2021

# Columbia River Cold Water Refuge for Salmonids

WASHINGTON DEPARTMENT OF FISH AND WILDLIFE

## Contents

## I. The issue

To minimize their exposure to lethal or near lethal warm temperatures during adult migration, salmonids will temporarily move into areas of cooler water. During their temporary residence in cold-water refuges, these fish may be subjected to recreational harvest (both target and non-target indirect). Therefore, cold-water refuges simultaneously benefit anglers by concentrating fish, while potentially posing conservation risks if angling mortality exceeds harvest constraints. The purpose of this white paper is to provide recommendations for fishery management within cold-water refuges (CWR).

## II. What and where are cold-water refuges?

In the mainstem Columbia River, average August water temperatures are around 22°C (71.6°F; 2011-2016). Many migrating salmon and steelhead move into areas of cooler water for temporary relief, called cold water refuges (CWRs). Refuges are found where cooler tributaries flow into the river (EPA 2021). CWRs from the mouth of the Columbia River to McNary Dam as described by the EPA are identified in Table 1.

In addition to the CWR areas described by EPA (2021) below McNary Dam, additional areas further upstream also function as CWR. In the Snake River, average August water temperatures are between 21-23 °C, with temperatures in September cooling to an average of 19-21 °C (data from USGS station: #13334300-Snake River near Anatone, WA). While similar in temperature, the lower Clearwater River (from Orofino to the mouth) is augmented with cold-water withdrawals from Dworshak reservoir in July and August. Modeled temperature changes expected downstream at Lower Granite Dam (Connor et al., 2003) were typically 1-4°C cooler but could be lower depending on base and augmented flow volumes.

This flow augmentation results in a 30 plus mile portion of the Clearwater River, and a large plume of cool water at the confluence of the Clearwater and Snake rivers, that functions as a CWR for late arriving summer Chinook and sockeye as well as early arriving fall Chinook and summer Steelhead. Because this CWR is so much further upstream it does not harbor as many fish seasonally as the more critical areas downstream. However, without this cold-water area these stocks would encounter lethal temperatures during the hottest portion of the summer which would result in temperature related mortality.

The mainstem pools of the Upper Columbia River (UCR) between Priest Rapids and Chief Joseph dams serve as CWR for migrating adult summer steelhead. Water temperatures in UCR pools tend to be cooler (i.e., less days of ≥20°C) during summer through early fall than Lower Columbia River (LCR) pools. Unlike other CWRs (e.g., Drano Lake at the mouth of the Little White Salmon River and Wind River) where steelhead hold before completing their upstream migration, steelhead using the UCR migrate past (i.e., overshoot) their natal tributaries and reside there for long periods of time (> 4-months). On average, 34% (14-67%) of the natural-origin steelhead counted at Priest Rapids Dam are out-of-basin overshoots from primarily the Snake and Yakima rivers, but also from other mid-Columbia tributaries (personal communication, A. Murdoch, WDFW, 2021). Depending upon the length of stay and upstream migration distance, some steelhead may not reach their natal tributaries to spawn.

*Table 1. The 23 CWR from the mouth of the Columbia River to McNary Dam as identified by the Environmental Protection Agency (EPA 2021). The highlighted tributaries are the 12 primary CWR that constitute 98% of the CWRs in this portion of the Columbia River Basin. For the 12 primary CWRs, pink indicates the tributary is > 4°C cooler than the mainstem, while green indicates the tributary is 2-4°C cooler than the mainstem Columbia River.*

| Tributary Name | River Mile | August Mean Mainstem Temperature (DART) | August Mean Tributary Temperature (NorWeST) | August Mean Temperature Difference | August Mean Tributary Flow (NHD & USGS*) | Plume CWR Volume (> 2°C Δ) | Stream CWR Volume (> 2°C Δ) | Total CWR Volume (> 2°C Δ) |
|---|---|---|---|---|---|---|---|---|
| | | °C | °C | °C | cfs | $m^3$ | $m^3$ | $m^3$ |
| Skamokawa Creek (WA) | 30.9 | 21.3 | 16.2 | -5.1 | 23 | 450 | 1,033 | 1,483 |
| Mill Creek (WA) | 51.3 | 21.3 | 14.5 | -6.8 | 10 | 110 | 446 | 556 |
| Abernethy Creek (WA) | 51.7 | 21.3 | 15.7 | -5.6 | 10 | 81 | 806 | 887 |
| Germany Creek (WA) | 53.6 | 21.3 | 15.4 | -5.9 | 8 | 72 | 446 | 518 |
| **Cowlitz River (WA)** | 65.2 | 21.3 | 16.0 | -5.4 | 3634 | 870,000 | 684,230 | 1,554,230 |
| Kalama River[2] (WA) | 70.5 | 21.3 | 16.3 | -5.0 | 314* | 14,000 | 27,820 | 41,820 |
| **Lewis River (WA)** | 84.4 | 21.3 | 16.6 | -4.8 | 1291* | 120,000 | 493,455 | 613,455 |
| **Sandy River (OR)** | 117.1 | 21.3 | 18.8 | -2.5 | 469 | 9,900 | 22,015 | 31,915 |
| Washougal River[1] (WA) | 117.6 | 21.3 | 19.2 | -2.1 | 107* | 740 | 32,563 | 33,303 |
| Bridal Veil Creek (OR) | 128.9 | 21.3 | 11.7 | -9.6 | 7 | 120 | 0 | 120 |
| Wahkeena Creek (OR) | 131.7 | 21.3 | 13.6 | -7.7 | 15 | 220 | 0 | 220 |
| Oneonta Creek (OR) | 134.3 | 21.3 | 13.1 | -8.2 | 29 | 820 | 54 | 874 |
| **Tanner Creek (OR)** | 140.9 | 21.3 | 11.7 | -9.6 | 38 | 1,300 | 413 | 1,713 |
| **Eagle Creek (OR)** | 142.7 | 21.2 | 15.1 | -6.1 | 72 | 2,100 | 888 | 2,988 |
| Rock Creek[1] (WA) | 146.6 | 21.2 | 17.4 | -3.8 | 47 | 530 | 1,178 | 1,708 |
| **Herman Creek (OR)** | 147.5 | 21.2 | 12.0 | -9.2 | 45 | 168,000 | 1,698 | 169,698 |
| **Wind River (WA)** | 151.1 | 21.2 | 14.5 | -6.7 | 293 | 60,800 | 44,420 | 105,220 |
| **Little White Salmon River (WA)** | 158.7 | 21.2 | 13.3 | -7.9 | 248* | 1,097,000 | 11,661 | 1,108,661 |
| **White Salmon River (WA)** | 164.9 | 21.2 | 15.7 | -5.5 | 715* | 72,000 | 81,529 | 153,529 |
| **Hood River (OR)** | 165.7 | 21.4 | 15.5 | -5.9 | 374 | 28,000 | 0 | 28,000 |
| **Klickitat River (WA)** | 176.8 | 21.4 | 16.4 | -5.0 | 851* | 73,000 | 149,029 | 222,029 |
| **Deschutes River (OR)** | 200.8 | 21.4 | 19.2 | -2.2 | 4772* | 300,000 | 580,124 | 880,124 |
| Umatilla River[1] (OR) | 284.7 | 20.9 | 20.8 | -0.1 | 87* | 0 | 10,473 | 10,473 |

[1] Only provides intermittent cold water refugia; CWR volume represents volume when river is greater than 2°C colder than Columbia River.
[2] Tidally influenced and may be inaccessible during low tides.

## III. Why are CWRs important?

***CWR use by salmonids***

The utilization of CWR by salmonids in the Columbia River largely depends on the migration timing and presence of each species in the Basin. Because summer Chinook and sockeye salmon migrate prior to the warmest water temperatures occurring in the mainstem Columbia River in June and July, they may only use CWRs for a few hours if at all (EPA 2021). Conversely, fall Chinook salmon and summer steelhead make more extensive use of CWRs, as both species have migration times that overlap with the warmest mainstem river water temperatures; about 22°C (71.6°F) in mid-August. Even then, use by fall Chinook salmon is typically for a few days during their migration when the mainstem exceeds 21°C (70°F), while summer steelhead may spend weeks in CWRs, beginning when water temperatures exceed 19°C (66.2°F; EPA 2021). Given this extensive use by summer steelhead, the remainder of this white paper will primarily focus on fishery impacts to summer steelhead in CWRs.

The EPA (2021) developed a method to estimate the number of steelhead in CWRs between Bonneville and The Dalles dams. In brief, the EPA summed daily passage counts of steelhead at these two dams and subtracted steelhead not expected to pass The Dalles Dam due to harvest, straying, and spawning in local tributaries. Based on data from 2007-16, and the relationship of temperature and percentage of steelhead that enter CWRs, the EPA estimated an average of 80,000 steelhead accumulate in the Bonneville reach (Bonneville Dam to The Dalles Dam) in August. Of these, approximately 68,000 (85%) are in CWRs.

Some tributaries below Bonneville discharge sufficient volumes of cold water to function as a CWR. The largest of these tributaries is the Cowlitz River. The cold water from the Cowlitz attracts fish as dip-ins, potentially within the lower ~10 miles of the river, but the bulk of the fish are thought to utilize the cold-water plume in the mainstem Columbia at the mouth. There is angling activity for steelhead in the Cowlitz River and in the mainstem plume but impacts to dip-ins are assumed to be minor. This assumption is based on three observations:

1) **Channel morphology:** the mouth of the Cowlitz River is shallow and continues to silt-in over time. Steelhead dip-ins must navigate a shallow bar that is commonly, in the summer months, less than 2 feet in depth. While not impossible for a fish to navigate, it likely discourages most dip-in fish from moving upstream into the Cowlitz River.

2) **Timing**: the time at which summer steelhead are at their highest prevalence in this area coincides with fall Chinook and early coho run timing. As a result, most of the angling fleet are pursuing salmon in the mainstem plume where incidental steelhead impacts are low (<10% of non-treaty recreational fishing impacts below Bonneville Dam).

3) **Residence duration**: steelhead use this area as CWR but likely tend to have a much shorter residency as compared to Drano Lake or the Wind River resulting in lower potential fishery encounter rates (personal communication; D. Rawding, B. Glaser, C. Donley; WDFW, December 15, 2021).

Within CWRs in the Bonneville pool, the largest percentage (68%) of steelhead are in the Little White Salmon River (Drano Lake) and a significant percentage (≤ 7%) are in Herman Creek, White Salmon River, and the Klickitat River CWR based on 59 radio-tagged steelhead in August 2017. From the summer steelhead population perspective, a large proportion (> 60%) of steelhead populations from the John Day, Umatilla, Grande Ronde, Imnaha, Yakima, Snake, Salmon, Clearwater, and Walla Walla Rivers use CWR, while steelhead populations that mostly migrate through the Lower Columbia River before peak warm temperatures (Tucannon, Hanford, upper Columbia, and Lyons Ferry) use CWRs to a lesser extent (< 50%) (EPA 2021).

Salmonid species that use the augmented CWR in the Clearwater River and confluence area include Snake River summer Chinook, Snake River sockeye, Snake River fall Chinook (early portion of the run) and Snake River steelhead (early portion of the run). Generally, about 90% of the sockeye, and the last half of the summer chinook run cross Lower Granite Dam between July 1 and August 30, respectively. On average, between 5-10% of the Snake River basin steelhead and fall Chinook cross Lower Granite Dam during August, with the peak entering the Snake in September and October.

### ***Benefits to fish of using CWRs***

Reducing the thermal stress on migrating salmonids potentially results in many physiological benefits. These were summarized in a table included in the EPA's 2021 plan, and that table is included here for reference.

*Table 2. Summary of temperature effects to migrating salmonids in the Lower Columbia River (EPA 2021).*

| Temperature Range | Effects |
|---|---|
| Less than 18°C | ☐ Minimal effects to salmon and steelhead |
| 18-20°C | ☐ Elevated disease risk<br>☐ Low proportion of steelhead seek CWR<br>☐ Slight increase in sockeye mortality |
| 20-21°C | ☐ Significant disease risk<br>☐ Increased stress and energy loss<br>☐ Majority of steelhead seek CWR<br>☐ Significant sockeye mortality<br>☐ Low proportion of Chinook seek CWR |
| 21-22°C | ☐ High disease risk<br>☐ High stress and energy loss<br>☐ High percentage of steelhead move into CWR<br>☐ High sockeye mortality<br>☐ Moderate proportion of Chinook seek CWR |
| 22-23°C | ☐ Very high disease risk<br>☐ Very high stress and energy loss<br>☐ Very high percentage of steelhead move into CWR<br>☐ Very high sockeye mortality<br>☐ Significant proportion of Chinook seek CWR |
| 23-24°C | ☐ Very high disease risk<br>☐ Very high stress and energy loss<br>☐ High avoidance behavior for steelhead and all salmon<br>☐ High mortality for steelhead and salmon species |

Some scientific work on the topic of CWRs has been published since the EPA plan was drafted that provides more context on the benefits of CWR to salmonids. Siegel et al. (2021) identified 3 migratory strategies for steelhead: fast (no use of CWR below McNary), slow (weeks to months below McNary), and overwintering (many months). In their analysis, Siegel et al. (2021) found that fast fish (8 days median travel time) had a higher total survival in the reach from Bonneville to McNary dams than slow fish, demonstrating that delay is associated with lower total reach survival. This lower total reach survival for fish that use CWRs was also cited in a few studies in the EPA plan (2021). However, the authors also found that migration delay is associated with lower daily mortality rates.

The authors acknowledged the possibility that fast fish may just be dying further upstream. Another recent study by Snyder et al. (2020) provided more on this possibility with their finding that the modeled loss of CWRs had a substantial effect on steelhead trout migration duration and thermal exposure, perhaps resulting in earlier arrival at natal tributaries, which could be problematic. As our comments on the Draft EPA plan suggested (Rawding, 2019), Snyder et al. (2020), found that simulated cooling of the Columbia River decreased reliance of steelhead on CWRs and resulted in slight reductions in energy expenditure.

The work of Siegel et al. (2021) also suggests that fish origin and age affect migration survival. Their models estimated lower survival for older individuals and for hatchery fish compared to natural-origin fish. One explanation for this result is that the lower survival is a consequence of harvest/handle in the reach. However, estimates of fisheries impact is uneven on populations/stocks, and mortality assessments would benefit from stock-specific exploitation estimates. Another consideration is that hatchery fish may have lower survival because of reduced fitness. For example, Upper Columbia steelhead (as defined by the Federal Endangered Species Act (ESA) listing) were 95% hatchery-origin and had relatively lower survival and less ability to tolerate high temps.

In the long-term, Keefer et al. 2018 cautioned that it remains to be seen if reliance on patchy, cold-water habitats hundreds of kilometers downstream from spawning sites is an evolutionarily sustainable response to river warming. In the long-term, selection for steelhead with higher thermal tolerance, altered migration and spawning phenology, etc., may occur as opposed to delaying migration in CWRs. Though there is variability each year due to snowpack, run-off events, drought, and where the temperature is measured in the mainstem Columbia River, temperatures peak in August (Figure 1).

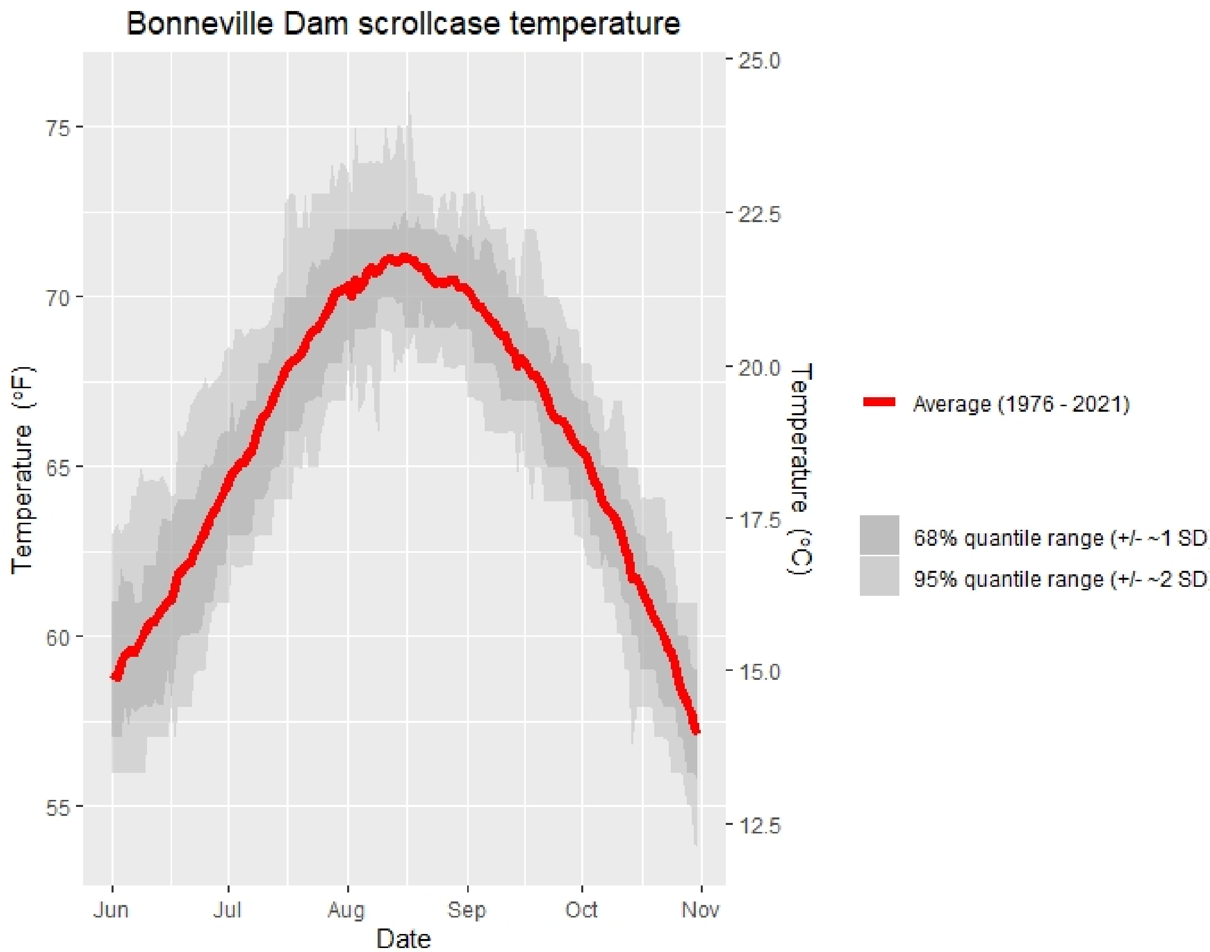


*Figure 1. Average water temperature June – November as measured at the Bonneville Dam scrollcase gauge.*

***Populations/stocks of summer steelhead in the Columbia River***

The summer steelhead run in the Columbia River Basin is made up of populations originating from both lower river and upper river tributaries. Summer steelhead enter the Columbia River primarily from April through October each year, with most of the run entering from late June to mid-September.

The Lower Columbia River (LCR) component includes both natural and hatchery-origin fish but is primarily hatchery produced and derived from Skamania stock. This component tends to be earlier-timed than the upriver stocks with peak return timing from May through June. Summer steelhead caught in mainstem Columbia River mark-selective fisheries downstream of Bonneville Dam during May through June are categorized as lower river Skamania stock (destined for areas downstream of Bonneville Dam; see Table 3).

Upriver summer steelhead include hatchery and natural-origin fish that pass Bonneville Dam from April through October. Fish passing from April 1 through June 30 are categorized as upriver Skamania stock steelhead (Table 3). This stock is primarily hatchery-origin fish destined mainly for tributaries within Bonneville Pool inclusive of the Klickitat River.

Hatchery- and natural-origin steelhead that pass Bonneville Dam during July through October are categorized as either A- or B-Index fish, based on fork length (A-Index < 78 cm; B-index ≥ 78 cm). A-Index steelhead return to tributaries above Bonneville Dam throughout the Columbia and Snake basins (including the Salmon and Clearwater rivers), and usually spend only one year in the ocean. These steelhead return earlier than B-index steelhead, with a 50% aggregate run passage date at Bonneville Dam around mid-August.

B-Index steelhead primarily return to tributaries in the Salmon and Clearwater rivers in Idaho and usually spend two years in the ocean. Their 50% aggregate run passage date at Bonneville Dam is around mid-September. For both A- and B-index steelhead the natural-origin component of the aggregate run tends to be earlier timed, reaching 50% passage at Bonneville Dam 1 to 2 weeks earlier than the aggregate. These two stocks of summer steelhead are the focus of this white paper because they return in the timeframe that overlaps with the warmest temperatures in the mainstem Columbia River. Upriver summer steelhead (A- and B-index) comprise several Distinct Population Segments (DPS's), including the LCR (populations above Bonneville Dam only), Mid-Columbia, Snake River, and Upper Columbia but for the purposes of fishery management, are classified as A- and B-index.

### *The concept of tributary "dip ins"*

Non-local steelhead "dip in" to the lower reaches of some tributaries but subsequently leave to continue their upstream migration. Since these fish are destined for areas further upstream, they are considered part of the upriver steelhead run as a whole and may include stocks from any of the tributaries above Bonneville Dam. These "dip in" areas include Drano Lake at the mouth of the Little White Salmon River, the lower Wind River, the lower Deschutes River (downstream of Shearers Falls), and the John Day River Arm of John Day Reservoir (*U.S. vs. Oregon* Technical Advisory Committee, 2017). Fisheries that occur in these areas are accounted for in the Columbia River mainstem fisheries ESA impacts.

*Table 3. Crosswalk of summer steelhead populations in the Columbia Basin with fishery management stock classifications; AP = acclimation time; MPG = Major Population Group; Ext. = functionally extirpated. Based on NOAA status reviews and Recovery plans.*

| DPS | MPG/Strata | Natural-origin Populations | Hatchery Programs | Stock* |
|---|---|---|---|---|
| Lower Columbia | Coast | None | Beaver Creek | Skamania |
| | Cascade | Kalama, EF Lewis, NF Lewis (ext.), and Washougal rivers (WA) | Kalama River, Cowlitz River, Lewis River, Washougal River, SF Toutle Acclimation site (WA), and Sandy River (OR) | Skamania |
| | Gorge | Wind River (WA), Hood River (OR) | None | Skamania |
| Willamette | | None | Upper Willamette River summer steelhead (OR) | Skamania |
| Middle Columbia | Cascades Eastern Slope | Klickitat River, White Salmon River (WA) | Klickitat River (WA) | Skamania |
| | | Crooked River (ext.), Deschutes River East, Deschutes River West (OR), Rock Creek (WA) | Deschutes River (OR) | A-Index |
| | Yakima Basin | Satus and Toppenish creeks, Naches, and upper Yakima rivers (WA) | None | A-index |
| | John Day | Lower mainstem, North Fork, Middle Fork, South Fork, and Upper mainstem rivers (OR) | None | A-index |
| | Walla Walla/Umatilla | Walla Walla, and Touchet River (WA); Willow Creek (ext.) and Umatilla River (OR) | Touchet (WA) and Umatilla (OR) rivers | A-index |
| Upper Columbia | | Entiat, Wenatchee, Methow, and Okanogan rivers (WA) | Wenatchee River, Okanogan River, Wells Complex (Methow), Winthrop NFH (WA) | A-index |
| Snake River Basin | Lower Snake | Tucannon River, Asotin Creek (WA) | Tucannon River (WA) | A-index |
| | Grande Ronde | Joseph Creek (OR), Lower Grande Ronde (OR/WA), Upper Grande Ronde, and Wallowa rivers (OR) | (Cottonwood AP (WA); Wallowa Hatchery, and Big Canyon AP (OR) | A-index |
| | Imnaha | Imnaha River (OR) | Little Sheep Creek (OR) | A-index |
| | Clearwater | Lolo Creek, SF Clearwater, Lower Clearwater, Lochsa and Selway rivers (ID) | Dworshak NFH, SF Clearwater B-run (ID) | A- and B-index |
| | Salmon | SF Salmon, Secesh, lower and upper MF Salmon, Little Salmon, NF Salmon, Lemhi, Pahsimeroi, and upper mainstem Salmon rivers and Chamberlain Creek (ID) | Salmon River B-run, EF Salmon River Natural (ID) | A- and B-index |

* *US v OR* stock corresponds to natural-origin population.

## IV. What are allowable fishery impacts and relationship to CWR?

***Managing within allowable fishery impacts***

For Federal actions, or actions with a federal nexus, such as the *US v OR* Management Agreement, the allowable impacts for Columbia River fisheries are developed through the *US v OR* parties and determined by NOAA Fisheries through a Biological Opinion. NOAA Fisheries and the U.S. Fish and Wildlife Service (USFWS) are provided with a Biological Assessment of the action to consult on under the ESA. NOAA Fisheries requires a Fishery Management and Evaluation Plan (FMEP), a specific form of a Biological Assessment, for non-federal entities that prosecute a fishery (i.e., the action) that could directly or incidentally impact ESA-listed species. The USFWS often uses this FMEP for their ESA evaluation as well.

The Federal consultation evaluates the action and determines if it exceeds the jeopardy standard, which is to not appreciably reduce the likelihood of survival and recovery of the ESA-listed species being considered. As a result, WDFW, co-managers, and other states, establish fisheries to provide opportunity using the allowable fishery impacts as a ceiling. These rates are consistent with recovery standards and do not pose jeopardy to the species. Additionally, the impact rates in fisheries managed by WDFW and ODFW, have a track record of consistently remaining below the non-treaty impact limits (WDFW and ODFW 2021).

Allowable fishery impacts are established for the Columbia River mainstem fisheries, including the mouths of some tributaries, in the *U.S. vs. Oregon* Management Agreement. This agreement is the product of the *US v OR* parties, which include the states of Oregon, Washington, Idaho, the Nez Perce, Yakama Nation, Umatilla, Warm Springs, and Shoshone Bannock Tribes as well as the United States as represented by NOAA Fisheries and the USFWS. The current agreement was signed in 2018, and is valid for ten years, expiring December of 2027. Columbia River fisheries are not managed based on specific populations but are managed as aggregated stocks (see "Populations/stocks of summer steelhead in the Columbia River"). Population-specific information could provide useful information but is outside the scope of this document and would require support from other agencies.

Allowable fishery impacts for tributary fisheries are often defined in FMEPs and may be synonymous with or reference a co-manager agreement in tributaries where multiple co-managers manage the resource (e.g., Yakima River). The FMEPs may or may not have an expiration date, but for all actions, the Federal agencies maintain the ability to reconsult on actions as needed.

*Table 4. Fishery impact rates on A- and B-index natural-origin steelhead.*

| Fishery Area | A/B-index Fishery Impacts |
|---|---|
| Columbia River (Buoy 10 to Highway 395 at Pasco) | ≤4% for A-index and ≤4% for B-index, with ≤2% during fall and ≤2% during the combined spring/winter/summer management seasons for each stock. Includes "dip-in" impacts accrued in the Wind River mouth and Little White Salmon River mouth (Drano Lake). Run size based on Bonneville Dam. |
| Tributaries from Columbia R. mouth up to (but not including) Cowlitz River | Tributary populations are not ESA-listed; fisheries assumed not to impact A/B stocks |
| Tributaries from Cowlitz River up to (and including) Wind River (WA only) | LCR FMEP: ≤10% each for winter and summer runs (as measured at the tributary mouth), except summer run above Bonn (≤4%). Does not include ESA impacts to A- or B-index steelhead except in "dip in" areas described above. |
| WA Tributaries from Little White Salmon River to confluence with Yakima (WA only, excludes Snake) | Fishery impacts to Cascade East Slope populations estimated to be ≤3.5% in planned/proposed Mid-Col FMEP. Does not include ESA impacts to A- or B-index steelhead except in "dip in" areas described above. |
| Snake River (WA waters) | 5-10% of each MPG based on the Lower Granite Dam return. |
| Upper Columbia & Tributary (Priest Rapids to Wells dams, & Wenatchee, Methow, and Okanogan/Similkameen rivers) | Permanently closed to steelhead fishing by default because natural- and hatchery-origin fish are ESA-listed. When run-sizes are ≥9,550 (≥1,300 natural-origin) total steelhead recreational fisheries may be prosecuted to removed adipose clipped steelhead. Allowable impacts rates range between 2-10% and differ by mainstem/tributary area based on run size. |

Under the *U.S. vs. Oregon* Management Agreement (NMFS 2018), the States of Oregon and/or Washington are authorized to conduct fisheries occurring downstream of Hwy. 395 near Pasco, Washington within an overall allowed impact of ≤2% each for both natural-origin A- and B-Index summer steelhead during the fall season and ≤2% the remainder of the year; B-Index impacts are typically the most constraining for fall fisheries (Table 4).

Most Columbia River summer steelhead that return annually are bound for natal tributaries and hatcheries within the Snake River basin. Recreational fisheries occur in the Snake River and tributaries, which incidentally impact natural-origin Snake River summer steelhead and have separate ESA coverage with Idaho and Oregon (see Table 4).

In the UCR, recreational fishing for steelhead is closed. However, when total returns of steelhead are moderate to high, the WDFW is authorized under ESA-permit for adult management, which allows for the ability to remove adipose clipped hatchery-origin steelhead via dams, traps, weirs, and recreational fisheries (termed conservation fisheries; Table 4). The objective of adult management is to reduce/manage the proportion of hatchery-origin spawners (pHOS) on the spawning grounds. The minimum run-size when conservation fisheries can be prosecuted is 9,550 total steelhead with a minimum of 1,300 being natural-origin fish. Conservation fisheries are prosecuted in real-time when steelhead have mostly or completely migrated past Priest Rapids Dam and through emergency regulations filed by WDFW and announced to the public using WDFW's Fishing Rule Change process.

## V. What are A- and B-index steelhead fishery impacts in WA CWRs?

Recreational fisheries occur in the mainstem Columbia River waters that are included in the EPA CWR plume areas. Fisheries in these plume areas are included as part of the overall mainstem Columba River fishery impacts that are accounted for in the 2018-2027 *U.S. vs. Oregon* Management Agreement. Bonneville Reservoir tributary fisheries that incidentally encounter ESA-listed, "dip in" summer steelhead are also accounted for within the non-treaty impact limits.

*Table 5. Estimated 10-year average fishery impacts* to natural-origin A/B index summer steelhead by non-treaty WA CWR area**. NA = not applicable and denotes no impacts are assumed to occur. ESA impacts for the mainstem, Wind River, and the Little White Salmon River are calculated based on the run to Bonneville Dam.*

| Location | ESA Impacts to A/B-index | Notes |
|---|---|---|
| Columbia Mainstem Below Bonneville | 0.373% A-index<br>0.192% B-index | Includes impacts in WA tributary (e.g., Cowlitz, Lewis) plumes in the mainstem |
| Columbia Mainstem Bonneville to McNary | 0.057% A-index<br>0.039% B-index | Includes impacts in WA tributary plumes in the mainstem |
| Wind River* | 0.004% A-index<br>0.000% B-index | |
| Little White Salmon River* | 0.208% A-index<br>0.256% B-index | |

*10-yr average rates with two exceptions: The absence of the year 2013-2014 in the Snake River, and data for years 2009/2010 to 2015/2015 in the UCR since no steelhead fisheries have occurred since the 2015/2016 season. The plume estimates are a portion of the mainstem Columbia River estimates and combined by geographical reach.
** Non-treaty WA CWR areas include a large proportion of recreational mainstem impacts given the inability to estimate to just the plume level.

Mainstem recreational fisheries in the LCR are sampled from February through October to estimate total effort and catch (including kept and released fish). The creel program began in 1968 and was designed to estimate total effort and catch of salmon and steelhead in bank and boat fisheries by Oregon and Washington anglers below Bonneville Dam. This program, with modification and expansion, has continued through the present. The sampling program estimates the numbers of fish kept and released based on angler interviews. A similar sampling program has been in effect in the mainstem above Bonneville Dam since 2017.

For "dip in" fisheries above Bonneville Dam, catch record cards are used to estimate kept catch. The adipose-clip rates of the kept fish stock are used to estimate the number of fish that are released by dividing the number of kept fish by the adipose-clip rate to estimate total handle; the difference between the number handled and the number kept is the number of fish released.

Below Bonneville Dam, structured creel programs within tributaries do not generally occur; monitoring is opportunistic when funds allow but is not structured to allow us to evaluate stock composition in CWRs (e.g., A- and B-index versus local population).

***Impacts of closing fishing in CWR***

There has been some advocacy for closing steelhead angling (both retention and non-retention), as well as closing all fisheries that impact steelhead in Washington CWRs similar to the approach taken by the Oregon Department of Fish and Wildlife (ODFW) in specific thermal angling sanctuaries. From a conservation standpoint, this management action would result in negligible change to the fishery impacts on steelhead, because the current rate for all fisheries (including 'dip-in impacts') below McNary on A- and B-index steelhead is ≤ 2% in the fall, and ≤2% the remainder of the year.

Because the allowable impacts are so low, there would likewise be a negligible benefit to steelhead populations. Additionally, through consultation on the 2018-2027 *U.S v. Oregon Management Agreement*, the National Marine Fisheries Service concluded through its Biological Opinion that the proposed action (i.e., fisheries detailed in the MA) is not likely to jeopardize the continued existence of LCR steelhead, UWR steelhead, MCR steelhead, UCR steelhead, and Snake River Basin steelhead DPS (NMFS 2018).

Furthermore, without a reduction in the allowable fishery impacts as described above in Table 4, there would be nothing precluding other fisheries from increasing their steelhead impacts until the ceiling was reached, which would relegate closing CWRs to be a measure affecting allocation rather than conservation. Thus, there is likely no change in population status from preventing fishery impacts in CWRs as opposed to other areas of the Columbia River Basin (mainstem, natal tributaries, upriver dip-in fisheries).

In addition, closing fisheries could have a negative impact on those populations that use fisheries as a tool to manage pHOS. For example, in recent years, adult spawner surveys for fall Chinook in the White Salmon and Wind rivers have found substantial numbers of bright Chinook originating from Little White Salmon National Fish Hatchery (LWSNFH). Due to limitations in the number of adult fall Chinook that can be held at LWSNFH, it is sometimes necessary for the facility to close the ladder to ensure that the holding capacity is not exceeded. This action was found to cause increased rates of straying to the White Salmon River of fall Chinook (Engle et al. 2006). Closing Chinook fisheries in Drano Lake (that remove bright hatchery Chinook) to preserve steelhead impacts could exacerbate the number of stray Chinook that enter the Wind and Little White Salmon rivers, potentially leading to reduced bright production at LWSNFH to meet pHOS goals in adjacent rivers.

Lastly, CWRs tend to be popular steelhead and salmon fishery areas during the time of year when steelhead congregate. There have been many years where steelhead abundance supported robust steelhead target fisheries in these areas prior to fall chinook and coho abundance periods. Eliminating fishing opportunity for salmon target fisheries, and when steelhead abundance is sufficient, steelhead target fisheries, would have social, economic, and biological ramifications. Anglers tend to have a vested interest in the resource and are willing to pay license fees, buy fishing gear etc., when opportunities to fish exist. If those opportunities are removed, they may decide to spend their free time pursuing other hobbies. For example, in the highly popular Drano Lake fall Chinook fishery and fall Chinook/early coho fisheries in the CWR areas of the Cowlitz and Lewis rivers during August through October. Full fishery closures in high abundance salmon years would provide negligible biological benefit to steelhead but would be very unpopular with a significant portion of the angling public, reducing the economic benefits in these areas from recreational fishery opportunities and/or shifting their focus to other fisheries.

## VI. How do WA CWR non-treaty fishery impacts compare to total mortality?

Fisheries that impact A- and B-index summer steelhead include the mainstem Columbia River from the mouth upstream to Chief Joseph Dam, Columbia River tributaries above Bonneville Dam, and the Snake River Basin including Washington, Oregon, and Idaho tributaries. Fisheries include non-treaty recreational, non-treaty commercial, treaty mainstem, and treaty tributaries.

### *Non-Treaty Fishery Impacts*

Recreational fisheries for hatchery summer steelhead downstream of Bonneville Dam are comprised of boat and bank anglers, with the proportion of catch varying annually depending on effort and water conditions. Many bank anglers downstream of Bonneville Dam target hatchery steelhead during the late-spring and summer months. Boat anglers in the area between Tongue Point and Bonneville Dam primarily target salmon during the summer and fall, but some fishers do target hatchery steelhead through mid-August, primarily near cool water tributaries. All non-treaty recreational fisheries targeting steelhead are mark-selective and release natural-origin steelhead.

Steelhead impacts in non-treaty commercial fisheries result from fish caught incidentally (and released) while targeting other species; harvest of steelhead has not been allowed in non-treaty commercial fisheries since 1975 (WDFW and ODFW, 2021). Most natural-origin steelhead impacts during the fall season occur in Chinook-directed fisheries due to their larger scale and timing. Coho-directed fisheries occur later in the fall (late September/October) after most summer steelhead have passed Bonneville Dam. Mainstem summer-season non-treaty commercial gillnet fisheries also impact natural-origin summer steelhead, but this fishery hasn't occurred since 2016. Over the last ten years, the impact rates in all non-treaty fisheries have remained below the two percent limit for both A- and B-index steelhead during the fall season (WDFW and ODFW 2021; Table 6).

Recreational angling for summer steelhead begins in earnest in late August around the confluence of the Snake and Clearwater Rivers; this portion of the river attracts the first large number of steelhead because it functions as a CWR. As water temperatures cool in late September, summer steelhead are caught from the mouth of the Snake River to Idaho/Oregon border on the mainstem Snake River and in some key tributaries (e.g., Grande Ronde, Tucannon). The fishery continues through the winter months until mid-April, as the fish slowly migrate to their natal tributaries or destination hatcheries. The summer steelhead fishery in the

Snake basin is unique because anglers have over 6 months to target these fish as they migrate and prepare to spawn.

Summer steelhead fisheries in the Upper Columbia River typically start in September and can extend through March. However, seasons are often shorter based on in-season assessment of ESA impacts on steelhead returns in the fisheries.

*Table 6. Fall season A- and B-Index summer steelhead natural-origin impacts (10-year average) in mainstem Columbia River non-treaty fisheries, 2011-2020. ESA impacts for the mainstem are calculated based on the natural-origin run to Bonneville Dam. In the Snake River, impacts are calculated based on the natural-origin return to Lower Granite Dam, and for the Upper Columbia, impacts are calculated based on the natural-origin return at Rock Island Dam. NA = not applicable.*

| | **A-Index** | | **B-index** | |
|---|---|---|---|---|
| | Run Size | ESA Impacts | Run Size | ESA impacts |
| Non-treaty Mainstem Total | 57,861 | 1.11% | 4,945 | 1.23% Combined with A-index |
| Snake River Mainstem | 19,971 | 1.07% | 2,764 | |
| Upper Columbia mainstem (Priest Rapids to Wells dams) and Tributary (Wenatchee, Methow, and Okanogan/Similkameen) | 4,662 | 1.84% | NA | NA |

Data sources: Run sizes for Bonneville Dam and Snake River, along with mainstem impacts, are from WDFW and ODFW (2021). Snake River impacts were provided by C. Donley, WDFW, and Upper Columbia run size and impact data were provided by C. Jackson.

### *U.S. vs Oregon Fishery impacts*

Th*e U.S. vs. Oregon* Management agreement covers the largest proportion of fishery impacts to stocks in the Columbia River Basin. Table 7 below demonstrates that steelhead impacts in Washington CWR's constitute a small portion of the total fishery impacts allowed in the *U.S. vs Oregon* Management Agreement. Most natural-origin summer steelhead impacts accrued in non-treaty Columbia River fisheries covered by the *U.S. vs Oregon* Management Agreement have typically occurred in recreational fisheries from Bonneville Dam upstream to the Hwy 395 Bridge in Pasco. In the area between Bonneville and McNary dams, substantial angling effort focused on hatchery summer steelhead occurs in and around certain tributary mouths.

*Table 7. Non-treaty ESA Impacts to A- and B-index natural-origin steelhead in WA CWRs compared to total allowable impacts across all fisheries within the US v OR Management Agreement.*

| **Stock** | **Non-Treaty WA CWR* (Avg. 2011-2020)** | **Total Allowable Maximum All Fisheries** |
|---|---|---|
| A-index | <0.642% | 7%** |
| B-index | <0.488% | 24% |

* Non-treaty WA CWR includes a large proportion of recreational mainstem impacts given the inability to estimate to just the plume level; data from Table 5.

** There is no specific harvest rate limit proposed for treaty fisheries on A-Index summer steelhead, but they are expected to remain within recent (2008 – 2016) average rates (0.5 – 3.0%; NMFS 2018).

### *Total Mortality: Asotin Creek Steelhead Case Study*

Based on PIT (Passive Integrated Transponder) tag data from Asotin Creek (Snake Basin) summer steelhead, from 2007 to 2020 the estimated fishery impacts from the commercial and sport fishery below Bonneville Dam were about 1% and ranged from 0.5% to 2.2%. The annual recreational fishery mortality above Bonneville Dam was estimated at about 1% and ranged from 0.5% to 1.3%. The estimated annual mortality in Snake River fisheries were less than 0.5%. Thus, annual cumulative sport fishery related mortality between Bonneville Dam and Lower Granite Dam has been less than 1.5% (Appendix A).

Taking this one step further, the cumulative mortality of Asotin Creek steelhead from Bonneville to Lower Granite Dams estimated from PIT tag data was ~ 30% and ranged from 28% to 36% (Appendix A, Figure 6). However, only about 1.5-4% of that 30% total mortality can be attributed to non-treaty fisheries (including both commercial and recreational in Washington and Oregon). Therefore, greater than 87% of mortality for Asotin Creek steelhead can be attributed to other factors such as passage at hydro system projects, temperature stress, and disease.

## VII. Gaps in our fisheries assessment knowledge

Despite our ability to estimate impacts to A- and B-index summer steelhead and manage those impacts within allowable limits, some uncertainties remain regarding our knowledge of steelhead in CWRs. Improved understanding of these uncertainties may provide for refined management actions that further reduce steelhead impacts within allowable limits, while simultaneously providing meaningful angling opportunities for healthy stocks. Key uncertainties surrounding fisheries in CWRs and steelhead use of CWRs include:

- Do we accumulate impacts at a faster rate in CWRs? If so, is this a question of fishery duration, not steelhead protection?
- How do rates of salmon harvested/natural-origin steelhead impact compare with other fisheries? Are CWRs effectively 'non-Select Areas'?
- Are mortality rate assumptions valid for CWRs: i.e., does warmer water result in higher mortality rates?
- Is there a differential impact on certain populations in CWRs?
- Assessment of night fishery impacts if/when open.
- How does the public perceive steelhead angling, or impacts to steelhead in CWRs? Does a "social acceptability" metric have a place in CWR management? How do we measure and identify appropriate socially acceptable levels? Within a large CWR (such as LWS/Drano) where there is a temperature gradient below 19°C, how do steelhead spatially and temporally distribute?

## VIII. Summary

In summary, our work demonstrates that Washington's recreational fisheries have a small impact on natural-origin A- and B-index steelhead. While we have identified gaps above in assessment of impacts on these stocks, the data we have suggests this impact is small. Appendix A highlights this fact for a case study of the Asotin Creek Steelhead population demonstrating that ~1.5-4% of a total estimated 30% mortality can be attributed to non-treaty fisheries (including both commercial and recreational in Washington and Oregon). Furthermore, when more conservative regulations were adopted to protect steelhead, no noticeable increase in adult Asotin Creek steelhead survival was measured compared to less conservative regulations. As mentioned previously, this lack of a noticeable increase may be due to the reality that without a reduction in the allowable fishery impacts, there would be nothing precluding other fisheries from managing within their allowable steelhead impacts.

As indicated in our comments to the U.S. EPA (Rawding 2019), the greatest threat to Columbia River salmon and steelhead populations is the increase in mainstem Columbia River water temperatures due to operation of the hydro-electric facilities, degradation of mainstem and tributary habitat that leads to increases in water temperature and predicted increases in mainstem and CWR temperatures due to climate change. This is not to say that more management and fisheries assessment actions will not be considered as needed to protect steelhead, but we do want to emphasize the need for addressing the larger problem, and not merely focusing on a symptom of the larger problem.

## IX. Recommendations

The information shared in this document demonstrates that impacts to A- and B-index steelhead from non-treaty recreational fisheries in CWRs are small (< 1%). As a result, attempts to reduce this impact further will not result in meaningful conservation gains for A- and B-index steelhead, especially if impacts are transferred to other fisheries (either directly or indirectly).

However, we acknowledge that we have some data gaps and thus a precautionary approach to steelhead management throughout the basin has been taken in recent years of low abundance, especially when temperatures are higher than normal. The recommendations provided here support a precautionary approach to steelhead fisheries management throughout the basin that provides more certainty we will be able to remain within the fishery impact limits outlined in our various Management agreements.

### *Fisheries Assessment (additional funding would be needed)*

- Evaluate current creel methods to improve estimation of impacts and effort (e.g., mainstem dip-ins)
- Pursue and support additional PIT tag arrays at key basin sites
- Parental Based Tagging (PBT) of steelhead sampled during creel for stock composition

### *Fisheries Management*

Our recommendations for implementing the precautionary approach to steelhead fisheries management in the Columbia Basin are:

- Closing night fishing in areas that remain open to salmon/steelhead due to lack of effective monitoring/enforcement
- Continuing and encouraging, a consistent, coordinated approach for basin wide regulations based on annual fish abundance and conservation need

To implement this latter recommendation, we have developed the table below (Table 8) that suggests management tools that could be used to reduce impacts to steelhead under several abundance and temperature scenarios. In years of higher abundance and average temperature, we suggest no additional impact restrictions would be needed (above average viability). Conversely, in years where temperatures are higher than average and/or abundance is moderate to low (reduced and lower viability), we include a suite of management tools for limiting impacts below even the allowable limits to achieve a precautionary approach to management. However, it should be recognized that there is no one-size-fits-all approach to steelhead fisheries management, and these tools can and should be tailored based on the specific needs for each area. For example, with reduced viability, perhaps portions of the mainstem are closed to steelhead angling based on factors of each fishery such as angler trips, steelhead timing through that area, etc., but when viability is lower, that tool is expanded to include all the Columbia River mainstem. It should also be noted that any actions in the Columbia River need concurrence with ODFW.

We also recognize that Table 8 presents a qualitative approach to fisheries management. We believe this is a logical first step, but also are interested in continuing work on this concept to derive quantitative values for the temperature and abundance parameters in the table. More time would be needed to achieve this objective, and may necessitate additional research, particularly on steelhead stock composition in various areas.

*Table 8. Columbia River menu of management tools used in the recent past to manage our fisheries based on two criteria: temperature and natural-origin A- and B-index steelhead abundance. Impact rates are based on A-index fish during the fall season period (>July) since this management group is most impacted by warm water temperatures and has exhibited high CWR use.*

| | Average Temperature | Higher Temperature |
|---|---|---|
| **High abundance** | **Above Average Viability**<br>No additional impact restrictions = Max allowable opportunity<br>Daily limit = 2 hatchery fish | **Above Average Viability**<br>No additional impact restrictions = Max allowable opportunity<br>Daily limit = 2 hatchery fish |
| **Moderate abundance** | **Above Average Viability**<br>No additional impact restrictions = Max allowable opportunity<br>Daily limit = 2 hatchery fish | **Reduced Viability**<br>< allowable impacts = Reduced opportunity<br>**Actions may vary by area and include:**<br>• Reduced daily hatchery limits (≤2 fish)<br>• Steelhead angling closures<br>• Prohibiting fishing from a floating device<br>• Tributary selective gear rules |
| **Low abundance** | **Reduced Viability**<br>< allowable impacts = Reduced opportunity<br>**Actions may vary by area and include:**<br>• Reduced daily hatchery limits (≤2 fish)<br>• Steelhead angling closures<br>• Prohibiting fishing from a floating device<br>• Tributary selective gear rules | **Lower Viability**<br><< allowable impacts = Very limited opportunity<br>**Actions may vary by area and include:**<br>• Reduced daily hatchery limits (≤1)<br>• Steelhead angling closures<br>• Prohibiting fishing from a floating device<br>• Tributary selective gear rules |

*2*

## X. Appendix A (Rawding, 2021)

### *Freshwater Survival of Columbia River Adult Summer Steelhead: A Case Study of Asotin Creek*

Adult summer steelhead enter freshwater months before spawning and mortality occurs before they reach their natal spawning areas. Mortalities may be natural or human induced. For example, natural origin steelhead are subject to release mortality when caught and released in non-retention (i.e., mark selective) sport and commercial fisheries. Other sources of human induced mortality include operation of dams on the mainstem Columbia River that create upstream passage delays and increased exposure to warm water temperatures in fish ladders and reservoirs. Funding of passive integrated transponder (PIT) tagging, and detection programs at mainstem dams, allows freshwater mortality of adult summer steelhead to be estimated.

To illustrate the mortality impacts on natural-origin summer steelhead, PIT tag adult steelhead data from Asotin Creek that migrated past Columbia and Snake River dams from return year 2007 to the present were collected and analyzed (Rawding 2021). Asotin Creek enters the Snake River just upstream of Clarkston, WA. Since peak passage timing at Bonneville Dam (BON) occurs in the middle of the summer, these steelhead are assumed to frequent CWRs and represent other Group A index steelhead populations in behavior and survival. The Asotin PIT tag data were analyzed using a Cormack-Jolly-Seber model to estimate the probability of survival between PIT tag detection sites (i.e., dams). Through 2014 adult detection was limited to BON, McNary (MCN), Ice Harbor (IHR), and Lower Granite (LGR) dams. The Dalles (TDA), Lower Monumental (LMN), and Little Goose (LGS) dam detections sites were added in 2015 with John Day (JDA) added in 2018.

Based on the data available, between dam survival for all reservoirs was examined from 2015 onwards. The probability that a fish passing a dam was detected was ~ 98% except ~ 92% at TDA. The probability that a fish survived was variable and was ~ 85% between BON and TDA, ~ 95% in the TDA, JDA, and MCN reservoirs, and ~ 97% in the Snake River reservoirs Figure 4. Using the full data set, from 2007 onward, the survival from BON to MCN was ~ 80%, and was ~ 88% from MCN to LWG. The cumulative survival from BON to LWG was ~ 70% and varied annually from 64% to 72% (Figure 5).

### *Relative Scale of Recreational Fishing Mortality to Total Mortality*

The fishery release mortality from the Columbia River mouth to HWY 395 from recreational and commercial fisheries for natural origin Group A steelhead, of which Asotin Creek is a part, is limited to 2% in the Columbia and dip-in tributaries in spring/summer fishery and an additional 2% during the fall period. Fishery mortality estimates for 2020 and 2021 are preliminary and were extrapolated from the time series.

From 2007 to 2020 the estimated fishery impacts from the commercial and sport fishery below BON were ~ 1% and ranged from 0.5% to 2.2%. The annual recreational fishery mortality above BON were estimated at ~ 1% and ranged from 0.5% to 1.3%. The estimated annual mortality in Snake River fisheries were less than 0.5%. Thus, the annual cumulative sport fishery related mortality between BON and LWG were less than 1.5%.

Figure 4 illustrates the cumulative mortality on adult Asotin steelhead as they migrate upstream from BON to LWG. This figure was developed to illustrate the relative impact of mainstem and tributary non-treaty fisheries on conversion of adult steelhead from BON to LWG. During the exceptionally poor return years beginning in 2017, Washington and Oregon applied conservative fishing rules to the steelhead fisheries in the mainstem and tributaries to ensure that both hatchery brood and natural- origin fish safely returned to their natal tributaries. The hypothesis was that closing these fisheries would decrease mortality and result in higher conversion rates of steelhead through the basin and ultimately to the spawning grounds.

However, closing recreational fisheries between BON and LWG in Washington and Oregon added only a small survival benefit to Asotin steelhead (Figure 4). Since mortality is equal to 1, the cumulative mortality from BON to LWG estimated from the PIT tag data was ~ 30% and ranged from 28% to 36% (Figure 5). The above BON sport fishery related mortality comprised a small portion (~1%) of the total cumulative mortality (~30%).

In conclusion, in all years tested, approximately 1.5% to 4% of the basin wide mortality that occurred across the run can be explained by the impacts of non-treaty recreational and commercial fisheries. Related to recreational fishing, comparing years with standard fishery rules (2007-2016) to years with conservative rules (2017-2021) there is almost no statistical difference in mortality. Indicating that adjusting our recreational fishery rules has only a minor impact on reducing adult steelhead mortality and that other sources of mortality comprise most of the 30% loss of adult fish from BON to LWG.

### ***Acknowledgements***

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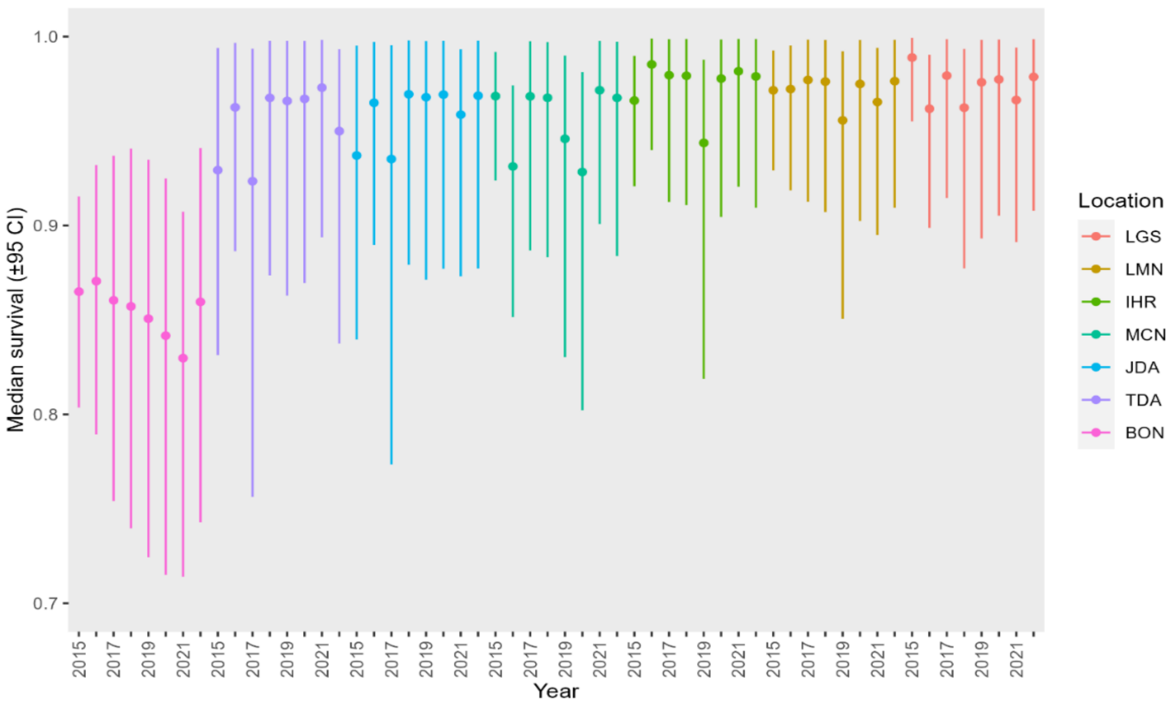


*Figure 3. Estimated survival of natural-origin Asotin Creek summer steelhead from PIT tag data in Columbia and Snake River reservoirs.*

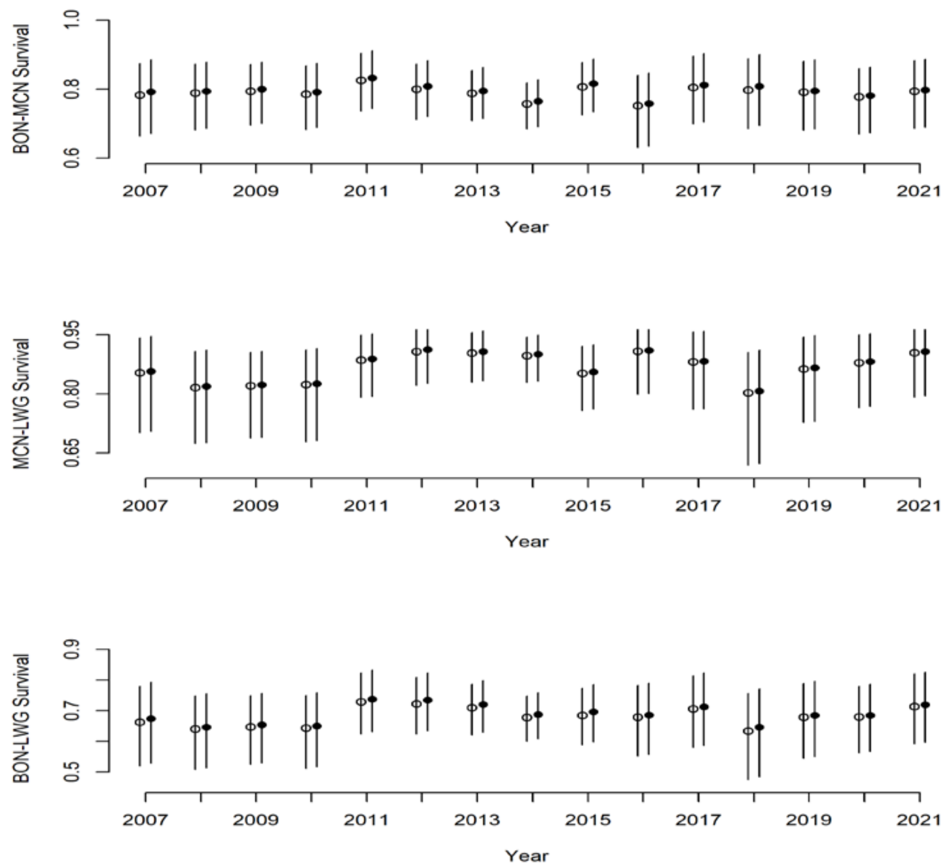


*Figure 4. Estimated survival of natural-origin Asotin summer steelhead from PIT tag data. Open circles are current survival estimates and closed circles are the estimated survival estimates without recreational fisheries between Bonneville to Lower Granite dams. Vertical lines are the 95% CI.*

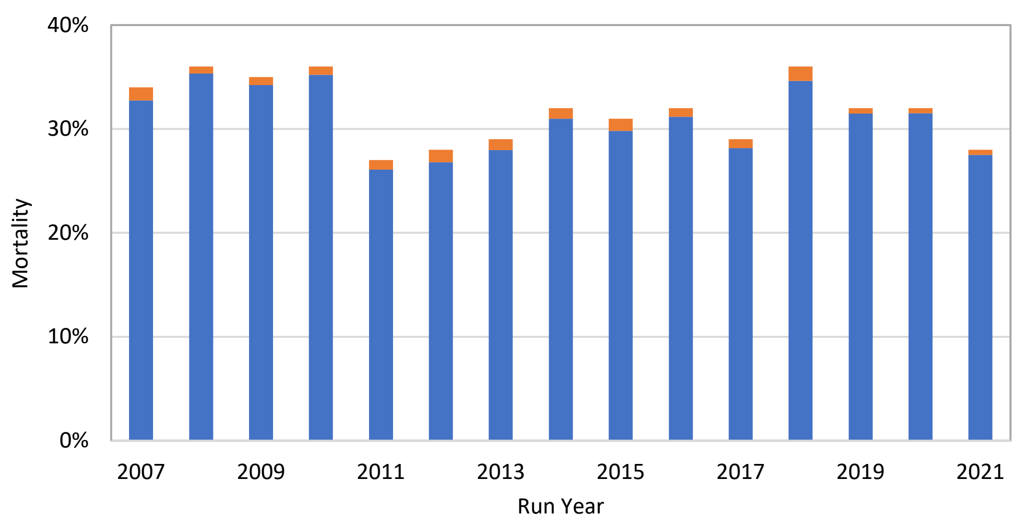


*Figure 5. Mortality of natural-origin adult Asotin Creek summer steelhead estimated from PIT tag data from Bonneville to Lower Granite dams partitioned into recreational fishery (orange portion of bar) and other sources of mortality (blue portion of bar).*

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