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New Marking and Monitoring Technologies for the Passive Integrated Transponder, 2025

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U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
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New Marking and Monitoring Technologies for the Passive Integrated Transponder, 2025

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Executive Summary

One of the primary goals for expansion of passive integrated transponder (PIT) technology is to develop interrogation systems that will collect data on tagged salmonids migrating through the Columbia River Basin. An important component of this goal is to provide interrogation capability for juveniles passing dams via surface-collection routes, such as removable or temporary spillway weirs, as well as to capture detections below the hydropower system in order to monitor annual survival.

This expanded capability will be applicable to interrogation systems in streams and rivers, where fish implanted with PIT tags can potentially be monitored at all life stages. These systems will provide data for determining the effectiveness of stock recovery and restoration programs supported by the Action Agencies (BPA, U.S. Bureau of Reclamation, and USACE).

This report summarizes work conducted by NOAA in 2025 to 1) incorporate additional pile dike PIT detection sites below Bonneville Dam and, 2) work directly with Pacific States Marine Fisheries Commission (PSMFC) to provide feasible concepts for new detection capabilities at Bonneville and McNary Dams. Progress in each of these areas is summarized below.

Pile Dike Detection Systems below Bonneville Dam— In 2025, we installed six stationary PIT interrogation sites along pile dikes to detect out-migrating juvenile salmonids in the tidal freshwater reach of the Columbia River estuary, between river kilometer 58 and 80. Working in collaboration with USACE two experimental pile dike sites were identified using an Eulerian-Lagrangian-agent Method / Evaluating Likely Animal Movement (ELAM). The two new sites were installed along consecutive pile dikes above Puget Island.

Detection System Development at Bonneville and McNary Dams—We continued work with PSMFC to develop additional PIT-detection capability for migrating juvenile fish at Bonneville Dam. Specifically through the development of the Ice and Trash Sluicway (ITS) detection system. The system is being installed during spring 2026 and should be operational during juvenile outmigration.

A regional need for boosted juvenile salmonid detection at other USACE sites pointed to possibilities of detection at McNary Dam. Working alongside PSMFC and USACE a project delivery team (PDT) was created to determine possibilities for detection at McNary. Following a process of alternative selection, the development and design process are underway to add detection in a Temporary Spillway Weir (TSW) bay of McNary Dam.

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Introduction

Fish-tracking technologies based on the passive integrated transponder (PIT) tag have proven critical in assessing the effectiveness of management actions and strategies to recover stocks of Pacific salmon *Oncorhynchus* spp. listed under the U.S. Endangered Species Act. Data from detections of PIT-tagged fish are used to evaluate smolt-to-adult survival for transportation studies and passage survival for operational strategies at dams within the Federal Columbia River Power System (Widener et al. 2024). Due to the fact that around 2 million fish are implanted with PIT tags annually, monitoring systems that help to fully utilize this existing resource are essential.

This project is intended to expand PIT technologies, which provide the means to conduct the research and monitoring prescribed by National Marine Fisheries Service (NMFS) biological and supplemental opinions for operation of the Federal Columbia River Power System. Expansion of these technologies is critical to implementation of the *reasonable and prudent alternatives* identified in these biological opinions. "Action Agencies," or those collaborating to implement these alternatives include the Bonneville Power Administration (BPA), NMFS, U.S. Fish and Wildlife Service (USFWS), and U.S. Army Corps of Engineers (USACE).

Since the 1980s, NMFS has been at the forefront of development, testing, adaptation, and transfer of PIT technologies (Downing et al. 2001). During the 1980s and 1990s, we developed and tested PIT monitoring systems for juvenile bypass systems and adult fishways at dams, as well as for a pair trawl operated in the Columbia River estuary (Ledgerwood et al. 2004). In 2002, we deployed the first instream monitoring system in Valley Creek, Idaho (Achord et al. 2012). In 2006, we led development and installation of a detection system in the corner collector bypass at Bonneville Dam. Nearly four decades of development culminated in the 2020 installation of the world's largest Radio-frequency Identification (RFID) detection system for fish passing through a spillbay at Lower Granite Dam.

In recent years, with continuing advances in antenna technology and tag-reading range, instream monitoring systems have multiplied rapidly. During 2025, there were 20 new instream remote detection sites added to the PTAGIS database. Present development efforts are focused on adapting detection systems for larger, higher-flow areas.

In addition to leading development of PIT antenna technology, NMFS has played a central role in the design and implementation of monitoring system components to improve existing installations (Anderson and Downing 2009; Axel et al. 2016). We continue to test, evaluate, and collect user input for improvement of existing monitoring systems and infrastructure. This work is essential to Pacific salmon *Oncorhynchus spp.* restoration and to recovery programs supported by BPA. To this end, we focus research effort on developing technologies to monitor depressed stocks at critical life stages and locations.

During the downstream migration, many stocks of threatened juvenile salmonids pass dams via spillbays, which are outfitted with temporary or removable spillway weirs (TSWs or RSWs). Spillway passage routes are encouraged, as they are thought to afford rapid passage with high rates of survival. However, until recently we were unable to monitor PIT-tagged fish using these passage routes because spillways lacked PIT interrogation systems. The exception is at Lower Granite Dam with the new spillway detection system. Previously, interrogation was available only for PIT-tagged fish that passed dams via the juvenile bypass systems.

Consequently, while annual numbers of PIT-tagged fish remain high, higher spill within the hydropower system in recent years has caused a decline in our ability to collect data, resulting in smaller sample sizes and reduced accuracy in estimates of passage survival (Widener et al. 2024). To overcome these data losses, we are developing new PIT-tag interrogation systems that can obtain detection data from dam-passage routes other than the juvenile bypass system. Components for these new systems include tags,

antennas, transceivers, and communication systems that will ensure successful monitoring of tagged fish through additional passage routes.

This project addresses the need for expansion of fish-tracking technologies to enable the fisheries community to carry out the actions, research, and monitoring activities outlined in NMFS biological opinions (NMFS 2000, 2004, 2008, 2014, and 2020). The work also addresses recovery goals articulated by those agencies responding to the remanded biological opinion, which recommends continued "development and implementation of new fish detection and tagging techniques" (USACE et al. 2004).

Our project objective is to satisfy these monitoring needs by advancing interrogation systems that collect data on migrating juvenile and adult salmonids through mainstem Columbia River Basin dams. These new systems will monitor salmon transiting surface-bypass systems during the juvenile migration stage as well as those rearing, migrating, or spawning in small streams at all life stages. Toward these goals, we completed the following tasks during the period from January to December 2025:

1. Fabricated and installed new Pile Dike PIT detection sites below Bonneville Dam
2. Continued work to support installation of new detection system at Bonneville Dam and provide feasible concepts for new detection capabilities at McNary Dam
3. Continued to provide outreach and collaboration opportunities for researchers throughout the basin

Pile Dike Detection Systems below Bonneville Dam

Since 2012, an autonomous, stationary PIT detection system has been mounted on Pile Dike 43.30 to sample PIT-tagged salmonids in the tidal freshwater reach of the Columbia River estuary (site code “PD7” in the regional database PTAGIS). Annually, this site has detected between 115 and 1,024 fish of varying species, runs, and age-classes.

In 2022, a second interrogation site (site code “PD6” in PTAGIS) was constructed across the channel from PD7 at Pile Dike 42.93. The new site recorded over 3,000 detections in its first 2 months of operation. We had two objectives for site development: 1) determine feasibility of deploying electronics at a site that lacks an elevated king piling, and 2) deploy antennas in a manner that maximizes juvenile salmonid detections.

Pile Dike 42.93 (PD6) was chosen because it had several characteristics aligning with objectives. Its proximity to PD7 and to the lower estuary sample reach used by the PIT-trawl detection system allowed for efficient site monitoring and maintenance. Additionally, the dike maintained good structural integrity despite not having an elevated king pile. Finally, we hypothesized that its orientation to river flow (approximately 45 degrees) was unique to nearby pile dikes and would be ideal for juvenile detection. We theorized that this orientation would naturally funnel fish along the upstream face of the dike and concentrate them towards the terminal end, where the antennas were to be deployed.

Subsequently, we aimed to replicate our success at PD6 by establishing new sites at pile dikes that demonstrated similar characteristics. In 2023, we installed two new sites in addition to PD6 and PD7 (PD5 at pile dike 38.26 and PD8 at pile dike 51.10). Each site operated 4-8 antennas, with the majority placed upstream and oriented perpendicular to the dikes and at least one antenna placed on the downstream side of each dike. In 2024, we moved the location of PD8 further downstream to pile dike 43.55 due to relatively

low detection totals at the original location. Also during 2024, we added ‘towers’ to house electronics boxes at PD5 and PD6, and redesigned an electronics ‘barge’ for deployment at PD8.

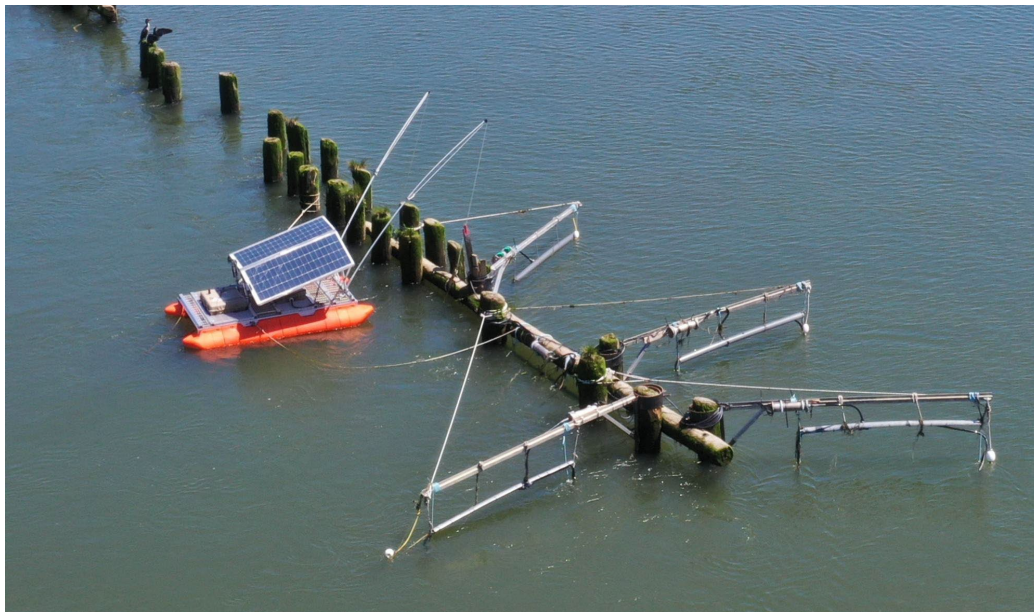


Figure 1. Aerial view of PD5 (2024) double site configuration (top). Aerial view of PD8 (2024) after relocation to pile dike 43.55 (bottom).

In 2025, we installed six stationary PIT interrogation sites at pile dikes (Figure 2; Table 1) to detect out-migrating juvenile salmonids in the tidal freshwater reach of the Columbia River estuary, between river kilometer 58 and 80. Four sites were those used in the past (PD5, PD6, PD7 & PD8) and two new experimental sites were installed, PDW at pile dike 46.87 and PDO at pile dike 47.35.

All pile dike sites detected PIT-tagged fishes of various species and age classes, including adult, jack and juvenile Chinook (*Oncorhynchus tshawytscha*), Coho (*O. kisutch*), Sockeye (*O. nerka*), and steelhead (*O. mykiss*), as well as white sturgeon (*Acipenser transmontanus*), green sturgeon (*A. medirostris*), cutthroat trout (*O. clarkii*), and northern pikeminnow (*Ptychocheilus oregonensis*).

Methods

In March 2025, six stationary PIT interrogation sites were installed along pile dikes between RKM 59 and 80 in the lower Columbia River (site codes: PD5, PD6, PD7, PD8, PDO, and PDW in PTAGIS; Figure 2). These sites operated from March through September 2025, with PD7 running year-round. During 2025, sites were specifically chosen to target detection of PIT tagged juvenile salmonids (adult detection was not intentional).

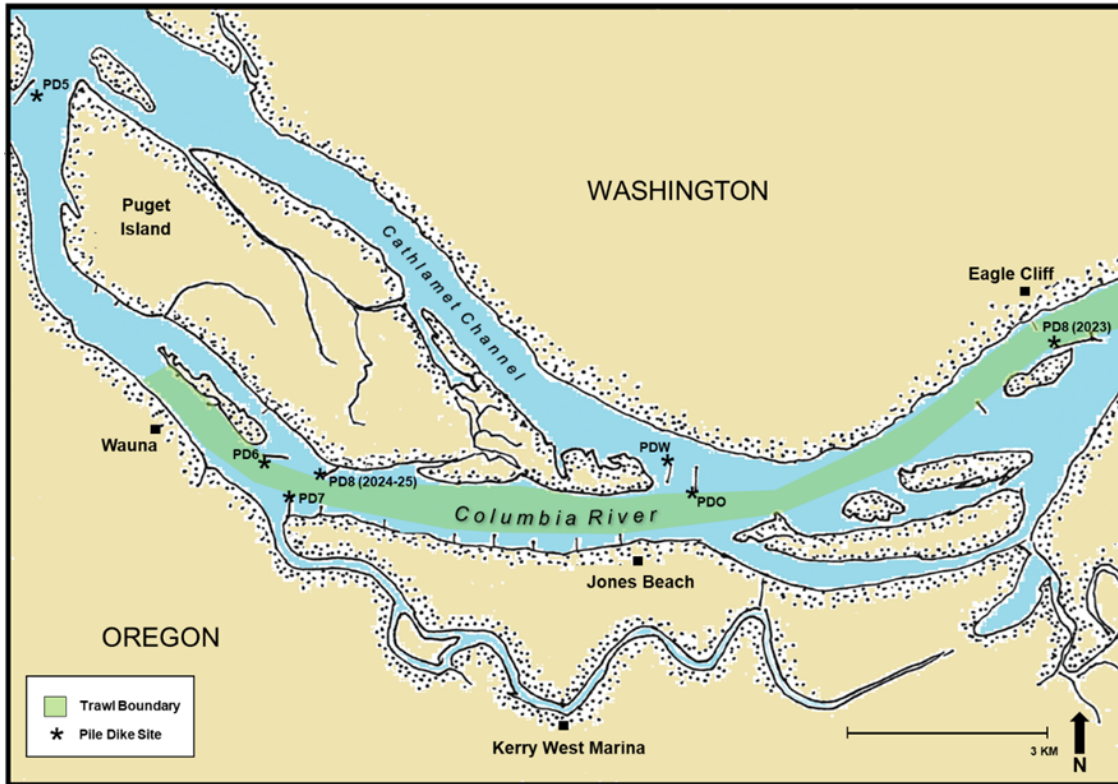


Figure 2. Map of the Jones Beach sample area including pile dike site locations and matrix trawl sampling reach.

Each site contained an array of 2-10 antennas controlled by a single Biomark IS1001-MTS transceiver. Individual antennas were housed within an aluminum watertight enclosure and contained an individual Biomark IS1001 reader, external capacitors, desiccant pack, and a pair of 8-pin CANbus wet-mate connectors. Arrays were powered through a single 400 watt solar panel which charged a set of four 12V marine deep cycle batteries. A 24V-28V DC-DC converter was used to amplify exciter voltage across the array, and CANbus cables connected each antenna into the array. Cellular modems allowed us to remotely transmit data from each site, update settings, and monitor site performance. Standard rectangular antennas were constructed from manufactured cable, and measured 2.6m by 6.1m. Antennas were installed in various

locations along each dike and hung from fabricated aluminum spars brackets to orient them perpendicular to the structure.

During 2025, two additional sites (PDW & PDO) were installed within the study area that did not exist in previous years. The new sites were installed at the terminal ends of two pile dikes located just upstream of Puget Island (Table 1). Pre-season ELAM modeling from the US Army Corps of Engineers (USACE) predicted salmonid migration through Cathlamet Channel for forecasted flow scenarios. Based on those predictions we installed PDW at the North end of the dike to target fish bound for the Cathlamet Channel. The PDO site was installed at the South end of the dike, in closest proximity to the thalweg, in an effort to target fish migrating through the mainstem.

The experimental sites (PDW & PDO) ran autonomously, 24/7 from April through September 2025, though regular maintenance was required throughout the spring to manage debris and repair damaged equipment. Electronics (ie. transceivers) were housed using electronic barges (similar to PD8). Sites were accessed weekly for data downloads, antenna maintenance, and debris removal.

Table 1. Pile dike PIT interrogation site locations, years of operation, and pile dike structure type.

PTAGIS Site Code	USACE Reference Number	Years of operation	Site coordinates	RKm	Pile Type*
PD5	38.26	2023 - 2025	46.205748, - 123.431179	62	Training
PD6	42.93	2022 - 2025	46.152253, - 123.384675	69	Training
PD7	43.33	2011 - 2025	46.146553, - 123.379867	70	Spur
PD8	51.10	2023	46.166489, - 123.225002	82	Training
PD8	43.55	2024 - 2025	46.149669, - 123.372903	70	Spur
PDW	46.87	2025	46.150972, - 123.305667	75	Spur
PDO	47.35	2025	46.148131, - 123.297803	76	Spur

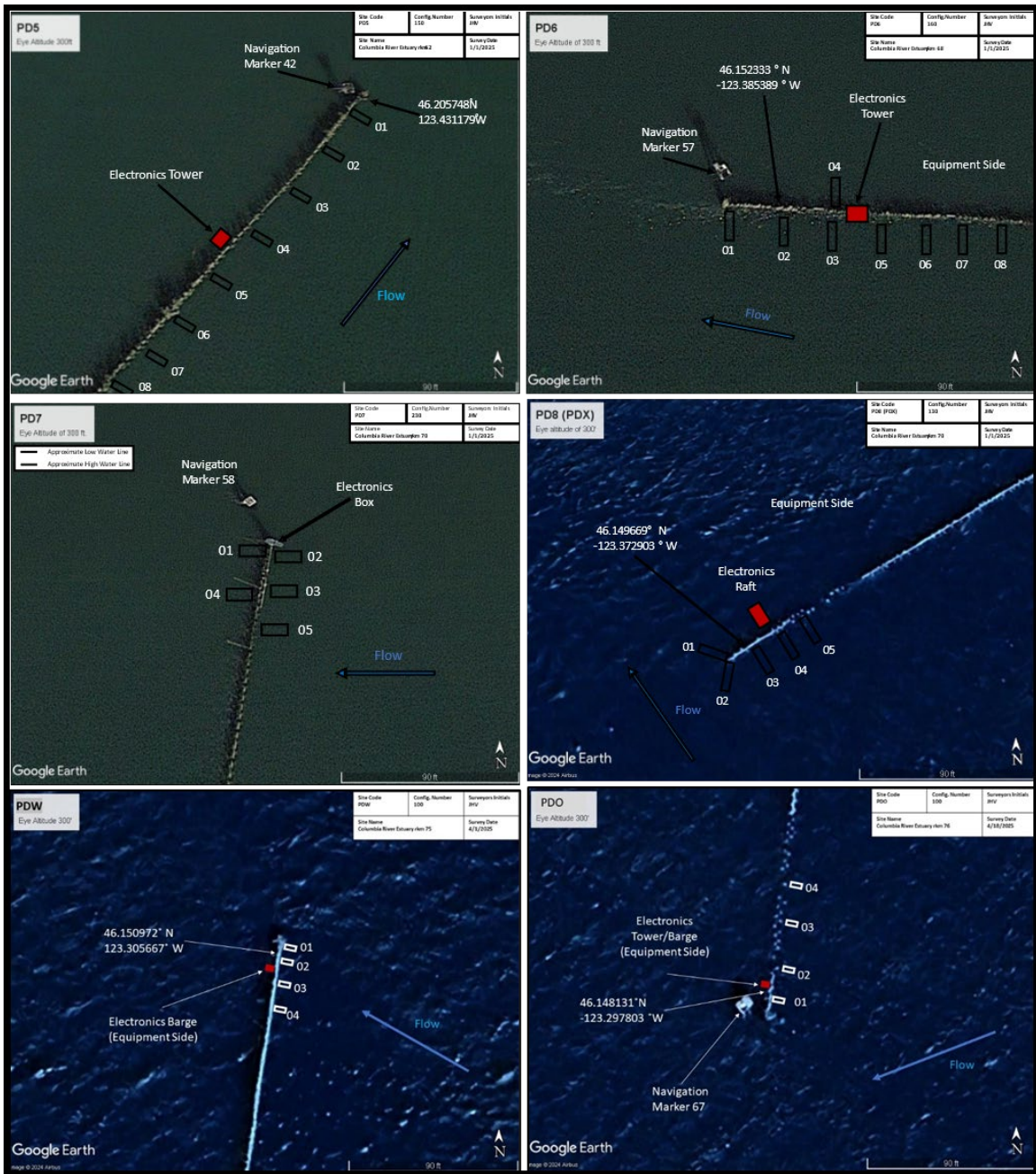


Figure 3. Pile dike PIT interrogation site layouts for targeting juvenile salmonid detections, 2025. Diagrams depict PIT antenna locations, electronics tower/barge locations, site coordinates, and river flow.

Results

In 2025, our six pile dike PIT interrogation sites detected a combined total of 14,764 pit-tagged fish of various species and age classes. Of these fish, species composition was 69% Chinook, 16% steelhead, 7% coho, 1% sockeye, <1% white sturgeon, cutthroat trout, and northern pikeminnow, and 5% unknown species, at time of reporting (Table 1). Total detections by rear type were 13% wild, 81% hatchery, and 6% unknown origin.

Table 2. Composition of species detected by pile dike site, 2025.

Year/species	PD5	PD6	PD7	PD8	PDO	PDW	Total
Chinook	1,991	692	522	2,976	1,827	2,245	10,253
Coho	382	72	64	146	103	295	1,062
Sockeye	37	2	11	54	57	22	183
Steelhead	781	89	152	526	225	587	2,360
Cutthroat Trout	11	3	7	1	1	14	37
White Sturgeon	15	4	22	12	16	2	71
Northern Pikeminnow	2	1	1	1	2	2	9
Pacific Lamprey	0	1	0	0	0	0	1
Unknown	127	38	44	270	112	197	788
Total	3,346	902	823	3,986	2,343	3,364	14,764

Overlap between sites was minimal, approximately 2% (n=304) of overall detections were recorded at more than one site. Similarly, detections of tags across multiple antennas subsequent to the first detection at a site were minimal, ranging from 3 to 26% redundancy across sites. Juveniles accounted for 98% (n=13,612) of all 13,858

PIT tagged salmonids detected on pile dikes in 2025 (Table 3), with 80% (n=10,901) of those occurring during the intensive PIT trawl sample period from 28 April through 12 June. Species composition of juveniles detected at pile dike sites was 56% spring and summer Chinook, 18% fall Chinook, 17% steelhead, 8% coho, and 1% sockeye (Appendix Table 3). Basin of origin among juvenile salmonids was 44% Snake River, 31% Upper Columbia River, 18% Middle Columbia River, and 7% Lower Columbia River (Figure 4).

Table 3. Species and life history stage of salmonids detected on pile dike arrays, 2025.

Species	Salmonid Lifestage			Total
	Adult	Jack	Juvenile	
Chinook	59	99	10,095	10,253
Coho	3	21	1,038	1,062
Sockeye	6		177	183
Steelhead	55	3	2,302	2,360
Total	123	123	13,612	13,858

Of all juvenile salmonids detected by pile dikes in 2025, 4% were transported, 11% were detected passing Bonneville Dam, and the remaining 86% had neither been transported nor detected at Bonneville Dam, though at least 93% of juvenile detections originated upstream from Bonneville Dam (Figure 4).

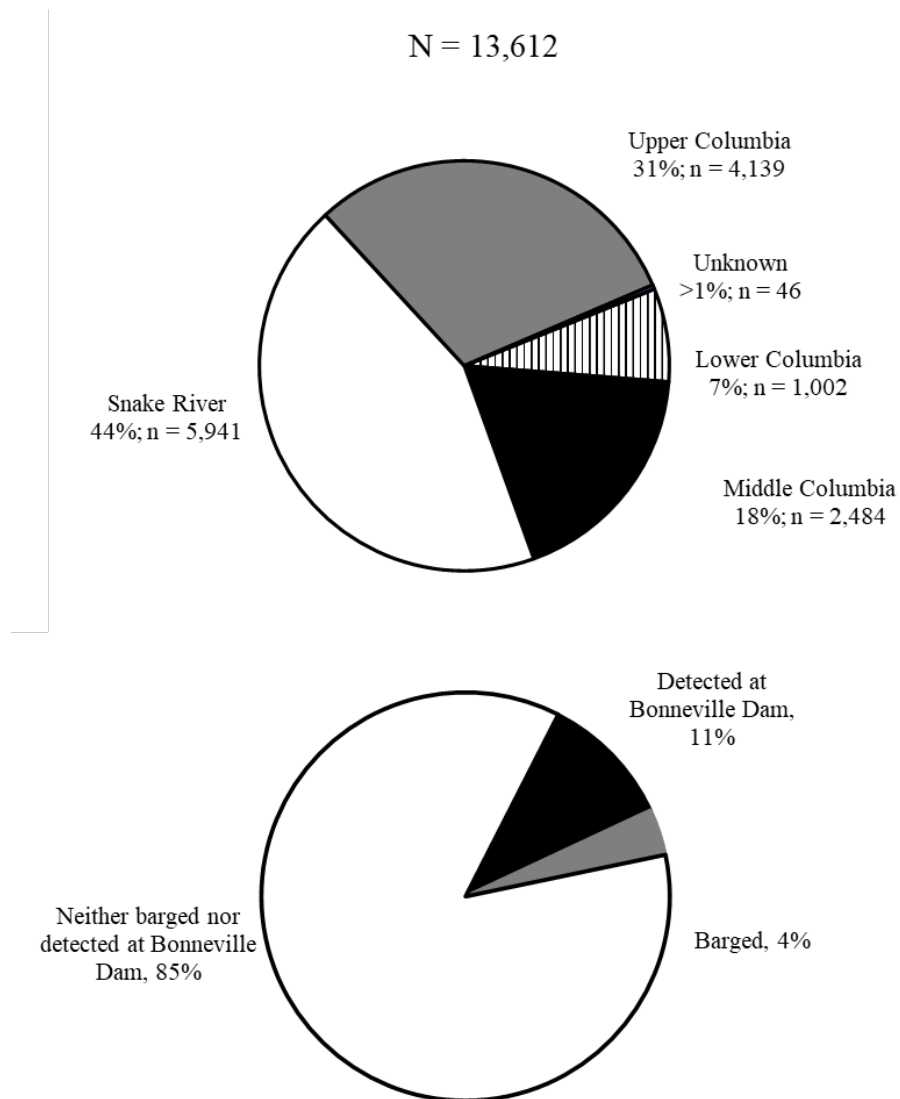


Figure 4. Proportions of all juvenile salmonids by source (top pie chart) and migration history (bottom pie chart) detected in the Columbia River estuary by pile dike arrays in 2025. Upper and middle Columbia River sources were defined relative to McNary Dam. Fish that originated in the Columbia River below Bonneville Dam could not be transported, nor could they pass Bonneville Dam.

For adults (n = 123), species composition was 48% Chinook, 45% steelhead, 2% coho, and 5% sockeye. The majority of adult detections were recorded on PD5 and PD7, which accounted for almost half of adult detections. Detection rates were highest for adults from mid-June through the end of August. For jacks (n = 123), species

composition was 81% Chinook, 17% Coho, and 2% steelhead. Detection rates were highest for jack salmonids from late June through early August. In 2025, 71 white sturgeon were detected among our pile dike sites. These included 15 at PD5, 4 at PD6, 22 at PD7, 12 at PD8, 16 at PDO, and 2 at PDW (Table 2). Peak detection rates for sturgeon occurred between June and August.

Discussion

Detections in the lower Columbia River are vitally important to estimating juvenile salmonid survival. With over 13,000 detections of juvenile salmonids on the pile dike systems alone, we felt the efforts were a great success during 2025. The newly added sites at PDO and PDW contributed roughly a third of the ~13,000 detections. The breakdown of species composition shows that we are very effective at detecting spring/summer Chinook. With continued site expansion, development, and use of available tech (ie. ELAM modeling) we are optimistic that we can increase detections of Steelhead as well.

Based on results from pile dike sites in 2025, we plan to continue our expansion of PIT interrogation efforts in 2026. We plan to operate 6-8 total sites, primarily focusing on building out small sites with 2-4 antennas each for PD7, PD8, PDO, PDW, and up to two new locations, with 6-10 antennas deployed at PD5 and PD6. As a more permanent investment to our infrastructure, we designed an aluminum electronics enclosure that mounts directly to the pilings. This new structure reduces the risk of debris damage to equipment and allows for shorter cable runs. These structures will be installed to sites that have proven to record high detection rates and also retain good structural integrity to support them. Our streamlined electronics barge design incorporates all electronics and a solar array onto a single unit. These are easy to move around to different locations and are better suited for weaker and degrading pile dike structures. This mobile design will allow us to easily test out new locations for future interrogation sites, with minimal infrastructure dedicated to a site.

New Detection System Development at Bonneville and McNary Dam

Through ongoing discussions pertaining to the prescribed spill operations within the Federal Columbia River Power System and the subsequent reduction of PIT tag detections, we have been tasked with developing options to boost detection capabilities. In 2019, we began developing options to boost detections at Bonneville Dam by incorporating PIT detection into the existing ice and trash sluiceway system. During 2025, NOAA remained involved in project planning for installation of the Ice and Trash Sluiceway (ITS) antenna. PSMFC successfully built and tested the antenna with installation occurring during February 2026.

During 2025, an engineering design and development team including members from USACE, PSMFC, and NOAA began the process of selection and development of an additional juvenile detection system at McNary Dam. Study goals are focused on increasing PIT tag detection of fish passing the McNary spillway in order to improve survival estimates within the FCRPS.

Through a formal process with the USACE Walla Walla District, the development team came up with a list of eleven design concepts that were evaluated by the team and stakeholders from the Fish Facilities Design Review Work Group (FFDRWG). Using a list of criteria and limiting constraints the eleven alternative concepts were evaluated. Alternatives that did not violate necessary constraints were then rated and scored. The top ranking alternative utilizes IS1001 transceivers and antennas attached to or built into a framed 'matrix' structure that spans the width (52') of a spill bay directly up-stream of a temporary spill weir (TSW). The matrix would be placed into the up-stream slot within the spill bay and detect previously PIT tagged fish as they pass. Development and collaborative discussions with PSMFC, USACE and BPA are ongoing.

Conclusion

PIT Tag Detection Development at Bonneville and McNary Dam—We continued work to develop additional PIT-detection capability for migrating juvenile fish at Bonneville Dam with additional development plans for McNary Dam. The ITS detection system is slated to be operational for the 2026 migration season. Our collaboration with the USACE and PSMFC resulted in completion of an engineering documentation report (EDR) recommending monitoring systems for the TSW gates at McNary Dam. The project development team and USACE are in the process of review and design related to the new system. Contractor selection related to construction for the project is scheduled for bid during FY26.

We will continue working to develop cost-efficient methods for PIT tagging, detection, and data transmittal, all of which are critical for monitoring of endangered salmonid stocks.

Outreach and Collaboration

A major goal of this project is to increase collaboration effort throughout the region with respect to priorities for new PIT detection and marking technologies. To this end, we are active on the regional PIT Tag Steering Committee that focuses on these same goals. This committee provides a hub, or central contact point to receive feedback from monitoring-system users throughout the Columbia River Basin. Through this collaboration, we hope to engage end users and to spur new ideas, pinpoint detection priorities, and identify data gaps that will help direct research and development toward making the most efficient use of new and expanded PIT technology.

The following is a summary of our outreach and collaborations during 2025. Our goal is to include as many stakeholders as possible so that feedback and observations from users of PIT technology will continue to drive development of PIT detection capabilities.

- As a contributing member of the PIT Tag Steering Committee, NOAA made a significant contribution to the revision of the PTAGIS Marking and Procedures Manual (v4.0). The manual provides technical guidance and standardizes tagging techniques, handling protocols, and data reporting within the Columbia Basin.
- Worked with PTAGIS to beta test the new tagging software (P5).
- Worked with PSMFC and COE at Bonneville dam to remove and rebuild an exit antenna located within the Washington shore fish ladder at BO4. Post construction evaluation was completed regarding fish passage timing and detection probability. Contract report to COE in process, should be available Fall 2026.
- Worked alongside NOAA researchers from the Point Adams field office on a pilot project to investigate PIT detection on a Pinniped haulout site within the East Mooring Basin in Astoria, OR.

- Worked in collaboration with Benton Conservation District as part of the Salmon in the Classroom program. The program educates fourth grade students within Benton County about the salmon lifecycle and provides examples of how research is conducted using PIT tags throughout the Columbia Basin.

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