The 2009-2023 NMFS methodology of estimating adult upstream survival (or conversion rates) through the Columbia River System

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Background

Initial estimates of adult upstream survival (also termed conversion rates) using passive integrated transponder (PIT) tags were undertaken by Charlie Paulsen (Paulsen Environmental Research), a statistician who worked as a contractor for Bonneville Power Administration (BPA) in the early 2000's. NOAA took over the process in 2008. The primary means of reporting has been a spreadsheet that calculates and reports adult upstream survival from 2002 to the present. This spreadsheet has been shared with BPA and the US Army Corps of Engineers (COE) for their annual reporting requirements and other parties upon request. The survival and conversion rate estimates have appeared on NOAA websites and on the Northwest Power and Conservation Council's website as Strategy Performance Indicators, mostly as graphs.

The spreadsheet was developed to meet reporting and analysis requirements for the various Columbia River System (CRS) Biological Opinions (BiOps; NOAA WCRO 2024) and used by other agencies as well in their annual reports. Survival estimates were generated and reported for the Bonneville (BON) to McNary (MCN), McNary to Lower Granite (LGR) and BON to LGR reaches. Two estimates were reported for each Evolutionarily Significant Unit (ESU) or Distinct Population Segment (DPS), one for fish that migrated in-river as adults and one for fish that were transported during the juvenile life stage as results. No distinctions were made between hatchery and wild fish.

One of the reasons that the survival was not subdivided into smaller reaches in the original reporting format was that not all dams had PIT tag detection in the adult ladders. As more PIT tag detectors came online NMFS calculated shorter reach survivals, though the official reporting remained at the BON to MCN, MCN to LGR and BON to LGR reach levels. With the installation of a detector in the JDA fish ladder in 2018, all reaches of the CRS can be directly estimated. These shorter reach and project level estimates have been used for various analyses and to resolve with greater detail, where losses of fish were occurring in the CRS. Shorter reach estimates also appeared in some of the later CRS BiOps (NOAA WCRO 2024).

Methodology

Due to the high detection efficiencies (approx. 97-100%) of PIT tag detectors in adult ladders, a simple binomial method, as a simple division (Eq. 1), was used to estimate reach survival. The most likely reason a PIT tagged fish would not be detected at a dam include tag collision, where two fish pass through a detector simultaneously. Passage via navigation locks has also been suggested, with some anecdotal evidence to support it. In any case, detections of fish at an upstream dam, which was not detected at the downstream dam, is extremely rare. So with properly maintained equipment, significant changes in survival indicated by these analyses are unlikely to be due to detection failures or passage by alternate routes which lack detectors.

$$\boldsymbol{survival\ estimate} = \frac{\boldsymbol{upstream\ dam\ detections}}{\boldsymbol{downstream\ dam\ detections}} \qquad \text{(Eq. 1)}$$

Eq. 1 was used to calculate all conversion and survival estimates. Though the estimate produced is actually $Survival \times Detection\ efficiency$. Since the detection efficiency is so close to 1 it was decided this method was sufficient for our purposes. It also had the advantage of being transparent and accessible. These factors of transparency and access are very important when estimates are used for management decisions in a frequently contentious process.

The PIT tag detections at all adult ladders in the CRS for a particular migration year were downloaded from the PTAGIS website (https://www.ptagis.org/; PSMFC 2024) and entered into a Microsoft (MS) Access database. This database used MS Access queries to filter data, and track detections by PIT tag code at each dam. Thus the numbers of PIT tags at each dam represent a true tracking of individual PIT tags between dams rather than just a general count of PIT tags detected at each dam. Databases were also used to examine other information including travel time. PIT tag counts for BON, MCN and LGR were then entered into the Excel spreadsheet for further analysis.

In the spreadsheet basic reach survival estimates were calculated using the upstream/downstream method described (Eq. 1). These reach estimates were corrected for harvest for each reach and straying in each reach. Harvest corrections were based on harvest rates reported in the annual Joint Staff Report produced by Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife (ODFW and WDFW 2024a,b). Harvest corrections are calculated separately for the BON to MCN and MCN to LGR reaches. The harvest correction is calculated as:

$$\boldsymbol{Reach\ survival\ estimate\ corrected\ for\ harvest} = \frac{\boldsymbol{Reach\ survival}}{\boldsymbol{1 - harvest\ rate}} \qquad \text{(Eq. 2)}$$

The same harvest rate correction is applied to survival estimates for both transported and in-river fish.

Straying is corrected for by applying a fixed estimate of straying based on those estimated in Keefer et al. (2005). The calculation takes the same form as that applied to the harvest correction:

$$\boldsymbol{Reach\ survival\ estimate\ corrected\ for\ straying} = \frac{\boldsymbol{Reach\ survival}}{\boldsymbol{1 - stray\ rate}} \qquad \text{(Eq. 3)}$$

The same straying rate is applied to transported and in-river fish. The study (Keefer et al. 2005) that the straying rate was based on did not include separate estimates for fish that were transported as smolts or migrated in-river.

The estimate for the BON to LGR, BON to MCN and MCN to LGR reaches are calculated, respectively, as:

$$BON\ to\ LGR\ survival\ estimate\ corrected\ for\ harvest\ and\ straying\ = \qquad \text{(Eq. 4)}$$

$$= \frac{\frac{LGR\ tag\ count}{BON\ tag\ count}}{(1-BON\ to\ MCN\ harvest\ rate)(1-MCN\ to\ LGR\ harvest\ rate)(1-stray\ rate)}$$

$$BON\ to\ MCN\ survival\ estimate\ corrected\ for\ harvest\ and\ straying\ = \qquad \text{(Eq. 5)}$$

$$= \frac{\frac{MCN\ tag\ count}{BON\ tag\ count}}{(1-BON\ to\ MCN\ harvest\ rate)(1-stray\ rate)}$$

$$MCN\ to\ LGR\ survival\ estimate\ corrected\ for\ harvest\ and\ straying\ = \qquad \text{(Eq. 6)}$$

$$= \frac{BON\ to\ LGR\ survival\ estimate\ corrected\ for\ harvest\ and\ straying}{BON\ to\ MCN\ survival\ estimate\ corrected\ for\ harvest\ and\ straying}$$

There are other columns in the spreadsheet that produce a per project survival estimate for the reaches by taking the nth root (n = number of projects in reach) of the reach survival. This methodology is now obsolete as reach survivals can be directly calculated for each project in the CRS. Direct calculations have also indicated that mortality is not evenly distributed across reaches. Other columns convert survival to mortality.

This methodology is simple and straightforward, but far more information can be derived from the data that is available. Changes to the methodology were avoided to maintain comparability between years (though it would be relatively simple to recalculate all years with any new method) and because reporting requirements remained as the BON to MCN, MCN to LGR and BON to LGR reaches.

Selection of data to be used in the analysis

Selection of the tags to be used in analysis and how to assign them to a particular group faced two competing factors, the need to use tags from fish which were representative of the ESU/DPS, and the need to have sufficient tags to make a precise estimate of survival.

Since fish used in adult survival analysis were generally tagged as juveniles for other projects, populations are almost certain to be over-represented or under-represented in the pool of tags available for an ESU or DPS. Thus, there is always some degree of surrogacy in the analysis. In interpreting results, it should be remembered that there may be factors that may result in the actual survival of a particular population being significantly different than the survival for the population as a whole.

A protocol of a minimum of 40 detections at Bonneville was established to control the precision of the estimates. In survival estimates, confidence intervals decrease as more fish are included in the sample and increase at lower survival rates. The confidence interval for a sample of 40 fish with a 50% survival rate would be 33.8-66.2% based on the methodology of Clopper and Pearson (1934). In practice, with the exception of Snake River Sockeye described below, the 40 fish minimum was well exceeded almost every year for the ESU/DPS that survival estimates were calculated for. Calculating a confidence interval for the corrected survival estimate is somewhat problematic due to the nature of the straying and harvest estimates. Confidence intervals or other measures of precision were generally not included in BiOps or other reports.

Survival estimates for all 7 ESU/DPS that passed through the CRS were calculated for each year. In the case of Upper Columbia, ESU/DPS survivals were only calculated for the BON-MCN reach.

Only adults which were PIT tagged as juveniles, and thus had a known origin, were used for analysis. Fish were assigned to ESU based on the geographical location of their release point. Large numbers of adults are tagged annually at the Bonneville Adult Fish Facility (BONAFF) and sometimes other research projects. However, without knowing their true origin, the assumption that they will continue to the end of the reach is violated because their natal stream may lie within the reach. Snake River (SR) ESU/DPS populations originating below LGR were excluded from analysis of survival for SR ESU/DPS to avoid issues with turnoff error. Turnoff error in this sort of survival analysis is when you include fish whose natal stream is downstream of the final dam of the reach. Unlisted Chinook and Steelhead originating from the Clearwater Basin were included in survival estimates for SR ESU/DPS because their run timing was similar.

The Mid-Columbia Steelhead DPS was more problematic because its populations are distributed along the BON to MCN reach and so have differing levels of exposure to the effects of the CRS. The estimate for Mid-Columbia Steelhead was based on the BON to MCN reach survival for Yakima and Walla Walla steelhead populations. This was chosen because it represents a “worst case” scenario, which errs on the cautious side and thus preferred when estimating negative effects on listed species under the ESA. A more accurate method would be to calculate the survivals of each population based on the reach survival of the reaches they actually traversed and then weighting the survivals by the proportion of the total DPS each population represents and then combining them to make a survival estimate for the entire DPS. However, there was insufficient data available to take this approach. Not every population had the minimum of 40 PIT tagged fish for a survival estimate of sufficient precision. Until relatively recently not all dams were equipped with PIT tag detections so not all reaches could be separated. There are also difficulties with finding the population proportions within the DPS for each year which would be required to do a weighted approach to total DPS survival. Essentially the Yakima and Walla Walla populations were surrogates for the rest of the populations in the DPS, and had the longest exposure to the CRS so would suffer the maximum effect. The actual difference in survivals between these populations and the downstream populations is probably small. The average estimated BON to MCN survival corrected for harvest and straying for 2010-2023 using Yakima and Walla Walla populations was 96.9%. The major mortality factor on these populations is harvest, most of which occurs in the Bonneville and The Dalles pools.

For species other than Steelhead, all detections within the calendar year of interest were used. For Chinook ESU which are separated by run (SR Spring/Summer Chinook, etc.) all tags that were identified as originating from a location with ESU boundaries, and of the specific run listed were assigned to that

ESU and used in the analysis. Thus the analyses may have included fish identified as Spring/Summer Chinook which were detected at BON in September, or Fall Chinook detected at BON in May.

All of the listed Steelhead which traverse the CRS are "Summer steelhead", that is they arrive at BON mostly from June to September, but do not spawn until March-June of the following year. Thus it is possible for detections of a Steelhead in the CRS to span two calendar years. In the case of Upper Columbia this was not a problem as they tend to pass through the BON to MCN reach relatively quickly. In contrast, a significant (10-20%) proportion of Snake River Steelhead may arrive in Summer, but remain in the BON to MCN reach until the following spring when they rapidly move upstream. This has been known from fish counts from a number of years, with a springtime pulse of steelhead passage observed at dams where there are only Summer Steelhead present. PIT tag detections confirm this behavior. Thus, for SR Steelhead DPS the survival for a return year is calculated from June 1 in one year to May 30 of the following year. This cutoff date was based on examining patterns of fish passage and the information that some high elevation populations of SR steelhead spawn in June, so fish moving as late as May can still arrive in time for spawning. In assigning survival to a particular year, the convention of Spawn year-1 was used. That is, for the fish that passed BON in July 2009 and is expected to spawn in April 2010, they are assigned to the 2009 year class. Harvest estimates for the year the fish entered the CRS (2009 in the example above) are used for the entire year class when making survival corrections for harvest. Most harvest is likely to occur during the main migration period, but fish remaining in the CRS through the winter and early spring are subject to additional harvest exposure. The true harvest rate that the entire DPS is exposed to would be very difficult to calculate, so the harvest rate in the year the steelhead pass BON is used. This is likely to be a slight underestimate of total harvest for this ESU, which should be considered when interpreting survival estimates corrected for harvest.

As noted before, since tags are highly unlikely to be distributed evenly across an ESU, there is always some degree of surrogacy in estimates. In the case of SR Sockeye, unlisted Upper Columbia Sockeye have been used for surrogates in a number of years (noted on spreadsheet) because less than 40 tags were detected at Bonneville. Before 2009, Unlisted Upper Columbia Sockeye (originating from Wenatchee and Okanagan lakes) were used to provide an estimate of survival for SR Sockeye. In 2018-2020 UC Sockeye and SR Sockeye were combined to provide a survival estimate because of low SR Sockeye returns related to difficulties with hatcheries in Idaho. These surrogate estimates only provide an estimate for the BON to MCN reach. Since UC Sockeye have earlier run timing, a significant number pass through the CRS before the Summer Chinook harvest openings, so UC sockeye tend to have higher survival rates through the BON to MCN reach. So, using them as a surrogate for SR Sockeye will likely result in overestimates of reach survival.

At any level of analysis, a population smaller than ESU/DPS is very likely to require surrogates to be used to provide survival estimates with acceptable levels of precision (minimum 40 tags). As long as assumptions that the fish will behave in a similar manner to the target population and they are present in the reaches of interest during the same time as the group of interest, it should provide an acceptable methodology. Using the same species, but from a different ESU is a good approach to meet these assumptions.

However, the individual experiences of a particular subgroup may have an effect as well. Fish which were captured and tagged at the Bonneville Adult Fish Facility show a higher survival through the BON to MCN reach than those tagged as juveniles (and not captured at the facility) passing through the reach. There could be some sort of sampling bias in effect related to the selection parameters for tagging fish at the facility, but there is also the possibility that the experience of being captured, handled and tagged makes the fish more wary and thus likely to be captured by a gill net. In either case, use of BONAFF fish in a survival estimate would inflate the survival estimate of fish passing through the BON to MCN reach.

Quality control and Filtering Data

After collecting the initial tag data and assigning it to an ESU/DPS, further filtering is required. Typical estimates of adult survival do not include jacks (age 1-ocean and presumed 3-year-olds) or precocial fish (return upstream in the same year that they migrated downstream; age 0-ocean and presumed 2-year-olds). This is primarily an issue for Chinook salmon. Both jacks and precocial fish have significantly different survival rates through the CRS than older fish (age $\geq$2-ocean). In the case of jacks, they generally have a higher rate of survival especially through the BON to MCN reach. This is probably due to the size selectivity of gillnet harvest. Precocial fish generally have much lower survival rates than older fish, possibly due to predation, or not having sufficient energy reserves for the migration. The decision of what ages of fish to include in the analysis is based on the reporting requirements and maintaining consistency for between year comparisons. Due to the size selectivity of gill net harvest which is the primary means of harvest in the BON to MCN reach (Zone 6), there also appear to be differences in survival between year classes of older fish as well. Although, if one assumes that tags are proportionately divided among the year class, the pooled survival will provide an accurate estimate.

One of the hazards of the data mining approach used for adult survival estimates is the potential that the fish may have been tagged by a study that affects their BON to MCN survival in some way that makes them not representative of the population. Unless it is known that this is true of a particular group of fish, either through previous analyses or something that can be determined from the metadata included in PTAGIS, it is generally assumed that the negative effects of most studies will have resulted in the death of the fish in 2-4 years in the ocean. Given the high mortality experienced in the ocean (approx. 95-99.5%), this seems like a reasonable assumption, but there is always the chance of some bias. The risk of bias from this source is also related to the total number of tags in the analysis, and should be more seriously considered (and is easier to identify) when a relatively small number of tags is available for the analysis.

In the methodology used to do the actual analysis of survival, employing MS Access databases, duplicate detections of tags can be very problematic. BON detections present a problem from the beginning because of its adult fish ladder layout. There are 4 separate observation sites in PTAGIS for the fish ladders, and their arrangement means that fish may be detected at 1-2 sites, even if they pass the ladder in one trip. For survival analysis the most important information is that they were detected at least once at the observation site, so a query or filter that selects only the first or last observation is sufficient. Other dams in the BON to MCN reach have two ladders which are listed as separate observation sites by PTAGIS, once again employing a query or filter strategy that chooses only the first or last observation for the entire dam will be sufficient for survival analysis. However, the cause of multiple observations at dams other than BON is likely to be due to fallback and re-ascension of the fish ladder.

In terms of determining the survival estimates, fallbacks are mostly significant in how they can potentially cause error (typically double counting a fish). Using a methodology that matches tags across dams rather than a simple count of tags detected at the dam can help avoid this. Some species, such as sockeye, tend to have high fallback rates and may re-ascend the ladder multiple times. This can lead to very confusing results if a simple tally of detections is used. Fish falling back over dams is a matter of concern for fish managers (though it is typically only weakly related to a particular dam's operations) and there are various strategies that can be used as part of the survival analysis to identify fallbacks, delay time, etc. These are beyond the intended scope of this paper so I will not discuss them further here. I typically use an "interrogation summary" query to extract data from PTAGIS for analysis, it includes one result per PIT tag for each observation site with a first and last observation (summarizes observations from multiple antennas) date and time. If you wish to try to determine a more detailed picture of the fish's behavior within the ladder, you can use an "interrogation detail" query which will report every observation at every antenna within an observation site. This may result in a very large amount of data though, because some sites have multiple antennas, as well as fish being detected multiple times at the same antenna.

<u>**Workflow**</u>

My workflow has changed over the years, generally in the direction of becoming more efficient.

1. Download Data from PTAGIS database. Use an "Interrogation Summary query" for all 8 adult ladders in the CRS for the calendar year of a particular migration season for the species of interest. Ensure that the attributes of the query include information that will allow you to parse the data into ESU/DPS and perform needed filtration of data. Though much filtering may be done in the PTAGIS database, that may also result in needing to do further queries and downloads in the future.
    a. The default query includes most of the information you will need. Adding "migration year" and "first (observation) year" will allow easier filtering of precocial fish (or mini-jacks; age 0-ocean) and jacks (age 1-ocean). The Ice Harbor observation site combines juvenile bypass and fish ladder observations so it will require this information to sort adults from juveniles. "Release site sub basin" may also be useful information to add.
    b. If you know you will not be calculating survival for jacks or mini-jacks you can filter
    c. It is good practice to use uniform queries for each year. Standard queries may be saved in PTAGIS, only the "first observation year" parameter then needs to be changed for each new download. This saves time and helps ensure the same group of fish is used for analyses each year.
    d. Results from Ice Harbor can be problematic as the PTAGIS site includes both upstream (presumably adult) and downstream (presumably juveniles) detections. By applying a filter to the "first year" column the juvenile detections from Ice Harbor, as well as minijacks can be removed. Use a conditional filter: "first year greater than migration year". The queries used in the MS Access database also will filter out Ice Harbor juvenile and mini-jack detections, but by doing it before download you are putting less unused information in the MS Access database.

e. Steelhead, whose migration spans a calendar year, require an entry of Jun 1, 20XX in the "first observation date" attribute, and an entry of May 31, 20XX+1 in the last "observation date" attribute. The migration year is assigned to 20XX (year they passed Bonneville). This is only applicable to Summer Steelhead, especially Snake River Steelhead. Significant numbers overwinter below MCN (and other locations) before resuming their migrations in the early spring. So though they pass Bonneville in one year, they may not pass the last dam on their migration (LGR for Snake River Steelhead) until spring of the following year.

2. Download files. I typically download files in .csv format and open them in Excel to check for any obvious problems. If any post-processing of data needs to be done, Excel is often far better for this than the MS Access database where the rest of the processing will occur.
3. Load the downloaded data into the MS Access database. Unless it is a new database, you will be appending the data to a central observations table. This is another reason for using uniform queries, you can only append data to a table if there is a perfect match of metadata.
4. The basic MS Access database for survival estimation includes 3 main tables:
    a. Observations: PIT tag Observation data for all 8 dams of the CRS (probably multiple years) downloaded from PTAGIS
    b. ESU/DPS-release site crosstalk table: lists the ESU/DPS for each release site (exact name match required) in PTAGIS. This is used to assign fish to a particular ESU/DPS for analysis
    c. Transportation: This file contains a record of each PIT tag detected by migration year and if the fish migrated in-river or was transported to the estuary. This is only needed for Snake River ESU/DPS after MCN ceased collection and transportation. Currently I use files provided by DART (https://www.cbr.washington.edu/dart/metadata/pit#transport). These files, and any I have produced myself are actually inferences that a fish was transported rather than a direct detection of fish being loaded into a barge. The basic algorithm for identifying a transported fish includes: detection in a bypass system of a collector dam (LGR, LGS, LMN) on a date within the specified transportation window, the final detection antenna (requires "interrogation detail" query of PTAGIS) of the fish in the bypass system that does not lead to a return to the river, and that the day was not a day when fish collected for transport were released to the river for some reason (typically listed on the Fish Passage Center website, https://www.fpc.org/).
5. Query structures: Originally, I downloaded detections for each dam separately and kept them in separate tables. I later changed to a mass download of data from all dams in the CRS and kept it in one central data table. This greatly reduced the amount of work to download and handle the data. So in my current methodology a query is used to establish a list of fish observed at Bonneville for a particular year; this query also crosslinks to the transportation table (via PIT tag code) and the ESU table (via release site) and adds the transportation status and ESU information to each record. The first year value provides the information to group observations by migration year, except for steelhead whose returns span more than one calendar year. Ocean age is also calculated at this step by including a field for First year - Migration year. Depending on what sort of analysis is desired various ages can be excluded. Jacks (age 1-ocean) are typically excluded from most conversion analyses so a value of >1 one may be entered in the criteria field of the ocean age. It is also possible to not put in a criteria which will provide

conversion estimates by ocean age (if you filtered mini-jacks, age 0-ocean, before downloading you will not get any results for them).

A difficulty at BON is that the fish ladders actually comprise of 4 PTAGIS detection sites (hereafter sites) and typically fish passing the ladder will be detected at more than one site. To solve this issue, the query is a summation grouped by PIT tag number, excluding site identifiers, and with observation times/dates selected as first. This should result in only one record per PIT tag in the list created by this query.

Lists are created for other dams and sites included in the analysis by more queries. One for each dam/site. These are simpler, typically only including the PIT tag and the observation time. Since Lower Columbia dams have 2 fish ladders, listed as different sites there is a risk of duplication of a PIT tag in the list due to fallback and re-ascension of the other ladder. For this reason, the queries are also summations, grouping by PIT tag and with a qualifier of first on the observation time/date.

The survival estimate is generated by a trace query. The BON query, which provides the base list for a year, is linked to all the dam/site queries included in the analysis. There is a prompt to enter the desired migration year at the start of the query (provides information to the first year selection criteria in the BON query). The tables are linked by PIT tag codes. The relationship of the links are a result for everything in the BON query and only the results from the other queries that match the BON query. The structure of the query includes the PIT tag code from the BON query and the first observation. I typically used first observation as the value produced by the queries from each of the other tables. It really doesn't matter what value from the table is used from the tables as this is just really a query to establish presence or absence. Any result produced by a link between the BON list and observation of the matching PIT tag at the particular dam can be used. Using first observation facilitates modification of the query to produce travel time estimates.

The structure of the query is the PIT tag from the BON list, and observations (or no observation) for the PIT tag as the fish moves upstream through the CRS in geographical order. For estimation of survival in this list the most important information from each detection site is detection/ no detection. So you have a row for each fish that shows if it was detected or not at each dam as you move upstream in the CRS.

One of the issues that occasionally arises with these databases are duplicate records. They can occur for many reasons, e.g., errors in query structure, fallback, etc. Using summation queries that group according to PIT tag and use a qualifier such as minimum or maximum to reduce multiple observations for a particular site to a single value. Anything that is different between two observations, and is not resolved by a summation operation like selecting the minimum or maximum value available will produce another line for a particular PIT tag. Since we are producing an observation/no observation matrix, multiple lines for a single PIT tag are the largest likely source of error if observations are summed for each dam to estimate survival.

To summarize the data, and help eliminate duplicate lines, a secondary trace query is used. This query is a summary query, grouping by the PIT tag, and using a “count” qualifier for each observation site. With no duplicate lines in the original matrix, the value for each observation site should be 1 or 0. If there were multiple lines in the first trace query for the same PIT tag, the value will be greater than one. Since we are mainly interested in presence/absence, if the actual values present are greater than one, it does not really matter as long as there is only one line for each PIT tag it will produce valid results. The problem arises when we want to go from individual results to summarize observations for each dam. If each value is equal to 1 then we can simply add all of them together for each dam (column) to give the total observations for each dam. If some are greater than one to summarize them another step is needed to reduce all values so they are not greater than 1.

Results of the secondary trace should be checked to verify that there are no values greater than 1. This can be done fairly simply with a sort operation (largest to smallest) for each dam (column). If none are found, another summary query is applied to the secondary trace query that sums the total observations by dam. This provides the raw data for the simple binary (upstream/downstream) calculation of survival for each reach. Another summary query can be used to calculate the actual survivals. However, since the reporting format for the BiOp is a standard spreadsheet, generally the numbers are entered into the spreadsheet for the actual survival calculation. It is very simple to copy/paste the results of any MS Access query into an Excel spreadsheet. Since Excel has more capacities for data manipulation and analysis I typically paste results of the summary queries into an Excel spreadsheet for further analysis.

If there are duplicate lines with the same PIT tag code produced by the first trace query, I will generally try to identify the source of the duplication as it can also be a sign of some error in the database. If you are confident that there are no sources of duplication other than multiple observations of a fish at one site (no multiplying through some database operation), then the detection/no detection information included in the analysis is still valid. Queries can be designed in MS Access to reduce the results to 1 or 0. Simpler workarounds include cutting and pasting the results of the second query into an Excel spreadsheet and using sort and editing procedures to manually change all the non-zero observations into values equal to 1. It is then very simple to produce the total numbers of observations per dam, and calculate the reach survival.

As noted before, the issue most likely to produce errors in survival estimates is multiple lines with the same PIT tag code. MS Access includes a "detect duplicates" query, this can be used to detect duplicates in any table or the results of queries. Data tables may have duplicates because of updates that overlap the current data in the query in time. Checking for duplicates after updates is a good practice to avoid this error. Using this function to check summary queries that still include PIT tag codes is a good practice to detect and correct this potential error. Excel includes an "eliminate duplicates" function that can be used to detect errors after data is transferred. I suggest copying the total list of PIT tags and then applying the detect errors to that list. Excel will report if any errors were detected.

The end product of the MS Access process is a number of observations for each dam in the CRS for a particular migration year. For Snake River ESU/DPS (except Sockeye) separate results are provided for fish that migrated in-river or were transported as smolts. These dam counts were then transferred to the Excel spreadsheet that performed the calculations described in Eqs. 1-4.

Other Uses:
The matrix of PIT tag codes, 1's and 0's produced by the trace summary are also the input data for Cormack-Jolly-Seber survival analysis. Additional work is likely required to match the input format required by a particular software package such as SURPH (https://www.cbr.washington.edu/analysis/apps/surph). Travel time is also easily calculated using the same structure as the trace query but including observation times rather than just detection/no detection. Selecting the first or last observations for use in travel time calculations have an effect on the actual estimate. If you select the first observations for two dams in a series you will include the time it takes the fish to pass the first dam (possibly including delays associated with fallback and re-ascension) and the time it takes to traverse the reservoir and ascend to the first detector on the second dam. If you select the last detection on the first dam and the first detection on the second dam it will provide an estimate of the time required to traverse the reservoir (including how long it takes the fish to reach the first detector on the second dam). As noted here, different combinations of first and last observations will provide different estimates of travel time. It is important to match the desired result (time to pass the dam, time to traverse the reservoir, etc.) or a specific standard (first at downstream dam, first at upstream dam) to produce useful results. The locations of detectors in the fish ladders (diagrams for all sites are available on the PTAGIS website, https://ptagis.org/Sites/InterrogationSites; text representations available through the DART website, https://www.cbr.washington.edu/downloads/paramest/sites_config.txt) will also affect the travel time estimates. Sites where there are detectors near the entrance and exit of the ladder can provide good estimates of ladder passage times (BON, LGR). Other sites where there are only 2 detectors (TDA, JDA) may only provide transit time through the count window. Basic fallback detection is also possible, the most obvious example being observations of the same fish ascending two different ladders at the same dam (only applicable in the lower Columbia). If the difference between the first and last observations at a site is greater than 24 hours it is also a strong indication that the fish may have fallen back and then re-ascended the same ladder. Though some fish have been observed to remain in the ladder overnight, stopping movement when darkness falls and resuming at first light. There are also anecdotal accounts of steelhead overwintering in fish ladders, though we have not detected this in our analysis. This is a basic methodology and will fail to detect fish that rapidly re-ascend the ladder, or misinterpret fish that "camp out", remaining in the ladder for more than the usual passage time and then resume climbing the ladder and leave. The number of antennas and their arrangement should also be considered in using the methods described to detect fallback.

Data for Harvest Corrections

There are two types of managed harvest in the CRS, recreational and Tribal harvest. There are no non-tribal commercial fisheries upstream of Bonneville. Harvest is managed by the Technical Advisory Committee (TAC). The TAC includes representatives from state and federal fisheries management agencies, the Columbia River Tribal Fisheries Commission (CRITFC), and Tribal Nations with treaty fishing rights on the Columbia and Snake rivers. The TAC operates under the authority of the US. V. Oregon management agreement (ODFW and WDFW 2024a,b,c,d), setting the allowable harvest, and scheduling fishing seasons to keep total harvest within the set allowable harvest rates.

Harvest estimates are published annually by the Columbia River Compact (see references) comprised of the Oregon Department of Fish and Wildlife (ODFW) and the Washington Department of Fish and Wildlife (WDFW). Three reports are published each year. The first provides harvest estimates for Spring and Summer Chinook and Sockeye, and the second report for Fall Chinook and summer Steelhead.

The harvest rates used for the 2002-2008 survival estimates were provided by Stuart Ellis (CRITFC) a member of TAC. From 2009 onward they were calculated from the annual harvest estimates described above as part of the conversion calculation process.

The BON to MCN reach is classified as Zone 6 by the TAC. Thus, the harvest estimate for that reach is the reported harvest for Zone 6. However, the report uses harvest rates based on an estimate of the number of fish entering the river. Since there is significant harvest downstream of BON this would result in an underestimate of harvest occurring in Zone 6 alone. The rates must be recalculated as:

Zone 6 Harvest rate = Number of fish harvested in Zone 6 / Number of fish at BON (Eq. 7)

Information for tribal and recreational harvest is presented separately and must be added together to estimate the total harvest rate. The tribal harvest comprises both commercial and subsistence/ceremonial harvests that are presented separately and must be combined to provide the total harvest estimate.

There is no managed tribal harvest in the IHR to LGR reach, only occasional recreational fisheries. These are directly reported. For use in the conversion estimate they must be converted to a harvest rate based on the number of fish at BON rather than the estimate of fish at the river mouth that is used in the reports

IHR to LGR Harvest = Number of fish harvested IHR-LGR / Number of fish at BON (Eq. 8)

Upper Columbia Spring Chinook, Snake River Spring/Summer Chinook ESU:
Harvest estimates for these ESUs are derived from the harvest rates for Spring Chinook published in the Columbia River Compact report bearing their name (typically published the following spring). For simplicity, the Spring Chinook harvest rate was applied to the entire Snake River Spring/Summer Chinook ESU. Reporting levels of harvest are generally for larger categories of fish than ESU and are based on calendar dates.

As an example (format may vary over time), in Table 5, page 67 of the 2024 Harvest report (ODFW and WDFW 2024c), the count of upriver Spring Chinook is provided. The next section includes both treaty and non treaty harvest for Zone 6 (BON to MCN) so the estimated harvest rate for the BON to MCN reach for Spring Chinook is:

2023 Estimated BON to MCN Harvest rate (9.4%) = Total Zone 6 harvest (12,868) / Count at Bonneville (136,786) (Eq. 9)

This estimate is the entire harvest rate used in the calculations for Upper Columbia Spring Chinook. Snake River Spring/Summer Chinook continue through the CRS after entering the Snake River. Historically there is no treaty harvest in this reach, only occasional small recreational fisheries.

In the 2024 Harvest Report (ODFW and WDFW 2024c), the number harvested in this reach is given on table 25. Recreational fisheries upstream of Bonneville Dam, 2002–2023, Page 96. Spring Chinook count at Ice Harbor must be acquired from an outside source such as the DART website.

2023 Estimated MCN to LGR harvest rate (1.0%) = (411) Snake River Spring Chinook Harvest / (41,084) Ice Harbor Spring chinook Count (DART website) (Eq. 10)

<u>Snake River Sockeye</u>
Harvest Estimates for Sockeye are used to correct the survival estimates calculated for Snake River Sockeye. The Columbia River Compact publishes these estimates in the same volume as Spring Chinook (ODFW and WDFW 2024c). Though there are specific estimates published for Snake River Sockeye, we prefer to use the numbers published for all sockeye.

All Sockeye Harvest occurs in Zone 6. Historically there has been no treaty or non treaty harvest in the Snake River. In the example of the 2024 Compact River Compact report (ODFW and WDFW 2024c) the data is presented in Table 15, page 78.

2023 estimated Sockeye BON to MCN harvest rate (6.7%) = (22,061) Zone 6 Sockeye Treaty harvest (all) / (327,600) Bonneville Sockeye count (all) (Eq. 11)

There is some sport harvest in Zone 6, but non-treaty harvest estimates include fish taken both above and below Bonneville so that number is not used. Recreational harvest in Zone 6 is typically very small in relation to treaty harvest. Since the estimate does not include the recreational harvest it is a minimum harvest estimate. Historically, there have been no treaty or non-treaty sockeye fisheries in the MCN to LGR reach.

<u>Mid Columbia Steelhead, Upper Columbia Steelhead, Snake River Steelhead:</u>
The Summer Steelhead harvest estimates used for the 2023 steelhead year are in the volume of harvest estimates that also includes fall Chinook. This can be somewhat confusing as the volume containing Spring Chinook also includes summer steelhead harvest estimates. However,

the steelhead reported in that volume will spawn in 2023, so they would be assigned to the 2022 steelhead year. The harvest estimate for summer Steelhead is applied to Mid-Columbia, Upper Columbia, and Snake River Steelhead DPS. The Zone 6 fishery comprises both treaty and non-treaty recreational harvest. Results are reported for both “A run” and “B run” Steelhead. These results should be combined to give a value for all steelhead. The total number of upriver summer steelhead for 2023 is given in the 2024 compact report (ODFW and WDFW 2024c) in Table 6. Returns of upriver summer steelhead to Bonneville Dam (April-October), 1984-2023, on Page 42. Estimates of harvest are found in Table 19a. Fall season A-Index summer steelhead harvest and incidental release mortalities in mainstem Columbia River non-treaty fisheries, 1999-2023 on page 62 and Table 19b. Fall season B-Index summer steelhead harvest and incidental release mortalities in mainstem Columbia River non-treaty fisheries, 1999-2023 on Page 63. Treaty harvest estimates are found in Table 29. Fall mainstem Columbia River treaty fishery landings, 1980-2023, Page 74. All harvest above Bonneville should be summed (hatchery and wild) and estimates for A and B Run Steelhead added together to give an estimate of total Zone 6 harvest. Do not use the season totals listed at the end of the table as they include harvest below BON.

2023 estimated BON to MCN harvest rate (5.7%) = (0 + 16 + 5 + 0 + 5 + 4 + 16 + 19 + 44) A run non treaty harvest + (0 + 4 + 0 + 0 + 2 + 0 + 6 + 13 + 5) B run Non Treaty harvest + (8,311) Zone 6 treaty harvest) / (147,491) number of upriver steelhead at BON

(Eq. 12)

All treaty fishing is below MCN in Zone 6, the reports for the non treaty fishery extend upstream to the Highway 395 bridge, just upstream of the Snake River Mouth. After 2012 there is no recreational steelhead harvest reported on the Snake River downstream of Lower Granite Dam. For estimates after 2012, equation 12 is the total estimate for Snake River Steelhead as well as Upper and Mid Columbia Steelhead DPSs. Prior to that date an equation similar to Equation 10 was used, employing Summer Steelhead counts for Ice Harbor and reported Snake River Harvest Rates.

<u>Snake River Fall Chinook ESU</u>

Harvest estimates for Fall Chinook reported in the Columbia River Compact report bearing Fall Chinook in its title are used for the Snake River Fall Chinook survival estimate. Using the 2024 Compact harvest report (ODFW and WDFW 2024d) as an example: The number of Fall Chinook at Bonneville in 2023 were taken from the DART website. Estimates of zone 6 recreational fishery harvest (upstream to just above SR mouth at highway 395 bridge are given in Table 27. Mainstem fall Chinook recreational fisheries upstream of Bonneville Dam, 2003-2023 page 73. Zone 6 Treaty harvest is given in Table 29. Fall mainstem Columbia River treaty fishery landings, 1980-2023, page 74

2023 Fall Chinook Harvest BON to MCN Harvest estimate (31.4%) = (15,992) Zone 6 recreational Harvest + (151,516) Zone 6 Treaty Harvest/ (532,986) Upriver Bright Fall Chinook at BON (from DART website) (Eq. 13)

Similar to Snake River Steelhead, there has been no harvest of Fall Chinook in the Snake River downstream of Lower Granite in recent years. Treaty harvest stops at MCN, and the recreational harvest reported includes the McNary Pool to highway 395 bridge. So for recent years Equation 13 represents the total estimated harvest of Fall Chinook in the CRS.

Estimation of harvest rates for use in conversion estimates can be problematic. The structure of the harvest reports is complex and occasionally changes. Additionally, historic harvest estimates may be updated in later reports as new information becomes available. Harvest estimates included in the Excel spreadsheet are based on the harvest estimate published the year the survival was calculated. They have not been updated, so estimates derived from later Columbia River Compact publications may be slightly different.

Other issues/notes:

The number of PIT tagged Snake River Sockeye returns to Bonneville in many years has been less than 40 fish (minimum number established for survival estimates). In those years, PIT tagged Upper Columbia Sockeye (unlisted populations originating from the Okanagan and Wenatchee) were used to estimate Bonneville to McNary survival for Snake River Sockeye.

Conversion estimates (Bonneville to McNary) for Middle Columbia Steelhead were estimated based on conversion rates of the Yakima and Walla Walla populations of that DPS. This represents a "worst case scenario" as other populations in this DPS pass fewer dams and have less exposure to Zone 6 fisheries so they likely have higher conversion rates.

Historical Data and Estimates for Conversion Rates

Documentation and files are accessible at the following GitHub repository folder:
https://github.com/Columbia-Basin-Research-CBR/ConvRateTools/tree/main/Methods/NMFS-Method

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