



FISH PASSAGE CENTER

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MEMORANDUM

TO: Charlene Hurst, NOAA

FROM: Michele DeHart

DATE: September 14, 2017

RE: Juvenile survival and travel times for Snake River hatchery yearling spring/summer Chinook, yearling fall Chinook, subyearling fall Chinook, steelhead, sockeye, and coho and Upper Columbia hatchery yearling spring Chinook, yearling summer Chinook, subyearling summer Chinook, steelhead, and coho (2012-2016).

In response to your request, The Fish Passage Center (FPC) is providing estimates of juvenile survival and travel time for Snake River hatchery yearling spring/summer Chinook, yearling fall Chinook, subyearling fall Chinook, steelhead, sockeye, and coho for migration years 2012 through 2016. In addition, we are providing estimates of juvenile survival and travel time for Upper Columbia hatchery yearling spring Chinook, yearling summer Chinook, subyearling summer Chinook, steelhead, and coho for migration years 2012 through 2016.

Specifically, you requested the FPC to estimate juvenile survival and travel time from Lower Granite Dam to McNary Dam for hatchery Snake River species. For Upper Columbia groups, you requested estimates of survival and travel time of Upper Columbia hatchery fish to McNary Dam. Due to limited juvenile PIT-tag detection capabilities in the Upper Columbia, we separated Upper Columbia hatchery species into two groups: 1) those released into the Columbia River, or its tributaries, above Rock Reach Dam (herein referred to as Above RRH) and 2) those released in the Wenatchee River. For the Above RRH group, we estimated juvenile survival and travel times from Rocky Reach Dam to McNary Dam. For the Wenatchee River groups we estimated juvenile survival and travel time from release to McNary Dam.

Travel Time

For this portion of the request, we estimated separate minimum, median, and maximum fish travel times for each migration year. For the Snake River groups, travel time was estimated from detection at Lower Granite Dam (LGR) to detection at McNary Dam (MCN). For the Upper Columbia groups, travel time was estimated from detection at Rocky Reach Dam (RRH) to detection at McNary Dam (MCN) for the Above RRH groups and release to MCN for the Wenatchee River groups. In addition, we provide estimates of the 95% confidence limits around these estimated median travel times.

Snake River Groups

For the Snake River groups, PIT-tag release numbers, and subsequent downstream detections were sufficiently large to generate estimates of median fish travel times (LGR-MCN) and 95% confidence intervals for nearly all of the species and migration years (Table 1). There was only one exception to this, 2015 hatchery coho. Due to low detection probabilities, only four PIT-tagged hatchery coho were detected at both LGR and MCN. Therefore, we could not estimate a 95% confidence interval for this group.

Table 1. Estimated Lower Granite to McNary travel times for Snake River hatchery yearling spring/summer Chinook (Sp/Su CH1), yearling fall Chinook (Fa CH1), subyearling fall Chinook (Fa CH0), steelhead (ST), sockeye (SO), and coho (CO) in migration years 2012-2016.

Species	Migration Year	Number Detected	Travel Time (Days)			95% Confidence Limits	
			Min	Med	Max	Lower	Upper
Sp/Su CH1	2012	6,959	3.9	9.8	54.9	9.7	10.0
	2013	3,871	4.5	9.6	171.6	9.5	9.8
	2014	7,437	4.4	10.9	74.3	10.8	11.0
	2015	2,455	5.2	10.8	41.2	10.6	11.0
	2016	12,355	4.1	9.3	42.8	9.3	9.4
Fa CH1	2012	1,949	4.4	12.5	66.7	12.3	12.8
	2013	265	4.9	10.5	42.3	9.8	11.1
	2014	145	6.2	10.3	29.5	9.6	10.7
	2015	43	6.9	9.5	31.5	8.8	10.3
	2016	153	5.2	9.8	28.4	9.2	10.5
Fa CH0	2012	2,175	5.0	10.6	90.6	10.4	10.8
	2013	329	5.5	11.0	46.8	10.3	11.7
	2014	383	5.4	10.9	44.5	10.5	11.4
	2015	126	7.2	13.6	32.0	12.5	15.1
	2016	204	5.1	9.2	27.7	9.0	9.7
ST	2012	2,245	3.2	6.9	37.1	6.8	7.0
	2013	1,299	3.8	9.0	35.9	8.8	9.1
	2014	1,973	3.6	7.9	40.7	7.8	8.0
	2015	668	5.1	9.4	39.4	9.2	9.5
	2016	5,086	3.7	6.7	33.5	6.6	6.7
SO	2012	476	4.4	9.4	32.7	9.0	9.7
	2013	299	3.7	6.2	31.2	5.8	6.6
	2014	104	4.3	5.8	25.7	5.5	6.1
	2015	39	5.3	7.5	15.7	6.8	8.0
	2016	59	4.5	7.5	11.9	6.8	7.7
CO	2012	65	3.8	6.7	16.7	6.0	7.2
	2013	15	4.5	7.7	12.3	5.3	8.9
	2014	26	4.7	7.3	10.9	6.8	8.0
	2015	4	6.9	7.0	8.3	---	---
	2016	72	4.7	6.8	13.9	6.4	7.0

Upper Columbia Groups

For the Upper Columbia groups originating above Rocky Reach Dam, PIT-tag release numbers, and subsequent downstream detections were sufficiently large to generate estimates of median fish travel time (RRH-MCN) and 95% confidence intervals for each species and migration year (Table 2). We were also able to estimate median travel time (and 95% confidence interval) for the Upper Columbia hatchery fish that were released into the Wenatchee River for all migration years and species (Table 3), with one exception. The one exception was yearling summer Chinook in migration year 2012. Although releases of hatchery yearling summer Chinook occurred in this migration year, no PIT-tags were released and, therefore, we could not estimate travel time or survival for this group.

Table 2. Estimated Rocky Reach to McNary travel times for Upper Columbia hatchery yearling spring Chinook (Sp CH1), yearling summer Chinook (Su CH1), subyearling summer Chinook (Su CH0), steelhead (ST), and coho (CO) released into the Columbia, its tributaries, above Rocky Reach Dam in migration years 2012-2016.

Species	Migration Year	Number Detected	Travel Time (Days)			95% Confidence Limits	
			Min	Med	Max	Lower	Upper
Sp CH1	2012	425	4.4	10.7	40.8	10.2	11.6
	2013	842	3.7	9.4	33.9	9.0	10.0
	2014	293	3.7	11.5	46.6	10.5	12.2
	2015	752	5.0	11.6	31.0	11.3	11.7
	2016	1,552	4.6	9.4	32.7	9.2	9.6
Su CH1	2012	394	5.4	26.6	91.5	25.3	27.8
	2013	457	4.5	11.2	116.0	10.0	11.9
	2014	571	3.9	14.5	93.5	13.2	15.5
	2015	336	5.7	13.9	56.2	12.7	15.4
	2016	1,465	5.2	14.6	59.0	14.0	15.5
Su CH0	2012	16	6.1	13.0	39.4	8.5	21.6
	2013	28	4.3	14.8	48.1	6.3	18.6
	2014	60	6.9	23.1	51.0	17.9	25.3
	2015	26	5.5	11.0	23.7	9.2	13.8
	2016	61	5.0	8.7	22.3	8.0	9.6
ST	2012	761	3.2	7.2	35.8	6.9	7.6
	2013	471	3.5	7.1	30.6	6.8	7.4
	2014	796	2.7	5.9	36.2	5.7	6.0
	2015	787	4.7	9.1	30.6	8.9	9.4
	2016	1,633	3.8	8.0	39.2	7.9	8.1
CO	2012	452	3.7	6.6	22.8	6.3	6.8
	2013	460	4.1	6.9	29.7	6.7	7.1
	2014	506	3.4	5.6	39.6	5.4	5.8
	2015	186	5.2	8.5	42.3	8.1	8.9
	2016	1,252	4.2	8.0	30.9	7.8	8.1

Table 3. Estimated Release to McNary travel times for Upper Columbia hatchery yearling spring Chinook (Sp CH1), yearling summer Chinook (Su CH1), steelhead (ST), and coho (CO) released into the Wenatchee River, migration years 2012-2016.

Species	Migration Year	Number Detected at MCN	Travel Time (Days)			95% Confidence Limits	
			Min	Med	Max	Lower	Upper
Sp CH1	2012	3,298	1.0	25.4	115.4	25.1	25.7
	2013	7,478	0.9	23.2	233.4	23.0	23.4
	2014	3,989	5.5	21.0	82.1	20.7	21.3
	2015	2,719	8.8	25.9	55.7	25.6	26.5
	2016	4,491	0.0	19.9	101.4	19.7	20.1
Su CH1	2012	---	---	---	---	---	---
	2013	490	6.4	18.9	57.6	18.3	19.6
	2014	2,181	4.1	12.1	93.6	11.9	12.2
	2015	835	7.3	15.7	63.0	15.2	15.9
	2016	2,381	6.4	17.1	49.1	16.9	17.2
ST	2012	902	1.1	13.6	81.6	12.9	14.6
	2013	708	0.5	18.3	70.7	17.5	19.0
	2014	338	4.9	16.5	61.0	15.0	17.4
	2015	463	7.5	21.8	176.8	20.9	22.9
	2016	1,397	4.5	15.4	68.8	14.9	15.9
CO	2012	1,747	0.8	20.0	81.4	19.3	20.8
	2013	1,253	7.2	27.9	86.8	26.9	28.9
	2014	1,064	17.2	35.2	71.8	34.7	35.6
	2015	824	3.8	35.8	88.5	34.9	36.8
	2016	3,135	6.6	22.9	55.0	22.7	23.0

Juvenile Survival

Snake River Groups

For the Snake River groups, we estimated juvenile survival from Lower Granite Dam to McNary Dam (LGR-MCN) for each species, by migration year (2012-2016). For yearling spring/summer Chinook, yearling fall Chinook, steelhead, sockeye, and coho, we developed a 6-digit capture history for all PIT-tagged hatchery fish released above LGR. This 6-digit capture history included the following: 1) release, 2) detection at LGR, 3) detection at Little Goose Dam (LGS), 4) detection at Lower Monumental Dam (LMN), 5) detection at MCN, and 6) detection at either John Day Dam (JDA), Bonneville Dam (BON), or the estuary trawl.

Due to the potential of holdovers, we were forced to limit our analyses for hatchery subyearling fall Chinook to those that were released above LGR but were detected at LGR before July 1st of the migration year of interest. Past FPC and Comparative Survival Study (CSS) reports have relied on a similar methodology to reduce the impact of holdovers on the estimation of juvenile survival and SARs (Tuomikoski et al. 2011, FPC 2017). Therefore, we relied on a 5-digit capture history for these fish. This 5-digit capture history included the following: 1) detection at LGR, 2) detection at LGS, 3) detection at LMN, 4) detection at MCN, and 5) detection at either JDA, BON, or the estuary trawl. Using these capture histories, single mark-release mark-recapture survival estimates were generated using Cormack-Jolly-Seber (CJS) methodology, as described by Burnham et al. (1987)

with program MARK (software available free from Colorado State University). (White and Burnham 1999).

This methodology generated estimates of survival for each of the individual reaches: 1) LGR-LGS, 2) LGS-LMN, and 3) LMN-MCN. These individual reach survivals were combined to estimate survival for the overall reach (LGR-MCN). Variance estimates for the product of individual reach survivals were generated using the delta method (Burnham et al. 1987). Using this methodology, estimates of individual reach survival (e.g., LGR-LGS, LGS-LMN, or LMN-MCN) can exceed 100%. However, individual reach estimates are often negatively correlated with adjacent reaches. Therefore, when estimating combined reach survivals (e.g., LGR-MCN) we allow individual reach survival estimates to exceed 100%. An overall reach survival was considered unreliable when its point estimate exceeded 100% or its coefficient of variation exceeded 25%.

Due to unreliable estimates for individual reaches (e.g., LGR-LGS, LGS-LMN, and/or LMN-MCN) we were unable to estimate survival from LGR-MCN for yearling fall Chinook in 2015, subyearling fall Chinook in 2016, coho in 2014, and coho in 2015. Estimates of LGR-MCN survival were possible for all other years and species (Table 4).

Table 4. Estimated juvenile survival (LGR-MCN) for Snake River hatchery yearling spring/summer Chinook (Sp/Su CH1), yearling fall Chinook (Fa CH1), subyearling fall Chinook (Fa CH0), steelhead (ST), sockeye (SO), and coho (CO) in migration years 2012-2016. Numbers in parentheses are the 95% confidence intervals.

Species	Migration Year	LGR-MCN Survival
Sp/Su CH1	2012	0.84 (0.80-0.89)
	2013	0.90 (0.84-0.97)
	2014	0.86 (0.80-0.91)
	2015	0.85 (0.77-0.94)
	2016	0.78 (0.74-0.82)
Fa CH1	2012	0.78 (0.69-0.88)
	2013	0.80 (0.66-0.95)
	2014	0.73 (0.59-0.86)
	2015	---
	2016	0.77 (0.64-0.90)
Fa CH0	2012	0.74 (0.65-0.83)
	2013	0.67 (0.48-0.86)
	2014	0.77 (0.61-0.93)
	2015	0.55 (0.25-0.86)
	2016	---
ST	2012	0.78 (0.70-0.86)
	2013	0.72 (0.65-0.79)
	2014	0.74 (0.65-0.83)
	2015	0.80 (0.69-0.90)
	2016	0.78 (0.73-0.82)
SO	2012	0.73 (0.54-0.93)
	2013	0.69 (0.52-0.85)
	2014	0.78 (0.67-0.90)
	2015	0.62 (0.52-0.71)
	2016	0.31 (0.21-0.41)
CO	2012	0.84 (0.66-1.04)
	2013	0.91 (0.60-1.22)
	2014	---
	2015	---
	2016	0.71 (0.58-0.83)

Upper Columbia Groups

The only mainstem site in the Upper Columbia River with juvenile PIT-tag detection capabilities is Rock Reach Dam. Although estimating juvenile survival from Rocky Reach to McNary is possible, these survival estimates are limited to fish that were released above Rocky Reach Dam. This means that a large portion of Upper Columbia hatchery fish, those released into the Wenatchee River, would not be included in these estimates. Because of this, we separated Upper Columbia hatchery fish into two groups: 1) those released into the Columbia River, or its tributaries, above Rock Reach Dam (herein referred to as Above RRH) and 2) those released in the Wenatchee River.

For the Above RRH group we estimated juvenile survival from Rocky Reach Dam to McNary Dam (RRH-MCN) for each species, by migration year (2012-2016). Species in the Above RRH group include yearling spring Chinook, yearling summer Chinook, subyearling summer Chinook, steelhead, and coho. For this group, we developed a 4-digit capture history which included the following: 1) release, 2) detection at RRH, 3) detection at MCN, and 4) detection at either John Day Dam (JDA), Bonneville Dam (BON), or the estuary trawl.

For the Wenatchee River groups we estimated juvenile survival from Release to McNary Dam (Rel-MCN) for each species, by migration year (2012-2016). Species in the Wenatchee River group included yearling spring Chinook, yearling summer Chinook, steelhead, and coho. For this group we developed a 3-digit capture history, which included the following: 1) release, 2) detection at MCN, and 3) detection at either John Day Dam (JDA), Bonneville Dam (BON), or the estuary trawl.

Using these capture histories, single mark-release mark-recapture survival estimates were generated using Cormack-Jolly-Seber (CJS) methodology, as described by Burnham et al. (1987) with program MARK (software available free from Colorado State University). (White and Burnham 1999). For the Above RRH group we report the individual reach survival estimates (and 95% confidence intervals) for the RRH-MCN reach. For the Wenatchee River group, we report the individual reach survival estimate (and 95% confidence intervals) for the Rel-MCN reach. Both of these individual reach survival estimates were provided by the MARK program. An estimate of individual reach survival was considered unreliable when its point estimate exceeded 100% or its coefficient of variation exceeded 25%.

Estimates of RRH-MCN survival were possible for nearly all years and species in the Above RRH group (Table 5). The one exception to this was subyearling summer Chinook in 2015 when low detection probabilities at McNary Dam in the summer hindered our ability to obtain reliable estimates of survival for the RRH-MCN reach.

Estimates of Rel-MCN survival were possible for nearly all years and species in the Wenatchee River group (Table 5). The one exception to this was yearling summer Chinook in 2012. As mentioned in the travel time section, no PIT-tags were released for the yearling summer Chinook hatchery release in the Wenatchee River in migration year 2012.

Table 5. Estimated juvenile survival for Upper Columbia hatchery yearling spring Chinook (Sp CH1), yearling summer Chinook (Su CH1), subyearling summer Chinook (Su CH0), steelhead (ST), and coho (CO) released Above RRH (RRH-MCN) or into the Wenatchee River (Rel-MCN) in migration years 2012-2016. Numbers in parentheses are the 95% confidence intervals.

Species	Migration Year	Above RRH (RRH-MCN Survival)	Wenatchee River (Rel-MCN Survival)
Sp CH1	2012	0.72 (0.65-0.77)	0.46 (0.43-0.48)
	2013	0.81 (0.72-0.88)	0.46 (0.44-0.48)
	2014	0.72 (0.61-0.81)	0.42 (0.40-0.44)
	2015	0.69 (0.62-0.76)	0.39 (0.36-0.42)
	2016	0.75 (0.71-0.79)	0.54 (0.51-0.56)
Su CH1	2012	0.71 (0.63-0.79)	---
	2013	0.77 (0.67-0.84)	0.75 (0.59-0.87)
	2014	0.62 (0.56-0.67)	0.76 (0.69-0.82)
	2015	0.68 (0.57-0.77)	0.76 (0.65-0.85)
	2016	0.73 (0.68-0.77)	0.79 (0.72-0.85)
Su CH0	2012	0.47 (0.29-0.66)	---
	2013	0.69 (0.41-0.88)	---
	2014	0.62 (0.43-0.78)	---
	2015	---	---
	2016	0.40 (0.27-0.55)	---
ST	2012	0.61 (0.57-0.65)	0.23 (0.21-0.26)
	2013	0.58 (0.52-0.64)	0.39 (0.34-0.44)
	2014	0.73 (0.65-0.80)	0.32 (0.26-0.39)
	2015	0.60 (0.54-0.66)	0.20 (0.17-0.24)
	2016	0.70 (0.66-0.74)	0.34 (0.32-0.38)
CO	2012	0.67 (0.60-0.74)	0.32 (0.30-0.35)
	2013	0.84 (0.70-0.92)	0.44 (0.40-0.48)
	2014	0.74 (0.65-0.81)	0.39 (0.35-0.43)
	2015	0.75 (0.54-0.88)	0.32 (0.28-0.37)
	2016	0.70 (0.65-0.74)	0.38 (0.36-0.40)

Discussion

To put into context the conditions that Snake River and Upper Columbia juveniles may have experienced during their out-migration in 2012-2016, Figure 1 provides the spring and summer flow volumes for the Snake and Columbia River (above McNary), along with the average spring and summer spill proportions at each of the dams in these regions.

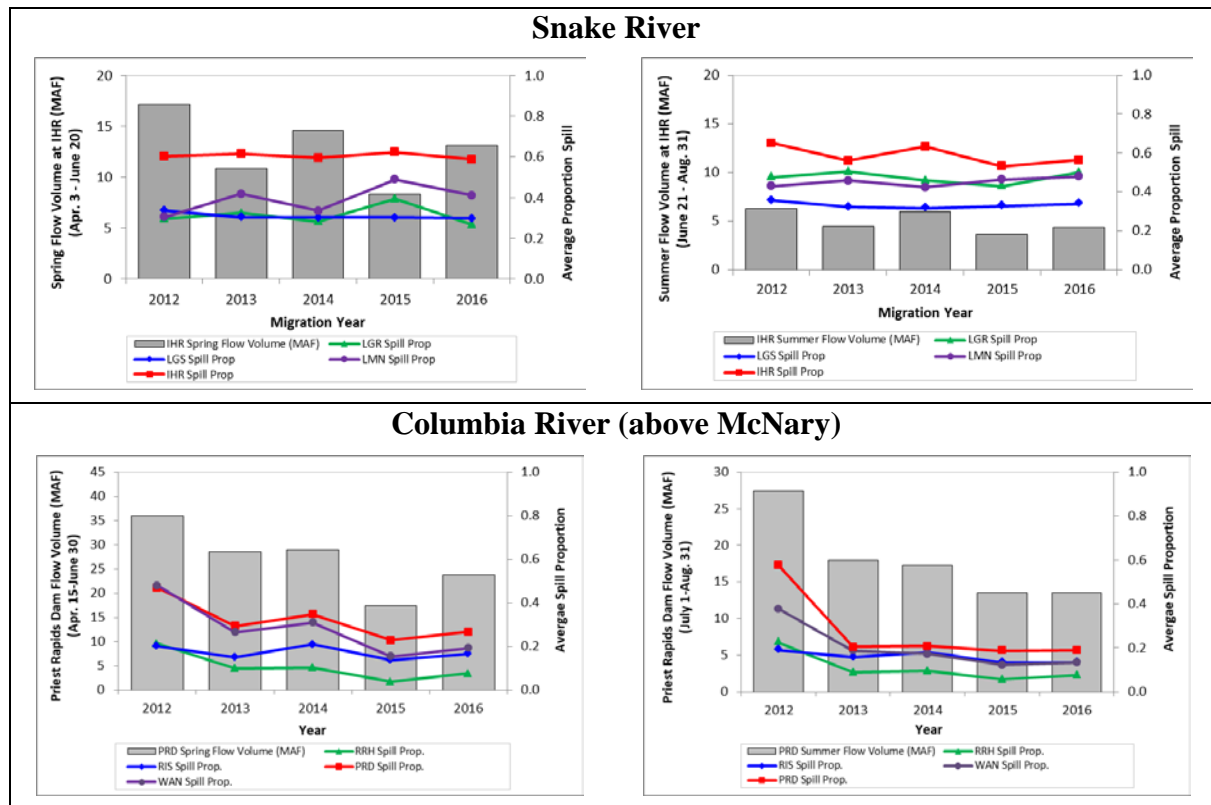


Figure 1. Spring and summer flow volume (MAF) in the Snake and Columbia River (above McNary) rivers and average spill proportion at each dam in these regions, 2012-2016. Note the different scales on the y-axes and different spring and summer periods between the two regions: Snake River (Spring- Apr 3-June 20, Summer- June 21-August 31) and Columbia River (above McNary) (Spring- Apr. 15-June 30, Summer- July 1-August 31).

Finally, there are a few items to consider when evaluating the survival estimates provided in this memo. First, as per your request, we provided annual juvenile survival estimates for all PIT-tagged hatchery fish of a given species. However, there is great variability in survival between hatchery release groups (McCann et al., 2017). For example, in its Annual Reports (Appendix A) the CSS provides estimates of survival from LGR to BON (S_R) for several groups of Snake River hatchery yearling spring Chinook, yearling summer Chinook, subyearling fall Chinook, steelhead, and sockeye. For migration year 2016, the estimate of S_R for the ten groups of hatchery yearling spring and yearling summer Chinook varied between 0.37 (Pahsimeroi Hatchery yearling summer Chinook) to 0.63 (Clearwater Hatchery yearling summer Chinook) (McCann et al., 2017). Combining all hatchery groups into one, as we did for this request, may not fully capture the variability between groups.

Second, the annual juvenile survival estimates provided here can be considered a weighted average survival for a given species and migration year, with the weighting based on the number of PIT-tags released for a particular hatchery or release site. When interpreting these data, it is important to note whether there were any large PIT-tag groups that may contribute disproportionately to the annual survival in a given year. We have

observed a real-world example of this in recent years with Snake River sockeye. Survival of Snake River hatchery sockeye was relatively low in 2015 and 2016, despite relatively favorable environmental conditions (Table 4, Figure 1). It is worth noting that there was a major change in the production of Snake River hatchery sockeye, beginning in migration year 2015. Prior to 2015, hatchery sockeye were reared at Sawtooth Hatchery and Oxbow Hatchery (Oregon) and released at or near Redfish Lake. In addition to Sawtooth and Oxbow reared fish, Springfield Hatchery began releasing hatchery sockeye at Redfish Lake in 2015. In 2016, releases of Sawtooth Hatchery reared sockeye were terminated, which meant that hatchery sockeye releases were of Oxbow and Springfield reared fish. Springfield Hatchery sockeye releases in 2015, 2016, and 2017 have experienced several fish health problems that have affected juvenile survival (McCann et al., 2017). In 2015 and 2016, the Springfield Hatchery group comprised approximately 49% and 96% of the overall PIT-tag release groups, respectively. These fish health problems, in addition to the increasing proportion of the PIT-tagged group that are from Springfield Hatchery, help to explain the low survival estimates for this group in recent years (Table 4) and help illustrate our point above about considering whether particular release/PIT-tag groups may be contributing disproportionately to survival estimates and how that might affect the applicability of an annual survival estimate.

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