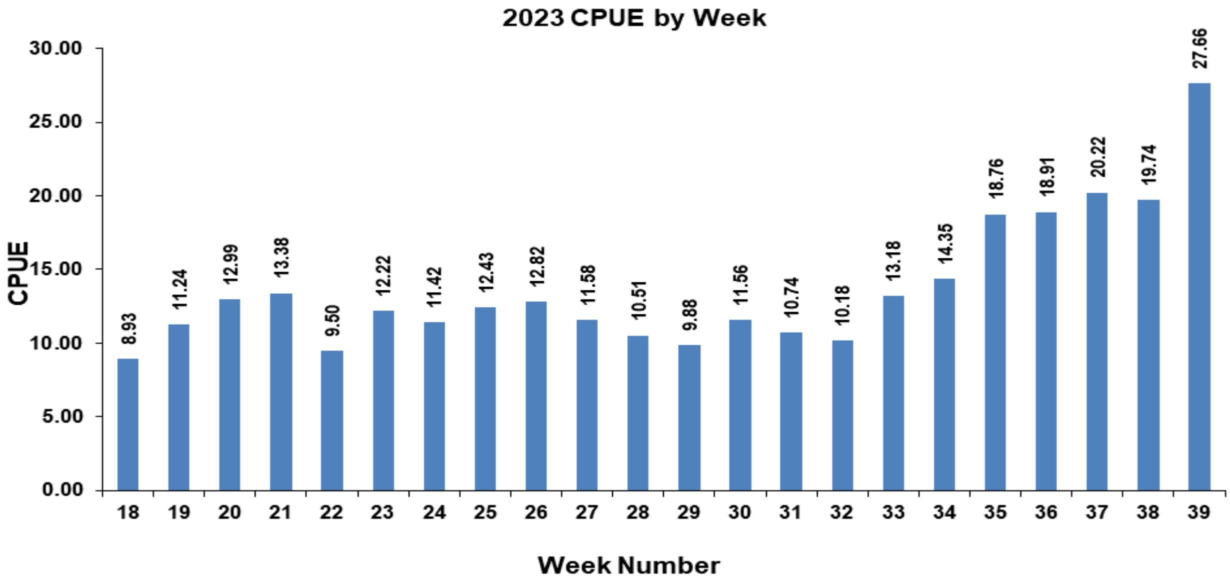


Figure 18. 2023 Northern Pikeminnow Sport-Reward Fishery angler CPUE by week

CPUE by Fishing Location

Angler success rates for the 2023 NPSRF (as indicated by CPUE), represent returning anglers only and varied by fishing location. Success rates ranged from a high of 26.38 Northern Pikeminnow per angler day in fishing location 02 (Bonneville Reservoir) to a low of 0 fish per angler per day in fishing location 05 (McNary Dam to the mouth of the Snake River) (Figure 19). CPUE increased at fishing locations 02, 04, 07 and 10 in 2023. The average CPUE by fishing location was 11.28 Northern Pikeminnow per angler day in 2023 compared to 13.58 in 2022 (Werlau et al. 2023).

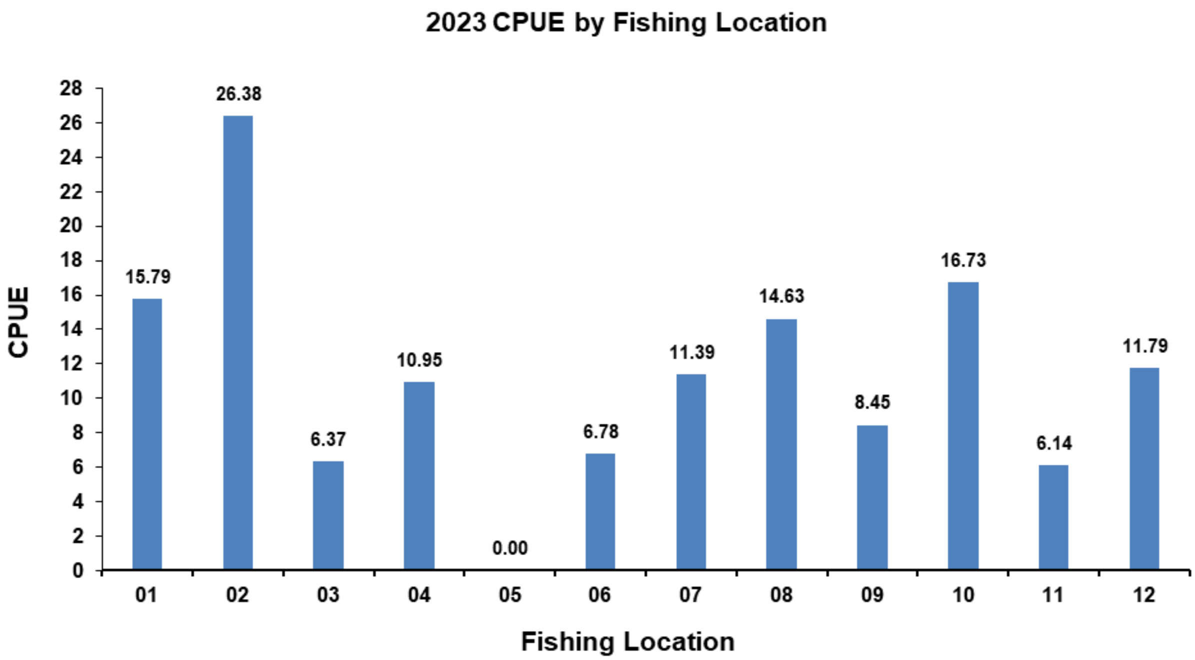


Figure 19. 2023 Northern Pikeminnow Sport-Reward Fishery angler CPUE by fishing location. *
*Fishing Location Codes for **Columbia River**; 01 = Below Bonneville Dam, 02 = Bonneville Reservoir, 03 = The Dalles Reservoir, 04 = John Day Reservoir, 05 = McNary Dam to the mouth of the Snake River, 06 = Mouth 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 stations with the highest CPUE during the 2023 NPSRF were the Stevenson and Cascade Locks stations where anglers averaged 34.54 and 30.47 Northern Pikeminnow per angler day respectively (Figure 20). The next highest registration station CPUE was the Washougal station with 25.06 fish per angler, per day and the station with the lowest CPUE was the Vernita station with a CPUE of .95 Northern Pikeminnow per angler day. The station average for angler CPUE was 12.07 in 2023, down from 13.25 in 2022 (Werlau et al. 2023). The largest CPUE increase occurred at the Stevenson station, where CPUE increased from 27.46 in 2022 (Werlau et al. 2023) to 34.54 in 2023.

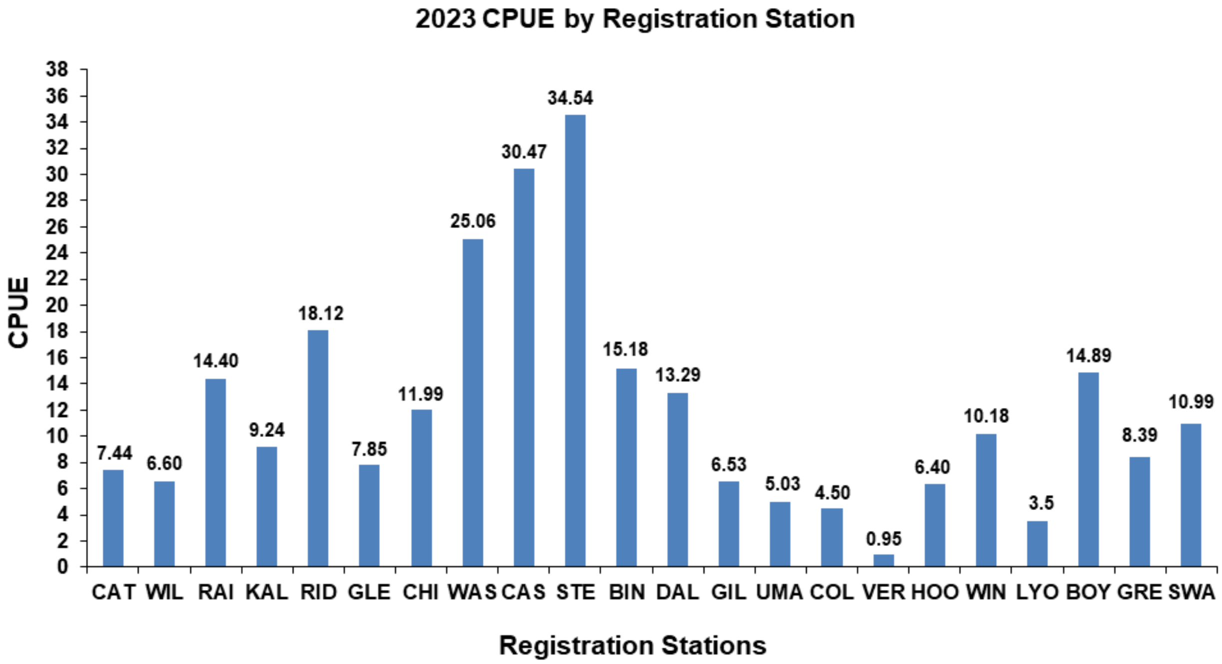


Figure 20. 2023 Northern Pikeminnow Sport-Reward Fishery angler CPUE by registration station
CAT-Cathlamet, WIL-Willow Grove, RAI-Rainier, KAL-Kalama, RID-Ridgefield, GLE-Gleason, CHI-Chinook, WAS-Washougal, CAS-Cascade Locks, BIN-Bingen, DAL-The Dalles, GIL-Giles, UMA-Umatilla, COL-Columbia Point, VER-Vernita, HOO-Hood Park, WIN-Windust, LYO-Lyon's Ferry, BOY-Boyer Park, GRE-Greenbelt, SWA-Swallows.

Angler Totals

There were 1,553 separate anglers who participated in the 2023 NPSRF, an increase of 378 participants from 2022. Six hundred forty-nine of these anglers (41.8% of total vs. 48.9% in 2022 were classified as successful, harvesting at least one reward size Northern Pikeminnow (for which a voucher was issued) during the 2023 season. Of the successful anglers, 74.6% (484 anglers) sent in their vouchers to PSMFC for payment (PSMFC 11/20/23 Sport-Reward Payment Summary) while 165 anglers (25.4%) did not. The average successful angler harvested 241 Northern Pikeminnow during the 2023 NPSRF compared to 244 in 2022 (Werlau et al. 2023).

When we break down the 649 successful anglers by tier, 394 of these anglers (60.71%) harvested fewer than 25 Northern Pikeminnow and were classified as Tier 1 anglers (Figure 21). This is down from the 442 individual Tier 1 anglers in 2022 (Werlau et al. 2023). The number of Tier 2 anglers more than doubled with 138 (21.26%) in 2023, compared to 59 in 2022 and the number of Tier 3 anglers (known as "highliners") also increased from 73 anglers to 117 (18.03%) in 2023 (Werlau et al. 2023).

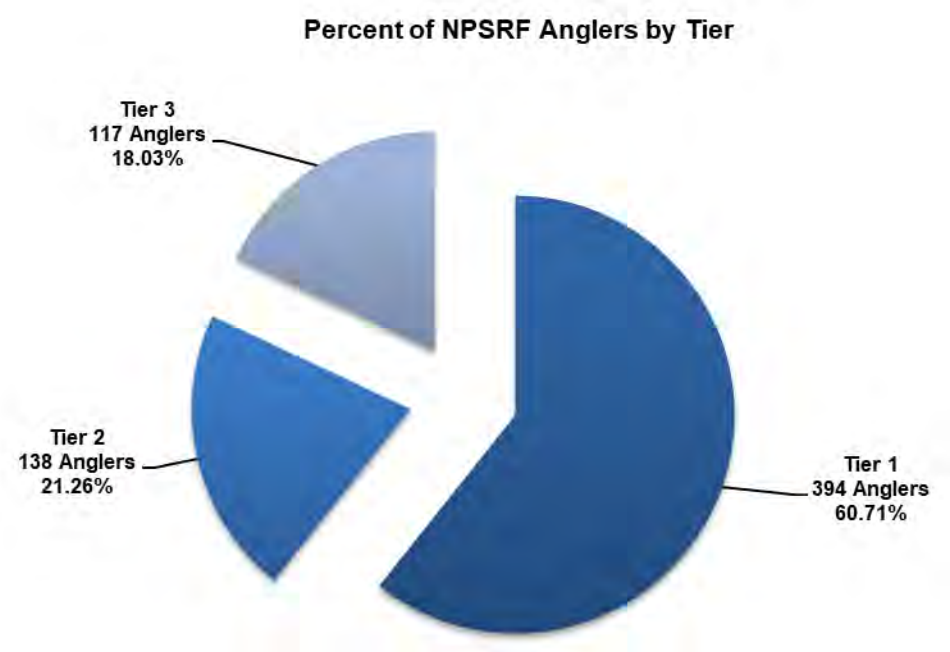


Figure 21. 2023 Percentage of NPSRF anglers by tier (returning anglers) based on total harvest

The continued high percentage of overall NPSRF harvest by Tier 3 anglers remained especially important for successfully achieving 2023 NPSRF harvest and exploitation objectives. Historically, Tier 3 anglers have much higher harvest and CPUE levels than Tier 1 or 2 anglers (Hisata et al. 1996), and even though there were reduced levels of participation at Tier 1 during the 2023 NPSRF, the overall effect was mitigated by the increased levels of participation at the other two tiers.

While Tier 1 anglers made up 60.71% of all successful NPSRF participants in 2023, they accounted for only 1.4% of total NPSRF harvest (2,197) Northern Pikeminnow) (Figure 22). Tier 2 anglers made up 21.26% of all successful anglers and harvested 6.77% of total NPSRF harvest (10,593 fish). Tier 3 anglers made up only 7.5% of all NPSRF participants (both returning and non-returning anglers) but were 18.03% of all successful anglers and accounted for 91.83% of total 2023 NPSRF harvest (143,723 fish).

Average annual harvest per angler was down for Tier 1, Tier 2 and Tier 3 anglers. Tier 1 anglers annual average harvest was 6 fish per year in 2023, compared to 17 fish per year in 2022. Tier 2 anglers harvested an annual average of 77 fish per year in 2023, down from 444 fish per year in 2022. Average annual harvest for Tier 3 anglers decreased to 1,228 fish per year in 2023 compared to 1,457 fish per year in 2022 (Werlau et al. 2023).

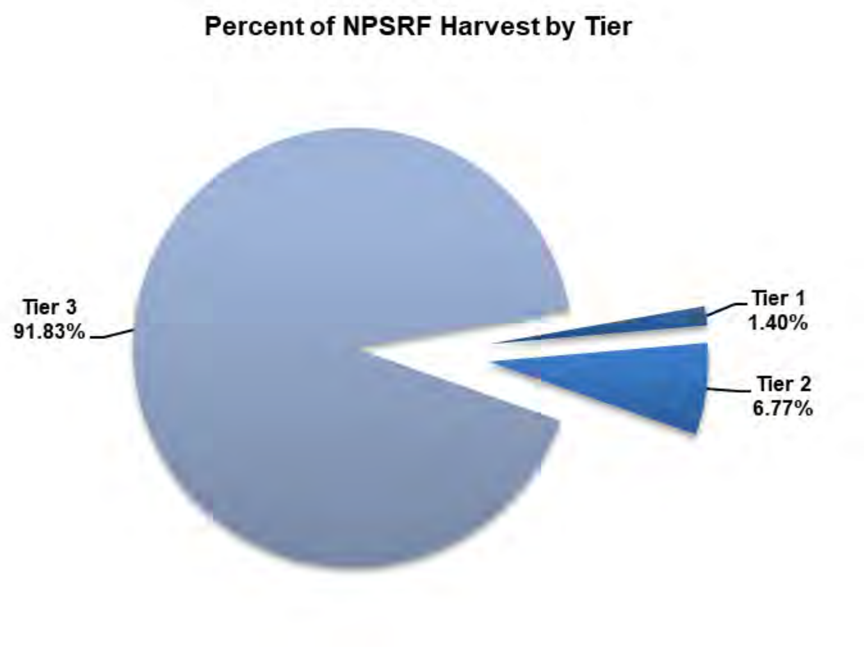


Figure 22. 2023 NPSRF harvest by angler tier (Tier 1 = <25, Tier 2 =26-200, Tier 3 = > 200)

The overall average NPSRF participant (returning + non-returning anglers) expended less effort pursuing Northern Pikeminnow during the 2023 season than in 2022 (7.75 vs. 8.99 angling days of effort). When we look at successful anglers only, the average successful angler spent slightly less average annual effort during the 2023 NPSRF with 13.00 average angler days spent in 2023 compared to 13.21 days in 2022. When we break down successful angler effort by tier, only one of the three tier levels spent more annual effort in 2023 than they did in 2022. Tier 1 anglers spent an average of 4 days fishing in 2023, up from 3 days in 2022 (Figure 23). Tier 2 anglers spent an average of 17 days fishing in 2023, down from 36 days in 2022. Tier 3 anglers averaged 58 days fishing in 2023, down from 84 days in 2022 (Werlau et al. 2023).

Figure 23. Average effort (angler days) of 2023 NPSRF anglers by tier (Tier 1 = < 25, Tier 2 = 26-200, Tier 3 = > 200)

When 2023 CPUE by tier is compared to 2022 there was an increase in CPUE at only one tier level. CPUE for anglers at Tier 1 decreased from 5.39 fish per angler day in 2022 to 1.36 in 2023 (Figure 24). CPUE for Tier 2 anglers decreased from 12.41 fish per angler day in 2022 to 4.65 in 2023. CPUE for Tier 3 anglers substantially increased from 17.38 fish per angler day in 2022 to 21.36 in 2023 (Werlau et al. 2023).

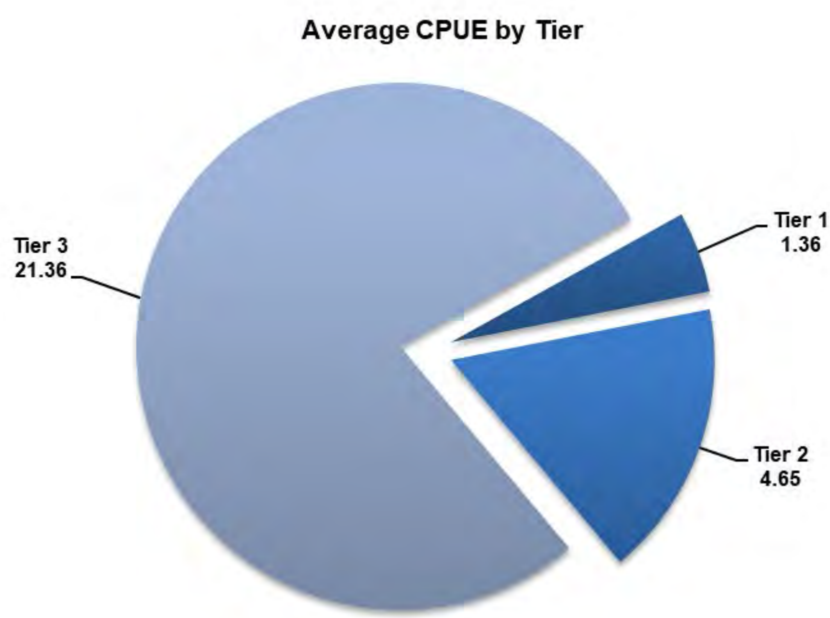


Figure 24. Average CPUE of 2023 NPSRF anglers by tier (Tier 1 = <25, Tier 2 =26-200, Tier 3 = > 200)

The top individual angler (based on number of fish caught) for the 2023 NPSRF harvested 10,755 Northern Pikeminnow, which also included 1 externally tagged Northern Pikeminnow and 1 tag-loss Northern Pikeminnow worth total earnings of $107,800 (PSMFC 11/20/2023 Sport-Reward Payment Summary). The 2023 top angler caught 3,897 more reward sized Northern Pikeminnow than the top angler did in 2022. The CPUE for this year's top angler (76.81 fish per angler day) was up from the top angler in 2022 (61.02 fish per angler day) reflecting more productive fishing/river conditions seen for all Tier 3 anglers in 2023. The top angler for the 2023 season spent 26 more days of effort (140 days total) than the top angler did in 2022 (Werlau et al. 2023). By comparison, the top angler in terms of participation (rather than harvest) for the 2023 NPSRF fished 145 days of the 153 available days (94.8% of available days) and harvested 2,615 Northern Pikeminnow.

Tag Recovery

Northern Pikeminnow Tags

Returning anglers harvested 14 Northern Pikeminnow tagged with external spaghetti or Floy tags during the 2023 NPSRF compared to 37 external spaghetti/Floy tags harvested in 2022 (Werlau et al. 2023). There were 71 Northern Pikeminnow recovered containing ODFW PIT tags in 2023 (ODFW has not deployed any external tags since 2021, using only PIT tags instead). Tag recoveries (both external and PIT) peaked during week 23 (Figure 25), which was three weeks earlier than the weeks 26 and 27 peak tag recoveries in 2022 (Werlau et al. 2023). Of the 14 externally tagged Northern Pikeminnow recovered in the 2023 NPSRF, 11 retained PIT tags added by ODFW. ODFW used WDFW's tag recovery data from the 2023 NPSRF (Spaghetti/Floy and/or PIT) to estimate a 9.2% exploitation rate for the NPMP in 2023 (Waltz et al. 2024).

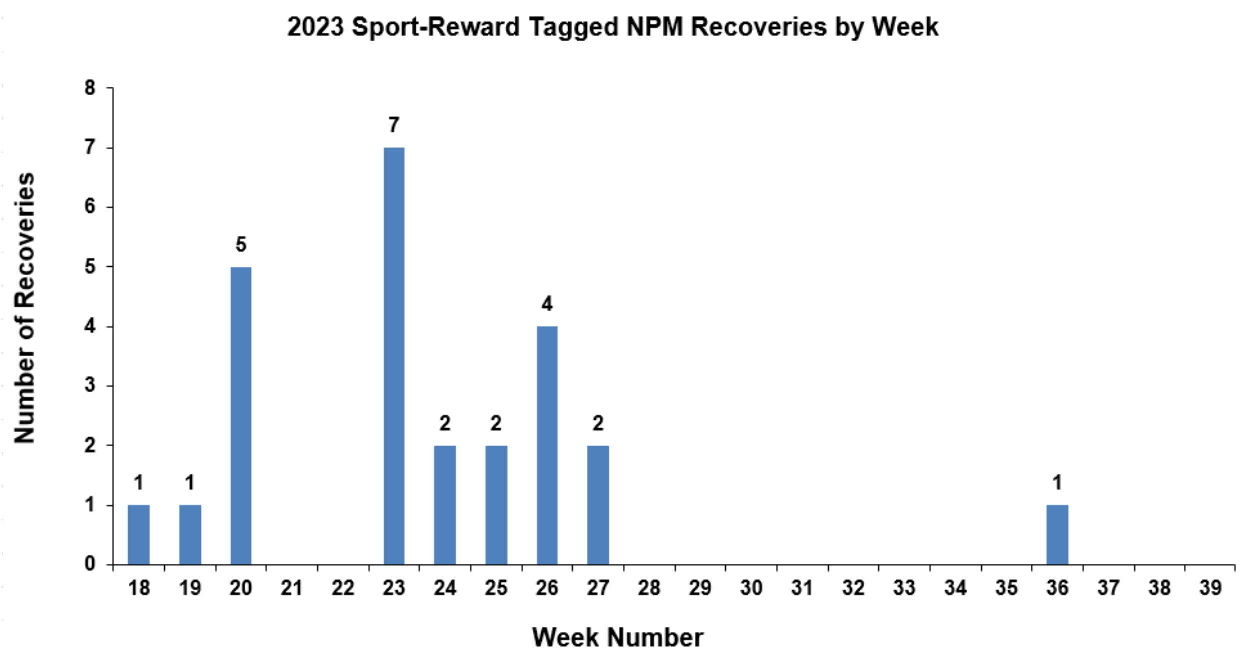


Figure 25. 2023 NPSRF tagged NPM recoveries by week

Ingested PIT Tags

A total of 156,513 Northern Pikeminnow were individually scanned for the presence of PIT tags in 2023. This represents 100% of the total harvest of qualifying reward-size fish for the 2023 NPSRF (Northern Pikeminnow not qualifying for rewards were also scanned whenever possible). Technicians recovered a total of 25 PIT tags from consumed smolts that had been ingested by Northern Pikeminnow harvested during the 2023 NPSRF, an overall occurrence rate of 1:6,261 compared to 1:6,092 in 2022. Total ingested PIT tag recoveries in 2023 was 3 more recoveries than the previous year. PIT tag recoveries of salmonid smolts ingested by Northern Pikeminnow peaked during week 24 of the 2023 NPSRF and the final ingested PIT tag recoveries for the 2023 NPSRF occurred during week 37 (September 4th – Sept 10th) (Figure 26), two weeks later than in 2022 (Werlau et al. 2023).

Ingested PIT tag recoveries by fishing location during the 2023 NPSRF showed that Northern Pikeminnow harvested from fishing location 10 (Little Goose Reservoir) consumed the largest number of PIT tagged juvenile salmonids totaling 14 (Figure 27).

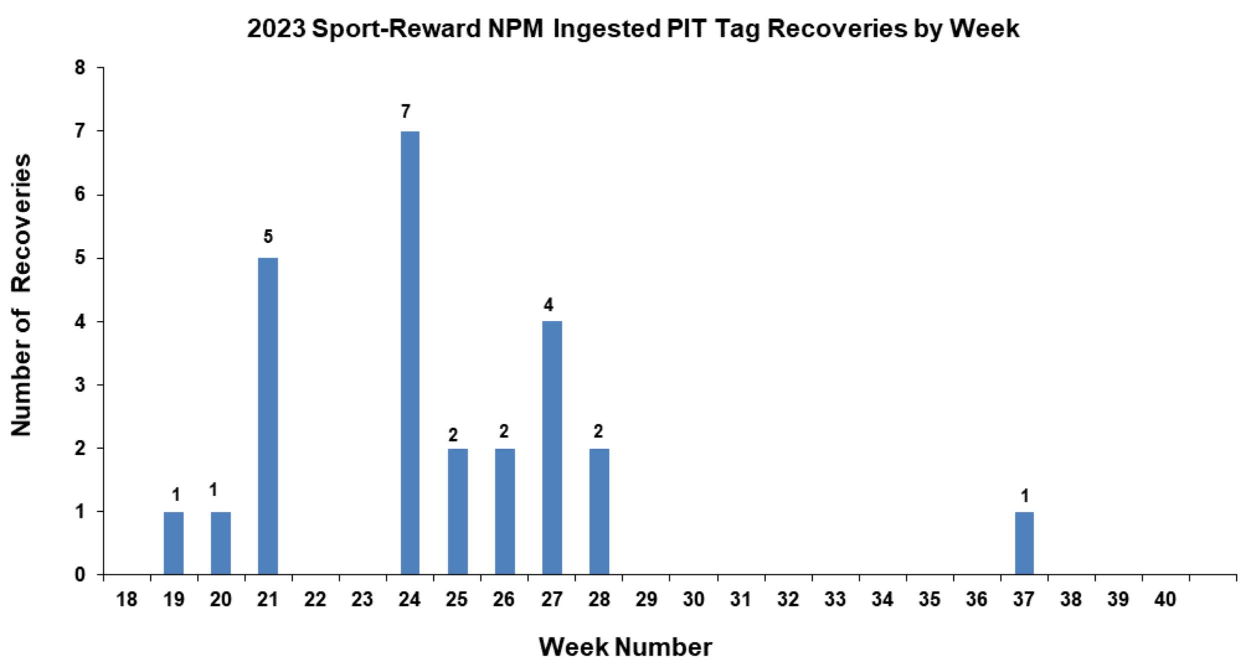


Figure 26. 2023 NPSRF ingested PIT Tag recoveries by week

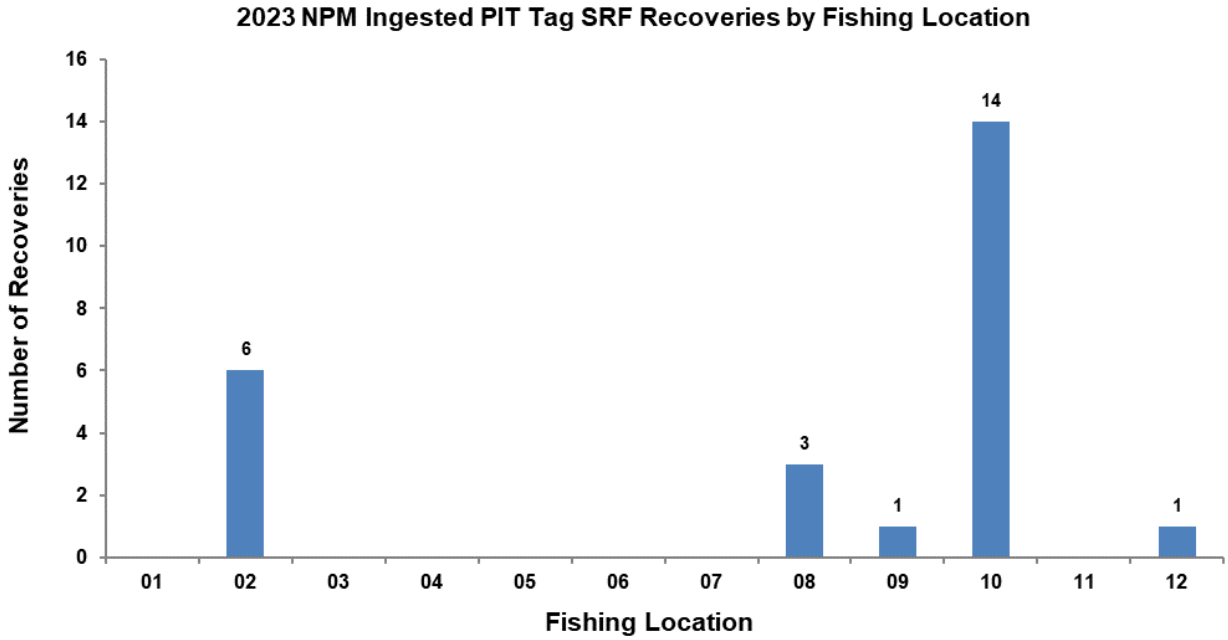


Figure 27. 2023 NPSRF ingested PIT Tag recoveries by fishing location*
*Fishing Location Codes – **Columbia River**; 01 = Below Bonneville Dam, 02 = Bonneville Reservoir, 03 = The Dalles Reservoir, 04 = John Day Reservoir, 05 = McNary Dam to the mouth of the Snake River, 06 = Mouth of the Snake River to Priest Rapids Dam. **Snake River**; 07 = Mouth of the Snake River to Ice Harbor Dam, 08 = Ice Harbor Reservoir, 09 = Lower Monumental Reservoir, 10 = Little Goose Reservoir, 11 = Lower Granite Dam to the mouth of the Clearwater River, 12 = Mouth of the Clearwater River to Hells Canyon Dam.

Species composition of PIT tagged smolts ingested by Northern Pikeminnow harvested in the 2023 NPSRF was obtained from PTAGIS and showed that most recoveries occurred in June and that 20 of the 25 ingested PIT tag recoveries (80%) were from Chinook smolts (Figure 28). All of the 20 Chinook smolts PIT tags indicated that the smolts were of hatchery origin. PTAGIS queries further revealed that the hatchery Chinook PIT tag recoveries consisted of 13 Fall Chinook, 5 Spring Chinook, 2 Summer Chinook. Finally, PTAGIS queries revealed that the other 5 ingested PIT tag recoveries consisted of 3 hatchery summer Sockeye, 1 hatchery Coho, and 1 Pacific Lamprey PIT tag recovery.

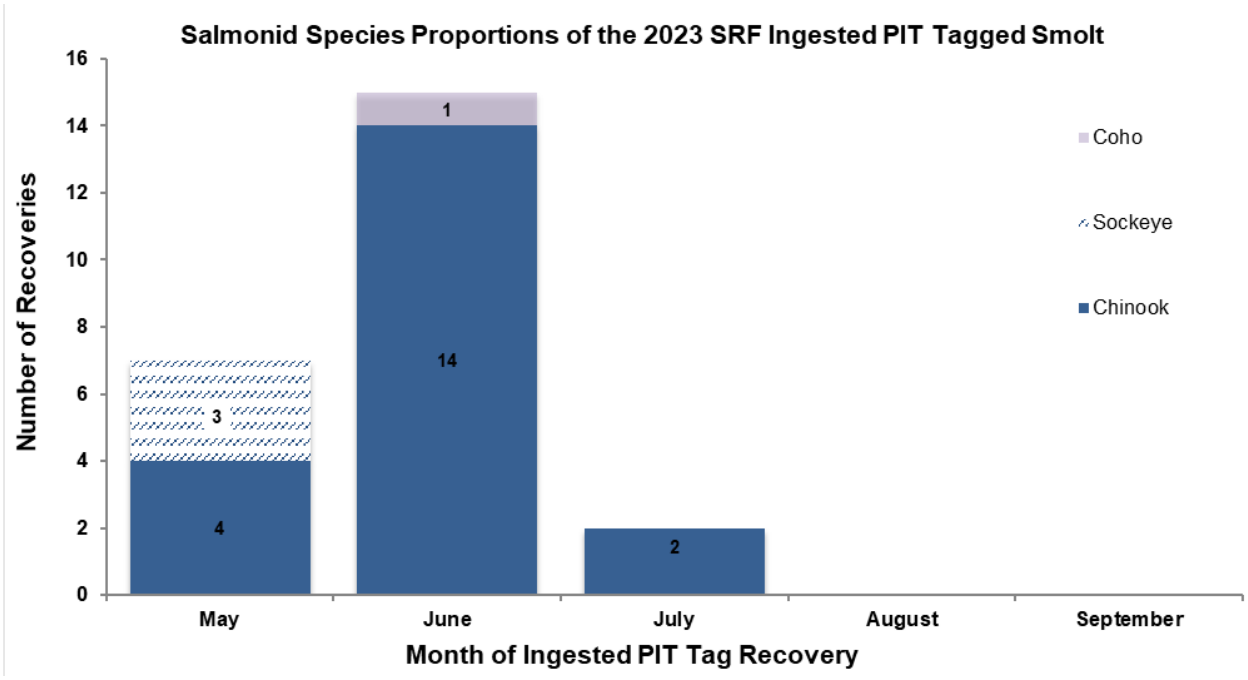


Figure 28. Recoveries of ingested Salmonid PIT Tags from the 2023 NPSRF

Analysis of PIT tag recovery data from the 2023 NPSRF continues to document actual Northern Pikeminnow predation on downstream migrating juvenile salmonids (and lamprey) and may help to 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 and juvenile lamprey to predation while migrating through the Columbia River System.

SUMMARY

- The 2023 NPSRF season resulted in a significant improvement in harvest from the previous two seasons which had marked the lowest harvest points in the program's 30+ year history. It also saw an increase in angler effort, likely due to more favorable river conditions which improved 2023 angler success (although also partially due to the addition of electronic registration via the new phone App). CPUE was near the highest in NPSRF history, although angler CPUE increased at only the top tier level (T3) compared to 2022.

- While total 2023 NPSRF harvest was below 1991-2022 average annual harvest (169,867), it was above the 2022 harvest level and very nearly met (estimated at 9.2%) the NPMP's 10-20% exploitation goal as it had for every year since 1997. NPSRF harvest in 2023 continued an upward trend of the past two years and was 70,000 more fish higher than 2021 harvest (which was the lowest in NPSRF history).

- With the 12,040 angler days recorded by Pikeminnow anglers in 2023, the NPSRF has now accumulated more than **1 million angler days** (1,002,249) of effort since the NPSRF's inception in 1991. Annual angler effort in 2023 increased by 1,479 angler days from 2022 while the number of individual anglers increased by 378 anglers.

- CPUE decreased slightly from 13.27 in 2022 to 13.00 in 2023 (Werlau et al. 2023). Peak weekly harvest occurred during week 20 (May 15th-21st), rather than during the peak of the spawn which is typically in week 26. The Boyer Park registration station was the NPSRF's top station for harvest in 2023 (26,051 fish) as well as the station with the most angler effort with 1,750 angler days of effort spent.

- We recovered only 14 Northern Pikeminnow with external spaghetti or Floy tags in 2023 as ODFW did not use external tags in 2023, exclusively using PIT tags to estimate NPMP biological exploitation. We recovered an additional 71 Northern Pikeminnow which had no external tags but retained ODFW PIT tags (formerly "tag-loss"). Mean fork length for Northern Pikeminnow harvested in the 2023 NPSRF was 263 mm, the same as in 2022. Incidental catch consisted primarily of Peamouth, Smallmouth Bass, and Sculpin, reflecting a similar pattern seen in past NPSRF seasons, and no salmonids were caught by surveyed non-returning anglers.

- 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 decreased to 1:6,261 compared to 1:6,092 in 2022, and species composition of the 25 ingested PIT tags recovered from harvested Northern Pikeminnow continued to indicate that most (20) were from Chinook smolts of hatchery origin. There were also 3 hatchery Sockeye, 1 hatchery coho, and 1 Pacific Lamprey recorded according to PTAGIS.

RECOMMENDATIONS

1.) Continue to evaluate the use of adjusting season dates (typically May 1st-Sept 30th) for implementation of the 2024 NPSRF in order to provide additional angler opportunities for NPSRF angler participation. Consider reinstituting and evaluating use of 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.

a) Early opening stations (as the NPSRF did in the 1990's) may enhance Northern Pikeminnow harvest opportunities, increase program efficiency, and improve exploitation estimates for some areas by operating the SRF during earlier dates when exploitable numbers of predatory Northern Pikeminnow may be more available to anglers.
b) Continue to evaluate efficiencies of closing stations prior to September 30th or reducing late season station hours if low harvest or participation warrants.

2.) Continue to use, develop, and expand the use of the smart phone App and related electronic data collection options. Development of the ability to electronically collect angler exit interviews, catch data and biological data should be tied to existing electronic angler registrations from the phone App, along with ability to electronically capture PIT tag data.

3.) Continue to implement and evaluate angler incentives such as the $6 base reward level used in 2023 as an incentive designed to recruit new anglers to the 2024 NPSRF. Continue to utilize the standard Tier levels used in 2023 which were designed to incentivize current, proficient, knowledgeable anglers to expend additional effort participating in the 2024 NPSRF.

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

5.) Continue to develop video content for use in improving angler education, NPMP awareness using Facebook, Instagram and other online/ social media as a means to maintain or increase NPM harvest.

6.) Review NPSRF Rules of participation as needed, adjusting to the dynamics of the fishery (especially related to new phone app angler registration) and fishery participants in order to maintain NPSRF integrity.

7.) Continue to scan all Northern Pikeminnow for PIT tags from ingested juvenile salmonids, from Northern Pikeminnow tagged by ODFW as part of the biological evaluation of the NPMP, and as a way to deter fraud by identifying PIT tagged Northern Pikeminnow coming from outside NPSRF boundaries. Investigate the feasibility of using PIT tag scanners to communicate with Ipad type devices (used for phone App) for data collection.

8.) Continue to evaluate and expand the use Floy or Spaghetti type tags as external promotional tags deployed by WDFW on Northern Pikeminnow as an angler incentive.

9.) 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

2023 Annual Report

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March 2024

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.*

In 2023, there was no early startup or season extension and there were no late season increases to the dollar amount paid for eligible Northern Pikeminnow or verified tagged fish. All vouchers issued from May 1 through September 30, 2023 were paid at $6, $8 and $10 per fish for the three payment tiers (1-25 fish, 26-200 fish and 201-up). The rewards for tagged fish were $200 per fish with a PIT tag only and $500 per fish with an external tag.

A total of 155,350 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 $1,467,770.

A combined total of 14 tagged fish (having an external spaghetti or floy tag) were paid in 2023. The season total paid for tag rewards was $7,000.

A total of 71 tag-loss fish (external tag missing but still possessing a verifiable PIT tag or PIT tag only as of 2022) were paid a *bonus* reward of $200. The season total paid for tag-loss *bonus* was $14,200.

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 1,175 separate anglers registered to fish, of which 484 (38%) caught one or more fish and received payments during the season. The total value for all 155,364 Northern Pikeminnow submitted for payment in 2023 (including all coupons, tagged fish and tag-loss *bonus* payments) was $1,493,020.

INTRODUCTION

The **Northern Pikeminnow Sport Reward Program** was again administered by PSMFC in 2023. 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, externally tagged fish for promotional purposes 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 2023 SEASON

The 2023 Northern Pikeminnow Sport-Reward Fishery started May 1 and ran through September 30. The season was characterized by average catch, below average effort and above average catch per unit effort. Of the 156,513 pikeminnow vouchered, 155,364 (99.3%) were successfully submitted for payment (Table 1). There were 7,778 (5.0%) vouchered fish paid at the Tier 1 level, 27,309 vouchered fish were paid at the Tier 2 level and 120,263 vouchered fish were paid at Tier 3. Anglers that obtained Tier 2 status by the end of the season harvested 10,084 (6.5%) of the total paid. Anglers that obtained Tier 3 status by the end of the season harvested 143,675 (92.5%) of the total paid.

PSMFC distributed $1,493,020 (87.1%) of the $1,714,661 Sport-Reward fund to anglers participating in the program. Of the funds distributed, $46,668 (3.1%) were paid at the Tier 1 rate ($6/fish), $218,472 (14.6%) at Tier 2 ($8/fish) and $1,202,630 (80.6%) at Tier 3 ($10/fish) for successful submission of a standard voucher. Another $25,250 (1.7%) in Sport-Reward funds were paid out for tag vouchers, tag loss fish and one-time bonus coupons.

Table 1. Total number of Northern Pikeminnow vouchered and rewarded by tier group in 2023.

	Angler Catch					
	Tier 1 ($6)	Tier 2 ($8)	Tier 3 ($10)	Incentives	Payout (% of Total)	Total
Northern Pikeminnow	7,778	27,309	120,263	14	155,364 (99.3%)	156,513
Rewards	$46,668	$218,472	$1,202,630	$25,250	$1,493,020 (87.1%)	$1,714,661

Four hundred eighty-four anglers successfully submitted vouchers for payment by the November 15 deadline. Out of the 237 (49%) Tier 1 anglers paid, 183 caught ten or less pikeminnow (Figure 1). One hundred thirty (27%) anglers paid achieved Tier 2 status by the end of the season and 117 (24%) achieved Tier 3 status by the end of the season. The top 20 anglers caught 80,103 (52%) of all pikeminnow paid and earned $802,690 (53.8%) of the total funds disbursed.

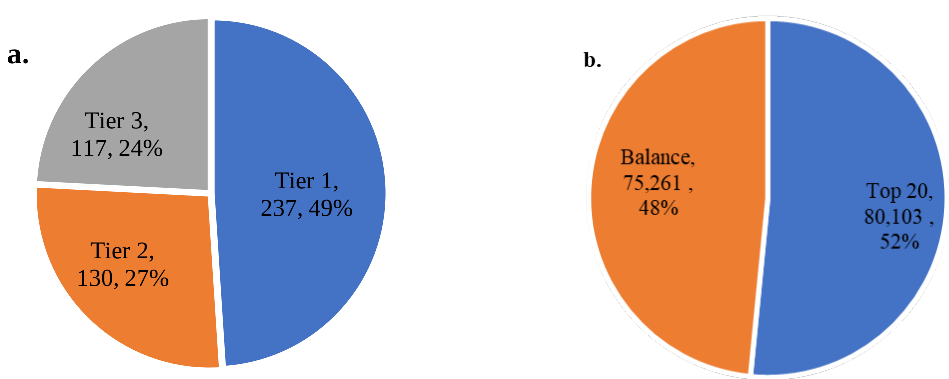


Figure 1. Number and percent of anglers with successful voucher submissions by tier level (a) and number and percent of vouchered fish successfully submitted by the Top 20 anglers versus the balance (b).

PARTICIPATION AND PAYMENT

A total of 574 anglers who registered were successful in catching one or more fish in 2023. Of those anglers; 484 caught one or more fish, submitted their voucher before the payment deadline (with no unresolved issues preventing payment) and received payment during the season.

In 2023 a total of 156,505 fish were harvested in the sport-reward fishery. Of this total, 155,364 (99%) fish were submitted for payment and paid preceding the 2023 payment deadline. To obtain payment, vouchers must have been received no later than November 15, 2023. 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, 2023 became null and void.

TAGGED FISH AND PAYMENTS

Registered anglers caught and submitted a total of 14 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 $7,000.

TAG-LOSS BONUS PAYMENT

Prior to 2022, all tagged Northern Pikeminnow initially had 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 $6, $8, and $10 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 $200 *bonus* check and congratulatory letter which included the tagging date and approximate area of release. As of 2022, ODFW began a PIT tag only protocol. These PIT tag only fish were paid at the same bonus rate as tag-loss fish. In 2023, a total of 71 tag-loss fish qualified for and were paid the *bonus* reward of $200. The season total paid for tag-loss *bonus* was $14,200.

ONE-TIME $10 BONUS COUPON

Leading up to the start of the season, "coupon" postcards were mailed to anglers in the pikeminnow database who participated in the program within the past 5 years (2018 – 2022) and to those who signed up for our mailing list at the various sportsmen's shows. The 2023 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.

Table 2. Incentives received and processed by category in 2023.

	External Tags	PIT Tags	Coupons	Total
Value	$500	$200	$10	
Submitted Incentives	14	71	405	490
Total	$7,000	$14,200	$4,050	$25,250

TOTAL ACCOUNTING

Total payments for the season of regular vouchers, *$10 bonus coupons,* tag vouchers and *tag-loss bonus* payments were $1,493,020.

All IRS Form 1099-NEC Statements were sent to the qualifying anglers for tax purposes on February 16, 2024. Appropriate reports and copies were provided to the IRS on January 13, 2024.

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.

Table 3. 2023 Sport-Reward Payment Summary.

2023 SPORT REWARD PAYMENTS SUMMARY

The following is a summary of all vouchers received and paid in 2023

	Fish	Incentives	Reward
Fish paid @ tier 1 ($6 each):	7,778	0	$46,668
Fish paid @ tier 2 ($8 each):	27,309	0	$218,472
Fish paid @ tier 3 ($10 each):	120,263	0	$1,202,630
Tags paid (@ $500 each):	14	0	$7,000
Coupons issued (@ $10 each):	0	405	$4,050
Tag-loss issued (@ $200 each):	0	71	$14,200
Total:	155,364		$1,493,020

Anglers @ tier 1	*237*
Anglers @ tier 2	*130*
Anglers @ tier 3	*117*
Number of separate anglers	*484*

Anglers with 10 fish or less:	*183*
Anglers with 2 fish or less:	*88*

	Total Fish	$500 Tags	Tag Loss	Coup.	Total Reward
1.	10,755	1	$ 200	$ 10	$ 107,800
2.	9,786	1	$ 1,200	$ 10	$ 99,110
3.	6,237	0	$ 600	$ 10	$ 62,530
4.	5,734	0	$ 400	$ -	$ 57,290
5.	4,758	0	$ 200	$ 10	$ 47,340
6.	4,681	1	$ -	$ 10	$ 46,860
7.	4,149	0	$ 200	$ 10	$ 41,250
8.	3,686	1	$ 600	$ 10	$ 37,510
9.	3,585	0	$ -	$ 10	$ 35,410
10.	3,012	3	$ 600	$ 10	$ 31,750
11.	2,947	0	$ 400	$ 10	$ 29,430
12.	2,931	0	$ -	$ -	$ 28,860
13.	2,762	1	$ -	$ 10	$ 27,670
14.	2,616	1	$ 200	$ 10	$ 26,410
15.	2,453	0	$ -	$ 10	$ 24,090
16.	2,345	0	$ -	$ -	$ 23,000
17.	2,112	0	$ 400	$ -	$ 21,070
18.	1,942	1	$ 200	$ 10	$ 19,670
19.	1,809	0	$ 200	$ 10	$ 17,850
20.	1,803	0	$ 200	$ 10	$ 17,790
	80,103	10	$ 5,600	$ 160	$ 802,690

NORTHERN PIKEMINNOW
SPORT-REWARD FISHERY VOUCHER

2023 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 - By providing your email, you are agreeing to receive email communications from the Sport-Reward Program)

@

MONTH | DAY | 2 0 2 3 | DOCUMENT # | STATION

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

(NUMBER) X (WRITTEN TOTAL)

LAST 4 DIGITS SS# –

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

X **TECHNICIAN SIGNATURE**

X **SIGN HERE**

ANGLER SIGNATURE (Must be signed in the presence of Technician) | **DATE** | **STATION**

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

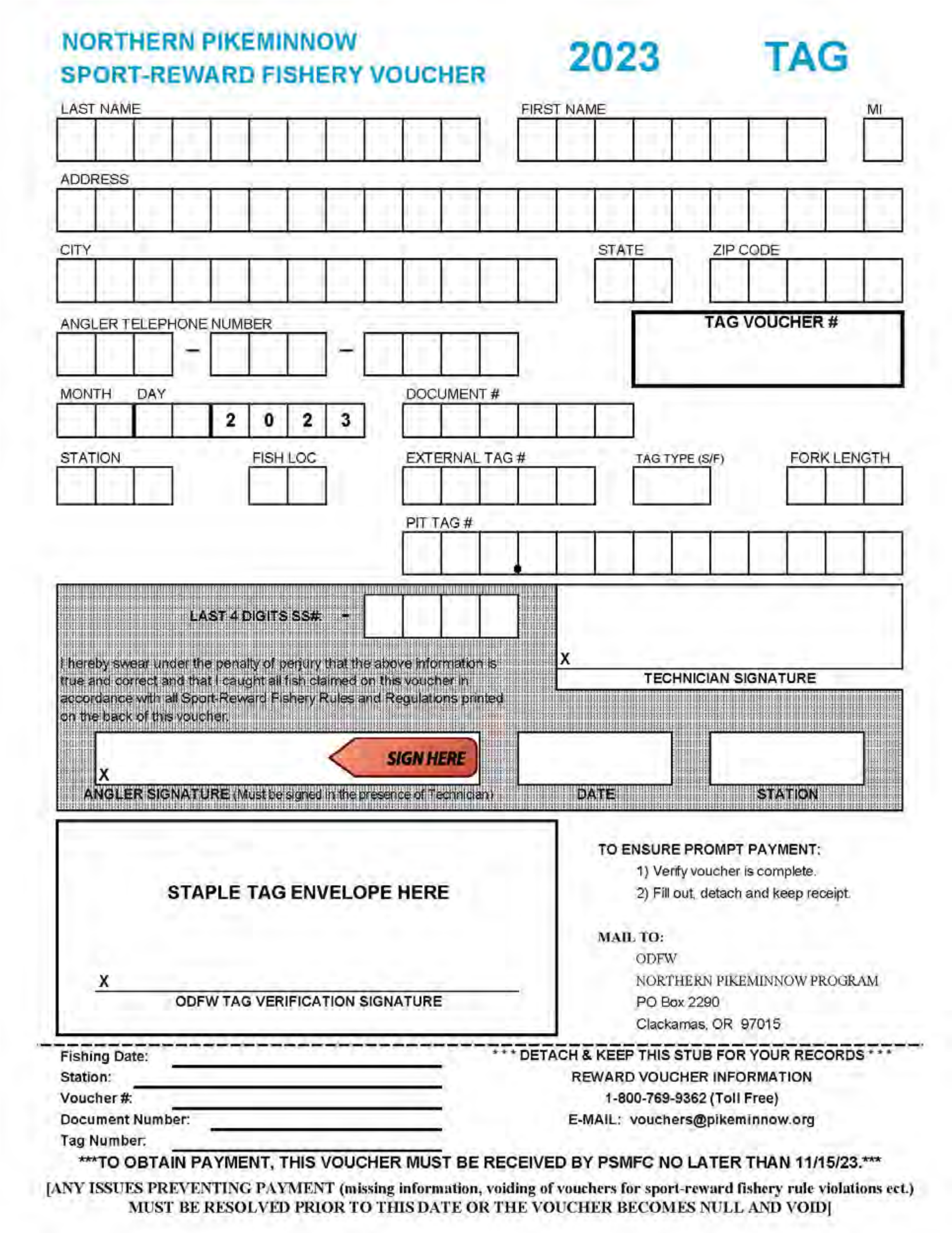
* * * DETACH & KEEP THIS STUB FOR YOUR RECORDS * * *

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 11/15/23.*****

[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]

Figure 2. 2023 Northern Pikeminnow Sport-Reward Fishery Standard Voucher.



NORTHERN PIKEMINNOW
SPORT-REWARD FISHERY VOUCHER
2023 TAG

LAST NAME
FIRST NAME
MI
ADDRESS
CITY
STATE
ZIP CODE
ANGLER TELEPHONE NUMBER
TAG VOUCHER #
MONTH DAY 2 0 2 3
DOCUMENT #
STATION
FISH LOC
EXTERNAL TAG #
TAG TYPE (S/F)
FORK LENGTH
PIT TAG #
LAST 4 DIGITS SS#:
X
TECHNICIAN SIGNATURE
I hereby swear under the penalty of perjury that the above information is true and correct and that I caught all fish claimed on this voucher in accordance with all Sport-Reward Fishery Rules and Regulations printed on the back of this voucher.
SIGN HERE
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 11/15/23.
[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]

Figure 3. 2023 Northern Pikeminnow Sport-Reward Fishery Tag Voucher.

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, 2023. Any issues preventing payment (missing information, voiding of voucher for program violations, etc.) must be resolved by Nov. 15, 2023 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.

Figure 4. Northern Pikeminnow Sport-Reward Fisher Rules and Regulations.

Report C

System-wide Predator Control Program: Fisheries and Biological Evaluation

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ABSTRACT

Since 1990, the Northern Pikeminnow Management Program (NPMP) has applied targeted 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 2023, 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 by Northern Pikeminnow; 2) characterize population parameters of Northern Pikeminnow, Smallmouth Bass (Micropterus dolomieu), and Walleye (Sander vitreus) in the area below Bonneville Dam, Bonneville Reservoir, and the lower four Snake River reservoirs, and 3) assess evidence of possible intra- and inter-specific compensatory responses by Northern Pikeminnow, Smallmouth Bass, and Walleye related to the sustained removal of Northern Pikeminnow from the lower Columbia and Snake rivers. To quantify exploitation during 2023, a Brownie bird band mark/recovery model was used in tandem with ODFW marking and Washington Department of Fish and Wildlife (WDFW) Sport Reward Fishery (SRF) recovery data, 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 2023 was 9.2% (lower - upper confidence limit, 6.6 – 13.0%). Based on this level of exploitation, modeled results predict that predation by Northern Pikeminnow in 2024 will be reduced by 28% (range: 10–42%), relative to pre-program levels. These metrics suggest that NPMP continues to be successful to reduce predation on juvenile salmonids by Northern Pikeminnow. Fisheries independent biological evaluation was conducted during spring in the area below Bonneville Dam, Bonneville Reservoir, Ice Harbor Reservoir, Lower Monumental Reservoir, Little Goose Reservoir, and Lower Granite Reservoir, to generate additional information about trends in the indices of abundance, consumption, and predation for Northern Pikeminnow and Smallmouth Bass. An index of abundance was also estimated for Walleye. These indices showed variable patterns during the 33-year time series of the data with some decreasing trends for Northern Pikeminnow and increasing trends for Smallmouth Bass and Walleye in several areas. Substantial increases in the index of abundance for Walleye in the Snake River in 2023 coincides with evidence of expansion upstream in that river system. NPMP continued to effectively restructure the Northern Pikeminnow population to reduce predation on out-migrating salmonids by more than 25%. Fisheries independent data provided a means to assess long-term trends in population structure and potential compensatory responses among Northern Pikeminnow, Smallmouth Bass, and Walleye. This information provides the region with an important piscine predation reduction tool as well as fisheries management relevant information about three piscine predators to out-migrating juvenile salmonids.

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 multiple factors, including habitat degradation and overexploitation (Nehlsen et al. 1991; Wismar et al. 1994), and 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 upper reaches of the reservoir were 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) the 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 the John Day Reservoir provided evidence that 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 the 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. Management strategies aimed at decreasing predation on juvenile salmonids were examined, according to 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 NPMP.

From its inception, 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 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 estimates Northern Pikeminnow exploitation from SRF and DAF, salmonid predation reduction, and curation of long-term data to assess piscine 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 mark Northern Pikeminnow to incentivize the SRF and inform a mark/recovery-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 monitoring). Laboratory techniques were applied 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.

ODFW biological monitoring efforts deviated from the historical pattern during the 2023 season. Historically, the monitoring area has been divided into sub-units (below Bonneville Dam/Bonneville Reservoir, The Dalles Reservoir/John Day Reservoir, and the Snake River reservoirs from Ice Harbor to above Lower Granite Dam). Since 2005, ODFW has collected biological monitoring data from one river sub-unit on a three-year rotating cycle. However, due to the coronavirus pandemic in 2020, the Snake River sub-unit was sampled one year later than the historical three-year sampling frequency in 2023. Additionally, in 2023 we implemented biological monitoring in two sub-units; the area below Bonneville Dam/Bonneville Reservoir and the Snake River sub-unit. This was done to opportunistically expand the sampling frequency in the area below Bonneville Dam and Bonneville Reservoir allowing for further assessment of Northwest Power and Conservation Council Independent Scientific Review Panel (ISRP) recommendation regarding the metrics used to monitor Northern Pikeminnow, Smallmouth Bass, and Walleye.

NPMP received ISRP recommendations in 2019, as part of the five-year cycle to assess the scientific validity of Bonneville Power Administration (BPA) funded projects. Through this process, ISRP provided a number of recommendations for NPMP to address with respect to the biological monitoring and evaluation component. Field, laboratory, and analytical approaches were implemented by NPMP to address those recommendations. For recommendations that showed promise for implementation into NPMP, the data and analyses were incorporated into the results and Appendices A and B. Specifically, NPMP assessed updated mark/recovery models to calculate SRF exploitation, bioenergetics models to estimate consumption of juvenile salmonids by piscine predators, and the potential to improve estimates of predation using information available from PIT and CWT juvenile salmonids predated upon by Northern Pikeminnow, Smallmouth Bass, and Walleye.

This report augments historical information with data collected in 2023 from areas of the Columbia and Snake rivers and evaluates spatiotemporal changes of fish population parameters and their relation to reductions in juvenile salmonid predation from SRF and DAF activities where possible. Specific goals for this reporting period were to:

(1) Estimate rates of exploitation of Northern Pikeminnow and quantify potential predation reduction resulting from the targeted removal fisheries;
(2) Characterize population parameters of Northern Pikeminnow, Smallmouth Bass, and Walleye in the area below Bonneville Dam, Bonneville Reservoir, Ice Harbor Reservoir, Lower Monumental Reservoir, Little Goose Reservoir, and Lower Granite Reservoir.
(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.
(4) Assess ISRP recommendations to improve biological monitoring and evaluation related to NPMP.

METHODS

Sport Reward Fishery Evaluation and Predation Reduction Estimates

Field Procedures

Boat electrofishing to mark Northern Pikeminnow used for estimates of exploitation and predation reduction to juvenile salmonids described below was paused for the 2023 field season. However, Northern Pikeminnow marked prior to 2023 were used to assess a new analytical method to estimate exploitation. Therefore, the field marking methods were reported here.

Boat electrofishing was used to collect and tag (mark) Northern Pikeminnow in the Columbia River from river kilometer (rkm) 76 (near Clatskanie, Oregon) upstream to rkm 637 (Priest Rapids Dam), and in the Snake River from Little Goose Dam to rkm 251 (near Asotin, WA) upstream of Lower Granite Dam (Fig. 1). Sampling consisted of four individual sessions (runs) of 900s electrofishing within each 1.61 river kilometer. ODFW researchers conducted marking efforts 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. Two boom arms extend forward from the bow of each boat, each supporting an array of six electrodes that functions as an anode. Electrodes hanging from the boat and the hull itself, 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. These protocols included, but were not limited to, discontinuing electric current when encountering listed species, or terminating sampling transects when encountering 500 or more out-migrating juvenile salmonids or 50 adult salmonids.

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 generally ranged from early April to mid-June 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. When weather or other reasons required, sampling was strategically adjusted to eliminate sampling areas with historically low rates of mark deployment. The most recent full scale marking events occurred in 2022 for the area below Bonneville Dam, along with Bonneville, McNary, Little Goose and Lower Granite reservoirs. ODFW discontinued marking efforts in John Day Reservoir following the 2019 season and in The Dalles Reservoir following the 2021 season due to continued declines in electrofishing catch. These declines made it infeasible to continue fishery evaluation marking because of time and budget constraints.

Northern Pikeminnow ≥ 200 mm fork length (FL) were marked with an internal 134.2 MHz passive integrated transponder (PIT) tag injected into the dorsal sinus cavity (Fig. 2). In 2022, ODFW initiated a PIT tag only marking strategy in which Northern Pikeminnow were not marked externally. This strategy was deployed in an effort to increase survival of marked fish and increase our recapture rate through increased tag retention and fish survival.

Working with WDFW, tag recovery information was obtained from the SRF and DAF (Report D). The SRF occurred daily from 1 May to 30 September 2023 (Report A). Participating anglers received payment for all harvested Northern Pikeminnow ≥230 mm (9 in) total length (TL). This size criterion for TL corresponds to the minimum FL (200 mm) of Northern Pikeminnow marked. The 2023 reward payment schedule consisted of three tiers (see Report B for details). Further, anglers were eligible for a $500 reward for each externally marked fish returned to a check station and a $200 reward for each "tag-loss" fish (i.e., 2022 PIT tag only fish or fish marked prior to 2022 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 31 May to 10 October 2023 (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. Marked Northern Pikeminnow removed during DAF were accounted for when estimating exploitation rates for SRF.

Data Analysis

Sport Reward Fishery Exploitation

Exploitation has historically been calculated using within year estimates based on Lincoln-Peterson derived mark-recovery models. These models rely on tags (marks) being deployed before or during the early stages of SRF. Recovery data were reported for same-year marks through fish returned by anglers to NPMP creel stations operated by WDFW. Marking was not conducted during the 2023 season due to limited resources. Instead, a multi-year mark-recovery model was assessed that incorporated a Brownie bird band framework (Brownie, 1978). This allowed exploitation to be estimated for 2023 using tags deployed in previous years. Exploitation was estimated using a Brownie bird band model structure in the program Mark (White and Burnham, 1999) within the package RMark (Laake, 2013) via the R statistical analysis framework (R Core Team, 2021). The Brownie bird band model produces the probability of survival between marking periods (years) and the probability of recovery (exploitation) using mark-recovery data where marks were deployed through electrofishing activities (ODFW) and recoveries were obtained through creel stations with SRF (WDFW). Because NPMP had numerous years of mark-recovery data, a model was fit using variable survival and recovery, year to year. Due to the lack of marking in 2023, the probability of survival from 2022 – 2023 was estimated using the 10-year average survival from 2012 – 2022. The proportion of the

Northern Pikeminnow population removed during program fisheries was quantified using mark-recovery data for the entire area covered by SRF (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 two size-classes: 1) ≥ 200 mm FL (all marked fish); and 2) ≥ 250 mm FL. The subset of fish ≥ 250 mm FL was used for long-term temporal comparisons.

Predation Reduction

Indirect measures of predation reduction were used 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 implemented to estimate changes in predation on juvenile salmon that have occurred since before the onset of the program. The model was designed to estimate the effects of the NPMP on predation of juvenile salmonids if all other factors were held constant (e.g., river and ocean conditions, number of migrating juvenile salmonids, passage conditions/mortality at dams). The model also assumed no compensation by non-native predators and remaining Northern Pikeminnow. That assumption was 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. Historically, area specific exploitation rates were calculated using within year estimates based on Lincoln-Peterson derived mark/recovery models for the area below Bonneville Reservoir, the pooled Columbia River reservoirs and the pooled Snake River reservoirs. In 2023, as previously mentioned, one system-wide exploitation rate was calculated using a Brownie bird band model structure. The 2023 Predation Reduction model assumes this system-wide exploitation rate is representative of these three individual areas. 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. A 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 1:

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

where

A_{h+j} = abundance index for size-h 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 (2) was converted to consumption rates:

$$C = -0.077 + 0.618(CI) \qquad (2)$$

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, 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 (not calculated for 2023), biological evaluation, and from DAF. Models describing PSD for Walleye and Smallmouth Bass populations sampled during biological evaluation; were applied using the equation 3:

$$PSD_i = 100 \times \frac{FQ_i}{FS_i}, \quad (3)$$

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 DAF and biological evaluation using equation 4:

$$PSD - P_i = 100 \times \frac{FP_i}{FS_i}, \quad (4)$$

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. 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 5:

$$W_r = 100 \times \frac{W}{W_s}, \tag{5}$$

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 fish 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. 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 using the model of Ward et al. (1995) for Northern Pikeminnow (CI_{NPM}) using the equation 6:

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

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 Monitoring

Field Procedures

Standardized boat electrofishing techniques were used to evaluate Northern Pikeminnow, Smallmouth Bass, and Walleye population parameters in the area below Bonneville Dam, Bonneville Reservoir, Ice Harbor Reservoir, Lower Monumental Reservoir, Little Goose Reservoir, and Lower Granite Reservoir during 2023 (Ward et al. 1995; Zimmerman and Ward 1999). Sampling was conducted in the early morning (0200–1000 hours) during Spring (23 April – 2 June 2023) in the forebay, mid-reservoir, and tailrace of all reservoirs, except Lower Granite Reservoir and the area below Bonneville Dam. Sampling areas in Lower Granite Reservoir included the shoreline areas adjacent to Clarkston, Washington and Lewiston, Idaho, approximately 56 rkm upstream of Lower Granite Dam, near the confluence of the Snake and Clearwater rivers. Sampling areas below Bonneville Dam included the tailrace area below the dam, and three separate areas near Troutdale, OR (rkm 188–194), Portland, OR (rkm 173–181) and Kalama, WA (rkm 116–121). 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 marked were euthanized 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 2023 DAF in Bonneville and The Dalles reservoirs. Diets were collected from a representative subsample of catches at each dam weekly from 31 May– 10 October, 2023, 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.

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 lower Snake reservoirs, a random subsample of diets was selected and analyzed for the mid and tailrace sections of Lower Monumental Reservoir, the forebay section of Little Goose Reservoir and the upper section of Lower Granite Reservoir. Gut contents were subsampled so that the proportion analyzed were based on initial catch distribution by area. All diet samples in 2023 were scanned for the presence of Coded Wire Tags (CWT). Positive CWT detections were analyzed as per methodology described in Appendix A of this report and excluded from consumption calculations. When subsampling occurred, CWT positive diet samples were replaced with diets from a Smallmouth Bass from the same area and size class. All Northern Pikeminnow and Walleye gut contents collected in the field, excluding positive CWT detections, during 2023 were processed in the laboratory as described below.

Frozen field samples were thawed in the laboratory and the diet contents were sorted 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 tissue. 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 taxon 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 only 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. A similar assumption was made for instances where lamina of lampreys (family Petromyzontidae) were present in diet samples. Diet samples containing large numbers of juvenile shad bones were sampled to estimate the total number of shad using a subset of the diagnostic bones. The dentaries and parasphenoid bones were used as rapid identification diagnostic bones, allowing staff to process these samples in a fraction of the time needed for full diagnostic bone enumeration. Shad quantified in this way were identified in our database and the complete sample of bones was stored for future enumeration, should the need arise.

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 artificially 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

<u>Biological Monitoring Abundance Index (AI)</u>

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 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 7:

$$AI_i = \frac{(D_i \times S_i)}{1{,}000}, \tag{7}$$

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 Monitoring 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 6 and 8:

$$CI_{\mathrm{SMB}} = 0.0407 \times e^{(0.15)(T)} \times W^{0.23} \times (S \times GW^{-0.29}), \qquad (8)$$

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 Monitoring 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 9:

$$PI_i = AI_i \times CI_i, \qquad (9)$$

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 3.

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 4.

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 (5).

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”. Data that were normally distributed were tested for differences in mean PSD between early and late periods for each DAF location using ANOVA. A non-parametric Mann-Whitney U test was used to compare PSD values between early and late years for each reservoir when PSD data were not normally distributed. 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

Sport Reward Fishery Exploitation

The system-wide exploitation rate for Northern Pikeminnow ≥ 250 mm FL during the Sport Reward Fishery was estimated at 9.2% (lower - upper confidence limit, 6.6 – 13.0%). This estimate was nearly within the targeted exploitation range of 10-20% and the upper confidence interval was within the target exploitation range. System-wide exploitation of Northern Pikeminnow ≥ 200 mm FL was estimated at 12.4% (lower - upper confidence limit, 9.6 – 16.0%).

In 2022, the last year that we conducted fishery evaluation marking, the system-wide exploitation rate for Northern Pikeminnow ≥ 250 mm FL during the Sport Reward Fishery was estimated at 14.9% (95% confidence interval ±5.9%). This estimate was within the targeted exploitation range of 10-20% (Fig. 3).

Sport Reward Fishery Predation Reduction

The model-estimated median reduction of predation on juvenile salmonids by Northern Pikeminnow relative to pre-program levels for 2023 for 2024 will be 28% (range: 10–42%; 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 2027 with an estimated median reduction near 31% (Fig. 4).

Dam Angling Fishery

During the 2023 DAF season, 584 Northern Pikeminnow diet samples were processed from fish harvested at the angler accessible areas in the powerhouse turbine outflow areas (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 240-583 mm FL. In Bonneville Reservoir, the most prevalent diet item was fish while in The Dalles it was invertebrates, other than crayfish, followed by fish (Table 1). The proportion of salmonids in the diets of Northern Pikeminnow caught in the powerhouse tailrace areas of Bonneville Dam and The Dalles Dam in 2023 was relatively small (1%) while the proportion of American Shad was higher (7 – 20%).

There were consistent weekly trends in diet prey item composition for Northern Pikeminnow caught during DAF in Bonneville Reservoir and The Dalles Reservoir with lamprey, salmonids, and other fish being present in the first few weeks of DAF which transitioned to a diet composed primarily of American Shad around statistical week 31 (Fig. 5). This pattern was more distinct in Bonneville Reservoir during 2023 as there were samples obtained every week through week 37 whereas The Dalles Reservoir had a number of weeks with insufficient sample size or gaps in fishing effort throughout the season.

The 2023 weekly juvenile salmonid consumption index for Northern Pikeminnow removed during DAF in Bonneville and The Dalles reservoirs was the greatest during weeks 24 and 26, respectively. This time period corresponded with pulses of outmigration of sub-yearling Chinook salmon (Fig. 6).

PSD of Northern Pikeminnow in Bonneville Reservoir during DAF was significantly greater during the early years (1990-1996) of sampling than during the later years (2006-2023) ($F=23.02$, $P < 0.01$, Fig. 7). There was no significant difference in PSD at The Dalles Reservoir during the early years (1990-1996), relative to the later years (2007-2023) ($W = 74$, $P = 0.12$) (Fig. 7). PSD for DAF caught fish in both reservoirs has followed an upward trend since 2018.

Relative weight of female Northern Pikeminnow from DAF in Bonneville Reservoir in 2023 was 105.7%, and there was not a significant monotonic trend (Mann-Kendall $\tau = -0.16$, $P = 0.36$) (Fig. 8). Relative weight of male Northern Pikeminnow from DAF in Bonneville Reservoir in 2023 was 97.2%, and there was not a significant monotonic trend (Mann-Kendall $\tau = -0.19$, $P = 0.29$) (Fig. 8). Relative weight of female Northern Pikeminnow from DAF in The Dalles Reservoir in 2023 was 111.9%, and there was not a significant monotonic trend (Mann-Kendall $\tau = -0.01$, $P = 0.97$) (Fig. 9). Relative weight of male Northern Pikeminnow from DAF in The Dalles Reservoir in 2023 was 103.8%, and there was not a significant monotonic trend (Mann-Kendall $\tau = -0.09$, $P = 0.65$) (Fig. 9).

Biological Monitoring

Field staff conducted a total of 284 electrofishing runs during spring 2023 to collect fishes for biological monitoring in the area below Bonneville Dam/Bonneville Reservoir and the Snake River sub-unit. Due to time, budget, and ESA species constraints, total effort was reduced to only include a spring biological monitoring season. In 2023, ODFW sampled 1,187 Smallmouth Bass (62.0% of the total piscine predator catch), 368 Northern Pikeminnow (19.2% of the total piscine predator catch), and 360 Walleye (18.8% of the total piscine predator catch). The timing of our annual biological evaluation field work was planned to coincide with predicted peak juvenile salmon outmigrations. Spring sampling in the lower Snake River reservoirs in 2023 overlapped with peak yearling salmon outmigration at Lower Granite Dam (Fig. 10). Spring sampling in Bonneville Reservoir and below Bonneville Dam was slightly later than peak outmigration at Bonneville Dam (Fig. 11).

Below Bonneville Dam/Bonneville Reservoir

Diet Composition

Detailed results of the diet assessments are found in Table 2A and 2B but relevant trends are listed here. Diets were examined from 56 Northern Pikeminnow and 47 Smallmouth Bass below Bonneville Dam and from 270 Northern Pikeminnow, 253 Smallmouth Bass, and 16 Walleye in Bonneville Reservoir. Food items were present in the majority of digestive tracts assessed during biological monitoring (52% - 100%, Table 2). Fish were found in all predator species digestive tracts (14% - 81%). Salmonids were detected in the digestive tracts of all predator species (3% -

56%). Walleye in Bonneville Reservoir had the highest proportion (56%) of diets containing salmonids. Proportions of diets containing lampreys were low (0% - 6%) across all species below Bonneville dam and in Bonneville Reservoir.

<u>AI, Northern Pikeminnow</u>

Northern Pikeminnow AI showed a declining trend over the course of the 33-year timeseries in all biological monitoring sites below Bonneville Dam though the trend seemed to stabilize in 2023 (Fig. 12). Northern Pikeminnow AI in Bonneville Reservoir had a declining trend in the forebay and mid-reservoir sites while the tailrace had a stable trend over the 33-year timeseries (Fig. 13).

<u>AI, Smallmouth Bass</u>

Smallmouth Bass AI showed a declining trend over the course of the 33-year timeseries in biological monitoring sites between rkm 173 – 181 and rkm 188 – 194 below Bonneville Dam and a slight increasing trend between rkm 116 – 121 and the tailrace. All three sites showed an increase in AI from the previous biological evaluation in 2017 (Fig. 12). Smallmouth Bass AI in Bonneville Reservoir had an increasing trend over the 33-year time series in the forebay and mid-reservoir sites and a stable trend in the tailrace (Fig. 13).

<u>AI, Walleye</u>

Walleye were not detected in biological monitoring sites below Bonneville Dam in 2023 and historically have been infrequently detected in this area (Fig. 12). Walleye AI in Bonneville Reservoir was low during the 33-year time series though there were some detected in 2023 in the mid-reservoir and tailrace sites (Fig. 13).

<u>CI, Northern Pikeminnow</u>

Northern Pikeminnow CI showed mixed trends among the four biological monitoring sites below Bonneville Dam and was generally increasing in rkm 116 – 121 and the tailrace while it was flat to slightly declining in rkm 173 – 181 and rkm 188 – 194, though there was variability CI in all sites throughout the time series. CI was elevated in rkm 116 – 121 and the tailrace in 2023 and zero in the other two sites (Fig. 14). Northern Pikeminnow CI had a stable trend in Bonneville Reservoir in the forebay over the 33-year time series though CI was 0 in 2023. CI was variable in the mid-reservoir and tailrace areas with increasing trends over the 33-year time series. CI in the mid-reservoir in 2023 was well above the trend line in 2023 while CI was below the trend line in 2023 in the tailrace (Fig. 15).

<u>CI, Smallmouth Bass</u>

Smallmouth Bass CI was low in all biological monitoring sites below Bonneville Dam over the 33-year time series. However, CI was greater in 2023 than any previous year in rkm 173 – 181 (Fig. 14). Smallmouth Bass CI in Bonneville Reservoir showed an increasing trend in all three biological evaluation sites over the 33-year time series (Fig. 15).

PI, Northern Pikeminnow

Northern Pikeminnow PI was variable in the four biological monitoring sites below Bonneville Dam over the 33-year time series and showed a general increasing trend in rkm 116 – 121. Northern Pikeminnow PI was above the trendline in 2023 in rkm 116 – 121 (Fig. 16). Northern Pikeminnow PI was variable in the three biological monitoring sites in Bonneville Reservoir over the 33-year time series with a decreasing trend in the forebay and an increasing trend in the mid-reservoir and tailrace sites. Northern Pikeminnow PI was well above the trend line in the mid-reservoir site in 2023 (Fig. 17).

PI, Smallmouth Bass

Smallmouth Bass PI was low in all biological monitoring sites below Bonneville Dam during the 33-year time series. However, PI was greater in 2023 than any previous year in rkm 173 – 181 (Fig. 16). Smallmouth Bass PI showed an increasing trend in Bonneville Reservoir in all three biological monitoring sites. PI was above the trend line for the most recent three biological evaluation periods in the mid-reservoir site (Fig. 17).

PSD, Northern Pikeminnow (see Fig. 18)

Northern Pikeminnow PSD below Bonneville Dam in 2023 was 41.5%, and there was not a significant monotonic trend (Mann-Kendall $\tau = 0.24$, $P = 0.16$). Northern Pikeminnow PSD in Bonneville Reservoir was 5.8% and there was a significant decreasing monotonic trend (Mann-Kendall $\tau = -0.42$, $P = 0.03$).

PSD, Smallmouth Bass (see Fig. 19)

Smallmouth Bass PSD below Bonneville Dam in 2023 was 40.4%, and there was not a significant monotonic trend (Mann-Kendall $\tau = -0.26$, $P = 0.24$). Smallmouth Bass in Bonneville Reservoir in 2023 was 66.28%, and there was not a significant monotonic trend (Mann-Kendall $\tau = 0.33$, $P = 0.08$).

PSD-P, Smallmouth Bass (see Fig. 20)

Smallmouth Bass PSD-P Below Bonneville Dam in 2023 was 12.8%, and there was not a significant monotonic trend (Mann-Kendall $\tau = -0.23$, $P = 0.30$). Smallmouth Bass PSD-P in Bonneville Reservoir in 2023 was 24.4%, and there was a significant increasing monotonic trend (Mann-Kendall $\tau = 0.42$, $P = 0.03$).

PSD/PSD-P, Walleye

Walleye PSD and PSD-P could not be calculated Below Bonneville Dam in 2023, due to insufficient sample size (n = 0, minimum for PSD n = 20). Walleye PSD and PSD-P could not be calculated in Bonneville Reservoir in 2023, due to insufficient sample size (n = 7, minimum for PSD n = 20).

W_r, Northern Pikeminnow (see Fig. 21)

Female Northern Pikeminnow relative weight Below Bonneville Dam in 2023 was 111.6%, and there was a significant increasing monotonic trend (Mann-Kendall τ = 0.35, *P* = 0.05). Male Northern Pikeminnow relative weight Below Bonneville Dam in 2023 was 102.6%, and there was a significant increasing monotonic trend (Mann-Kendall τ = 0.55, *P* = 0.003).

W_r, Northern Pikeminnow (see Fig. 22)

Female Northern Pikeminnow relative weight in Bonneville Reservoir in 2023 was 103.9%, and there was not a significant monotonic trend (Mann-Kendall τ = -0.01, *P* = 1). Male Northern Pikeminnow relative weight Bonneville Reservoir in 2023 was 104.6%, and there was not a significant monotonic trend (Mann-Kendall τ = 0.14, *P* = 0.49).

W_r, Smallmouth Bass (see Fig. 23)

Smallmouth Bass relative weight below Bonneville Dam in 2023 was 97.4%, and there was not a significant monotonic trend (Mann-Kendall τ = -0.26, *P* = 0.20). Smallmouth Bass relative weight in Bonneville Reservoir in 2023 was 95.5%, and there was not a significant monotonic trend (Mann-Kendall τ = -0.17, *P* = 0.39).

W_r, Walleye (see Fig. 24)

Walleye relative weight could not be calculated below Bonneville Dam in 2023, due to insufficient sample size (n = 0, minimum for *Wr* = 5). However, in previous years there has been a large enough sample size (n ≥ 5) to calculate relative weight. In 2021, the last year that relative weight was able to be calculated, relative weight was 96%, and there was not a significant monotonic trend (Mann-Kendall τ = 0.27, *P* = 0.28). Walleye relative weight in Bonneville Reservoir 2023 was 89.8%, and there was not a significant monotonic trend (Mann-Kendall τ = -0.07, *P* = 0.86).

Snake River Reservoirs

Diet Composition

Detailed results of the diet assessments are found in Table 3A, 3B, 3C and 3D but relevant trends are listed here. Diets were examined from 37 Northern Pikeminnow, 404 Smallmouth Bass, and 329 Walleye from the biological monitoring sites within the four Snake River Reservoirs. Food items were present in the majority of digestive tracts assessed during biological monitoring except for the few Northern Pikeminnow from Ice Harbor Reservoir and Lower Granite Reservoir (Table 3). Salmonids were found in the diets of all three species but in varying proportions among the four reservoirs.

AI, Northern Pikeminnow

Northern Pikeminnow AI trends over the 33-year timeseries were generally stable or slightly declining in the biological monitoring sites from the four Snake River reservoirs. There were increases in Northern Pikeminnow AI above the 33 year trend line in some of the biological monitoring sites in all four Snake River reservoirs. Ice Harbor (Fig. 25), Lower Monumental (Fig. 26), Little Goose (Fig. 27), Lower Granite (Fig. 28).

<u>AI, Smallmouth Bass</u>

Smallmouth Bass AI showed stable or increasing trends in all biological monitoring sites over the 33-year timeseries except in the mid-reservoir and tailrace areas of Little Goose Reservoir. Ice Harbor (Fig. 25), Lower Monumental (Fig. 26), Little Goose (Fig. 27), Lower Granite (Fig. 28).

<u>AI, Walleye</u>

Walleye AI showed stable or increasing trends in all biological monitoring sites over the 33-year time series. Walleye AI increased substantially in the mid-reservoir and tailrace area of Lower Monumental Reservoir. Walleye were first detected above Little Goose Dam in 2016 and above Lower Granite Dam in 2023. Ice Harbor (Fig. 25), Lower Monumental (Fig. 26), Little Goose (Fig. 27), Lower Granite (Fig. 28).

<u>CI, Northern Pikeminnow</u>

Northern Pikeminnow CI could not be calculated from biological monitoring sites in the four Snake River reservoirs in 2023. There has been limited data to calculate CI in Ice Harbor, Lower Monumental, and Little Goose Reservoirs in the 33 years of the time series, and for Lower Granite Reservoir since 2013. Ice Harbor (Fig. 29), Lower Monumental (Fig. 30), Little Goose (Fig. 31), Lower Granite (Fig. 32).

<u>CI, Smallmouth Bass</u>

Smallmouth Bass CI generally showed stable or increasing trends in the biological monitoring sites from the four Snake River reservoirs over the 33-year timeseries, with the exception of the forebay in Lower Monumental Reservoir, which shows a slight decrease. Ice Harbor (Fig. 29), Lower Monumental (Fig. 30), Little Goose (Fig. 31), Lower Granite (Fig. 32).

<u>PI, Northern Pikeminnow</u>

Northern Pikeminnow PI could not be calculated from biological monitoring sites in the four Snake River reservoirs in 2023. There has been limited data to calculate PI in Ice Harbor, Lower Monumental, and Little Goose Reservoirs in the 33 years of the time series, and for Lower Granite Reservoir since 2013. Ice Harbor (Fig. 33), Lower Monumental (Fig. 34), Little Goose (Fig. 35), Lower Granite (Fig. 36).

<u>PI, Smallmouth Bass</u>

Smallmouth Bass PI generally showed stable or increasing trends in the biological monitoring sites from the four Snake River reservoirs over the 33-year timeseries, with the exception of the mid-reservoir area of Ice Harbor Reservoir, which shows a slight decrease. Ice Harbor (Fig. 33), Lower Monumental (Fig. 34), Little Goose (Fig. 35), Lower Granite (Fig. 36).

PSD, Northern Pikeminnow

Northern Pikeminnow PSD could not be calculated in any Snake River reservoirs in 2023, due to insufficient sample size (Ice Harbor n = 1, Lower Monumental n = 1, Little Goose n = 2, Lower Granite n = 8, minimum for PSD n = 20). PSD was not plotted for Northern Pikeminnow due to limited data throughout the timeseries. There were no significant trends in PSD.

PSD, Smallmouth Bass (see Fig. 37)

Smallmouth Bass PSD in Ice Harbor Reservoir in 2023 was 53.4%, and there was not a significant monotonic trend (Mann-Kendall $\tau = 0.29$, $P = 0.39$). Smallmouth Bass PSD in Lower Monumental Reservoir in 2023 was 29.4%, and there was not a significant monotonic trend (Mann-Kendall $\tau = 0.06$, $P = 0.84$). Smallmouth Bass PSD in Little Goose Reservoir in 2023 was 31.4%, and there was not a significant monotonic trend (Mann-Kendall $\tau = 0.24$, $P = 0.35$). Smallmouth Bass PSD in Lower Granite Reservoir in 2023 was 49.8%, and there was not a significant monotonic trend (Mann-Kendall $\tau = 0.03$, $P = 0.95$).

PSD-P, Smallmouth Bass (see Fig. 38)

Smallmouth Bass PSD-P in Ice Harbor in 2023 was 21.9%, and there was not a significant monotonic trend (Mann-Kendall $\tau = 0.07$, $P = 0.90$). Smallmouth Bass PSD-P in Lower Monumental Reservoir was 2.4%, and there was not a significant monotonic trend (Mann-Kendall $\tau = -0.46$, $P = 0.06$). Smallmouth Bass PSD-P in Little Goose Reservoir in 2023 was 8.8%, and there was not a significant monotonic trend (Mann-Kendall $\tau = 0.24$, $P = 0.37$). Smallmouth Bass PSD-P in Lower Granite Reservoir in 2023 was 17.9%, and there was not a significant monotonic trend (Mann-Kendall $\tau = 0$, $P = 1$).

PSD, Walleye

Walleye PSD in Ice Harbor Reservoir in 2023 was 77.1%, and there was not a significant monotonic trend (Mann-Kendall $\tau = -1$, $P = 1$). Walleye PSD in Lower Monumental Reservoir in 2023 was 4.5%, and there was not a significant monotonic trend (Mann-Kendall $\tau = -1$, $P = 1$).Walleye PSD in Little Goose Reservoir in 2023 was 66.7%, and there was not a significant monotonic trend (Mann-Kendall $\tau = 1$, $P = 1$) Walleye PSD could not be calculated in Lower Granite Reservoir in 2023, due to insufficient sample size (n = 2, minimum for PSD = 20). PSD was not plotted for Walleye due to limited data throughout the timeseries. There were no significant trends in PSD.

PSD-P, Walleye

Walleye PSD-P in Ice Harbor Reservoir in 2023 was 52.1%, and there was not a monotonic trend (Mann-Kendall $\tau = 1$, $P = 1$). Walleye PSD-P in Lower Monumental Reservoir in 2023 was 2.2%, and there was not a monotonic trend (Mann-Kendall $\tau = -1$, $P = 1$). Walleye PSD-P in Little Goose Reservoir in 2023 was 21.7%, and there was not a significant monotonic trend (Mann-Kendall $\tau = 1$, $P = 1$). Walleye PSD-P could not be calculated in Lower Granite Reservoir in 2023, due to insufficient sample size (n = 2, minimum for PSD = 20). PSD-P was not plotted for Walleye due to limited data throughout the timeseries. There were no significant trends in PSD-P.

W_r, Northern Pikeminnow

Female Northern Pikeminnow relative weight in Ice Harbor Reservoir in 2023 could not be calculated, due to insufficient sample size (n = 0, minimum for *Wr* = 5). Male Northern Pikeminnow relative weight in Ice Harbor Reservoir in 2023 could not be calculated, due to insufficient sample size (n = 1, minimum for *Wr* = 5). Female Northern Pikeminnow relative weight in Lower Monumental Reservoir in 2023 could not be calculated, due to insufficient sample size (n = 0, minimum for *Wr* = 5). Male Northern Pikeminnow relative weight in Lower Monumental Reservoir in 2023 could not be calculated, due to insufficient sample size (n = 1, minimum for *Wr* = 5). Female Northern Pikeminnow relative weight in Little Goose Reservoir in 2023 could not be calculated, due to insufficient sample size (n = 1, minimum for *Wr* = 5). Male Northern Pikeminnow relative weight in Little Goose Reservoir in 2023 could not be calculated, due to insufficient sample size (n = 1, minimum for *Wr* = 5). Female Northern Pikeminnow relative weight in Lower Granite Reservoir in 2023 was 99.4%, and there was not a significant monotonic trend (Mann-Kendall τ = 0.22, P = 0.47). Male Northern Pikeminnow relative weight in Ice Harbor Reservoir in 2023 could not be calculated, due to insufficient sample size (n = 2, minimum for *Wr* = 5). Wr was not plotted for Northern Pikeminnow due to limited data throughout the timeseries. There were no significant trends in $W_{r,}$.

W_r, Smallmouth Bass (see Fig. 39)

Smallmouth Bass relative weight in Ice Harbor Reservoir in 2023 was 91.3%, and there was not a significant monotonic trend (Mann-Kendall τ = 0.14, P = 0.71). Smallmouth Bass relative weight in Lower Monumental Reservoir in 2023 was 91.7%, and there was not a significant monotonic trend (Mann-Kendall τ = 0.18, P = 0.45). Smallmouth Bass relative weight in Little Goose Reservoir in 2023 was 93.3%, and there was not a significant monotonic trend (Mann-Kendall τ = 0.03, P = 0.95). Smallmouth Bass relative weight in Lower Granite Reservoir in 2023 was 92.8%, and there was not a significant monotonic trend (Mann-Kendall τ = 0.18, P = 0.45) .

W_r, Walleye

Walleye relative weight in Ice Harbor Reservoir in 2023 was 95.4%, and there was not a significant monotonic trend (Mann-Kendall τ = 0.33, P = 1). Walleye relative weight in Lower Monumental Reservoir in 2023 was 85.7%, and there was not a significant monotonic trend (Mann-Kendall τ = -0.33, P = 0.45). Walleye relative weight could not be calculated in Little Goose Reservoir in 2023, due to insufficient sample size (n = 0, minimum for PSD = 20). Walleye relative weight could not be calculated in Lower Granite Reservoir in 2023, due to insufficient sample size (n = 2, minimum for PSD = 20). W_r was not plotted for Walleye due to limited data throughout the timeseries. There were no significant trends in W_r.

DISCUSSION

Overview

NPMP was tasked with reducing the predation by Northern Pikeminnow on juvenile salmonids, as they migrate through the hydropower systems of the Columbia and Snake rivers. NPMP is a multi-agency collaboration incorporating sport reward and dam fisheries managed by WDFW, which promotes 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 2023 Sport Reward Fishery system-wide exploitation rate of Northern Pikeminnow ≥ 250 mm FL was 9.2% (lower - upper confidence limits, 6.6 – 13.0%). The point estimate was just short of the exploitation management goal, though the upper confidence limit was within the range of the exploitation target. 2023 was the first year that NPMP incorporated a new mark/recovery analytical framework, a Brownie bird band model, utilizing tag recoveries from multiple years of marking. This model was necessary because NPMP discontinued all marking efforts in 2023 due to resource limitations. NPMP is still in the process of assessing how an exploitation estimate based on a Brownie bird band model and multiple years of recovery data compares to the historic mark/recovery model based on a Lincoln-Peterson model using only within-year recoveries. 2024 will allow NPMP to assess these two models side by side using mark/recovery data from Bonneville Reservoir and the area below Bonneville Dam as marking will occur in these two areas. 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

Median, system-wide predation reduction by Northern Pikeminnow in 2024 was estimated to be 28% relative to pre-program levels. 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 suggests that the removal program continued to be successful. These findings were designed to be presented in conjunction with biological monitoring of additional fisheries metrics, allowing NPMP to further assess whether long-term exploitation of Northern Pikeminnow contributed to predatory compensation with non-native piscivores. The biological monitoring metrics also provide a means to monitor for a chronic decline in the Northern Pikeminnow population.

Fishery Evaluation Trends

Trends in fishery dependent metrics associated with fishery evaluation marking could not be calculated in 2023 because marking efforts were suspended, system-wide, in 2023. These changes were required due to resource limitations in 2023 and highlight a key loss of data from a component of this program that can be used to augment the information generated through biological monitoring efforts. Additionally, there have been no biological monitoring data generated from the McNary Reservoir since 1993.The suspension of predator marking associated with fishery evaluation eliminated the only data NPMP had for estimates of length frequency, PSD, and relative weight for Northern Pikeminnow, Smallmouth Bass, and Walleye from this area.

DAF

Northern Pikeminnow removed in DAF appeared to be feeding regularly in the powerhouse tailrace areas of Bonneville and The Dalles reservoirs. Additionally, 5 - 6% of the diet composition of DAF caught Northern Pikeminnow was salmonids. These proportions were calculated from Northern Pikeminnow collected from 31 May– 10 October 2023. 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. There was intra-annual variation in the diet composition. Salmonids and lamprey were primarily predated during the early weeks of DAF (weeks 22-29), with diet composition largely consisting of American Shad in later weeks (30-41). These data suggest that Northern Pikeminnow feeding in the powerhouse tailrace areas may be influenced by prey availability. Though previous years of data indicate Northern Pikeminnow feeding on pulses of out-migrating salmonids (Carpenter et al. 2019), diet data from DAF 2023 showed salmon and lamprey consumption early in the season followed by diets consisting largely of American Shad. One possible explanation is that a particularly large outmigration of shad beginning week 30 and a concurrent decline of out-migrating salmonids around the same time, provided ample prey for Northern Pikeminnow in the powerhouse tailraces of The Dalles and Bonneville reservoirs. Because of this, salmonids and other prey items became a much smaller proportion of the diet of Northern Pikeminnow in the powerhouse tailrace areas.

Due to sampling, location, and timing differences, a comparison between the diets of DAF caught Northern Pikeminnow and diets sampled during biological evaluation was not possible. There were few Northern Pikeminnow sampled during the biological evaluation portion of the study in the Snake River sub-unit. 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 monitoring 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 data gaps surrounding potentially important Northern Pikeminnow feeding areas adjacent to the powerhouse tailrace areas. These data were useful in augmenting the understanding of the predator/prey dynamics between Northern Pikeminnow, juvenile salmonids, lampreys, American Shad, 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 (FCRPS) through a means that is inaccessible to anglers participating in the SRF. PSD for Northern Pikeminnow in Bonneville Reservoir powerhouse tailrace (The Dalles Dam), caught through DAF, was significantly lower during the more recent sampling time period (2006 – 2023) 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 powerhouse tailrace (John Day Dam) did not have a significant difference in PSD for late relative to early time periods. 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. Particularly, PSD for Northern Pikeminnow in The Dalles Reservoir powerhouse tailrace has increased to comparable levels similar to the older time sampling period (1990-1995), while PSD has increased in recent years in Bonneville Reservoir, it is not at historical levels. The mechanism for this difference remains unknown. Potential explanations include a shift in SRF effort and or catch between the two reservoirs (Winther et al. 2021) or differential population responses to abiotic and/or biotic factors (e.g., Jackson 2001). 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. Monitoring of these areas should continue as it provides important insight into shifts in predator dynamics that other sampling cannot address.

Biological Monitoring

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 population declines. The primary indicator of a compensatory response was whether the level of predation changed within Northern Pikeminnow populations and how it compared with other piscine 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. During the 2023 field season, ODFW doubled the spring biological monitoring effort to include two biological monitoring sub-units: the area below Bonneville Dam/Bonneville Reservoir and the four lower Snake reservoirs. This was the first time in decades that NPMP collected biological monitoring data from more than one sub-unit. This was done opportunistically due to the elimination of the fishery evaluation efforts to mark Northern Pikeminnow and provided a rare opportunity to collect biological data from two distinct sections of the Columbia River Basin during the same year. Sampling in this way will also allow NPMP to have four years of data over a five-year period for the biological monitoring sites below Bonneville Dam and Bonneville Reservoir, at the end of the 2024 field season. These data will be used to provide the program increased sampling frequency to better address ISRP concerns about the relationship between AI and fishery evaluation metrics like Northern Pikeminnow population or SRF CPUE.

Broad patterns in piscine predator indices suggest variable patterns in abundance, consumption, and predation in the sub-unit below Bonneville Dam and Bonneville Reservoir. Long-term trends in Bonneville Reservoir suggest stable to declining abundance, consumption, and predation by Northern Pikeminnow and stable to increasing trends of those indices for Smallmouth Bass. The Bonneville mid-reservoir site shows distinct inverse trends in AI, PI, and CI between Northern Pikeminnow and Smallmouth Bass where the index values are declining for Northern Pikeminnow over time. This trend could indicate a compensatory response from SRF or a signal from other factors affecting these fish populations that are not measured as part of this program. Walleye were detected in low abundance in Bonneville Reservoir and NPMP does not currently include an index of consumption or predation for this species.

In contrast, long-term trends in indices of abundance, consumption, and predation below Bonneville Dam show different patterns than Bonneville Reservoir. The abundance index of Northern Pikeminnow shows declining trends over time but this appears to be driven by an initial decline in the years following the initiation of SRF and a leveling of that pattern for the next couple of decades. Smallmouth Bass show relatively small changes in the index of abundance during the same time. The trends in consumption and predation indices for Northern Pikeminnow suggest variable but stable consumption with declining trends in predation, likely related to the declining trend in AI. Smallmouth Bass have lower index values for consumption and predation, though the long-term trend in predation suggests an increase over time. Walleye were infrequently encountered in the area below Bonneville Dam. The muted and variable patterns in trends of AI, CI, and PI of Northern Pikeminnow and Smallmouth Bass below Bonneville Dam may indicate differing ecological dynamics in this area relative to Bonneville Reservoir. Bonneville Reservoir is situated between two large hydropower facilities: The Dalles Dam upstream and Bonneville Dam downstream. In contrast, the area below Bonneville Dam encompasses more than 100 river kilometers downstream of Bonneville Dam without any hydropower facilities or other anthropogenic infrastructure to control water flow.

Trends in AI, for Northern Pikeminnow, Smallmouth Bass, and Walleye in Ice Harbor, Lower Monumental, Little Goose, Lower Granite reservoirs were variable within and between reservoirs. However, a general pattern of stable to declining Northern Pikeminnow and stable to increasing trends in Smallmouth Bass and Walleye AI was detected. Of note, there were relatively large increases in AI for Smallmouth Bass and Walleye in many biological monitoring areas of the Snake River sub-unit. The substantial increases in Walleye abundance in the Snake River reservoirs aligns with indications of expansion upstream within the Snake River. Prior to 2016, no Walleye were detected above Little Goose Dam during either biological monitoring or SRF evaluation field activities. Additionally in 2023, Walleye were detected for the first time during NPMP biological monitoring above Lower Granite Dam. CI and PI for Northern Pikeminnow and Smallmouth Bass followed similar trends as AI. Previous research has demonstrated that Smallmouth Bass can predate upon substantial numbers of out-migrating juvenile salmonids in areas of the Snake River that overlap with NPMP SRF and biological monitoring sites (e.g., Tiffan et al. 2020). Other research has demonstrated that large-scale variations in climate can affect modeled predation on juvenile salmonids by Northern Pikeminnow, Smallmouth Bass, and Walleye (Petersen and Kitchell 2001). Furthermore, NPMP biological monitoring diet data from 2023 shows that all three piscine predators can have substantial proportions of salmonids in their diets, though the trends are spatially variable. The patterns in NPMP biological monitoring indices and diet proportion among piscine predator species paired with research demonstrating substantial predation from all three species that increases with river temperatures suggest additional monitoring will be necessary to understand piscine predation as the ecological dynamics of this system continue to shift.

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 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 demonstrate 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 biological monitoring areas assessed in 2023. 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. PSD for Northern Pikeminnow showed a significant decline in Bonneville Reservoir while there was a significant increase in Smallmouth Bass PSD-P in the same reservoir. At the same time, there was no significant change in W_r for either species. These results could suggest processes related to compensatory responses that only led to changes in abundance but didn't affect the ability of the remaining Northern Pikeminnow to obtain similar levels of nutrients that would lead to a decline in W_r. It's also possible these patterns were unrelated to Northern Pikeminnow removals from SRF and may instead signal changes in piscine predator dynamics from other processes (e.g., recruitment of Northern Pikeminnow). W_r of Northern Pikeminnow significantly increased below Bonneville Dam, with no significant changes in PSD. This could represent a density-dependent effect and compensatory response by remaining Northern Pikeminnow as AI decreased across the time series in the area but the remaining fish had less competition for food leading to increasing weight. Additionally, there were no changes in PSD or W_r for Smallmouth Bass or Walleye in this same area.

With respect to the Snake River sub-units, trends in PSD and W_r could only be evaluated for Smallmouth Bass and did not show significant increasing or decreasing monotonic trends. These results suggest that Smallmouth Bass populations were stable in the Snake River sub-unit while Northern Pikeminnow and Walleye had more variable populations. Given the potential increase and expansion of Walleye in this area recently (unpublished, IDFG), ongoing monitoring should be continued and potentially expanded to assess how and to what degree piscine predation dynamics are changing in this area.

Taken in aggregate, the fisheries independent indices of abundance, consumption, and predation suggests spatiotemporally variable patterns in Northern Pikeminnow populations. Below Bonneville Dam, Northern Pikeminnow populations appear stable while in some areas of Bonneville Reservoir and the Snake River sub-unit, their populations and subsequent predation on juvenile salmonids may be reduced relative to Smallmouth Bass and Walleye. Walleye recently showed substantial increases in AI and expansion into areas they were not previously encountered during NPMP biological monitoring in the Snake River sub-unit. This trend should be tracked as Walleye are known contributors to significant predation on juvenile salmonids and a similar pattern could emerge to one detected by NPMP in John Day Reservoir (Waltz et al. 2023) where Northern Pikeminnow were detected in relatively low numbers and Walleye and Smallmouth Bass have shown substantial increasing trends over the 33 year timeseries. While it was not possible to say for certain that the patterns between declining metrics for Northern Pikeminnow and some increasing metrics for Smallmouth Bass and Walleye were indicative of a compensatory response, there was evidence that both species were considerably more prevalent than Northern Pikeminnow in John Day Reservoir in 2022 than at the start of NPMP in 1990. This also suggests that predation of juvenile out-migrating salmonids by Northern Pikeminnow has been reduced while it has increased by Smallmouth Bass and Walleye. While NPMP doesn't have consumption or predation index values for Walleye, the proportion of salmonids in their diets would suggest that the increase in the index of abundance would lead to an increase in predation of out-migrating juvenile salmonids by Walleye (Table 2 & 3).

Continued evidence of compensatory responses to Northern Pikeminnow removals across multiple reservoirs could justify a need to augment the current study design to expand 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 NPMP adapts and continues to monitor these areas through biological evaluation to assure a viable population of the native predator.

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 33 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. These methods provided evidence that there may be a compensatory response in Smallmouth Bass and Walleye, potentially due to the removal of Northern Pikeminnow in some areas of Bonneville Reservoir and sections of the Snake River sub-unit. Of particular interest is the distinct, inverse trend in Northern Pikeminnow to Smallmouth Bass AI, CI, and PI in Bonneville mid-reservoir areas, the substantial increase in Walleye in many monitoring areas of the Snake River reservoirs, and the detection of Walleye for the first time during biological monitoring above Lower Granite reservoir. These results all suggest the dynamics among piscine predators may be shifting which have important implications for juvenile salmonid predation. These potential compensatory responses need 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 will continue adapting the research methods to provide management actionable information about the predation of juvenile salmonids in the Columbia and Snake rivers.

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TABLES

Table 1. Number (n) of Northern Pikeminnow diets (≥ 200 mm FL) examined from Dam Angling Fishery catch from Bonneville (powerhouse tailrace of The Dalles Dam) and The Dalles (powerhouse 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). Note: Start and end dates for the Dam Angling Fishery and the affiliated fishery monitoring have varied year to year.

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
2022	221	0.71	0.54	0.04	0.20	0.09	0.14	0.31	0.11
2023	510	0.72	0.57	0.02	0.24	0.01	0.05	0.20	0.30
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
2022	161	0.70	0.48	0.06	0.37	0.27	0.21	0.06	0.06
2023	174	0.66	0.39	0.02	0.43	0.01	0.06	0.07	0.19

Table 2A and 2B. Number (n) of Northern Pikeminnow, Smallmouth Bass, and Walleye (≥ 200 mm FL) diets examined during biological evaluation in Bonneville Reservoir and below Bonneville Reservoir during spring 2023 and proportion of samples containing specific prey items (cray = crayfish, crust = all crustacea not identified as crayfish, sal = salmon or steelhead, lam = lamprey).

2A

Spring 2023	Bonneville Reservoir							
Species	n	$\hat{p}_{food}$	$\hat{p}_{fish}$	$\hat{p}_{cray}$	$\hat{p}_{crust}$	$\hat{p}_{insect}$	$\hat{p}_{sal}$	$\hat{p}_{lam}$
Northern Pikeminnow	270	0.52	0.14	0.08	0.05	0.13	0.03	0.06
Smallmouth Bass	253	0.93	0.37	0.38	0.25	0.12	0.07	0.03
Walleye	16	1.00	0.81	0.06	0.44	0.13	0.56	0.06

2B

Spring 2023	Below Bonneville							
Species	n	$\hat{p}_{food}$	$\hat{p}_{fish}$	$\hat{p}_{cray}$	$\hat{p}_{crust}$	$\hat{p}_{insect}$	$\hat{p}_{sal}$	$\hat{p}_{lam}$
Northern Pikeminnow	56	0.61	0.32	0.29	0.02	0.07	0.14	0.02
Smallmouth Bass	47	0.87	0.57	0.17	0.13	0.11	0.21	0.00
Walleye	—	—	—	—	—	—	—	—

Tables 3A-3D. Number (n) of Northern Pikeminnow, Smallmouth Bass, and Walleye (≥ 200 mm FL) diets examined during biological evaluation in the four lower Snake River reservoirs during spring 2023 and proportion of samples containing specific prey items (cray = crayfish, crust = all crustacea not identified as crayfish, sal = salmon or steelhead, lam = lamprey).

3A

Spring 2023	Ice Harbor Reservoir							
Species	n	$\hat{p}_{food}$	$\hat{p}_{fish}$	$\hat{p}_{cray}$	$\hat{p}_{crust}$	$\hat{p}_{insect}$	$\hat{p}_{sal}$	$\hat{p}_{lam}$
Northern Pikeminnow	4	0.50	0.00	0.00	0.25	0.25	0.00	0.00
Smallmouth Bass	73	0.92	0.34	0.23	0.45	0.18	0.04	0.00
Walleye	43	0.84	0.63	0.00	0.14	0.00	0.47	0.05

3B

Spring 2023	Lower Monumental Reservoir							
Species	n	$\hat{p}_{food}$	$\hat{p}_{fish}$	$\hat{p}_{cray}$	$\hat{p}_{crust}$	$\hat{p}_{insect}$	$\hat{p}_{sal}$	$\hat{p}_{lam}$
Northern Pikeminnow	3	0.67	0.00	0.67	0.33	0.00	0.00	0.00
Smallmouth Bass	144	0.94	0.11	0.71	0.40	0.16	0.02	0.02
Walleye	228	0.99	0.38	0.08	0.84	0.14	0.14	0.19

3C

Spring 2023	Little Goose Reservoir							
Species	n	$\hat{p}_{food}$	$\hat{p}_{fish}$	$\hat{p}_{cray}$	$\hat{p}_{crust}$	$\hat{p}_{insect}$	$\hat{p}_{sal}$	$\hat{p}_{lam}$
Northern Pikeminnow	3	0.67	0.33	0.00	0.00	0.33	0.33	0.00
Smallmouth Bass	126	0.97	0.38	0.21	0.62	0.07	0.10	0.02
Walleye	56	0.84	0.64	0.02	0.09	0.04	0.30	0.13

3D

Spring 2023	Lower Granite Reservoir							
Species	n	$\hat{p}_{food}$	$\hat{p}_{fish}$	$\hat{p}_{cray}$	$\hat{p}_{crust}$	$\hat{p}_{insect}$	$\hat{p}_{sal}$	$\hat{p}_{lam}$
Northern Pikeminnow	27	0.37	0.11	0.04	0.00	0.30	0.04	0.00
Smallmouth Bass	61	0.84	0.69	0.07	0.23	0.11	0.15	0.00
Walleye	2	1.00	1.00	0.00	0.50	0.50	0.50	0.00

FIGURES

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

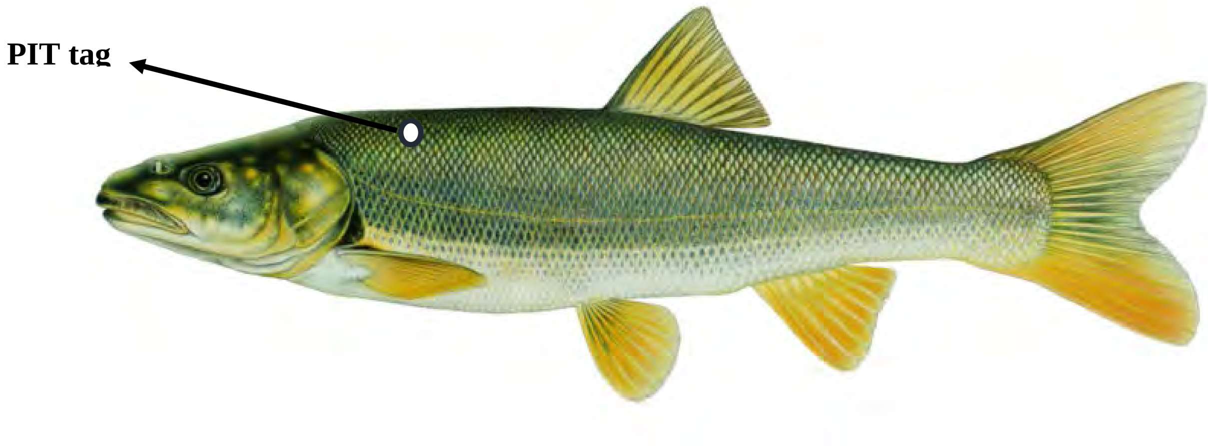

Figure 2. Tag placement areas for 134.2 MHz passive integrated transponder (PIT) tags for marked Northern Pikeminnow.

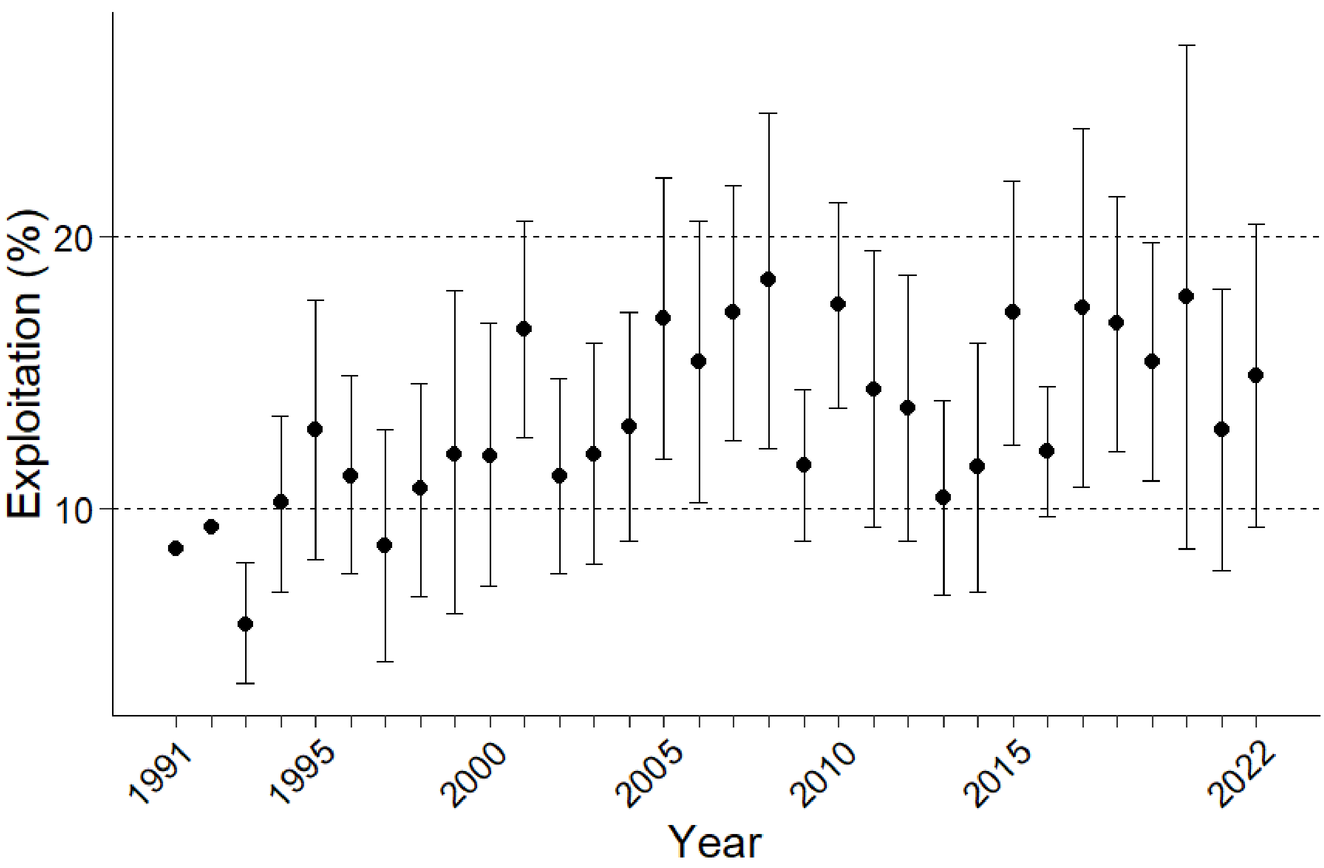

Figure 3. System-wide exploitation rates of Northern Pikeminnow (≥ 250 mm FL) in the Sport Reward Fishery, 1991–2022. Error bars represent 95% confidence intervals, though variation was not estimated for the years 1991–1992. Target exploitations 10–20% (dashed lines).

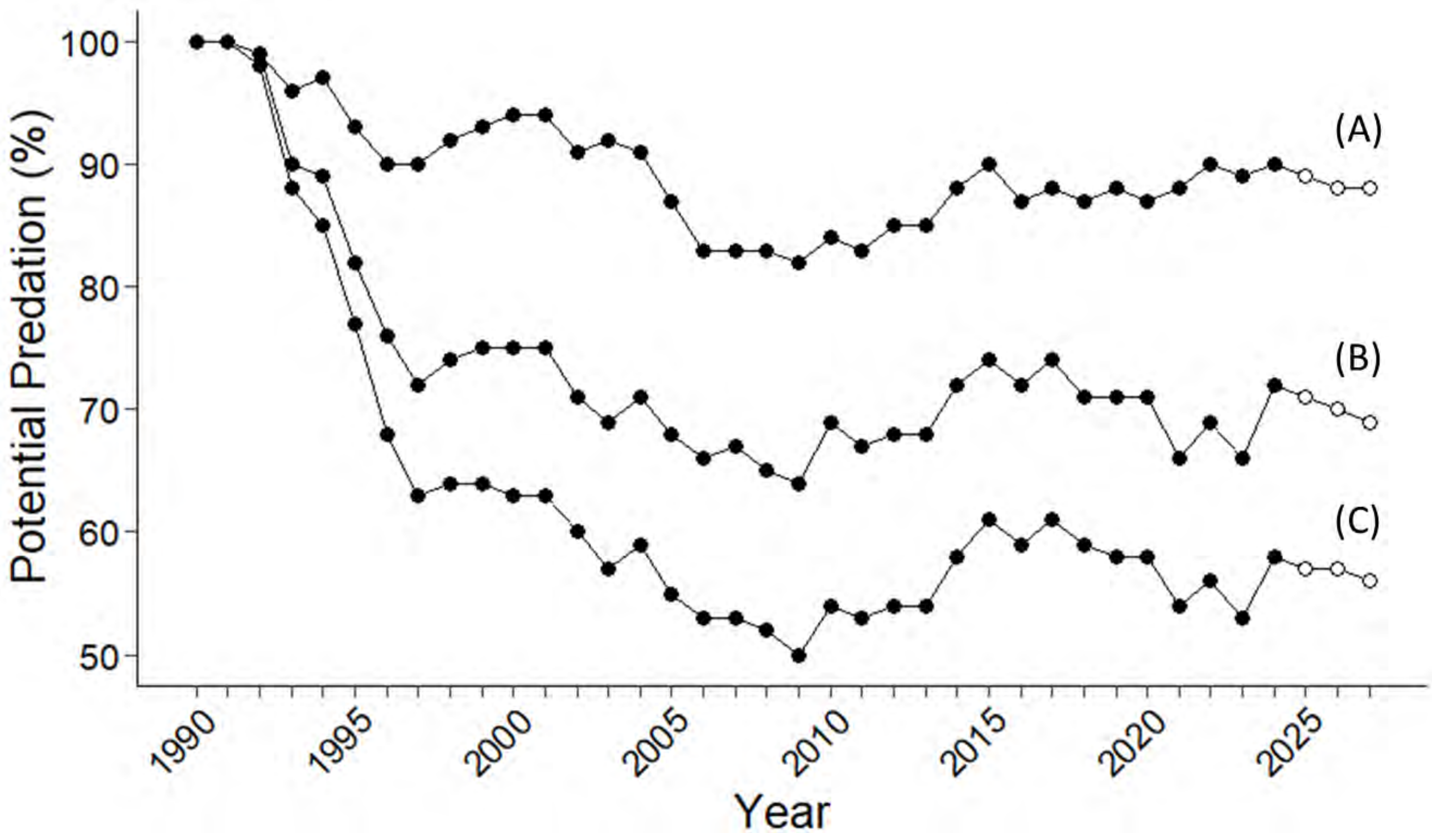

Figure 4. Estimates of (A) maximum, (B) median, and (C) minimum annual levels of potential predation by Northern Pikeminnow on juvenile salmon relative to predation levels before implementation of the Northern Pikeminnow Management Program. For the years 1991–2023, model estimates (filled circles) are based on exploitation rates from the previous year. Model forecast predictions after 2024 (open circles) are based on average exploitation estimates from years with similar fishery structure (2001, 2004–2023).

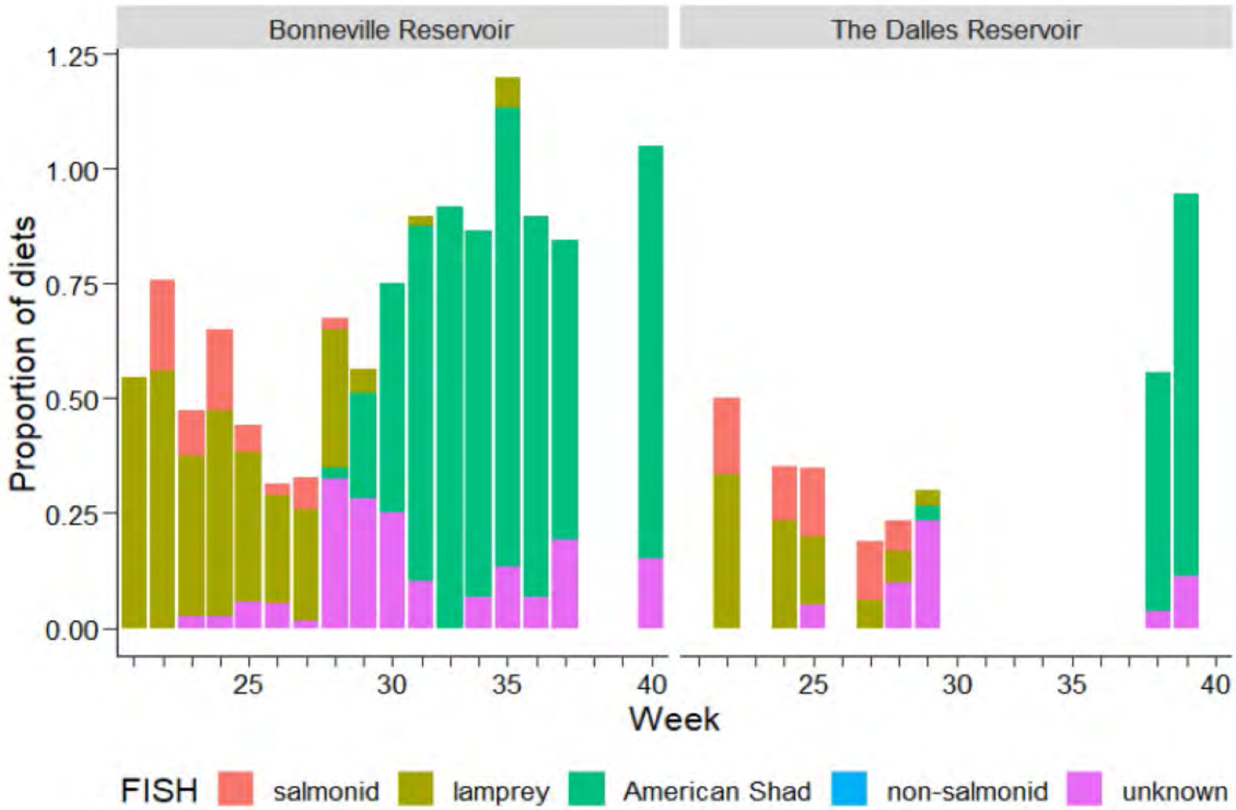

Figure 5. Proportion of all Northern Pikeminnow diet samples containing prey fish collected during the Dam Angling Fishery from the powerhouse tailraces of Bonneville (fishing from The Dalles Dam) and The Dalles (fishing from John Day Dam) reservoirs, May – October 2023. All Northern Pikeminnow diet samples collected were included in this analysis, including samples that were empty or fishless. Multiple fish groups may be represented in individual Northern Pikeminnow diets. Note: weeks without data indicate that sampling was not conducted, or sample sizes were insufficient for analyses (n < 6).

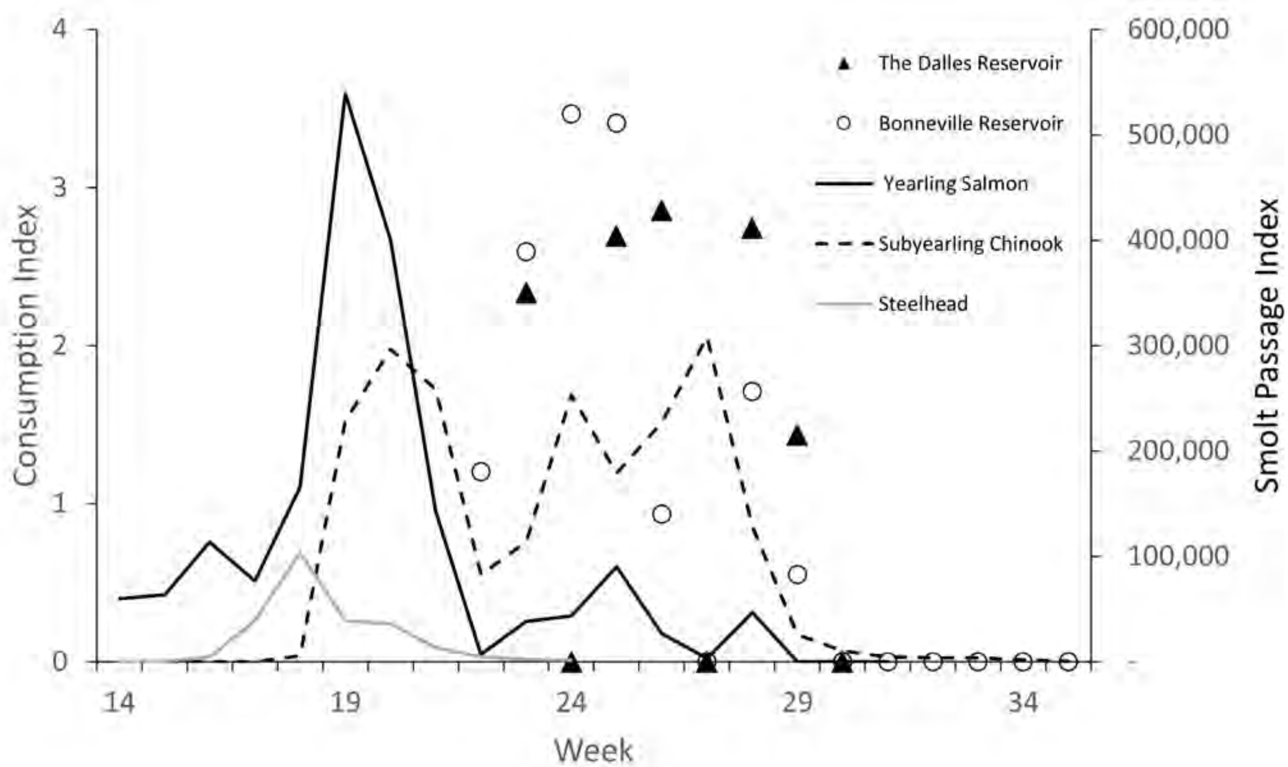

Figure 6. Mean weekly juvenile salmon consumption index for Northern Pikeminnow captured from the Dam Angling Fishery (DAF) in Bonneville (open circles) and The Dalles (filled triangles) reservoirs compared to the weekly smolt passage index at McNary Dam, 2023. Smolt passage data are summarized from Fish Passage Center (unpublished data). DAF sampling was conducted from Weeks 22-41. Weeks without data indicate that sampling was not conducted, or sample sizes were insufficient for analyses (n < 6).

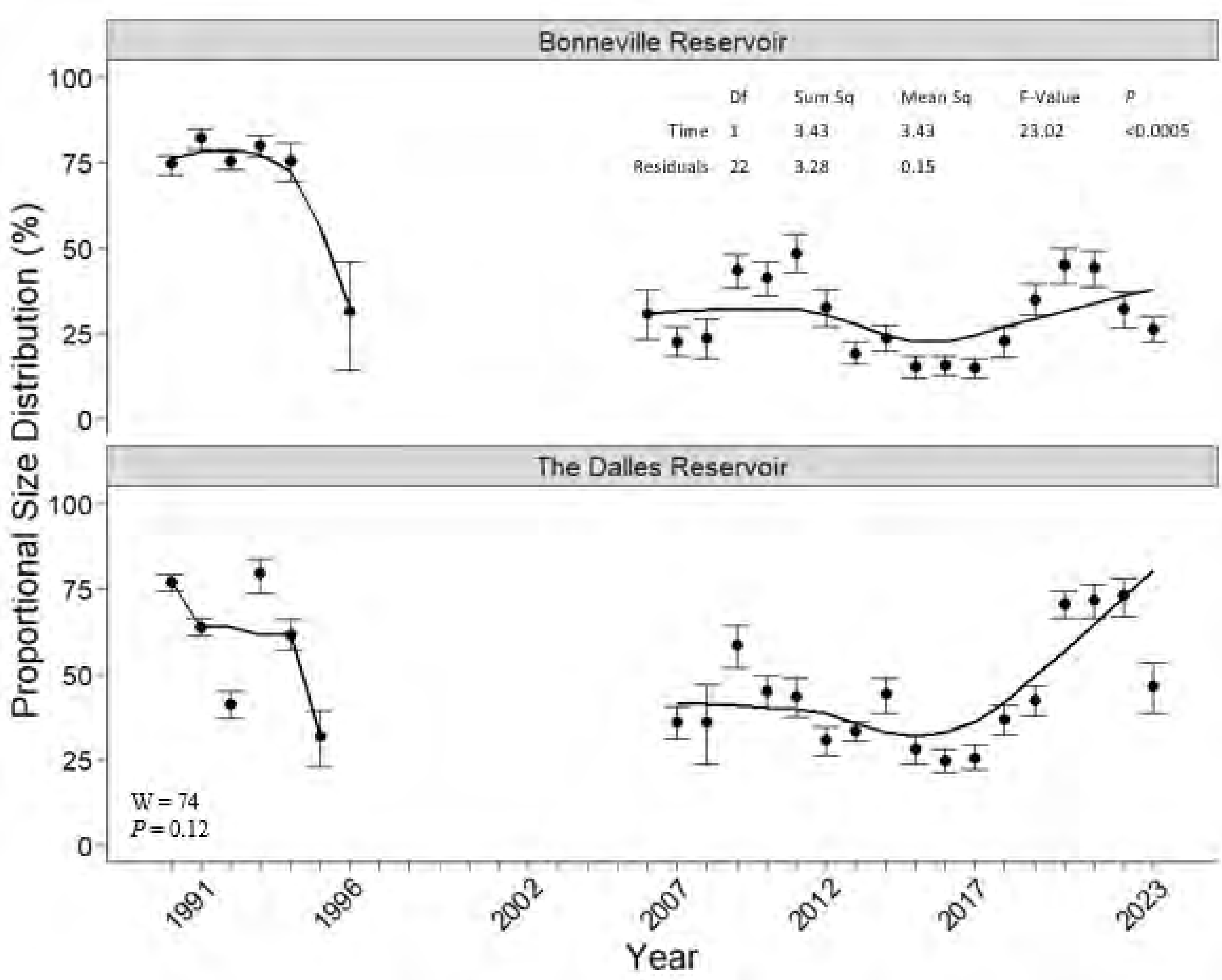

Figure 7. Estimates of proportional size distribution (PSD, %) of Northern Pikeminnow sampled in Bonneville and The Dalles reservoirs during the Dam Angling Fishery, 1990–2023. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves for two different time series: early (1990–1996) and late (2006–2023), 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).

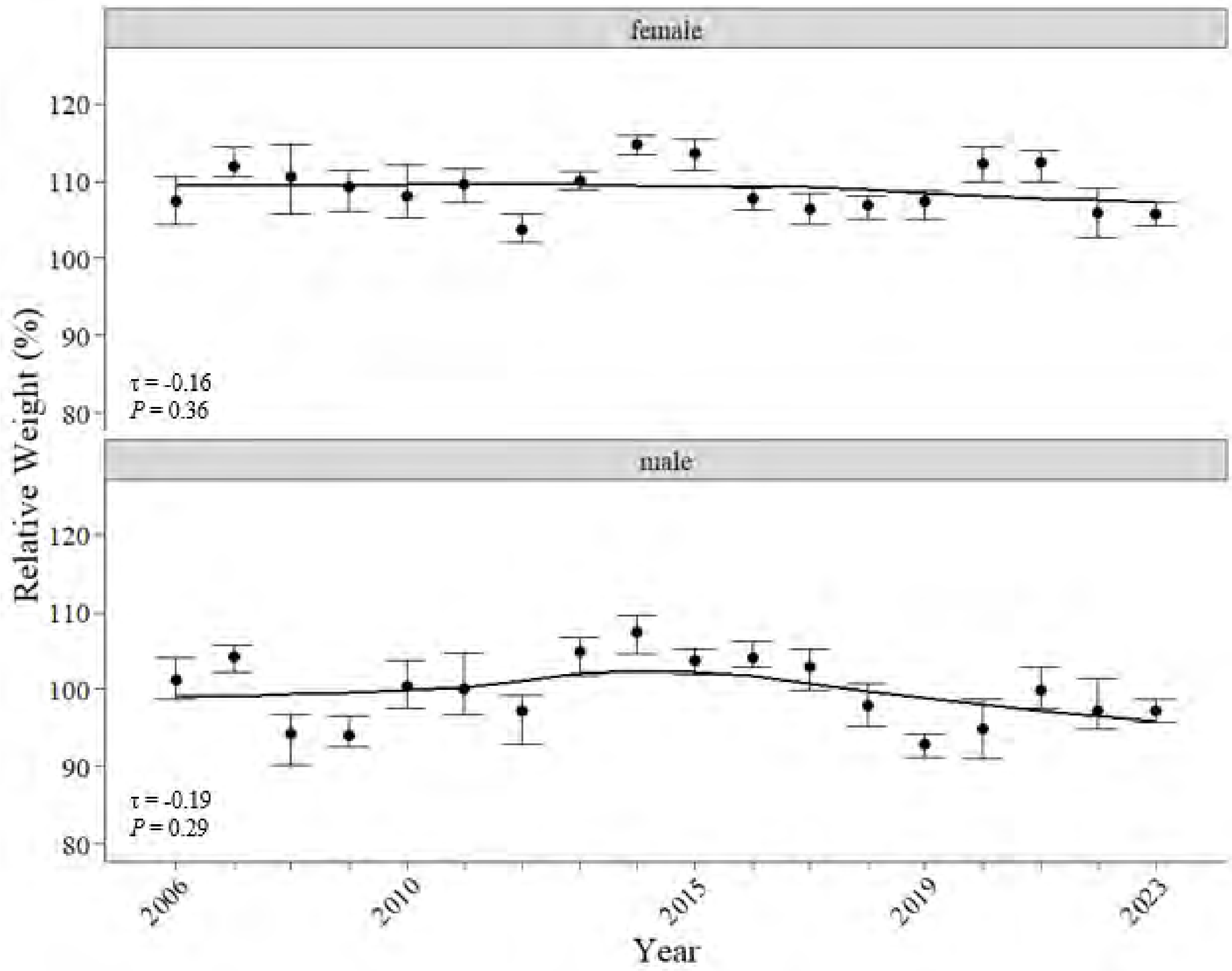

Figure 8. Median relative weight (Wr, %) for female and male Northern Pikeminnow collected in Bonneville Reservoir during the Dam Angling Fishery, 2006–2023. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each sex.

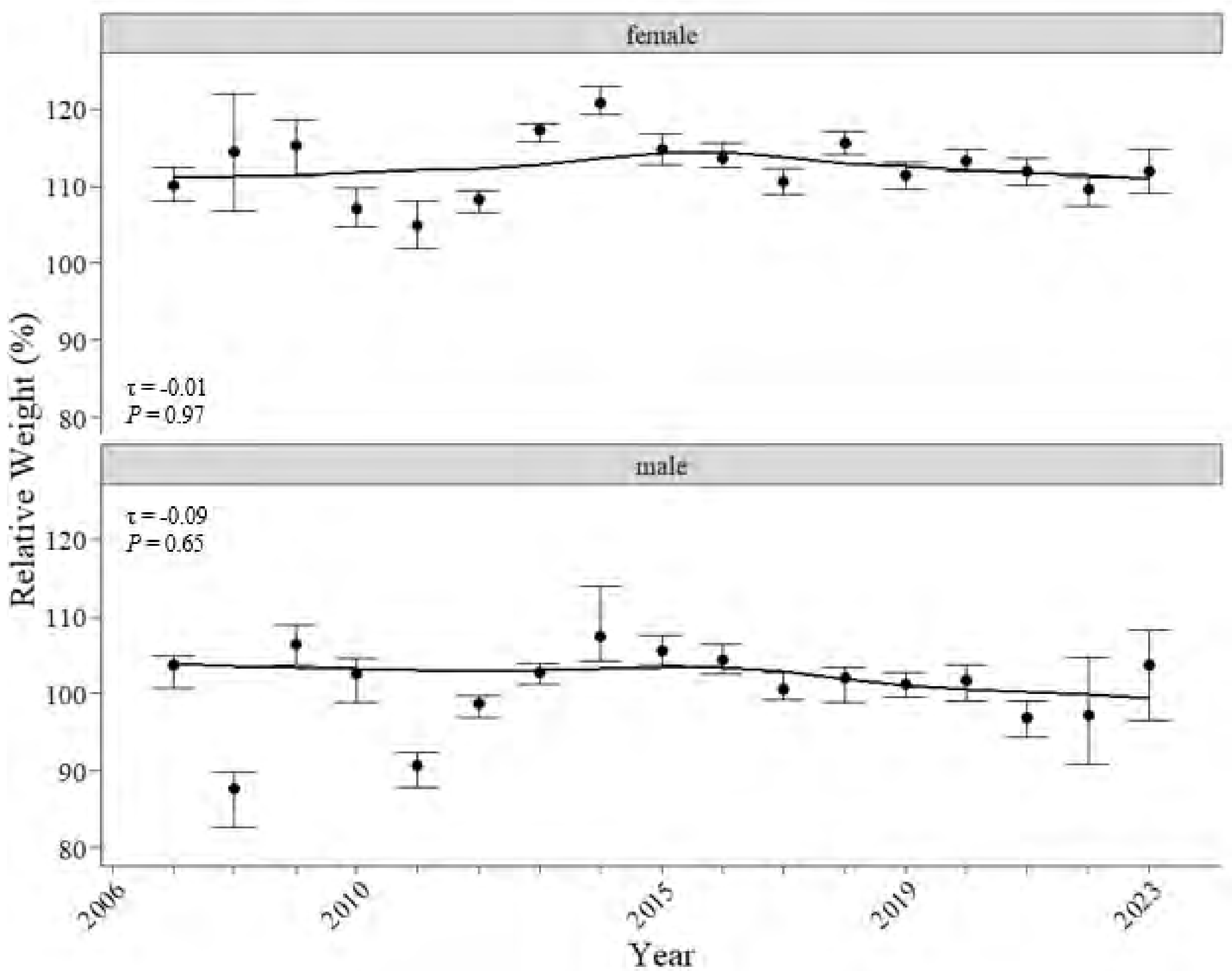

Figure 9. Median relative weight (Wr, %) for female and male Northern Pikeminnow collected in The Dalles Reservoir during the Dam Angling Fishery, 2007–2023. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each sex.

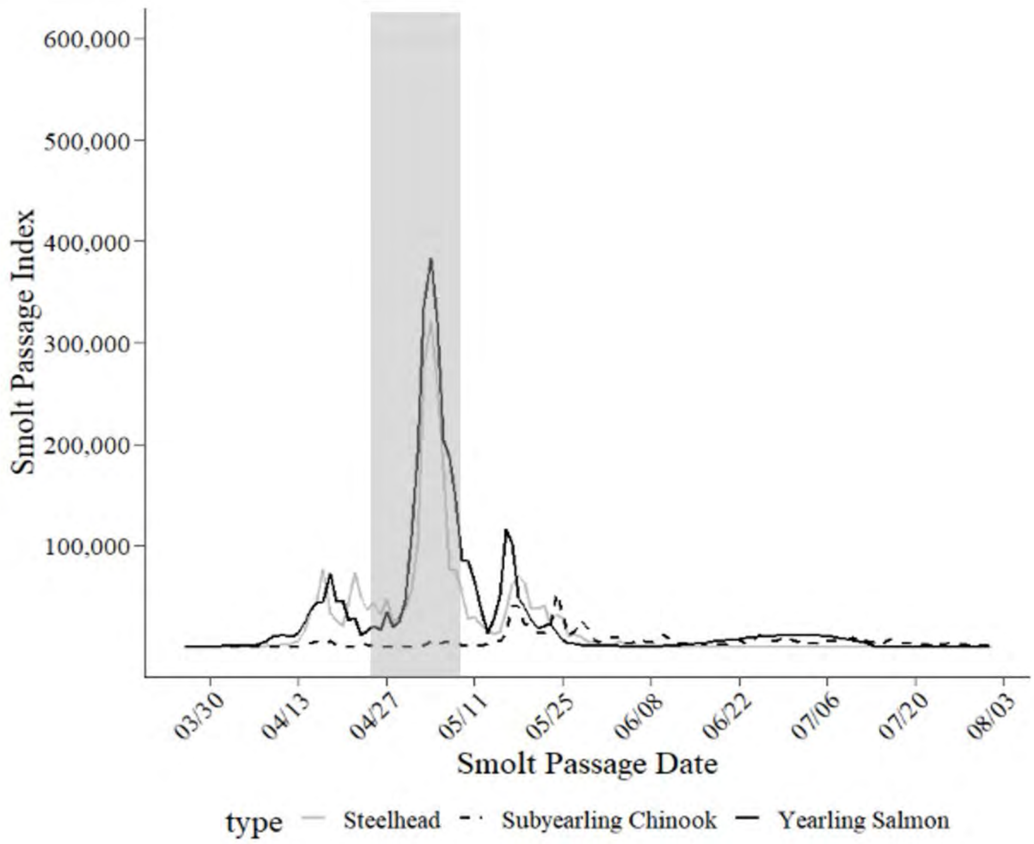

Figure 10. Period of biological evaluation (vertical bar) in Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Reservoirs and juvenile salmon and steelhead daily passage index through Lower Granite Dam, April–August 2023 (Source: Fish Passage Center, unpublished data).

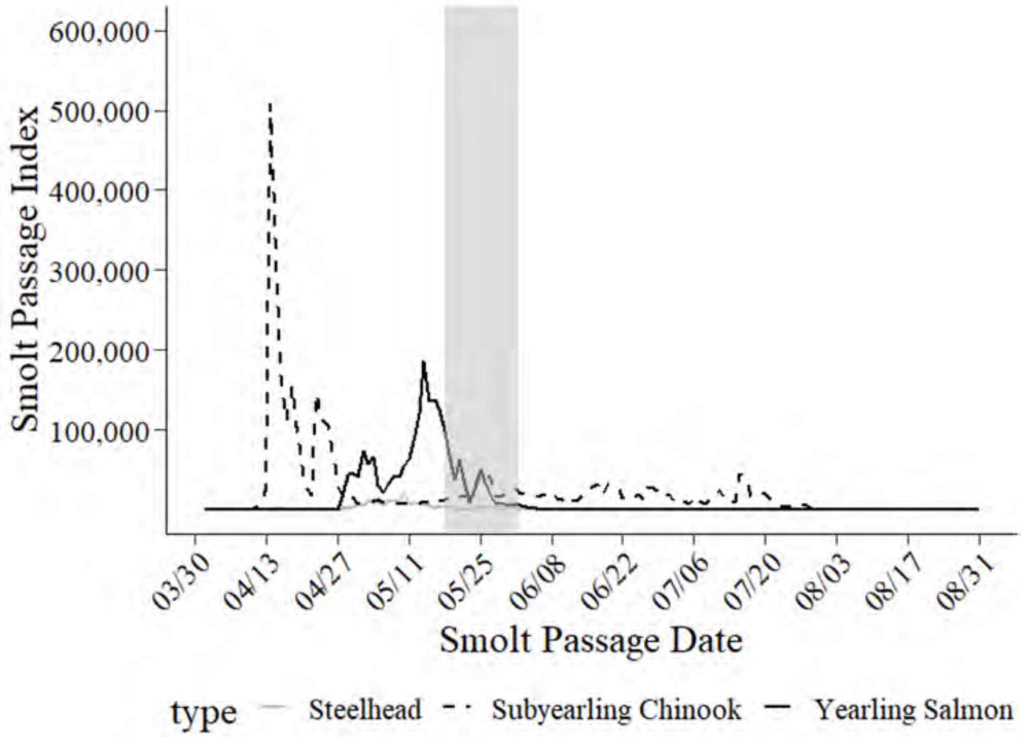

Figure 11. Period of biological evaluation (vertical bar) in the area below Bonneville Dam and Bonneville Reservoir and juvenile salmon and steelhead daily passage index through Bonneville Dam, April–September 2023(Source: Fish Passage Center, unpublished data).

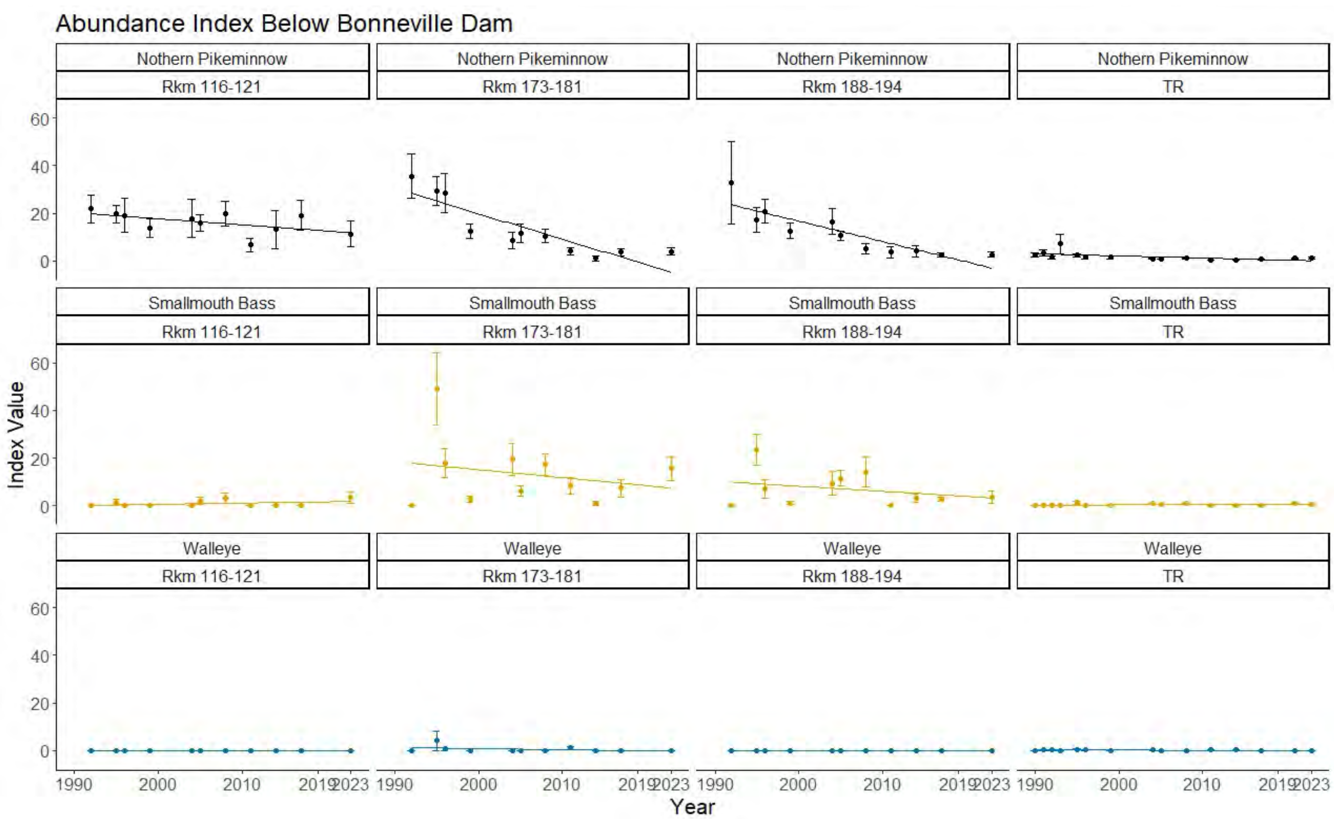

Figure 12. Spring abundance index values (mean catch per 900-s boat electrofishing scaled to surface area [ha] divided by 1,000; and SE) for Northern Pikeminnow (≥ 250 mm FL), Smallmouth Bass (≥ 200 mm FL), and Walleye (≥ 200 mm FL) Below Bonneville Dam, 1990 – 2023. Years without data indicate sampling was not conducted or sample sizes were insufficient for analysis.

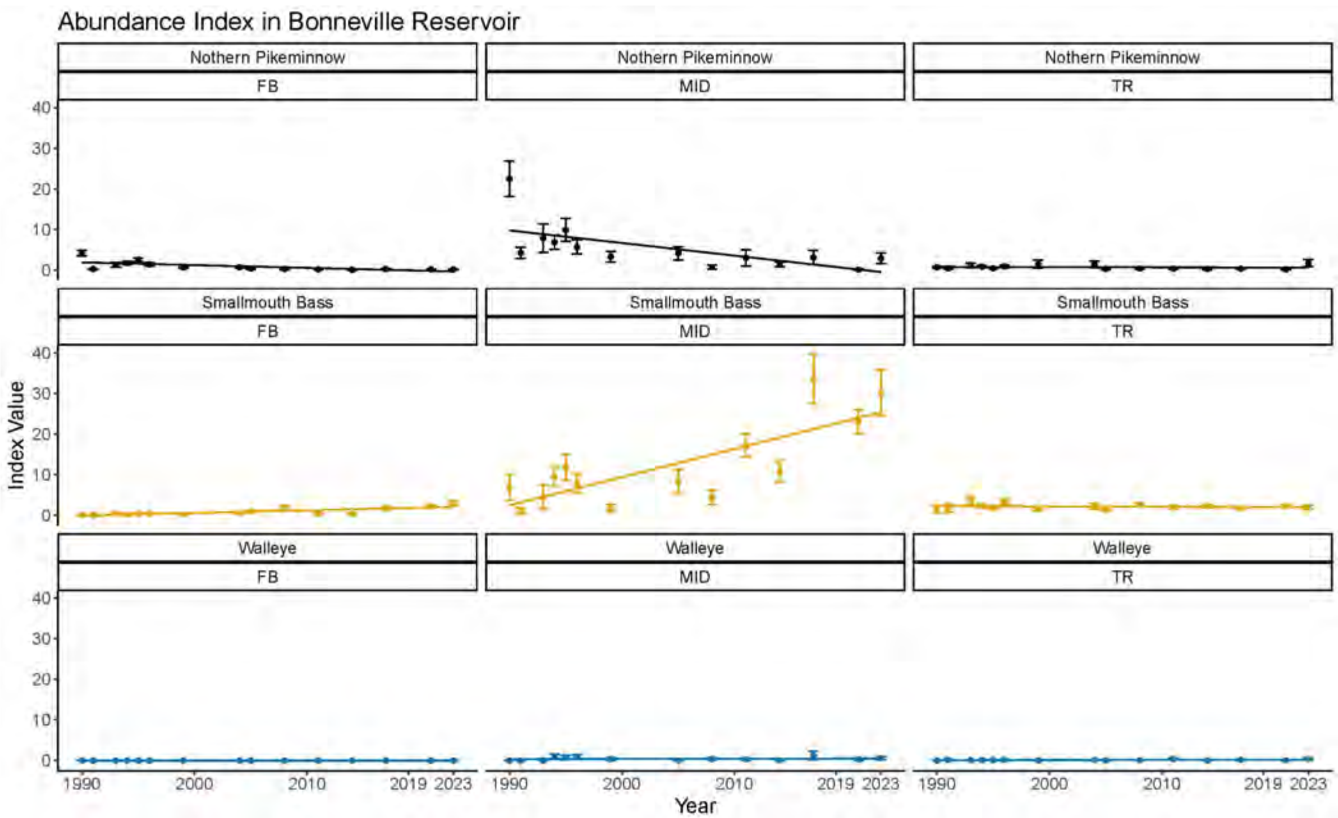

Figure 13. Spring abundance index values (mean catch per 900-s boat electrofishing scaled to surface area [ha] divided by 1,000; and SE) for Northern Pikeminnow (≥ 250 mm FL), Smallmouth Bass (≥ 200 mm FL), and Walleye (≥ 200 mm FL) in Bonneville Reservoir, 1990 – 2023. Years without data indicate sampling was not conducted or sample sizes were insufficient for analysis.

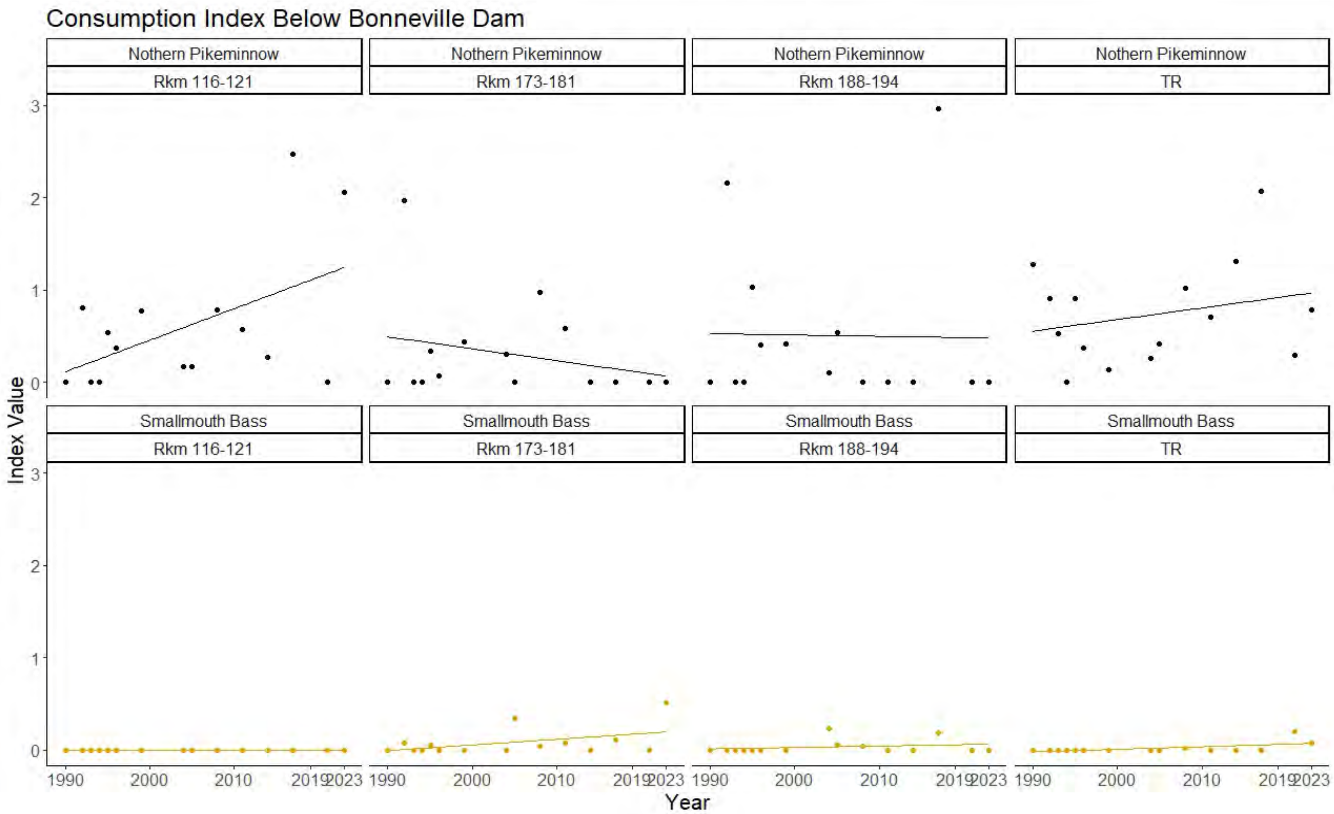

Figure 14. Annual spring consumption index values for Northern Pikeminnow (≥ 250 mm FL), and Smallmouth Bass (≥ 200 mm FL) captured during biological evaluation Below Bonneville Dam, 1990–2023. We were unable to calculate values for Walleye, due to a lack of existing predation index model for this species. Mean and SE were calculated for each location across the time series. Years without data indicate sampling was not conducted or sample sizes were insufficient for analysis.

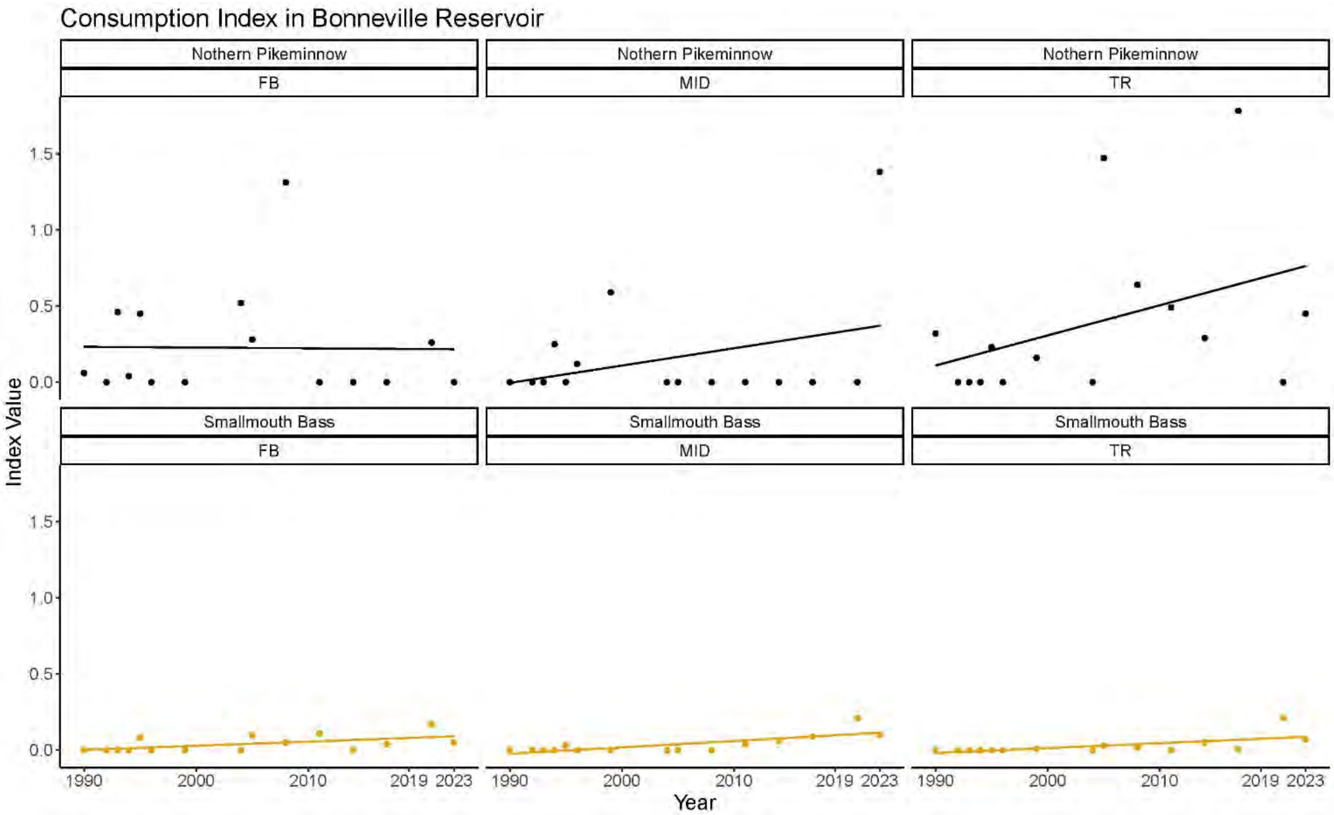

Figure 15. Annual spring consumption index values for Northern Pikeminnow (≥ 250 mm FL), and Smallmouth Bass (≥ 200 mm FL) captured during biological evaluation in Bonneville Reservoir, 1990–2023. We were unable to calculate values for Walleye, due to a lack of existing predation index model for this species. Mean and SE were calculated for each location across the time series. Years without data indicate sampling was not conducted or sample sizes were insufficient for analyses.

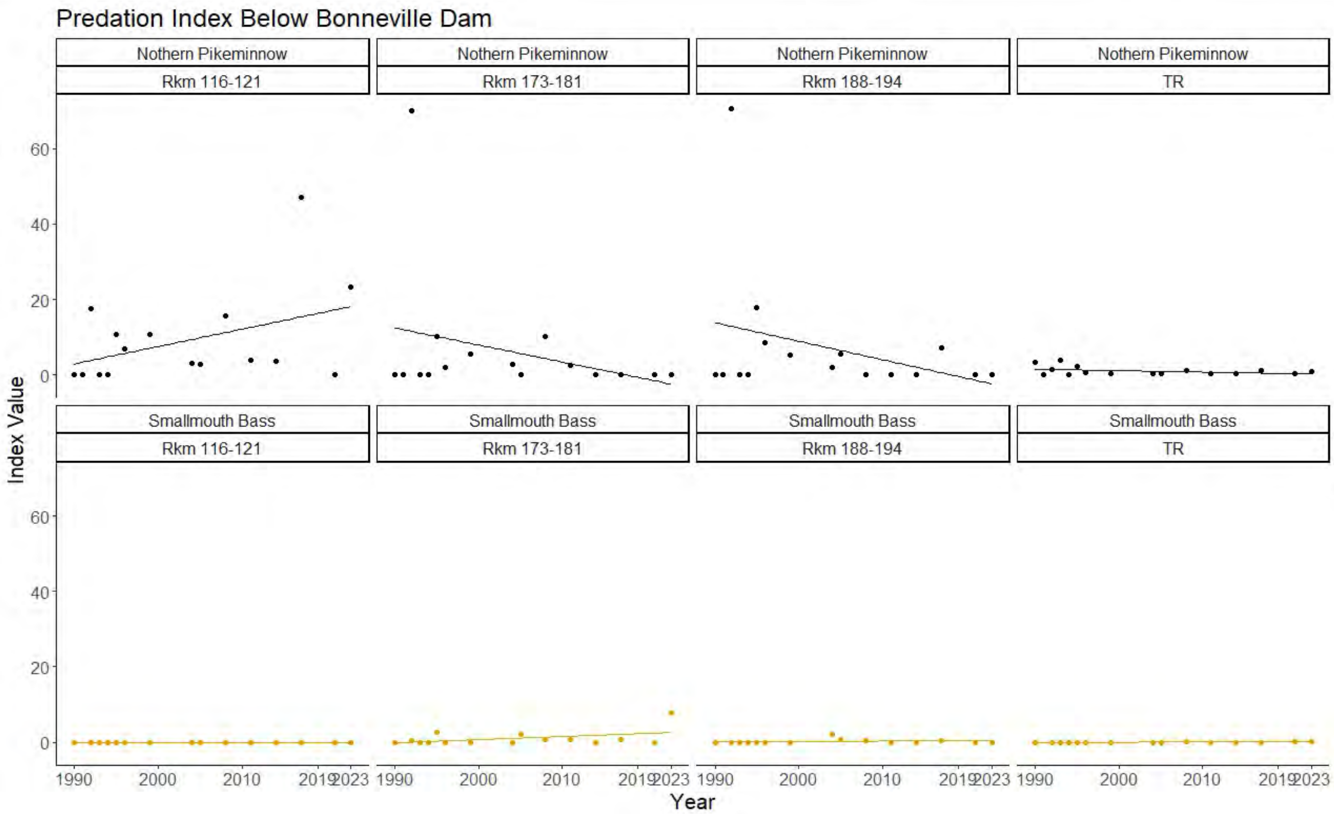

Figure 16. Annual spring predation index values for Northern Pikeminnow (≥ 250 mm FL) and Smallmouth Bass (≥ 200 mm FL) captured during biological evaluation Below Bonneville Dam, 1990–2023. We were unable to calculate values for Walleye, due to a lack of existing predation index model for this species. Mean and SE were calculated for each location across the time series. Years without data indicate sampling was not conducted or sample sizes were insufficient for analyses.

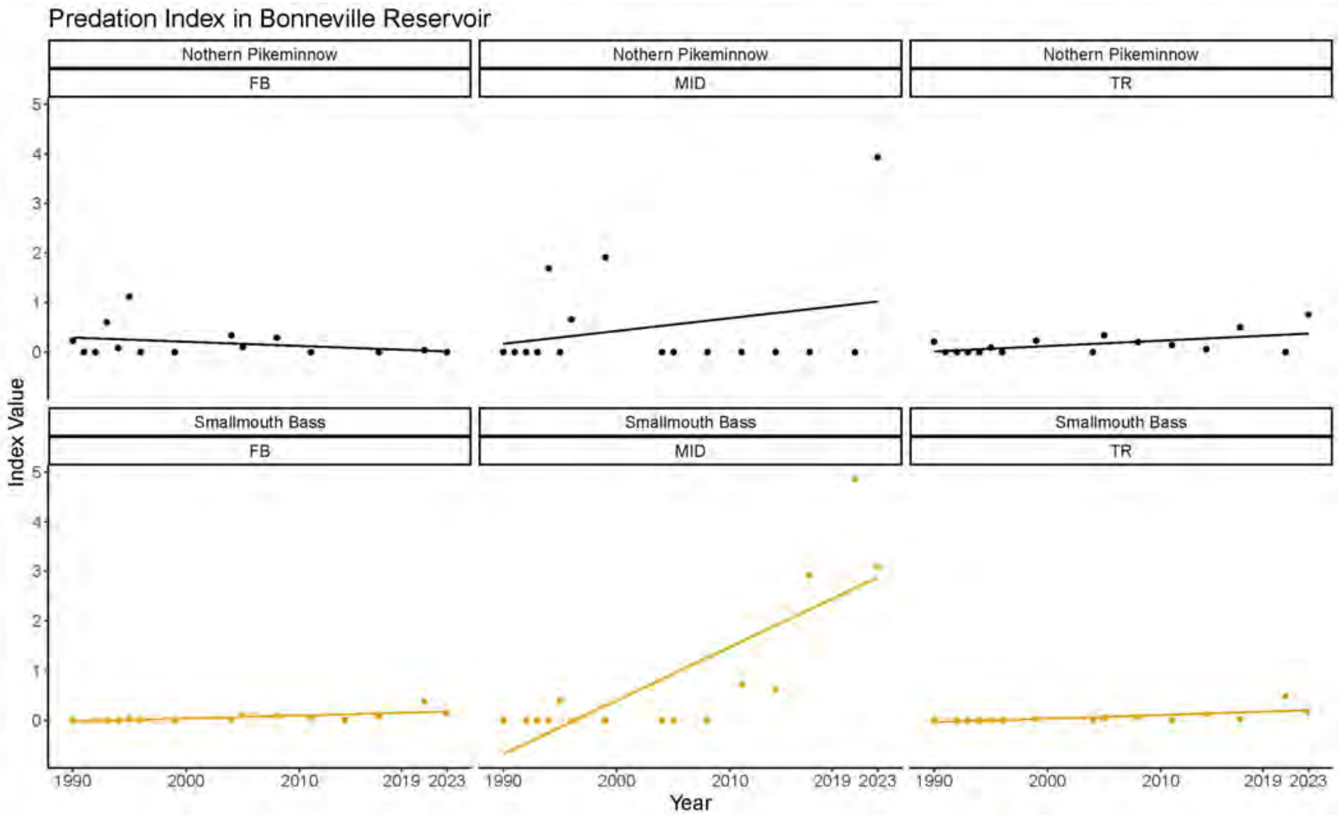

Figure 17. Annual spring predation index values for Northern Pikeminnow (≥ 250 mm FL) and Smallmouth Bass (≥ 200 mm FL) captured during biological evaluation in Bonneville Reservoir, 1990–2023. We were unable to calculate values for Walleye, due to a lack of existing predation index model for this species. Mean and SE were calculated for each location across the time series. Years without data indicate sampling was not conducted or sample sizes were insufficient for analyses.

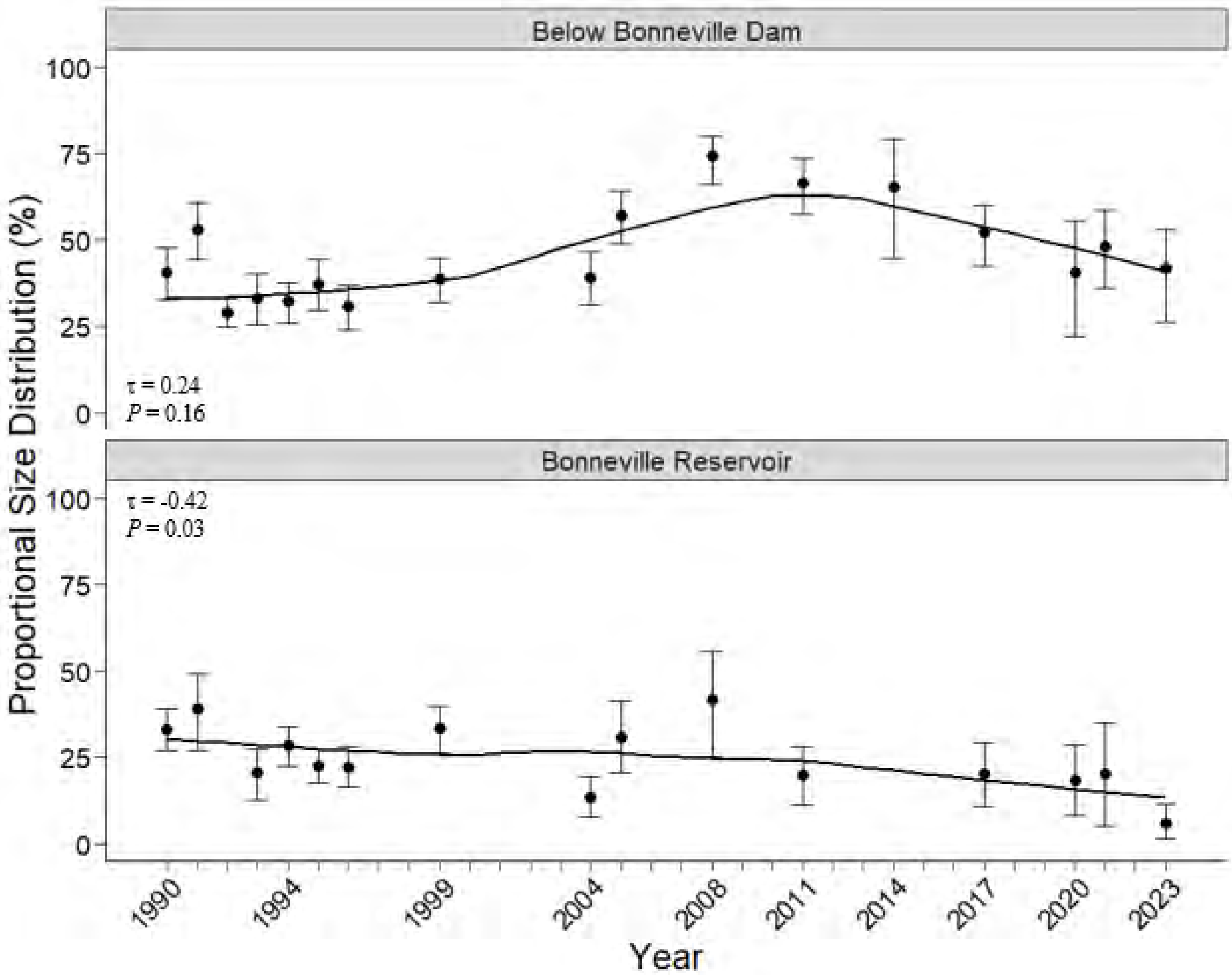

Figure 18. Estimates of proportional size distribution (PSD, %) of Northern Pikeminnow collected during biological evaluation Below Bonneville Dam and in Bonneville Reservoir, 1990–2023. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Years without data indicate sampling was not conducted or sample sizes were insufficient for analysis (n_s < 20).

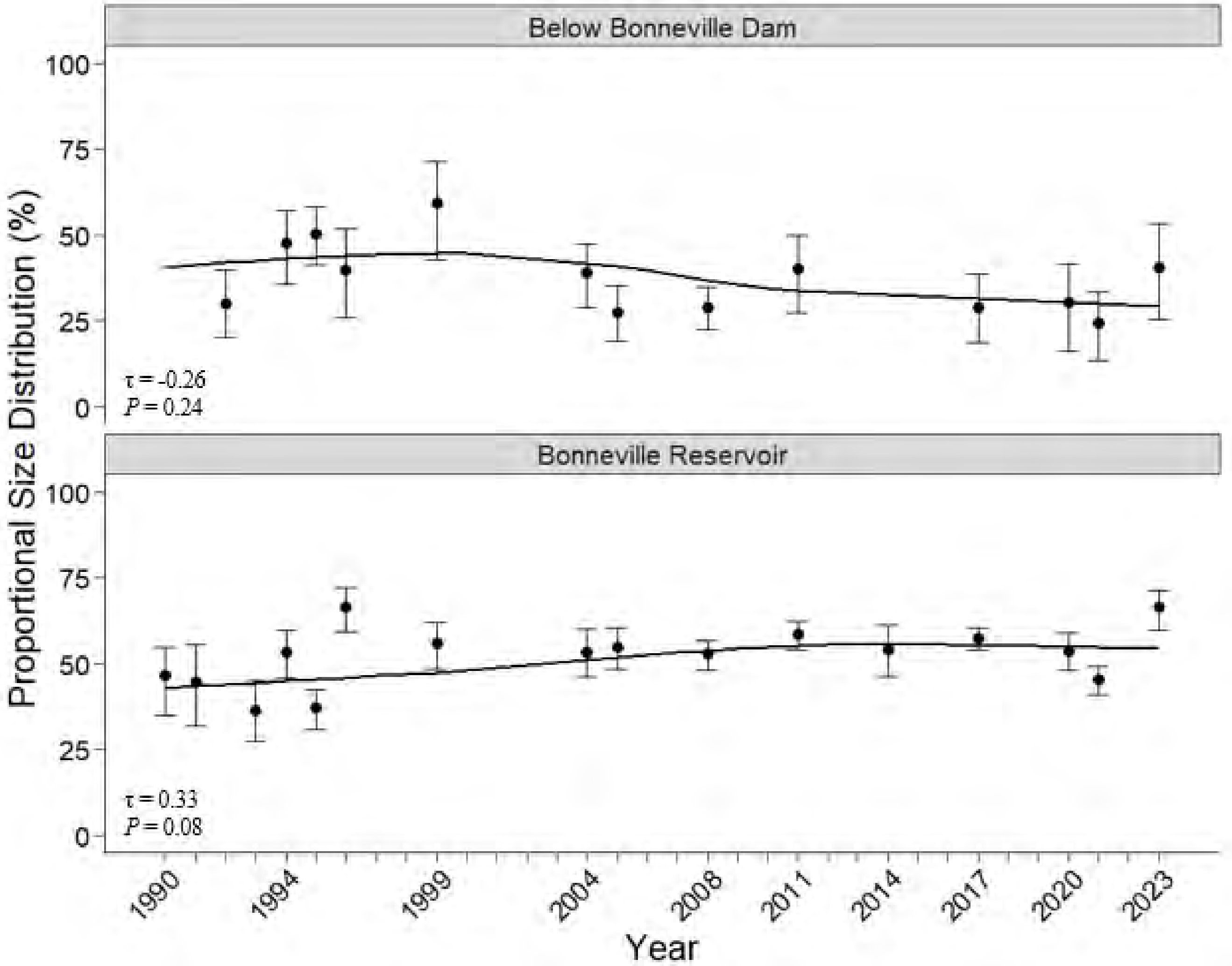

Figure 19. Estimates of proportional size distribution (PSD, %) of Smallmouth Bass collected during biological evaluation Below Bonneville Dam and in Bonneville Reservoir, 1990–2023. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Years without data indicate sampling was not conducted or sample sizes were insufficient for analysis (n_s < 20).

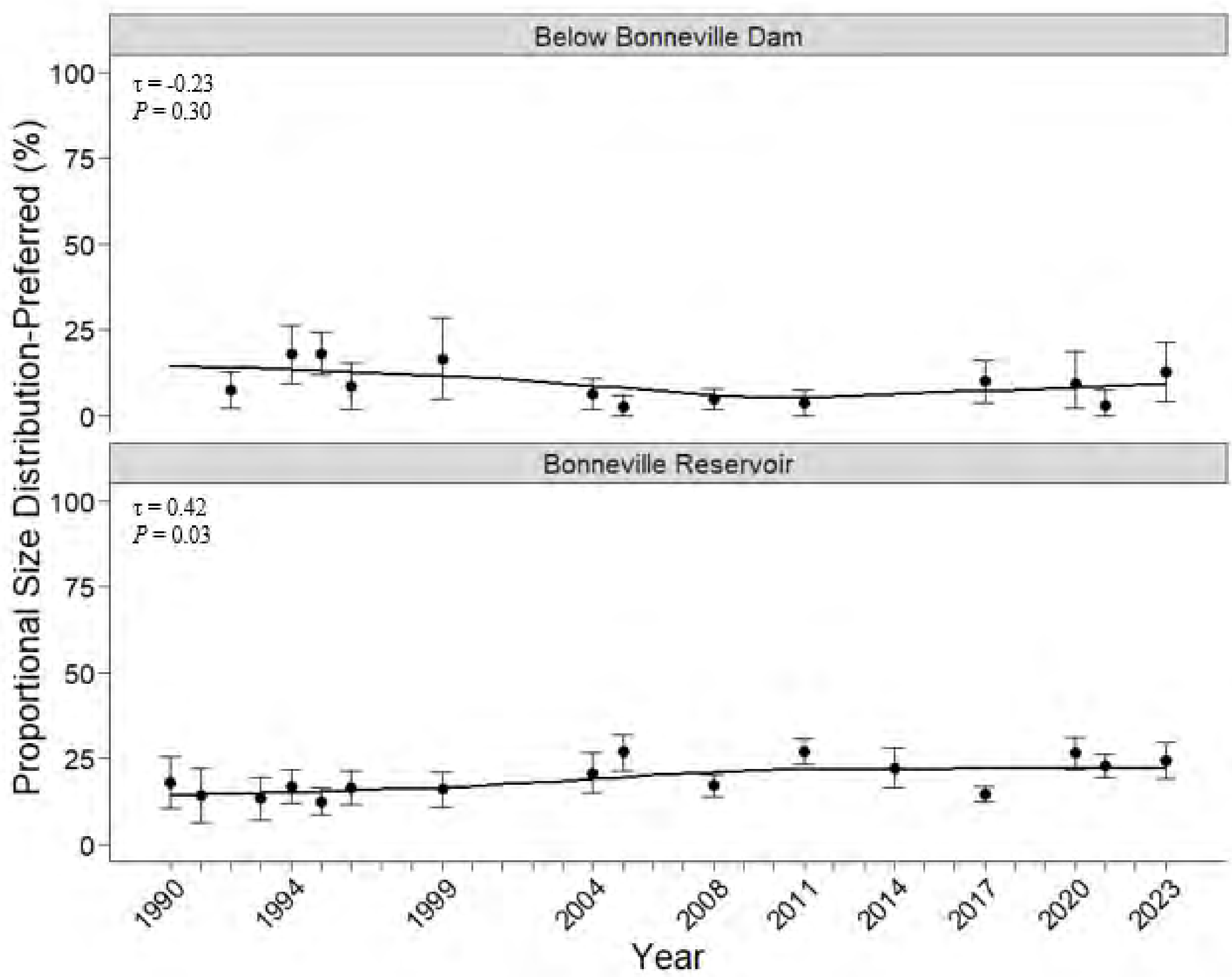

Figure 20. Estimates of proportional size distribution of preferred-length (PSD – P, %) Smallmouth Bass collected during biological evaluation Below Bonneville Dam and in Bonneville Reservoir, 1990–2023. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Years without data indicate sampling was not conducted or sample sizes were insufficient for analysis (n_s < 20).

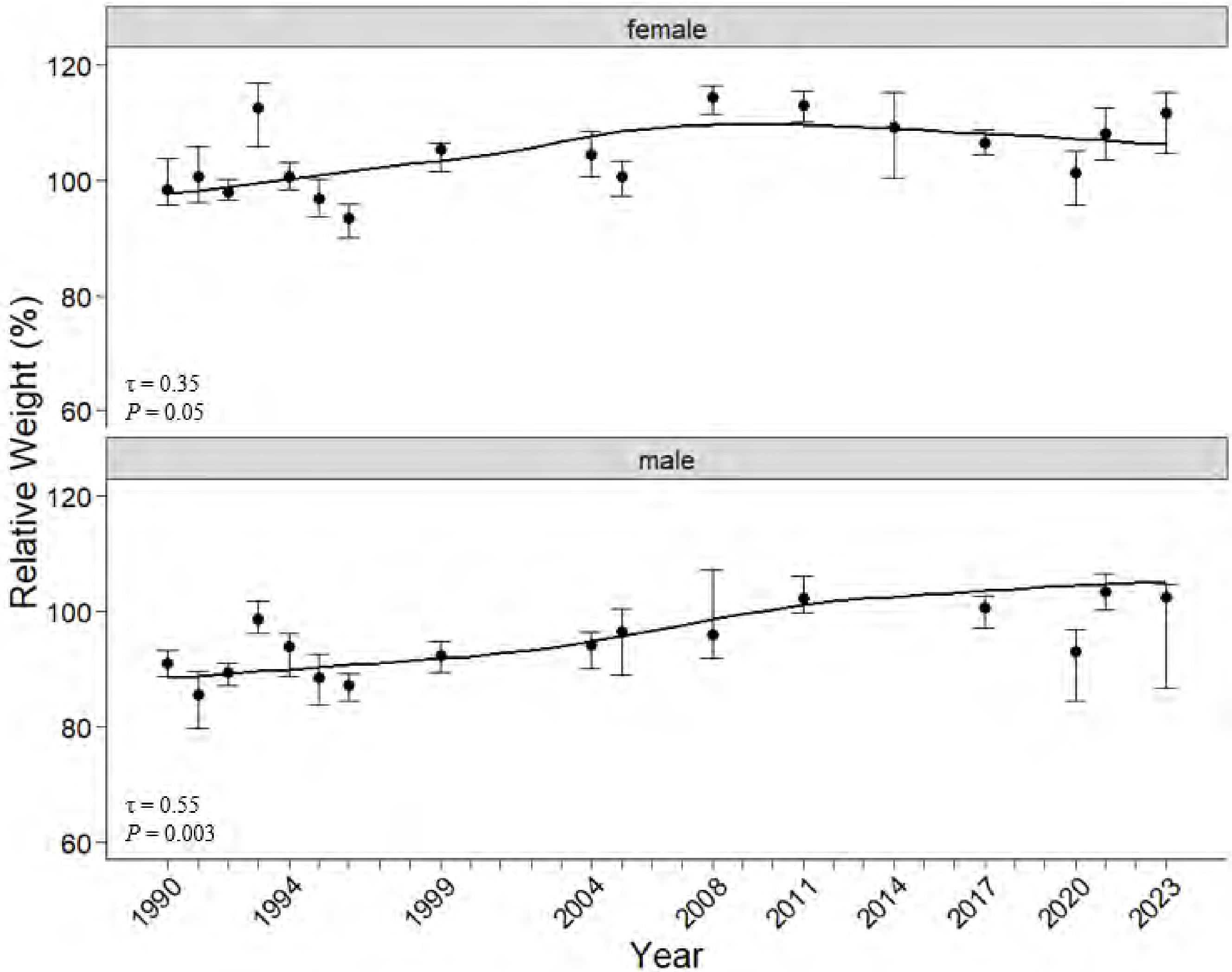

Figure 21. Median relative weight (Wr, %) of Northern Pikeminnow collected during biological evaluation Below Bonneville Dam, 1990–2023. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years without data indicate that sampling was not conducted, or sample sizes were insufficient for analyses (n < 5).

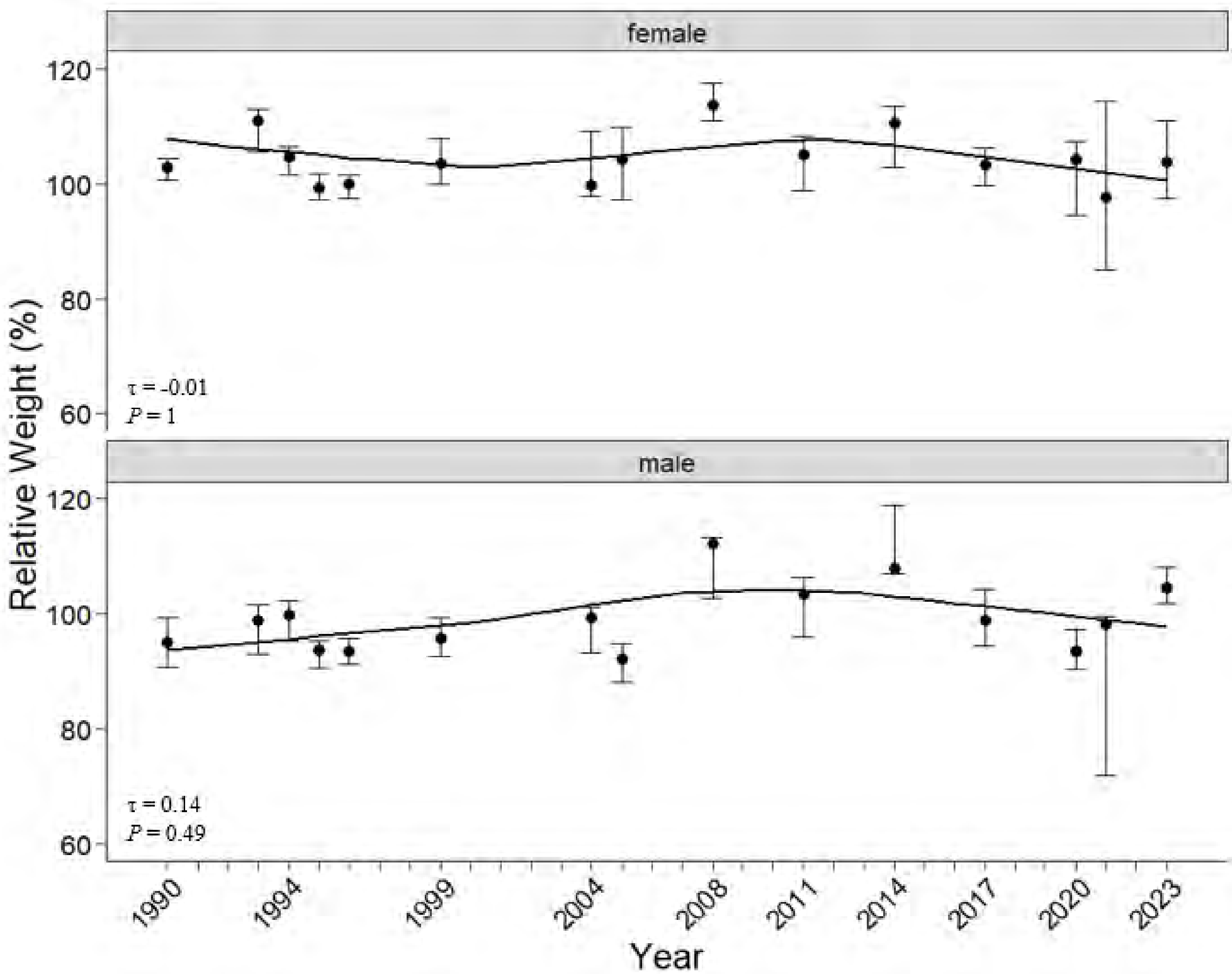

Figure 22. Median relative weight (Wr, %) of Northern Pikeminnow collected during biological evaluation in Bonneville Reservoir, 1990–2023. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic trend are presented for each time-series. Years without data indicate that sampling was not conducted, or sample sizes were insufficient for analyses (n < 5).

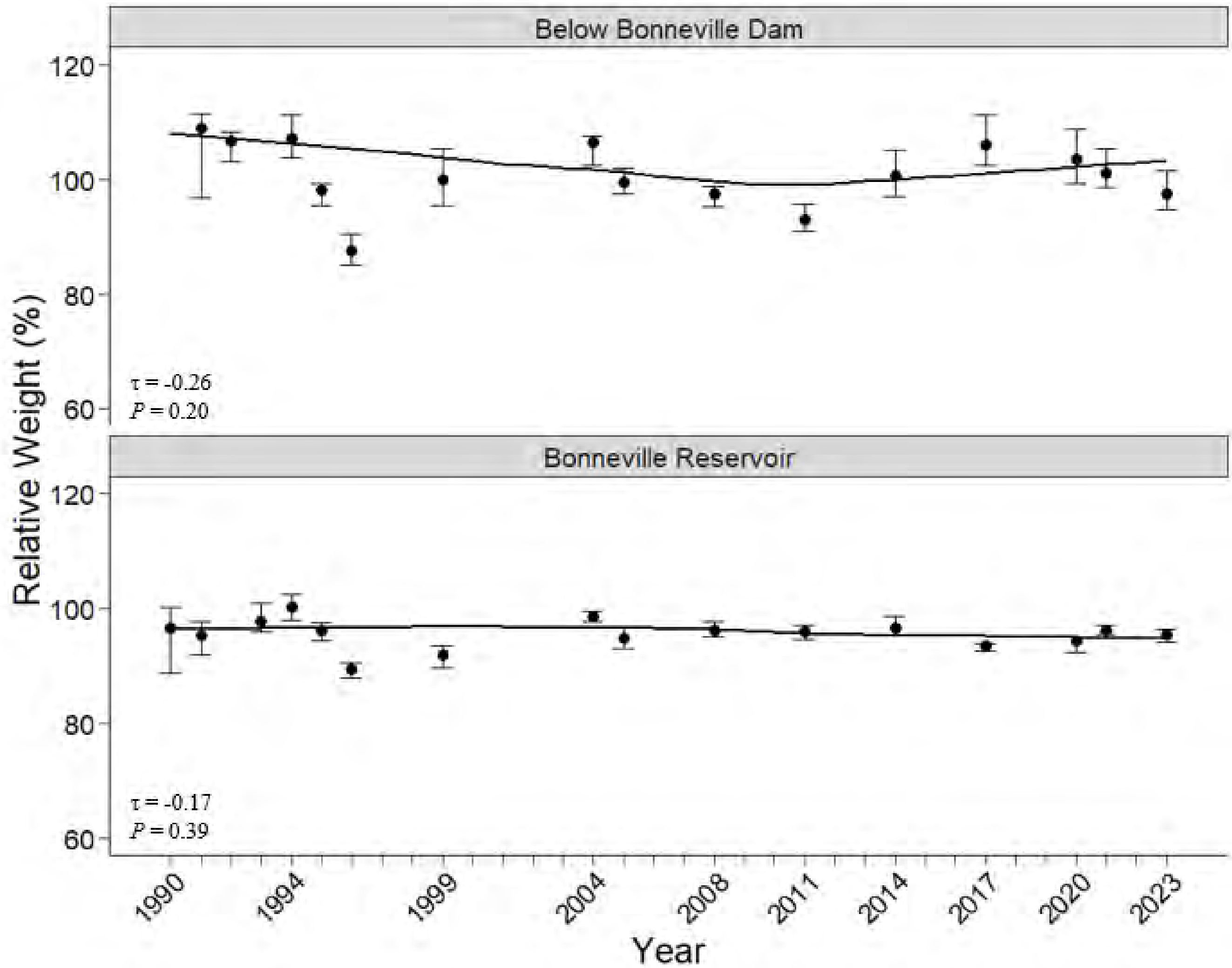

Figure 23. Median relative weight (Wr, %) of Smallmouth Bass collected during biological evaluation Below Bonneville Dam and in Bonneville Reservoir, 1990–2023. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic 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).

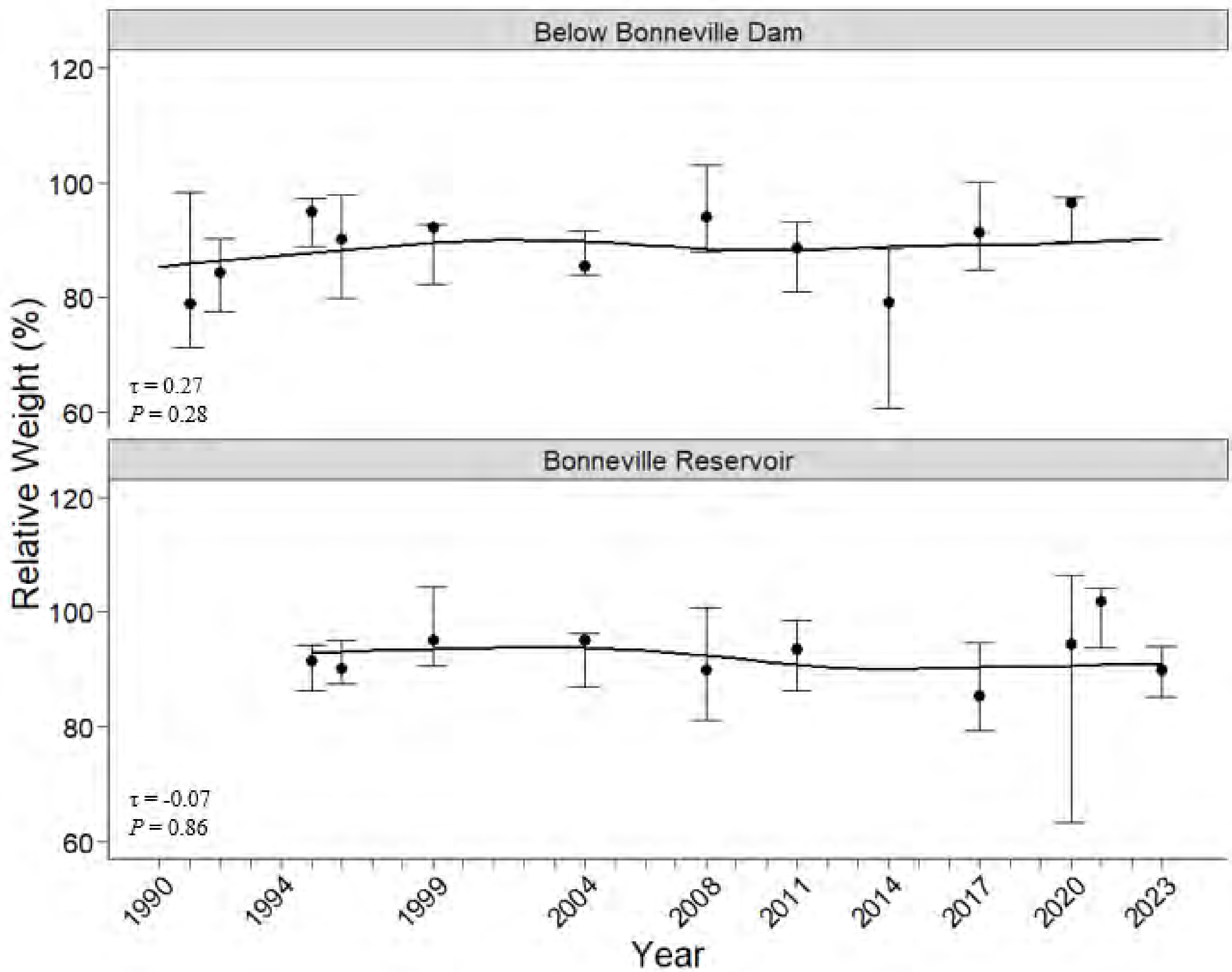

Figure 24. Median relative weight (Wr, %) of Walleye collected during biological evaluation Below Bonneville Dam and in Bonneville Reservoir, 1990–2023. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from a Mann-Kendall test of monotonic 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).

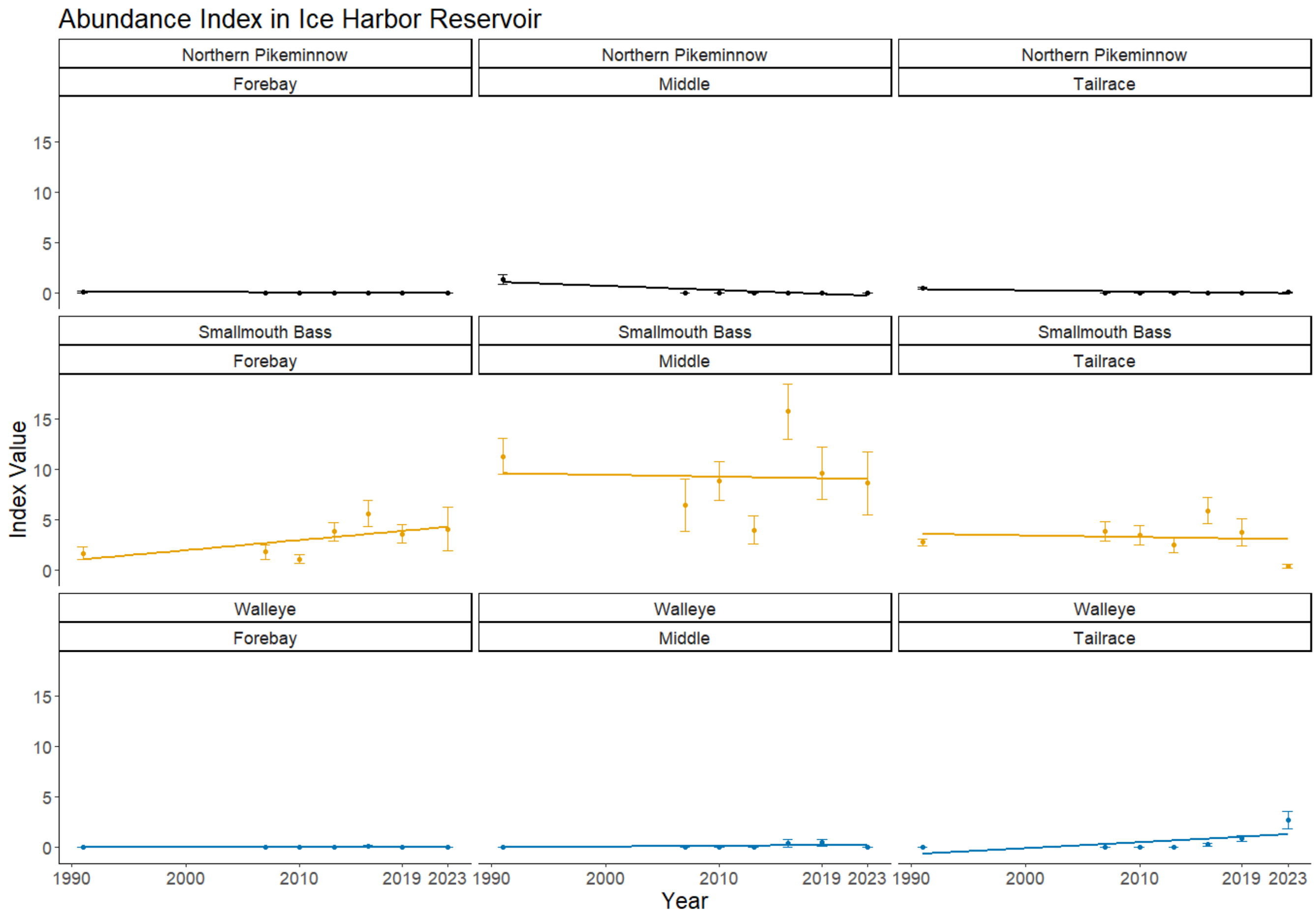

Figure 25. Spring abundance index values (mean catch per 900-s boat electrofishing scaled to surface area [ha] divided by 1,000; and SE) for Northern Pikeminnow (≥ 250 mm FL), Smallmouth Bass (≥ 200 mm FL), and Walleye (≥ 200 mm FL) in Ice Harbor Reservoir, 1990–2023. Years without data indicate sampling was not conducted or sample sizes were insufficient for analyses. No sampling was conducted in Ice Harbor from 1992–2006.

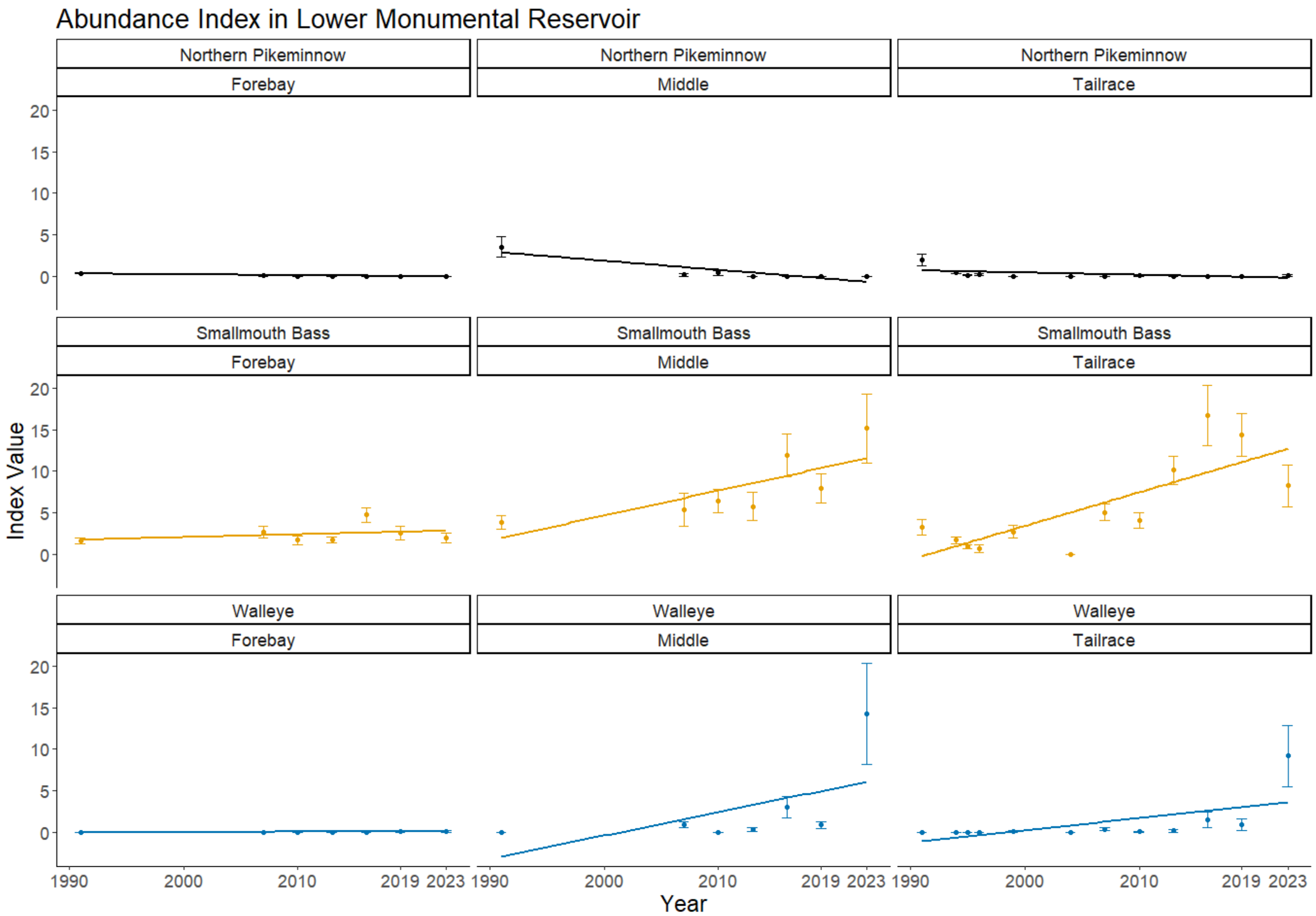

Figure 26. Spring abundance index values (mean catch per 900-s boat electrofishing scaled to surface area [ha] divided by 1,000; and SE) for Northern Pikeminnow (≥ 250 mm FL), Smallmouth Bass (≥ 200 mm FL), and Walleye (≥ 200 mm FL) in Lower Monumental Reservoir, 1990–2023. Years without data indicate sampling was not conducted or sample sizes were insufficient for analyses.

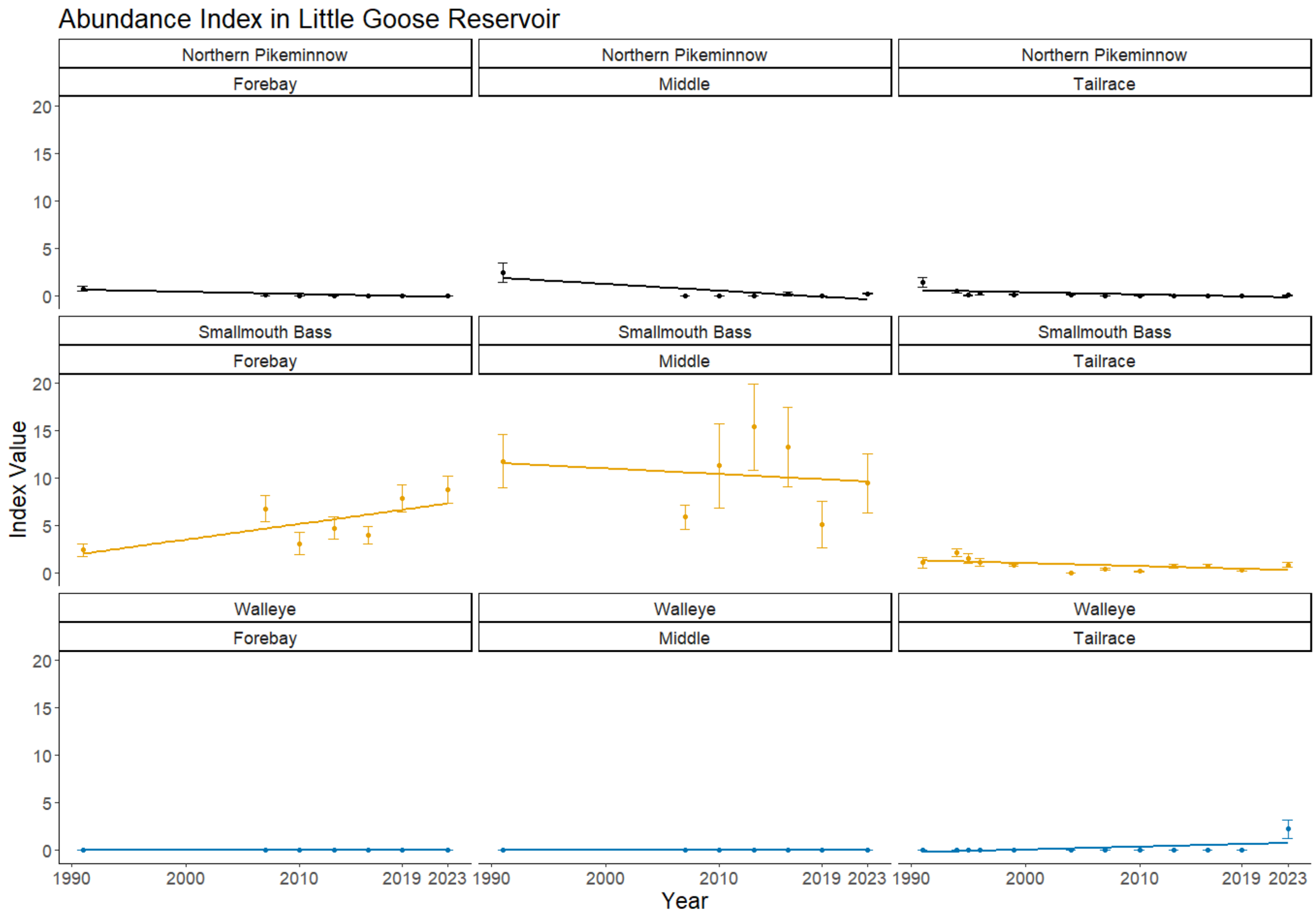

Figure 27. Spring abundance index values (mean catch per 900-s boat electrofishing scaled to surface area [ha] divided by 1,000; and SE) for Northern Pikeminnow (≥ 250 mm FL), Smallmouth Bass (≥ 200 mm FL), and Walleye (≥ 200 mm FL) in Little Goose Reservoir, 1990–2023. Years without data indicate sampling was not conducted or sample sizes were insufficient for analyses.

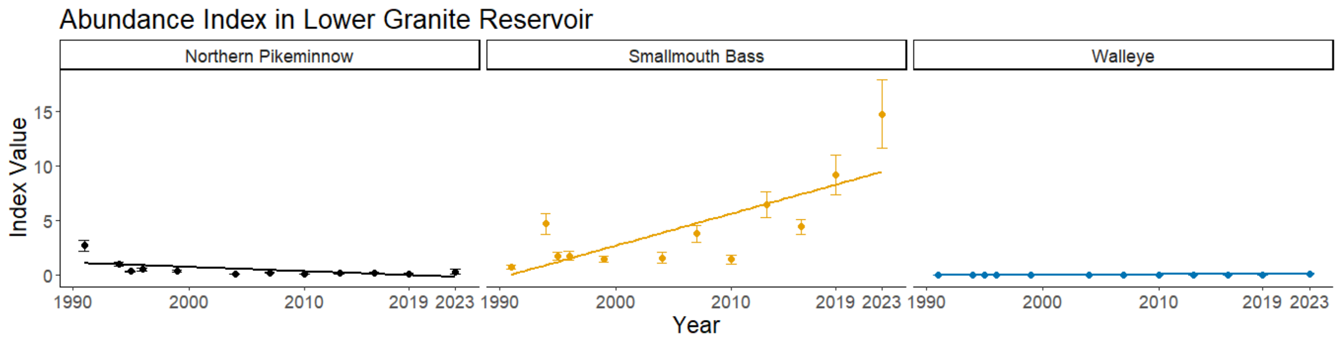

Figure 28. Spring abundance index values (mean catch per 900-s boat electrofishing scaled to surface area [ha] divided by 1,000; and SE) for Northern Pikeminnow (≥ 250 mm FL), Smallmouth Bass (≥ 200 mm FL), and Walleye (≥ 200 mm FL) in Lower Granite Reservoir, 1990–2023. Years without data indicate sampling was not conducted or sample sizes were insufficient for analyses.

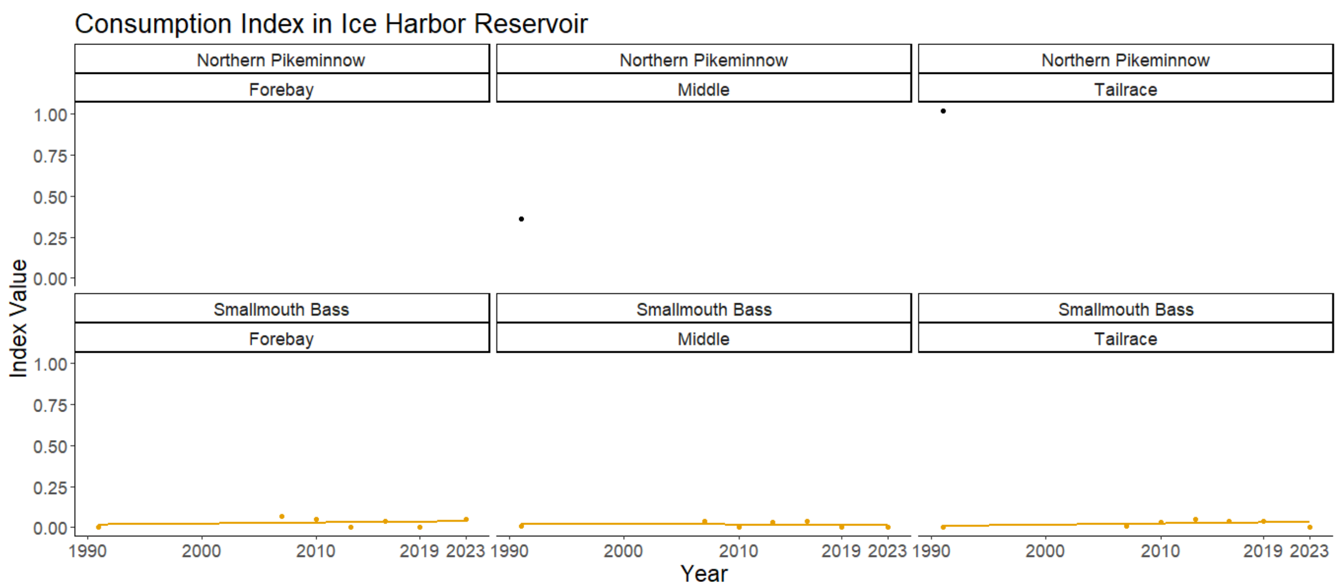

Figure 29. Annual spring consumption index values for Northern Pikeminnow (≥ 250 mm FL), and Smallmouth Bass (≥ 200 mm FL) captured during biological evaluation in Ice Harbor Reservoir, 1990–2023. Mean and SE were calculated for each location across the time series. We were unable to calculate values for Walleye, due to a lack of existing predation index model for this species. Years without data indicate sampling was not conducted or sample sizes were insufficient for analyses. No sampling was conducted in Ice Harbor from 1992–2006.

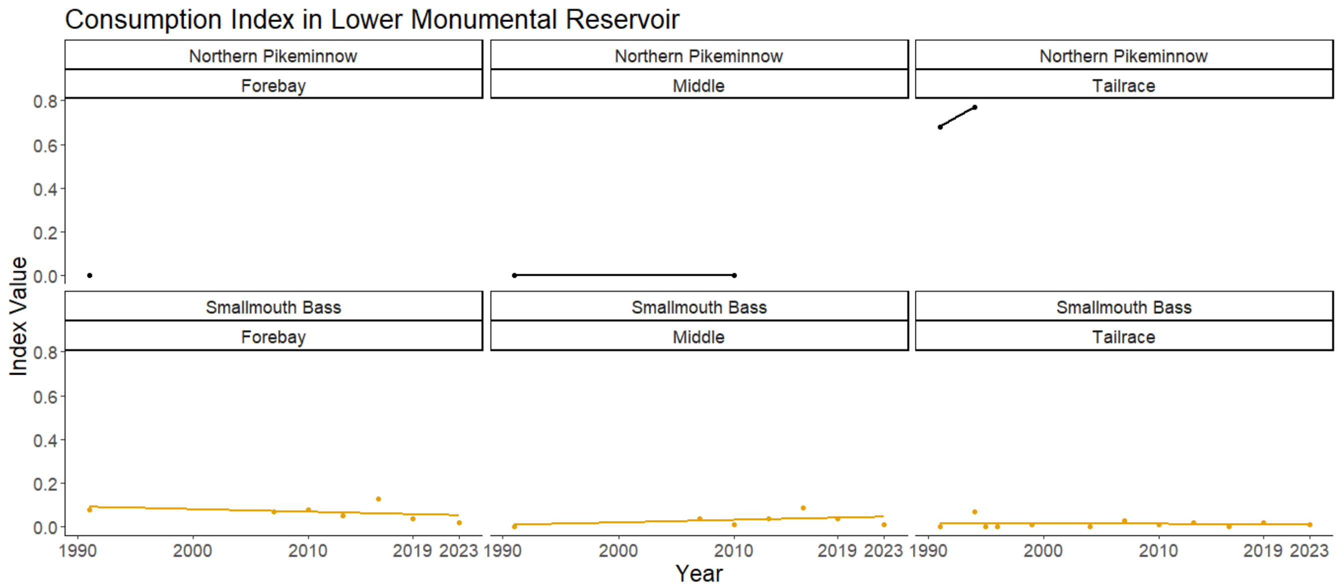

Figure 30. Annual spring consumption index values for Northern Pikeminnow (≥ 250 mm FL), and Smallmouth Bass (≥ 200 mm FL) captured during biological evaluation in Lower Monumental Reservoir, 1990–2023. We were unable to calculate values for Walleye, due to a lack of existing predation index model for this species. Mean and SE were calculated for each location across the time series. Years without data indicate sampling was not conducted or sample sizes were insufficient for analyses.

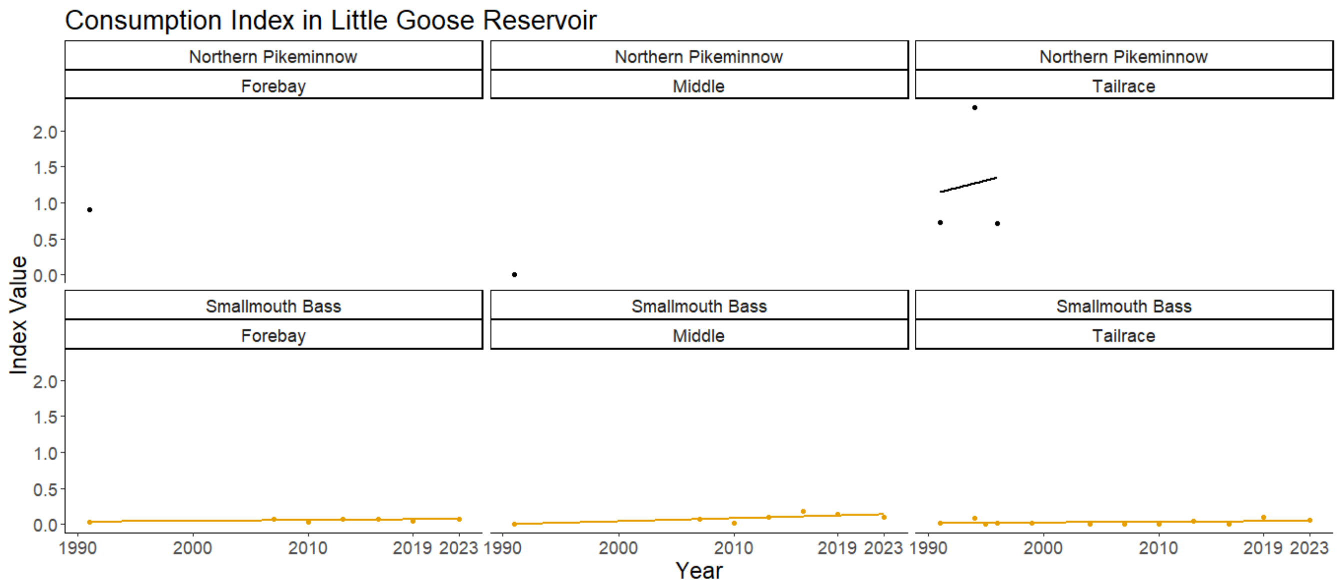

Figure 31. Annual spring consumption index values for Northern Pikeminnow (≥ 250 mm FL), and Smallmouth Bass (≥ 200 mm FL) captured during biological evaluation in Little Goose Reservoir, 1990–2023. Mean and SE were calculated for each location across the time series. We were unable to calculate values for Walleye, due to a lack of existing predation index model for this species. Years without data indicate sampling was not conducted or sample sizes were insufficient for analyses.

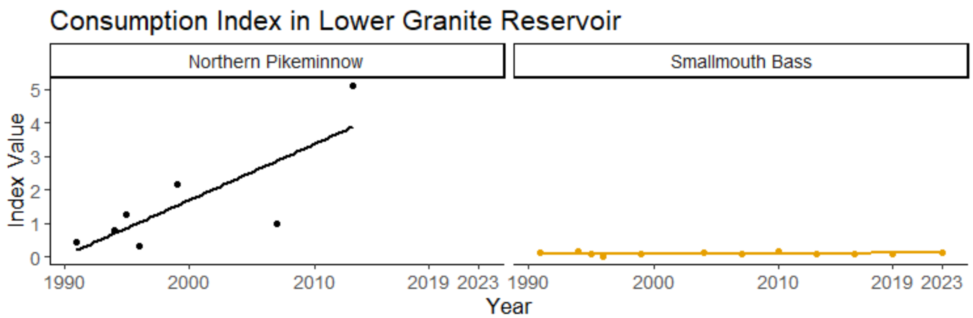

Figure 32. Annual spring consumption index values for Northern Pikeminnow (≥ 250 mm FL), and Smallmouth Bass (≥ 200 mm FL) captured during biological evaluation in the mid river section of Lower Granite Reservoir, 1990–2023. Mean and SE were calculated for each location across the time series. We were unable to calculate values for Walleye, due to a lack of existing predation index model for this species. Years without data indicate sampling was not conducted or sample sizes were insufficient for analyses.

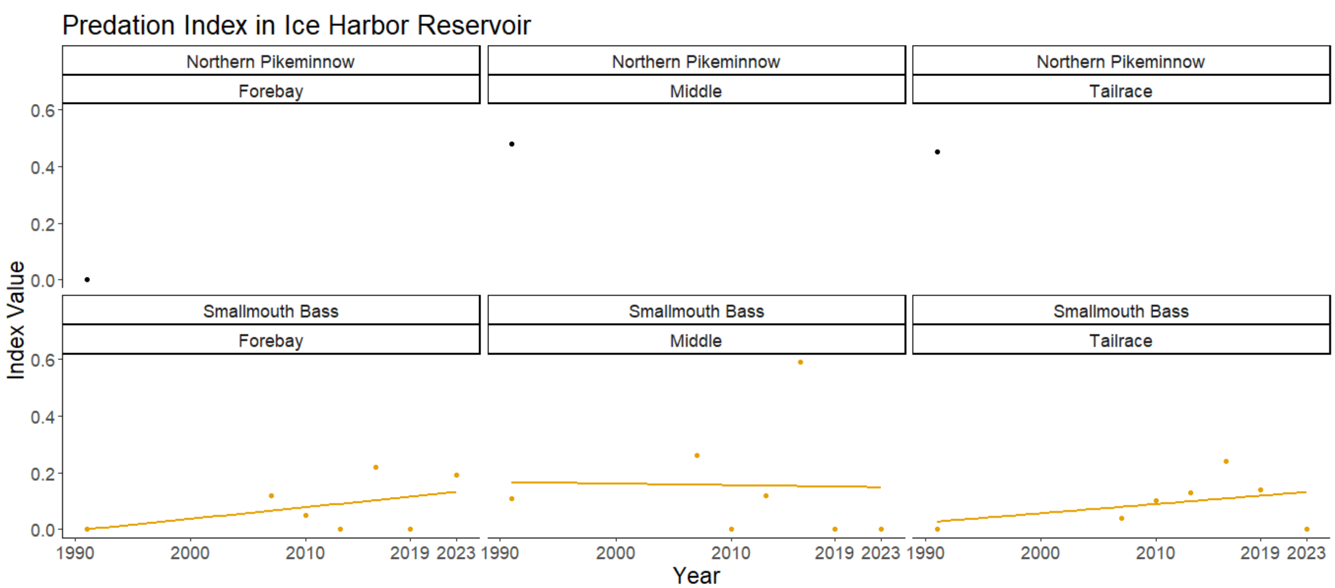

Figure 33. Annual spring predation index values for Northern Pikeminnow (≥ 250 mm FL) and Smallmouth Bass (≥ 200 mm FL) captured during biological evaluation in Ice Harbor Reservoir, 1990–2023. We were unable to calculate values for Walleye, due to a lack of existing predation index model for this species. Mean and SE were calculated for each location across the time series. Years without data indicate sampling was not conducted or sample sizes were insufficient for analyses. No sampling was conducted in Ice Harbor from 1992–2006.

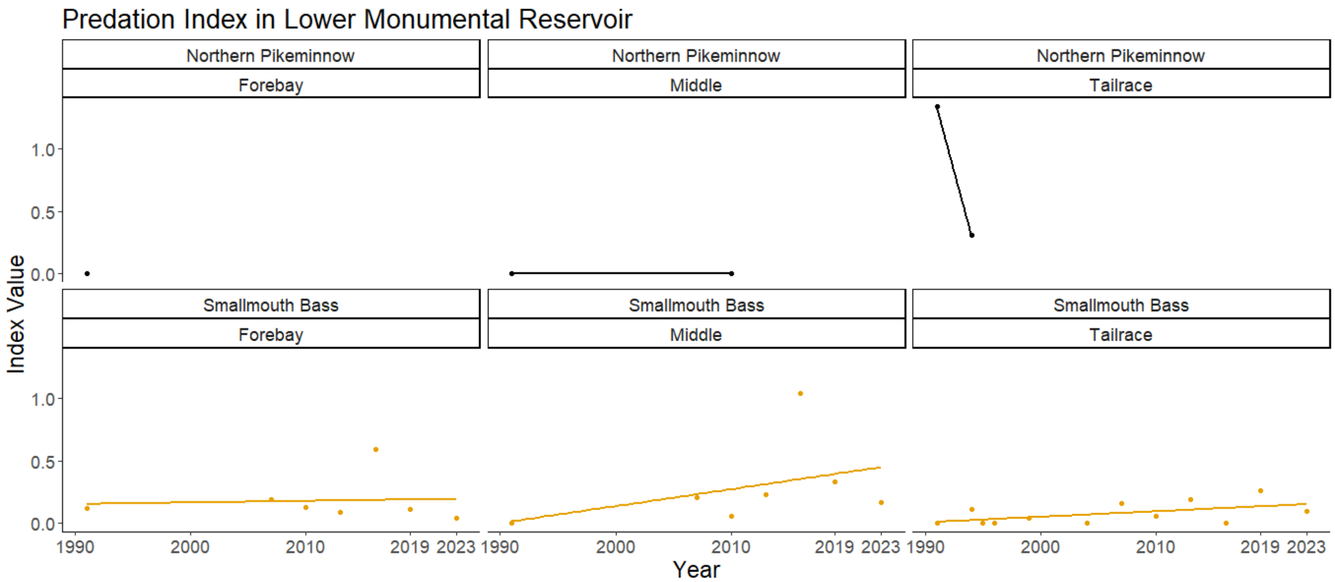

Figure 34. Annual spring predation index values for Northern Pikeminnow (≥ 250 mm FL) and Smallmouth Bass (≥ 200 mm FL) captured during biological evaluation in Lower Monumental Reservoir, 1990–2023. We were unable to calculate values for Walleye, due to a lack of existing predation index model for this species. Mean and SE were calculated for each location across the time series. Years without data indicate sampling was not conducted or sample sizes were insufficient for analyses.

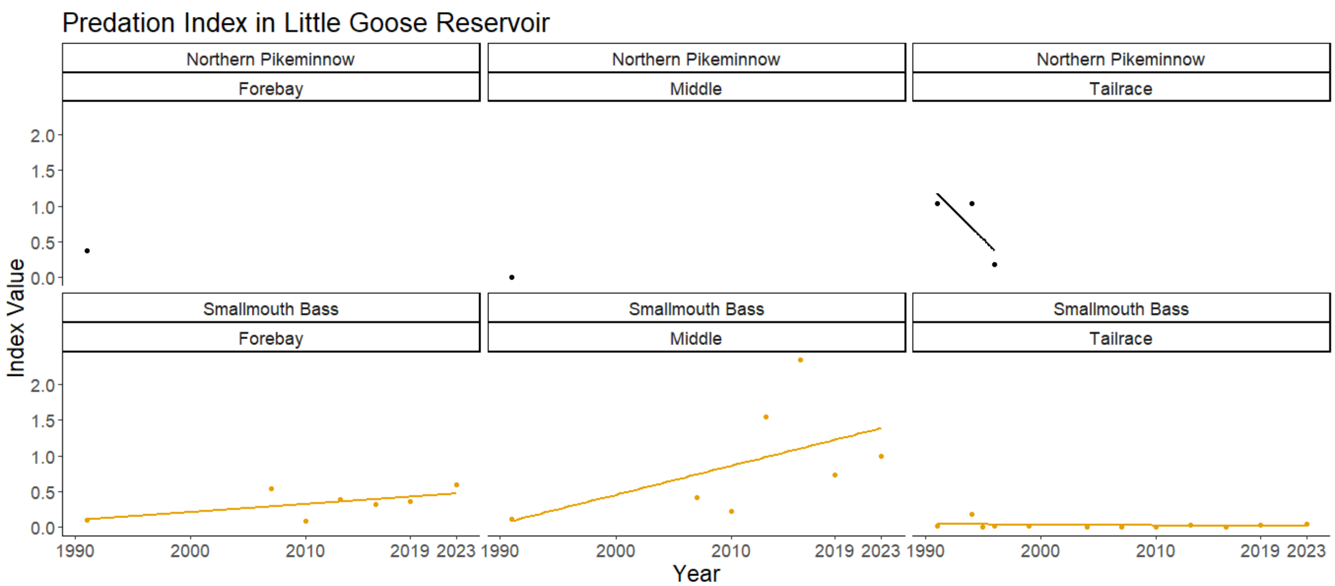

Figure 35. Annual spring predation index values for Northern Pikeminnow (≥ 250 mm FL) and Smallmouth Bass (≥ 200 mm FL) captured during biological evaluation in Little Goose Reservoir, 1990–2023. We were unable to calculate values for Walleye, due to a lack of existing predation index model for this species. Mean and SE were calculated for each location across the time series. Years without data indicate sampling was not conducted or sample sizes were insufficient for analyses.

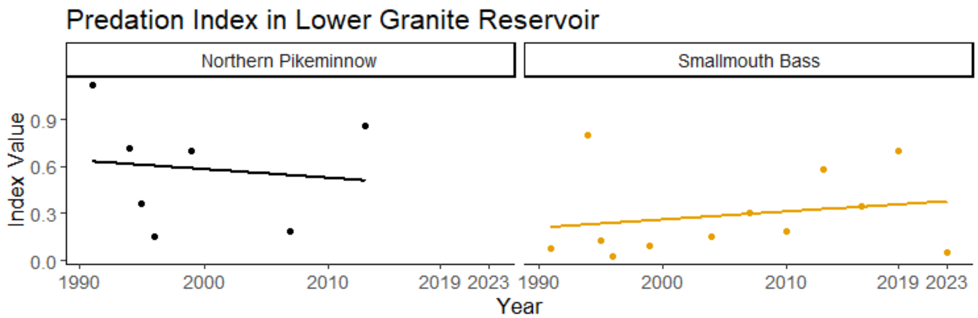

Figure 36. Annual spring predation index values for Northern Pikeminnow (≥ 250 mm FL) and Smallmouth Bass (≥ 200 mm FL) captured during biological evaluation in the mid-river section of Lower Granite Reservoir, 1990–2023. We were unable to calculate values for Walleye, due to a lack of existing predation index model for this species. Mean and SE were calculated for each location across the time series. Years without data indicate sampling was not conducted or sample sizes were insufficient for analyses.

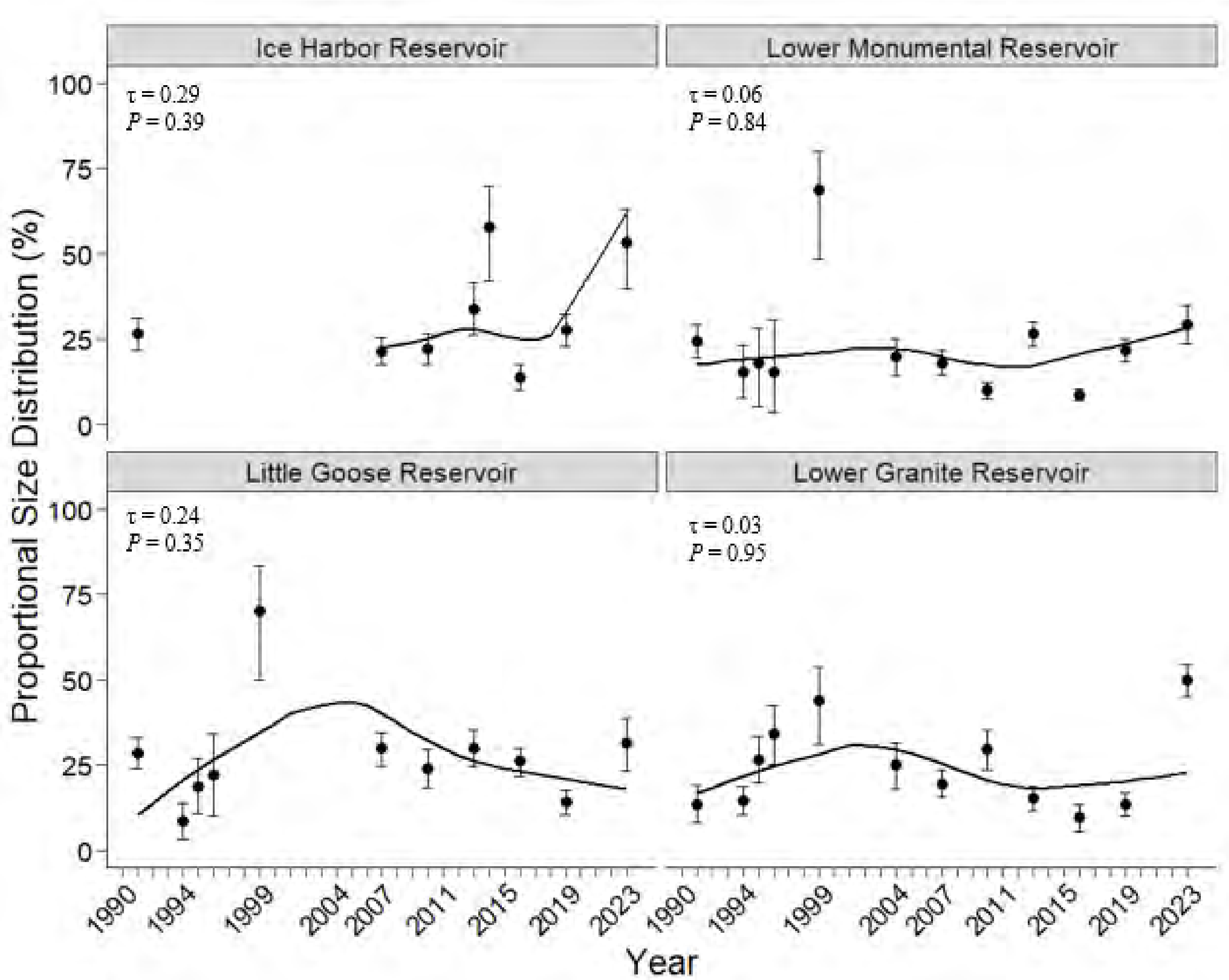

Figure 37. Estimates of proportional size distribution (PSD, %) of Smallmouth Bass collected during biological evaluation in Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Reservoirs, 1990–2023. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Years without data indicate sampling was not conducted or sample sizes were insufficient for analysis (n_s < 20). No sampling was conducted in Ice Harbor from 1992–2006.

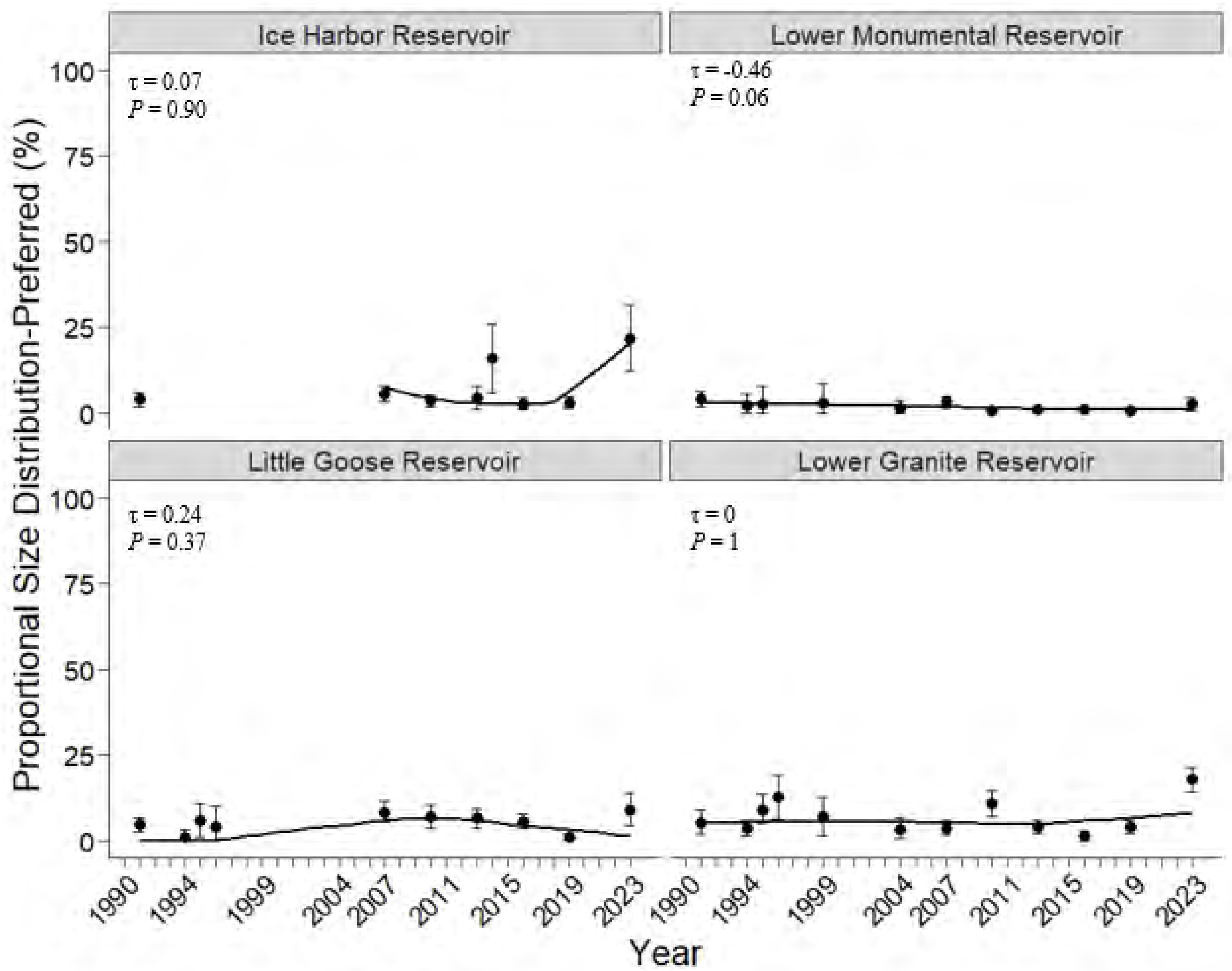

Figure 38. Estimates of proportional size distribution of preferred-length (PSD – P, %) of Smallmouth Bass collected during biological evaluation in Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Reservoirs, 1990–2023. Error bars represent 95% bootstrap confidence intervals. Data are fit with LOWESS curves. Years without data indicate sampling was not conducted or sample sizes were insufficient for analysis (n_s < 20). No sampling was conducted in Ice Harbor from 1992–2006.

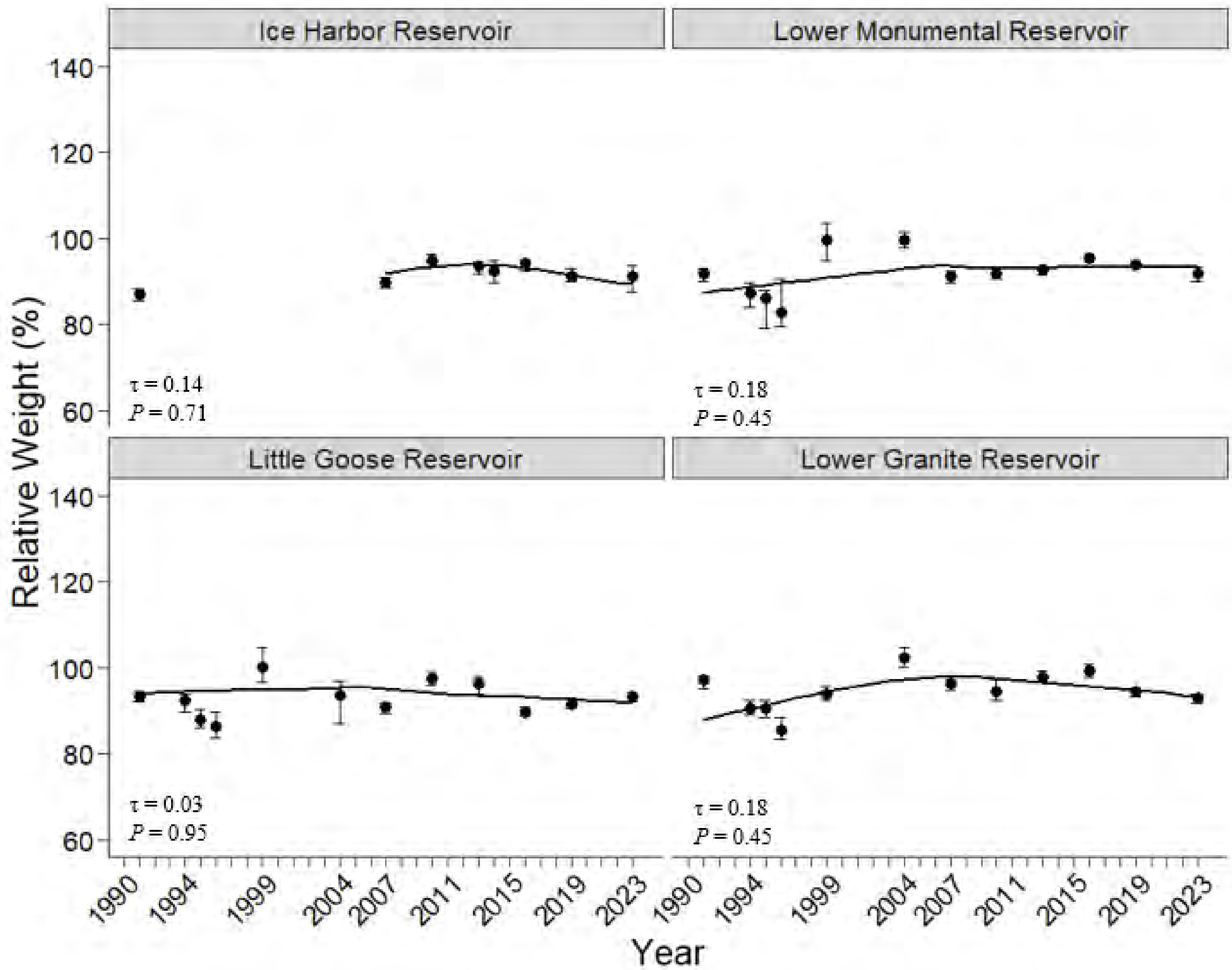

Figure 39. Median relative weight (Wr, %) of Smallmouth Bass collected during biological evaluation in Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Reservoirs, 1990–2023. Error bars represent 95% bootstrap (percentile) confidence intervals. Data are fit with LOWESS curves. Results from 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). No sampling was conducted in Ice Harbor from 1992–2006.

Northern Pikeminnow Dam Angling on the Columbia River

2023 Annual Report

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ACKNOWLEDGEMENTS

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We appreciate the efforts of Kyle Beckley as the Pikeminnow Dam Angling crew leader, along with Steve Lines, Benjamin Veysey and Cooper Sargent who served as our 2023 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 2023 season.

ABSTRACT

We are reporting on the 2023 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 21 weeks from May 8th through October 12th 2023. The objectives of this project were to (1) implement a recreational-type hook and line fishery harvesting Northern Pikeminnow from within the boat restricted zones (BRZs), where angling is unavailable to the public at The Dalles and John Day dams, (2) allocate Dam Angler effort between The Dalles and John Day dams based on Dam Angler CPUE in order to maximize harvest of Northern Pikeminnow, (3) collect, compile and report data on Dam Angler harvest, CPUE, gear/techniques and incidental catch for each project, (4) scan, record and report Passive Integrated Transponder (PIT) tag data from all Northern Pikeminnow, Smallmouth Bass, Walleye, and Channel Catfish caught by the Dam Angling crew and record with the presence of any external spaghetti tags, fin-clips, or signs of tag-loss from these fishes for use in coordination with other predation studies, (5) collect relevant biological data on all Northern Pikeminnow and other fishes caught by the 2023 Dam Angling crew.

A Dam Angling crew of four anglers harvested a total of 2,946 Northern Pikeminnow during the 2023 season. Of those, 2,497 Northern Pikeminnow were harvested at The Dalles Dam and 449 were harvested at the John Day Dam. The crew fished a total of 1,150.3 hours during the 21 week fishery, averaging 140 fish per week and for a combined overall average catch per angler hour (CPUE) of 2.6 Northern Pikeminnow. At The Dalles Dam, the crew averaged 2.9 fish per angler hour, and cumulatively 35.2 Northern Pikeminnow per day. At the John Day Dam, the crew averaged 1.6 fish per angler hour with a cumulative crew total of 9.2 fish per day.

Based on the previous success of the WDFW Dam Angling Crew in implementing the Dam Angling component of the NPMP from 2010-22, the 2023 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 by the Dam Angling crew in 2023 were Smallmouth Bass *Micropterus dolomieue* and Walleye *Sander vitreus.*

INTRODUCTION

Mortality of juvenile salmonids *Oncorhynchus spp.* migrating through the Columbia River system is a major concern of the Columbia Basin Fish and Wildlife Program, and predation is an important component of mortality (Northwest Power Planning Council 1987a). Northern Pikeminnow *Ptychocheilus oregonensis*, formerly known as northern squawfish (Nelson et al. 1998), are the primary piscine predator of juvenile salmonids in the Lower Columbia and Snake River Systems (Rieman et al. 1991). Rieman and Beamesderfer (1990) predicted that predation on juvenile salmonids could be reduced by up to 50% with a sustained exploitation rate of 10-20% on Northern Pikeminnow ≥ 275 mm FL (11 inches total length). The Northern Pikeminnow Management Program (NPMP) was created in 1990, with the goal of implementing fisheries to achieve the recommended 10-20% annual exploitation on Northern Pikeminnow ≥275 mm FL within the program area (Vigg and Burley 1989). The primary component of the NPMP is the Northern Pikeminnow Sport-Reward Fishery (NPSRF) implemented by the Washington Department of Fish and Wildlife (WDFW) (Burley et al. 1992). Beginning in 2010, WDFW was also contracted to conduct the Dam Angling component of the NPMP (Hone et al. 2011) and 2023 marked the 14th 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 2023.

The objectives of the 2023 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 2023 Dam Angling crew.

METHODS

Project Area

In 2023, 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 2023 were planned to occur during an approximately five-month season scheduled to run from May through September. All angling activities at both The Dalles, and John Day Dams were conducted within the tailrace BRZs where no public angling was permitted. For The Dalles Dam, the Dam Angling crew fished primarily along the turbine deck (Figure 2), and at the John Day Dam, the crew fished exclusively along the turbine deck (Figure 3).

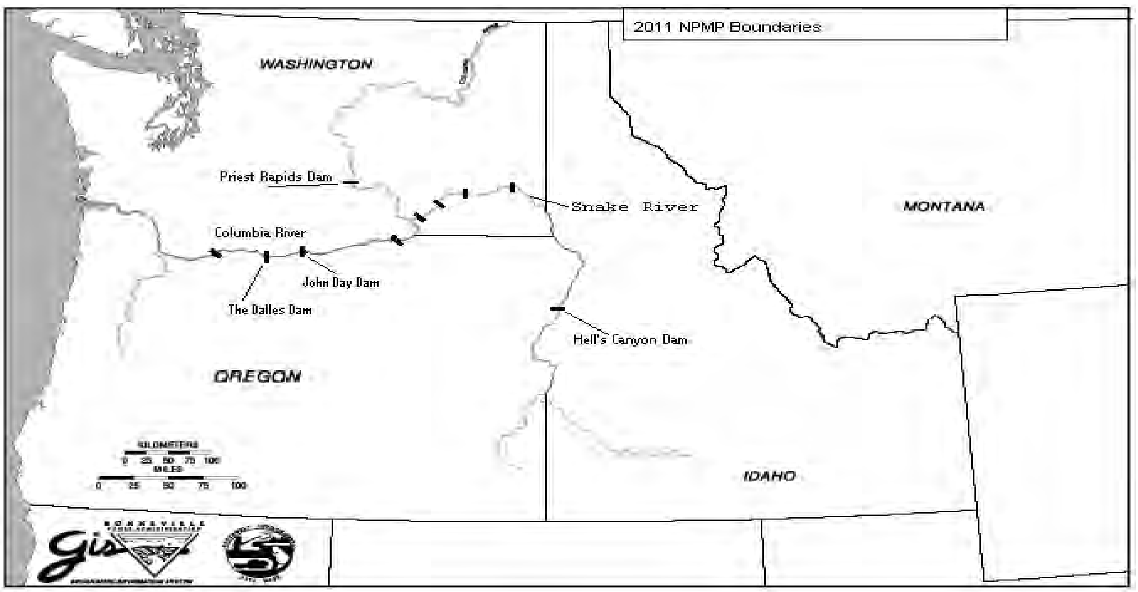

Figure 1. Northern Pikeminnow Management Program boundaries, including 2023 Dam Angling sites.

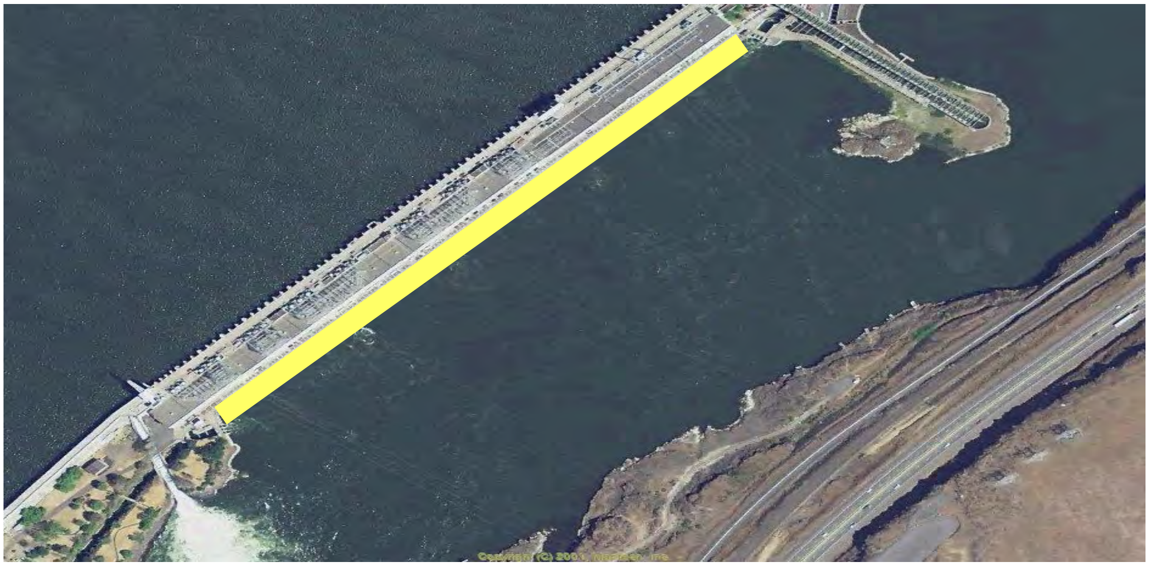

Figure 2. Angling locations for 2023 Dam Angling at The Dalles Dam

Figure 3. Angling locations for 2023 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 2023, the WDFW Dam Angling crew continued to use WDFW's Dam Angling Strategy (DAS) established in 2011 (Dunlap et al. 2012), which implemented and maintained full scale angling activities when CPUE was ≥ 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 2023 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 start 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 oversee angler safety and supervision, to collect, record and compile data on Northern Pikeminnow harvest, other fish species caught, and ensure that all NPMP project protocols and Corps of Engineers (USACE) rules were adhered to.

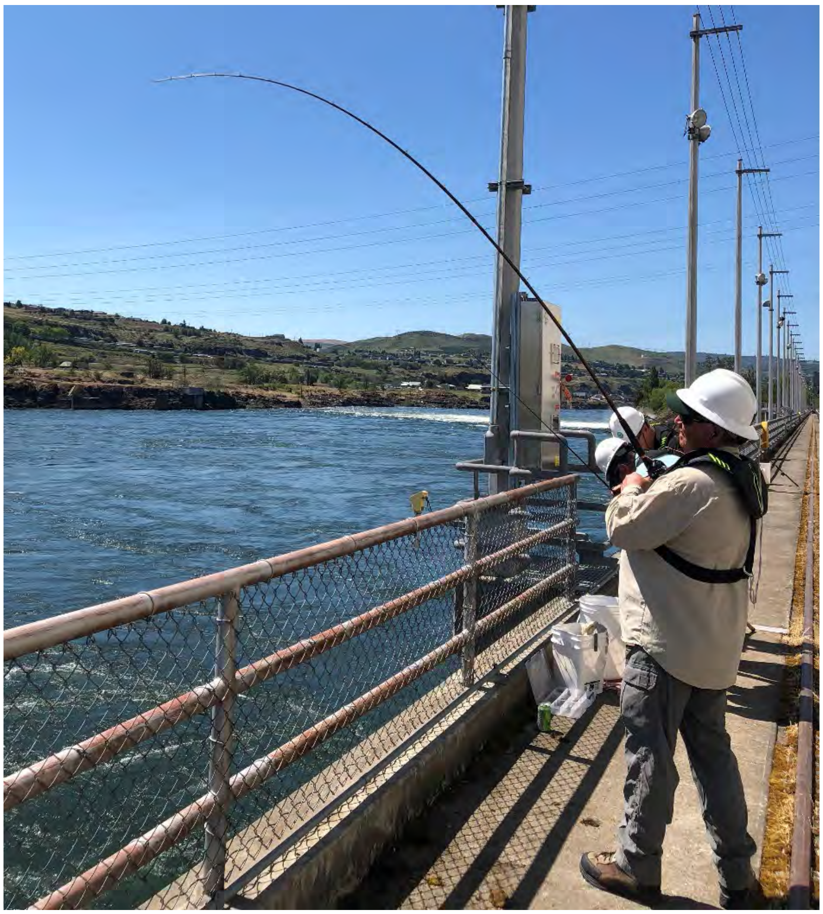

Figure 4. The Dam Angling Crew at John Day Dam

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.

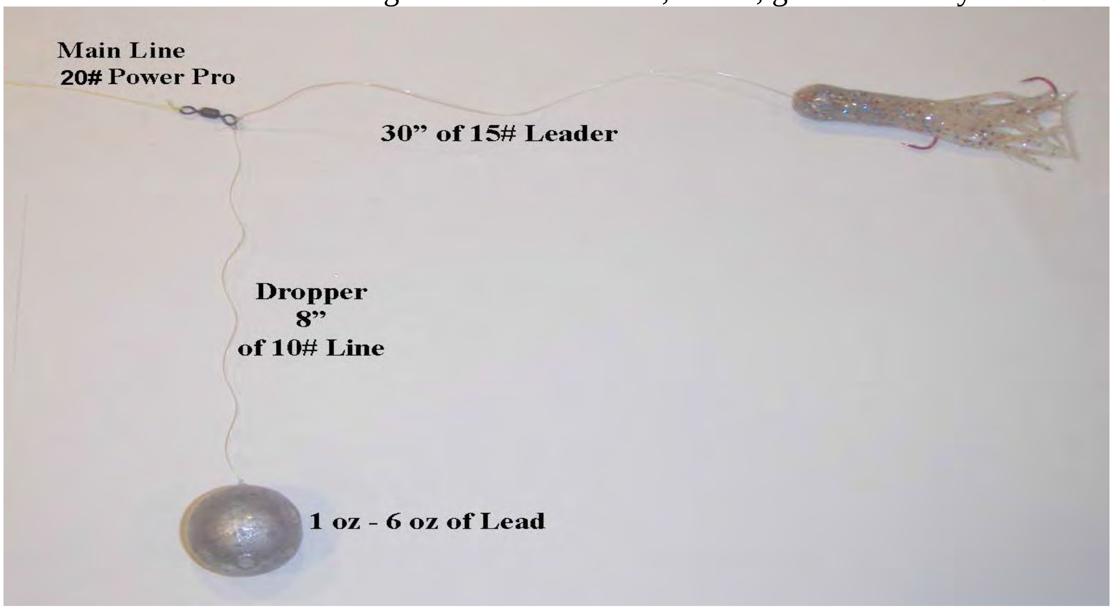

Figure 5. Example of typical rigging used by 2023 NPMP Dam Anglers

Figure 6. Examples of soft plastic tube lures used by 2023 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 2023 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), and as a primary mark beginning in 2022. 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 juvenile salmonids. Scanning began on the first day of dam 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 required.

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

2023 Dam Angling Season

The 2023 Dam Angling Season took place from May 8th through October 12th. Total harvest for The Dalles and John Day dams combined was 2,946 Northern Pikeminnow in 1,150.3 angling hours, for a combined angler CPUE of 2.6 fish per angler hour. Peak weekly harvest occurred in week 28 (Figure 7). The Dam Angling crew was not able to achieve the CPUE goal of 2.0 fish/angler hour until week 23 during the 2023 season and maintained that level through week 30 (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 27-31) 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 may be present and/or available.

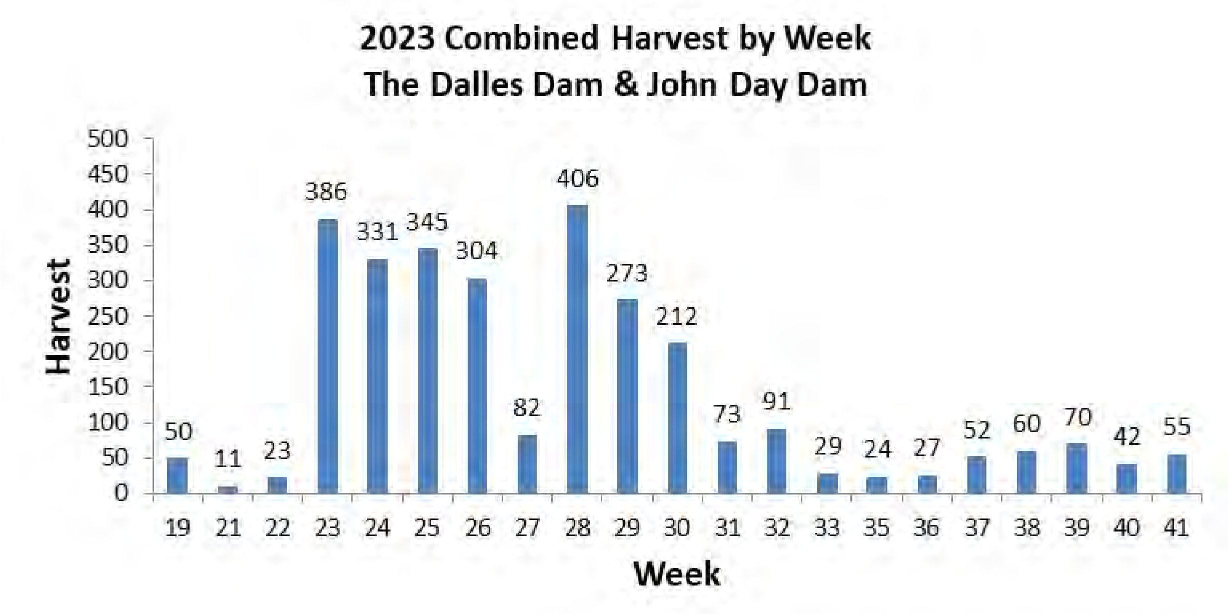

Figure 7. 2023 Weekly harvest of The Dalles (TD) and John Day (JD) Dams combined

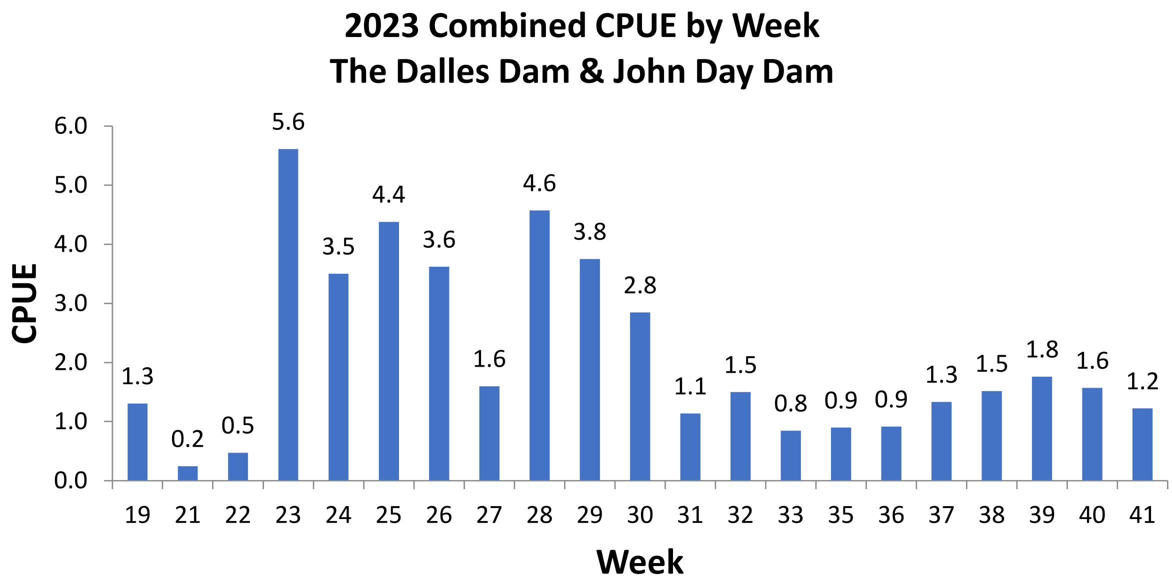

Figure 8. 2023 Combined Weekly CPUE (fish/angler hour) for The Dalles (TD) and John Day (JD) Dams.

Angling Gear and Technique

The 2023 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 2023 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 1 while targeting Northern Pikeminnow at The Dalles and John Day dams in 2023. Data from all incidentally caught fish were recorded and all incidentally caught fish other than Smallmouth Bass, Walleye, and Channel Catfish were released in 2023. All Smallmouth Bass, Walleye and Channel Catfish were harvested and removed according to the WDFW Non-native Predator Policy approved by the Washington Fish and Wildlife Commission (wdfw.wa.gov). Incidental species most often caught in 2023 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, Smallmouth Bass and Walleye caught at The Dalles Dam and John Day Dam during May and June (figure 9).

Figure 9. Juvenile lamprey regurgitated by Northern Pikeminnow.

Table 1. 2023 WDFW Dam Angler incidental catch by project

Incidental Catch

Species	The Dalles Dam	John Day Dam
Smallmouth Bass	120	160
Walleye	12	112
Sculpin	10	2
American Shad	3	0
Channel Catfish	4	7
White Sturgeon	1	0

The Dalles Dam

Harvest

The Dam Angling crew harvested 2,497 Northern Pikeminnow in 21 weeks of Dam Angling at The Dalles Dam in 2023. Weekly harvest for the Dam Angling crew averaged 119 fish per week during the 2023 season (Figure 10).

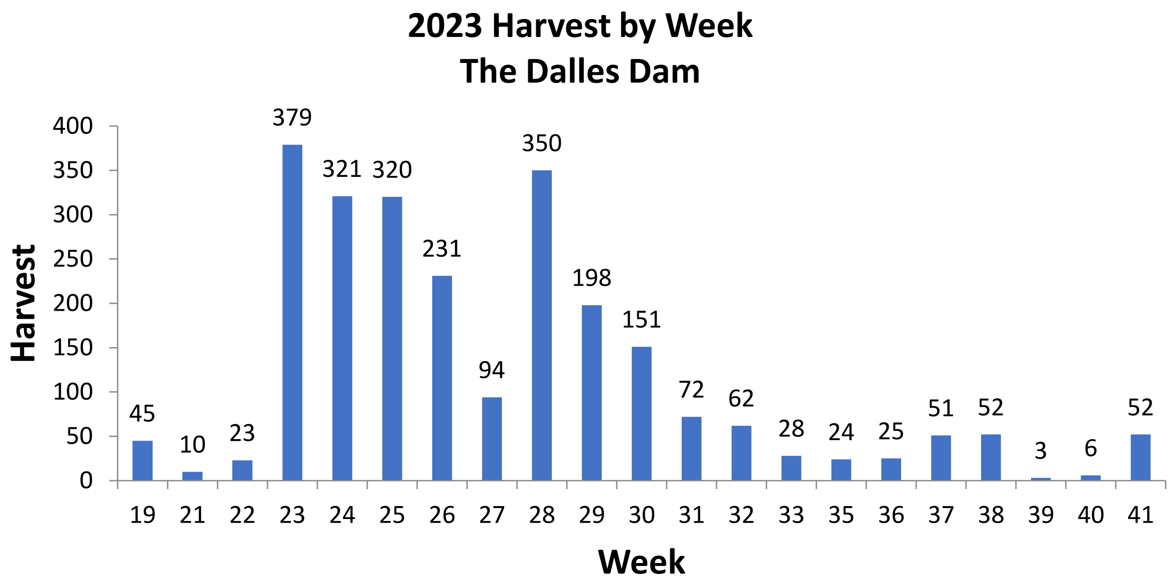

Figure 10. 2023 Weekly Dam Angler harvest of Northern Pikeminnow at The Dalles Dam

Effort

Total Dam Angler effort at The Dalles Dam was 862.5 angler hours in 2023. The Dam Angling crew fished 71 days at The Dalles Dam over 21 weeks equaling 75% of combined total Dam Angling effort (both projects) in 2023.

CPUE

The Dam Angling crew harvested 2,497 Northern Pikeminnow in 862.5 angler hours at The Dalles Dam in 2023 for an overall average CPUE of 2.9 fish/angler hour (Figure 11). Peak weekly CPUE at The Dalles Dam occurred during week 23.

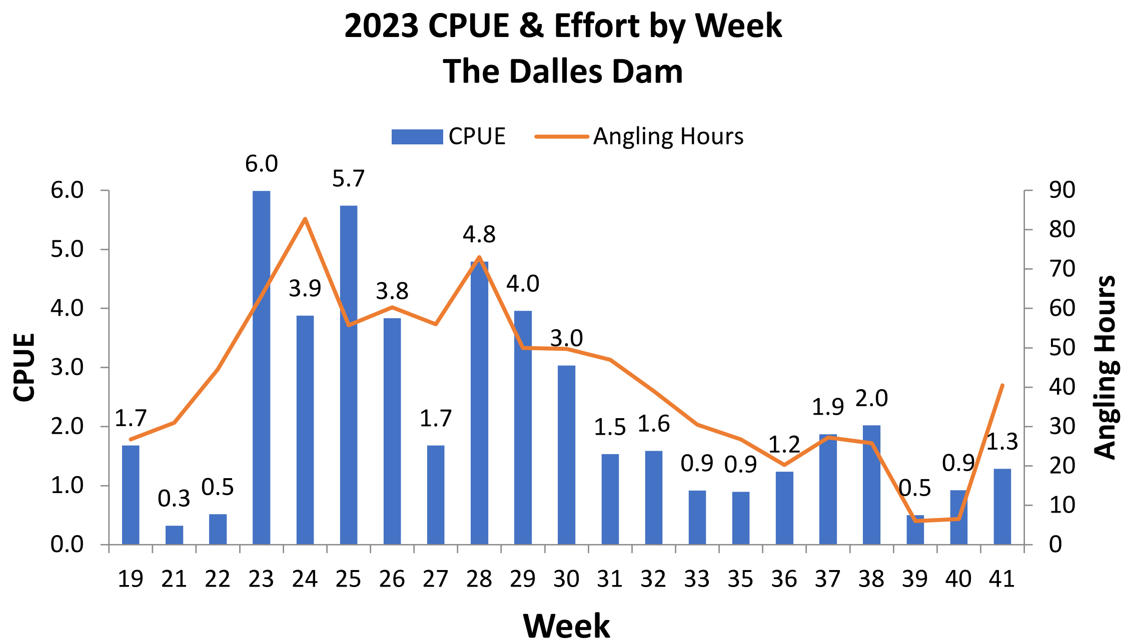

Figure 11. 2023 Weekly Dam Angler CPUE and Effort at The Dalles Dam

Fork Length Data

Fork lengths were recorded from 2,497 (100%) Northern Pikeminnow harvested by the Dam Angling crew at The Dalles Dam during the 2023 Season. The length frequency distribution of Northern Pikeminnow harvested at The Dalles Dam in 2023 is presented in Figure 12. Mean fork length for Northern Pikeminnow caught by the Dam Angling crew at The Dalles Dam in 2023 was 349 mm. By comparison, the mean fork length for the 2023 NPSRF was 263 mm (Hone et al. 2024).

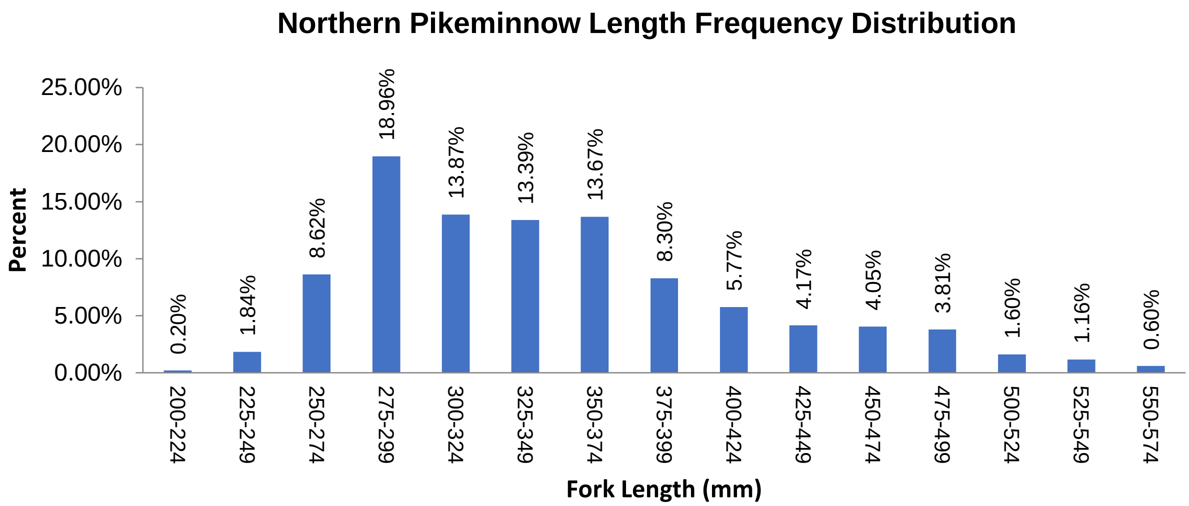

Figure 12. Northern Pikeminnow length frequency distribution at The Dalles Dam in 2023

John Day Dam

Harvest

The Dam Angling crew harvested 449 Northern Pikeminnow over 20 weeks at the John Day Dam in 2023. Peak weekly harvest at the John Day Dam occurred in week 29 and harvest was generally below expectations throughout the 2023 season (Figure 13).

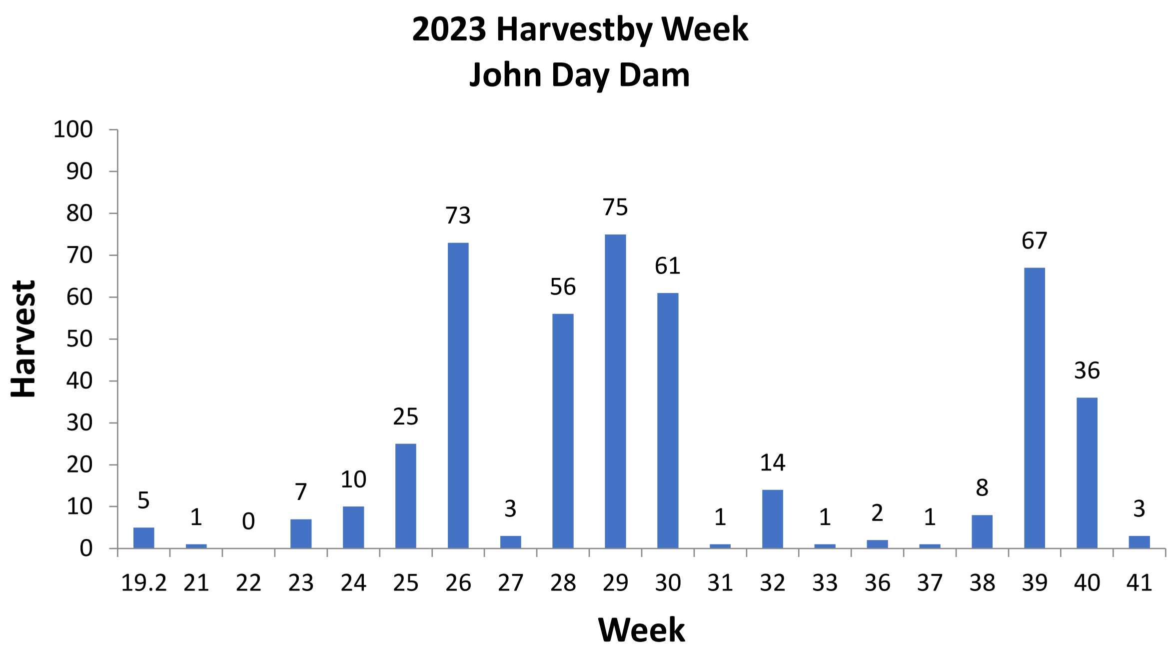

Figure 13. 2023 Weekly Dam Angler harvest of Northern Pikeminnow at the John Day Dam

Effort

Total effort at the John Day Dam was 287.8 angler hours in 2023. The Dam Angling crew fished 49 days at John Day Dam over 20 weeks equaling 25% of total combined Dam Angling effort (for both projects) in 2023.

CPUE

The Dam Angling crew harvested 449 Northern Pikeminnow in 287.8 angler hours at the John Day Dam in 2023 for an overall average CPUE of 1.6 fish/angler hour. Peak weekly CPUE at the John Day Dam occurred during week 28 (Figure 14).

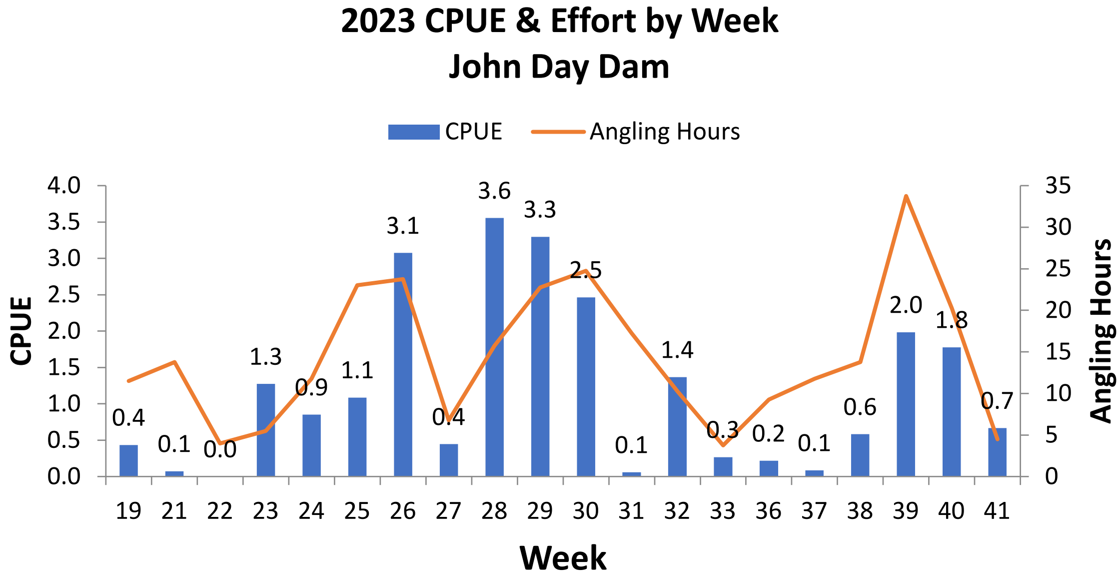

Figure 14. 2023 Weekly Dam Angling CPUE at John Day Dam

Fork Length Data

Fork lengths were recorded from 449 (100%) Northern Pikeminnow harvested by the Dam Angling crew at the John Day Dam during the 2023 Season. The length frequency distribution of harvested Northern Pikeminnow from the John Day Dam in 2023 is presented in (Figure 15). Mean fork length for Northern Pikeminnow from the John Day Dam in 2023 was 385 mm compared to 349 mm at The Dalles Dam, and 263 mm for the 2023 NPSRF (Hone et al. 2024).

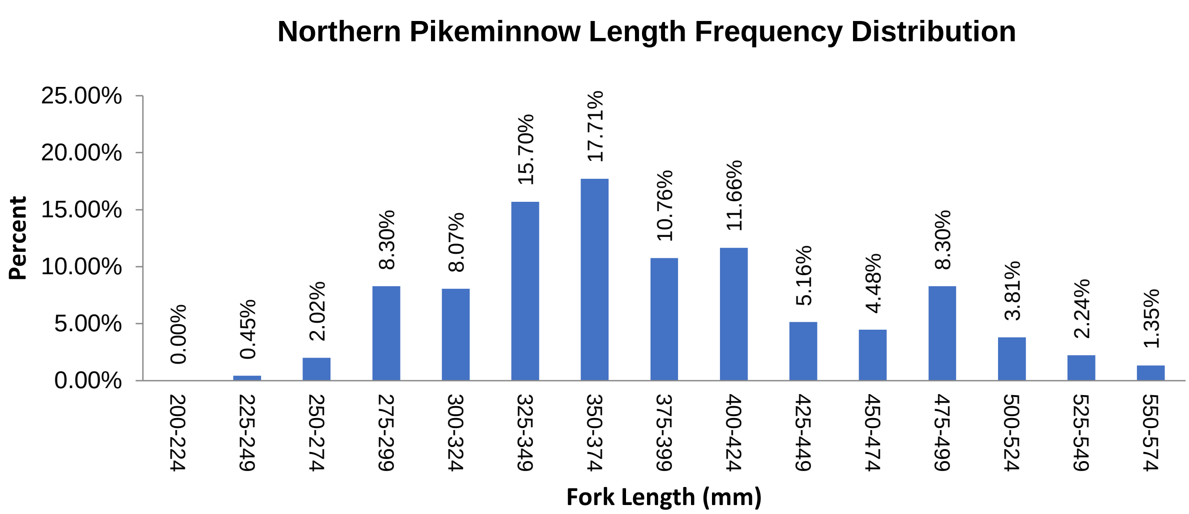

Figure 15. Northern Pikeminnow length frequency distribution at the John Day Dam in 2023

SUMMARY

During the core harvest period of May-July, of the 2023 Dam Angling season, harvest was good (above the 2.0 CPUE goal) at The Dalles Dam. Harvest was down significantly (below 2.0 CPUE goal) at the John Day Dam, as challenging water conditions (based on turbine operation) continued such that NPM were not consistently available to the DA crew.

Mean Fork lengths for Northern Pikeminnow harvested by the 2023 Dam Angling Crew at The Dalles and John Day dams were considerably larger than the mean fork length for the NPSRF with the means being 349 mm at The Dalles Dam, and 385 mm at the John Day Dam, versus a mean of 263 mm from the 2023 NPSRF.

While targeting Northern Pikeminnow, the 2023 Dam Angling crew incidentally harvested and removed a combined total of 280 Smallmouth Bass, 124 Walleye, and 11 Channel Catfish. The Dam Angling crew also caught and released 3 American Shad, 12 Sculpin and 1 White Sturgeon between the two projects.

RECOMMENDATIONS FOR 2024

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 2024 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 2024.

6.) Use HPR PIT tag scanners for scanning all incidentally caught predatory fishes.

7.) Continue to investigate and further develop Northern Pikeminnow angling techniques in 2024 such as finding additional exploitation opportunities of Northern Pikeminnow in areas not previously fished or currently fishable.

8.) Continue retaining and removing incidentally caught Smallmouth Bass, Walleye, and Channel Catfish according to WDFW's Non-Native Predator Policy.

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Appendix A

INTRODUCTION

Juvenile salmonids have been coded wire tagged (CWT) for decades by numerous agencies (Nandor et al. 2010). The recovery of these CWT in piscine predator digestive tracts may provide an additional source of stock information from predated juvenile salmonids in the Columbia River Basin and may provide a mechanism to enhance estimates of predation to juvenile salmonids. During the 2023 field season we tested the ability to retrieve ingested CWTs from diet samples of known piscine predators and investigated the potential insight on predation of juvenile salmonids. If we were able to retrieve CWTs from our collected samples, we may then be able to obtain additional information about the impacts of piscine predation on juvenile salmonids.

METHODS

Contents of diets from Northern Pikeminnow (*Ptychocheilus oregonensis*), Smallmouth Bass (*Micropterus dolomieu*), and Walleye (*Sander vitreum*) collected during biological evaluation field activities, and Northern Pikeminnow collected from the Dam Angling Fishery were examined to quantify relative consumption of juvenile salmonids. All samples were scanned with Northwestern Marine Technologies CWT T-wand and V-board to detect metallic materials. Frozen field samples were thawed in the laboratory. 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. A pencil magnet was used to detect CWT(s) in the sample. If no CWT was found the contents of each sample bag were then poured into a 3-tier sieve stack consisting of a 425 µm, 230 µm, and a final solid catch pan and rinsed through with water. The pencil magnet was again used on each sieve to collect any CWTs that may have been missed initially. CWT codes were then recorded in a database and the Regional Mark Information System (RMIS) was queried to acquire stock information (e.g., species, rearing location, and location and date of release).

RESULTS

In the spring of 2023, ODFW collected 1,263 stomach contents from Smallmouth Bass (n=882), Walleye (n=344) and Northern Pikeminnow (n=37) in the four lower Snake River reservoirs (Ice Harbor, Lower Monumental, Little Goose, and Lower Granite, Figure 1.). Using our updated methods, we were able to successfully detect CWTs in the field and obtain 14 CWTs from Walleye and Smallmouth Bass through our laboratory process (Table 1). No CWTs were recovered from Northern Pikeminnow.

DISCUSSION

We were able to develop field and lab protocols to capture CWT in piscine predator digestive tracts. These data have been summarized and presented at a scientific conference (Chambliss et al. 2024) and there are plans to continue testing the feasibility of collecting CWT to evaluate the utility of these data to better understand predator-prey dynamics. Information obtained from predated, CWT juvenile salmonids when paired with information about piscine predators, like catch location and predator species could help resource managers better understand the dynamics of piscine predation and enhance the information available about prey species, run type, ESU, release location, or hatchery of origin to inform resource management decisions about piscine predation.

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TABLES

Table 1. Count of CWTs recovered during the 2023 NPMP biological evaluation in the lower Snake River reservoirs by predator and prey species. Percentages represent proportion of CWTs recovered by each predator fish.

	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
Walleye 28.6%				
Chinook	1	—	—	—
Steelhead	3	—	—	—
Walleye 21.4%				
Chinook	—	3	—	—
Walleye 7.1%				
Chinook	—	1	—	—
Walleye 7.1%				
Chinook	—	—	1	—
Smallmouth Bass 21.4%				
Chinook	—	—	—	2
Coho	—	—	—	1
Smallmouth Bass 14.3%				
Coho	—	—	—	2
Northern Pikeminnow 0.0%				
	—	—	—	—
Total Count	**4**	**4**	**1**	**5**

FIGURES

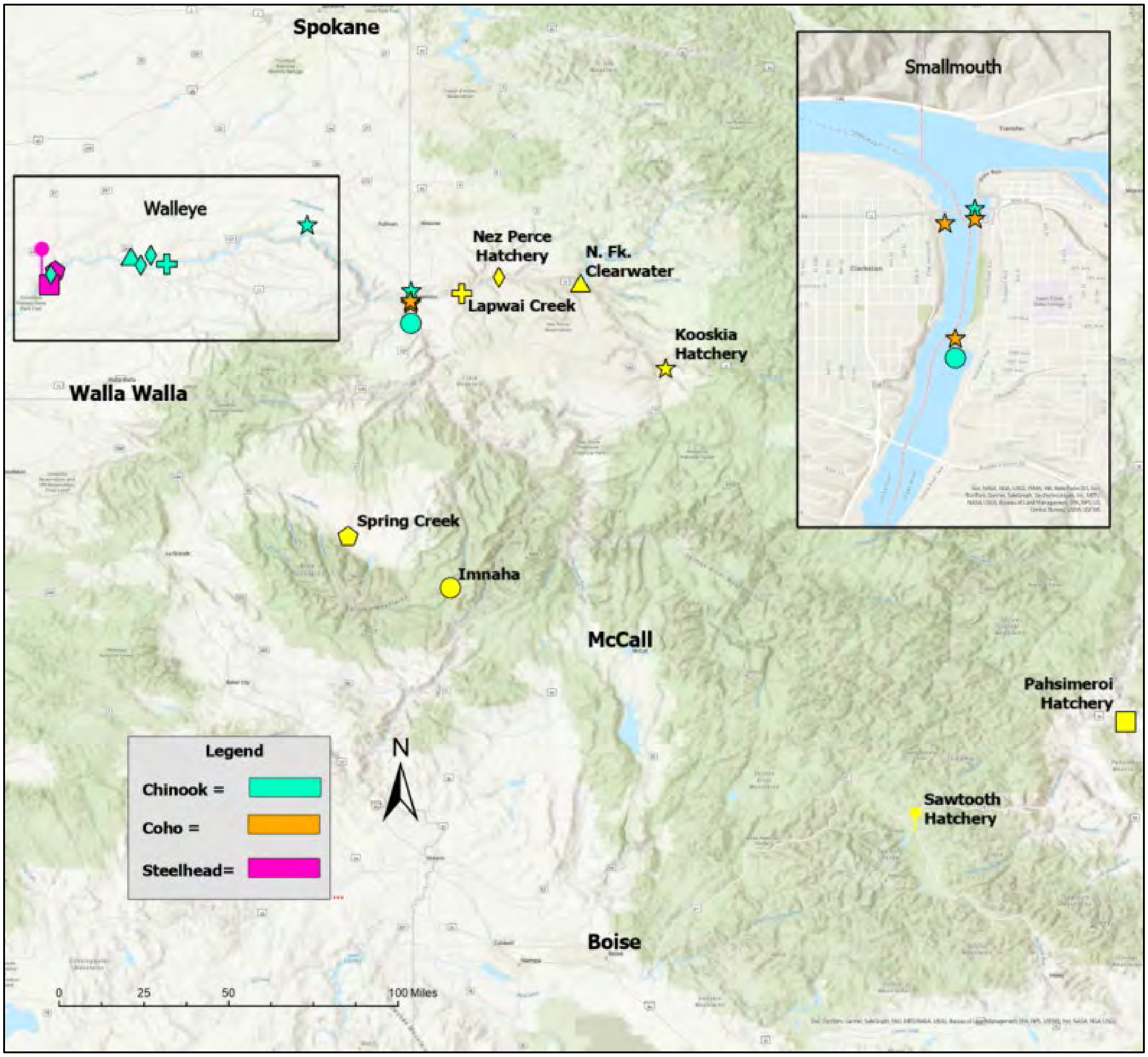

Figure 1. Release locations of coded wire tagged salmonids with corresponding capture locations, by predator and prey species. Enlarged map area shows all CWTs recovered from Smallmouth. The remaining CWTs came from Walleye.

Appendix B

INTRODUCTION

In 2019 the Northern Pikeminnow Management Program (NPMP) was reviewed by the Independent Scientific Review Panel (ISRP) to evaluate if the project 1) is based on sound scientific principles, 2) benefit fish and wildlife, 3) have clearly defined objectives and outcomes, and 4) contain provisions for monitoring and evaluation of results (ISRP, 2019). One recommendation of the review process was to determine whether current bioenergetic models could provide improved estimates of consumption of juvenile salmonids by piscine predators in conjunction with or in lieu of current indices of consumption. Bioenergetics models present a sound, theoretical approach for estimating energy allocation in fish by distributing consumed energy into three basic physiological processes. Energy is first allocated to metabolism while some is lost to waste, then whatever is left over can be allocated to somatic or gonadal growth (Winberg, 1956). These models, based on mass balance equations, can be used to estimate consumption, when given information on other biological and environmental parameters. These models are simplifications of reality. How well they describe the real world depends on appropriate parameterization of the model and the accuracy of input data used to drive them (Bartell et al. 1986). NPMP recognizes that a bioenergetics model capable of assessing piscine predation of juvenile salmonids, while incorporating parameters that can be changed to better reflect biological and physical conditions in the Columbia River Basin, could provide improved estimates of consumption and calibration of the current consumption indices. These indices were designed, in the context of a 'rapid assessment' process, to estimate the number of salmonids consumed by the "average predator" in a specified section of the river. The current consumption index for Northern Pikeminnow, as described in this report (Report C), uses water temperature, mean mass of predator fish, mean number of salmonids per diet, and mean mass of all gut contents measured during field and lab procedures of the biological evaluation and are based on the concept of meal turnover time (Ward et al. 1995). However, the model for this index has limited flexibility to adjust parameters that may change over time due to biological and physical changes in the system. Because of this and the recommendation from ISRP, ODFW is in the process of evaluating a software-based bioenergetics analytical tool, Fish Bioenergetics 4.0 (FB4), (Deslauriers et al. 2017), to assess the consumption of juvenile salmonids by Northern Pikeminnow and Walleye. FB4 uses published biological parameters for numerous species of fish and the Wisconsin Bioenergetics modeling framework (Deslauriers et al. 2017) to calculate an energy budget for fishes. FB4 could function as a 'rapid assessment' tool that provides ODFW the technical capacity to rapidly assess bioenergetic budgets for piscine predator species, as well as include modularity to update the bioenergetics models as new data becomes available or biological or physical conditions change.

This appendix provides an overview of NPMP's initial exploration of bioenergetic modeling through:

1) Assessing the compatibility of Fish Bioenergetics 4.0 with NPMP catch and diet data.
2) Detailing methods to estimate consumption.
3) Identifying model assumptions.
4) Discussing preliminary results.

METHODS

Field Procedures

Field data for bioenergetics analyses were taken from biological evaluation efforts from 2011 to 2022. Due to variations in the spatial abundance of the two predators, a parallel analysis is unfeasible. Therefore, Northern Pikeminnow information was derived from biological monitoring data from the tailrace area (rkm 225-233) below Bonneville Dam and the area (rkm 116-121) near Kalama, Washington in 2011, 2014, 2017, 2020 and 2021. Biological information for Walleye was derived from biological monitoring data from the tailrace area (rkm 461 – 469) of the John Day Reservoir below McNary Dam in 2012, 2015, 2018, 2022. Both spring and summer evaluations were used when sampling occurred. Specific field procedures can be found in the Methods section of this report (Report C) under Biological Evaluation: Field Procedures.

Laboratory Procedures

Diet data for bioenergetics analyses was taken from the corresponding field data as listed above. Specific laboratory procedures can be found in Methods section of this report under Biological Evaluation: Laboratory Procedures.

Data Analysis

Fish Bioenergetics 4.0

The first step of this process involved determining whether the bioenergetics software tool, FB4, is suited to NPMP diet and catch data. FB4 uses taxon-specific physiological estimates of food consumption (or growth), respiration, egestion and excretion that drive the energy balance equation. These estimates and other physiological parameters are developed from peer reviewed published journals including research by Petersen and Ward (1999) on Northern Pikeminnow and Kitchell et. al (1977) on Walleye. Each of the processes is described by a set of functions that are regulated primarily by water temperature and body size. FB4 uses an Rstudio-based operating platform linked via Shiny, by Rstudio, to a web-based user interface. This web-based platform models consumption or growth based on the user's initial settings and input files. Initial settings include species of interest, initial and final days (time) for the model to simulate, initial mass and an input value contingent on a user defined "fit to" option. The model is fit to either a user defined final weight or consumption value. To model consumption, FB4 requires a user defined final mass. Minimum user input files utilized for this rapid assessment included water temperature, proportions of different prey items per diet, and the respective energy densities of both prey and predators. FB4 outputs of interest for this analysis included daily and mean consumption of salmonids in grams and a proportionality constant (p). The proportionality constant is the feeding rate calculated as the proportion of the maximum feeding rate based on the size of the fish and water temperature. FB4 simulates daily values for each variable to balance the mass energy equation to the specified user inputs.

Initial Settings:

Species

For each of the major physiological processes (consumption, metabolism, egestion, and excretion), several different forms of the underlying equations are employed depending on unique physiologies of the species provided. FB4 has over 103 published bioenergetics models for a variety of species at different life stages and can be updated as new models become available (Deslauriers, 2017). This report explored models for adult Northern Pikeminnow and Walleye based on published work by Peterson and Ward (1999) and Kitchell et. al (1977) respectively.

Initial and Final Day

Each simulation modeled consumption by either Northern Pikeminnow below Bonneville Dam or Walleye in the John Day Reservoir. Simulations were divided into a spring or summer season. These seasons represent the two distinct periods of outmigration by juvenile salmonids. Dates defining each season have been developed and incorporated into the annual predation reduction model used in this report (Report C) where spring begins on 1 April (day 1) and ends 30 June (day 91), and summer begins 1 July (day 1) and ends 31 August (day 62).

Initial and Final Mass

As described above, to model consumption, FB4 needs inputs of initial and final mass. An intended use of bioenergetics modeling is to compare it to the existing NPMP index of consumption for Northern Pikeminnow, which uses the mean mass of Northern Pikeminnow in an area to examine consumption by the average predator. We used the mean mass of Northern Pikeminnow or Walleye for area/year combinations to represent the initial mass. To determine final mass, growth was predicted over the course of each specified season. Methodologies for modeling growth in Northern Pikeminnow and Walleye are described below.

Northern Pikeminnow

Mark-recapture data was used to estimate growth during the spring and summer seasons. Northern Pikeminnow are measured to the nearest mm FL during marking periods by ODFW staff and when recovered in the Sport Reward Fishery (SRF) by WDFW staff. Northern Pikeminnow recovered in the same year as marking were used to determine growth. Because the mark-recovery period (1 April through 30 September) of the SRF overlaps with the spring and summer out-migration periods, this data was considered the best representation of growth during that short period of time. Because of the overlap between both seasons, growth was assumed to be consistent between spring and summer. To account for variability of growth over time, mark recovery data from the current year and the two years prior were used to determine growth per day for a particular biological evaluation year. Recaptures that occurred less than 7 days after marking events were excluded from the growth analysis as any difference in size would likely be due to measuring error. To capture differences in growth rates at different size classes, a modal analysis was employed using the multimode package in R (Ameijeiras et. al., 2021). The multimode package used a Kernel Density Estimation to determine modes and anti-modes representing different cohorts of similar sizes for each annual biological evaluation dataset. Recapture data for years *x*, *x*-1 and *x*-2 were then separated into these cohorts and outliers were identified and removed using Box and Whisker plots for each cohort. Because fish have been known to shrink in size postmortem, particularly SRF caught Northern Pikeminnow when not put on ice immediately after capture (Chesnes et. al. 2009, WDFW personal communication) all fish that demonstrated negative measured growth were considered to have had no growth during the spring and summer seasons. The growth rate for each cohort ($\Delta mm\ Fl * d^{-1}$) was then estimated as the mean of each individual growth rate of all Northern Pikeminnow in the sample. Because growth data was determined in length and bioenergetics uses biomass to model growth, a length mass relationship was used to determine change in mass. First, we used a generalized additive model (GAM) to predict an initial length (L) based on the initial mass (M) with year (Y) and season (S) as predictor variables:

$$L = f(M) + Y + S \tag{1}$$

where:

- L is the predicted initial length of the "average predator."
- *f*(M) represents the smooth function of initial mass, capturing potential non-linear relationships between mass and length.
- Y is the effect of year as a categorical variable with levels (2011, 2014, 2017, 2020 and 2021).
- S is the effect of season as a categorical variable with two levels (spring or summer).

The growth rate for the cohort that encompassed the predicted initial length was then multiplied by the number of days in the corresponding season to get a final length. The GAM was then used to get a predicted final mass to use in the simulation as per equation below:

$$M = f(L) + Y + S \tag{2}$$

where:

- M is the predicted final mass of the "average predator" at the end of the simulation.
- f (L) represents the smooth function of final length, capturing potential non-linear relationships between length and mass.
- Y is the effect of year as a categorical variable with levels (2011, 2014, 2017, 2020 and 2021).
- S is the effect of season as a categorical variable with two levels (spring or summer).

<u>Walleye</u>

Walley lack mark and recapture data to predict growth for the "average predator" simulated in the bioenergetics model therefore a Von Bertalanffy Growth Curve was used to estimate growth. Like Northern Pikeminnow, we used a GAM to predict an initial length based on the initial mass, with year and season as predictor variables (equation 1). The Walleye growth coefficients for the John Day Reservoir, described by Connolly and Rieman (1986) were used to fit a Von Bertalanffy Growth Curve. Recognizing the temporal variability in growth over a twelve-month period, we modeled two distinct growth scenarios for each spring or summer season. We used a conservative estimate where annual growth was consistent over the 365 days. Generally, Walleye grow the most during the warmer months (Connolly and Rieman, 1986), therefore we also modeled growth where all annual growth was assumed to occur between April and August. Growth estimates for length using a Von Bertalanffy Curve were as follows:

$$L_{final} = L_{initial} + (L_{\infty} - L_{initial}) * (1 - e^{(-K*(t-t_0)})$$ (3)

where:

- L_{final} is the predicted final length of the "average walleye" after the season.
- $L_{initial}$ equals 715
- K $equals$ 0.335
- t_0 equals -0.143
- t is $\frac{number\ of\ days\ in\ the\ season}{number\ of\ days\ of\ growth\ in\ the\ year}$

As with Northern Pikeminnow, a GAM was employed to predict a final mass for the Walleye based on the final fork length with year and season as predictor variables (equation 2).

Temperature

Mean daily water temperature data was derived using Columbia River DART (Data Access in Real Time) queries for dates of the simulations. Locations queried included Cascade Island for the tailrace area below Bonneville Dam, Camas/Washougal WA for rkm 116-121 near Kalama, and McNary Tailwater for the tailrace are of John Day Reservoir.

Diet Proportions

Most fish recovered in the diet samples were highly digested and degraded, so accurate data on ingested mass are difficult to obtain for prey fish, and diagnostic bones were therefore used to both identify and enumerate prey fish. The lowest taxonomical class identified with juvenile salmonid diagnostic bones were often the family Salmonidae. This analysis assumed that all salmonids consumed coincided with the most abundant species out-migrating through the system when sampling occurred. Consequently, during spring biological evaluation efforts, all salmonid prey items were assumed to be yearling Chinook Salmon (*Oncorhynchus tshawytscha*) with a wet weight of 23.5g in the Bonneville Dam tailrace area and 23.2g in the McNary Dam tailrace. Wet weights were based on direct measurements by Rodorf et al (1985) at these respective dams. Salmonids identified in the diets of predator fish during summer biological evaluation were assumed to be subyearling Chinook salmon with wetted weight of 12.4g, based on data from the Army Corps. of Engineers (Ploskey et. al., 2012). Due to limitations of identifying non-salmonid species to their lowest taxonomic levels, all non-salmonid fish items were assumed to be Shorthead Sculpin (*Cottus confusus*), the most common non-salmonid species found in NPMP diet analyses. Wet weight for non-salmonids were based on the Bayesian length weight relationship for Shorthead Sculpin with a common size of 8 cm TL (Page and Burr, 1991). Unlike fish prey items categorized into salmonids or non-salmonids, other prey items were categorized as crayfish, other invertebrates, or miscellaneous. Because these prey items are not traditionally enumerated in laboratory procedures, measured weights were used to calculate diet proportions. Diet proportions for each prey category (salmonid, non-salmonid fish, crayfish, other invertebrates and miscellaneous) were calculated as the total mean mass divided by the mean mass for each prey category.

Prey Energy Density

Energy density of prey types, measured in Joules/gram ($J*g^{-1}$) wet weight, contained in fish diets, is one of the input parameters for bioenergetics models. Prey energy densities can either be directly measured or obtained from published studies. We used similar prey energy densities as Petersen and Ward (1999) where crayfish have an energy density of 4,506 J J*g-1 and other invertebrates have an energy density estimated to be 2,615 $J*g^{-1}$ (Cummins and Wuycheck, 1971). Prey energy densities for Chinook Salmon were used for all salmonids with a prey energy density of 4,310 $J*g^{-1}$ and *Cottid spp.* were used for non-salmonid species with a prey energy density of 5,439 $J*g^{-1}$(Petersen and Ward, 1999).

Predator Density Energy

Predator energy densities can also be modeled as a function of body mass or input from published studies. Energy densities in these analyses were input based on published studies as 6,703 $J*g^{-1}$ for Northern Pikeminnow (Peterson and Ward, 1999) and 4,186 $J*g^{-1}$ for Walleye (Kitchel e.t al., 1977).

RESULTS

Northern Pikeminnow

Initial and Final Mass

Initial mass for Northern Pikeminnow below Bonneville Dam ranged from 608 grams in the summer of 2020 to 1,323 grams in the spring of 2014. Growth, modeled as change in mass, ranged from 4 grams in the summer of 2020 to 63 grams in the spring of 2021 (Table 1).

Diet Proportions

The proportion of salmonids in the diets of Northern Pikeminnow below Bonneville Dam ranged from 7.9% in the tailrace area during the summer of 2017 to 92.0% in the tailrace area during the spring of 2011. Mean proportions for salmonids in Northern Pikeminnow diets below Bonneville Dam was 52.5% (Table 1).

Salmonid Consumption

Mean consumption of salmonids by Northern Pikeminnow in the area blow Bonneville Dam ranged from 2.13 grams per day ($g \cdot d^{-1}$) in the tailrace area during the summer of 2020, to 14.15 $g \cdot d^{-1}$ in the tailrace area during the spring of 2017. Proportionality constants ranged from 0.39 in both the tailrace area during the summer of 2011 and near Kalama during the spring of 2014 to 0.53 in the tailrace area during the spring of 2011 (Table 1). Figure 1 graphically illustrates FB4 simulations of Northern Pikeminnow consumption and temperature variations across two distinct seasons.

Walleye

Initial and Final Mass

Initial mass for Walleye in the tailrace area of John Day Reservoir ranged from 343 grams in the spring of 2022 to 1,770 grams in the spring of 2012. When growth was considered constant throughout the year, change in mass ranged from 19 grams in the summer of 2012 to 84 grams in the spring of 2018 (Table 2). When all annual growth was assumed to occur between April and August, change in mass ranged from 191 grams in the summer of 2018 to 340 grams in the spring of 2018 (Table 3).

Diet Proportions

The proportion of salmonids in the diets of Walleye in the tailrace area of John Day Reservoir ranged from 64.1% in the spring of 2022 to 93.1% in the spring of 2012. Mean proportions for salmonids in Walleye diets in the tailrace area of John Day Reservoir was 79.3% (Tables 2 and 3).

Salmonid Consumption

When growth was considered constant throughout the year, mean consumption of salmonids by Walleye in the tailrace area of John Day Reservoir ranged from 1.95 $g \cdot d^{-1}$ in the spring of 2022, to 12.70 $g \cdot d^{-1}$ in the summer of 2018. When all annual growth was assumed to occur between April and August, mean consumption of salmonids ranged from 3.71 $g \cdot d^{-1}$ in spring of 2022, to 15.61 $g \cdot d^{-1}$ in summer of 2018. Proportionality constants ranged from 0.27 in summer of 2012, to 0.32 in spring of 2018 when growth was consistent throughout the year and from 0.37 in summer of 2018, to 0.51 in the spring of 2018 when all annual growth was assumed to occur between April and August. Figure 2 graphically illustrates FB4 simulations of two different Walleye consumption estimates and temperature variations across two distinct seasons.

DISCUSSION

Fish Bioenergetics 4.0

NPMP biological monitoring and evaluation was developed to monitor the piscine predator populations for signs of intra- and interspecies compensation related to the SRF using 'rapid assessment' techniques. Within this rapid assessment framework, the potential exists for FB4 to be employed to monitor long term trends in piscine predator consumption of juvenile salmonids. This tool also presents NPMP an opportunity to monitor trends in salmonid consumption by Walleye, for which peer reviewed indices of consumption are not available. The primary modifications to adapt NPMP data to a bioenergetics model include modeling short-term growth and calculating diet proportions. Applying SRF mark and recovery to Northern Pikeminnow data and the Von Bertalanffy Growth Curve to Walleye data are valuable tools to model short-term growth for this rapid assessment tool. NPMP laboratory collection procedures are designed to enumerate fish species consumed to calculate a consumption index for Northern Pikeminnow. Measuring wet weight of fish and other prey at the time of consumption is infeasible due to the various stages of digestion of prey items observed. Assumptions are necessary to adapt NPMP diet data to FB4 input parameters. To interpret FB4 modeled consumption and draw any conclusions on predator-prey or predator-predator dynamics, it is important to understand the assumptions that pertain to these input parameters and the model itself. Understanding these assumptions can not only help interpret rapid assessment results and long-term trends, but also direct research objectives if bioenergetics were to be used beyond the rapid assessment framework.

Input parameters

There are assumptions with the bioenergetics modeling approach presented here. Diet proportions are assumed consistent throughout the spring or summer periods due to the timing of field sampling. Piscine predator diets are only collected from each specific location on two sampling days during one week of the season as per current resources and the existing study design. These sampling events are coordinated to coincide with peak outmigration for juvenile salmonids. In the real world, diet proportions vary throughout the season and are likely associated with prey availability. Another assumption with regards to diet proportions has to do with laboratory procedures, and our ability to determine prey items to species and size based on digesting prey diagnostic bones. All salmonids found in diets are assumed to be yearling or subyearling chinook, depending on the season, and all non-salmonid prey fish are considered sculpin. Chinook are the most abundant salmonid species in the smolt passage index during the time of sampling and sculpin are the most prevalent non-salmonid species found in predator diets. The categorization of dietary items into higher taxonomic levels is more prevalent among prey items other than fish. Measured mass is used for these prey items that are partitioned into broad categories with a wide range of mass and prey energy. Additionally, these categories use measured mass as opposed to prey fish where enumerations lead to a calculated mass. Another assumption with regards to input parameters involves the size of the predator fish. Larger predators have a more piscivorous diet than smaller fish. It is assumed that the sample population represents the actual population in both abundance indices and for an accurate representation of diets.

Preliminary Results

NPMP has not incorporated bioenergetics into the preexisting biological evaluation efforts because results are preliminary. Drawing conclusions from preliminary results will require consideration of the assumptions previously stated. Similarly, to existing biological evaluation indices, these rapid assessments are used to examine long-term trends and not specific data points. The range in consumption of salmonids by Northern Pikeminnow is due to the range in diet proportions. Proportion of salmonids in the diets were low in all three summer periods where sampling occurred, resulting in the lowest mean salmonid consumption estimates for Northern Pikeminnow. This could be a result of missing the peak summer out-migration or from larger, more piscivorous fish leaving the area (i.e. spawning) during the sampling period. Consumption of salmonids by Walleye in the John Day Reservoir tailrace area was lowest in 2022, when both initial mass (343 grams) and proportions of salmonids in the diet (64%) were also the lowest. When examining these consumption estimates, particularly for Walleye where no predation index exists, it is important to consider changes in abundance. Abundance index for Walleye in the John Day Reservoir tailrace was the highest on record and over five times the series mean (Waltz et. al. 2022). So, despite lower mean consumption per predator, overall consumption of salmonids by Walleye is likely high in this area.

Future Perspective

There is modularity within the FB4 to allow users to customize numerous biological and physical parameters relative to the species and system of interest. The core process in bioenergetics (respiration, active metabolism, specific dynamic action, egestion, excretion, and growth) are described by a set of function that are primarily regulated by water temperature and body size... Existing indices of consumption uses a static mean temperature and body mass for predators measured when sampling occurs. FB4 models include the entire water temperature regime, available without sampling, of the juvenile outmigration period to determine consumption needed to meet the energetic needs of each piscine predator to achieve the predicted growth. As temperature increases, consumption must increase to balance the energy budget of a fish (figures 1 and 2). The modular structure within FB4 offers the flexibility to easily adapt temperature inputs, and the capability to simulate consumption patterns within dynamic environments. This may allow NPMP to forecast consumption in the face of climate change and limited sampling due to a variety of constraints including time and budget, aligning predator diet analysis with peak juvenile salmonid outmigration, complying with take permits issued by NOAA, and temperature restrictions due to the presence of Endangered Species Act (ESA) listed salmonids in the study area.

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TABLES

Table 1: Input and output variables and the number (n) of Northern Pikeminnow sampled in two different areas and seasons below Bonneville Dam, 2011 -2021. Input variables include initial (minitial) and final (mfinal) mass in grams, proportion of salmonids ($Prop_{sal}$) in the diet and mean daily temperature (°C) of the simulation. Output variables include the mean daily consumption of salmonids ($Cons_{sal}$) by Northern Pikeminnow in grams and the proportionality feeding constant (*p*).

Year	Season	Area	*n*	$m_{initial}$ (g)	m_{final} (g)	$Prop_{sal}$	Temp°C	$Cons_{sal}$	*p*
2011	Spring	Tailrace	21	995	1046	0.9202	11.31	12.22	0.53
2011	Spring	Kalama	10	1162	1207	0.7202	11.44	9.93	0.44
2011	Summer	Tailrace	77	1056	1096	0.1642	18.97	4.74	0.39
2014	Spring	Tailrace	8	1323	1375	0.7307	12.79	12.97	0.40
2014	Spring	Kalama	13	759	780	0.4429	12.98	4.99	0.39
2017	Spring	Tailrace	20	1024	1083	0.9008	12.40	14.15	0.48
2017	Spring	Kalama	28	650	659	0.8260	12.52	8.32	0.44
2017	Summer	Tailrace	46	829	842	0.0793	21.30	2.15	0.44
2020	Summer	Tailrace	26	608	611	0.1055	20.12	2.13	0.43
2021	Spring	Tailrace	74	880	943	0.3570	13.67	5.41	0.41

Table 2: Input and output variables and the number (n) of Walleye sampled in spring and summer in the tailrace area of John Day Reservoir where growth is consistent over 12 months, 2012-2022. Input variables include initial ($m_{initial}$) and final (m_{final}) mass in grams, proportion of salmonids ($Prop_{sal}$) in the diet and mean daily temperature (°C) of the simulation. Output variables include the mean daily consumption of salmonids ($Cons_{sal}$) by Walleye in grams per day and the proportionality feeding constant (*p*).

Year	Season	*n*	$m_{initial}$ (g)	m_{final} (g)	$Prop_{sal}$	Temp °C	$Cons_{sal}$	*p*
2012	Spring	36	1770	1794	0.9313	11.39	8.33	0.28
2012	Summer	33	792	811	0.7693	18.84	6.32	0.27
2015	Spring	16	689	769	0.8413	14.18	5.56	0.31
2018	Spring	138	645	729	0.8524	12.47	4.90	0.32
2018	Summer	32	1741	1789	0.7202	20.54	12.70	0.31
2022	Spring	375	343	399	0.6406	11.20	1.95	0.30

Table 3: Input and output variables and the number (n) of Walleye sampled in spring and summer in the tailrace area of John Day Reservoir where all growth occurs between April and August, 2012-2022. Input variables include initial ($m_{initial}$) and final (m_{final}) mass in grams, proportion of salmonids ($Prop_{sal}$) in the diet and mean daily temperature (°C) of the simulation. Output variables include the mean daily consumption of salmonids ($Cons_{sal}$) by Walleye in grams per day and the proportionality feeding constant (*p*).

Year	Season	*n*	$m_{initial}$ (g)	m_{final} (g)	$Prop_{sal}$	Temp °C	$Cons_{sal}$	*p*
2012	Spring	36	1770	2003	0.9313	11.39	11.94	0.38
2012	Summer	33	792	986	0.7693	18.84	10.09	0.41
2015	Spring	16	689	1025	0.8413	14.18	9.75	0.49
2018	Spring	138	645	985	0.8524	12.47	9.06	0.51
2018	Summer	32	1741	1932	0.7202	20.54	15.61	0.37
2022	Spring	375	343	555	0.6406	11.20	3.71	0.51

FIGURES

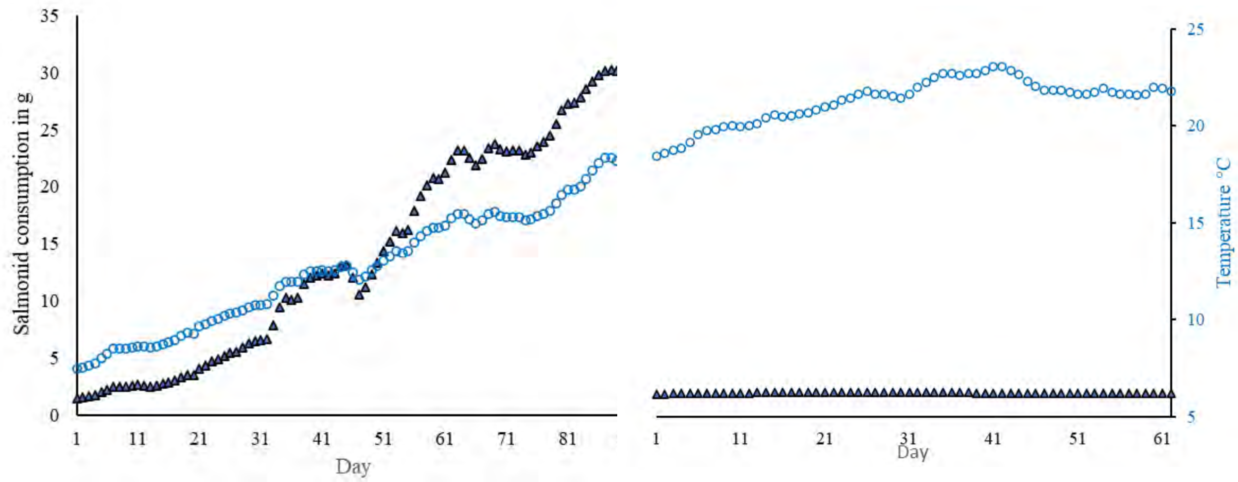

Figure 1: FB4 simulated consumption of juvenile salmonids in grams per day by Northern Pikeminnow in the tailrace area below Bonneville Dam for spring (A) and summer (B) of 2017. Graph displays mean daily temperature (secondary y-axis) along with initial mass and proportion of salmonids in Northern Pikeminnow diets.

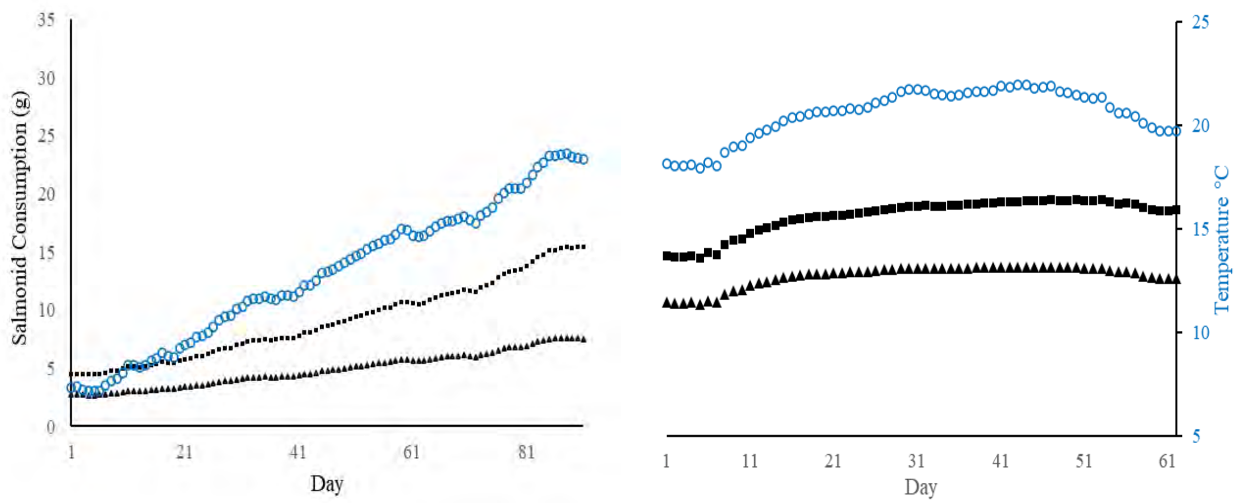

Figure 2: FB4 simulated consumption of juvenile salmonids in grams per day by Walleye in the tailrace area of John Day Reservoir for spring (A) and summer (B) of 2018. Graph displays two consumption models: One where growth is consistent across twelve months (triangles) and one where all growth occurs between April and August (squares),mean daily temperature (secondary y-axis) along with initial mass and proportion of salmonids in Walleye diets.