



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: Jeff Fryer, CRITFC

From: Michele DeHart

Date: September 20, 2018

Re: Okanogan River sockeye passage timing, travel times, juvenile survival, and smolt-to-adult returns, migration years 2013-2018 (Revised).

In 2013, the Comparative Survival Study (CSS) Oversight Committee was approached with a request to explore the feasibility of adding a long-term monitoring group for sockeye trapped and released from the Okanogan River. Upon the request from the Okanogan Nation Alliance (ONA) and the Columbia River Inter-tribal Fish Commission (CRITFC), the CSS Oversight Committee has transferred surplus PIT-tags to the ONA since 2013 to supplement PIT-tagging efforts at Skaha and Osoyoos lakes in the spring. Over the years, these efforts have been supported and/or funded by several agency and tribal organizations, including: Department of Fisheries and Oceans Canada, CRITFC, Chelan and Grant PUDs, and the ONA.

Based on the results from 2013 and 2014, the CSS Oversight Committee began including estimates of overall SARs from this group (Okanogan River sockeye) in their annual report. In response to your request, we have updated analyses from previous year's data requests to include estimates of juvenile survival, timing, and travel time for the 2018 PIT-tagged sockeye smolts. In addition, we provide updated estimates of overall SARs from migration years 2013-2016, with adults detected at Bonneville Dam through September 15, 2018. Below are results from these updated analyses, followed by more specific details.

- Estimating juvenile survival from Release to Rocky Reach Dam (Release-RRH) has been possible for all years of tagging (2013-2018). Juvenile survival for Release-RRH in 2018 was 0.62 (95% CI: 0.57-0.67).

- Reliable estimates of juvenile sockeye survival beyond Rocky Reach Dam has not always been possible and, therefore, it has not always been possible to estimate survival from Release to McNary Dam. However, we were able to estimate survival from Release-MCN in 2018, which was 0.54 (95% CI: 0.36–0.72).
- A total of 32 and 13 PIT-tagged Okanogan River sockeye juveniles were detected at Zosel Dam and/or at the Okanogan Channel in 2018, respectively. However, detection probabilities at these two sites were sufficiently low that we were unable to estimate survival from release to these sites.
- The 2018 Draft CSS Annual Report provides estimates of smolt-to-adult return (SAR) rates for Rocky Reach-to-Bonneville (RRE-to-BOA) for migration years 2013-2016 and McNary-to-Bonneville (MCN-to-BOA) for migration years 2014-2016. The RRE-to-BOA SARs for 2013-2016 have ranged from 1.30% (95% CI: 1.05-1.56%) to 8.13% (95% CI: 6.96-9.45%). The MCN-to-BOA SARs for 2014-2016 ranged from 1.58 (95% CI: 1.06-2.21%) to 2.99 (95% CI: 2.25-3.71%).

Methods

Timing and Travel Time

Juvenile passage timing and fish travel times were estimated for 2013-2018 out-migrants based on PIT-tag detections at various dams within the Rocky Reach to Bonneville Dam reach. For each year, we estimated cumulative juvenile passage timing based on PIT-tag detections at Rocky Reach (RRE), McNary (MCN), John Day (JDA), and Bonneville (BON) dams. Daily PIT-Tag detections at each of these projects were summed and adjusted based on the average proportion of flows that passed through the powerhouse. Minimum, median, and maximum fish travel times were estimated from release to detection at each dam in the reach that has detection capabilities. Due to a high number of PIT-tag detections in 2015 and 2018, we also include estimates of travel time and passage timing to Zosel Dam on the Okanogan River for these two migration years. Finally, we provide estimates of travel time and passage timing to Okanogan Channel in 2018.

Juvenile Survival

For each migration year, we attempted to estimate smolt survival and associated variance estimates for all PIT-tagged juvenile sockeye from their release in the Okanogan Basin to MCN. We relied on juvenile detections at RRE, MCN, JDA, and BON dams, 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 using the Cormack-Jolly-Seber (CJS) methodology as described by Burnham et al. (1987) with the Mark program (software available free from Colorado State University) (White and Burnham 1999). In addition to estimating individual reach survivals (e.g., Release-RRE and RRE-MCN) we also attempted to estimate combined reach survival (i.e., Release-MCN) by multiplying individual reach estimates and determining the approximate variance using the delta method (Burnham et al. 1987).

Over the years, wild Okanogan Basin sockeye have been tagged and released from various sites, including: Osoyoos Lake Narrows Highway 3 Bridge (OSOYBR), Osoyoos Lake (OSOYOL), Osoyoos Lake at Haynes Point Campground (OSOYHA), Skaha Dam or just below (up to 0.5 km) (SKA or SKATAL), and Skaha Lake (SKAHAL). Using the same methodologies outlined above, we estimated individual (e.g., Release-RRE and RRE-MCN) and combined reach survivals (Release-MCN) for each of these release sites, by migration year.

Finally, in response to your request, we investigated whether there were enough PIT-tag detections of juvenile Okanogan River sockeye at Zosel Dam (ZSL) and the Okanogan Channel (OKC) to estimate survival from release to each of these two interrogation sites.

Smolt to Adult Survival (SARs)

With the complete return of adults from the 2013-2015 out-migrations and the nearly complete return from the 2016 out-migration, we were able to estimate Smolt-to-Adult Returns (SARs). Given the juvenile detection capabilities at RRE, we estimated SARs for two different reaches: 1) juveniles at RRE to adult returns at BON (RRE-to-BOA) and 2) juveniles at MCN to adult returns at BON (MCN-to-BOA). The methodology for estimating SARs is discussed in Chapter 4 of the CSS Annual Report (McCann et al., 2018). Estimates of SARs that are provided in McCann et al. (2018) included adults detected at BOA through July 21, 2018. For this request, we investigated whether any additional Okanogan sockeye adults were detected at BOA through September 15, 2018. However, there were no additional detections of Okanogan sockeye adults at BOA between July 21st and September 15th.

Results

To put out-migration conditions into context, Table 1 and Figure 1 provide the average spring flow volumes (April 15–June 30) for the Upper Columbia River (as measured at Priest Rapids Dam), along with the average spring spill proportions at each of Wells, Rocky Reach, Rock Island, Wanapum, and Priest Rapids dams in 2013-2018.

Table 1. Average spring (April 15–June 30) flow at Priest Rapids Dam (PRD) and average spill proportion at Wells (WEL), Rocky Reach (RRH), Rock Island (RIS), Wanapum (WAN), and PRD dams in 2013-2018.

Migration Year	Average Flow at	Average Spill Proportion				
	PRD (Kcfs)	WEL	RRE	RIS	WAN	PRD
2013	186.6	0.11	0.10	0.15	0.26	0.29
2014	189.4	0.13	0.10	0.21	0.31	0.35
2015	114.3	0.08	0.04	0.14	0.15	0.23
2016	156.2	0.11	0.08	0.17	0.19	0.27
2017	238.0	0.18	0.32	0.36	0.47	0.53
2018	235.5	0.27	0.28	0.32	0.41	0.43

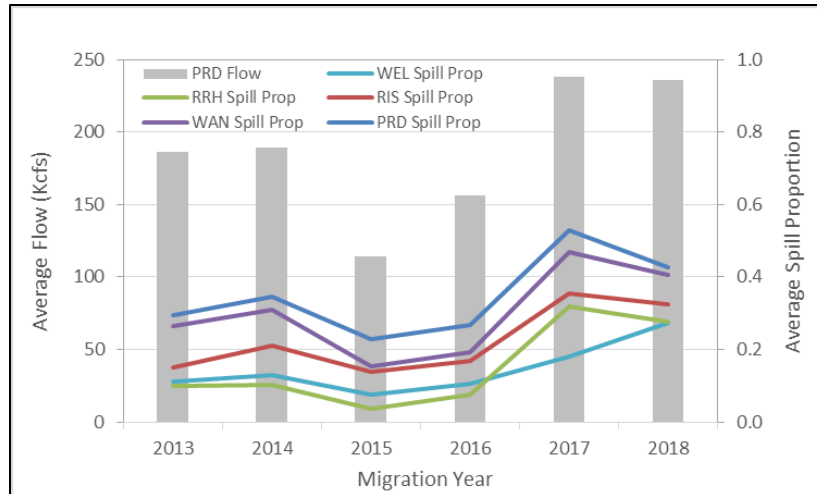


Figure 1. Average spring (April 15–June 30) flow at Priest Rapids Dam (PRD) and average spill proportion at Wells (WEL), Rocky Reach (RRH), Rock Island (RIS), Wanapum (WAN), and PRD in 2013-2018.

Travel Time and Timing

Over the last five years, PIT-tagging of juvenile sockeye in the Okanogan River Basin has varied, in both timing and the number of PIT-tags that have been released (Table 2). It is important to consider the variability in the timing of PIT-tagging efforts when assessing passage timing between years.

Table 2. Timing of PIT-tagging efforts and number of PIT-tagged Okanogan River Basin sockeye smolts released in migration years 2013-2018.

Migration Year	PIT-tagging Dates (Min and Max)	Total Tags Released
2013	Apr. 12-May 7	4,018
2014	Apr. 7-May 5	5,055
2015	Apr. 9-May 6	7,176
2016	Mar. 22-Apr. 29	10,238
2017	Apr. 26-May 3	11,588
2018	Apr. 16-18, May 2-9	10,943

Travel Time

Estimates of minimum, median, and maximum travel times from release to RRE, MCN, JDA, and BON dams are provided below (Table 3). These travel times are based on fish that were detected at each of the sites in their respective year of out-migration. Also provided are estimates of the 95% confidence limits around the estimated median travel time.

Due to a relatively high number of PIT-tag detections in 2015 and 2018, travel times to ZSL are also provided for these two years. It is important to note that the detection system at ZSL was not installed until April 25th in 2018, a week after tagging in Osoyoos Lake concluded. Therefore, many earlier fish tagged and released from Osoyoos Lake may have been missed at

this detection site. In addition, the last detection at ZSL was May 22nd, which is around the same time that flooding impacted the antenna and ultimately led to it being partially pulled from the water. Therefore, late migrating fish may have been missed at this site.

Finally, we estimated travel times from release to OKC in 2018, based on 13 PIT-tag detections. These travel time estimates are based on the fish tagged and released at Skaha Lake only, as this detection site is upstream of Osoyoos Lake.

Table 3. Travel times from release to juvenile detection site of PIT-tagged Okanogan River Basin sockeye smolts from migration years 2013 to 2018. PIT-tag detection sites include: Okanogan Channel (OKC), Zosel (ZSL), Rock Reach (RRE), McNary (MCN), John Day (JDA), and Bonneville (BON) dams.

Migration Year	Project	Release to Project Travel Time (days)			95% Confidence Limits	
		Min	Med	Max	Lower	Upper
2013	RRE	5.6	19.4	56.3	18.7	19.9
	MCN	10.0	23.7	63.7	22.1	24.7
	JDA	12.0	25.5	62.3	24.0	27.2
	BON	16.3	28.2	57.3	26.6	29.0
2014	RRE	4.4	16.7	40.6	16.4	17.4
	MCN	8.1	19.4	54.8	18.8	20.0
	JDA	13.0	23.0	67.5	22.1	24.0
	BON	11.8	22.7	59.0	20.8	24.6
2015	ZSL	4.7	14.2	31.0	12.0	16.0
	RRE	5.9	15.7	39.4	15.4	16.1
	MCN	14.0	23.2	43.0	21.6	24.0
	JDA	17.0	24.5	49.5	23.0	25.7
	BON	16.9	25.9	48.2	24.9	26.4
2016	RRE	3.8	16.7	49.5	16.4	17.4
	MCN	8.0	21.4	51.5	20.6	22.3
	JDA	11.2	22.0	71.1	21.0	23.0
	BON	12.4	23.7	58.9	23.3	24.6
2017	RRE	4.5	10.5	61.4	10.4	10.6
	MCN	8.1	15.0	31.5	14.2	15.4
	JDA	9.9	15.9	40.1	15.2	16.0
	BON	10.8	17.8	46.4	17.5	18.4
2018	OKC	0.9	3.1	7.7	1.8	3.7
	ZSL	7.1	11.2	33.1	10.3	12.3
	RRE	4.8	14.9	54.3	14.6	15.7
	MCN	7.8	19.1	43.6	18.4	19.7
	JDA	10.1	17.1	42.5	15.7	18.3
	BON	11.0	21.4	46.0	20.8	21.9

Timing

Overall, PIT-tagged sockeye smolts from the Okanogan River Basin passed through RRE from early to mid-May and Mid-Columbia Projects (MCN, JDA, and BON) in mid-May to early June (Table 4, Figure 2). In 2015, PIT-tagged sockeye smolts passed through ZSL Dam in late April to early May. Timing of PIT-tagged sockeye smolts at ZSL in 2018 was a bit later than 2015, with the estimated 50% and 90% passage dates occurring in mid-May (Table 4). However, it is important to note that the timing estimates at ZSL in 2018 may have been impacted by two things: 1) a later installation date and 2) flooding that caused the antenna to be partially pulled in late May. The detection system at ZSL was not installed until April 25th, a week after tagging at Osoyoos Lake had concluded. Therefore, many fish tagged and released from Osoyoos Lake may have been missed at this detection site. In addition, the last detection at ZSL was May 22nd, which is around the same time that flooding impacted the antenna and ultimately led to it being partially pulled from the water. Therefore, late migrating fish may have been missed at this site.

As requested, we estimated juvenile timing to OKC in 2018. As with the estimates of travel time to OKC, these timing estimates are based on fish tagged and released from Skaha Lake only, as this detection site is upstream from Osoyoos Lake. Tagging efforts on Skaha Lake occurred between May 2nd and May 9th in 2018. Arrival timing to some of the other sites (e.g., ZSL, RRE, and MCN) may appear to be earlier than, or the same as, OKC because they are based on all fish tagged and released in 2018, and not just those that were tagged and released from Skaha Lake in early May (Table 4).

Table 4. Migration timing of PIT-tagged Okanogan River Basin sockeye smolts detected at Zosel (ZSL), Rocky Reach (RRE), McNary (MCN), John Day (JDA), and Bonneville (BON) dams in migration years 2013 to 2018.

Migration Year	Project	Estimated Passage Date		
		10%	50%	90%
2013	RRE	8-May	13-May	18-May
	MCN	11-May	17-May	25-May
	JDA	14-May	21-May	27-May
	BON	15-May	24-May	2-Jun
2014	RRE	10-May	14-May	22-May
	MCN	12-May	19-May	24-May
	JDA	16-May	22-May	28-May
	BON	16-May	21-May	28-May
2015	ZSL	30-Apr	4-May	9-May
	RRE	6-May	12-May	19-May
	MCN	13-May	18-May	26-May
	JDA	16-May	20-May	25-May
	BON	17-May	21-May	27-May
2016	RRE	24-Apr	5-May	10-May
	MCN	27-Apr	10-May	18-May
	JDA	29-Apr	10-May	20-May
	BON	1-May	12-May	20-May
2017	RRE	8-May	11-May	20-May
	MCN	12-May	14-May	23-May
	JDA	13-May	16-May	24-May
	BON	14-May	18-May	26-May
2018	OKC*	7-May	9-May	12-May
	ZSL	28-Apr	14-May	19-May
	RRE	2-May	12-May	20-May
	MCN	7-May	14-May	23-May
	JDA	10-May	17-May	24-May
	BON	11-May	18-May	27-May

* The OKC detection system is located upstream of Osoyoos Lake. Therefore, timing at this site is based on fish tagged and released at Skaha Lake only. Tagging efforts on Skaha Lake occurred from May 2nd through May 9th in 2018. Timing at the other sites includes all fish tagged in 2018.

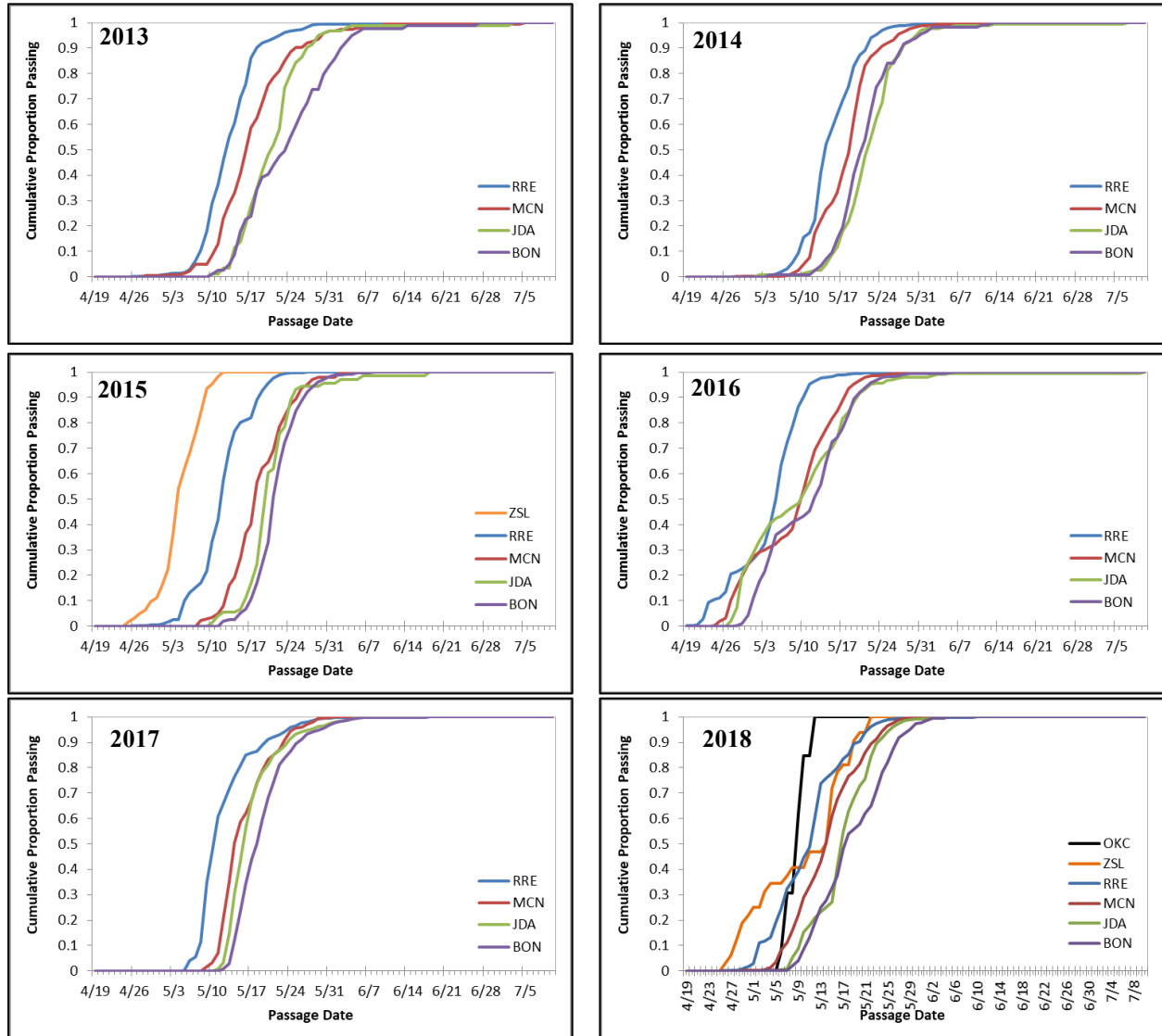


Figure 2. Cumulative passage timing of PIT-tagged wild Okanogan River basin sockeye smolts at Rocky Reach (RRE), McNary (MCN), John Day (JDA), and Bonneville (BON) dams in migration years 2013-2018. Cumulative passage timing to Zosel Dam (ZSL) is provided for MY 2015 and 2018 and the Okanogan Channel for MY 2018. Note: the OKC detection system is located upstream of Osoyoos Lake. Therefore, timing at this site is based on fish tagged and released at Skaha Lake only. Tagging efforts on Skaha Lake occurred from May 2nd through May 9th in 2018. Timing to the other sites includes all fish tagged in 2018.

Juvenile Survival

All Release Sites Combined

Estimates of individual reach survival (Release-RRE and RRE-MCN) and combined survival (Release-MCN) for each migration year (all release sites combined) are provided in Table 5. For 2013, we were only able to estimate survival from Release-RRE (0.49, 95% CI: 0.42-0.56). The total number of tags released in 2013 (4,018) was not sufficient to get reliable estimates of survival below RRE. This is largely due to low numbers of subsequent downstream detections. For example, of the 183 PIT-tagged sockeye smolts that were detected at MCN, only 19 were subsequently detected downstream of MCN. This low number of downstream detections led to an anomalous estimate of survival from RRE-MCN that was greater than 1.0 with a high standard error. Given the anomalous estimate of survival from RRE-MCN, we were also not able to estimate survival from Release-MCN for 2013.

Migration years 2014-2018 had higher total release numbers, which allowed for the estimation of not only individual reach survivals but also a combined (Release-MCN) reach survival for each year (Table 5).

Table 5. Survival of PIT-tagged sockeye juveniles tagged and released into the Okanogan River Basin in 2013-2018.

Migration Year	Number Tagged	Release-RRE (95% CI)	RRE-MCN (95% CI)	Release-MCN (95% CI)
2013	4,018	0.49 (0.42-0.56)	N/A	N/A
2014	5,055	0.57 (0.51-0.64)	0.68 (0.52-0.84)	0.39 (0.31-0.47)
2015	7,176	0.42 (0.38-0.45)	0.78 (0.53-1.03)	0.32 (0.22-0.42)
2016	10,238	0.56 (0.53-0.59)	0.80 (0.65-0.94)	0.45 (0.28-0.62)
2017	11,588	0.67 (0.62-0.72)	0.96 (0.09-1.00)	0.65 (0.51-0.78)
2018	10,943	0.62 (0.57-0.67)	0.87 (0.61-0.96)	0.54 (0.36-0.72)

Survival by Release Site

Of the 4,018 total wild sockeye that were tagged and released in 2013, 1,178 were tagged and released from Skaha Dam or just below (SKA or SKATAL), 2,783 were tagged and released from Osoyoos Lake Narrows Bridge (OSOYBR), and 57 were tagged and released from Osoyoos Lake (OSOYOL). Too few tags were released from OSOYOL to estimate survivals for this release location. For the SKA-SKATAL and OSOYBR release sites, we were only able to obtain reliable estimates of survival for the Release-RRE reach, which were 0.46 (95% CI: 0.36-0.57) for fish released at SKA-SKATAL and 0.50 (95% CI 0.41-0.58) for fish released at OSOYBR (Table 6). Estimates of survival for the RRE-MCN reach were unreliable for both release sites and, therefore, are not reported in Table 6.

In 2014, a total of 5,055 PIT-tagged sockeye were released in the Okanogan Basin. Of these, 1,348 were tagged and released from Skaha Dam or just below (SKA or SKATAL) and 3,707 were tagged and released from Osoyoos Lake Narrows Bridge (OSOYBR). For 2014, we were able to generate estimates of both individual reach survival (Release-RRE and RRE-MCN) and combined reach survival (Release-MCN) for each of the two release sites (Table 6). Fish tagged and released from SKA-SKATAL had a Release-MCN survival of 0.25 (95% CI: 0.13-

0.36) whereas those from OSOYBR had a Release-MCN survival of 0.44 (95% CI: 0.34-0.54) (Table 6).

In 2015, 7,176 total sockeye smolts were PIT-tagged and released into the Okanogan River Basin. Of these, 5,435 were tagged and released just below Skaha Dam (SKATAL) and 1,741 were tagged and released from Osoyoos Lake Narrows Bridge (OSOYBR). We were able to generate estimates of Release-RRE for both release sites (Table 6). However, we were only able to generate a reliable estimate of RRE-MCN survival for the SKATAL release site, which was 0.70 (95% CI: 0.46-0.95) (Table 6). The estimate of RRE-MCN survival for the OSOYBR release site was greater than 1.0 and, therefore, deemed unreliable. Similar to 2013, this was due to the lower release total for this group and the low number of detections at and below MCN. Of the 35 OSOYBR fish that were detected at MCN in 2015, only five were subsequently detected downstream of MCN. Because the RRE-MCN survival estimate was unreliable for the OSOYBR release site, we could not estimate survival from Release-MCN for this group. However, we were able to estimate Release-MCN survival for the SKATAL release site, which was 0.28 (95% CI: 0.19-0.38) (Table 6).

In 2016, 10,238 total sockeye smolts were PIT-tagged and released from four different release sites in the Okanogan River Basin. Of these, 2,338 were tagged and released at Skaha Lake (SKAHAL), 3,102 were tagged and released just below Skaha Dam (SKATAL), 1,754 were tagged and released from Osoyoos Lake Narrows Bridge (OSOYBR), and 3,044 were tagged and released from Osoyoos Lake (OSOYOL). We were able to generate estimates of individual reach survival (i.e., Release-RRE and RRE-MCN) for all four release sites (Table 6). In addition, we were able to estimate Release-MCN survival for all four release sites. These Release-MCN survivals were: 0.38 (95% CI: 0.23-0.53) for the SKAHAL release site, 0.39 (95% CI: 0.19-0.59) for the SKATAL release site, 0.53 (95% CI: 0.31-0.75) for the OSOYBR release site, and 0.51 (95% CI: 0.31-0.75) for the OSOYOL release site. Although the point estimates of Release-MCN survival appear to be lower for the two Skaha release sites (SKAHAL and SKATAL) compared to the two Osoyoos release sites (OSOYBR and OSOYOL), the confidence intervals for all four of these release sites overlap. This indicates that these differences in survival are likely not significant.

A total of 11,588 sockeye smolts were PIT-tagged and released from two different release sites in 2017. Of these, 2,794 were tagged and released from Osoyoos Lake Narrows Bridge (OSOYBR) and 8,794 were tagged and released from Osoyoos Lake (OSOYOL). We were able to generate estimates of Release-RRE survival for both release sites (Table 6). However, we were only able to estimate RRE-MCN survival for the OSOYOL release site, as the estimate for the OSOYBR release site was unreliable. Therefore, we were only able to estimate Release-MCN survival for the OSOYOL release site. The 2017 Release-MCN survival for the OSOYOL release site was 0.60 (95% CI: 0.46-0.73).

In 2018, 10,943 total sockeye smolts were PIT-tagged and released from three different release sites. Of these, 1,521 were tagged and released from Osoyoos Lake (OSOYOL), 3,562 were released from Osoyoos Lake at Haynes Point Campground (OSOYHA), and 5,860 were released from Skaha Lake (SKAHAL). We were able to generate estimates of Release-RRE and RRE-MCN survival estimates for all three release sites (Table 6). In addition, we were able to

estimate Release-MCN survival for each release site separately. The 2018 Release-MCN survivals for the OSOYOL, OSOYHA, and SKAHAL release sites were 0.36 (95% CI: -0.01-0.73), 0.62 (95% CI: 0.44-0.80), and 0.52 (95% CI: 0.39-0.66), respectively (Table 6). Finally, there were a total of 32 detections of PIT-tagged Okanogan River sockeye at ZSL and 13 detections at OKC in 2018. While we were able to estimate travel time and/or timing to these two sites, we were unable to get reliable estimates of survival from release to ZSL or release to OKC, as the estimated detection probabilities at the two sites were extremely low (~0.001).

It is worth noting that the different release sites utilized for Okanogan River Basin sockeye marking over the years have relied on three different capture methods: screw trap, purse seines, and fyke nets (Table 6). Unfortunately, it is not possible to isolate the effects of capture method on estimates of survival as each release site typically relied on a single capture method each year and, therefore, capture method effects would be confounded with the effects of release site. The one exception to this is OSOYBR in 2017, where both the fyke net and purse sein methods were used. However, of the 2,794 total sockeye smolts that were tagged and released at this site, only 152 were captured using the fyke net method. With so few tags being released from the fyke net capture method, we were unable to generate reliable estimates of reach survivals for this capture method. Therefore, we were unable to compare the two capture methods.

Table 6. Survival of PIT-tagged sockeye juveniles, by release site, tagged and released into the Okanogan River in 2013-2018.

Migration Year	Release Site	Number Tagged	Capture Method	Release-RRE (95% CI)	RRE-MCN (95% CI)	Release-MCN (95% CI)
2013	SKA-SKATAL	1,178	ST	0.46 (0.36-0.57)	N/A	N/A
	OSOYOL	57	FN	N/A	N/A	N/A
	OSOYBR	2,783	FN	0.50 (0.42-0.59)	N/A	N/A
2014	SKA-SKATAL	1,348	ST	0.41 (0.29-0.54)	0.60 (0.27-0.92)	0.25 (0.13-0.36)
	OSOYBR	3,707	FN	0.63 (0.56-0.71)	0.69 (0.52-0.87)	0.44 (0.34-0.54)
2015	SKATAL	5,435	ST	0.41 (0.37-0.45)	0.70 (0.46-0.95)	0.29 (0.19-0.38)
	OSOYBR	1,741	FN	0.44 (0.36-0.52)	N/A	N/A
2016	SKAHAL	2,338	PS	0.48 (0.44-0.53)	0.79 (0.47-1.11)	0.38 (0.23-0.53)
	SKATAL	3,102	ST	0.47 (0.41-0.53)	0.84 (0.59-1.09)	0.39 (0.19-0.59)
	OSOYBR	1,754	FN	0.74 (0.65-0.84)	0.71 (0.41-1.02)	0.53 (0.31-0.75)
	OSOYOL	3,044	PS	0.56 (0.51-0.62)	0.91 (0.57-1.24)	0.51 (0.31-0.75)
2017	OSOYBR	2,794	PS, FN	0.82 (0.63-0.93)	N/A	N/A
	OSOYOL	8,794	PS	0.64 (0.59-0.69)	0.93 (0.31-1.00)	0.60 (0.46-0.73)
2018	OSOYOL	1,521	PS	0.59 (0.46-0.70)	0.61 (0.32-0.84)	0.36 (-0.01-0.73)
	OSOYHA	3,562	PS	0.69 (0.61-0.76)	0.89 (0.31-0.99)	0.62 (0.44-0.80)
	SKAHAL	5,860	PS	0.59 (0.51-0.66)	0.89 (0.38-0.99)	0.52 (0.39-0.66)

Capture Methods: ST = Screw Trap, FN = Fyke Net, and PS = Purse Seine

Smolt to Adult Survival (SARs)

To date, the CSS Annual Report has provided SARs for Okanogan River Basin sockeye for both the Rocky Reach-to-Bonneville (RRE-to-BOA) and McNary-to-Bonneville (MCN-to-BOA) reaches for migration years 2013-2016. These estimates of SARs are based on all release sites combined and are summarized below (Table 7, Figure 3). Due to an unreliable estimate of

juvenile survival for the RRH-MCN reach in 2013 (Table 5), the MCN-to-BOA SAR for 2013 is not provided.

Table 7. Overall McNary-to-Bonneville (MCN-to-BOA) and Rocky Reach-to-Bonneville (RRE-to-BOA) SARs for Okanogan River wild sockeye, 2013-2016.

Juvenile migration year	Smolts arriving MCN ^A	MCN-to-BOA			Smolts arriving RRE ^B	RRE-to-BOA		
		%SAR Estimate	Non-parametric CI			%SAR Estimate	Non-parametric CI	
			90% LL	90% UL			90% LL	90% UL
2013 ^{C,D}	--	--	--	--	1,993	8.13	6.96	9.45
2014 ^C	2,110	2.99	2.25	3.71	2,937	2.15	1.70	2.66
2015	2,538	1.58	1.06	2.21	3,064	1.31	0.98	1.67
2016 ^{C,E}	4,522	1.68	1.30	2.07	5,777	1.30	1.05	1.56

^A Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.

^B CJS estimation of S1 uses both the detector and recaptures at Rocky Reach Dam, as well as PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.

^C PIT-tagged sockeye were coded as “unknown” rearing type. Some PIT-tagged smolts may have been hatchery sockeye released into Skaha Lake as fry.

^D Juvenile survival estimate for RRE-MCN reach was greater than 100%, resulting in an overestimate of the juvenile population at MCN. Therefore, SAR_{MCN-to-BOA} was not estimated for this year.

^E Incomplete, 2-salt returns through Sept. 15, 2018.

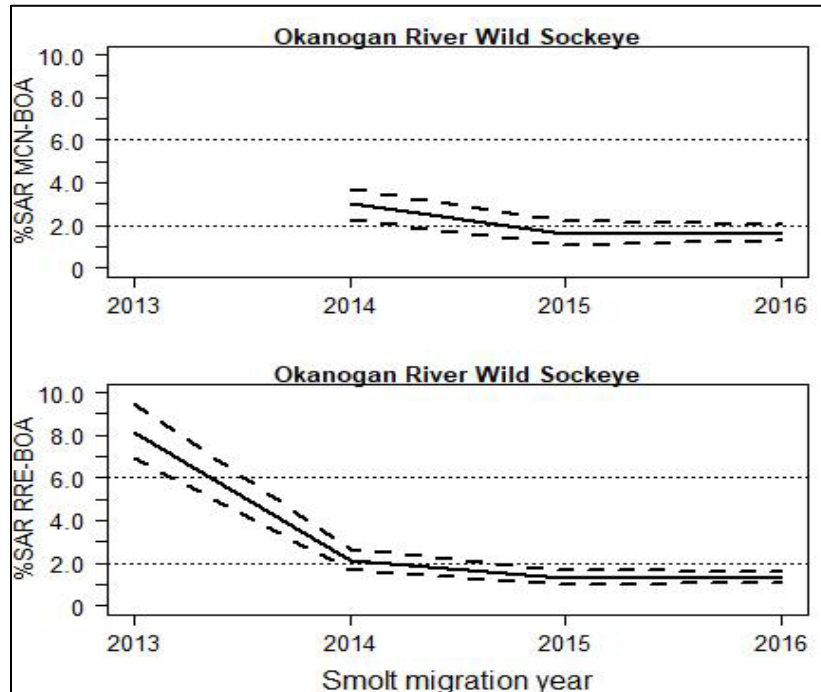


Figure 3. Bootstrapped SAR (MCN-to-BOA and RRE-to-BOA) and upper and lower CI for Okanogan River sockeye, 2013-2016 migration years. The NPCC (2014) 2%-6% SAR objective for listed wild populations is shown for reference. Figure adapted from Figure 4.20 of McCann et al. (2018)

Conclusions

The CSS Oversight Committee continues to believe that a long-term monitoring group for wild sockeye from the Okanogan Basin would be valuable. Results from the last five years of tagging indicate that, with a minimum of 5,000 PIT-tags released per year, the CSS will continue to be able to estimate juvenile survival from release to MCN and SARs for both the RRE-to-BOA and MCN-to-BOA reaches. The CSS Oversight Committee hopes to continue to incorporate results from this group into future annual reports.

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