FISH PASSAGE CENTER

847 NE 19th Avenue, #250, Portland, OR 97232

Phone: (503) 833-3900 Fax: (503) 232-1259

www.fpc.org/

e-mail us at fpcstaff@fpc.org

MEMORANDUM

TO: Paul Wagner, NOAA

FROM: Michele DeHart

DATE: November 7, 2014

RE: Evaluation of juvenile survival and smolt-to-adult returns of PIT-tagged juveniles passing through the McNary Dam (MCN) bypass system via the Primary Bypass versus Separator routes

In response to your request, the FPC staff has reviewed available PIT-tag data to investigate whether there is evidence of differential juvenile survival and/or Smolt-to-Adult returns (SARs) for juvenile salmonids that passed the McNary Bypass System through the Primary Bypass route (what the NOAA request refers to as Full Flow Bypass) versus those that passed through the Separator. Below is a brief summary of our findings from these analyses, followed by more detailed discussion of the methods and results.

- Every fish that passes through the juvenile bypass system at MCN experiences screen diversion, gatewell entry, orifice passage, and significant dewatering prior to its entry into the Primary Bypass or Separator routes of passage. Therefore, the analyses presented in this memorandum pertain only to the potential effects of dewatering at or below the Separator at MCN, compared to fish that passed through the Primary Bypass.
- There does not appear to be any statistical evidence of differential juvenile survival ($S_{\text{MCN-BON}}$) or SARs ($\text{SAR}_{\text{MCN-to-BON}}$) between juveniles passing MCN through the Primary Bypass versus those passing through the Separator.
- Although the analyses for this specific data request found no evidence of differential juvenile survival or SARs between the Primary Bypass and Separator passage routes, multiple analyses completed in recent years have found that that powerhouse passages do affect survival later in the salmon and steelhead life stages, resulting in reduced smolt-to-adult return rates.

Overview

It's worth pointing out that the term Full Flow Bypass is a misnomer, as it implies that the amount of water passing through this route is somehow "full flow." However, by the time a fish gets to this point in the MCN Bypass and Collection System, a great deal of dewatering has occurred. A fundamental component of any juvenile bypass systems is separating juvenile fish from water (i.e., dewatering). Significant dewatering occurs throughout the juvenile bypass system, both at or near the powerhouse and later in the Smolt Bypass and Collection System. Therefore, all fish passing through the juvenile bypass system, whether they ultimately pass through the Primary Bypass or the Separator, experience considerable dewatering. The following outline accounts for the total dewatering that occurs to all bypassed fish at MCN prior to their entry into the transportation flume (Figures 1 and 2).

1. A McNary turbine operating at the upper end of 1% of peak efficiency (at 75 feet of head) discharges approximately 12,350 cfs. A group of fish entering the project in this flow would be guided up the Extended Length Submersible Bar Screens (ESBS) into the gatewell, up the gatewell by the Vertical Barrier Screens (VBS), and discharged into the collection channel via three orifices (each discharging 14.3–16.7 cfs, under normal conditions). Upon initially entering the Juvenile Bypass at McNary, fish are separated from an average unit flow of 12,350 cfs into a 14.3–16.7 cfs orifice flow (three orifices per unit) which is routed into the juvenile collection channel at MCN. Only 0.4% of the original unit flow discharges through the orifices into the collection channel, which equates to a 99.6% reduction in flow.
2. According to the Operations and Maintenance manual at McNary, total flow in the collection channel can range from a minimum of 406 cfs to a maximum of 728 cfs. However, under normal operating conditions, the juvenile collection channel flow typically ranges between 600 and 700[1] cfs depending on forebay elevation (with one orifice per gatewell open) (Carl Dugger, USACE, personal communication). At the downstream end of the collection channel there is a dewatering structure comprised of floor and side screens that separates the fish from a flow of 600–700 cfs in the collection channel to a flow of 30 cfs in the transportation flume. Therefore, approximately 95% of the collection channel water is removed before fish enter the transportation flume.

Prior to the transportation flume, all fish moving through the juvenile bypass at MCN experience ESBS, VBS, gatewells, orifices, the collection channel, and the dewatering screens at the downstream end of the collection channel. As fish travel through the transportation flume, flows continue at 30 cfs through a set of four PIT-tag detectors after which the transportation pipe either routes fish directly to the river (Primary Bypass) or through the sampling facilities (Secondary Bypass).

On non-sample days, fish in the transportation flume are routed through the Primary Bypass. Under Primary Bypass, fish travel around the sample/raceway area through 30 cfs of water and directly into the tailrace below the project, without passing any further PIT-tag detection and without any further significant dewatering (Figures 1 and 2).

[1] At a collection channel flow of 600 cfs, with 42 orifices operating, each orifice would be passing 14.3 cfs. At a collection channel flow of 700 cfs, with 42 orifices operating, each orifice would be passing 16.7 cfs.

On sample days, fish in the transportation flume are routed through the Fish and Debris Separator (herein referred to as Separator). At the Separator, the 30 cfs flow in the transportation flume is further reduced to a discharge of approximately 1–2 cfs (Figure 1 and Figure 2). From the Separator, fish are routed through one of two branches (A or B) depending on size. At each branch, there is a small degree of dewatering that occurs prior to the sample gate (Figure 1 and Figure 2). Beyond this point, fish that are not sampled by the sample gate will continue through the McNary Bypass and Collection System and eventually exit into the tailrace. Prior to 2012, this exit was located next to the Primary Bypass exit (Figure 1). From 2012 to present, fish passing through Secondary Bypass will rejoin with the Primary Bypass and exit at the same location in the tailrace (Figure 2).

Given the great similarity in fish passage experience prior to the Separator, it is important to note that the analyses presented in this data request pertain only to the potential effects from dewatering that occurs at and below the Separator. All fish in these analyses have the shared experience from the dewatering that occurs prior to the transportation flume (as outlined in bullets 1 and 2 above).

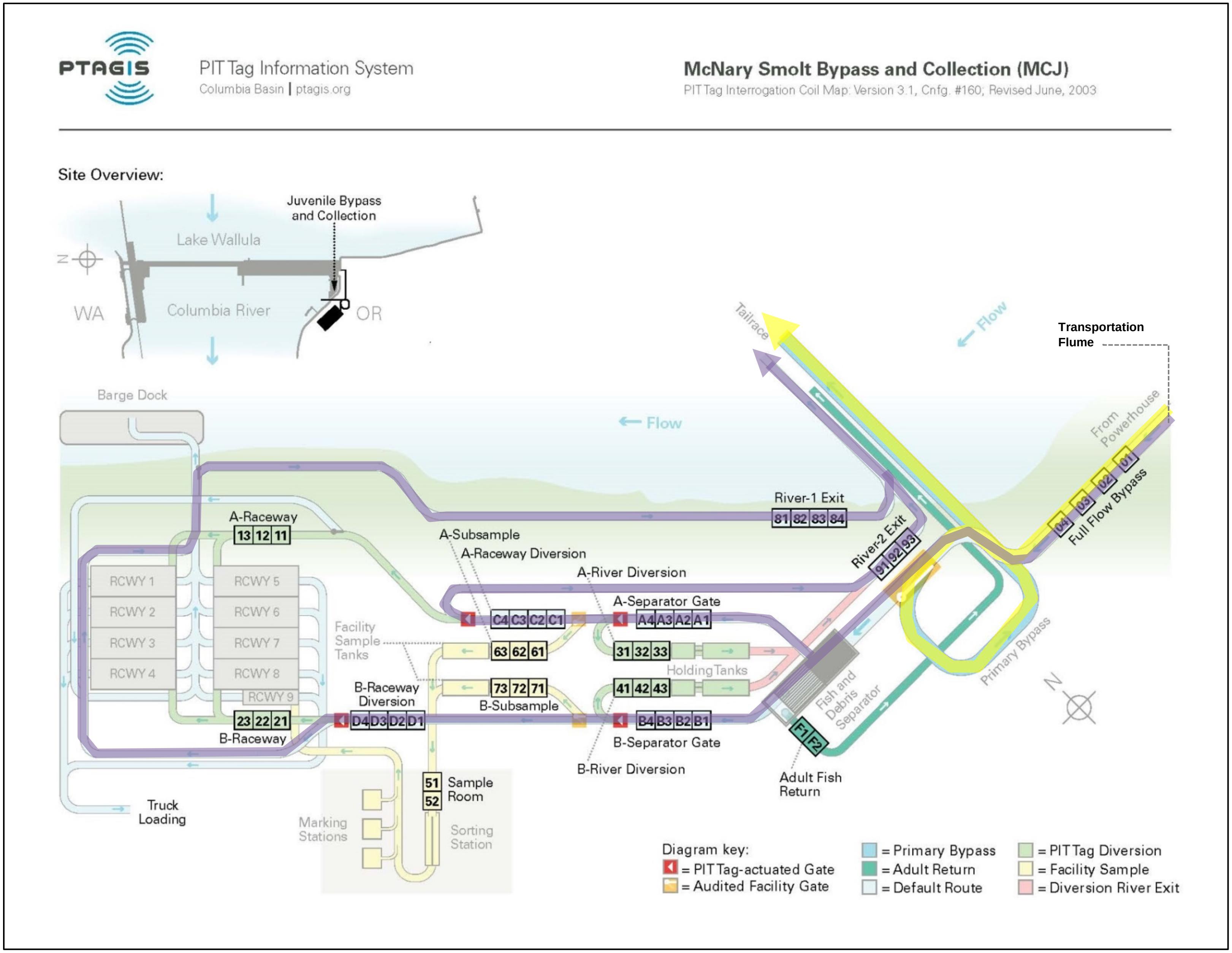

Figure 1. Configuration of McNary Smolt Bypass and Collection System at McNary Dam (2003–2011). Yellow line depicts path of fish passing through Primary Bypass route. Purple lines depict typical paths of non-sample fish passing through the Separator route.

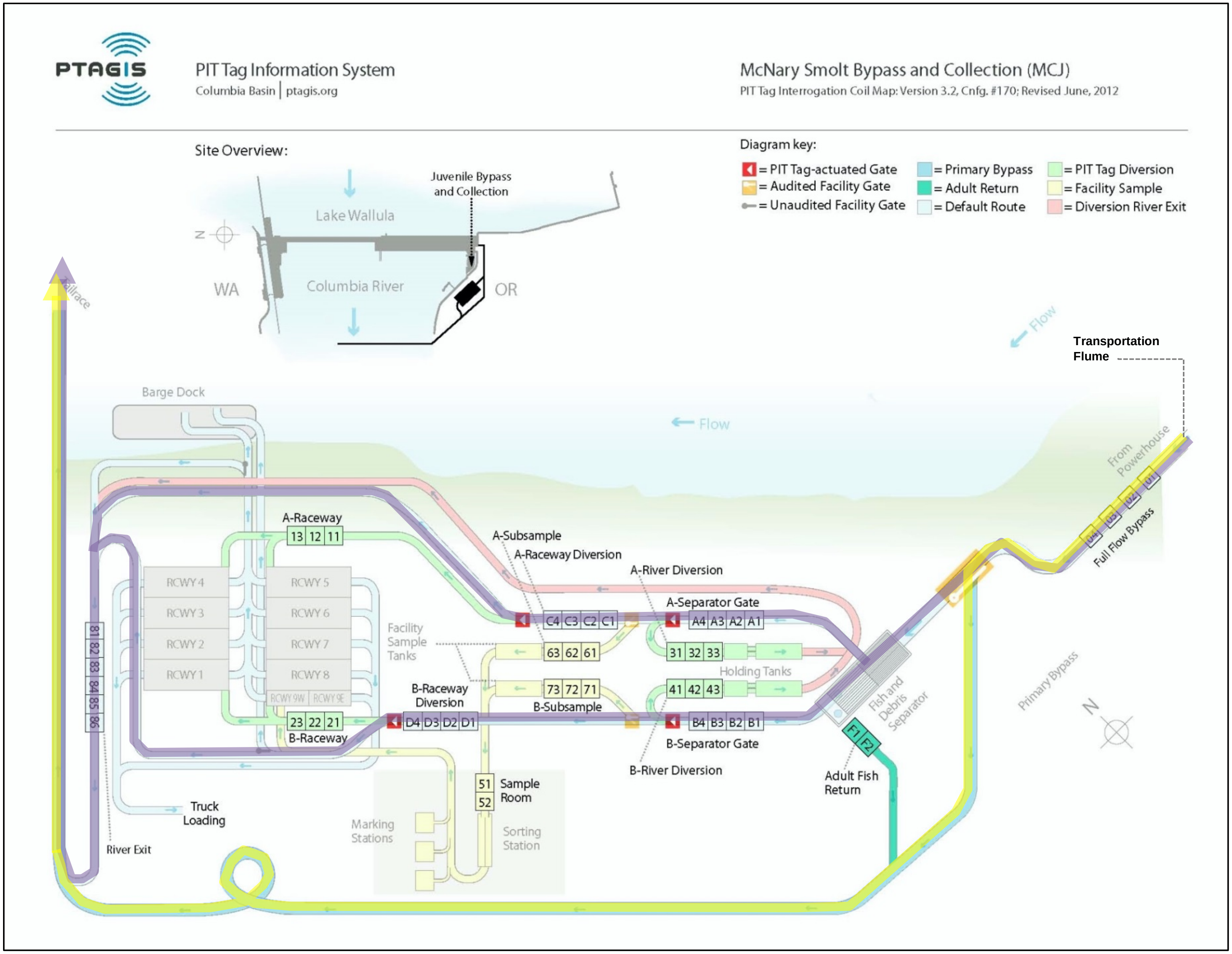

Figure 2. Configuration of McNary Smolt Bypass and Collection system at McNary Dam (2012–Present). Yellow line depicts path of fish passing through Primary Bypass route. Purple lines depict typical paths of non-sampled fish passing through the Separator route.

Methods

For these analyses, we relied on PIT-tagged wild and hatchery Snake River yearling Chinook and steelhead and Snake River hatchery sockeye from the Comparative Survival Study (CSS) that were tagged and released above Lower Granite Dam and were detected as juveniles at MCN. These PIT-tagged juveniles were assigned to one of two passage routes through the MCN bypass system, based on the Antenna Group of their last detection in the bypass system. Those that were last detected at the Full Flow Bypass antenna group were assigned to the Primary Bypass category. Those that were last detected at either the River-1 Exit (2006–2011), River-2 Exit (2006–2011), or River Exit (2012–2013) antenna groups were assigned to the Separator category. All PIT-tagged fish whose last MCN detection was at some other antenna group were not included in these analyses. Furthermore, all fish that were ever detected by the Sample Room antenna group were excluded from these analyses, as these fish would have experienced an additional level of handling than fish that experienced the Separator but were not diverted to the SMP sample tanks.

Juvenile Survival

Per the NOAA request, we estimated separate juvenile survivals for wild yearling Chinook, hatchery yearling Chinook, wild steelhead, hatchery steelhead, and hatchery sockeye. Survivals for Chinook and steelhead were estimated for migration years 2006–2013 while those for sockeye were estimated for migration years 2009–2013. To date, CSS data for migration year 2014 are not yet available for analysis. Survivals were estimated for each of the two passage routes outlined above (Primary Bypass and Separator).

To estimate juvenile survival, we relied on juvenile PIT-tag detections at John Day Dam (JDA) and Bonneville Dam (BON), as well as downstream of Bonneville Dam using specialized trawl equipment for PIT-tag detection. Using recapture data from fish detected at these sites, single-release mark-recapture survival estimates were generated for two reaches (MCN-JDA and JDA-BON) using the Cormack-Jolly-Seber methodology as described by Burnham et al. (1987) with the MARK program (software available free from Colorado State University) (White and Burnham 1999). Overall survival from MCN to BON ($S_{\text{MCN-BON}}$) is the product of these two individual reach survivals. Variance estimates for $S_{\text{MCN-BON}}$ were generated using the delta method (Burnham et al. 1987). Estimates of individual reach survival technically can exceed 100%; however this is often associated with an underestimate of survival in the preceding reach or overdispersion in the data. Therefore, when computing $S_{\text{MCN-BON}}$, we allowed individual reach survival estimates to exceed 100%. However, an estimate of $S_{\text{MCN-BON}}$ was considered unreliable when its point estimate exceeded 100% or its coefficient of variation exceeded 25%. Estimates of $S_{\text{MCN-BON}}$ that were deemed unreliable are not reported in the results section below.

Smolt-to-Adult Returns

Per the NOAA request, we estimated separate SARs ($\text{SAR}_{\text{MCN-to-BOA}}$) for each of the species/rear-type combinations outlined above. Chinook SARs were estimated for migration years 2006–2012, steelhead SARs were estimated for migration years 2006–2011, and sockeye SARs were estimated for migration years 2009–2012. SAR estimates for migration year 2012 include adults detected at Bonneville Dam through September 14, 2014, and should be considered incomplete as additional adults may return in 2015. All adult detections at BOA that occurred in the same year as the out-migration were considered mini-jacks and were not included as adults in the estimation of SARs. Although mini-jacks (i.e., 0-salts) were not included in these analyses, jacks (i.e., 1-salts) were included in the estimation of SARs. The smolt portion of the SAR estimates was simply the number of smolts that were detected at MCN and determined to have passed through the bypass system in each of the two passage categories (Primary Bypass vs. Separator). We also used the Clopper and Pearson methodology (Clopper and Pearson 1934) to estimate a 90% confidence interval for each SAR and relied on Chi-square tests to determine if SARs of the two passage categories (Primary Bypass vs. Separator) were significantly different ($\alpha = 0.1$).

Results

Juvenile Survival

In recent years, there have been several instances of anomalous survival estimates for the McNary to Bonneville Dam reach. For example, in 2008 estimates of survivals for the MCN-JDA reach were often unrealistically high (i.e., over 100%), which resulted in unrealistically low survival estimates in the JDA-BON reach. In the 2008 FPC Annual Report (FPC 2008), the FPC determined that these unrealistic reach survival estimates were largely due to significant operational changes in the Lower Columbia River. Among these changes were high flows and debris levels that led to the removal of the turbine intake screens at the BON second powerhouse from May 22nd to June 20th. In addition, TSW testing at JDA in 2008 resulted in an unanticipated increase in tailrace mortality due to avian predation (FPC 2008). Similarly, high flows and debris in 2011 resulted in the removal of the turbine intake screens at the BON second powerhouse from May 27th through July 12th (FPC 2011). Finally, the high flows in 2008 and 2011 likely affected the capture efficiency and detection probabilities of the trawl and, thus, detections were reduced (FPC 2008)

Sample sizes for certain species/rear-type combinations for each of the two passage categories were sometimes small. These small sample sizes, in addition to the anomalies discussed above, often meant that reliable estimates of $S_{\text{MCN-BON}}$ were possible only in some of the above mentioned migration years. For example, these factors prevented us from estimating $S_{\text{MCN-BON}}$ for wild steelhead and hatchery sockeye in all years. Finally, where estimates of $S_{\text{MCN-BON}}$ were possible, small sample sizes and/or anomalies in individual reach survivals often led to wide confidence intervals, which means that finding a statistical difference in $S_{\text{MCN-BON}}$ between the two MCN passage categories may be difficult.

Yearling Chinook

For hatchery yearling Chinook, we were able to estimate $S_{\text{MCN-BON}}$ for both MCN passage categories in all eight of the above mentioned migration years. However, there were no statistical differences in $S_{\text{MCN-BON}}$ between juveniles that passed MCN through the Primary Bypass versus those that passed through the Separator (Figure 3a). In fact, among the eight years we analyzed, the $S_{\text{MCN-BON}}$ point estimate for the Primary Bypass group was higher in half of the years (2008, 2009, 2011, and 2012) and lower in the other half of the years (2006, 2007, 2010, and 2013). This indicates that there was no discernable pattern of differential juvenile survival between the two MCN passage categories for hatchery yearling Chinook.

For wild yearling Chinook, we could estimate $S_{\text{MCN-BON}}$ for only the two passage categories in two years (2009 and 2010). Based on these two years, there were no statistical differences in $S_{\text{MCN-BON}}$ between the two routes (Figure 3b), as the 95% confidence intervals in both of these years overlapped.

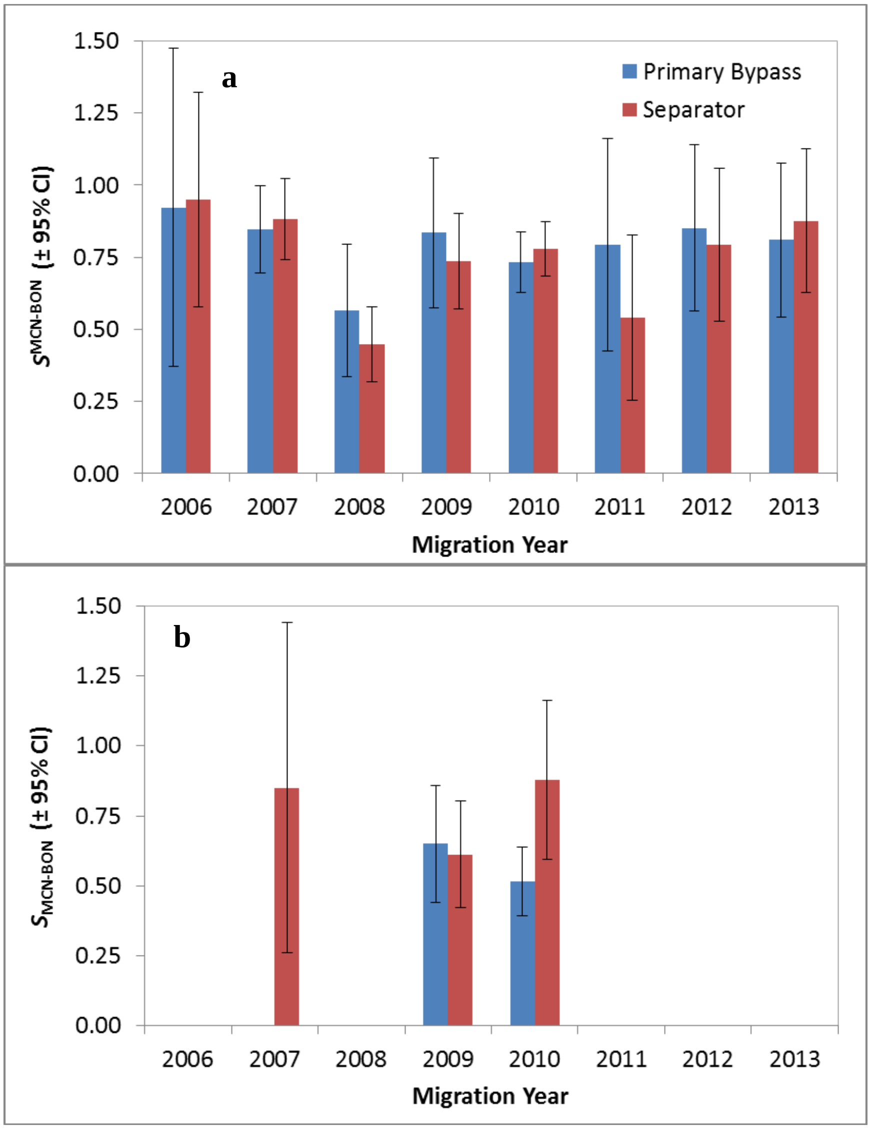

Figure 3. Juvenile survival ($S_{MCN\text{-}BON}$) of Snake River hatchery (a) and wild (b) yearling Chinook for individuals passing MCN through the Primary Bypass versus the Separator, migration years 2006–2013. Missing bars indicate that reliable estimates of $S_{MCN\text{-}BON}$ were not possible.

Steelhead

As mentioned above we could not estimate juvenile survival ($S_{MCN\text{-}BON}$) for wild steelhead. For hatchery steelhead, we were able to estimate $S_{MCN\text{-}BON}$ for the both MCN passage categories for four years (2008, 2010, 2011, and 2013) (Figure 4). As with yearling Chinook, there was no statistical evidence of differential survival between hatchery steelhead that passed MCN via the Primary Bypass versus those that passed through the Separator (Figure 4). Among the four years we were able to make comparisons, the $S_{MCN\text{-}BON}$ point estimate for individuals passing through the Separator was the highest in all four years (Figure 4). With so few years it is difficult to know if this pattern is biologically relevant or whether this is a function of the difficulties in estimating reach survivals in the Lower Columbia River, particularly when you consider the wide confidence intervals around most of the point estimates.

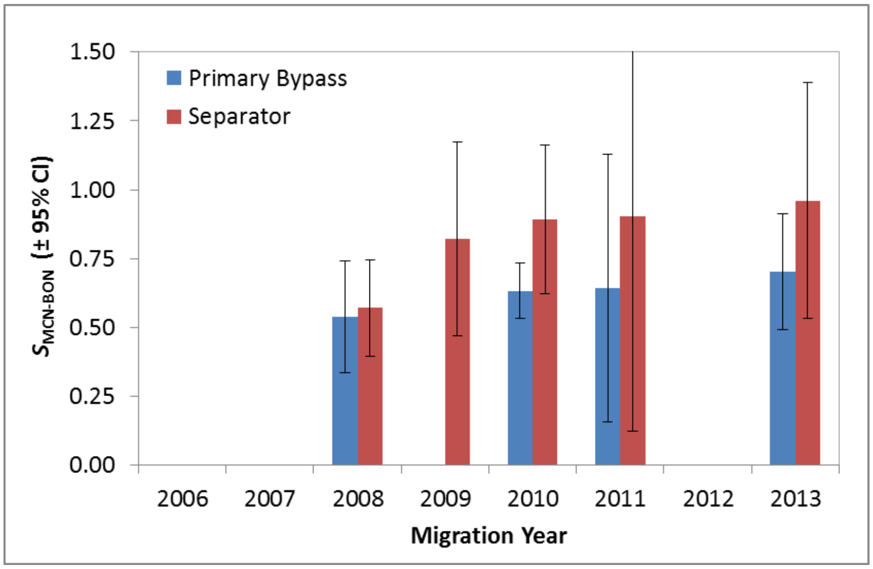

Figure 4. Snake River hatchery steelhead survival ($S_{MCN-BON}$) for individuals passing MCN through the Primary Bypass versus the Separator, migration years 2006–2013. Missing bars indicate that reliable estimates of $S_{MCN-BON}$ were not possible.

Smolt-to-Adult Returns

Unlike juvenile survivals ($S_{MCN-BON}$) the process of estimating SARs for the two passage categories is less sensitive to changes in project operations and/or flow conditions. For example, many of the issues highlighted above that hindered our ability to estimate juvenile survival ($S_{MCN-BON}$) do not hinder our ability to estimate SARs ($SAR_{MCN-to-BOA}$). Therefore, we were able to estimate $SAR_{MCN-to-BOA}$ for all species/rear-type combinations in all the years outlined in the methods above, which equates to 30 different comparisons of $SAR_{MCN-to-BOA}$ for fish that passed MCN through the Primary Bypass versus those that passed through the Separator.

Yearling Chinook

For hatchery and wild yearling Chinook, there were no statistical differences in $SAR_{MCN-to-BOA}$ between fish that passed MCN through the Primary Bypass versus those that passed through the Separator (Figure 5). In addition to the lack of significant differences between the two MCN passage categories, there does not seem to be an obvious pattern in $SAR_{MCN-to-BOA}$ between the two categories. For example, for both hatchery and wild yearling Chinook, the Primary Bypass group had the higher $SAR_{MCN-to-BOA}$ point estimate in five of the seven years (Figure 5). For hatchery yearling Chinook these five years were 2007–2010 and 2012, whereas those for wild yearling Chinook were 2006–2007 and 2009–2011. Finally, the differences in the point estimates of $SAR_{MCN-to-BOA}$ were generally small.

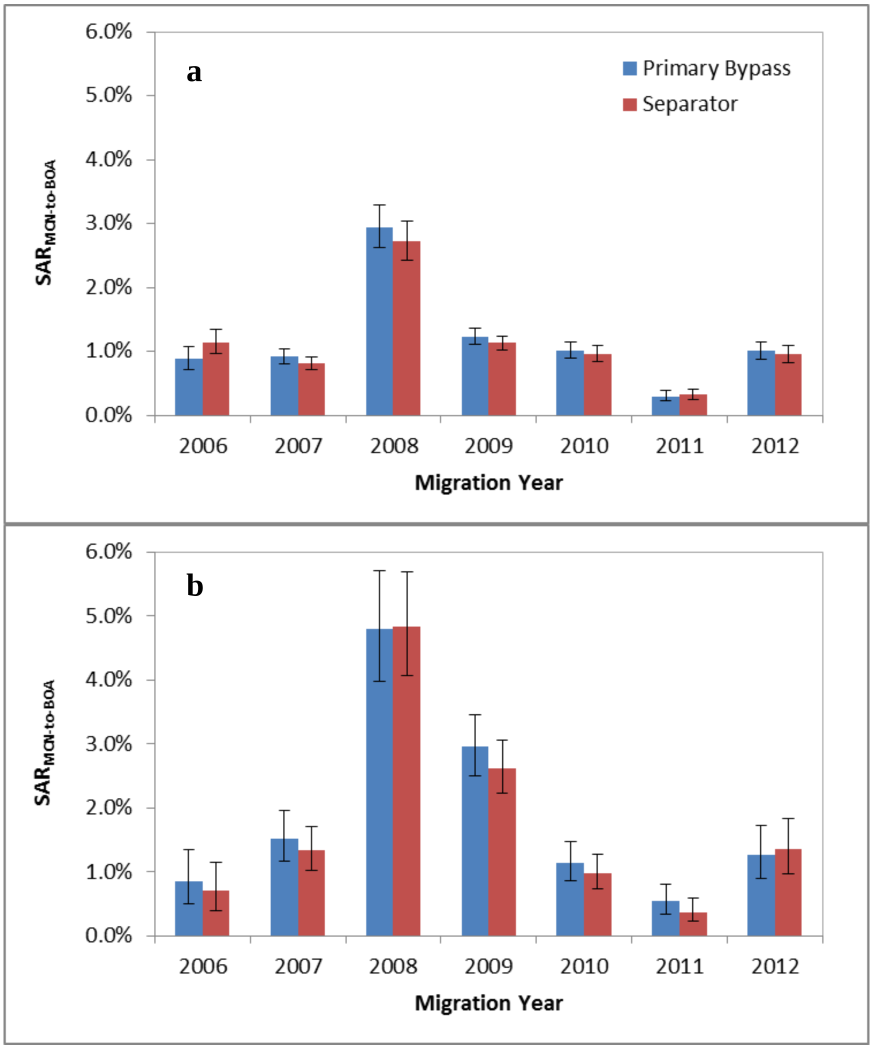

Figure 5. $SAR_{MCN\text{-}to\text{-}BOA}$ of Snake River hatchery (a) and wild (b) yearling Chinook that passed MCN through the Primary Bypass versus those that passed through the Separator for migration years 2006–2012. $SAR_{MCN\text{-}to\text{-}BOA}$ for 2012 should be considered incomplete, as only 2-salts through September 14, 2014, are included. Confidence intervals are 90% (Clopper and Pearson 1934).

Steelhead

For hatchery steelhead, we found only one year (2008) where there was a statistical difference in $SAR_{MCN\text{-}to\text{-}BOA}$ between fish that passed MCN through the Primary Bypass versus those that passed through the Separator (Figure 6a). In 2008, hatchery steelhead juveniles that passed MCN through the Primary Bypass had an $SAR_{MCN\text{-}to\text{-}BOA}$ of 4.69% (90% CI: 4.07%–5.37%), whereas those that passed through the separator had an $SAR_{MCN\text{-}to\text{-}BOA}$ of 3.48% (90% CI: 3.02%–4.00%) (Figure 6a). For the other five years, there were no significant differences in $SAR_{MCN\text{-}to\text{-}BOA}$ between the two MCN passage categories, although Primary Bypass had a higher point estimate in four of the five years. Overall, the differences in $SAR_{MCN\text{-}to\text{-}BOA}$ between the two passage routes were relatively small (Figure 6a).

For wild steelhead, we found no evidence of significant differences in $SAR_{MCN\text{-}to\text{-}BOA}$ between juveniles passing MCN through the Primary Bypass versus those passing through the Separator

(Figure 6a). Furthermore, there was not an obvious pattern in $SAR_{MCN\text{-}to\text{-}BOA}$ between the two passage categories. For wild steelhead, the Primary Bypass group had the higher $SAR_{MCN\text{-}to\text{-}BOA}$ point estimate in four of the six years (Figure 6b), although the difference in point estimates were generally small (Figure 6b).

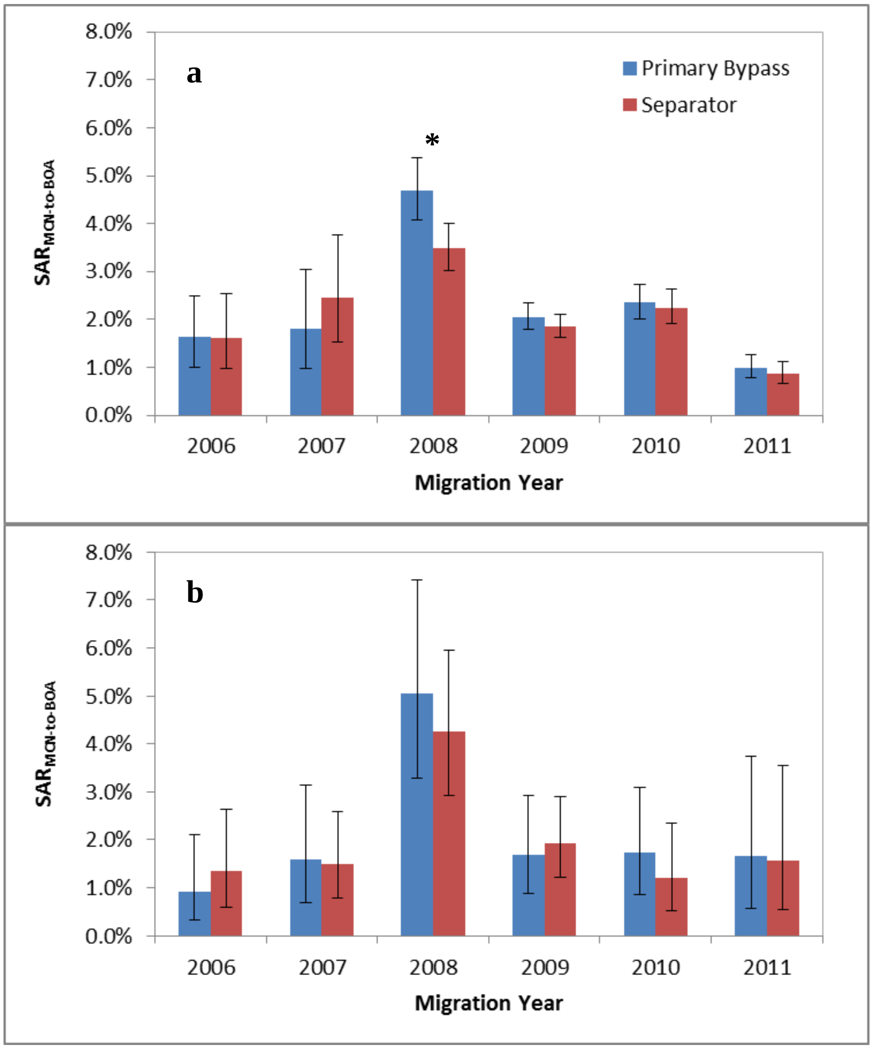

Figure 6. $SAR_{MCN\text{-}to\text{-}BOA}$ of Snake River hatchery (a) and wild (b) steelhead that passed MCN through the Primary Bypass versus those that passed through the Separator for migration years 2006–2011. Confidence intervals are 90% (Clopper and Pearson 1934). * indicates statistical difference between passage categories at $\alpha = 0.10$ level.

Sockeye

For hatchery sockeye there were no statistical differences in $SAR_{MCN\text{-}to\text{-}BOA}$ between fish that passed MCN through the Primary Bypass versus those that passed through the Separator (Figure 7). In addition, there does not seem to be a pattern in $SAR_{MCN\text{-}to\text{-}BOA}$ between the two categories. For example, the Primary Bypass group had the higher point estimate of $SAR_{MCN\text{-}to\text{-}BOA}$ in only two of the four years (Figure 7).

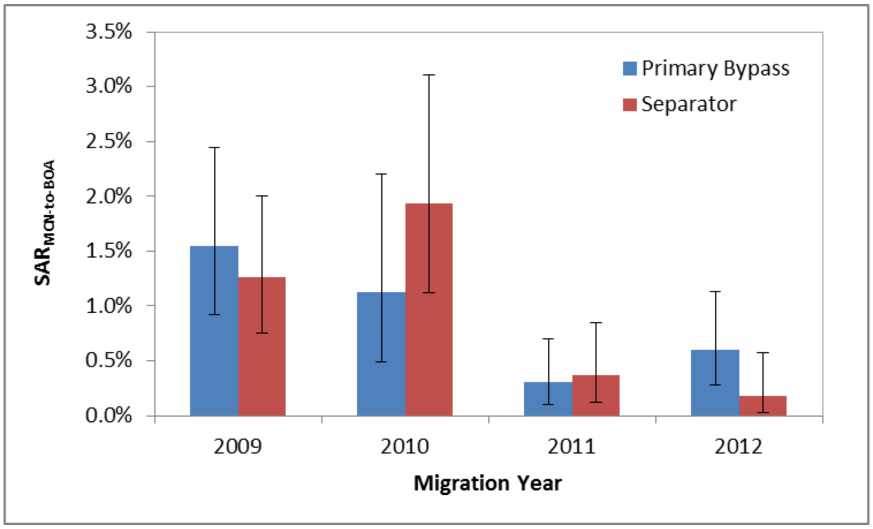

Figure 7. $SAR_{MCN\text{-}to\text{-}BOA}$ of Snake River hatchery sockeye that passed MCN through the Primary Bypass versus those that passed through the Separator for migration years 2009–2011. $SAR_{MCN\text{-}to\text{-}BOA}$ for 2012 should be considered incomplete, as only 2-salts through September 14, 2014, are included. Confidence intervals are 90% (Clopper and Pearson 1934).

Discussion

Based on these analyses, there does not appear to be any evidence of differential juvenile survival ($S_{MCN\text{-}BON}$) or smolt-to-adult return rates ($SAR_{MCN\text{-}to\text{-}BOA}$) between juveniles that pass the MCN Bypass and Collection System through the Primary Bypass versus those that pass through the Separator. As discussed in the overview, all fish passing through powerhouse passage routes experience significant dewatering and a stress throughout the juvenile bypass system. Our finding of no differences in juvenile survival ($S_{MCN\text{-}BON}$) or SARs ($SAR_{MCN\text{-}to\text{-}BOA}$) between the Primary Bypass (i.e., non-sample days) and Separator (i.e., sample days) routes at MCN is understandable, given the significant dewatering experiences that these fish share.

Although these analyses found no evidence of differential juvenile survival ($S_{MCN\text{-}BON}$) or SARs ($SAR_{MCN\text{-}to\text{-}BOA}$) between the Primary Bypass and Separator routes of passage, multiple analyses completed in recent years have indicated that powerhouse passages affect survival later in the salmon and steelhead life stages, resulting in reduced smolt-to-adult return rates. The long-term effects of passage routes for juvenile fish have been well documented in recent years. Fish that survive the juvenile bypass systems or powerhouse passage are less likely to survive the first ocean year and less likely to return as adults than those that avoid powerhouse passage routes and pass in spill (Haeseker et al. 2012, Petrosky and Schaller 2010, Tuomikoski et al. 2010, FPC Memos: October 6, 2010; January 19, 2011; July 14, 2011).

Finally, the Northwest Power and Conservation Council's Independent Scientific Advisory Board reviewed several FPC summaries of delayed mortality associated with powerhouse passage and reviewed Chapter 7 of the 2010 CSS Annual Report, which analyzed delayed mortality associated with powerhouse passage. The ISAB concluded (ISAB 2012) that these analyses indicated that delayed mortality is associated with powerhouse passage.

Literature Cited

Burnham, KP, DR Anderson, GC White, C Brownie, and KH Pollock. 1987. Design and analysis methods for fish survival experiments based on release–recapture. *American Fisheries Society Monograph*, *5*(5).

Clopper, CJ and ES Pearson. 1934. The use of confidence or fiducial limits illustrated in the case of the binomial. *Biometrika*, 26, 404–413.

FPC (Fish Passage Center). 2008. Fish Passage Center Annual Report, 2008. http://www.fpc.org/documents/FPC_Annual_Reports.html

FPC (Fish Passage Center). 2011. Fish Passage Center Annual Report, 2011. http://www.fpc.org/documents/FPC_Annual_Reports.html

FPC (Fish Passage Center) Memos:
October 6, 2010 - http://www.fpc.org/documents/memos/135-10.pdf
January 19, 2011 - http://www.fpc.org/documents/memos/08-11.pdf
July 14, 2011 - http://www.fpc.org/documents/memos/102-11.pdf

Haeseker, SL, JM McCann, JE Tuomikoski, and B. Chockley. 2012. Assessing freshwater and marine environmental influences on life-stage-specific survival rates of Snake River spring/summer Chinook and steelhead. *Transactions of the American Fisheries Society*, 141:1, 121–138.

ISAB (Independent Scientific Advisory Board). 2012. Follow-up to ISAB reviews of three FPC memos and CSS annual reports regarding latent mortality of in-river migrants due to route of dam passage. Prepared for Northwest Power and Conservation Council, Columbia River Basin Indian Tribes and National Marine Fisheries Service. ISAB/ISRP 2012-1. January 3, 2012.

Petrosky, CE and HA Schaller. 2010. Influence of river conditions during seaward migration and ocean conditions on survival rates of Snake River Chinook salmon and steelhead. *Ecology of Freshwater Fish* 19(4): 520–536.

Tuomikoski, J, J McCann, T Berggren, H Schaller, P Wilson, S Haeseker, J Fryer, C Petrosky, E Tinus, T Dalton, and R Ehlke. 2010. Comparative Survival Study (CSS) of PIT-tagged Spring/Summer Chinook and Summer Steelhead, 2010 Annual Report. Project No. 199602000. http://www.fpc.org/documents/CSS/2010%20CSS%20Annual%20Report--Final.pdf

White, GC and KP Burnham. 1999. "Program MARK: survival estimation from populations of marked animals." *Bird study* 46.S1 (1999): S120–S139.