Colville Tribes, Fish & Wildlife Department

2022 Okanogan Subbasin Steelhead Spawning Abundance and Distribution

BONNEVILLE
POWER ADMINISTRATION

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B.F. Miller, R.L. Johnson, M.L. Miller, R.S. Klett, and J.E. Arterburn
Colville Confederated Tribes, Omak, WA 98841

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Executive Summary

The Okanogan Basin Monitoring and Evaluation Program (OBMEP) has monitored summer steelhead (*Oncorhynchus mykiss*) spawning abundance and distribution within the Okanogan River subbasin from 2005 through 2022. Monitoring has been conducted through a combination of redd surveys, underwater video counts, and Passive Integrated Transponder (PIT) tag detections. In 2022, it was estimated that 314 summer steelhead (203 hatchery-origin and 111 natural-origin) spawned in the Okanogan subbasin in 2022. The total number of spawners is the lowest on the recent period of record (2005-2022). When specifically looking at natural-origin spawners, 2022 was also the lowest on the period of record. The two lowest years prior to 2022 occurred in 2017 and 2018, with 115 and 120 natural-origin spawners, respectively. Over the past 18 years of monitoring, the average number of adult steelhead spawners in the Okanogan subbasin was 1,360 (geomean = 1,095). The average number of natural-origin spawning steelhead was 269 (geomean = 230). Spawning estimates were also compared with recovery goals, as outlined by the Interior Columbia Basin Technical Recovery Team (ICBTRT). The Upper Columbia Spring Chinook and Steelhead Recovery Plan states that 500 naturally produced steelhead adults would meet the minimum abundance recovery criteria within the U.S. portion of the Okanogan subbasin; if the Canadian portion of the subbasin was included, minimum abundance recovery criteria would be 1,000 naturally produced adults (UCSRB 2007). The trend in the 12-year geomean of natural-origin steelhead spawning in the Okanogan River subbasin is fairly level and remains below the minimum abundance of the VSP (Viable Salmonid Population) threshold for natural-origin spawners (500 in the US portion of the subbasin).

In the Okanogan subbasin, the proportion of hatchery origin spawners (pHOS) from 2005 through 2013 averaged 0.85, but the average pHOS decreased to 0.71 from 2014 through 2022. The lowest recorded pHOS was 0.31 in 2020. The abundance of hatchery steelhead has been variable, ranging from a low of 203 in 2022 up to 2,768 in 2010. Historically, spawning has occurred throughout the mainstem Okanogan River, andhas been concentrated in distinct areas that contained suitable water velocities and substrates. The highest concentration of steelhead spawning has been documented below Zosel Dam on the Okanogan River and in braided island sections of the lower Similkameen River. According to estimated escapement and the number of redds found in 2022, all of the mainstem spawning was accounted for in river segment just below Zosel. The release location of juvenile hatchery steelhead likely influences the spatial distribution of spawning adults. Hatchery releases occur in Omak, Salmon, Antoine and Aeneas Creeks and the Similkameen River.

On years when spring runoff takes place after peak spawning is completed, redd surveys can provide a reasonable depiction of steelhead spawning distribution and an estimate of escapement. Defining the physical location of redds informs managers about which, and to what extent, habitats are being used for spawning and allow for tracking of spatial status and trends through time. However, conducting redd surveys on years with early runoff is not always effective due to poor water clarity. Since OBMEP began collecting steelhead spawning data in 2005, the importance of not relying solely on redd surveys for abundance estimates has become evident. Implementation of Upper Columbia Basin-wide PIT tag interrogation systems (Project # 2010-034-00), coupled with the representative marking of returning adults at Priest Rapids Dam, provides managers an additional means to estimate abundance for years with poor survey conditions. Data from instream PIT arrays also helps validate redd survey efficiency, describes spatial distribution, timing of migration, and the extent of upstream spawning where previously unknown. These efforts allow managers to more accurately describe the spatial extent of spawning in tributaries, monitor effectiveness of barrier removal projects, and better define escapement estimates.

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1.0 Introduction

Within the Upper Columbia River Basin, the furthest upstream and northern-most extent of currently accessible anadromous habitat is found in the Okanogan River. Summer steelhead (*Oncorhynchus mykiss*) are listed as threatened in the Upper Columbia Evolutionarily Significant Unit (ESU) under the Endangered Species Act (ESA) (NMFS 2009). To recover this ESU requires that all four populations (Wenatchee, Entiat, Methow, and Okanogan) meet minimum adult abundance thresholds, have positive population growth rates, and each population must be widely distributed within respective basins (UCSRB 2007). Within the Okanogan River subbasin, the Okanogan Basin Monitoring and Evaluation Program (OBMEP) monitors adult abundance attributes. OBMEP developed protocols derived from the Upper Columbia Strategy (Hillman 2004) that called for a complete census of all spawning. Preliminary methodologies for implementing redd surveys were developed in 2005 and revised in 2007 (Arterburn et al. 2007). In addition to redd surveys, we used a combination of adult weir traps, Passive Integrated Transponder (PIT) tag arrays, and underwater video counting to improve escapement estimates and coordinate with other on-going data collection efforts. In cooperation with the Washington Department of Fish and Wildlife (WDFW), OBMEP expanded the use of instream PIT tag arrays to enhance the monitoring of adult summer steelhead use of small tributaries to the Okanogan River.

This document builds upon knowledge and information gained from preceding years' surveys. A literature review of historic spawning information related to the Okanogan River subbasin can be found in Arterburn et al. 2005. Previous years' data and reports can be accessed at:

https://www.okanoganmonitoring.org/Reports/SteelheadSpawningSurveys

2.0 Methods

OBMEP - Adult Abundance - Redd Surveys v1.0 (ID:192)
https://www.monitoringresources.org/Document/Protocol/Details/192
OBMEP - Adult Abundance - Adult Weir and Video Array (ID:6)
https://www.monitoringresources.org/Document/Protocol/Details/6
OBMEP – Adult Abundance – Analysis v1.0 (ID:2125)
https://www.monitoringresources.org/Document/Protocol/Details/2125
Upper Columbia River ESU Steelhead Stock Assessment (2010-034-00) v1.0 (ID:235)
https://www.monitoringresources.org/Document/Protocol/Details/235

The Okanogan River flows from the northern headwaters near Vernon, BC to the confluence with the Columbia River near Brewster, WA (Figure 1). Counts of summer steelhead spawning occurred downstream of anadromous fish migration barriers in the mainstem Okanogan River and its tributaries accessible to anadromous fish within the United States (Arterburn et al. 2007, Walsh and Long 2006) following the OBMEP redd survey protocol. The area of the Okanogan River downstream from Chiliwist Creek has very low gradient and is inundated by the Columbia River (Wells Pool/Lake Pateros). Consequently, this lower reach (~23 km) of the Okanogan River was excluded from surveys because it lacks appropriate velocity and substrate needed for summer steelhead to spawn. Mainstem and tributary redd survey reaches are listed in Table 1. Redd surveys were supplemented with adult weir traps, instream PIT tag arrays, and underwater video counts at locations where habitat was too extensive or when access could not be arranged with private landowners.

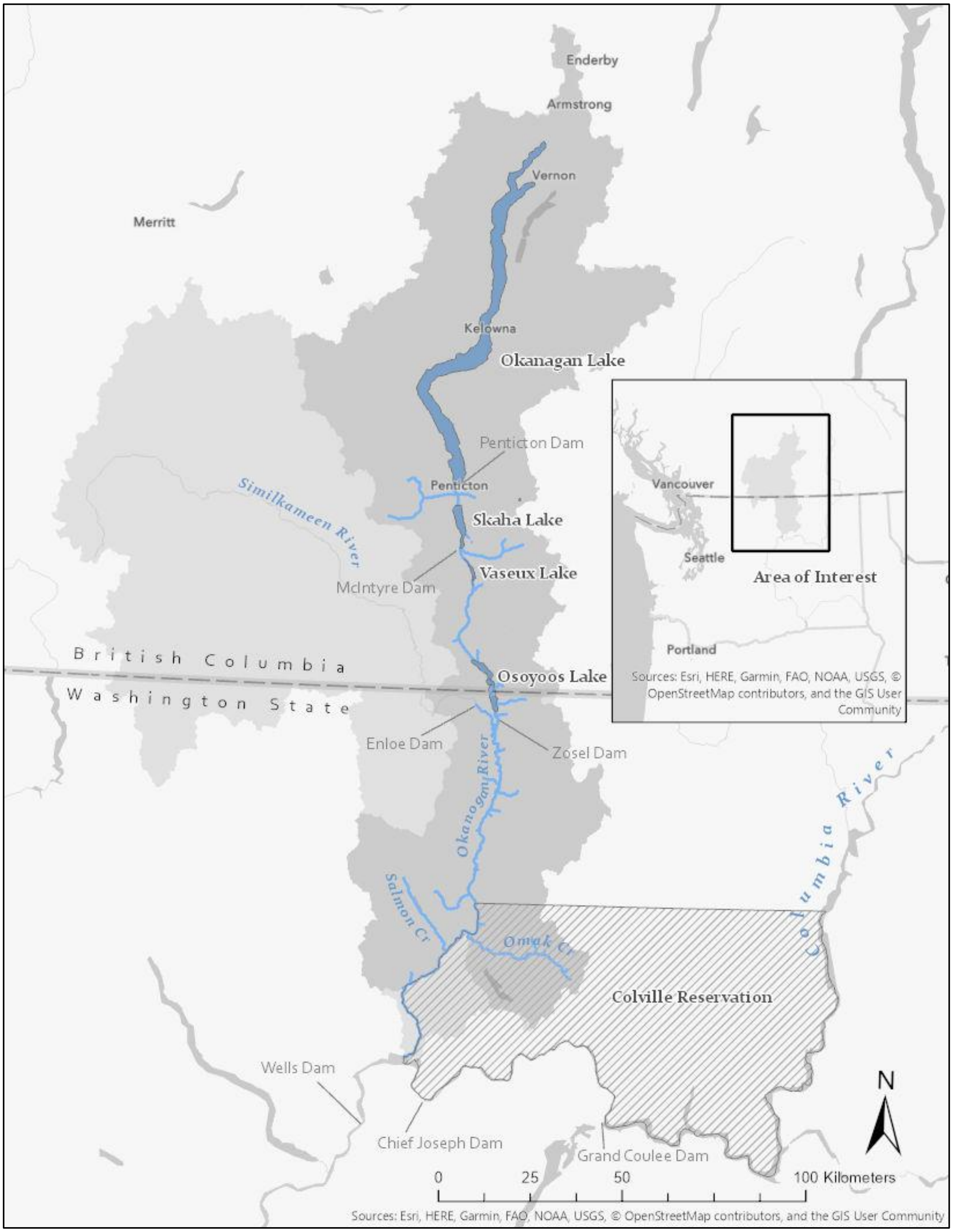

Figure 1. Study area, the Okanogan River subbasin in north-central Washington State and southern British Columbia. Stream segments shaded in blue represent habitat currently accessible to anadromous fish.

The Okanogan River was divided into seven survey reaches and the Similkameen River was surveyed as two reaches. Survey reaches were determined by access points along the river and outlined in Table 1. Discharge data, air and water temperature, and local knowledge of fish movements collected from previous years were used to determine when to begin surveys on the mainstem. Mainstem surveys were conducted from rafts, a jet boat and/or on foot in a downstream progression. All island sections or other mainstem areas that could not be floated due to limited access and/or obstacles (e.g. wood debris, braided channels, and diversions) were surveyed on foot. Raft surveys were conducted by a minimum of two people. Small tributaries were surveyed on foot, primarily walking in an upstream direction, and were typically attempted three times to document spatial distribution of spawning across the entire steelhead spawning period.

Table 1. Okanogan subbasin steelhead redd survey reaches.

Redd Survey Reach	Location and Description	Reach Length (km)
Okanogan River 1	Okanogan River at Loup Loup Creek (26.7) to Salmon Creek (41.4)	14.7
Okanogan River 2	Okanogan River at Salmon Creek (41.4) to the office (52.3)	10.9
Okanogan River 3	Okanogan River at the office (52.3) to Riverside (66.1)	13.8
Okanogan River 4	Okanogan River at Riverside (66.1) to Janis Bridge (84.6)	18.5
Okanogan River 5	Okanogan River at Janis Bridge (84.6) to Tonasket Park (91.4)	6.8
Okanogan River 6	Ok. R. at Horseshoe Lake (112.4) to confluence with Similk. R. (119.5)	7.1
Okanogan River 7	Okanogan River at Similk. R. confluence (119.5) to Zosel Dam (127.0)	7.5
Similkameen River 1	Similkameen/Okanogan Confluence (0) to sewer plant (6.6)	6.6
Similkameen River 2	Similkameen from sewer plant (6.6) Enloe Dam (14.6)	8.0

Geographic position of redds were collected with a Trimble GeoXT™ GPS unit and downloaded into GPS Pathfinder® after each survey. Waypoints were reviewed and differentially corrected. To avoid recounting, flagging was tied to bushes or trees adjacent to the area where redds were observed. Individual flags were marked with the survey date, direction and distance from the redd(s), consecutive flag number, total number of redds represented by the flag, and surveyor initials. Incomplete redds or test pits were not flagged or counted.

Abundance of steelhead spawning within survey reaches were then converted to Hydrologic Unit Code (HUC), which adds to consistency within other approaches. HUCs also directly correspond to the Diagnostic Units (DU) used in habitat modeling within the mainstem Okanogan River (Figure 2). Each unique tributary to the Okanogan River also represent individual HUCs.

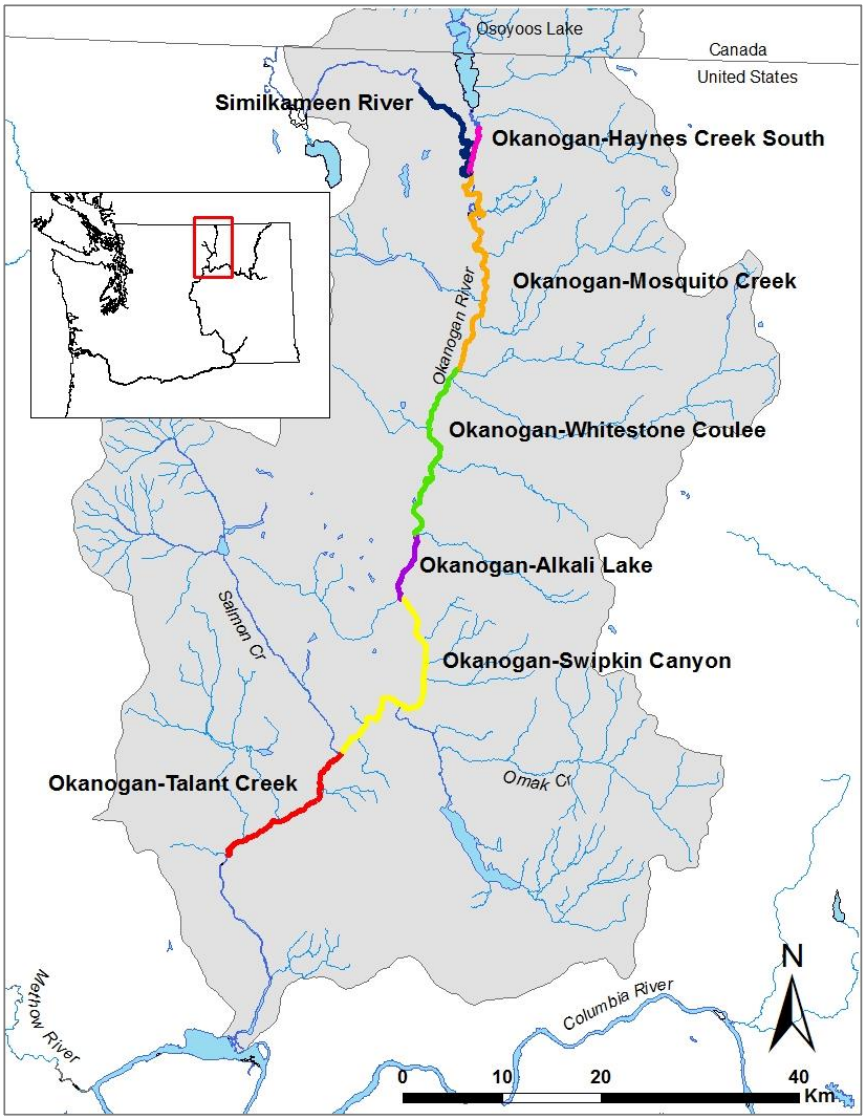

Figure 2. Mainstem Okanogan and Similkameen Rivers Hydraulic Unit Codes and diagnostic unit reaches.

2.1 Sex Ratio and Number of Fish Per Redd

OBMEP employed a method that has been used by the Washington Department of Fish and Wildlife (WDFW) in the Upper Columbia Basin to extrapolate spawning escapement estimates from redd counts using the sex ratio of fish collected randomly throughout the run at Priest Rapids Dam. A sub-sample of summer steelhead were captured, marked and sexed during the 2021 upstream migration (pers. comm. Katy Shelby, WDFW). A total of 38 female (27 hatchery, 11 natural-origin) and nine male steelhead (six hatchery, three natural-origin) from the PRD mark group were detected in the Okanogan subbasin. The proportion of female to male steelhead was similar for natural-origin (0.789:0.214) and hatchery-origin (0.818:0.182). As steelhead entered tributaries to spawn in the spring of 2022, a total of eight of these fish were recaptured at the Omak weir trap. Upon examination, it was determined that three of the eight fish were males misidentified as females during sampling the previous fall. It is more accurate to determine the sex of steelhead closer to their spawn timing due to more clear sexual dimorphic traits (color and morphological differences) and development of gametes. Due to the significant misidentification rate (~3/8), we felt it necessary to alter the sex ratio of steelhead entering the Okanogan. Originally, the averaged sex ratio would have been 0.809:0.191 F:M, but adjusted by the misidentification rate rendered 0.511:0.489. The misidentification of adult fish was noted at spring-time recapture sites in other subbasins (pers. comm. Katy Shelby, WDFW). Rounded, the new sex ratio of one female per 0.96 males or 1.96 fish per redd (FPR) was used to expand redd counts into steelhead spawning estimates for the subbasin. All calculations using sex ratio multipliers assume that each female will produce only one redd.

2.2 PIT Tag Expansion Estimates

Throughout the spring of 2022, permanent and seasonal PIT tag arrays were operated near the mouth of all perennial flowing and most ephemeral tributaries to the Okanogan River known to contain steelhead spawning. The CCT works in conjunction with the WDFW (the lead investigator on project number 2010-034-00), to operate and maintain PIT tag detection sites in the Okanogan subbasin, along with data collection and management of those datasets. Any expanded PIT tag estimates presented in this document should be considered preliminary estimates as data analyses are currently in progress for the entire Upper Columbia for multiple years of the project. Final analyses of *run escapement* numbers will be reported under BPA project number 2010-034-00. This report serves to calculate *spawn estimates* for the Okanogan subbasin.

Population estimates derived from PIT tag detections were calculated following the protocol developed by Murdoch et al. 2011. In the 2022 brood year, a representative sample of upstream migrating steelhead were captured at Priest Rapids Dam (PRD) from July through October, 2021. All fish were scanned for hatchery marks, sexed and marked with a PIT tag unless previously tagged. During this period approximately 10.7% of the total run was sampled, giving a tag rate of 0.107 for both natural- and hatchery-origin fish. These mark-rates were used to expand the number of PIT detections from the PRD mark-group on in-stream PIT arrays located near the mouth of creeks into escapement estimates. For example, if six hatchery-origin and two natural-origin steelhead from the PRD mark group were detected at the PIT array located at the mouth of a given tributary, the escapement estimate would be 56 hatchery (6/0.107 = 56) and 19 natural-origin steelhead (2/0.107 = 19). This method assumes that marked fish are representative of unmarked fish. Given relatively few detections at many locations (particularly at smaller tributaries) escapement estimate confidence bounds derived from PIT tag detections may be quite wide. In addition to fish tagged at Priest Rapids, adult steelhead may have also received PIT tags at other times and locations e.g., as out-migrating juveniles, adults returning to Bonneville Dam, Wells Dam, etc. However, it is unknown how representative those fish are to the run at large. Therefore, only PIT tags from the PRD release group, project 2010-034-00, were used to estimate steelhead escapement. It is important to note that reported tag rates are preliminary. Recent questions about the validity of dam counts at certain locations have been expressed, and solutions to this issue are being addressed. Should prior years' tag rates or sex ratios become altered, some historical escapement numbers may be restated.

3.0 Okanogan Subbasin Summer Steelhead Spawning Estimates

Based on expanded redd counts and PIT tag detections from project 2010-034-00, it was estimated that 314 summer steelhead (203 hatchery-origin and 111 natural-origin) spawned in the Okanogan subbasin in 2022. The total number of spawners is the lowest on the recent period of record (2005-2023). When specifically looking at natural-origin spawners, 2022 was also the lowest on the period of record. Over the past 18 years of monitoring, the average number of adult steelhead spawners in the Okanogan subbasin was 1,360 (geomean = 1,095). The average number of natural-origin spawning steelhead was 269 (geomean = 230). The number of natural-origin steelhead spawning in the Okanogan River subbasin has a fairly level, but slightly declining trend, which remains below the minimum VSP abundance threshold for natural-origin spawners (500 in the US portion of the subbasin).

The proportion of hatchery origin spawners (pHOS) from 2005 through 2013 averaged 0.85, but the average pHOS decreased to 0.71 from 2014 through 2022. The lowest recorded pHOS was 0.31 in 2020. The abundance of hatchery steelhead has been variable, ranging from a low of 203 in 2022 up to 2,768 in 2010. A summary of the estimated number of adult steelhead spawners, distributed by mainstem survey reach and individual tributaries, are presented in Table 3. Results for unique tributaries and mainstem reaches are further detailed in sections 3.1 to 3.3 of this document.

Table 2. Okanogan subbasin summer steelhead spawner abundance estimates, 2005–2023.

Year	Total	Hatchery Steelhead	Natural-Origin Steelhead	Natural-Origin 12-yr geomean
2005	1,226	1,080	146	
2006	899	702	197	
2007	1,268	1,116	152	
2008	1,386	1,161	225	
2009	2,133	1,921	212	
2010	3,496	2,768	728	
2011	1,674	1,341	333	
2012	2,802	2,475	327	
2013	1,937	1,687	250	
2014	1,356	838	518	
2015	1,461	1,009	452	
2016	1,566	1,175	391	292
2017	1,044	929	115	286
2018	453	333	120	274
2019	473	306	167	277
2020	374	114	260	280
2021	710	573	137	271
2022	314	203	111	234
Average	1,460	1,1096	269	273

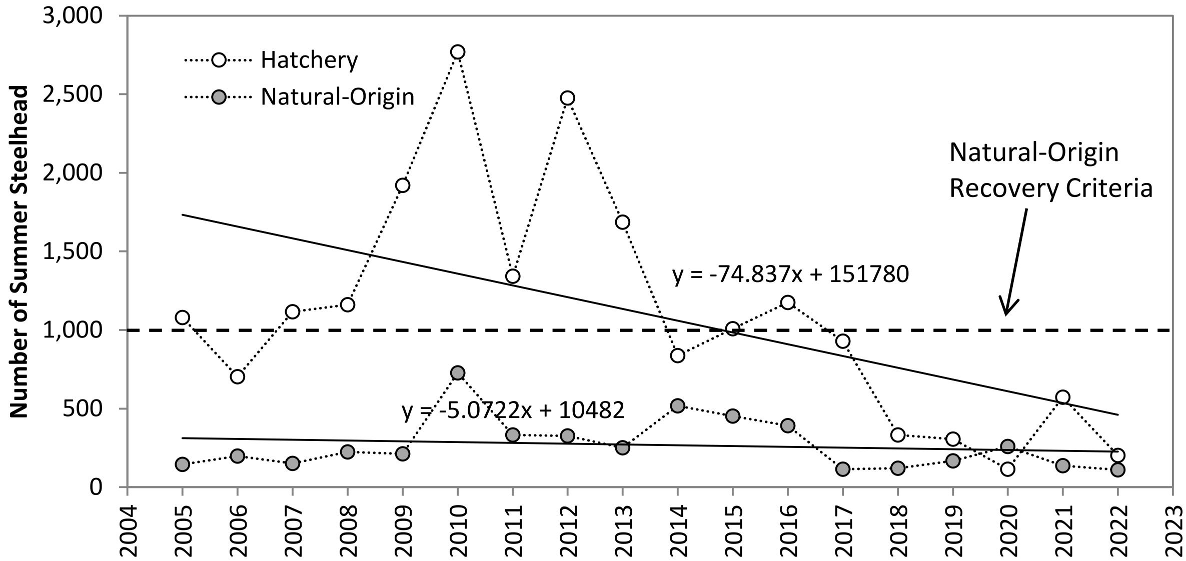

Figure 3. Trend in the estimated number of summer steelhead spawning in the Okanogan River subbasin, 2005–2022.

Table 3. Estimated number of hatchery and natural-origin steelhead spawning for each sub-watershed or assessment unit in 2022 compared with long-term averages.

Category	Location/HUC	2022 natural-origin spawner abundance	*Average # of natural-origin spawners 2005–2021*	2022 hatchery spawner abundance	*Average # of hatchery spawners 2005–2021*
WA Mainstem	Okanogan-Davis Canyon	0	*0*	0	*0*
WA Mainstem	Okanogan-Talant Creek	0	*1*	0	*10*
WA Mainstem	Okanogan-Swipkin Canyon	0	*5*	0	*44*
WA Mainstem	Okanogan-Alkali Lake	0	*3*	0	*25*
WA Mainstem	Okanogan-Whitestone Coulee	0	*6*	0	*54*
WA Mainstem	Okanogan-Mosquito Creek	0	*1*	0	*13*
WA Mainstem	Okanogan-Haynes Creek South	0	*35*	47	*310*
WA Mainstem	Similkameen River	0	*22*	0	*185*
WA Tributary	Loup Loup Creek	0	*10*	14	*33*
WA Tributary	Salmon Creek	18	*36*	9	*97*
WA Tributary	Omak Creek	19	*68*	53	*156*
WA Tributary	Wanacut Creek	0	*0*	2	*2*
WA Tributary	Johnson Creek	0	*5*	2	*17*
WA Tributary	Tunk Creek	19	*10*	1	*30*
WA Tributary	Aeneas Creek	0	*0*	0	*3*
WA Tributary	Bonaparte Creek	9	*27*	37	*55*
WA Tributary	Antoine Creek	0	*6*	0	*10*
WA Tributary	Wild Horse Spring Creek	9	*7*	0	*34*
WA Tributary	Tonasket Creek	19	*8*	9	*22*
WA Tributary	Ninemile Creek	9	*7*	28	*15*
Area	Washington State Mainstem	**0**	**73**	**47**	**641**
Area	Washington State Tributaries	**102**	**183**	**155**	**474**
Area	British Columbia	**9**	**23**	**1**	**12**

[a] Average from British Columbia only contain data from 2013-on.

3.1 Steelhead Spawning Estimates: Okanogan and Similkameen River Mainstem

In the fall of November of 2021, the Okanogan River experienced a rare fall-time flood event. An early snowpack in the Cascade Mountains suddenly melted after multiple strong atmospheric rivers impacted northern Washington and Southern British Columbia. The sudden run-off caused flooding in several rivers in British Columbia including the Similkameen River, and subsequently, the Okanogan River. Though the Okanogan River subbasin itself did not receive any precipitation from these weather events, the Okanogan River at Tonasket peaked on November 17, 2021 at 19,200 cfs, which was significant in a few ways. This fall peak was higher than either of the 2021 and 2022 spring freshet peaks as shown in Figure 4. In 93 years of record, this was the highest peak ever recorded outside the normal high flow months of April to June. Only one previous year in the 93-year period experienced its annual peak in the fall, which was in 2003. However, that peak was about half the magnitude as the fall peak in 2021. Interestingly, in the 2021 event, the upstream Canadian section of the Similkameen River had approximately double the peak discharge of the U.S. section.

The floodwaters were sediment laden and with a milky, light brown color, contrasting with the normal faint blue base flow color of the Okanogan River. Turbid conditions lasted through winter into spring, affecting mainstem steelhead surveys in all reaches downstream of the Similkameen. Locations of redds marked in previous years' surveys (2005–2021) on the mainstem Okanogan and Similkameen Rivers are shown in Figures 5–11.

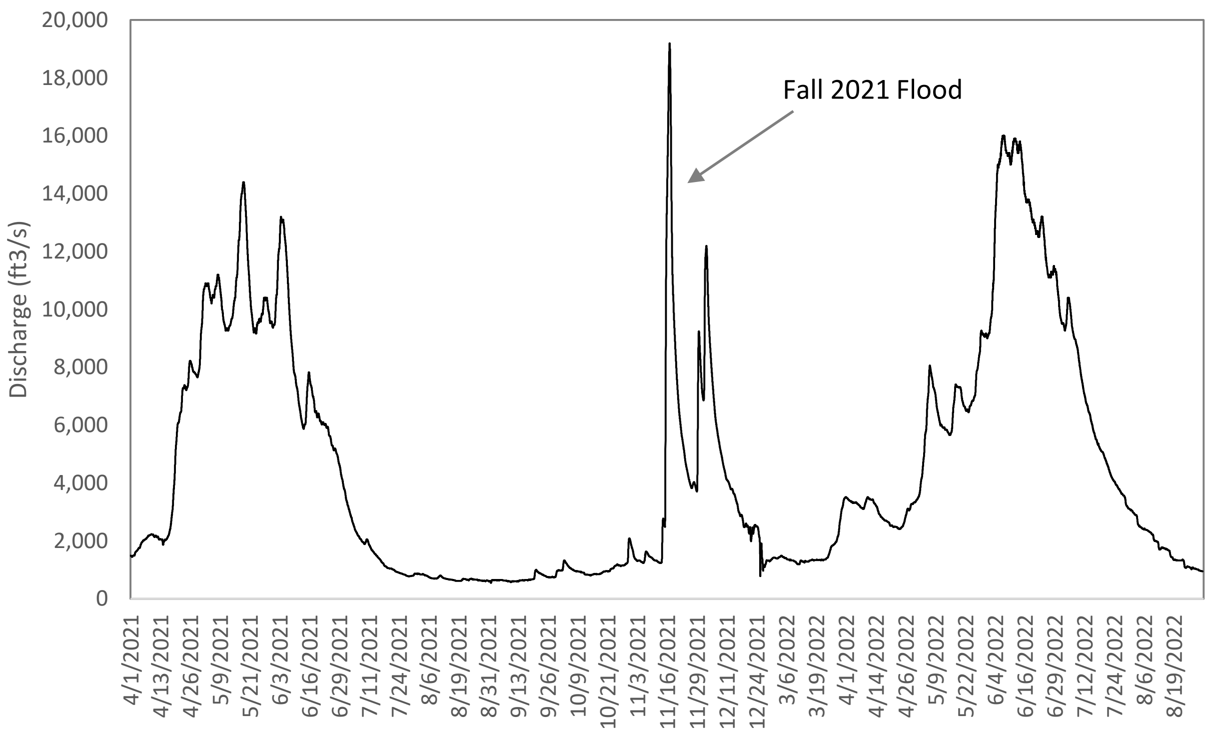

Figure 4. Discharge hydrograph for the Okanogan River from April 1, 2021 through August 31, 2022 showing the fall 2021 peak was higher than either spring peak from 2021 or 2022 (USGS Station 12445000, Okanogan River near Tonasket, WA).

One redd survey was attempted on Okanogan River Reach O2 on Mar 29, however it was ineffective due to the turbid conditions caused by the Similkameen flood. No other surveys were attempted downstream of the Similkameen confluence as conditions worsened with the increase in flow (Figure 4). Reach O7 became inundated (increased stage height), although water clearity remained acceptible for surveys to continue within that river segment. Surveys of Reach O7 occurred on Apr 12 (8 redds found), Apr 26 (10 redds), May 10 (6 redds) and May 24 (0 new redds). In all, a total of 24 redds were located in this section of river. Expanding the total number of redds located in Reach O7 (24) by the corrected 1.96 FPR value equaled a total spawning estimate of 47 fish in that reach. If the unadjusted FPR of 1.24 was applied, the estimate would be 30 total fish.

Although redd surveys were unable to capture the complete distribution of spawning activity in the rest of the mainstem Okanogan and Similkameen Rivers, an estimate of mainstem spawning by individual reach was calculated as follows:

The total number of natural-origin and hatchery steelhead that spawned in the mainstem Okanogan River in 2022 can be estimated by using the number of PRD tags detected at the interrogation site OKL, expanding by the priest mark rate and detection efficiency of OKL to come up with a total population, then, subtracting the estimated overwinter mortalities, collected broodstock, tributary spawners and those that went to Canada. The detection efficiency of the OKL PIT tag interrogation site was 0.868 for the 2022 spawn year, calculated by examining all adult steelhead in the PRD group detected upstream of that location (33 of 38 tags detected at OKL). Expanding detected PRD tags by the detection efficiency (0.868) and then by the PRD mark rate of 0.107 would render an estimate of the total number of steelhead entering the Okanogan River.

To account for potential overwinter mortalities in the mainstem, we divided the run into two groups: fall immigrants and spring immigrants. If a fish entered in the fall, fell back to the Columbia and entered again in the spring (but not detected as a kelt), it was determined to be a spring immigrant for the purpose of this exercise. Mainstem overwinter mortality was estimated over a two-year period by Fuchs (2018), using radio telemetry detections located by Colville Tribes and WDFW staff in 2016 and 2017. Based on these two years, the mortality rate of steelhead that entered Upper Columbia tributaries (Wenatchee, Okanogan, Methow, Entiat) in the fall was 0.137 for hatchery and 0.103 for natural-origin steelhead. A total of 14 hatchery steelhead from the PRD study entered the Okanogan in the fall of 2021. Expanding those tags by the efficiency of PIT tag interrogation site OKL (0.868) and the tag rate (0.107) rendered 151 total estimated hatchery steelhead entering in the fall (151=14/0.868/0.107). Using the same calculations for 11 natural-origin steelhead rendered a total of 118 natural-origin steelhead entering in the fall. Applying the overwinter mortality rate for hatchery and natural-origin steelhead rendered an estimated 21 hatchery and 12 natural-origin mortalities. This left an estimated 130 hatchery and 106 natural- steelhead fall immigrants. Seven hatchery and one natural-origin steelhead from the PRD group entered in the spring, which expanded by the detection rate of OKL and the tag rate estimated a total of 75 hatchery and 11 natural-origin fish. Thus, the total Okanogan subbasin spawning estimate is 205 hatchery and 117 natural-origin steelhead. Subtracting off the escapement to Canada (1 hatchery, 9 natural), and US tributary spawners (155 hatchery, 102 natural) renders 6 natural and 49 hatchery steelhead available to spawn in the Okanogan Mainstem. Refer to Appendix 1, Figure 44 for a diagram of the overwinter survival calculations. The Colville Tribes Broodstock and Acclimation Monitoring program (BAM) used hook and line collection in the spring to remove a total of 9 hatchery and 9 natural-origin steelhead from the mainstem Okanogan (pers. comm. Brooklyn Hudson, CCT), leaving 0 natural-origin and 40 hatchery steelhead to account for mainstem spawning.

The high pHOS (1.0) in the mainstem is not surprising, given that a large number of hatchery fish are released as juveniles in the Similkameen River and near the mouth of smaller tributaries (Aeneas and Antoine Creeks). Additionally, it is likely that the mainstem does not produce meaningful numbers of juveniles due to water temperatures that often exceed the upper tolerance of steelhead before they leave the gravel. In recent years, nearly all of the estimated number of wild spawners are attributed to tributaries. The mainstem natural-origin spawning estimate has averaged only 15 from 2018-2021, with a previous low of 6 in 2021.

The total estimated 47 fish accounted for in Reach O7 by redd surveys is similar to the estimated 40 mainstem hatchery spawners determined by the PIT-based equation. This would leave 0 fish for the remainder of the mainstem, continuing a declining trend in lower mainstem reaches observed in recent years. Typically, we would estimate spatial distribution of steelhead spawning for reaches that could not be surveyed, based on previous years' surveys when complete mainstem redd surveys occurred. However, with all fish accounted for in Reach 07, there were none left to distribute. Proportional distribution of spawning by survey reach is listed in Table 4 column A for the period of 2005–2011 for reference.

To estimate how many fish spawned in each survey reach, the remaining mainstem spawning estimates for natural-origin (0) and hatchery steelhead (0) were multiplied by the historical proportion of spawning recorded in each reach. This calculation assumes no change in the spatial distribution of spawning between the reference period (2005–2011) and in years when redd surveys could not be conducted due to turbid water conditions. Specific calculations are outlined below in Table 4.

Table 4. Modeled estimate of mainstem steelhead spawning in 2022.

Mainstem Survey Reach	A. Avg. Proportion of Mainstem Spawning by Reach (2005-2011)	B. Natural-Origin Steelhead (B=A*0)	C. Hatchery Steelhead (C=A*0)	D. Total Estimate (D=B+C)
Okanogan River 1	0.029	0	0	0
Okanogan River 2	0.107	0	0	0
Okanogan River 3	0.023	0	0	0
Okanogan River 4	0.091	0	0	0
Okanogan River 5	0.148	0	0	0
Okanogan River 6	0.039	0	0	0
Okanogan River 7	NA	NA	NA	NA
Similkameen River 1	0.321	0	0	0
Similkameen River 2	0.241	0	0	0
Mainstem Total [a]	1	0	0	0

[a] Does not include Okanogan River Reach O7, where physical redd surveys were conducted throughout the spawning season.

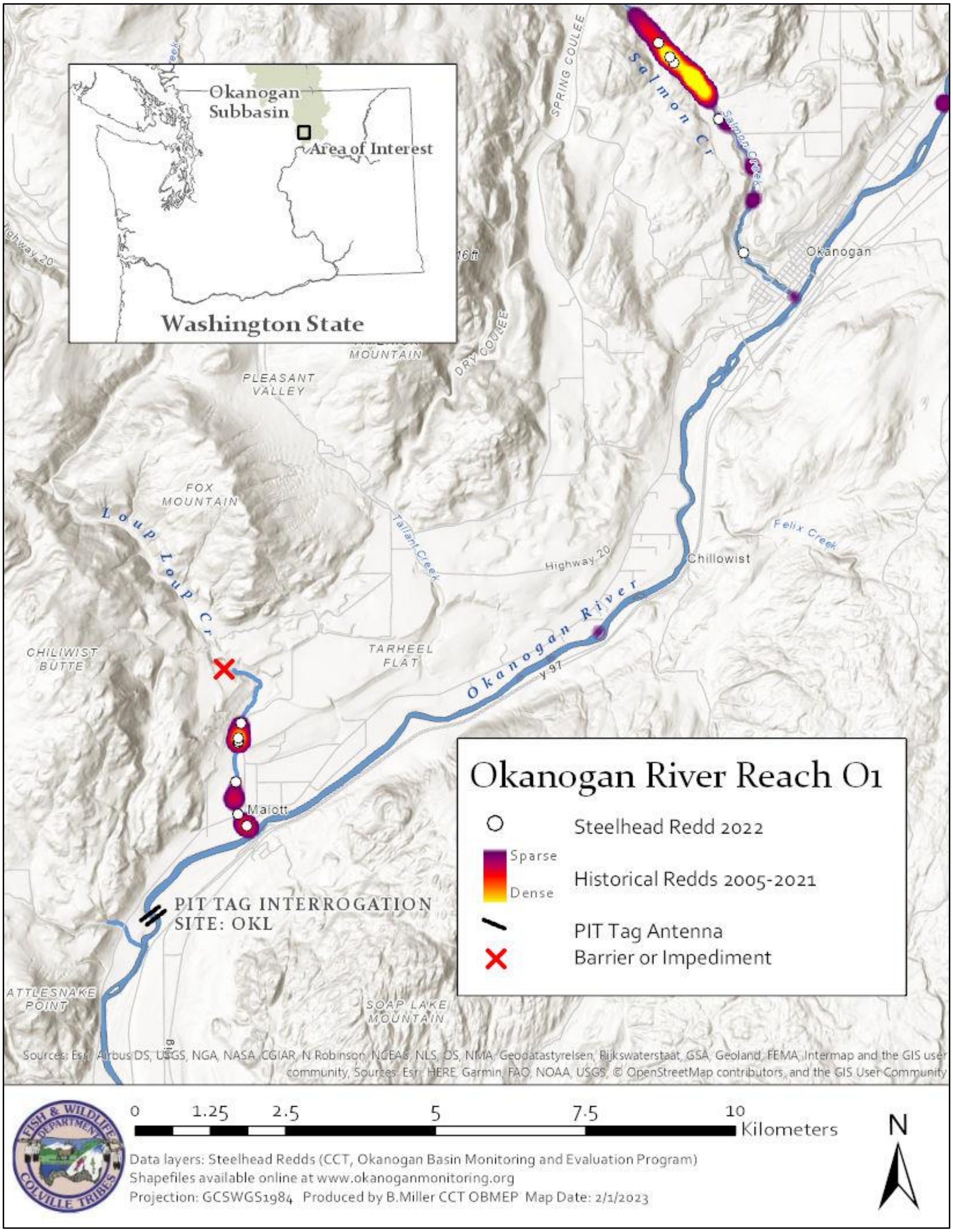

Figure 5. Spatial distribution of summer steelhead redds documented in Okanogan River survey reach RO1, from Salmon Creek to the Okanogan River weir site, located immediately upstream of the OKL PIT tag interrogation site.

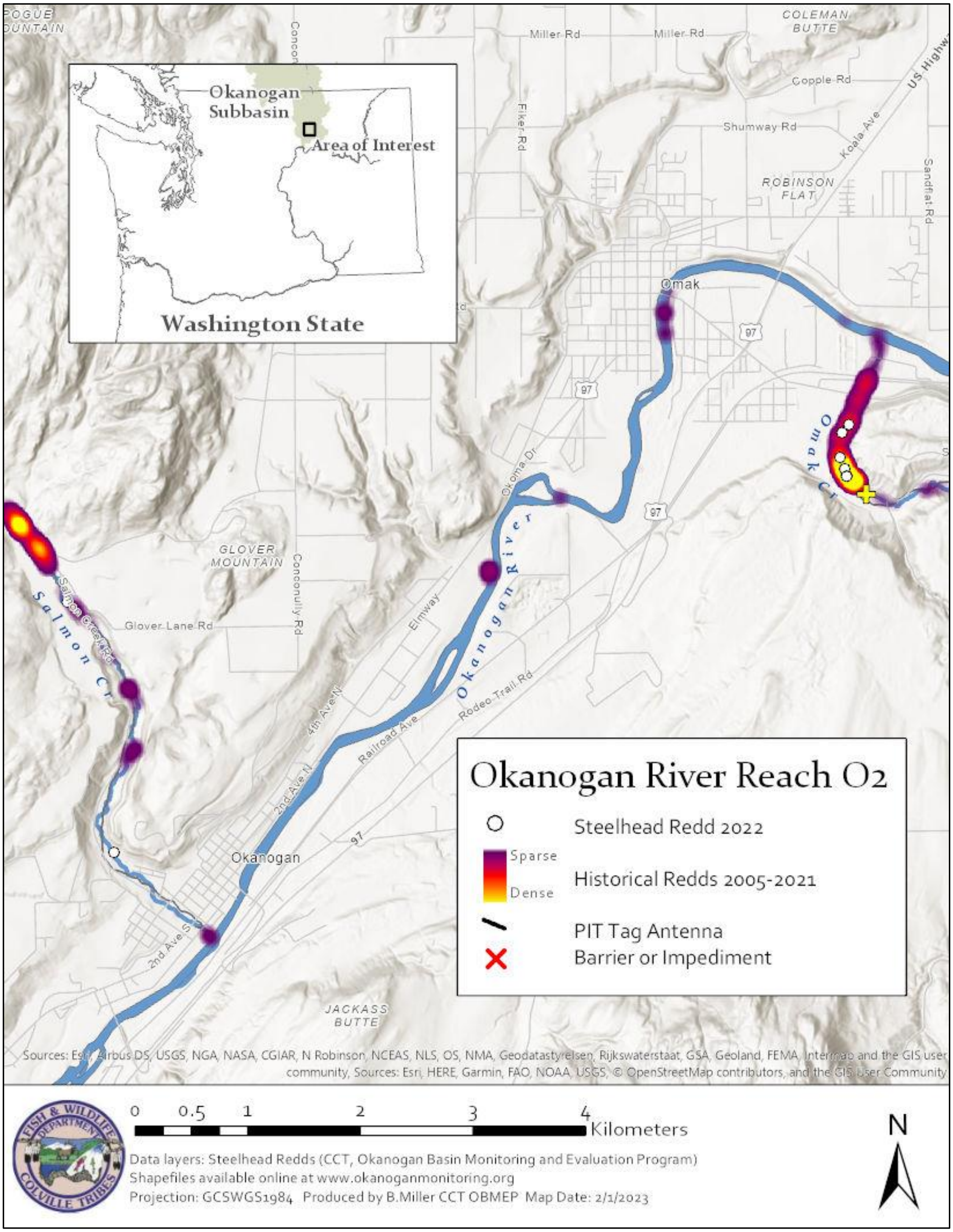

Figure 6. Spatial distribution of summer steelhead redds documented in Okanogan River survey reach RO2, from Omak Creek to Salmon Creek.

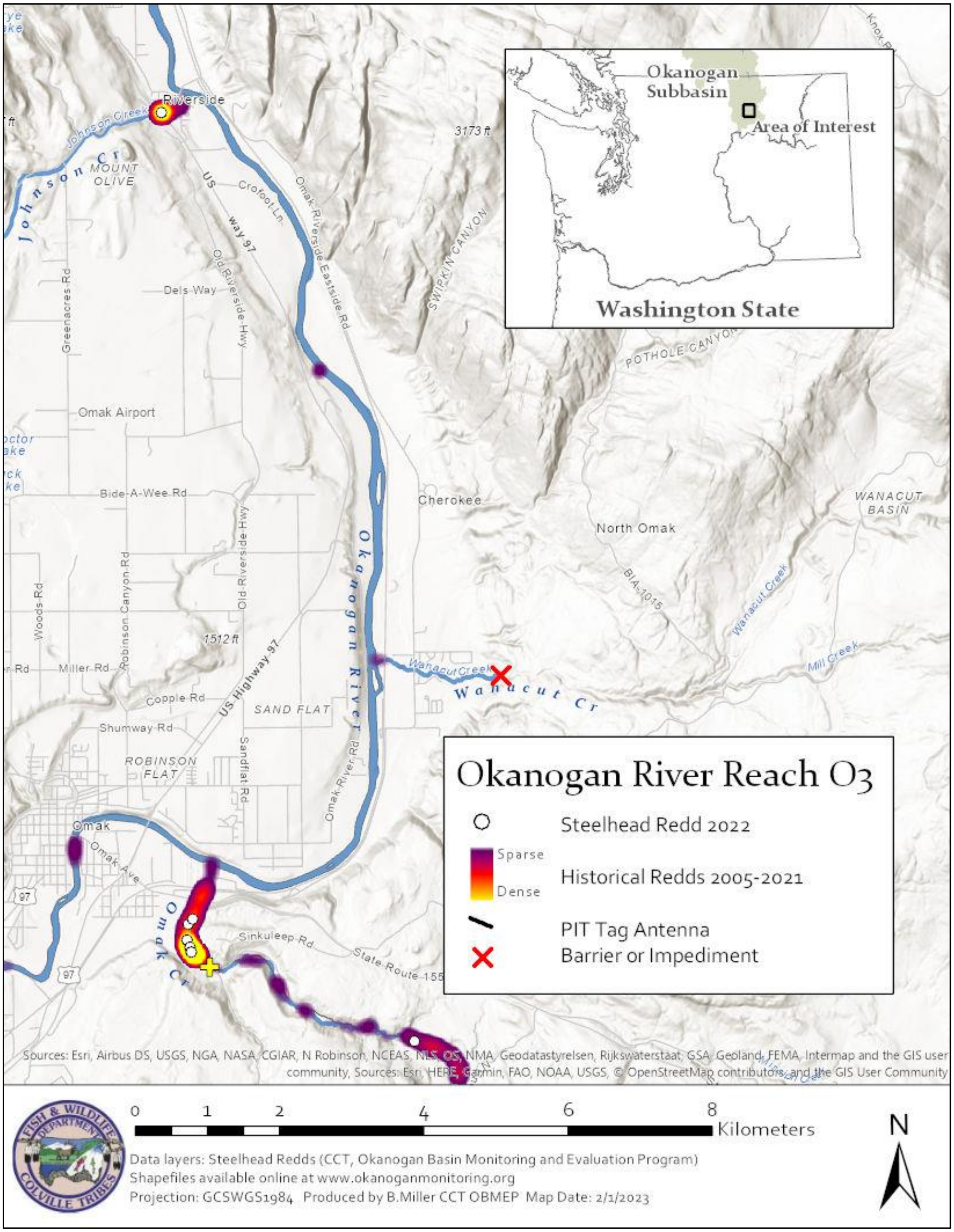

Figure 7. Spatial distribution of summer steelhead redds documented in Okanogan River survey reach RO3, from Johnson Creek to Omak Creek.

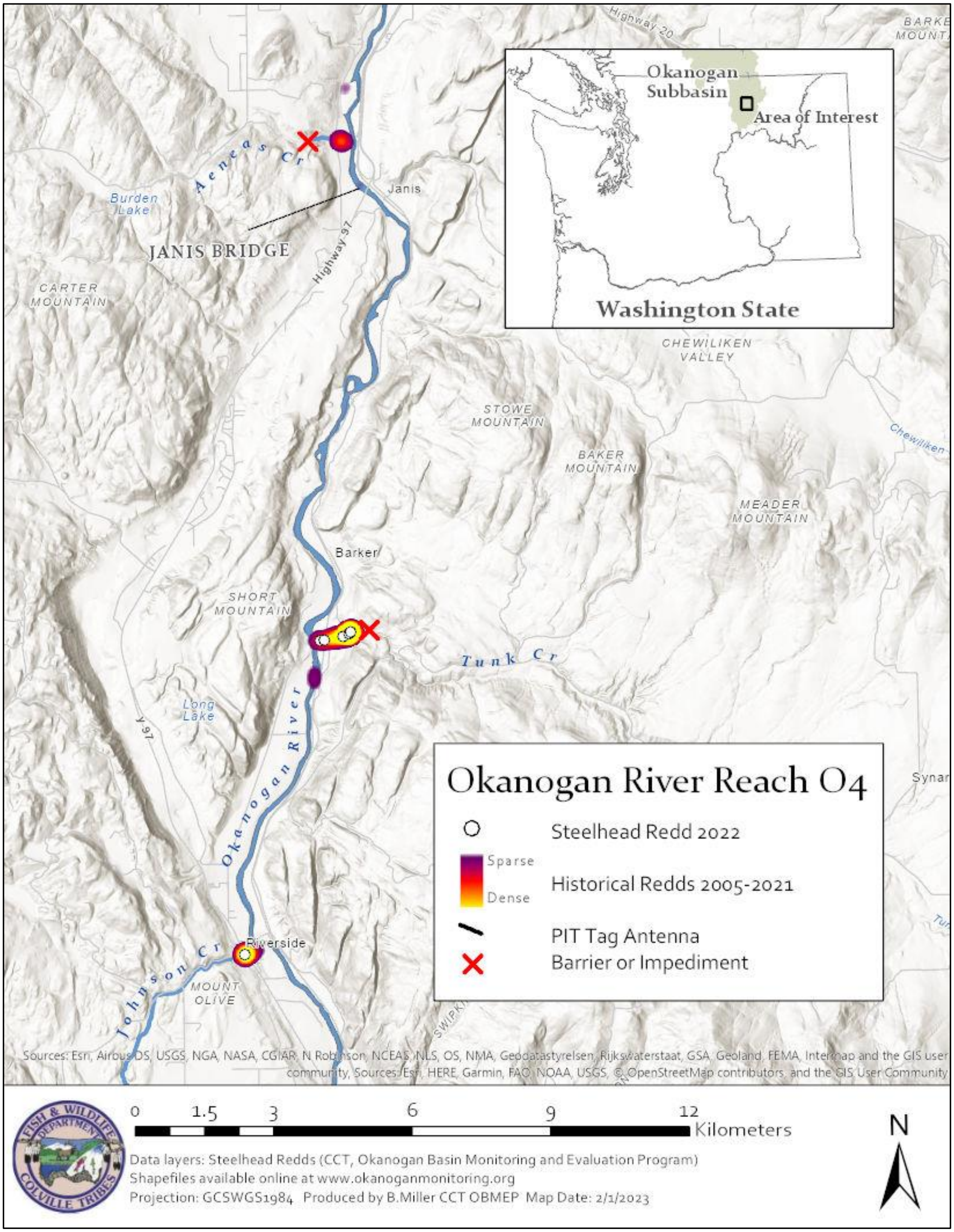

Figure 8. Spatial distribution of summer steelhead redds documented in Okanogan River survey reach RO4, from Janis Bridge to Johnson Creek.

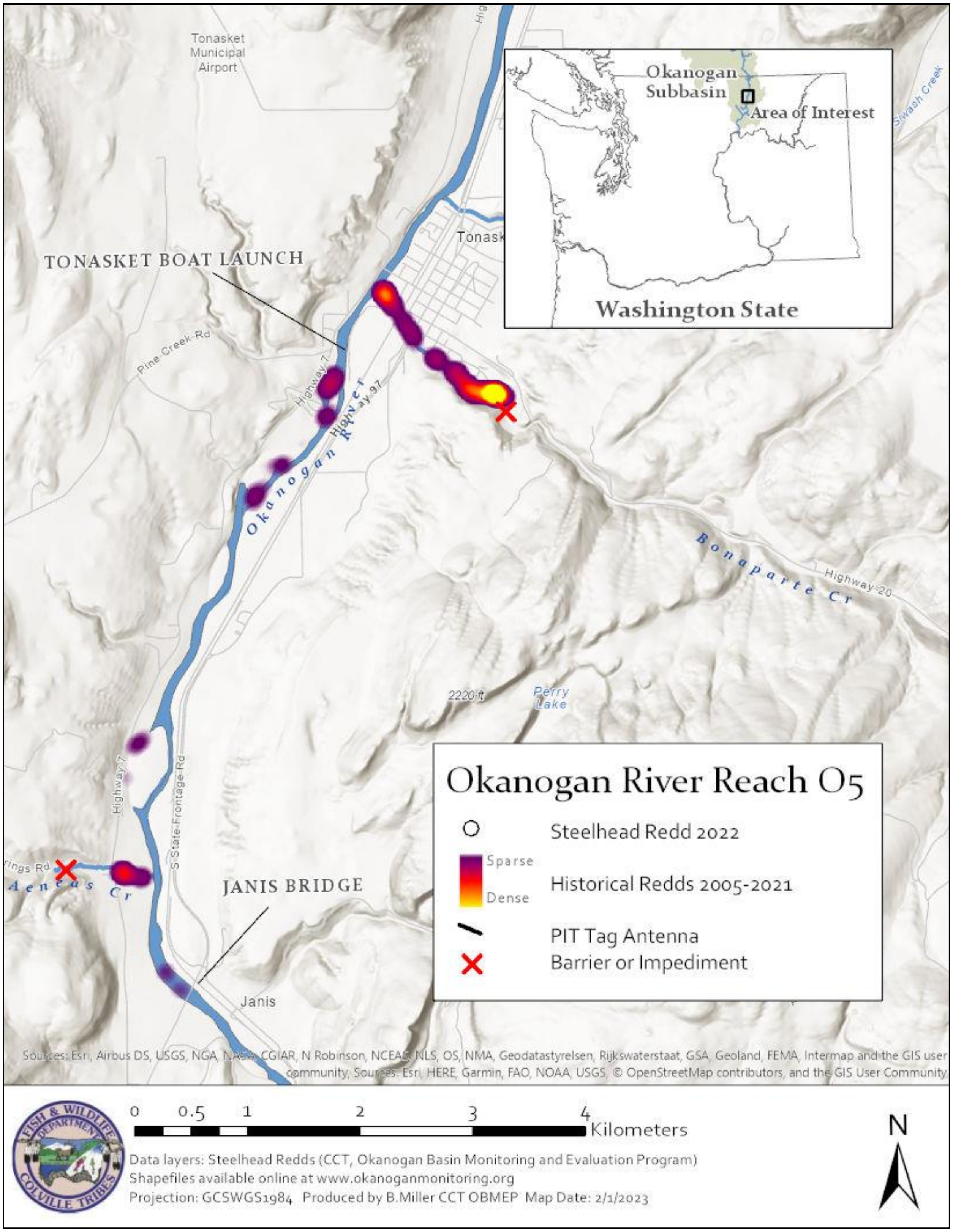

Figure 9. Spatial distribution of summer steelhead redds documented in Okanogan River survey reach RO5, from the Tonasket boat launch to Janis Bridge.

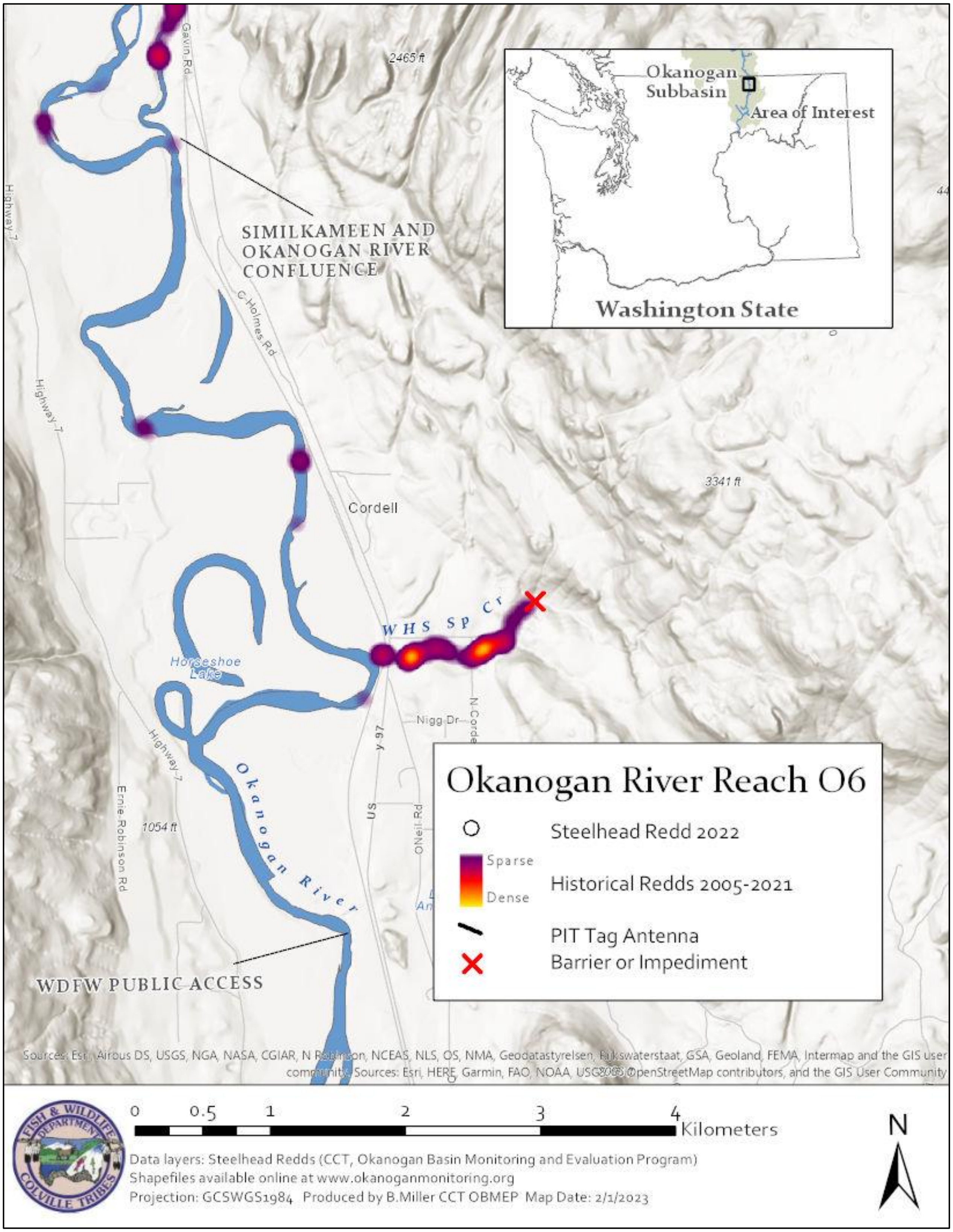

Figure 10. Spatial distribution of summer steelhead redds documented in Okanogan River survey reach RO6, from the confluence of the Similkameen and Okanogan Rivers to Horseshoe Lake.

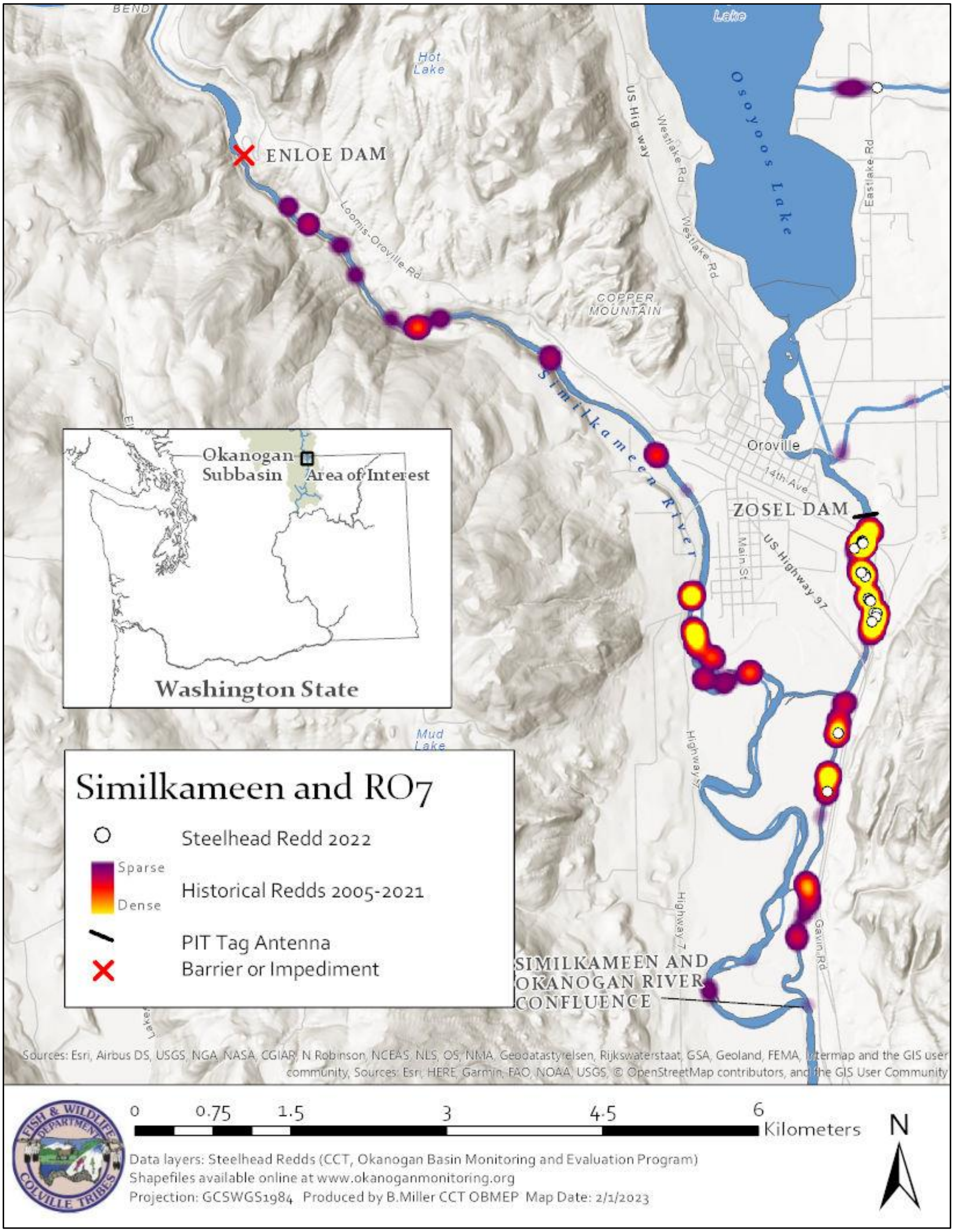

Figure 11. Spatial distribution of summer steelhead redds documented in the Similkameen River, from Enloe Dam to the confluence, and in Okanogan River survey reach RO7, from Zosel Dam to the confluence.

3.2 Steelhead Spawning Estimates: Tributaries to the Okanogan River

Tributary redd surveys were occasionally affected by high flows and turbid water conditions (Figure 12) from an early runoff period, which began early-April in Omak and Loup Loup Creeks and in mid-May in most other tributaries (Figure 13 and 14). For reference, peak steelhead spawning typically occurs around April 15th. Because some redd surveys in 2022 focused primarily on obtaining spatial distribution of spawning, many subwatershed steelhead spawning estimates were determined from PIT tag detections under project #2010-034-00. Others were determined from expanding redds by the adjusted FPR value (1.96).

In the following sections, we outline methods and a summary of spawning estimates for steelhead in tributaries to the Okanogan River, along with spatial distribution information. Detailed maps are presented in the following sections for each tributary which outline distribution of historic observations from 2005–2021. GIS shapefiles of documented steelhead redds can be downloaded at: www.okanoganmonitoring.org

Figure 12. Steelhead redd surveys during spring 2022. Clockwise from top: Large beaver dam at the base of the Antoine Creek Canyon (top two), a reach in upper Salmon Creek, poor survey conditions in mainstem Okanogan River.

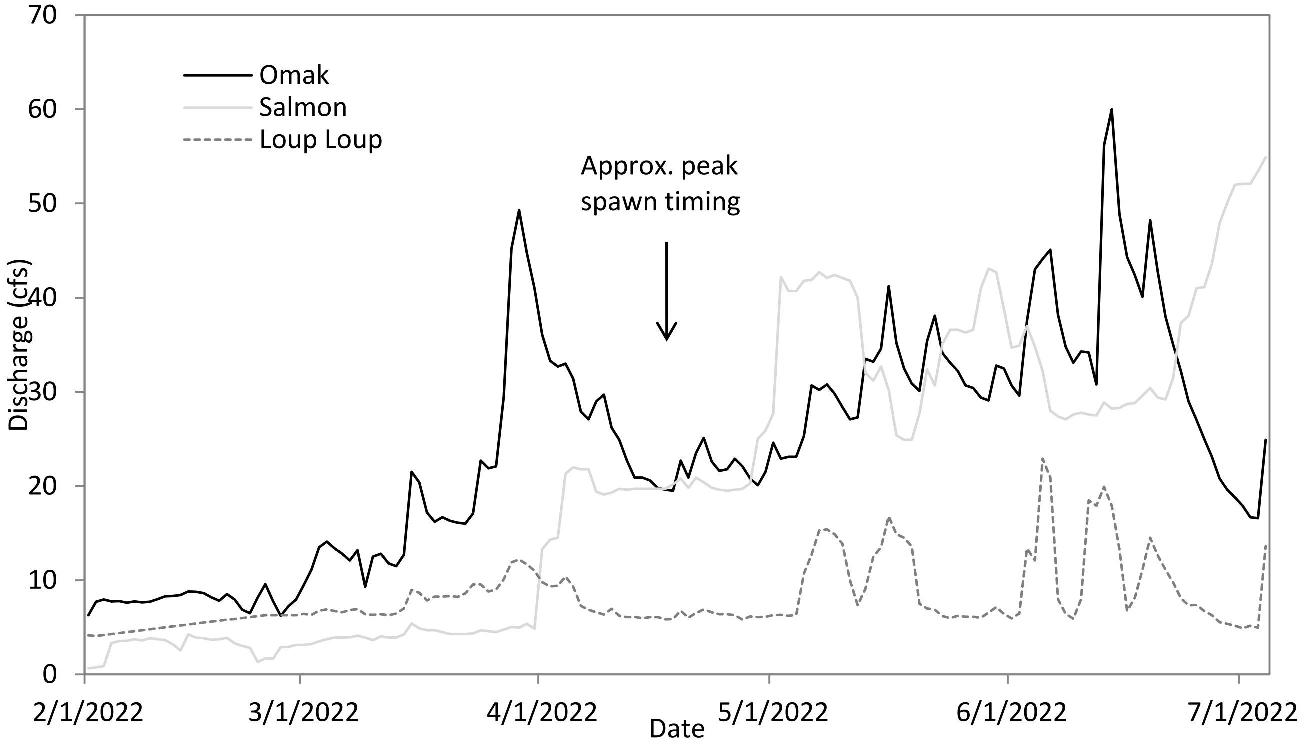

Figure 13. 2022 discharge in three tributaries in the southern Okanogan subbasin in Washington State.

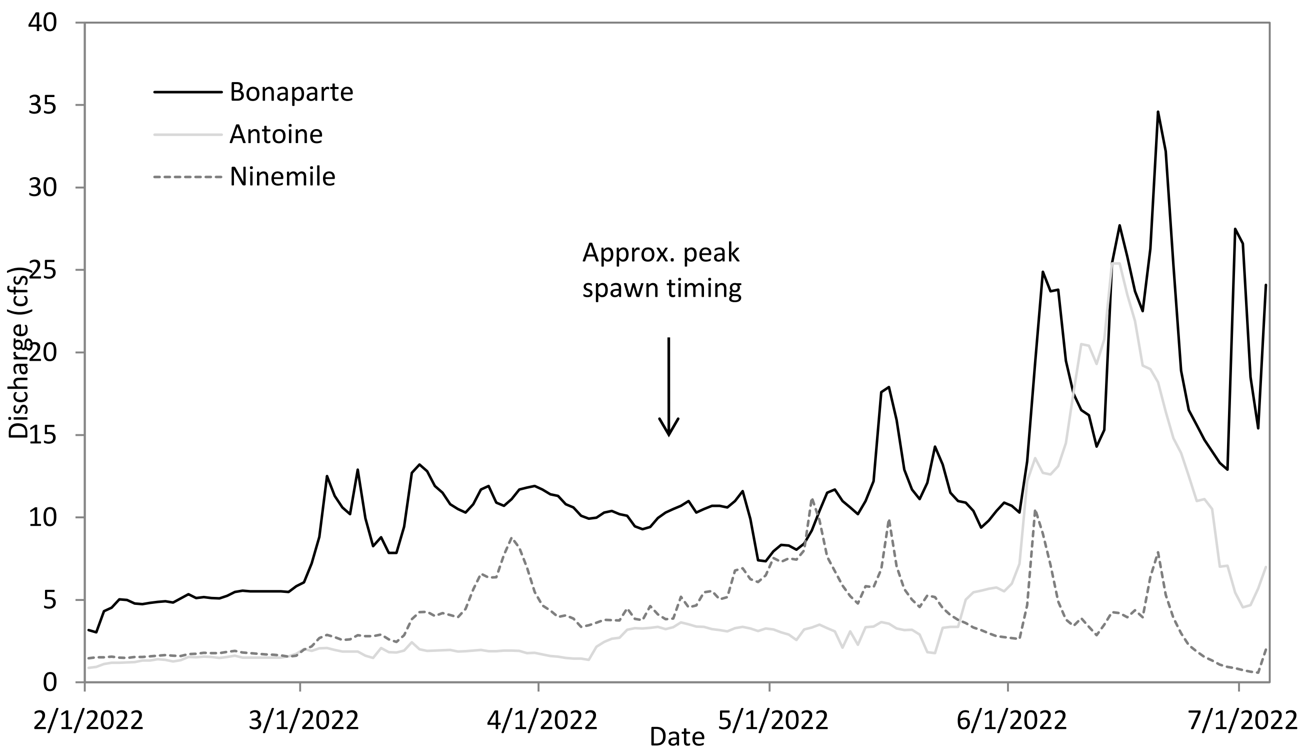

Figure 14. 2022 discharge in three tributaries in the northern Okanogan subbasin in Washington State.

3.2.1 Loup Loup Creek

Loup Loup Creek is a tributary that enters the Okanogan River at river kilometer (RKM) 24, in the town of Malott, WA. The lower sections of the creek frequently went dry during mid-summer, until 2010, when the point of diversion was transferred to the Okanogan River and the irrigation diversion on Loup Loup Creek was removed. PIT tag interrogation site LLC consists of three pass-over HDPE antennas configured in three separate rows near the mouth of the creek.

The instream PIT tag interrogation site LLC was operational throughout the spring of 2022 and detected one steelhead from the Priest Rapids Dam (PRD) mark group. However, this fish was later detected in Omak Creek and thus assigned to that tributary which would render a total spawning estimate of zero. However, two PIT tagged adults not from the PRD mark group were also detected in the creek, all of hatchery origin. Long term trends in steelhead spawning escapement for Loup Loup Creek are shown in Figure 15.

Conditions in Loup Loup Creek were generally favorable to conduct redd surveys throughout much of the spring (Figure 13). Surveys occurred on Apr 18 (0 redds), May 3 (4 redds) and May 24 (3 redds) (Figure 16). Those 7 redds were expanded by 1.96 FPR for a total spawning estimate of 14 steelhead. Because both tagged steelhead detected were hatchery fish, we assumed that same rate for the spawning fish. Due to the physical observations of redds, we relied solely on redd expansions for the spawner estimates in 2022. Observers did note that substrate in Loup Loup Creek had become embedded across much of the reach and most of the spawning gravels that existed in previous years were completely covered in sand stemming from recent fires and flooding.

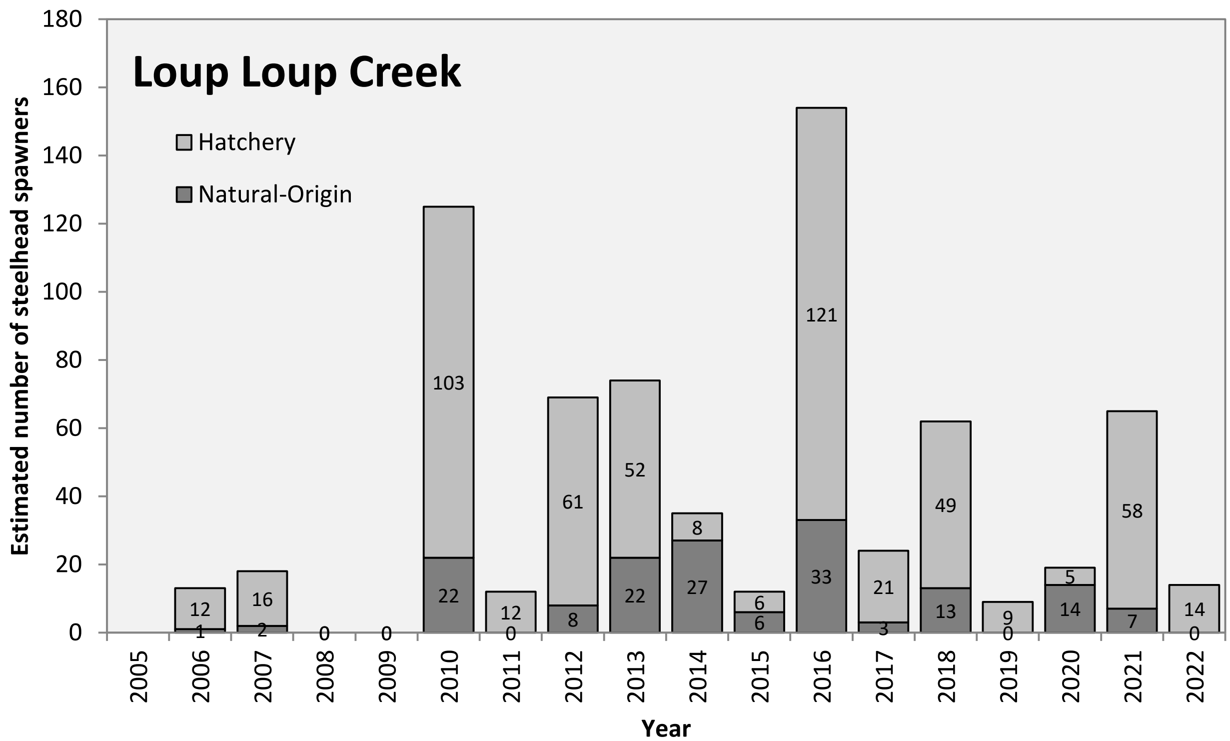

Figure 15. Trend in the number of steelhead spawners in Loup Loup Creek.

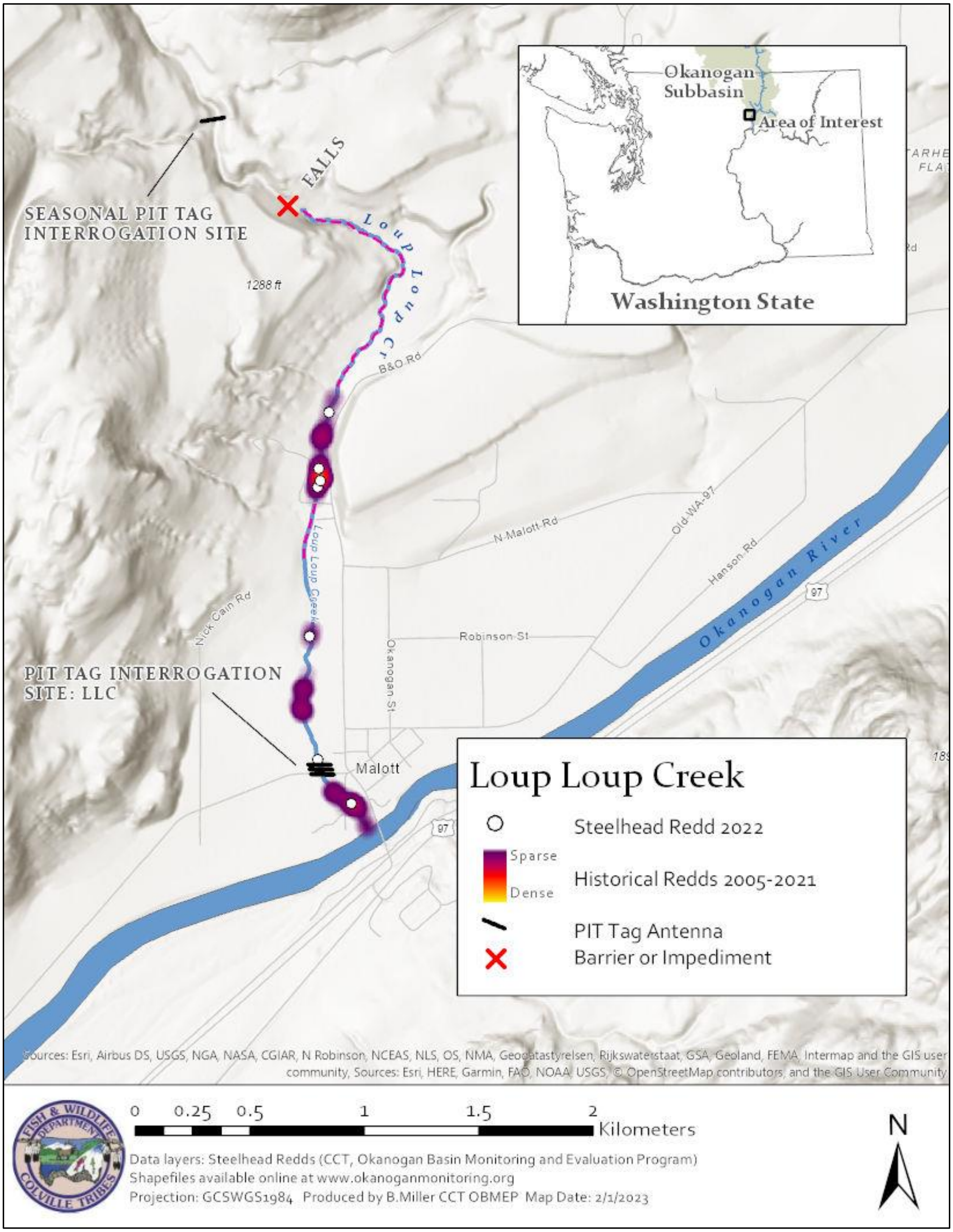

Figure 16. Spatial distribution of historical summer steelhead redds documented in Loup Loup Creek.

3.2.2 Salmon Creek

Salmon Creek is a highly managed medium sized tributary, which enters the Okanogan River at RKM 41.3 in the city of Okanogan, WA. Since the early 1900's, the majority of water from Salmon Creek had been diverted for irrigation usage. Resulting in a largely dry stream channel extended from the Okanogan Irrigation District (OID) diversion dam (7.2 km) to the confluence with the Okanogan River. Occasionally, uncontrolled spills occurred downstream of the OID diversion dam in high water years. These spills typically occurred in mid-May to June, which is after peak spawning for summer steelhead in the Okanogan basin. To provide sufficient water during the migration window of spring-spawning steelhead, the Colville Tribes purchased water from the OID and allowed it to flow down the channel to the Okanogan River. After several years of successful steelhead passage, the Tribes negotiated a long term water lease agreement with the OID. Since 2006, the long term water lease has provided seasonal water for returning adults and outmigrating juvenile salmonids. Further negotiations allowed for continuous flow, year-round since 2019.

A PIT tag interrogation site (SA1) is located 2.9 km upstream from the mouth of Salmon Creek. The instream array consists of four pass-over HDPE antennas configured in two separate rows. A second PIT tag interrogation site (SA0) is located immediately downstream of the OID diversion dam and consists of five pass-over PVC antennas configured in two separate rows (Figure 18). Site SAD consisting of one row of two HDPE antennas was installed above the diversion to determine an estimate of fish passing into the upper reaches of Salmon Creek. During the 2022 spawning season, a total of 2 natural and one hatchery-origin PIT tagged steelhead from the PRD mark group were detected at the lower SA1 array. Two of these fish were detected on SA0 (1 natural, 1 hatchery) and two fish tagged at other locations were detected on SAD. All of the tags detected on the upstream sites SA0 and SAD were detected on SA1, which rendered a detection efficiency estimate of 100% at the downstream detection site. Assuming 100% detection efficiency, an expanded total estimate of 27 steelhead (18 natural-origin and 9 hatchery) spawned in Salmon Creek in 2022. Based solely on tag detections, 9 hatchery and 9 wild may have spawned downstream of the diversion and 9 wild passed above the diversion.

The lower portion of Salmon Creek was surveyed three times from the confluence with the Okanogan River to above the irrigation diversion at Spring Coulee road. The first survey was conducted on Apr 13 and no redds were found. It was again surveyed on April 27, 4 redds were located, 1 below the diversion and 3 just upstream, but below a large beaver dam. On May 9, 1 redd was identified just upstream of interrogation site SAD while technicians were downloading data from the site. The final complete survey occurred over two days on May 18 and 19, which located 4 new redds, all below the diversion (Figure 18). In total, 5 redds were identified downstream of the diversion and 4 upstream. When expanded by 1.96 fish per redd, it is likely that 10 fish spawned in the reach below the diversion. The 4 redds located directly upstream of the weir accounted for 8 of the total fish. These numbers are similar to the estimates derived from PIT tag detections.

It is interesting that the number of hatchery steelhead spawners in Salmon Creek has generally been declining in recent years, including the unexpectedly low estimate of 3 in 2019, 14 in 2020, 8 in 2021 and 9 in 2022. Between 30,000 and 40,000 hatchery juvenile steelhead are released in the creek each year (Wes Tibbits, CCT, pers. comm.). It is certainly possible that spawning estimates could have been bias low due to error associated with small sample size and few detections. However, because a relatively large proportion of the total adult population (generally ~10-20%) is included in the PRD mark group and interrogation site SA1 had a high detection efficiency in 2019, 2020, 2021 and 2022 (all ~100%), it is unlikely that significant numbers of hatchery adults were unaccounted for. It is also possible that juvenile hatchery steelhead released in Salmon Creek are not returning to this stream, potentially due to lack of imprinting or insufficient attractant flows in April (typically ~5cfs). Low smolt-to-adult return rates in recent years potentially contributes to the decline in hatchery return numbers, as well. Additionally, between 500 and 2,000 hatchery juveniles from the release groups are estimated to residualize in the creek annually (OBMEP 2022, Appendix B).

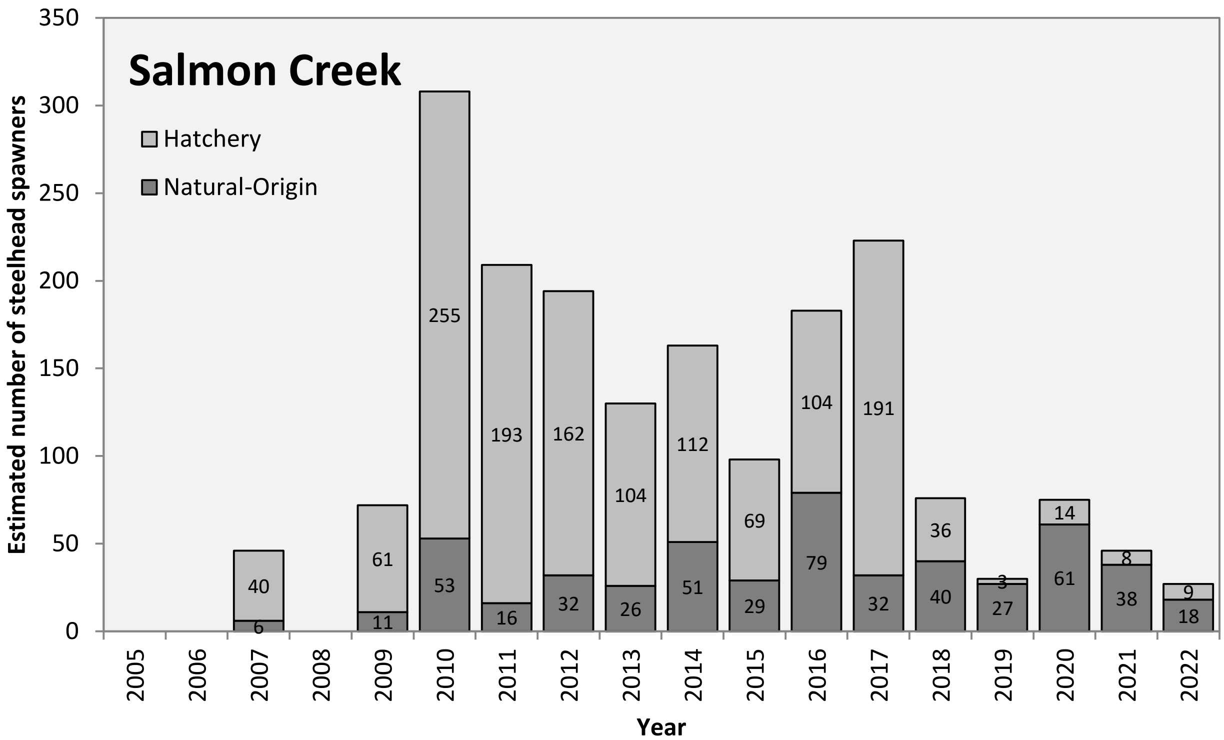

Figure 17. Trend in the number of steelhead spawners in Salmon Creek.

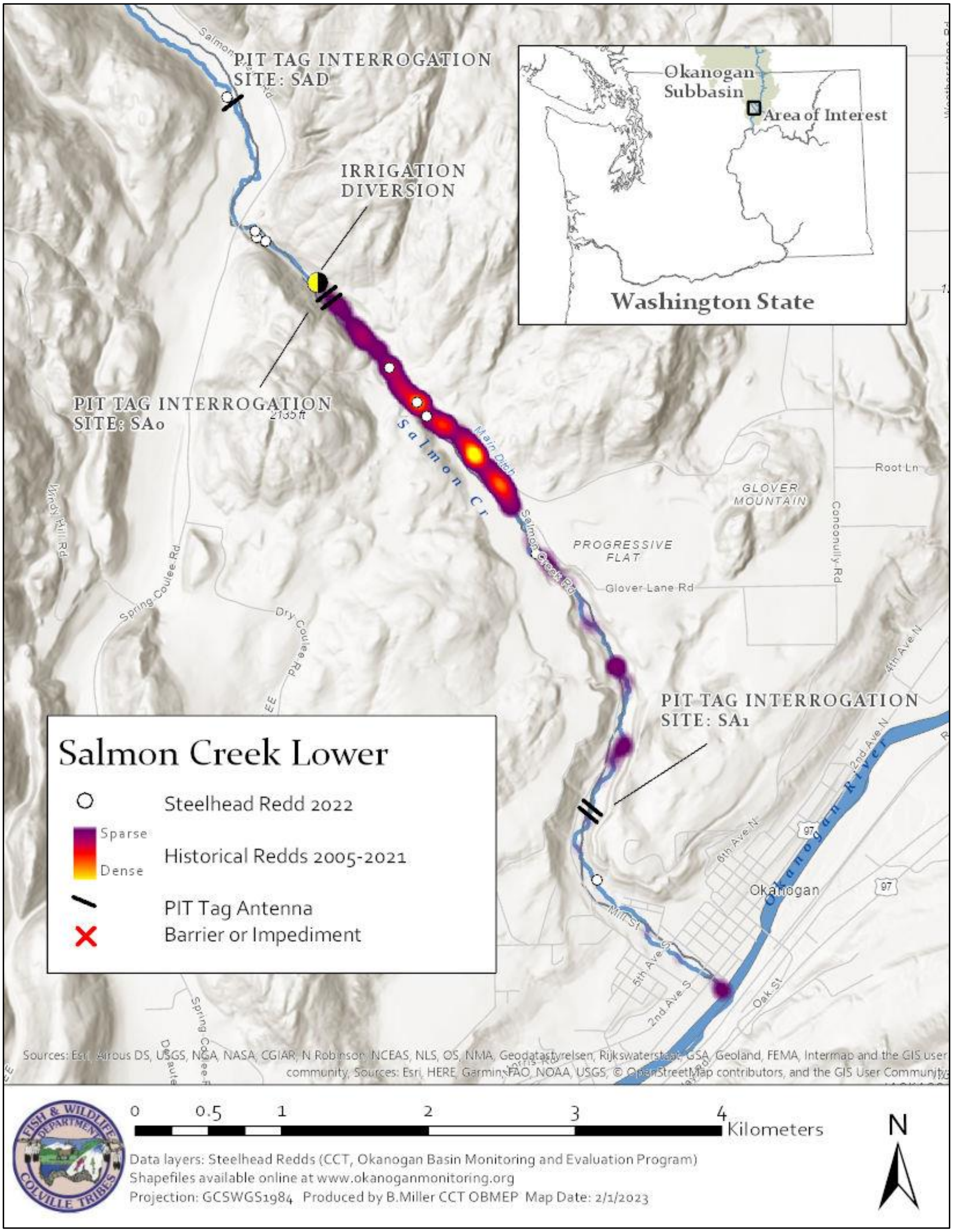

Figure 18. Spatial distribution of historical summer steelhead redds documented in lower Salmon Creek, from the confluence to the irrigation diversion.

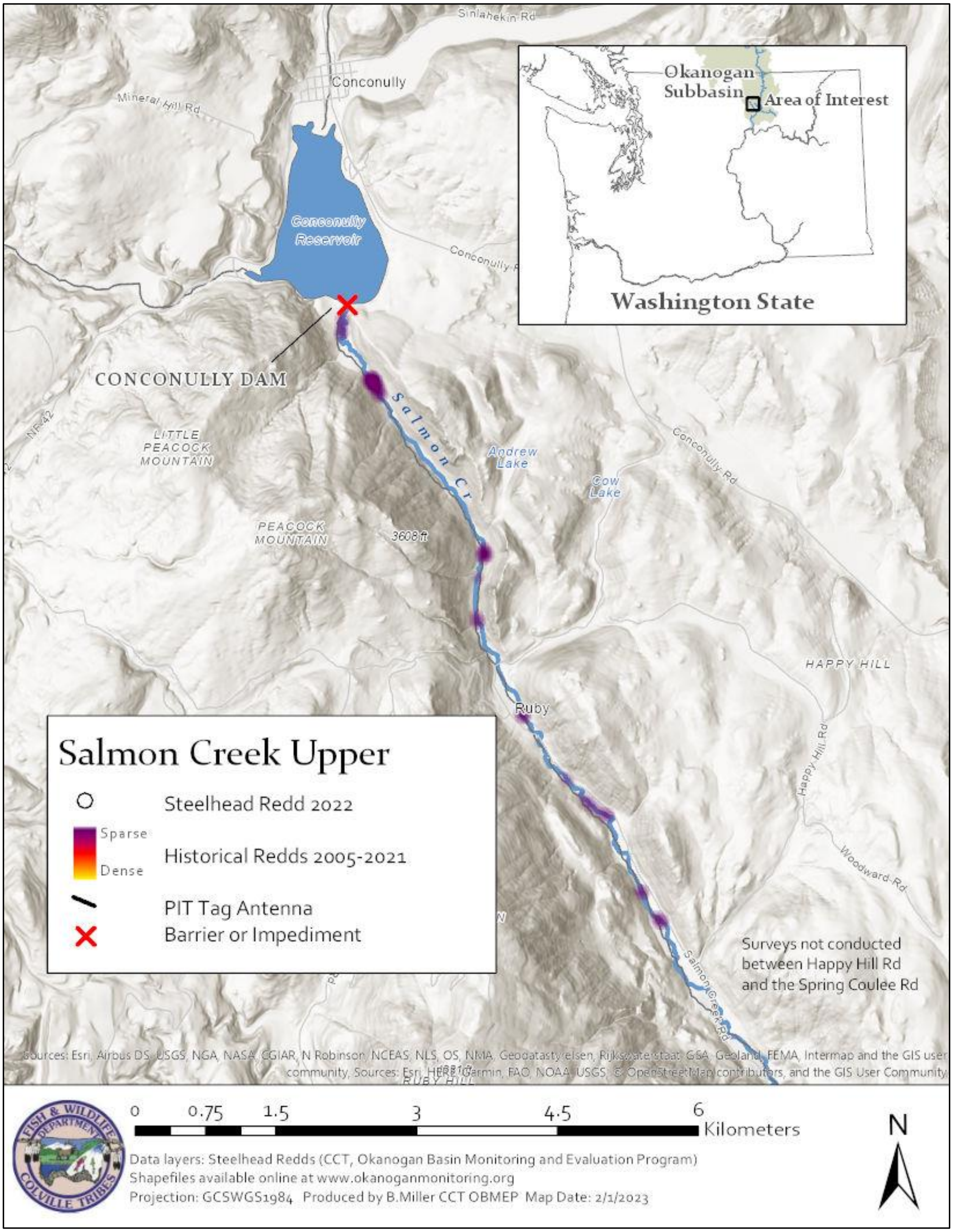

Figure 19. Spatial distribution of summer steelhead redds documented in upper Salmon Creek, below Conconully Dam.

3.2.3 Omak Creek

Omak Creek is characterized as a perennial, medium sized tributary that enters the Okanogan River at RKM 51.5, approximately 1.0 km upstream from the city of Omak, WA. Discharge rates in the creek generally range from a base flow of 2–4 cfs to over 150 cfs during peak runoff. During the base flow period, wetted widths range from approximately 2 to 8 meters. A PIT tag interrogation site (OMK) consists of four pass-over HDPE antennas configured in two separate rows is located 0.24 km upstream from the confluence with the Okanogan River. Two additional PIT tag interrogation sites were also operated below (OBF) and above (OMF) Mission Falls to monitor passage rates. Each of these sites consisted of a two pass-over HDPE antennas configured in a single row.

Water conditions in Omak Creek were turbid in mid-March but cleared by mid-April (Figure 13). A combination of three complete redd surveys covered the section of creek from the confluence with the Okanogan River to Mission Falls. The first occurred on Apr 14th, 19th and 20th which located 1 redd below and 1 redd above the weir. On May 3rd and 4th, 6 redds were found below and 5 above the weir. The creek became turbid in mid-May, but a final survey was conducted on June 2nd and 3rd, which found 1 redd below and 3 above the weir. In total, 8 redds were found below and 9 above the weir (Figure 22). These redds were expanded by 1.96 fish per redd for an estimated 16 steelhead below the weir and 18 above the weir, for a total of 34 fish accounted for by redd surveys. Redd surveys have not been conducted above Mission Falls due to the very few numbers of fish ascending the falls to date and the significant number of stream kilometers above that point.

The total spawning estimate for Omak Creek was estimated based on PIT tag detections and fish handled at the adult weir trap. A total of 2 natural-origin and 7 hatchery steelhead were detected at OMK. We assumed a 91.3% detection efficiency at OMK in 2022 because 21 of the 23 PIT tagged fish detected at the weir or the upstream sites (OBF and OMF) were detected previously at downstream OMK. Those tags were expanded by the mark rate (0.107) and detection efficiency (0.913) for a total number of 21 natural-origin and 71 hatchery steelhead entering the creek. A total of 2 wild and 18 hatchery fish were removed at the weir for broodstock, 8 natural-origin and 6 hatchery steelhead were passed upstream of the weir. To determine the efficiency of the adult weir trap in 2022, we looked at steelhead that were tagged *prior* to entering the creek and were detected at either OBF or OMF, both of which are located above the weir (3 total). Of those 3 fish, 1 was handled at the weir, rendering an estimated 0.33 efficiency across the season (0.33=1/3). This is not surprising because the weir was pulled early, on May 6th, due to sufficient broodstock needs being met. The number of fish passed above the weir was expanded by the weir efficiency of 0.33, for a total spawning estimate above the weir of 24 natural and 18 hatchery-origin steelhead. The number of fish spawning below the weir would be the total number of fish entering the creek, minus the number removed at the weir and minus the expanded estimate passed above the weir, for a total of 0 natural-origin and 35 hatchery steelhead (Table 5).

Table 5. Calculations used to estimate the number and distribution of spawning steelhead in Omak Creek in 2022.

Description (Variable)	Natural-origin	Hatchery
A. Total steelhead entering Omak Creek in 2022	21	71
B. Number of steelhead broodstock removed at weir	2	18
C. Number of steelhead passed upstream of weir	8	6
D. Estimated # steelhead spawning above weir (D = C/0.33)	24	18
E. Estimated # steelhead spawning below weir (E = A-B-D)	0	35
F. Number of steelhead above Mission Falls (a subset of D)	0	2
G. Total estimated number of SH spawning 2022 (G = D+E-B)	19	53

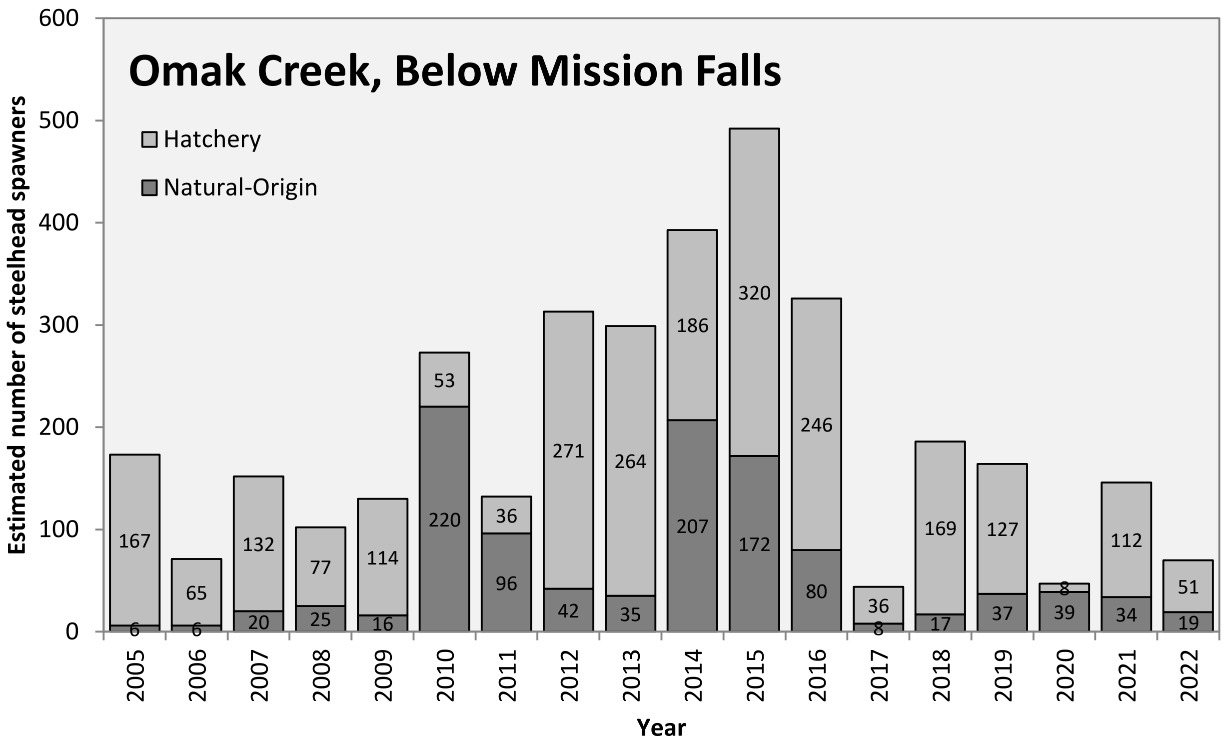

Figure 20. Trend in the number of steelhead spawners in Lower Omak Creek.

Passage through Mission Falls on Omak Creek

A total of six PIT tagged adult steelhead (3 natural- and 3 hatchery-origin) were detected at the base of Mission Falls on the OBF Pit array in 2022. Every fish handled at the weir (capture efficiency of 33.3%) received a PIT tag. Combining the new PIT tags with those already tagged (PRD tags) resulted in a new mark rate of 40%. Expanding that detection count by the new tag rate gave a total estimated 15 fish (15=6/0.4) to reach the falls. Spring flows in Omak Creek peaked earlier than recent years, reaching 50 cubic feet per second (cfs) on March 29th (Figure 21). This peak coincided with the first detection at OBF and also resulted in the only fish to successfully navigate the falls based on detections at the interrogation site located upstream (OMF). The fish, a hatchery-origin female tagged at Priest Rapids Dam, was detected above the falls on April 25th and was presumed to have spawned in upper Omak Creek since it was not observed afterwards. Expanding that tag by the mark rate of 0.40 resulted in an estimated 2 adult steelhead to spawn above the falls. It is difficult to conclude exactly when and at what flows fish navigated the falls due to the extended timeframe (28 days) between detections above and below, and based on previous years' passage data accessible flows persisted for the duration of that period.

In 2021, fifty-five PIT tagged adult steelhead were detected at the OBF array located below Mission Falls. The weir efficiency for this year was 92%, which expanded to an estimated 60 steelhead that made it to the base of Mission Falls (13 natural- and 47 hatchery-origin). In 2021, three PIT tagged steelhead were detected above Mission Falls. One fish was detected below the falls on April 21 and above the falls on April 30, another below on April 22 and above on May 5, and the final fish was detected below the falls on May 12 and above on May 16 (Figure 21). The first fish appeared to ascend the falls outside the range that has been seen in previous years, at a minimum of at least 80 cfs. Prior to this fish, all adult steelhead that have been detected passing through the falls were generally confined between 25-50 cfs.

In 2020, nine PIT tagged steelhead were detected at OBF (at the base of Mission Falls) before equipment at the site was stolen in mid-April. However, a total of 14 fish were detected above Mission Falls in 2020 (13 of natural-origin and 1 hatchery steelhead). These tags were not expanded to unmarked fish because every adult steelhead that was handled and passed upstream of the weir received a PIT tag. Because the lower antenna OBF below the falls was stolen in 2020, the passage data and timing of fish detected on the bottom to the top of the falls were incomplete this year. Timing data from 2019 was more compete. Passage through Mission Falls was documented between April 18 and May 20, 2019. Steelhead were first detected at the base of the falls (OBF) on April 1, 2019 (dashed grey line, Figure 21). Passage time was between one and six days as calculated by the time elapsed between the last detection below the falls (OBF) and the first detection above the falls (OMF), a distance of approximately 1200 meters. The single day passage occurrence on 5/2/2019 was the only female in the group and was recaptured at the Omak Creek weir six days after last detection above Mission Falls.

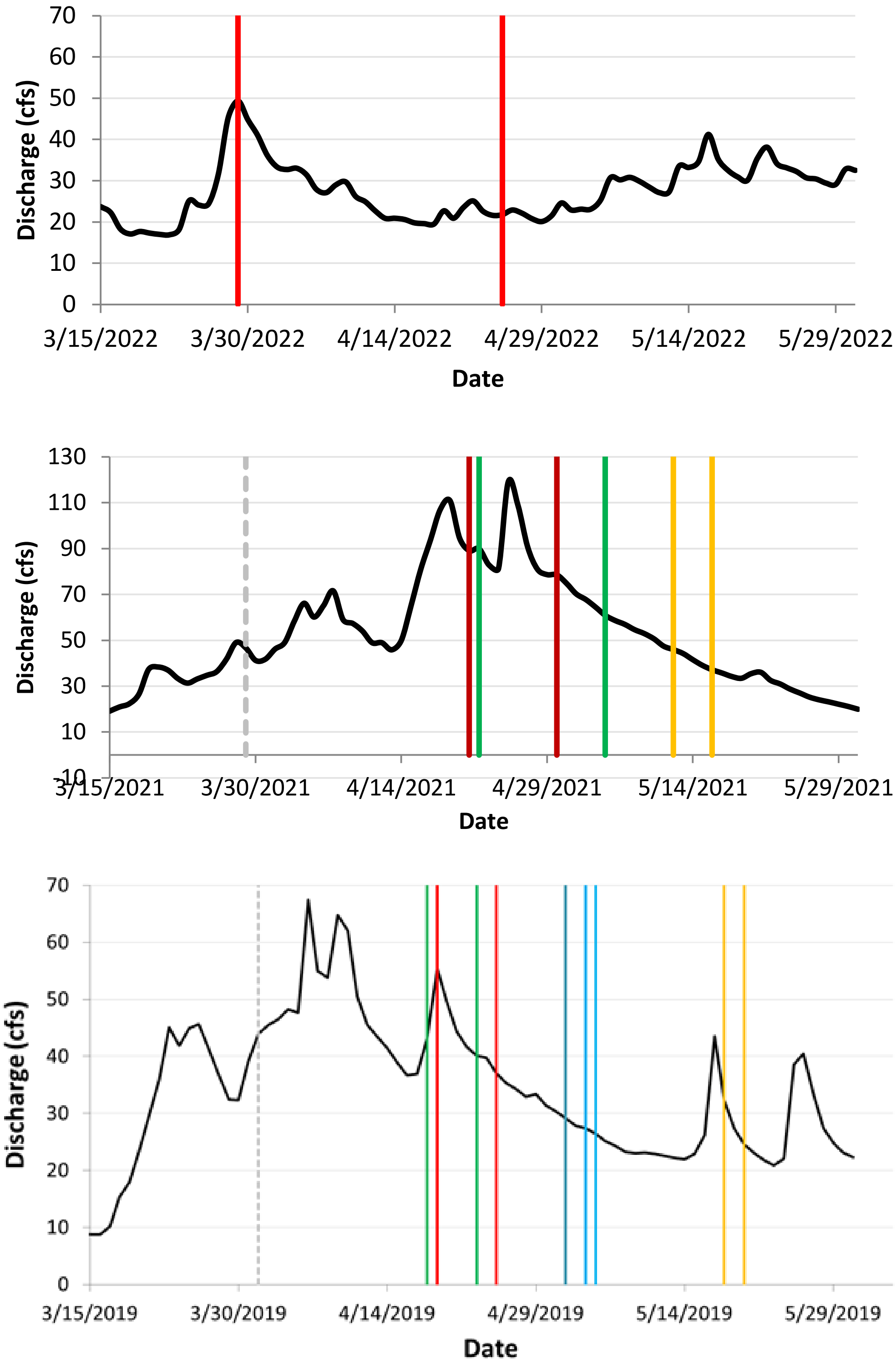

Figure 21. Timing of successful adult steelhead passage events at Mission Falls on Omak Creek 2022 (top), 2021 (middle) and 2019 (bottom). Dashed grey vertical line represents the date of first PIT tag detection below Mission Falls (OBF). Color coded lines are individual fish, with the first sequential color occurrence representing last detection below the falls (OBF) and the second occurrence is the first detection above the falls (OMF). One event occurred in a single day in 2019 (dark blue line).

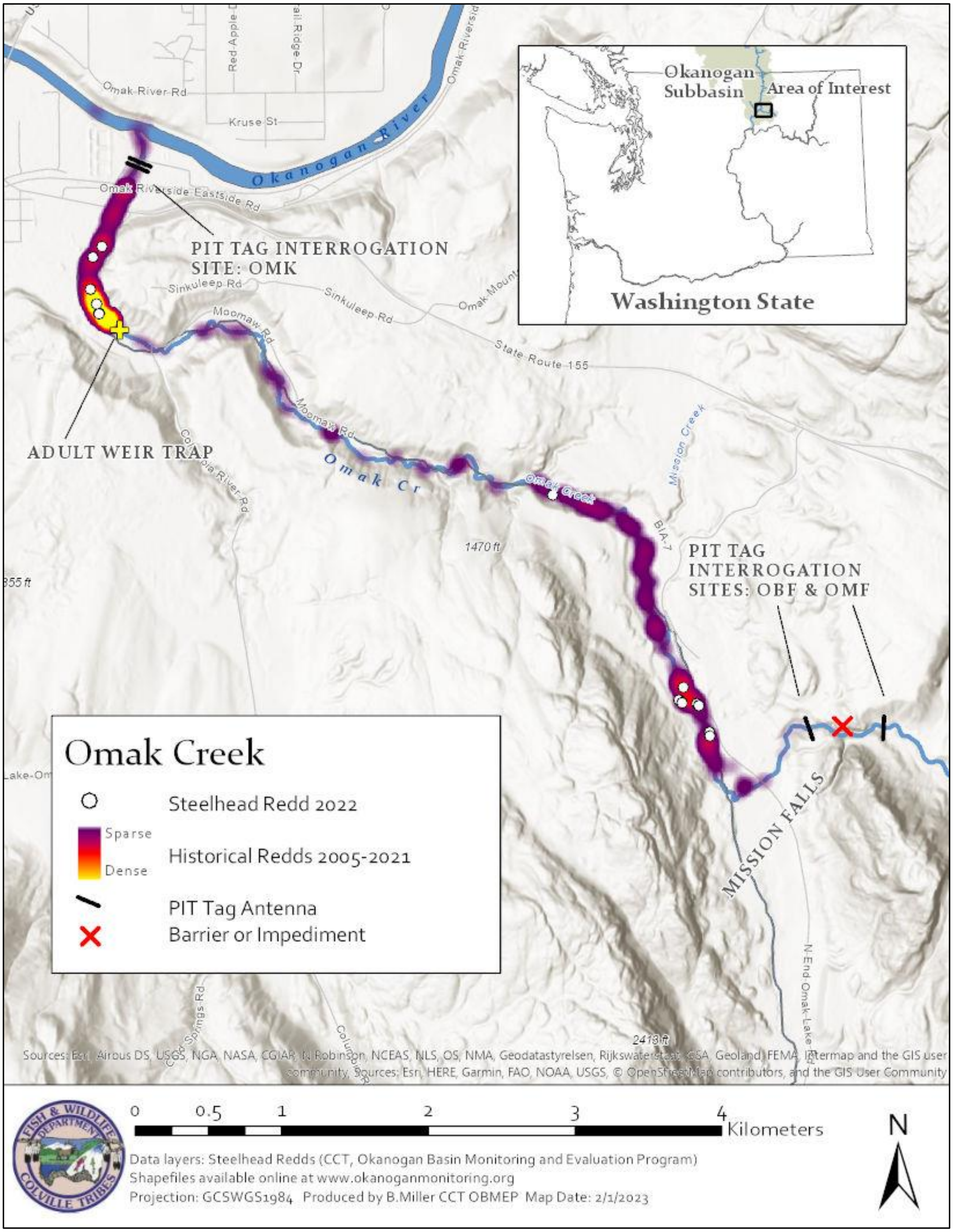

Figure 22. Spatial distribution of historical summer steelhead redds documented in Omak Creek, from the confluence to Mission Falls.

3.2.4 Wanacut Creek

Wanacut Creek is a small stream that joins the Okanogan River at approximately RKM 56, between Omak and Riverside, WA. The 51 km^2 Wanacut Creek drainage stems from Omak Mountain, located on the Colville Reservation. A large natural falls exists a short distance from the confluence with the Okanogan River and the creek frequently flows subsurface in the lower most reaches. A temporary PIT tag interrogation site (WAN) is operated seasonally near the mouth of the creek to record PIT tagged steelhead movements. No PIT tagged steelhead were detected on interrogation site WAN.

Redd surveys on Wanacut Creek occurred from the mouth to the upstream falls. The creek was too low for adult fish access until late-April. The first survey occurred on May 4 and no redds were found. A second survey occurred on May 24 and found one redd just above the PIT array, although the GPS file was lost on this occasion. The lower portion of the creek was dry in early July. The location of the redd observed in previous years (2005–2021) are shown in Figure 24. Based on previous years' data, we conservatively estimated 2 hatchery fish for this one redd. Over the previous 16 years of surveys conducted on Wanacut Creek (2007–2022), seven years had no steelhead spawning and the maximum spawning estimate was 12 in 2012 (Figure 23).

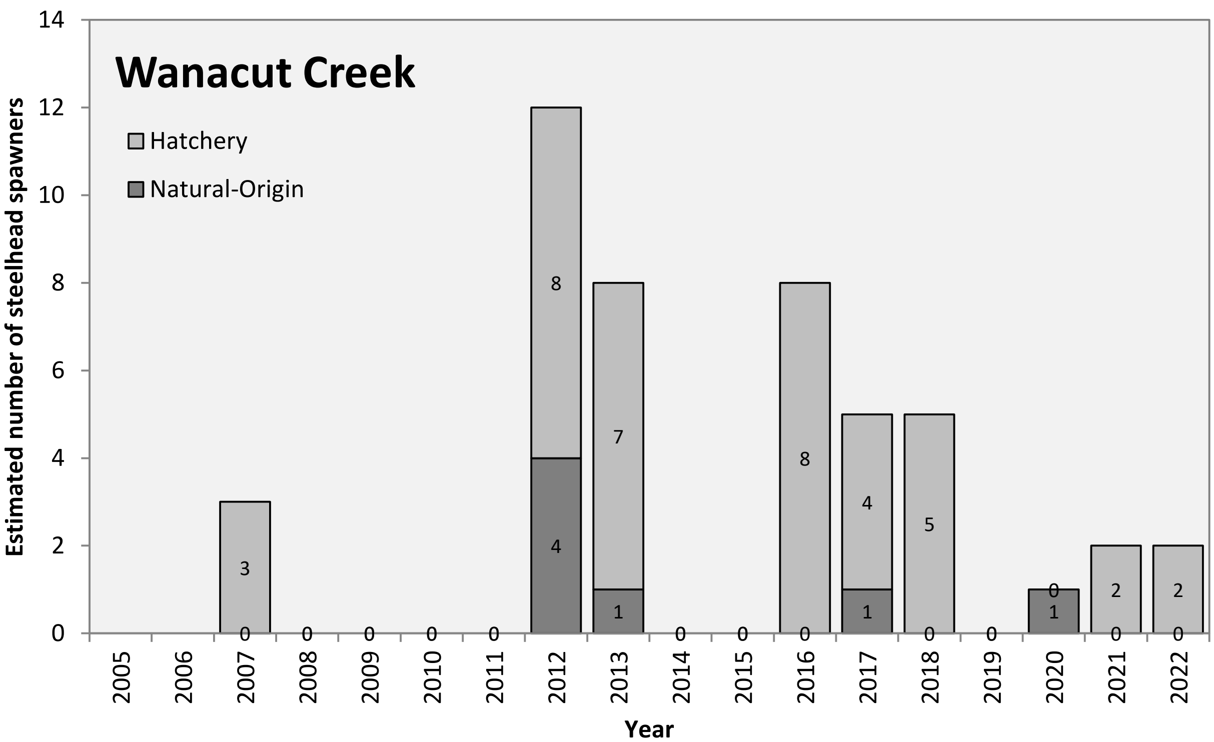

Figure 23. Trend in the number of steelhead spawners in Wanacut Creek.

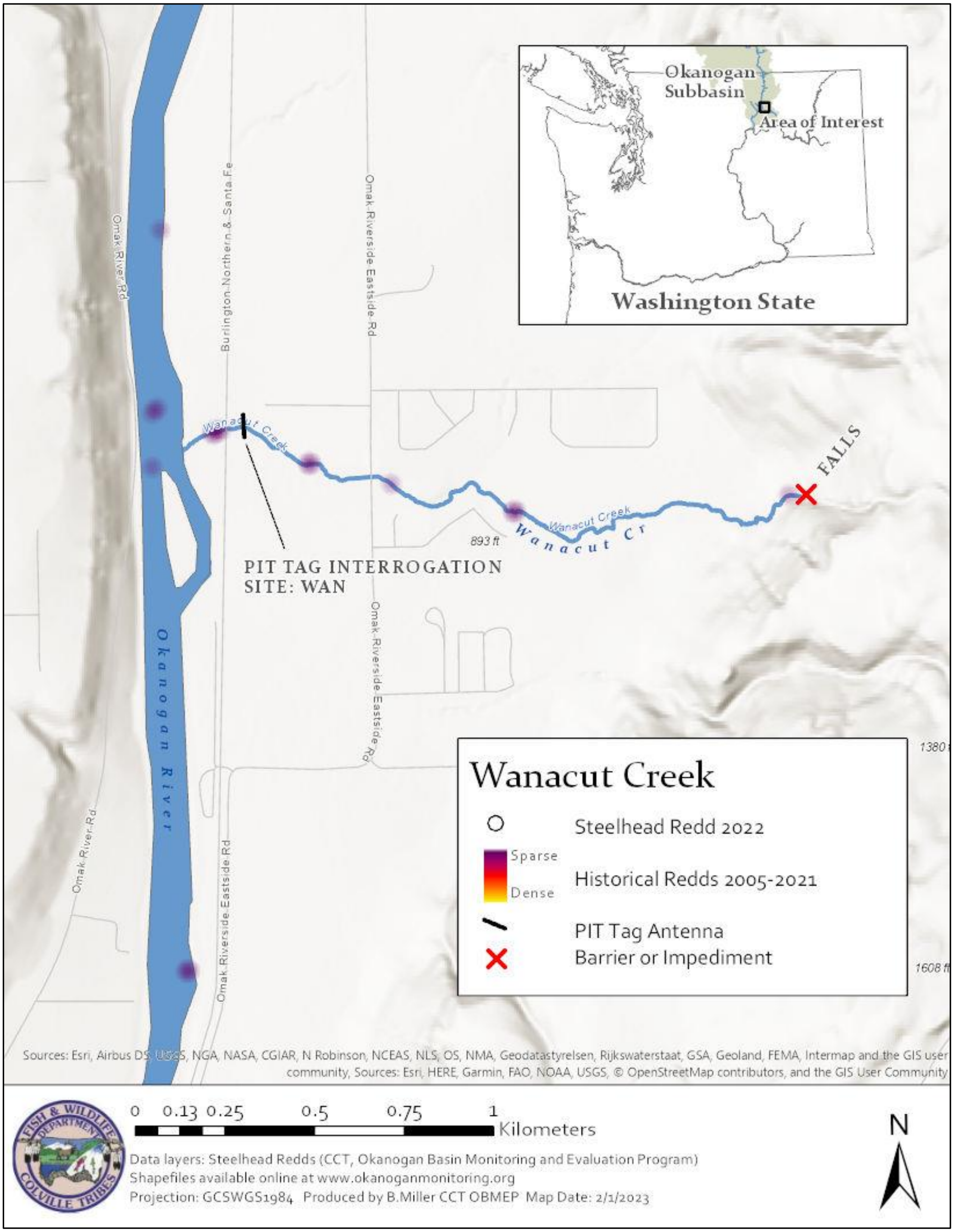

Figure 24. Spatial distribution of historical summer steelhead redds documented in Wanacut Creek.

3.2.5 Johnson Creek

Steelhead surveys have occurred in Johnson Creek since 2012 and two PIT tag arrays were again operated in the creek in 2022. A permanent single pass-through antenna located near the mouth (JOH) and a single temporary pass through antenna above the US 97 culvert. No PIT tagged steelhead were detected at either PIT tag interrogation site in Johnson Creek in 2022, which rendered a total spawning estimate of zero. Zero steelhead were also detected in 2020 and 2021. For reference, trends in steelhead spawning escapement for Johnson Creek are included in Figure 25, which generally show a declining trend in steelhead spawners since data collection began in 2012.

Redd surveys on Johnson Creek were conducted on April 6 (0 redds), April 21 (0 redds), May 4 (1 redd) and May 24 (0 Redds). The one redd was expanded by 1.96 FPR for an estimated 2 spawners. Because of recent trends of spawning in the creek being primarily hatchery fish and multiple occurrences of the creek going dry due to water diversions in recent years, we will assume these were both of hatchery-origin. Although there is no other evidence to corroborate this assumption. The spatial distribution of steelhead spawning in lower Johnson Creek in previous years are shown in Figure 26.

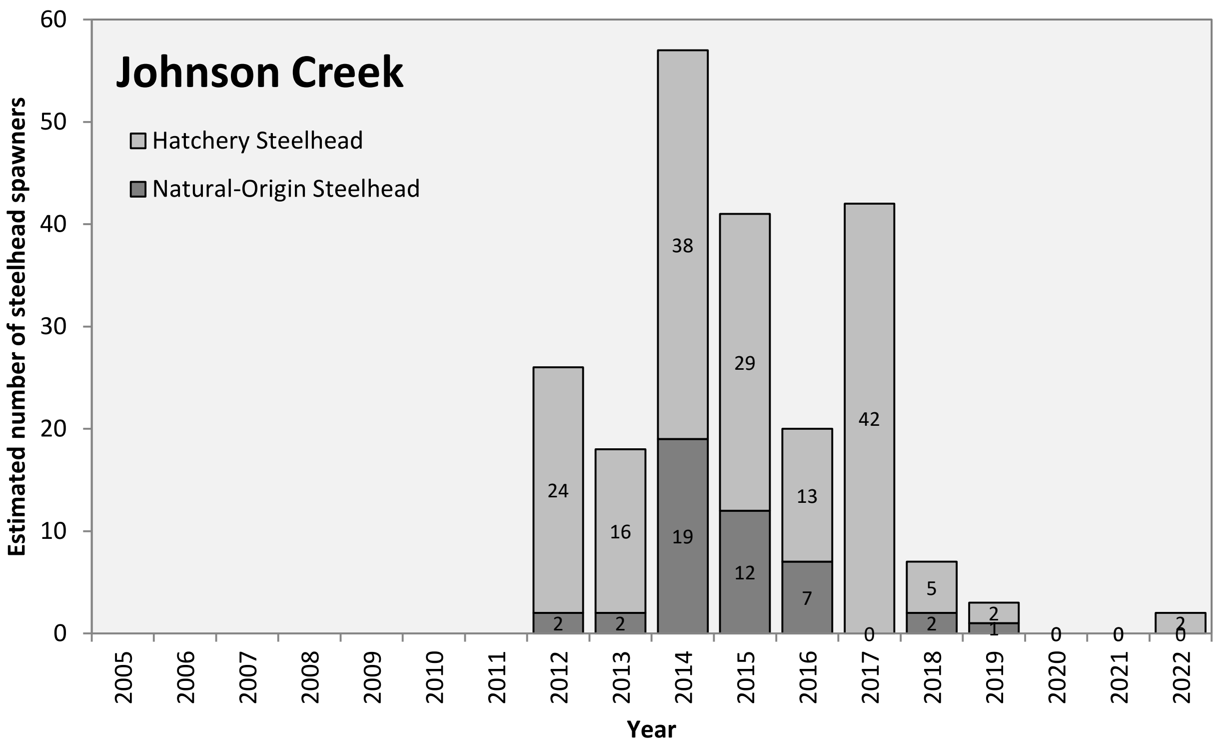

Figure 25. Trend in the number of steelhead spawners in Johnson Creek.

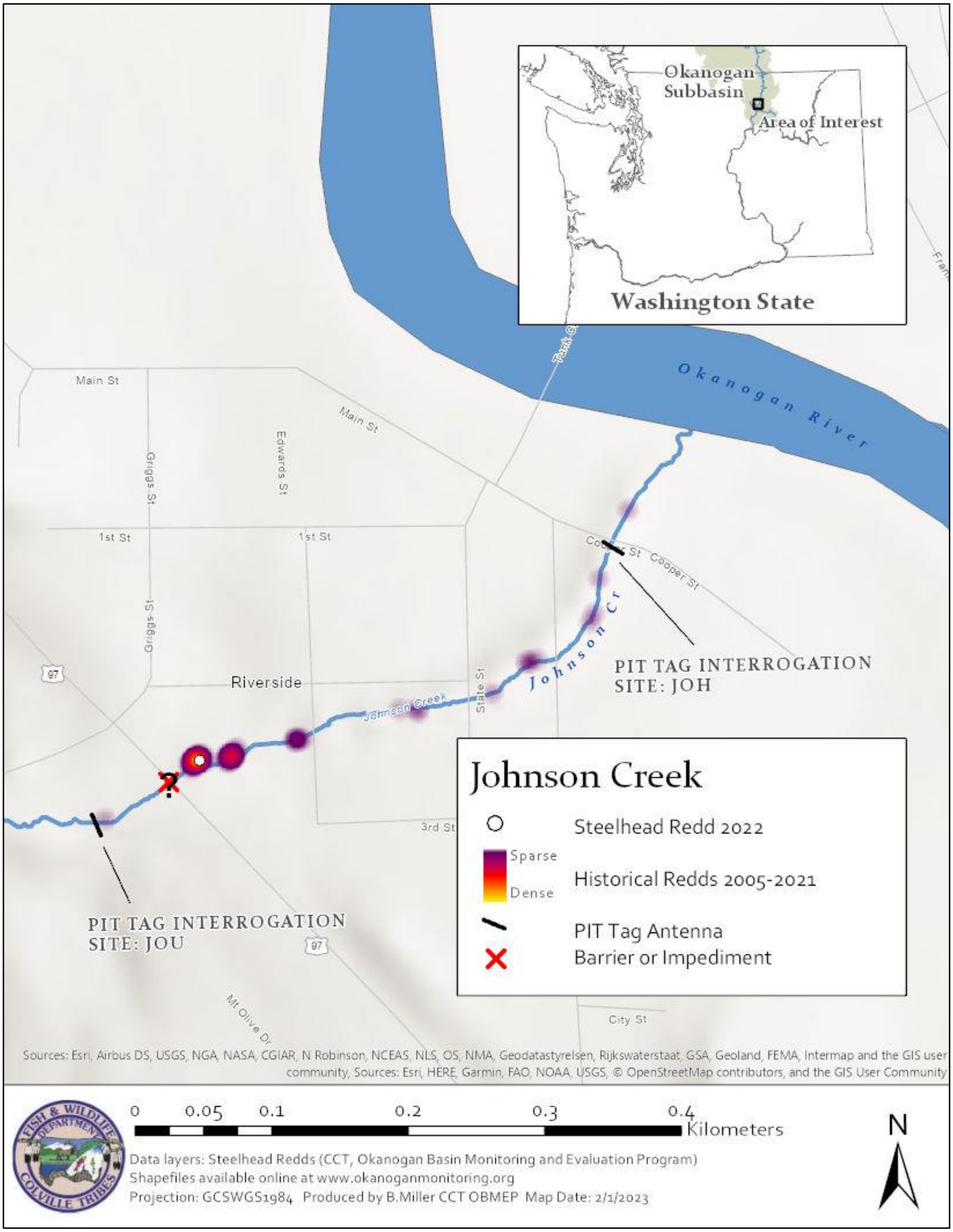

Figure 26. Spatial distribution of summer steelhead redds documented in Johnson Creek, from the confluence to the gabion weir.

3.2.6 Tunk Creek

Tunk Creek is a small tributary that joins the Okanogan River at RKM 72, upstream of Riverside, WA. Although the drainage area of Tunk Creek is approximately 186 km^2, only the lower 1.2 RKMs are accessible to anadromous fish, due to a natural falls. The creek frequently flows subsurface in the lower reaches during mid-summer. A PIT tag detection site (TNK) consisting of a single pass-through antenna is operated near the mouth of the creek.

Redd surveys in Tunk Creek were conducted on Apr 6 and Apr 21, no redds were observed either survey. Conditions were generally unfavorable throughout the rest of the spring due to elevated flows and turbid water conditions. On May 12, water clarity improved slightly and a redd survey was attempted, which located 5 redds. The creek remained turbid into June, when spawning had long since concluded. If these 5 redds were expanded by 1.96 FPR, this would account for approximately 10 spawners. The majority of steelhead spawning in Tunk Creek occurs in a relatively short reach just downstream of the falls where superimposition is common (Figure 28), therefore, this count is likely an underestimate.

Through the spring of 2022, two natural-origin steelhead from the PRD group were detected at site TNK. These fish were expanded by the mark rate to 19 natural-origin steelhead. One additional natural- and one hatchery-origin steelhead from other mark sites were detected, as well. The PIT tag expansion estimate was likely more reliable for a total spawner count due to surveyors likely missing redds turbid conditions (Figure 28). Given all available PIT tag information over the course of the season, we report the spawning estimate for Tunk Creek as 19 natural-origin and one hatchery steelhead for 2022.

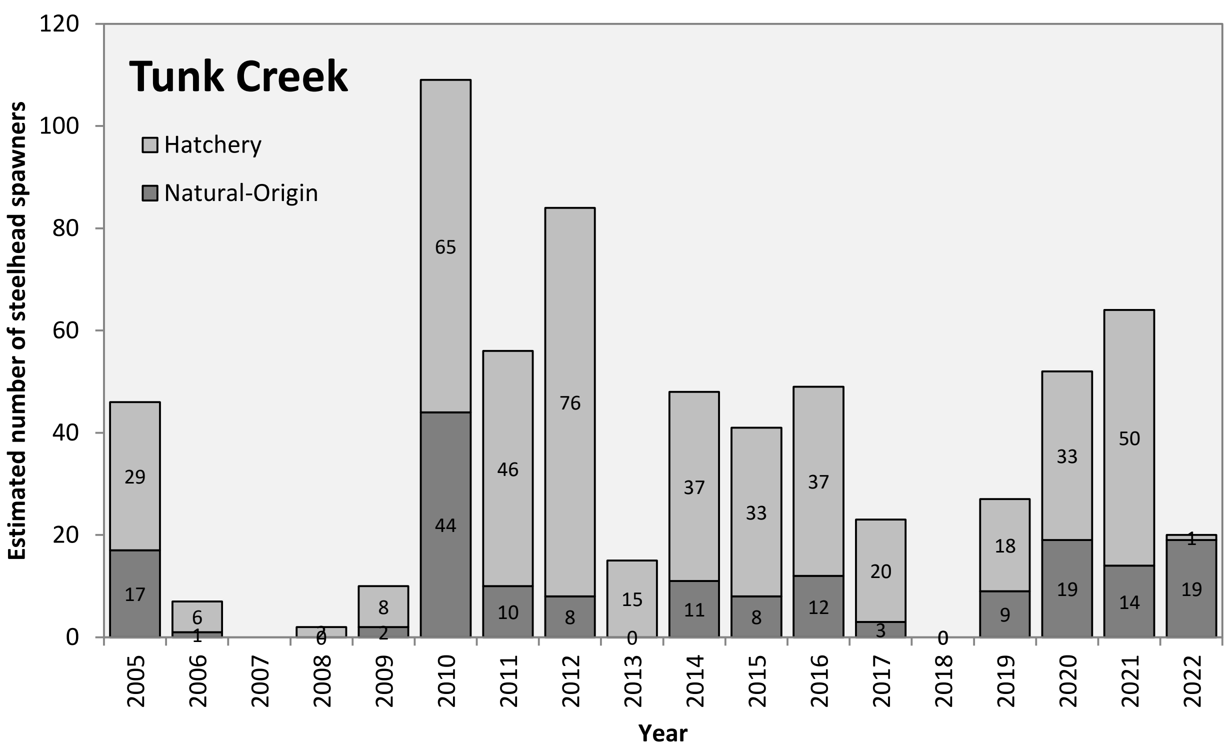

Figure 27. Trend in the number of steelhead spawners in Tunk Creek.

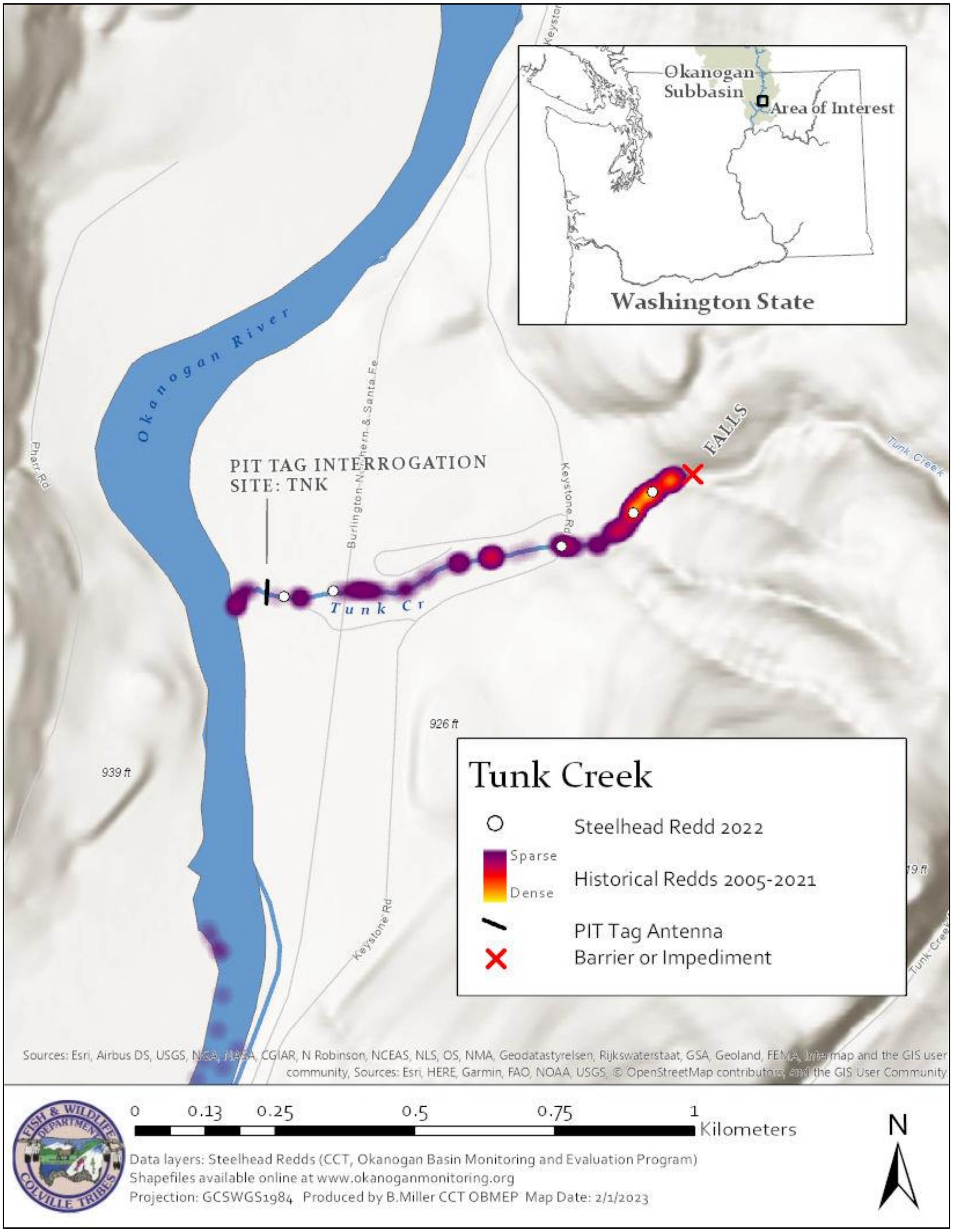

Figure 28. Spatial distribution of historical summer steelhead redds documented in Tunk Creek.

3.2.7 Aeneas Creek

Aeneas Creek is a small creek that enters the Okanogan River just south of the town of Tonasket, WA (RKM 85). The lower section of the creek was impounded with a series of very large beaver dams that were cemented in with calcified clay. In 2012, many of these structures were removed, allowing adult steelhead passage at the mouth of the creek. Although potential passage has not been studied at this location, the total habitat accessible to anadromous fish appears to be limited by a culvert and steep gradient (Figure 30). Redd surveys were conducted on April 7, Apr 21 and May 5. No redds were found on any of the surveys.

A permanent PIT tag detection site (AEN) consisting of a single pass-through antenna operated near the mouth of the creek to document utilization of the creek by adult steelhead. No PIT tagged steelhead were detected in 2022, resulting a total spawning escapement estimate of zero steelhead. In recent years, nearly all the estimated spawners in Aeneas Creek have been hatchery steelhead (Figure 29).

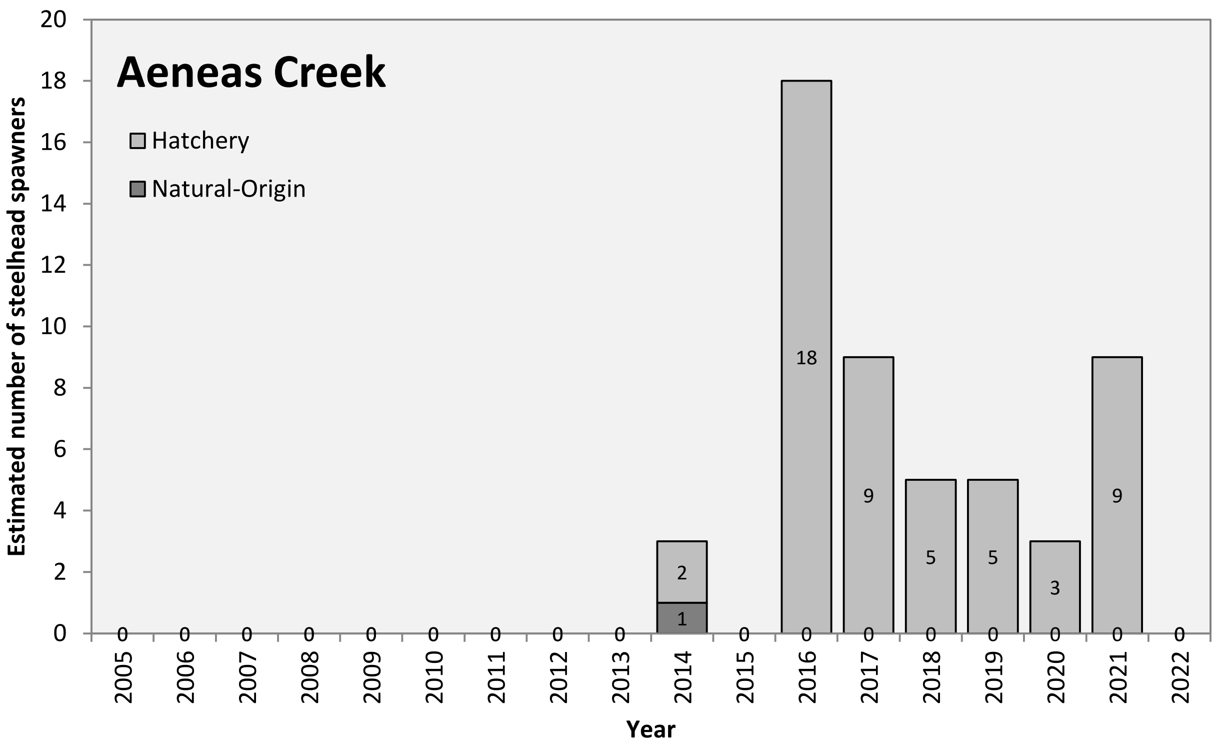

Figure 29. Trend in the number of steelhead spawners in Aeneas Creek.

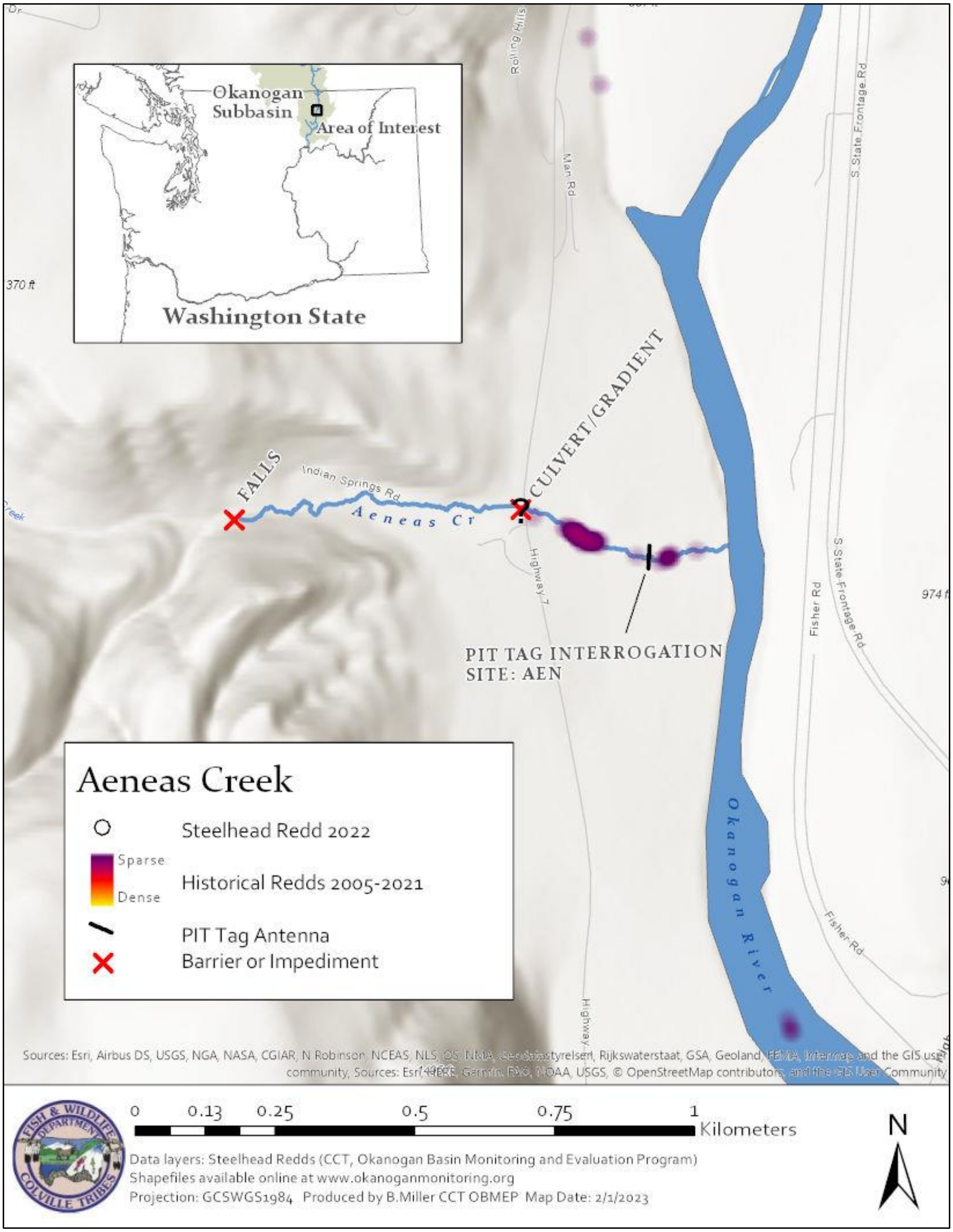

Figure 30. Spatial distribution of historical summer steelhead redds documented in Aeneas Creek.

3.2.8 Bonaparte Creek

Bonaparte Creek flows out of Bonaparte Lake, near Wauconda, WA, and enters the Okanogan River at RKM 91. The Bonaparte Creek watershed has a drainage area of 396 km^2; discharge ranges from 1 cfs during base flow conditions and usually reaches 20–40 cfs during runoff. During summer base flow, wetted widths range from 1.5 to 3 meters. Only 1.6 RKM of stream below a natural falls is accessible to anadromous fish (Figure 32).

A permanent PIT tag interrogation site (BPC) consisting of three pass-over HDPE antennas arranged in three separate rows was located just upstream from the confluence with the Okanogan River. Based on 1 natural-origin and 4 hatchery tag detections from the PRD mark group, the estimated spawning escapement was 9 natural-origin and 37 hatchery steelhead, or a total of 46 steelhead in Bonaparte Creek in 2022. Five other hatchery steelhead not from the PRD mark group were also detected at BPC in the spring of 2022, 4 hatchery- and 1 of natural-origin.

Conditions in Bonaparte Creek were largely unfavorable to conduct spawning surveys due to increased runoff and turbid water conditions. One survey was attempted on Apr 12, but located no redds. The creek was off-color for the remainder of the season. For reference, trends in steelhead spawning estimates for Bonaparte Creek are included in Figure 31. Distributions of redds found in the creek from current and previous years surveys (2005-2022) are shown in Figure 32.

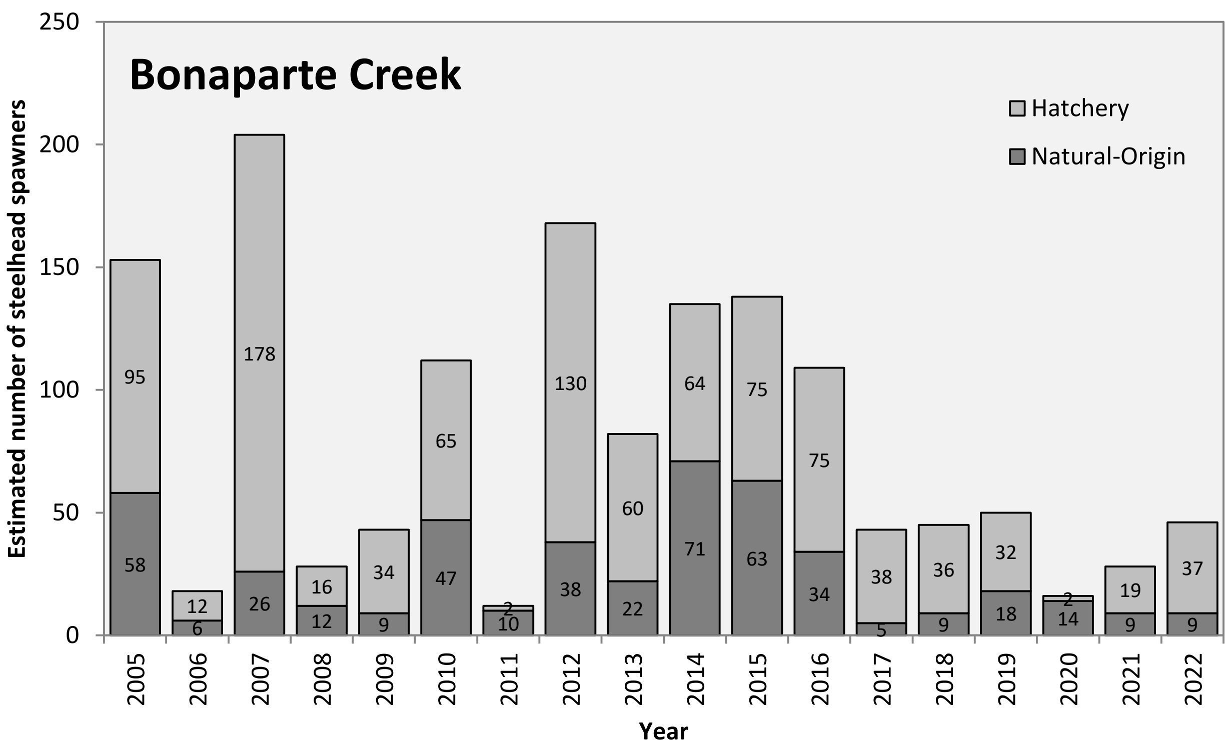

Figure 31. Trend in the number of steelhead spawners in Bonaparte Creek.

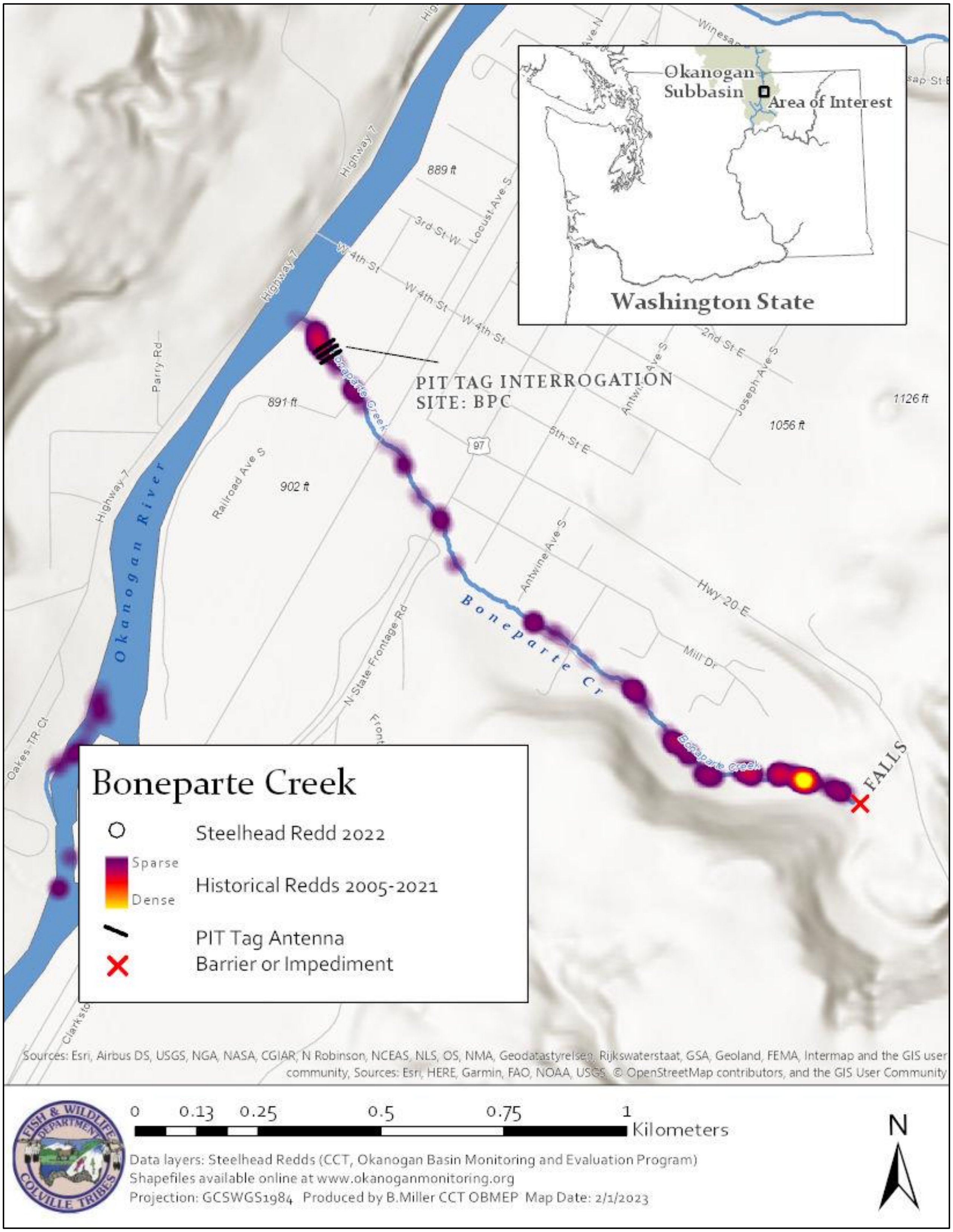

Figure 32. Spatial distribution of summer steelhead redds documented in Bonaparte Creek.

3.2.10 Antoine Creek

Steelhead surveys have occurred in the lower portion of Antoine Creek since 2006. The average number of estimated spawners is only five per year from 2006–2015. Utilization by adult steelhead had been relatively limited, potentially due to poor accessibility across the delta at the confluence with the Okanogan River. Additionally, access to Antoine Creek was at least partly impeded by an approximately 6-foot-high cut bank falls with a very shallow plunge pool near the confluence with the Okanogan River. Frequently, wood debris piled up in this slot and likely inhibited upstream passage. In late 2015, habitat modifications were completed near the mouth of Antoine Creek, designed to increase passage success for the 2016 spawning period (Keith Kistler, CCT, pers. comm.). Additionally, a small concrete dam was removed in Antoine Creek in the fall of 2013, which opened up an additional 11 RKM of habitat in the upper creek. In 2021, water was released from Fancher Reservoir in early April to act as an attractant flow and to facilitate adult steelhead passage into the creek (Figure 14). Since increasing instream flows and removing access barriers, the number of steelhead utilizing Antoine Creek has increased over the most recent seven years, compared with prior estimates (Figure 33).

A series of three pass-through PIT tag antennas are operated near the mouth of Antoine Creek, just on the upstream side of the highway (PTAGIS site ANT). No PIT tagged steelhead were detected on this site in 2022. Information collected during spawning surveys supported PIT tag information. The creek was surveyed on Apr 18 and no redds were found. Two complete surveys were conducted, on May 4 and 5, and again on May 25. No steelhead redds were found either survey. One small redd was observed just downstream of a very large beaver dam located at the base of the lower canyon, just upstream from the orchards. Two small ad-clipped fish were observed by the redd, likely adfluvial. One additional redd, likely made by small resident trout was also located in the lower canyon. These are shown on Figure 34 for reference. The total adult steelhead spawning estimate for Antoine Creek was zero for 2022.

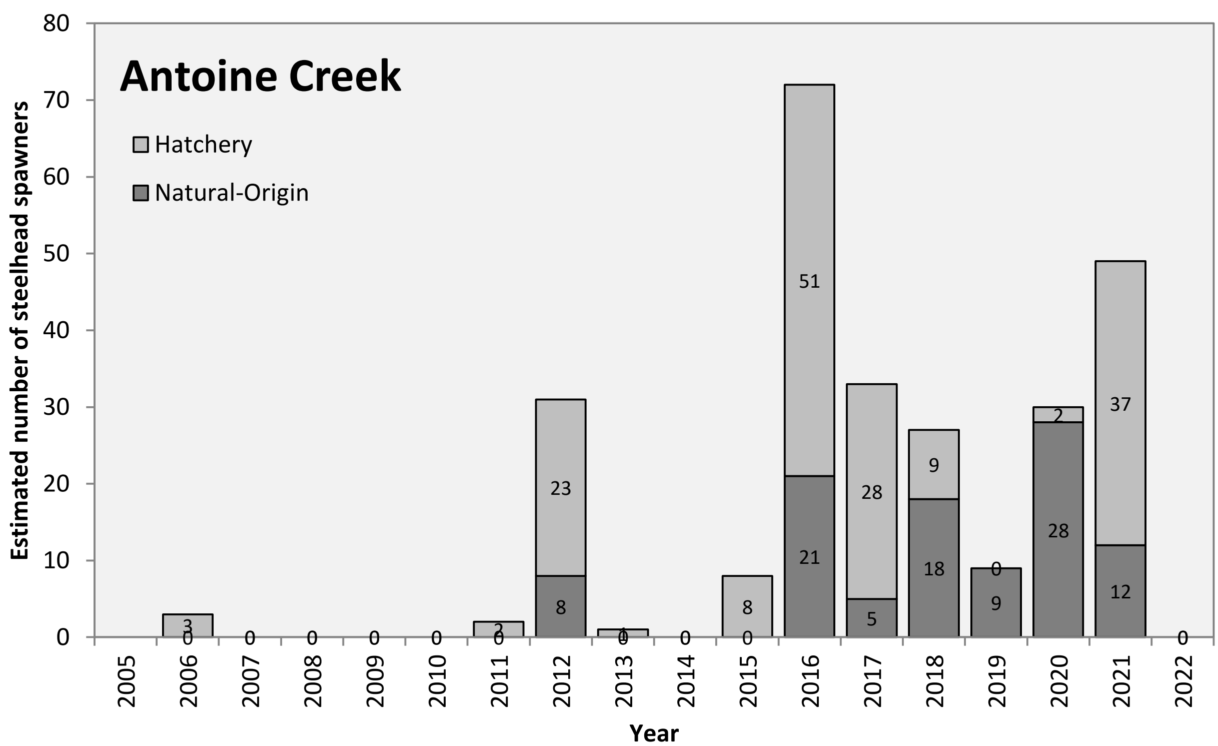

Figure 33. Trend in the number of steelhead spawners in Antoine Creek.

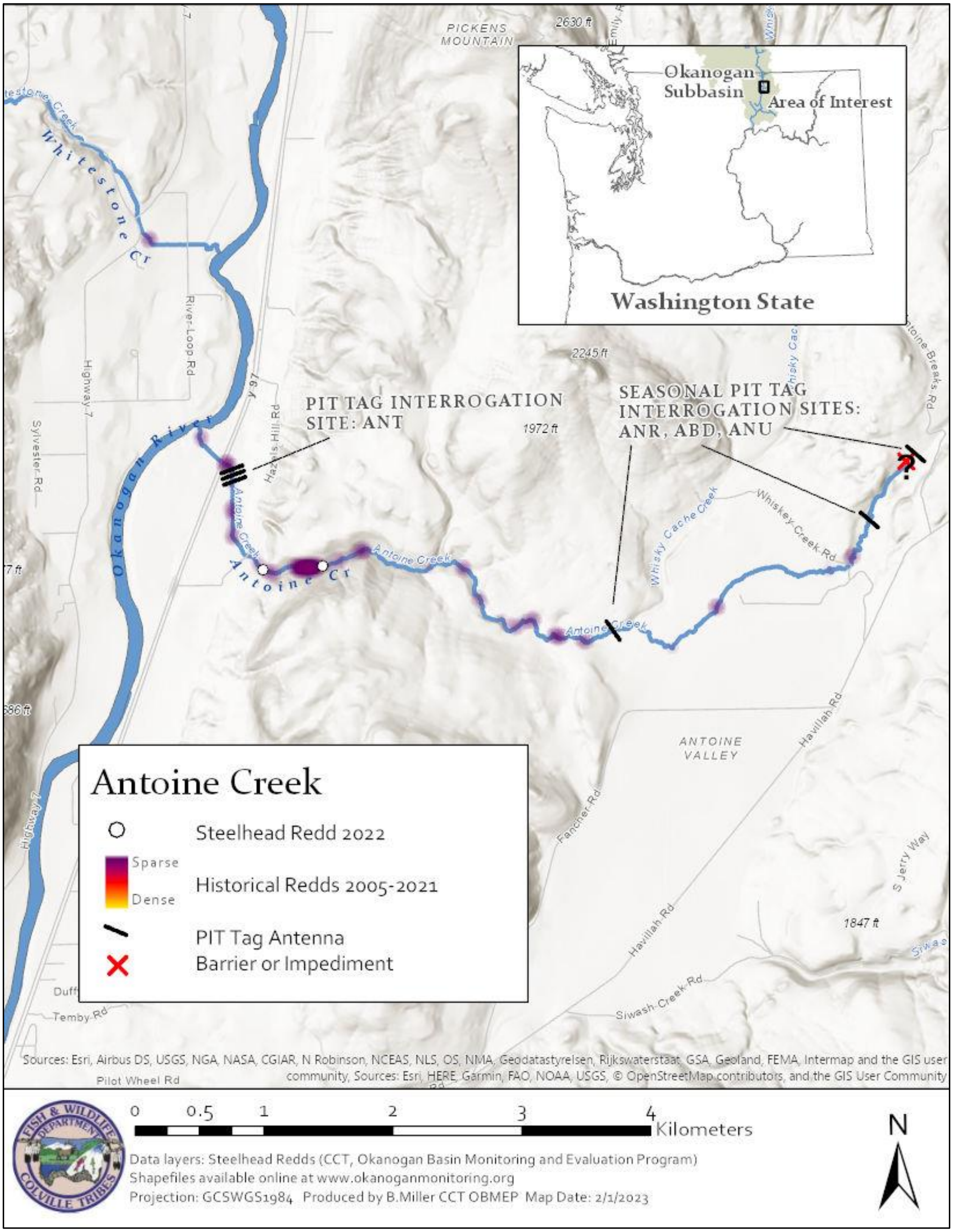

Figure 34. Spatial distribution of summer steelhead redds documented in Antoine Creek.

3.2.11 Wildhorse Spring Creek

Wildhorse Spring Creek is a fairly small watershed that flows off of the west side of Mt. Hull near Oroville, WA. Some years, there is not enough water depth for adult steelhead to access the creek. However, on years where sufficient water flows allow for adult steelhead access, it is not uncommon for relatively large numbers of fish to utilize this creek for spawning compared to its limited size. Surveys have occurred over the previous 16 years (2006–2021). On six of the years of record (2008, 2009, 2014, 2015, 2018, 2019) zero steelhead were estimated to have entered the creek.

Sufficient flow existed in 2022 to allow adult steelhead passage, although the BAM program operated a picket fence, designed to exclude steelhead from the creek. When the Okanogan River stage was high enough to overtop the pickets, one natural-origin steelhead from the PRD mark group was detected on PIT tag detection site WHS, operated just above the highway culvert and above the picket fence. This one detection was expanded to a total estimated 9 natural-origin spawners in 2022 (Figure 35). Previous years spawning is shown in Figure 36.

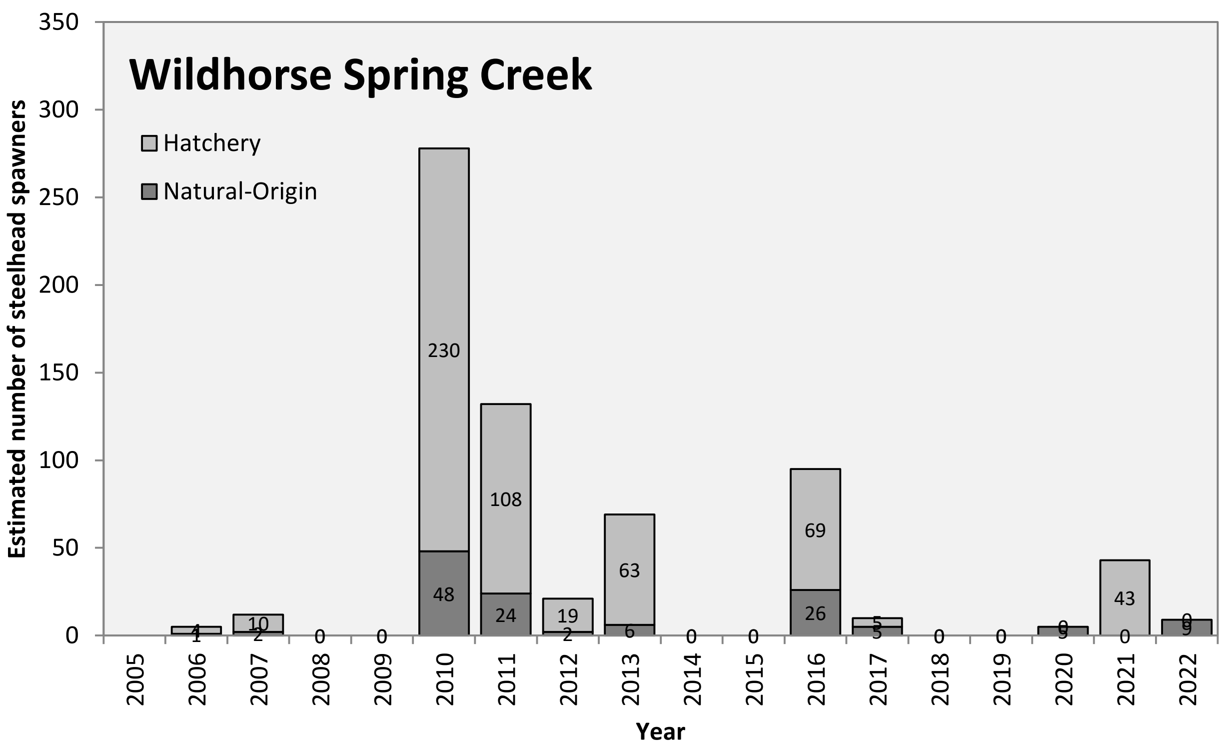

Figure 35. Trend in the number of steelhead spawners in Wildhorse Spring Creek.

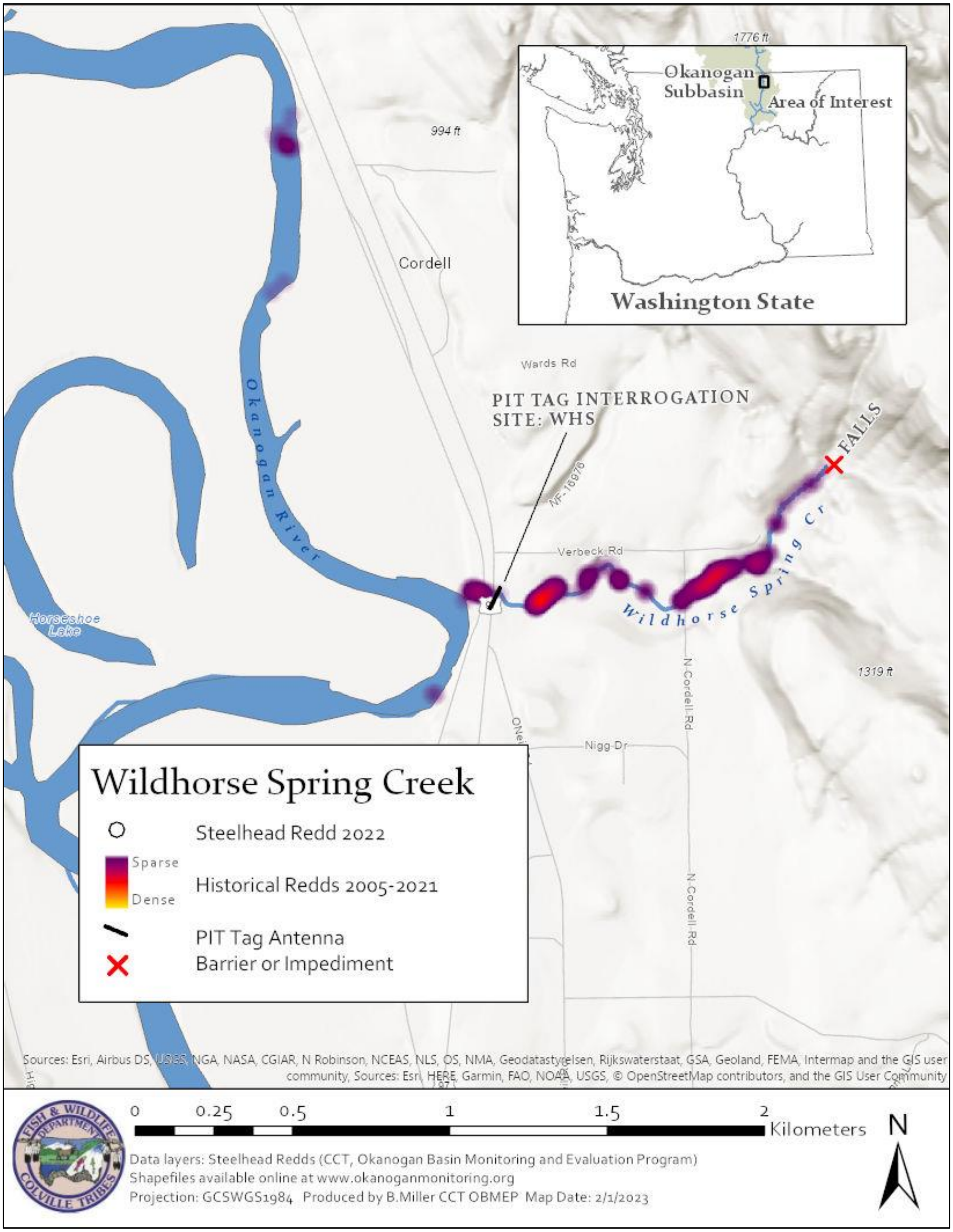

Figure 36. Spatial distribution of summer steelhead redds documented in Wildhorse Spring Creek.

3.2.12 Tonasket Creek

Tonasket Creek enters the Okanogan River at RKM 125, just upstream from Zosel Dam, at the tail end of Lake Osoyoos. The lower reach is known to go dry on an annual basis; however, there is typically some flow in the upper-most reach, below the natural falls (Figure 38). A seasonal PIT tag detection site (TON) consisting of a single pass-through antenna is operated near the confluence of the creek with the Okanogan River.

A total of two natural-origin and one hatchery steelhead from the PRD mark group were detected at site TON in 2022. This rendered a spawning estimate of 19 natural-origin and 9 hatchery steelhead spawners. Walking surveys occurred on April 11 and April 26, which found 0 redds. Two additional surveys were completed on May 11 and June 1; 5 redds were found on each survey. These 10 redds were expanded by the FPR rate of 1.96 to equal an estimated 20 spawners. The surveys noted numerous fish at the upper falls and a lot of cleaned gravel. The redd count may have been an under count do to superimposition. Because of likely superimposition, the PIT tag value is the more accurate estimate for total spawners. The lower portion of the creek was dry by July.

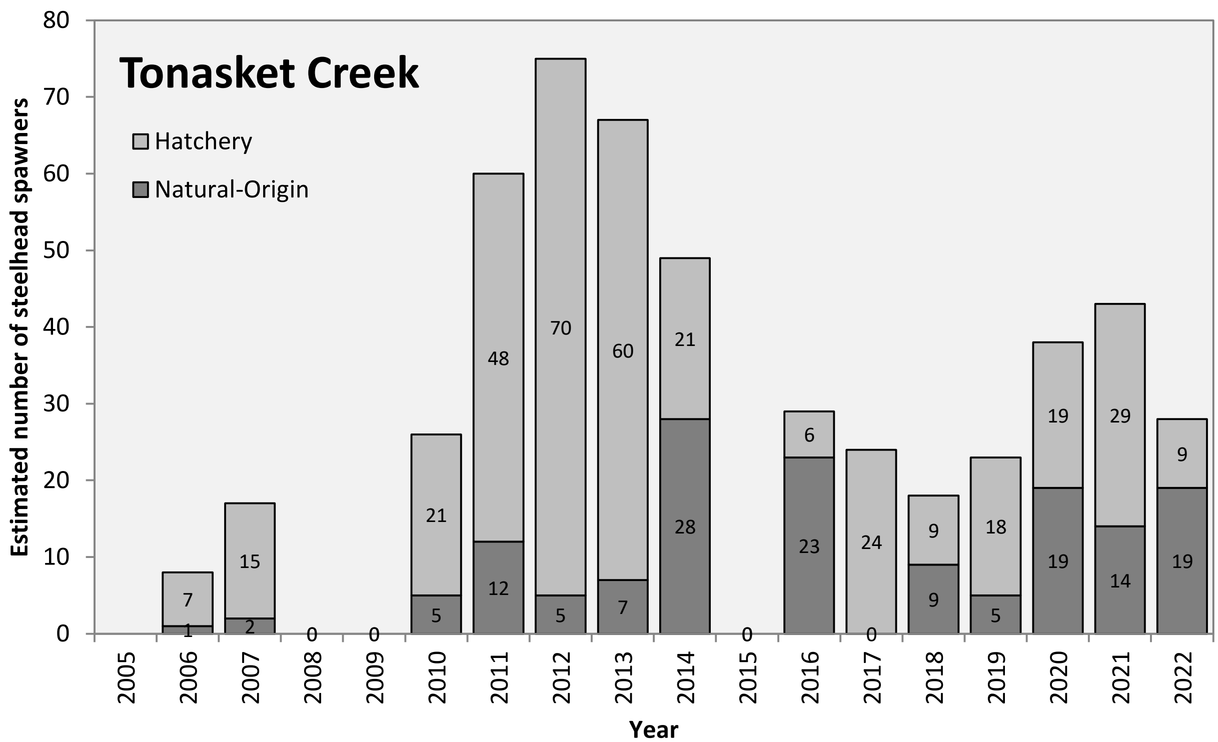

Figure 37. Trend in the number of steelhead spawners in Tonasket Creek.

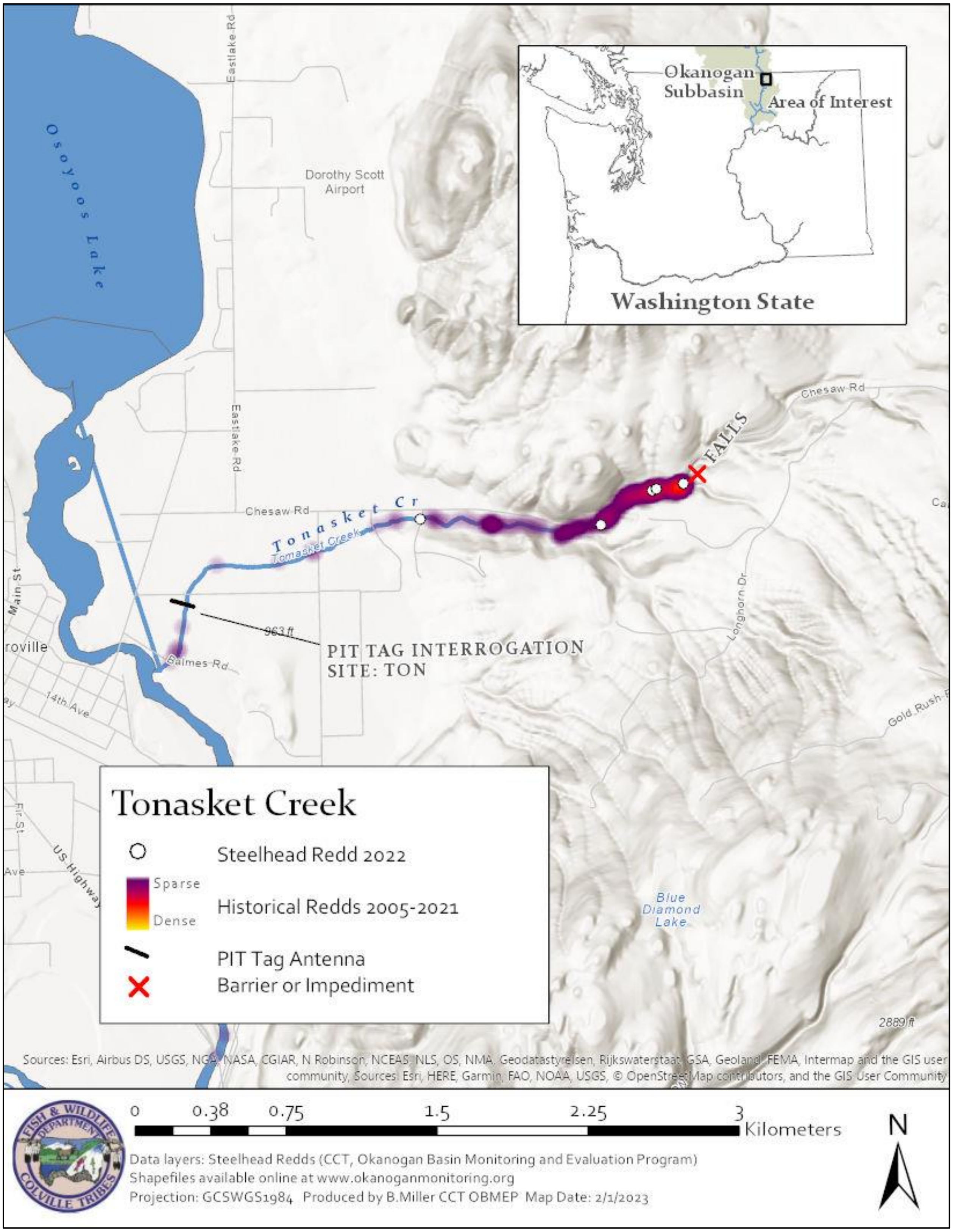

Figure 38. Spatial distribution of historic summer steelhead redds documented in Tonasket Creek.

3.2.13 Ninemile Creek

Ninemile Creek enters the eastside of Osoyoos Lake, just south of the British Columbia border. The creek is known to flow sub-surface annually in the middle reach during the summer, but surface flows are usually present in the upper and lower reaches. A permanent PIT tag interrogation site (NMC) consisting of three pass-through HDPE antennas is located near the mouth of the creek. Based on PIT tag detections in 2022, an estimated 9 natural-origin (1 PRD detection) and 28 hatchery steelhead (3 PRD detections) spawned in Ninemile Creek.

Walking surveys were conducted on lower Ninemile Creek, below the PIT tag interrogation site NMC, on April 1 (turbid water), April 11 (no redds found) and April 26 (turbid). A complete one pass survey was conducted on Ninemile Creek on May 11, from the mouth upstream through the WDFW Eder property, near the base of the upstream falls. A total of 7 redds were located. Another complete survey was conducted on June 1, which located an additional 4 redds (Figure 40). Expanding the total 11 redds by the 1.96 FPR renders 22 spawners, which is less than the PIT tag expansion estimate. Due to the turbid conditions between surveys, it is possible that surveyors could not located some of the redds made during that time. We default to the PIT tag expansion estimate of 37 steelhead (9 wild, 28 hatchery) for the 2022 spawn year.

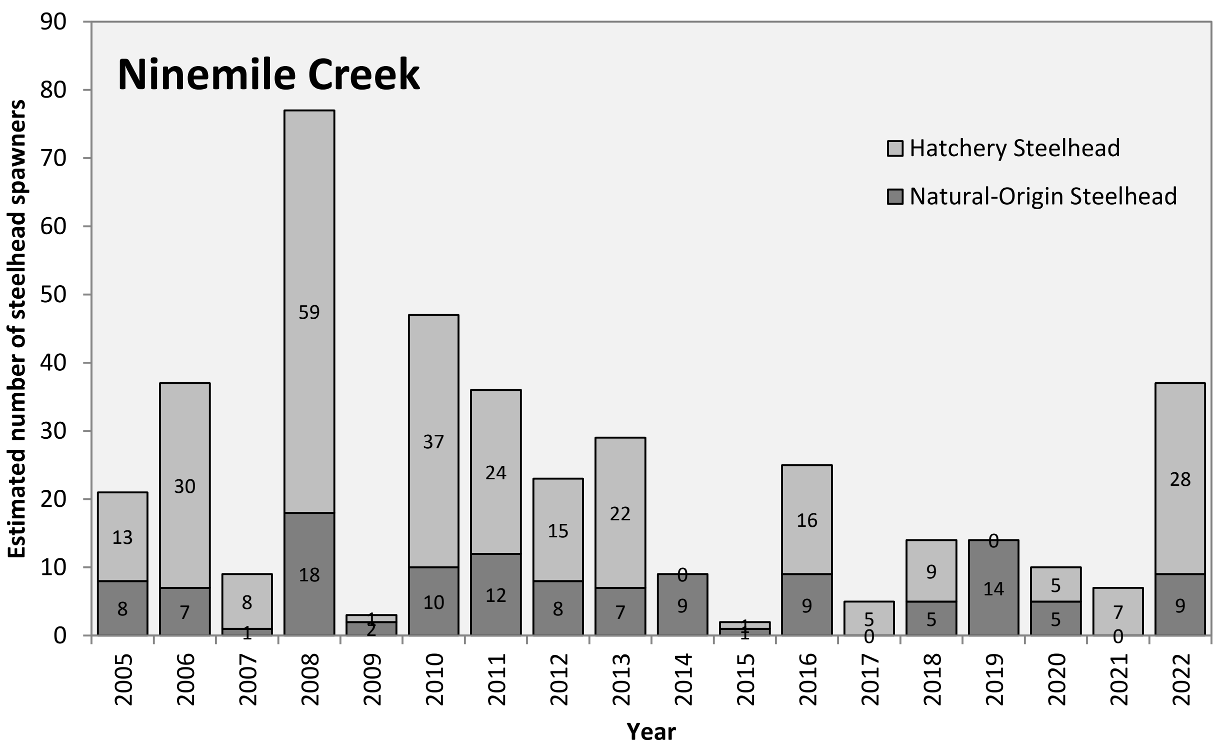

Figure 39. Trend in the number of steelhead spawners in Ninemile Creek.

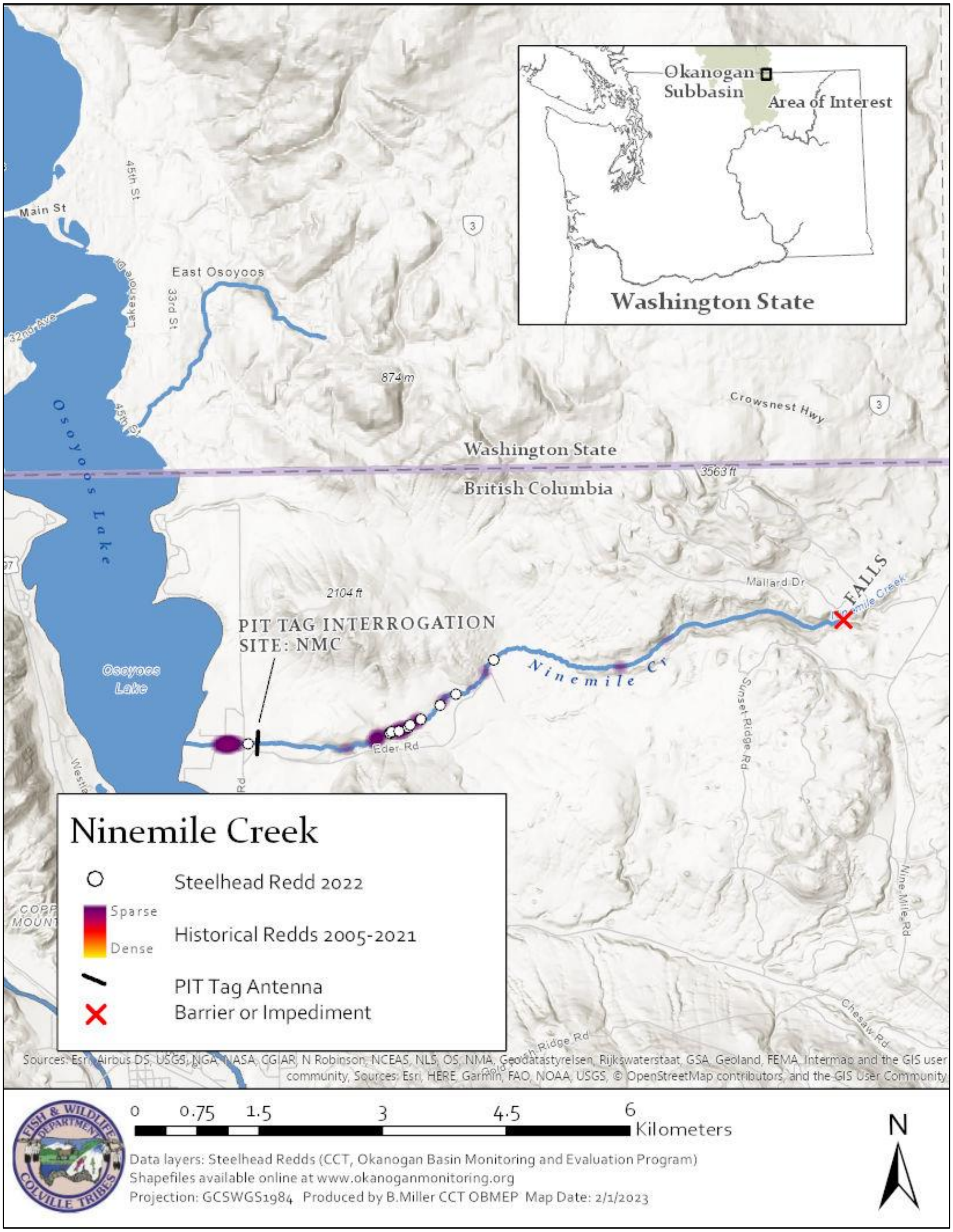

Figure 40. Spatial distribution of summer steelhead redds documented in Ninemile Creek.

3.2.14 Foster Creek (located outside the Okanogan subbasin)

Although Foster Creek is not located within the Okanogan subbasin, OBMEP operated a PIT tag detection site (FST) and conducted three redd surveys in 2022 to further describe the spatial extent of Upper Columbia River steelhead above Wells Dam. During 2022, sufficient water flowed down Foster Creek for adult steelhead to migrate into the upper reaches, past the dam outflow pipe. Foster Creek was surveyed on April 6 and April 27 and no redds were located. On May 4, 2 redds were found, 8 on May 19, the creek was turbid for a time, but cleared by June 8, and a final 3 redds were found. The 13 documented redds were expanded by 1.96 fish-per-redd for a total estimate of 26 steelhead.

A total of 1 natural-origin and 8 hatchery PIT tagged steelhead from the PRD mark-group were detected at PIT tag interrogation site FST in 2022. Those tags were expanded by the mark rate of 0.107 for a total spawning estimate of 9 natural-origin and 75 hatchery steelhead. It is interesting to note the difference in the spawning estimate between the redd surveys and PIT tag expansion methods in 2022. Surveyors did note significant superimposition of redds in the lower portion of the creek, below the bridges. Additionally, notes from survey crews indicated significant deposition and increases of fine sediment in the area below the falls/upper dam, potentially stemming from fires in previous summers. This likely limited suitable spawning substrate in the upper reaches, concentrating fish in the lower creek. Spatial distribution of redds located during the 2022 survey and on previous years' surveys are detailed on Figure 41. Spawning estimates of steelhead from 2013-2022 are presented in Table 6.

Table 6. Estimated number of spawners in Foster Creek.

Year	Hatchery-Origin	Natural-Origin	Total	pHOS
2013	27	3	30	0.90
2014	14	0	14	1.00
2015	12	6	18	0.67
2016	77	13	90	0.86
2017	14	0	14	1.00
2018	27	76	103	0.26
2019	23	45	68	0.34
2020	5	19	24	0.21
2021	50	7	57	0.88
2022	75	9	84	0.89
Avg.	32	18	50	0.70

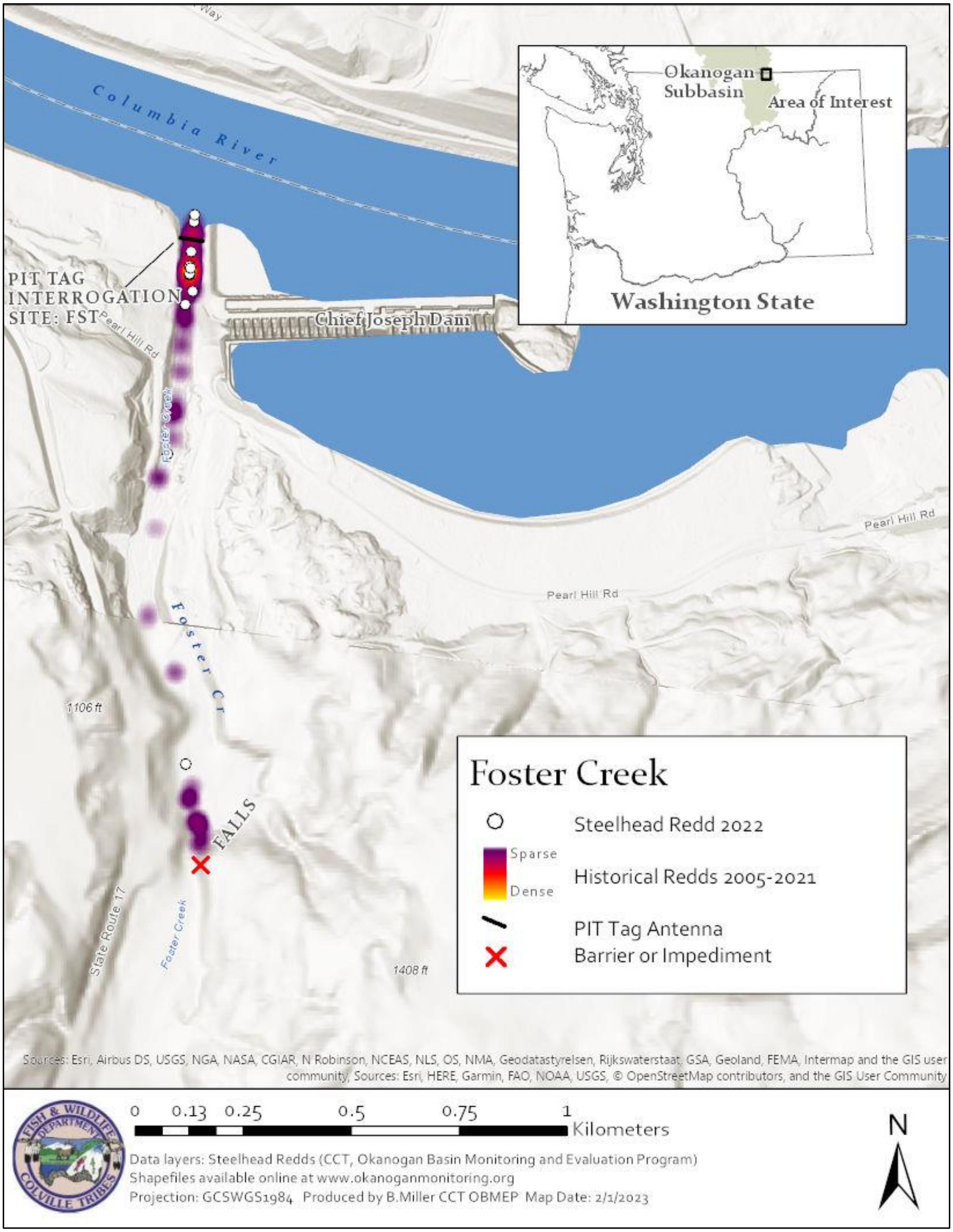

Figure 41. Spatial distribution of summer steelhead redds documented in Foster Creek.

3.3 Zosel Dam and Upstream Locations

Zosel Dam regulates Lake Osoyoos, which extends into the Canadian portion of the subbasin. A vertical-slot fishway provides upstream passage and is equipped with a PIT tag detection array (ZSL). Zosel Dam was constructed in its current state in 1987 with undershot spillways. When these spillway gates are raised to a height of more than 12 inches, fish may be able to ascend through the spillways and bypass the fishway where the PIT tag array is located. Underwater video enumeration of steelhead was discontinued at Zosel Dam in 2015 due to sufficient PIT tag detection sites upstream of that point. The fall back rate at Zosel Dam is currently unknown, but may be relatively large due to the heavily utilized spawning habitat available in Okanogan reach 07.

Three perennial tributaries flow into Lake Osoyoos, two on the Washington State side of the border (Ninemile and Tonasket creeks) and one in British Columbia (akskʷəkʷant (Inkaneep Creek)). Both Ninemile and Tonasket creeks have had PIT tag interrogation sites installed for a number of years; additionally, a permanent PIT tag interrogation site was installed in akskʷəkʷant (Inkaneep Creek) in 2015. Approximately 5 km upstream of Lake Osoyoos, on the q̓awsitkʷ (Okanagan River) mainstem, a permanent instream PIT array spans the entire channel (site OKC situated at Vertical Drop Structure 3) which has been in operation since 2010. Since all salmon migrating upstream of Lake Osoyoos must cross over OKC, it has been a pivotal detection site for enumerating adult salmon abundance and observing migration timing. PIT tag interrogation sites were also installed on three other British Columbia tributaries located further up the subbasin, nʕax̌ʷlqaxʷiya (Vaseux Creek), akɬxʷminaʔ (Shingle) and Shuttleworth creeks.

Until 2009, the outlet dam of Vaseux Lake (McIntyre Dam) was the upstream migration barrier for anadromous salmonids. The dam was redesigned in 2009 and currently, the outlet dam of Okanagan Lake at Penticton, BC is the upstream barrier. A dam also exists at the outlet of Skaha Lake (Okanagan Falls, BC), which had a fish ladder installed in 2014. As well, 17 Vertical Drop Structures (VDS) currently exist along the q̓awsitkʷ (Okanagan River) mainstem, 13 between Oliver, BC and Lake Osoyoos, and four between Skaha Lake and Vaseux Lake. The majority of the Canadian portion of the mainstem q̓awsitkʷ (Okanagan River) is characterized as being straightened and channelized. The main British Columbia tributaries to the mainstem q̓awsitkʷ (Okanagan River) include akɬxʷminaʔ (Shingle Creek), Ellis Creek, McLean Creek, Shuttleworth Creek, nʕax̌ʷlqaxʷiya (Vaseux Creek), and a number of other small perennial streams.

Total spawning estimates for steelhead in British Columbia were calculated the same as in the Washington portion of the subbasin, only using tags from the representitively marked Priest Rapids Dam sample group and expanded by the mark rate of 0.107. Within the entire Canadian Okanagan, only one tagged natural-origin steelhead from the mark group was detected on site OKC, located just above Lake Osoyoos. One additional tag, not from the representitively sampled PRD group was detected on OKV in nʕax̌ʷlqaxʷiya (Vaseux Creek) (Table 7). That tag was not expanded, but at least represented a single hatchery steelhead. In the interest of best describing total spawning distribution of steelhead based on a very small sample size, we added this fish to that respective creek segments. Any fish last detected on OKC or in other years in the Penticton Channel, likely spawned in the mainstem q̓awsitkʷ (Okanagan River), or potentially in another small stream that did not have a PIT antenna in operation, although would be considered more unusual. All adult steelhead detected on arrays upstream of that point were previously detected on OKC, so we assumed a 100% detection efficiency for this brood-year. No tagged steelhead were detected in in akskʷəkʷant (Inkaneep), Shuttleworth or akɬxʷminaʔ (Shingle) Creeks. The total spawning estimate in the British Columbia portion of the Okanagan subbasin for 2022 was 9 natural-origin and 1 hatchery steelhead (Table 8). The average number of steelhead spawning upstream of Lake Osoyoos over the last nine years (2013-2022) was 21 natural-origin and 11 hatchery steelhead.

Table 7. Brood-year 2022 steelhead detected on PIT tag sites in British Columbia.

Location	Status	Tag Group		
akskʷəkʷant (Inkaneep Creek)		PRD	Other	Total
	Natural-Origin	0	0	0
	Hatchery	0	0	0
	Total	0	0	0
nʕax̌ʷlqaxʷiya (Vaseux Creek)		PRD	Other	Total
	Natural-Origin	0	0	0
	Hatchery	0	1	1
	Total	0	1	1
Shuttleworth Cr		PRD	Other	Total
	Natural-Origin	0	0	0
	Hatchery	0	0	0
	Total	0	0	0
akɬxʷminaʔ (Shingle Creek)		PRD	Other	Total
	Natural-Origin	0	0	0
	Hatchery	0	0	0
	Total	0	0	0
Pentincton Channel		PRD	Other	Total
	Natural-Origin	0	0	0
	Hatchery	0	0	0
	Total	0	0	0
OKC Only		PRD	Other	Total
	Natural-Origin	1	0	1
	Hatchery	0	0	0
	Total	1	0	1

Table 8. Estimated distribution of steelhead spawning in British Columbia based on expanded PIT tag detections from the PRD mark group.

Location	Status	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Avg.
akskʷəkʷant (Inkaneep Creek)	Natural-Origin			1	0	0		2	0	0	0	0
akskʷəkʷant (Inkaneep Creek)	Hatchery			6	1	5		0	0	0	0	2
akskʷəkʷant (Inkaneep Creek)	Total			7	1	5		2	0	0	0	2
Shuttleworth Creek	Natural-Origin		0	0	0	0	0	0	0	0	0	0
Shuttleworth Creek	Hatchery		0	0	0	0	0	0	0	0	0	0
Shuttleworth Creek	Total		0	0	0	0	0	0	0	0	0	0
nʕax̌ʷlqaxʷiya (Vaseux Creek)	Natural-Origin						9	9	19	1	0	8
nʕax̌ʷlqaxʷiya (Vaseux Creek)	Hatchery						0	9	5	7	1	4
nʕax̌ʷlqaxʷiya (Vaseux Creek)	Total						9	18	24	8	1	10
akɬxʷminaʔ (Shingle Creek)	Natural-Origin			0	0	0	0	0	0	0	0	0
akɬxʷminaʔ (Shingle Creek)	Hatchery			0	0	0	0	0	0	0	0	0
akɬxʷminaʔ (Shingle Creek)	Total			0	0	0	0	0	0	0	0	0
Mainstem or Other	Natural-Origin	22	23	64	15	10	0	23	5	0	9	17
Mainstem or Other	Hatchery	2	16	20	14	5	0	14	0	2	0	4
Mainstem or Other	Total	24	39	84	29	15	0	37	5	2	9	24
Subtotal BC	Natural-Origin	22	23	65	15	10	9	34	24	1	9	21
Subtotal BC	Hatchery	2	16	26	15	10	0	23	5	9	1	11
Subtotal BC	Total	24	39	91	30	20	9	57	29	10	10	32

4.0 Discussion

OBMEP monitored adult Viable Salmonid Population (VSP) abundance attributes (McElhany et al. 2000) within the subbasin for Okanogan River summer steelhead. In 2022, it was estimated that 314 summer steelhead (203 hatchery-origin and 111 natural-origin) spawned in the Okanogan subbasin (Figure 42). The total number of spawners is the lowest on the recent period of record (2005-2023). When specifically looking at natural-origin spawners, 2022 was also the lowest on the period of record. The two previous lowest years occurred in 2017 and 2018, with 115 and 120 natural-origin spawners, respectively. Over the past 18 years of monitoring, the average number of adult steelhead spawners in the Okanogan subbasin was 1,360 (geomean = 1,095). The average number of natural-origin spawning steelhead was 269 (geomean = 230). The number of natural-origin steelhead spawning in the Okanogan River subbasin has a fairly level, but slightly declining trend, which remains below the minimum abundance threshold for natural-origin spawners (500 in the US portion of the subbasin) (Figure 43).

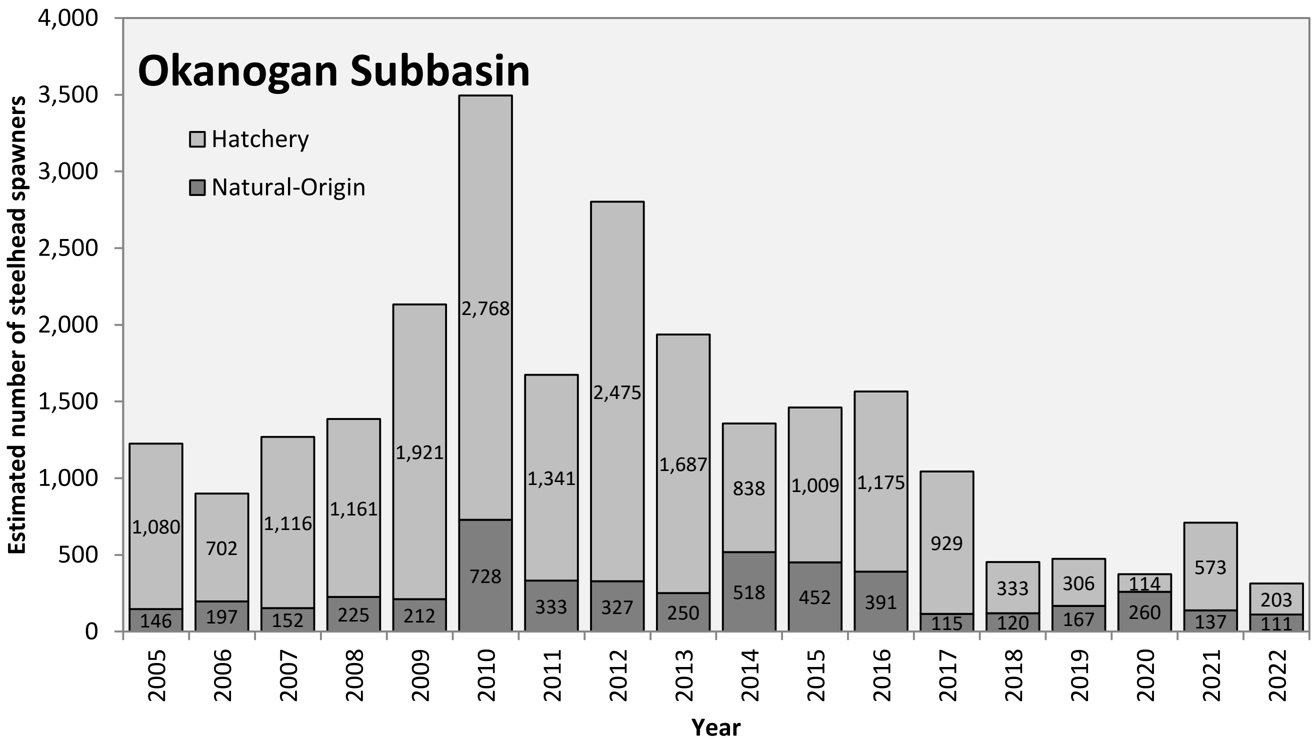

Figure 42. Estimated number of steelhead spawners in the Okanogan subbasin.

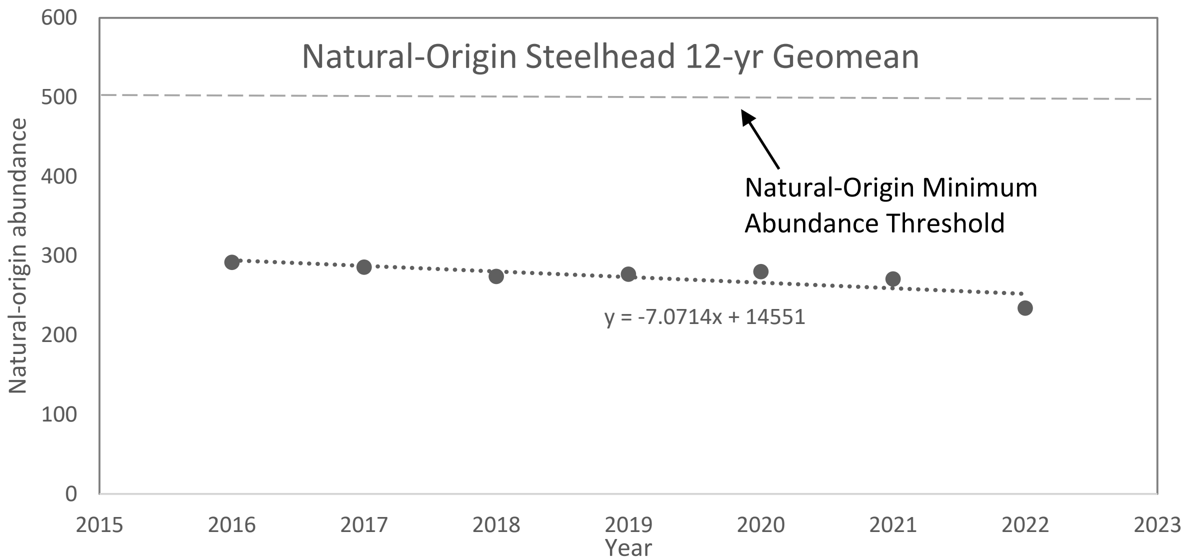

Figure 43. Twelve-year geomean for natural-origin summer steelhead spawners in the Okanogan River subbasin showing the trend (dotted line) and the ESA-recovery objective for the natural-origin minimum abundance thresholds (dashed line).

Spawning has been documented throughout the mainstem Okanogan River, although narrowly focused to distinct areas that contained suitable spawning substrates and water velocities. Steelhead spawning has been observed to be most heavily concentrated below Zosel Dam on the Okanogan River and in braided island sections of the lower Similkameen River. It is likely that distribution of spawning is influenced by stocking location because juvenile hatchery steelhead have been released in the Similkameen River, Omak Creek, and Salmon Creek where large numbers of spawners have been consistently recorded.

Detailed percent-wild information has been provided annually and every attempt has been made to ensure that these estimates are as accurate as stated methods currently allow. However, these data should be used with caution, as it is difficult to define natal origin through visual observation alone (i.e. intact adipose fin) on redd surveys and underwater video. Values presented in this document represent our best estimate from available information, but the variability surrounding point estimates are currently undefined.

Large variations in estimates exist in many reaches from year to year, but often, these accurately reflect real-world situations rather than survey bias or calculation error. Small creeks may have extremely low flows for two years, blocking access with no spawning occurring, and then experience a large run of fish the following year when sufficient flows exist (e.g. Loup Loup Creek escapement of 0, 0, and 125 for 2008, 2009, and 2010, respectively). This irregular nature of small scale population data frequently results in data being scattered loosely around a linear trend line. We have made every effort to ensure that the reported values are as accurate as possible, including using multiple data collection methods for validation, comprehensive on-the-ground surveys, and best scientific judgment based on extensive local experience with the subbasin.

Annual variations in physical habitat and environmental factors can profoundly impact redd distributions in small tributaries to the Okanogan River. Changes in summer steelhead spawning distribution within tributaries appear to be driven by the following four factors: 1) discharge and elevation of the Okanogan River, 2) discharge and turbidity of the tributary streams, 3) timing of runoff in relation to run timing of steelhead, and 4) stocking location of hatchery fish. The first three factors are largely based upon natural environmental conditions, which can be altered dramatically by such things as water releases from dams, irrigation withdrawals, and variations in climate (i.e. fires, snowpack, etc). Years such as 2006, 2008, and 2009 clearly show how low tributary discharge can dramatically alter spawning location and reduce the available tributary habitat for steelhead to utilize.

The overall outcome of adult steelhead monitoring in the Okanogan subbasin is to guide natural resource managers' decisions to minimize threats to steelhead, choose restoration actions that will have the most positive impact, and set measurable steelhead enhancement objectives to coincide with fiscal investments over multiple jurisdictions. As monitoring efforts proceed, the Okanogan Basin Monitoring and Evaluation Program expects to continually deliver practical status and trend monitoring data and to make those data useful and readily available for use in more comprehensive, broad-scale analyses.

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Appendix 1. Mainstem Spawner Calculation Flow Chart

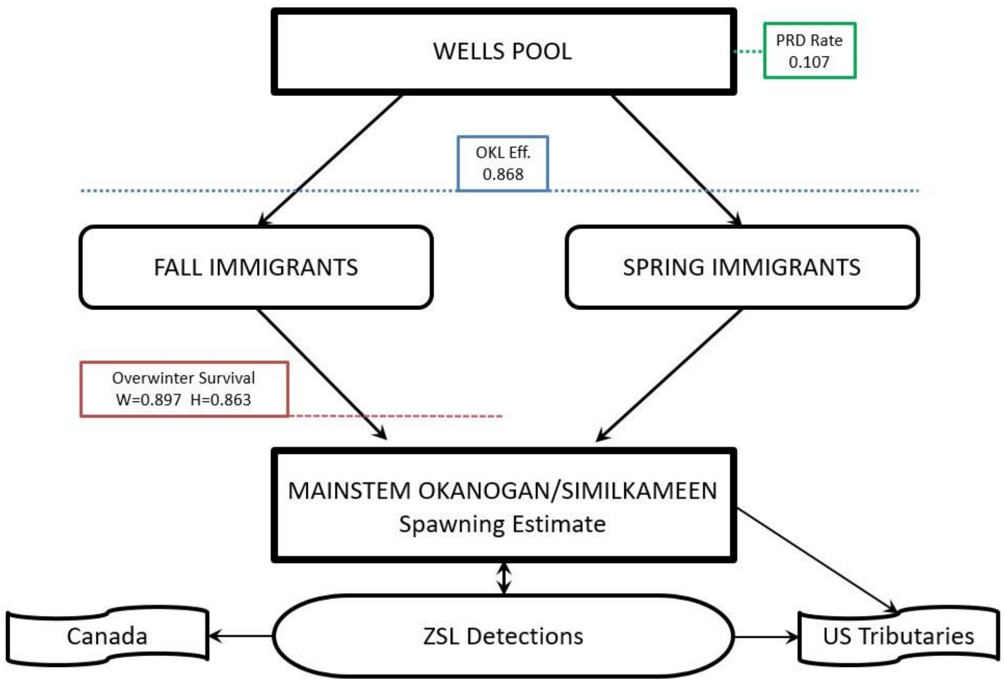

Figure 44. Overwinter survival calculations diagram.